DUKE COGEMA
STONE & WEBSTER

NRC Technical Exchange
Geology, Seismology and Geotechnical Engineering

City of Aiken Municipal Building Conference Center
19-20 September 2001

DUKE COGEMA
STONE & WEBSTER

NRC Technical Exchange
Geology, Seismology and Geotechnical Engineering

Introduction

J. M. McConaghy
19 September 2001

Objectives

DUKE COGEMA STONE & WEBSTER

- Inform NRC staff about development of SRS seismic criteria
  - Regional geology and seismology
  - Site-Specific Probabilistic Seismic Hazard Assessment
  - SRS Design Criteria
- Demonstrate that these criteria are also applicable to the MFFF site
- Describe selection of MFFF Design Basis
- Present results of geotechnical engineering evaluations
- Receive NRC feedback and questions

Agenda Day One

DUKE COGEMA STONE & WEBSTER

	TOPICS	
8:00 - 8:15	Welcome	Persinko
8:15 - 8:30	Introduction	McConaghy
8:30 - 8:45	Overview	Salomone
8:45 - 9:15	SRS Geology	Wyatt
9:15 - 9:45	SRS Seismology	Lee
	SRS Site-Specific PSHA	
10:00 - 10:30	Bedrock Spectra	Kimball
10:30-11:30	Soil Surface Spectra	Lee
11:30-12:00	SRS Design Spectra	Gutierrez
12:00 - 13:00	Lunch Break	
13:00 - 14:00	Confirmation of Inputs for MFFF Site	Lewis
14:00 - 15:30	Selection of MFFF Design Basis	McConaghy
15:30 - 16:00	Questions	Persinko
16:00 - 16:30	Summary, Action Items	McConaghy

Agenda Day Two

DUKE COGEMA STONE & WEBSTER

	TOPICS	
8:00 - 8:10	Introduction	McConaghy
8:10 - 8:30	Site Investigations and Testing	Meisenheimer
8:30 - 9:00	Engineering Properties	Meisenheimer
9:00 - 9:30	Soft Zones	Meisenheimer
9:30 - 10:00	Bearing Capacity and Settlements	Meisenheimer
10:00 - 10:30	Subsurface Profile	Meisenheimer
10:30 - 11:15	Liquefaction Evaluations	Meisenheimer
11:15 - 12:00	Post-EQ Dynamic Settlements and Soft Zone	Meisenheimer
12:00 - 12:30	Questions	Persinko
12:30 - 13:00	Summary, Action Items	McConaghy
13:00	Adjourn	Persinko

Introduction

DUKE COGEMA STONE & WEBSTER

- DCS is the MFFF license applicant
- DCS has approved SRS operating contractor WSRC as a supplier of engineering services
- DCS draws on the large body of technical data developed for SRS in selecting MFFF design basis.

DUKE COGEMA STONE & WEBSTER

Introduction

- Demonstrate development of SRS seismic criteria and PSHA align with NRC expectations.
- Demonstrate applicability of SRS criteria to MFFF site
- Describe selection of MFFF Design Basis
- Describe geotechnical analyses performed to demonstrate appropriateness of MFFF designs

DUKE COGEMA STONE & WEBSTER

Introduction

- NRC staff questions during presentations are encouraged.
- Outstanding issues will be recorded and discussed in daily summary.
- Action items will be recorded at close of each day.

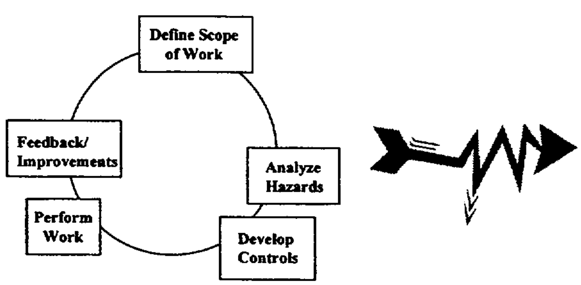
SRS Geology and Seismology Overview

L. A. Salomone
WSRC Chief Geotechnical Engineer
19 September 2001

Technical Challenge

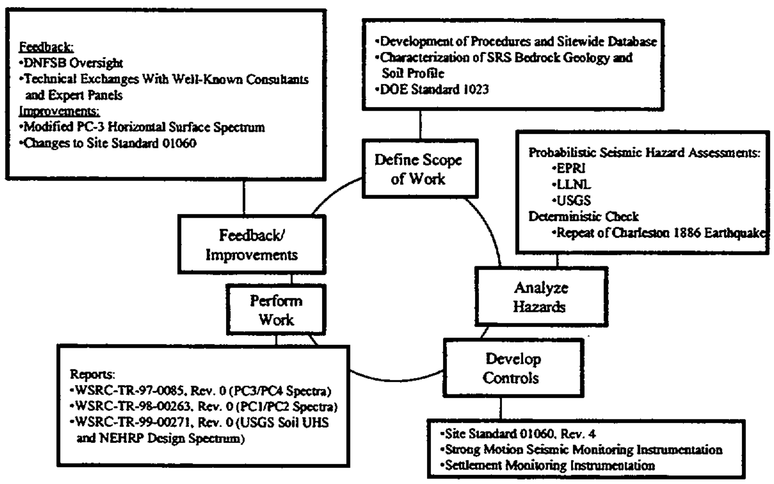
The objective of estimating annual frequencies of earthquake - caused ground motion is hampered by the lack of significant earthquakes in the vicinity of the Savannah River Site.

Disciplined, Systematic Approach to Seismic Safety

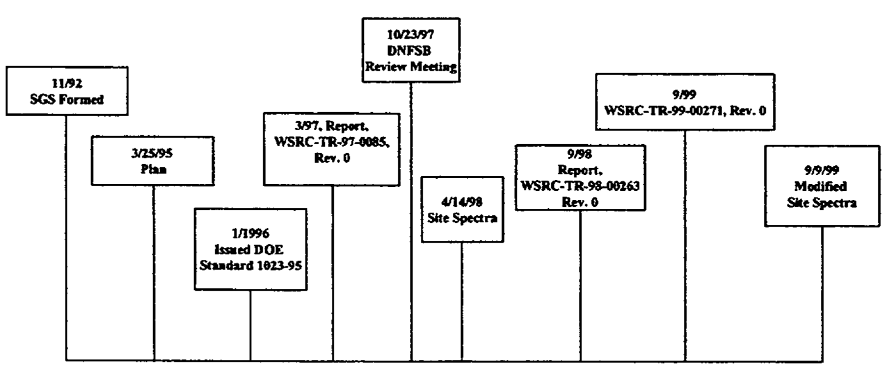


SRS developed a disciplined, systematic approach that allowed for multidisciplinary evaluation and development of a seismic design bases that has kept pace and contributed to current industry technologies and practices.

Disciplined, Systematic Approach to Seismic Safety



Timeline of Key Seismic Milestones



Summary

The WSRC baseline data has been made available to DCS and the MFFF project

DUKE COGEMA
STONE & WEBSTER

An Overview of the Geology of the Savannah River Site

D. Wyatt
WSRC
19 September 2001

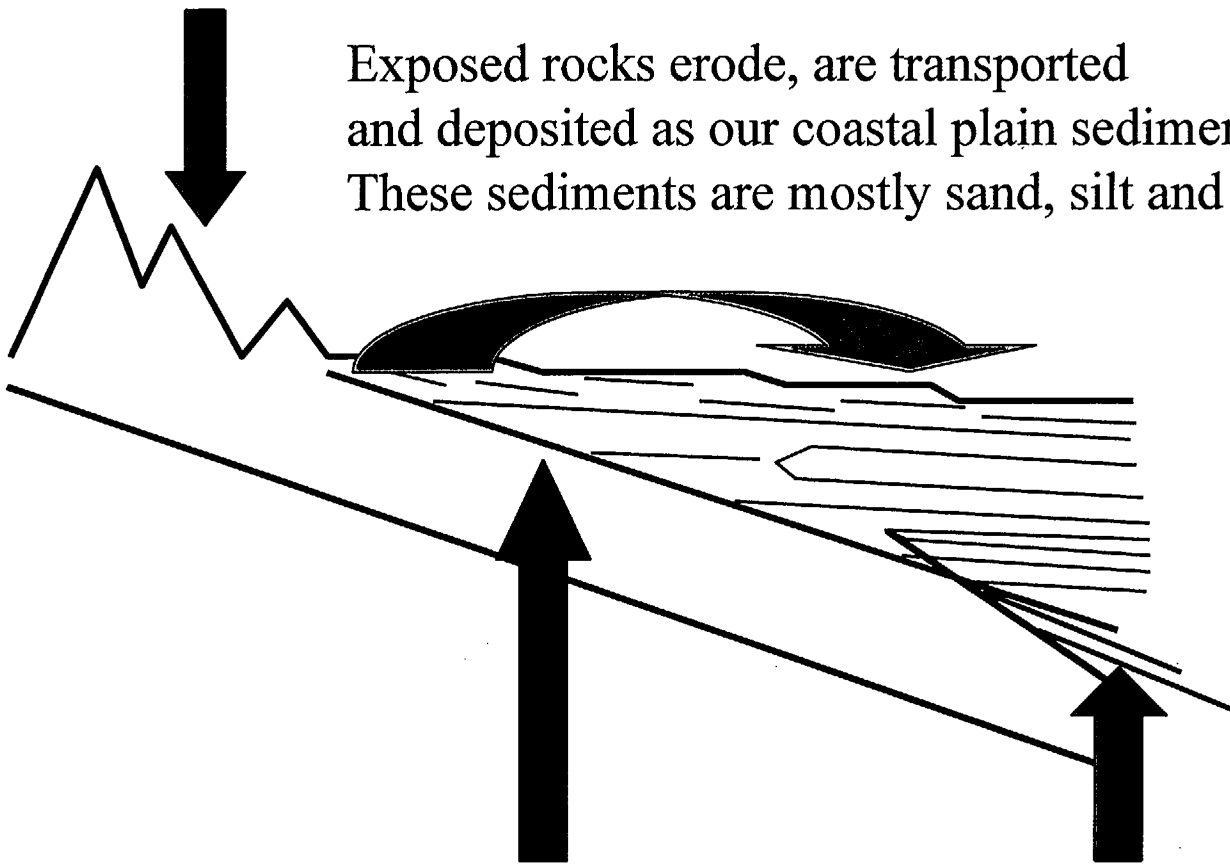
***The surface geology of the SRS area has been extensively mapped by SRS, major universities, the USGS and the SCDNR.**

- **There are 350+ published scientific and engineering studies, reports and papers that define and discuss the geology (mostly subsurface) of the SRS region!**
- **There are approximately <u>10,000</u> locations on or near the SRS with subsurface information! (borings, wells, cone penetrometer tests)**
- **More than 200+ line miles of seismic data exist on the SRS, plus gravity and aeromagnetic data.**

Some background concepts.

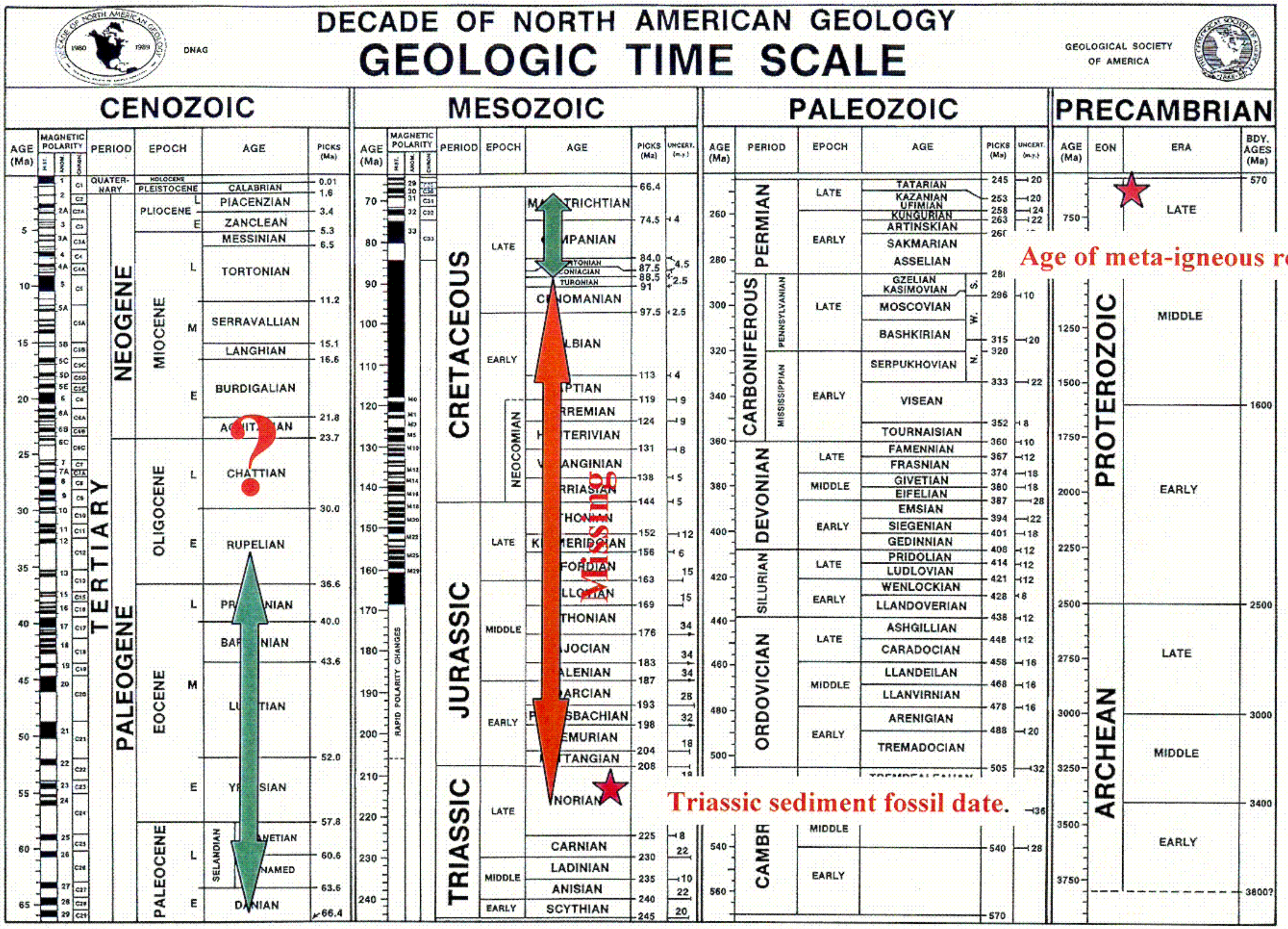
Metamorphic rocks mostly make up the Appalachians.

Exposed rocks erode, are transported
and deposited as our coastal plain sediments.
These sediments are mostly sand, silt and clay.



"Basement" rocks are those rocks underlying our unconsolidated sediments.
Igneous and metamorphic rocks generally form our basement complex.
Coastward, Triassic aged rocks, mostly sandstones, form our basement.

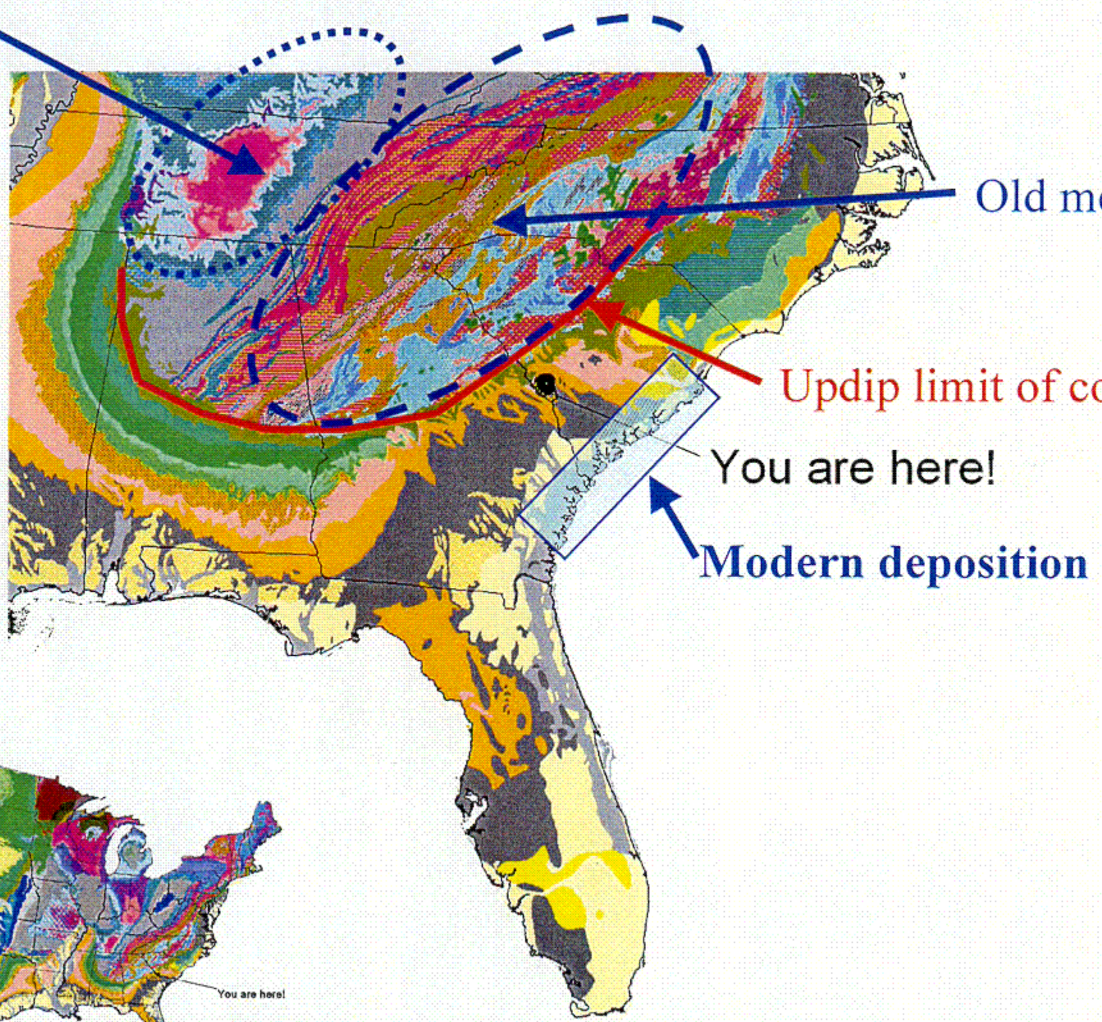
regional overview

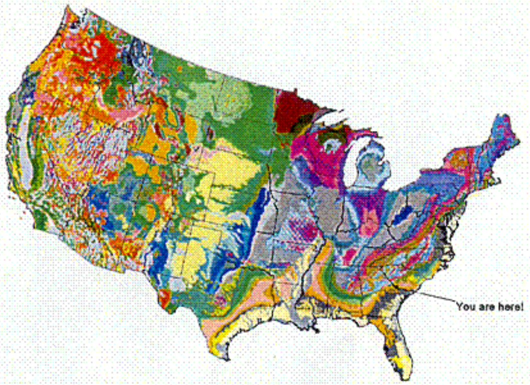


Our SRS unconsolidated sediments are Cretaceous through Oligocene/Miocene in age. Dating is generally based on fossils found in the sediments and relative positions.

Site concepts

SRS has a well-defined relationship with southeastern geology.

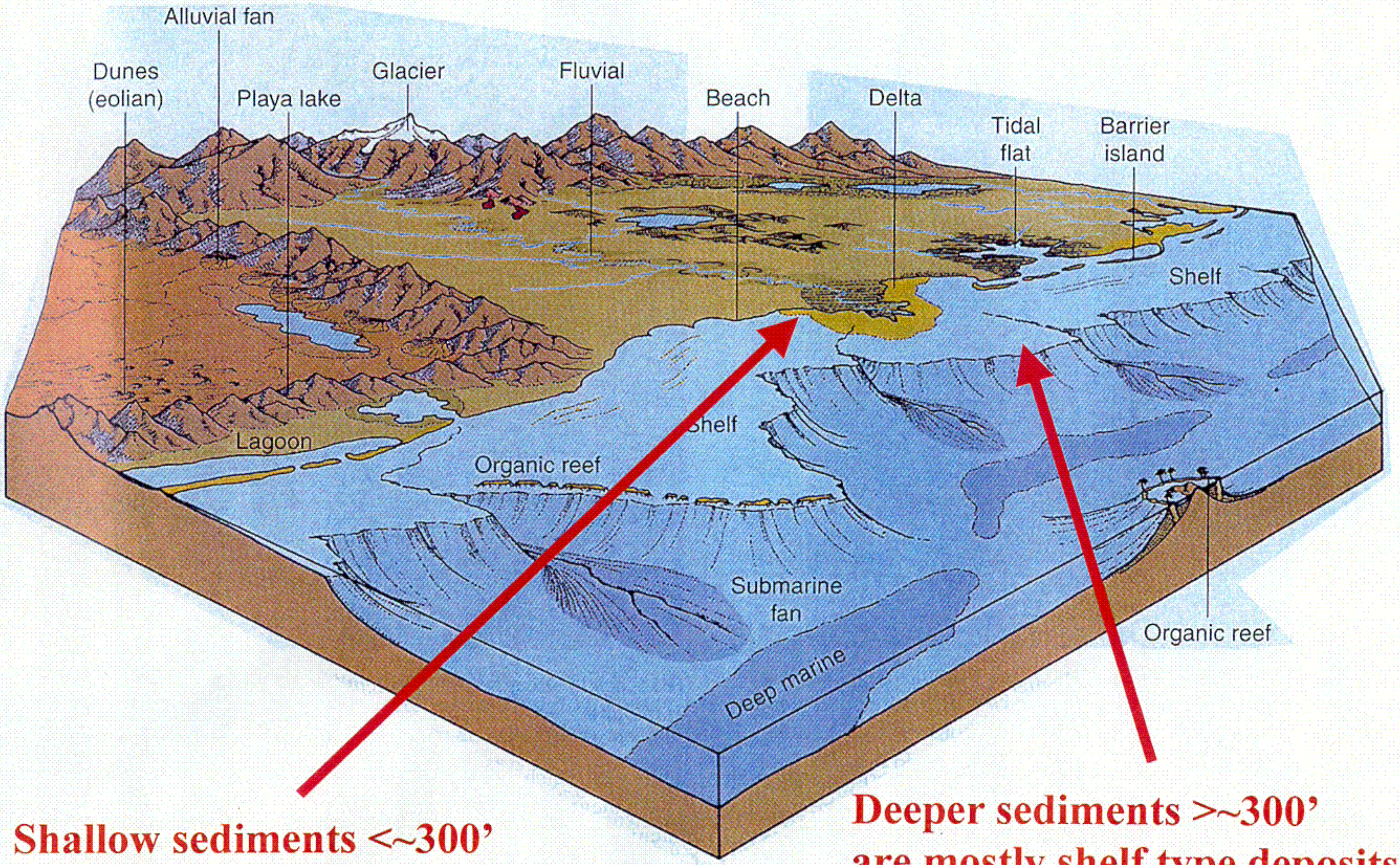




regional overview

C02

SRS unconsolidated sediments were generally deposited within a deltaic, near shore to shelf environment.



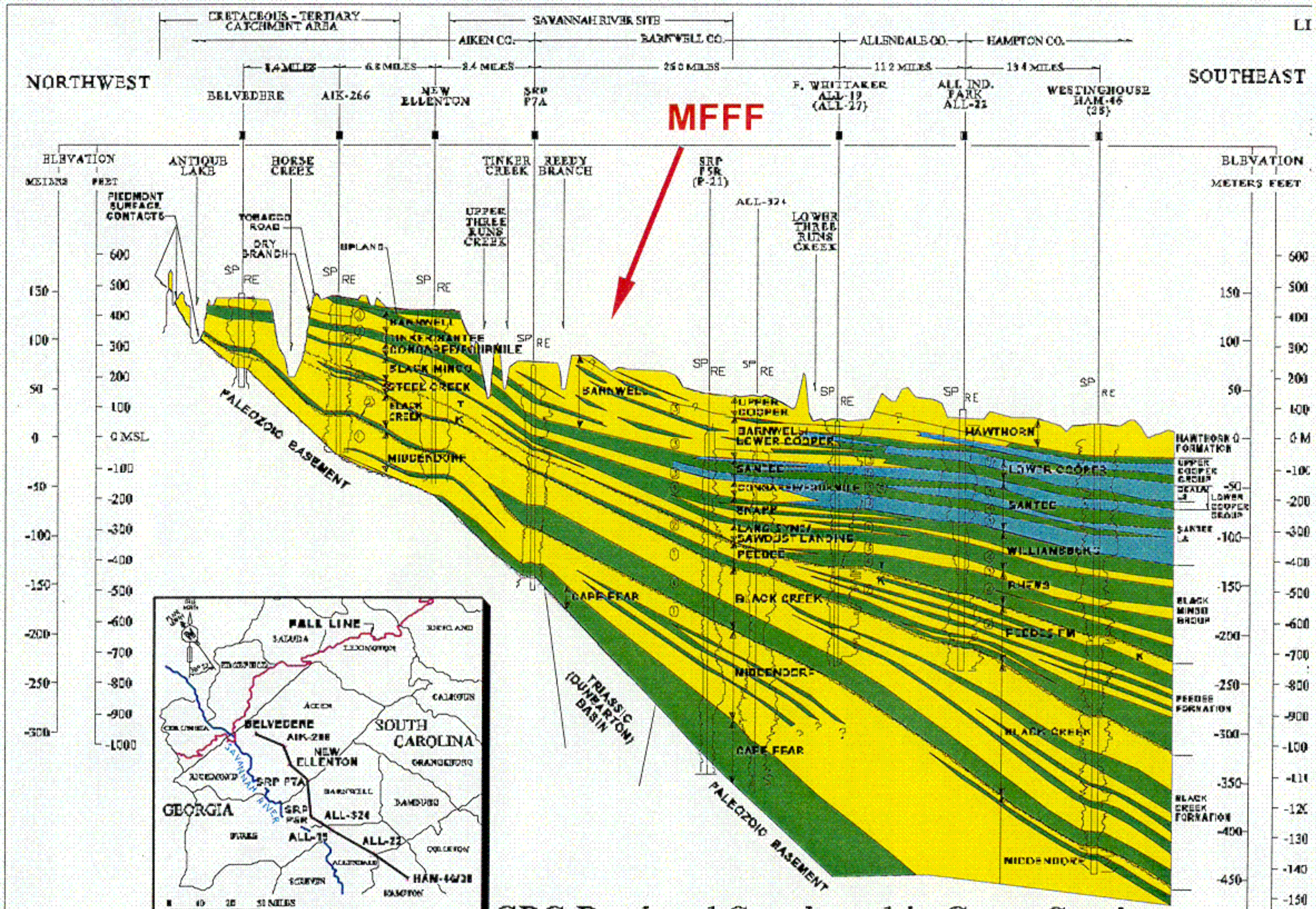
Shallow sediments <~300' are mostly deltaic, near shore deposits.

Deeper sediments >~300' are mostly shelf type deposits.

Site concepts

C03

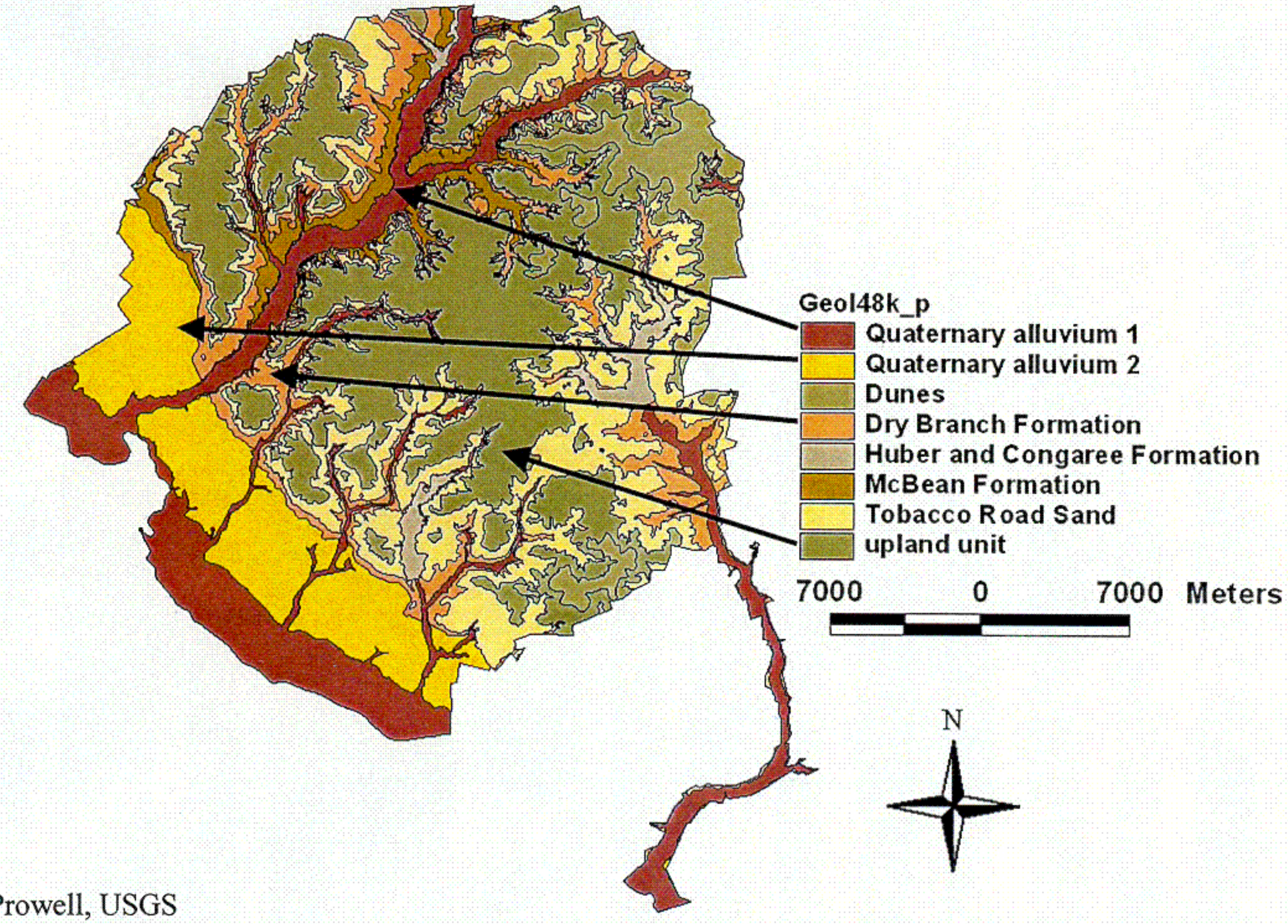
The SRS subsurface geology is part of a regional pattern of sediments that thicken towards the coast. These sediments may be classified and mapped. This pattern defines our stratigraphy by dividing the sediments into mappable formations.



SRS Regional Stratigraphic Cross-Section

C04

We have a well defined system of regional and local surface geology. The sediments we see on the surface at the SRS are beneath the surface down dip (closer to the coast) and those sediments beneath the surface at the SRS are exposed further up dip (approaching the Piedmont).



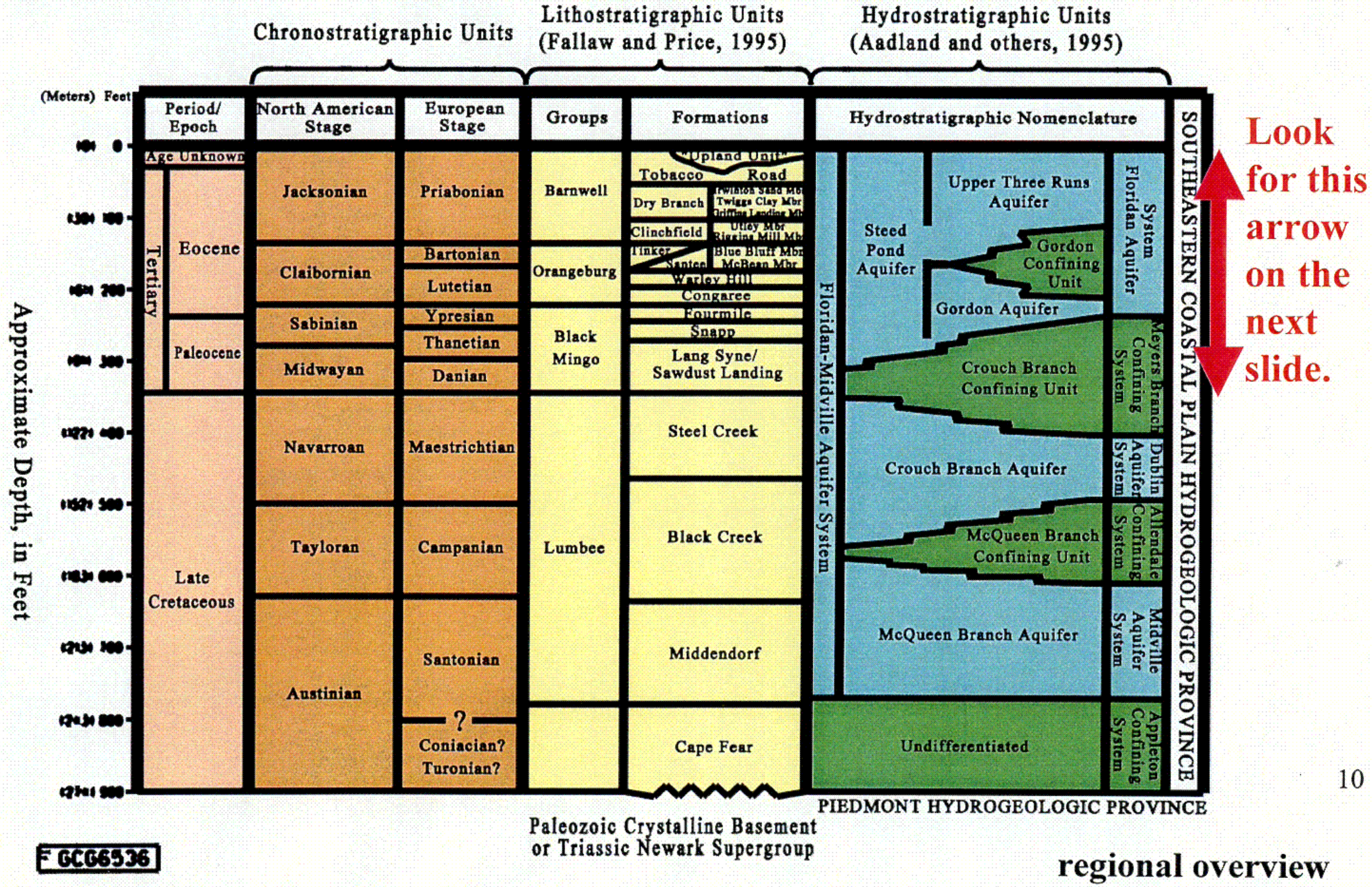
Geology from Prowell, USGS

regional overview

C05

Typical sediments within the upper 20 feet near the center of SRS.

SRS has a well defined regional hydrostratigraphy. Hydrostratigraphy divides the subsurface into mappable aquifers and aquitards.



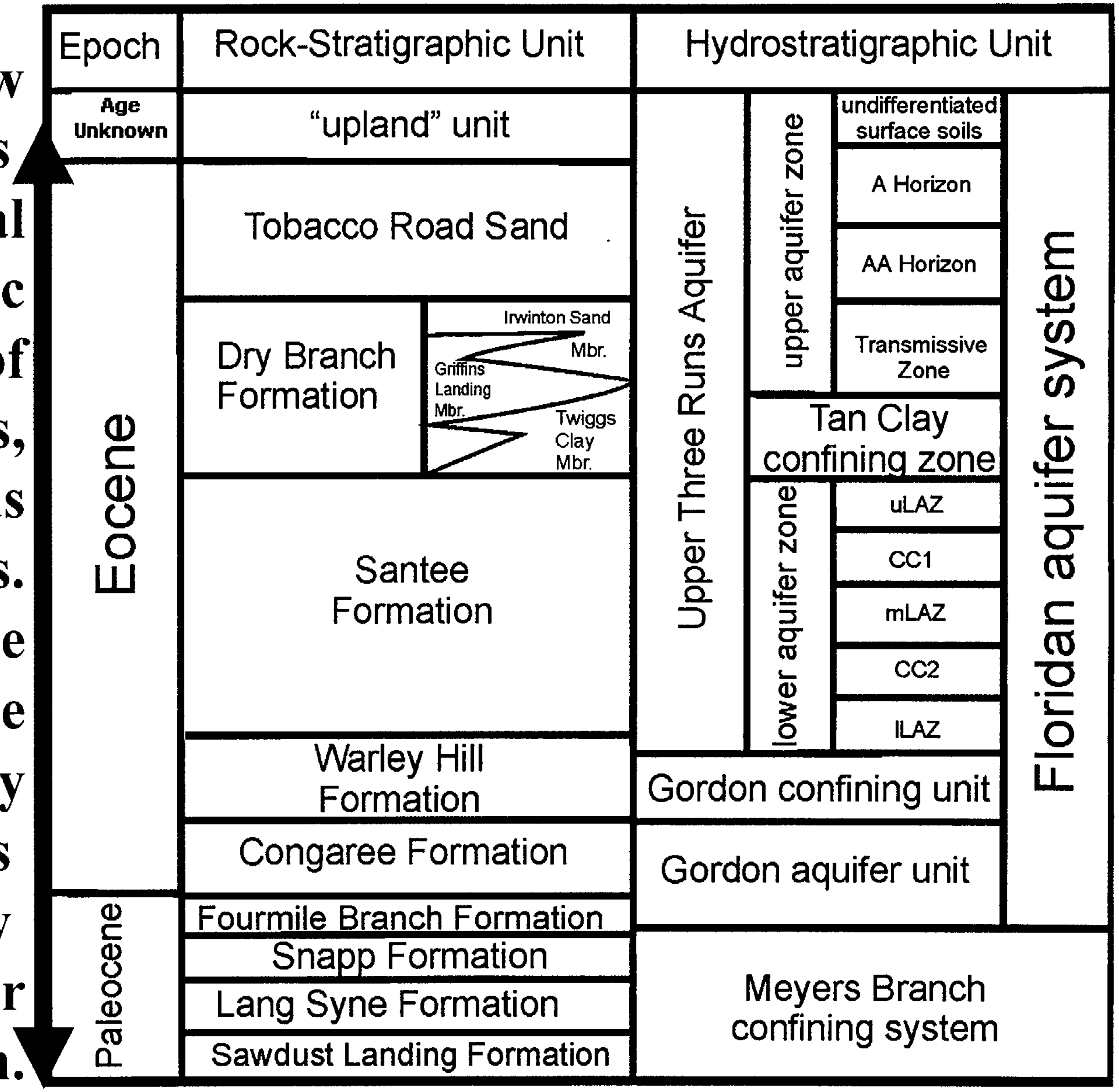
10

regional overview

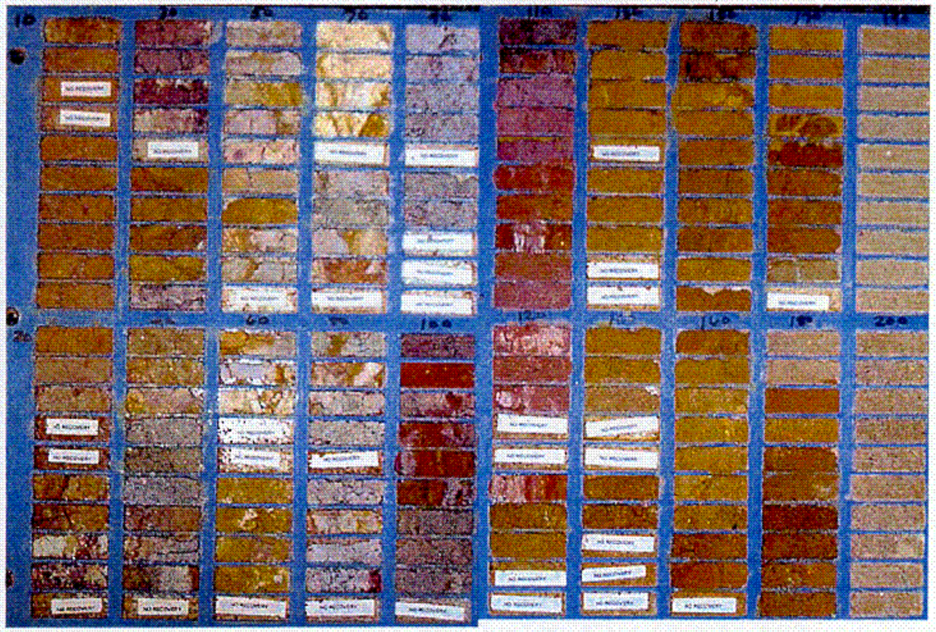
C07

SRS has a well defined localized hydrostratigraphy.

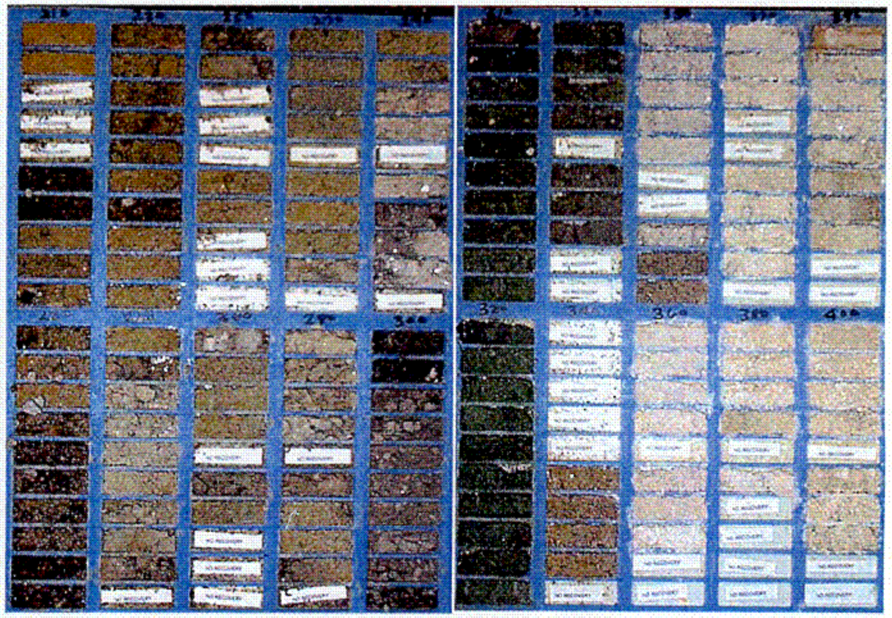
This arrow represents the principal stratigraphic interval of shallow aquifers, zones, aquitards and confining units. These are the units that are impacted by SRS activities and are actively monitored for contamination.



Sediment color and textural examples from the upper 400 feet. These samples are from a boring located near the center of the SRS and are typical for the region.



GCB-5 10' -- 210'

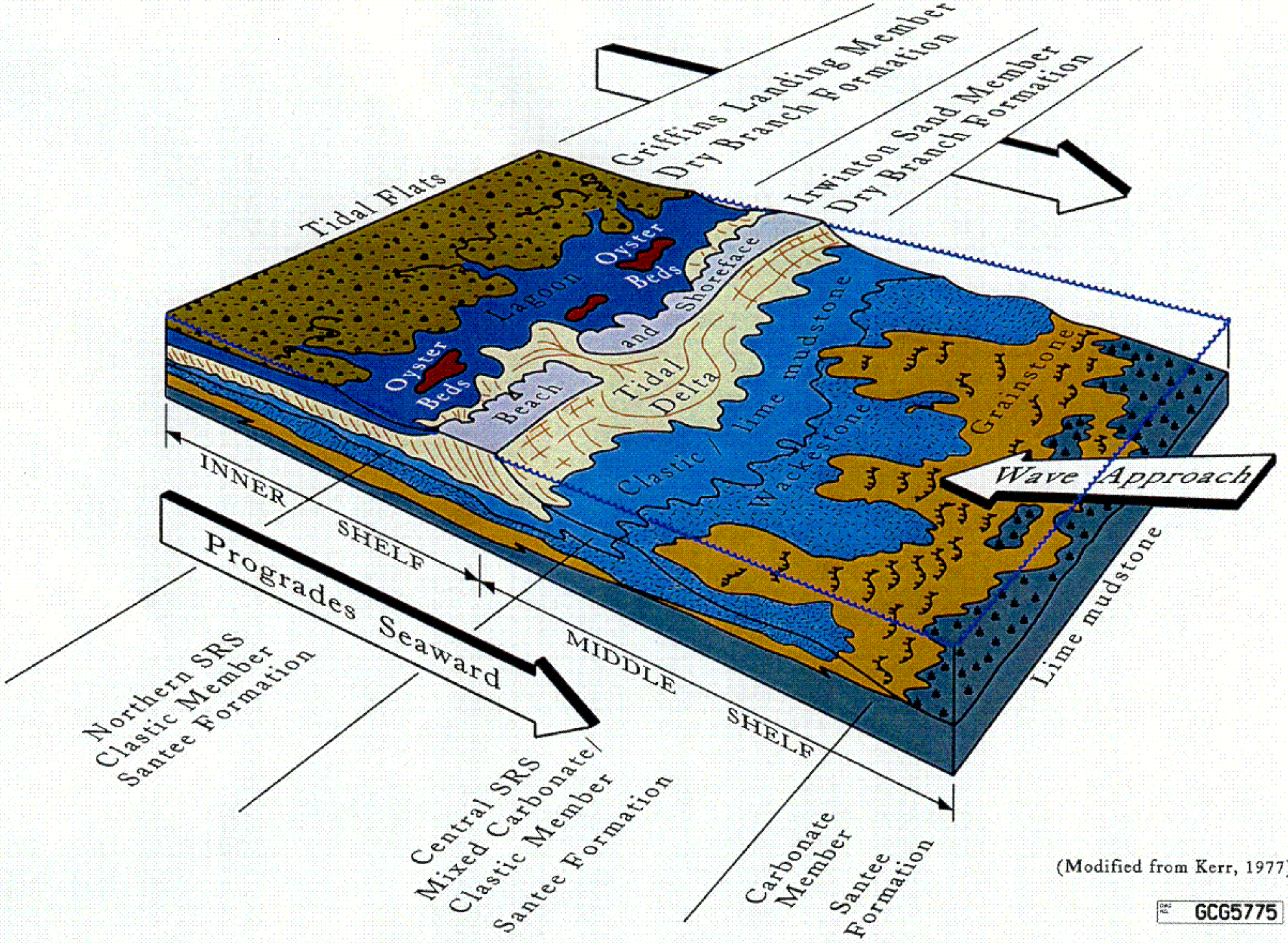


GCB-5 210' -- 410'

Below approximately 300 feet sediments are generally very similar until the crystalline or Triassic basement rocks are encountered. The average depth to basement rocks across the SRS is approximately 1000 feet.

Geo concepts

C08

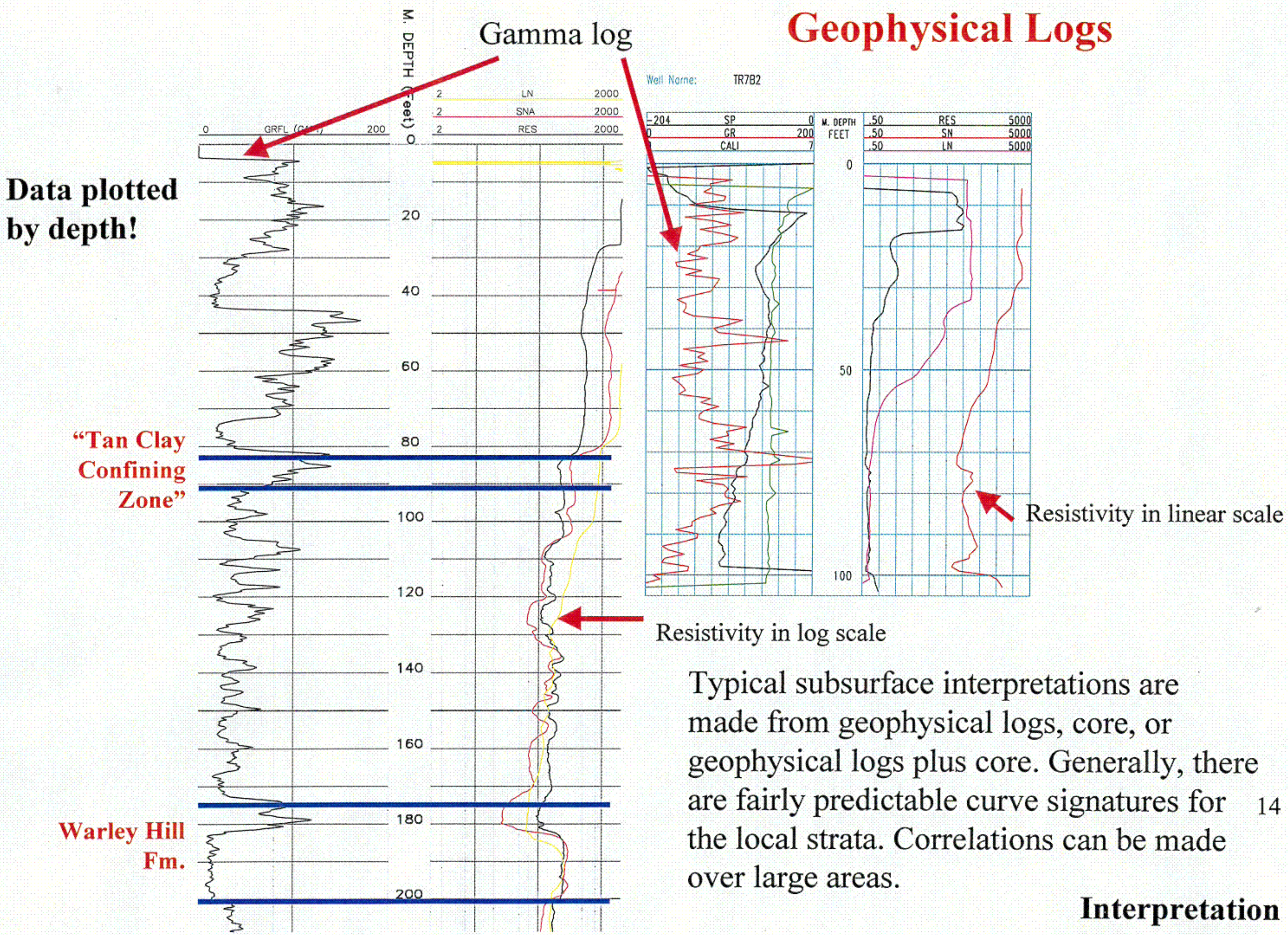


This is the classic SRS depositional model for our shallow sediments.[13]
It is very similar to the deposition now occurring along our coast.

Site concepts

C09

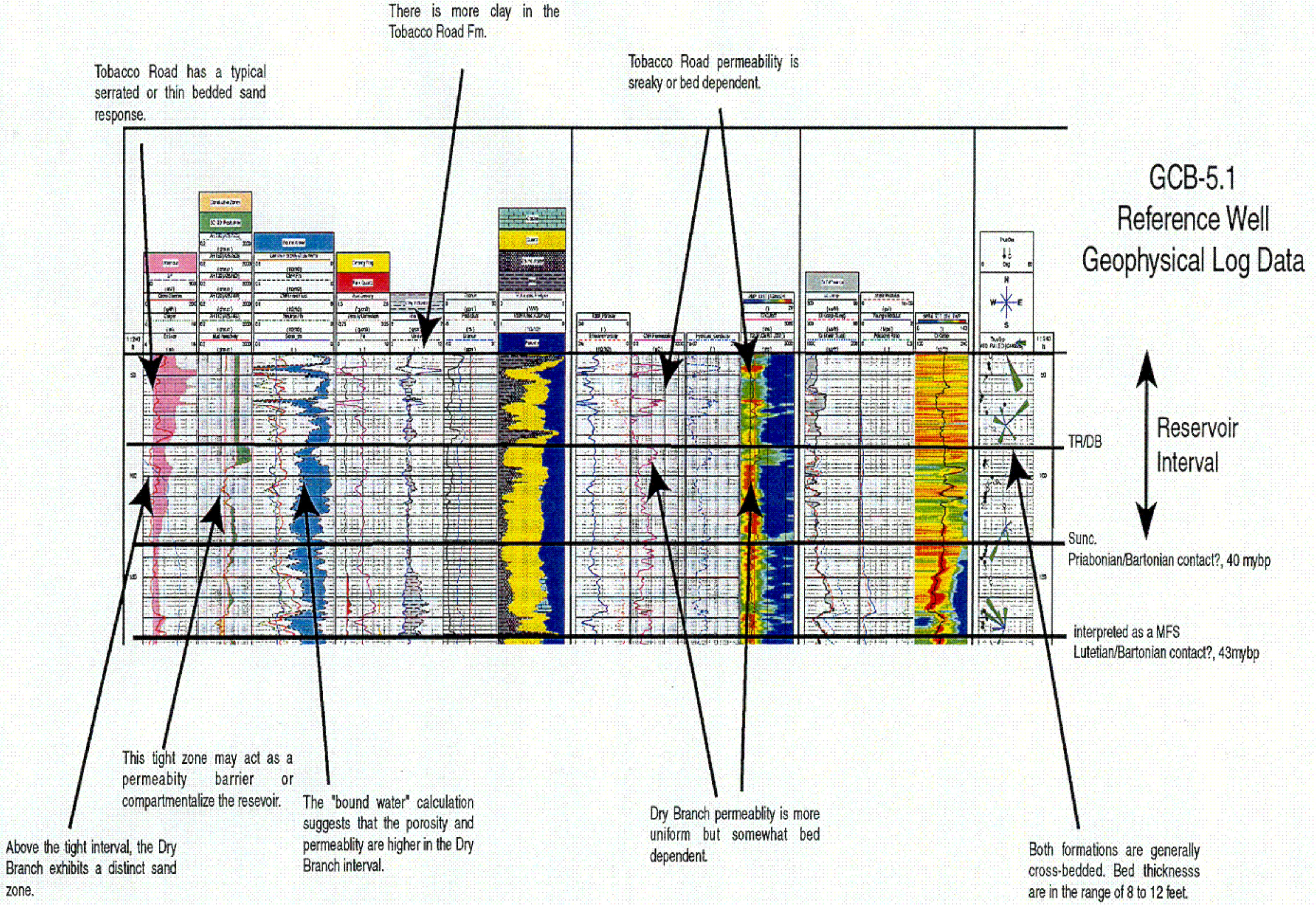
Geophysical Logs



Typical subsurface interpretations are made from geophysical logs, core, or geophysical logs plus core. Generally, there are fairly predictable curve signatures for the local strata. Correlations can be made over large areas.

Interpretation

GCB-5.1 Reference Well Geophysical Log Data

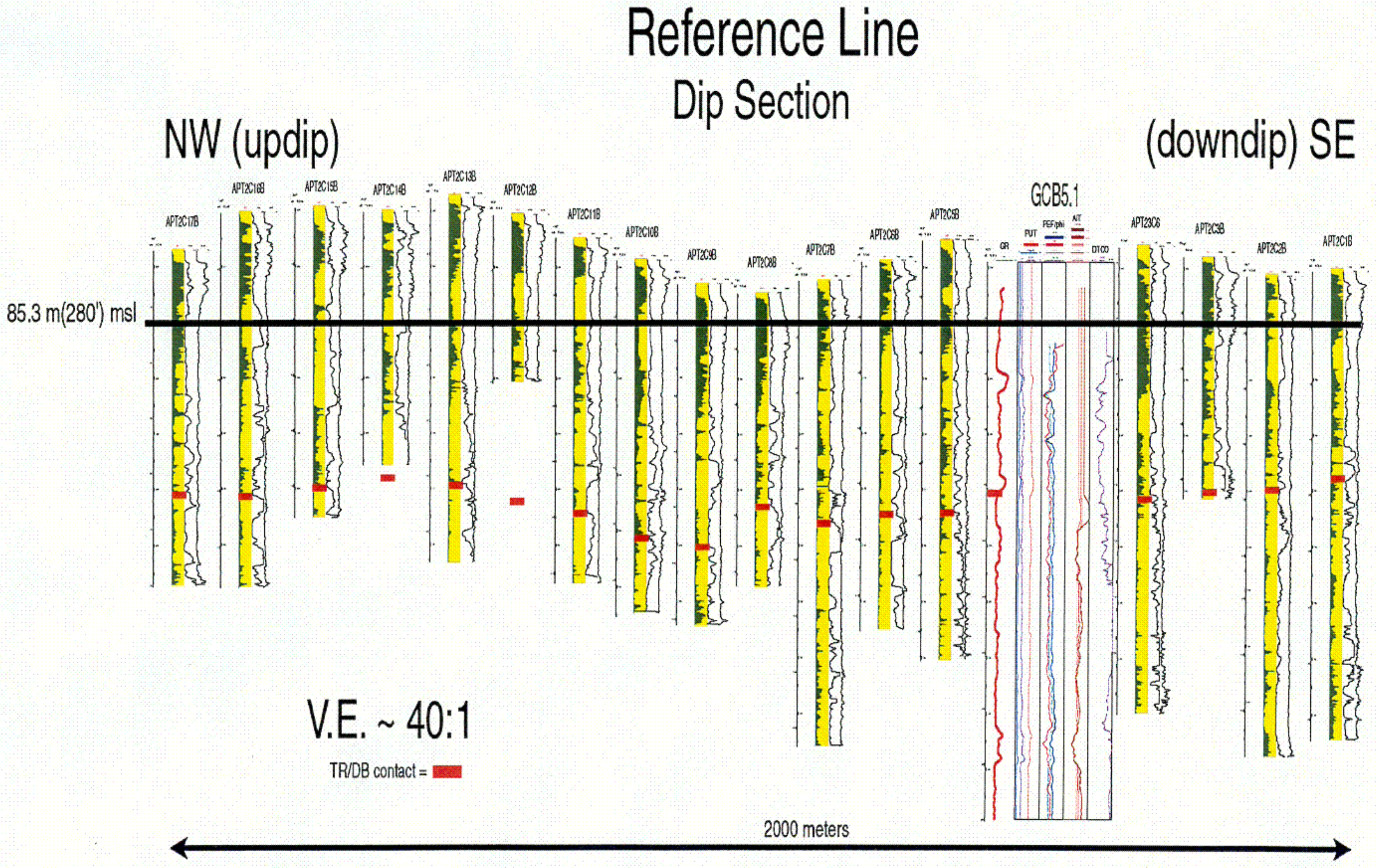


SRS has numerous reference borings with advanced geophysical and core data. These reference borings provide the geological framework for regional interpretations.

Interpretation

C11

Using borehole geophysics and core data it is possible to define and correlate our subsurface strata. Curve characteristics are generally predictable.

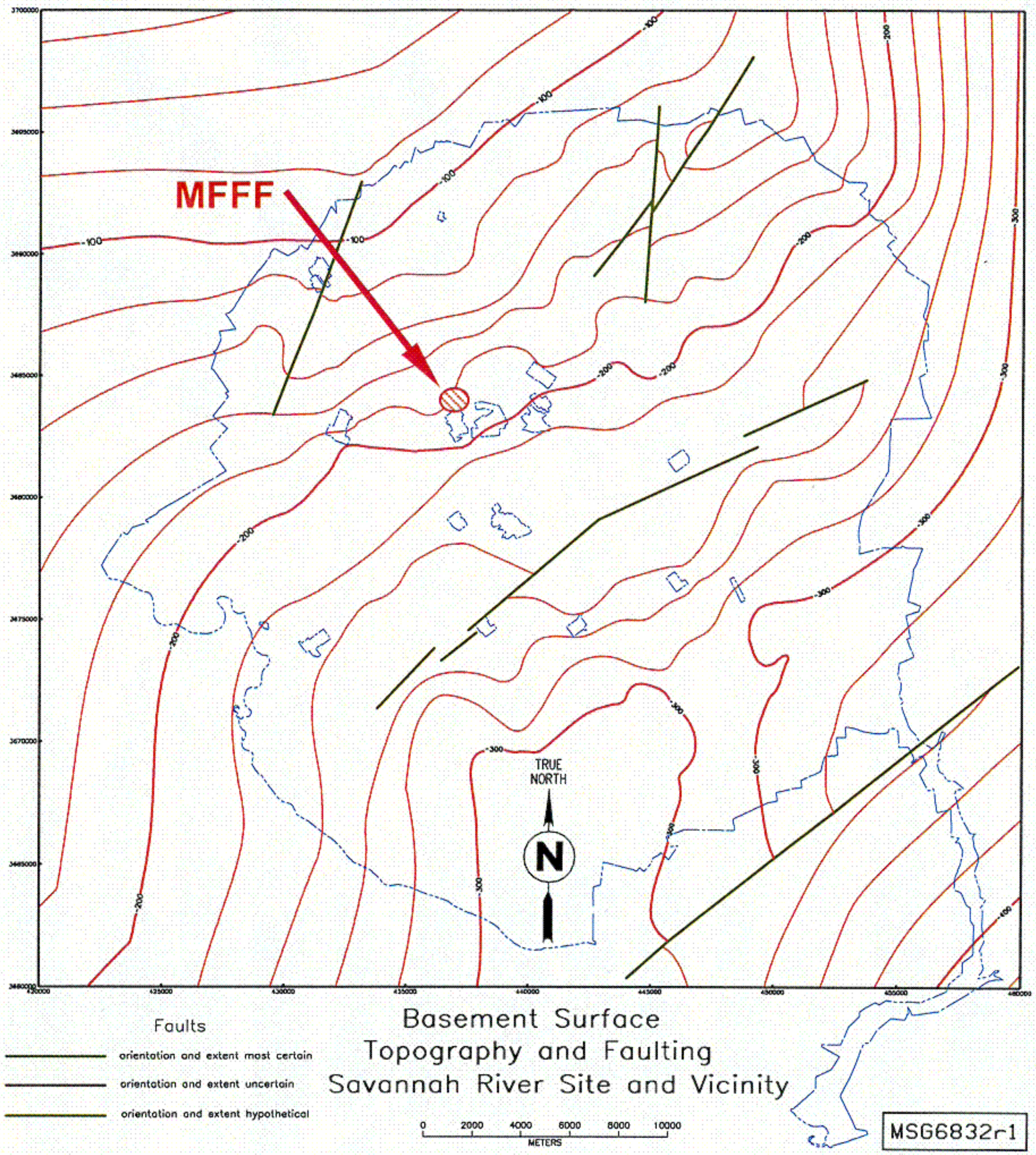


16

C12

We have numerous control points to make a basement topographical surface map. Basement rocks are the igneous, metamorphic or Triassic rocks that lie beneath our unconsolidated sediments. Regional faults are shown.

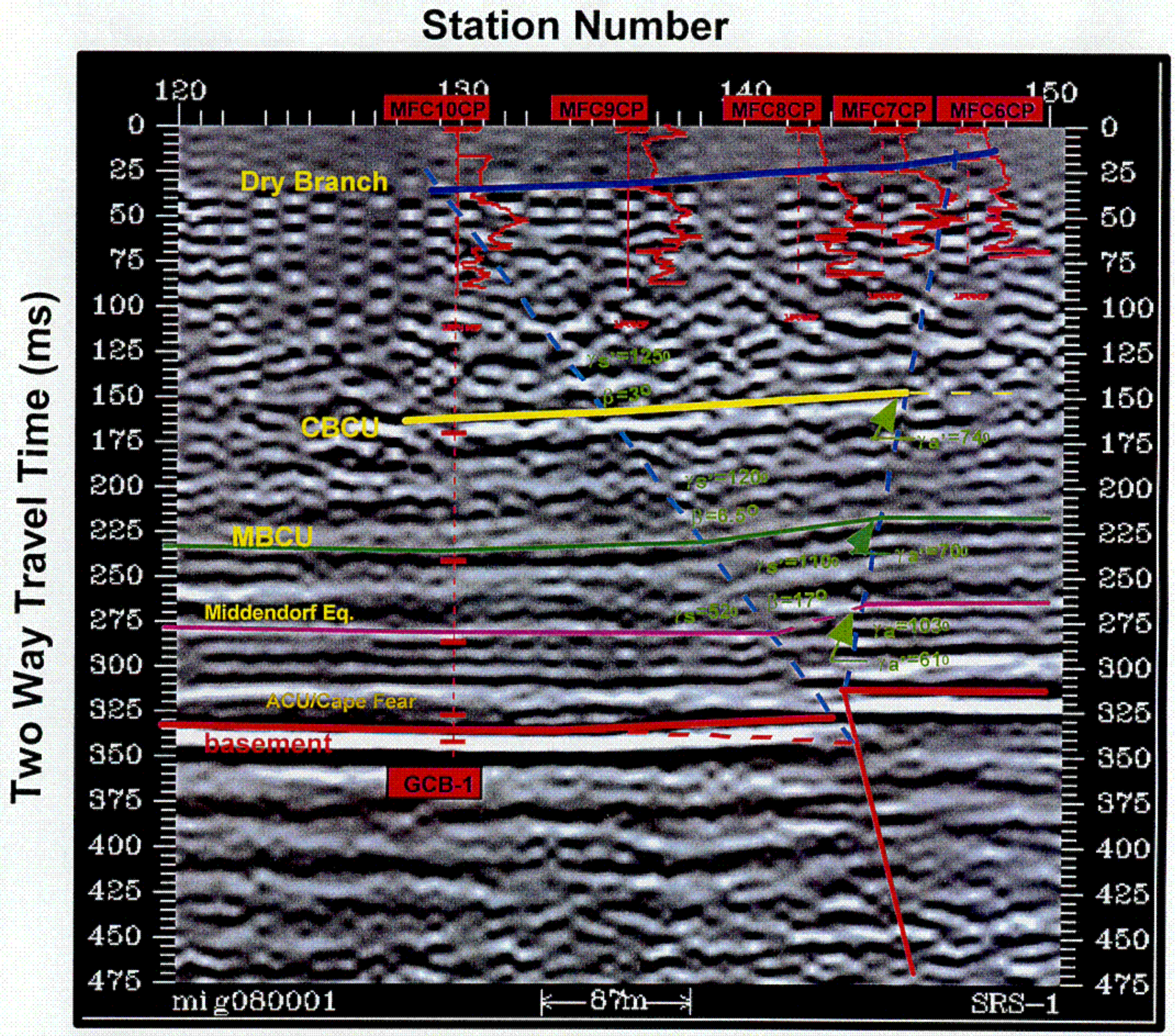
Modified from Cumbest et.al., 2000



regional overview

C13

Faults are structural breaks in our crystalline rocks that propagate through our sediments. These faults are generally compressive and form fault propagation folds in the overlying unconsolidated strata. These faults do not effect our recent Quaternary aged sediments.



(Modified from Cumbest et al., 2000)

A Summary of SRS Geology

- SRS sediments generally consist of unconsolidated sands, silts and clays eroded from the mountains, transported, and deposited in near shore, deltaic to shelf environments.
- Well known surface geology and data from approximately 10,000 boreholes and wells allows for a detailed understanding of the subsurface geology.
- These sediments have characteristics that allow them to be mapped over large areas therefore defining a regional stratigraphy and hydrostratigraphy.
- These unconsolidated sediments rest on metamorphic crystalline or Triassic sandstone basement rocks.
- The basement rocks are offset in many places by ancient faults that may affect the overlying sediments, however, our Quaternary sediments are not affected.

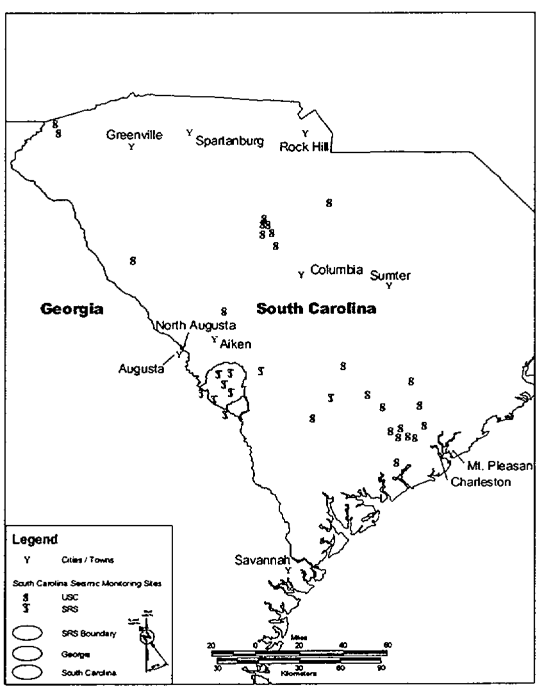
DUKE COGEMA
STONE & WEBSTER

SEUS Historical Seismicity

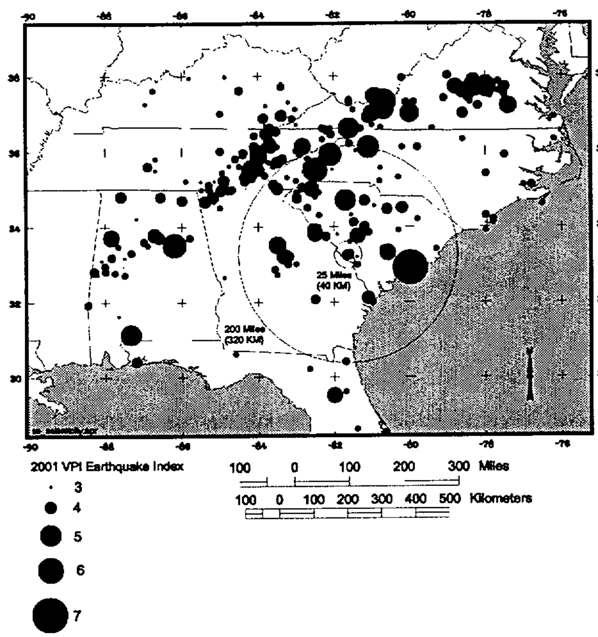
R. Lee
WSRC
19 September 2001

Significant Historical Earthquakes

- Earthquake historical record dates back to 1774
  - MMI's inferred from newspaper and other historical accounts
  - SEUS instrumental record began in earnest in mid-1970's (SRS seismic network began in 1976)
- Earthquake history of region is dominated by the occurrence of the 1886 Charleston earthquake
  - estimated magnitude of about 7 +
  - estimated epicentral Modified Mercalli Intensity (MMI) of X
  - produced MMI of about VI in what would be the SRS area
  - paleoseismic investigations suggest recurrence of M 7+ earthquakes about every 500-600 years



Seismic network for SRS and the surrounding region.



Seismicity of Southeastern United States

Comparison of Rates of Seismicity

Area	"a"	"a"/10^4 km^2	MMI_{max}	Mmax
SEUS	3.12	1.15	X	7.3
Valley & Ridge	2.67	1.52	VII	4.6
Piedmont	2.18	0.94	VII-VIII	5.0
Coastal Plain	2.22	0.67	VII	4.5
Charleston	1.69	1.99	X	7.3

August 31, 1886 Charleston Earthquake

(South Carolina Geological Survey, Bulletin 40)

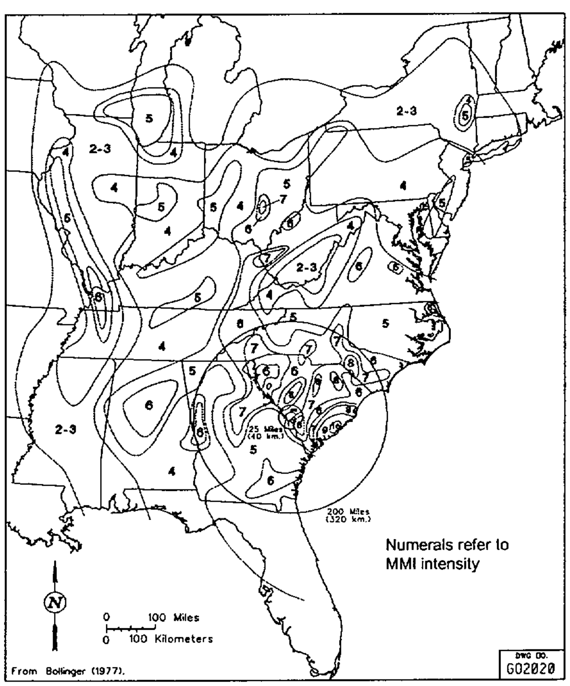
- Preceeded by several foreshocks (MMI < V)
- Hundreds of felt aftershocks (a few of MMI VII-VIII)
- Epicentral (MMI X) "Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed, slopped over banks"
- 27 lives taken
- Barnwell (MMI VII) (report- "Severe shock, alarming everybody; houses rocked and shook as if about to fall. Light objects thrown about, furniture moved, walls cracked, and plaster shaken down.")

August 31, 1886 Charleston Earthquake (Cont.)

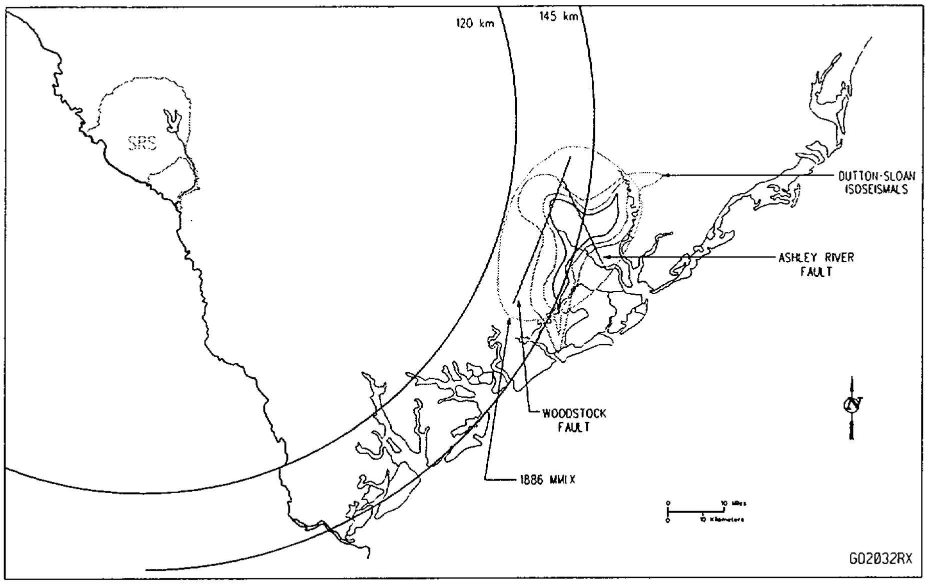
- Ellenton (MMI VI) (report- "The first and severest shook houses at a terrible rate. Six shocks felt in a little over an hour; others of less force perceptible to 8 a.m. A roaring as of heavy thunder could be heard for some time before and after each disturbance. Persons differ as to the direction: not much damage")
- Aiken MMI VI (report- "Church bells rang. Frame house, two stories, on brick piers: house rocked, window-weights rattled, pictures thrown down, plaster cracked")
- Beech Island (MMI V) (report- "Alarm among men and animals")

August 31, 1886 Charleston Earthquake (Cont.)

- Felt area of about $5x10^6$ km^2 (radius of over 1200 km)
- Inferred magnitude (Mw) 7.3 (based on areas of MMI isoseismals)



Bollinger Re-interpretation of 1886 Charleston reported intensities



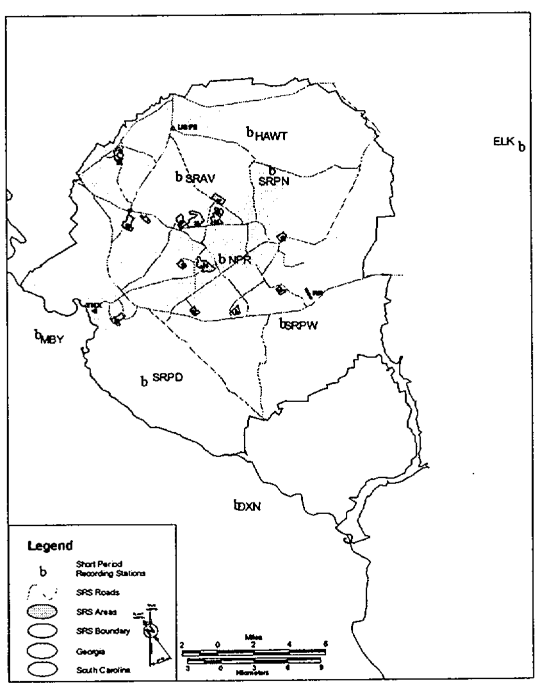
1886 Charleston Epicentral Area

Data Supporting Geographic Uniqueness of "Charleston"-type Earthquakes

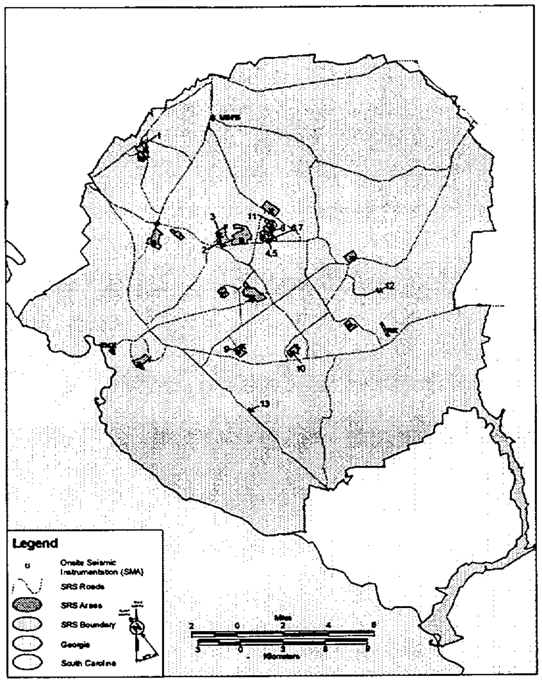
- Contemporary instrumental seismicity suggests well defined source zone, not diffuse and scattered.
- 1886 MMI X area and identified liquefaction zones are within this area of current seismicity.
- Inferred Woodstock and Ashley river faults as probable causative source.
- Paleoseismic data help constrain location, ages and magnitudes of prehistoric earthquakes; nearly all consistent with a central South Carolina coastal event.

Paleoearthquake Ages (Talwani & Schaeffer, 2001)

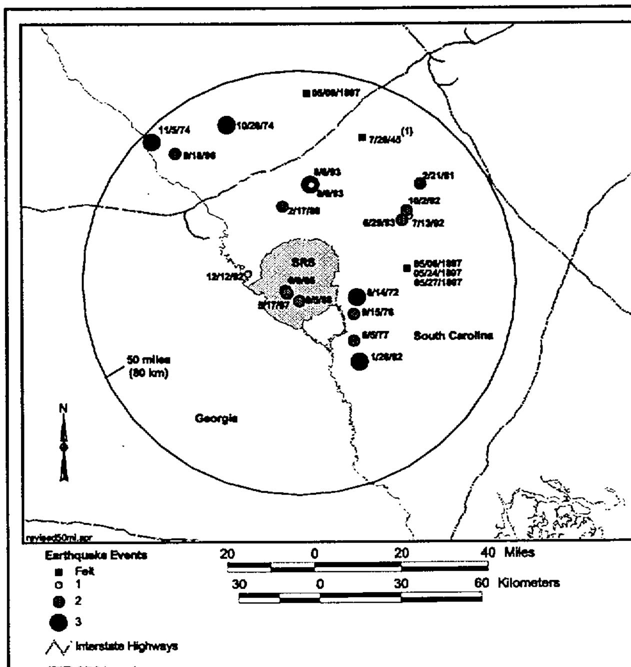
Episode	Age (yr BP)	Scenario 1 Source	Scenario 1 Mw	Scenario 2 Source	Scenario 2 Mw
1886 AD	115	Char.	7.3	Char.	7.3
A	548	Char.	7+	Char.	7+
B	1023	Char.	7+	Char.	7+
C	1650	north	~6	-	-
C'	1685	-	-	Char.	7+
D	1968	south	~6	-	-
E	3550	Char.	7+	Char.	7+
F	5040	north	~6	Char.	7+
G	5800	Char.	7+	Char.	7+



SRS short period recording stations



SRS strong motion instrumentation



(1) This event is mislocated. Based on a review of the historical accounts, this event is most probably located between Columbia and Newberry, SC.

Historical earthquakes within 50 mile radius of SRS (VPI, 2001)

Earthquakes in the Vicinity of the SRS

- Earthquake recorded in the site vicinity range in magnitude from about 1-3 (magnitude threshold for SRS network is about M 0).
- Felt earthquakes at the SRS occurred in 1985 (M 2.7), 1988 (M 2.2) and 1997 (M 2.5).
- Since 1976, the level of motions recorded at the site are less than 0.01g.
- Estimated historic earthquake levels of motion that would have been measured at the SRS are estimated to be less than 0.1g.

DUKE COGEMA
STONE & WEBSTER

SRS Site-Specific PSHA
Development of Bedrock Spectra

J. K. Kimball
DP-45, NNSA
19 September 2001

SRS DESIGN SPECTRA

DEVELOPMENT OF ROCK SPECTRA

Implementation of DOE Standard 1023-95 {Change Notice #1}

Establishing the Design Basis Earthquake (DBE)

- ✓ **Complete Probabilistic Seismic Hazard Analysis and Establish Mean Uniform Hazard Spectra**
- ✓ **Deaggregate the PSHA and Determine the Controlling Earthquakes**
- ✓ **Using Controlling Earthquakes Determine if the UHS is Sufficiently Broad to Represent Design Spectra**
- ✓ **Review Historic Earthquake Record and Determine if Site is <200 km of a M>6 earthquake – calculate ground motion**

SRS DESIGN SPECTRA DEVELOPMENT OF ROCK SPECTRA

Implementation of DOE Standard 1023-95 {Change Notice #1}

- ✓ **Establishment of DBE Depends on Facility Hazard Category, Classification of Structures, Systems, and Components and Link to Natural Phenomena Performance Categories**
  - **Performance Category (PC)3 = 5×10^{-4} per year (mean)**
  - **PC4 = 1×10^{-4} per year (mean)**
- ✓ **The 1886 Charleston Earthquake triggers the Historic Check – Assumed M = 7.3 @ 120 km distance**
- ✓ **The DBE is Established Based on the Envelope of the UHS and the Historic Earthquake**

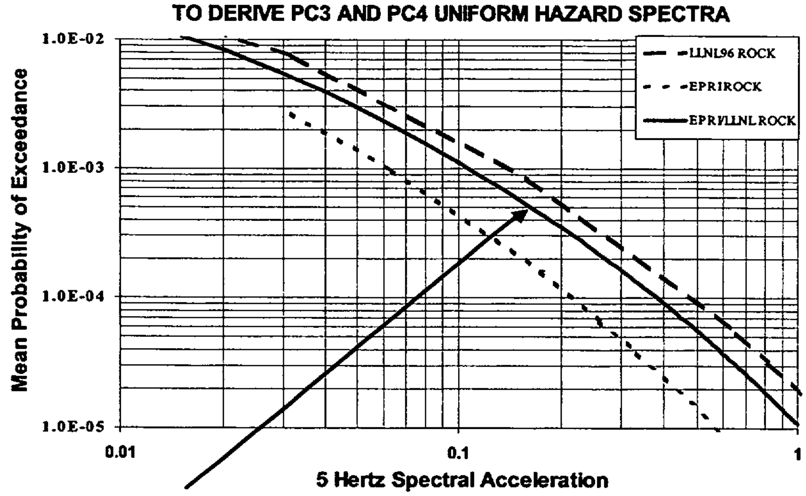
<u>While DOE-STD-1023 Was Developed in Advance of NRC Regulatory Guide 1.165 There Are Many Common Procedural Steps Between the Two Set of Requirements</u>

SRS DESIGN SPECTRA DEVELOPMENT OF ROCK SPECTRA

Execution of DOE STD 1023 @ SRS

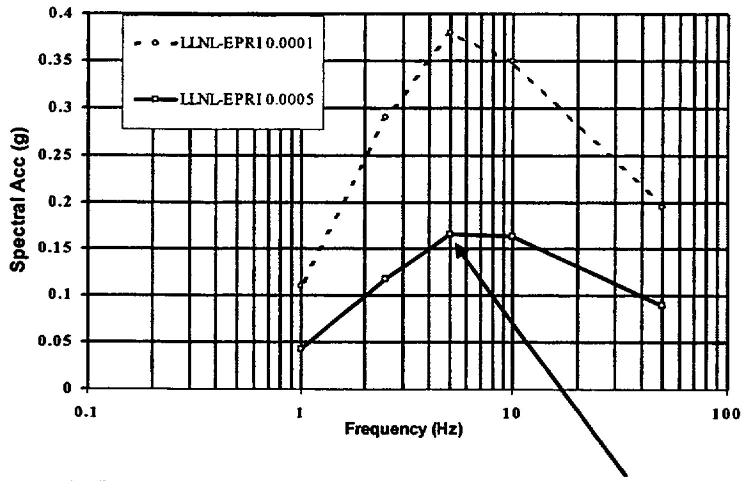
- ✓ **EPRI and LLNL Mean Rock PSHA Results Are Averaged**
  - **Decision Made to Perform Site Specific Soil Response Assessment to Ensure that Site Amplification Conservatively Quantified**
- ✓ **Using Combined EPRI/LLNL PSHA Curves Develop UHS at mean annual probabilities of $5x10^{-4}$ [PC3] and $1x10^{-4}$ [PC4]**
- ✓ **Check UHS Spectral Shape Using Deaggregated Controlling Earthquakes – Scale Rock Spectral Shapes at Average of 1 & 2.5 Hz., and at Average of 5 & 10 Hz.**
- ✓ **Develop PC3 and PC4 PSHA Rock Envelope**
- ✓ **Develop PC3 and PC4 Rock Spectra for Historic Earthquake Check**
- ✓ **Use Rock PSHA and Historic Check Spectra as Input to Soil Response Assessment to Develop SRS Soil Surface DBE**

SRS ROCK PSHA - ORIGINAL HAZARD CURVES
DEVELOPMENT OF COMBINED EPRI/LLNL HAZARD CURVES
TO DERIVE PC3 AND PC4 UNIFORM HAZARD SPECTRA



ROCK COMBINED EPRI/LLNL 5 Hz VALUE @ .0005 [PC3] SA=0.165g

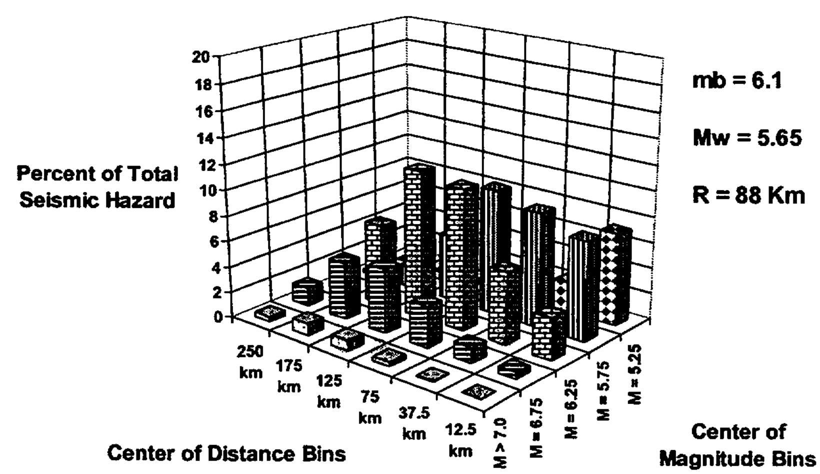
SRS ROCK PSHA - UNIFORM HAZARD SPECTRA
BASED ON COMBINED EPRI/LLNL



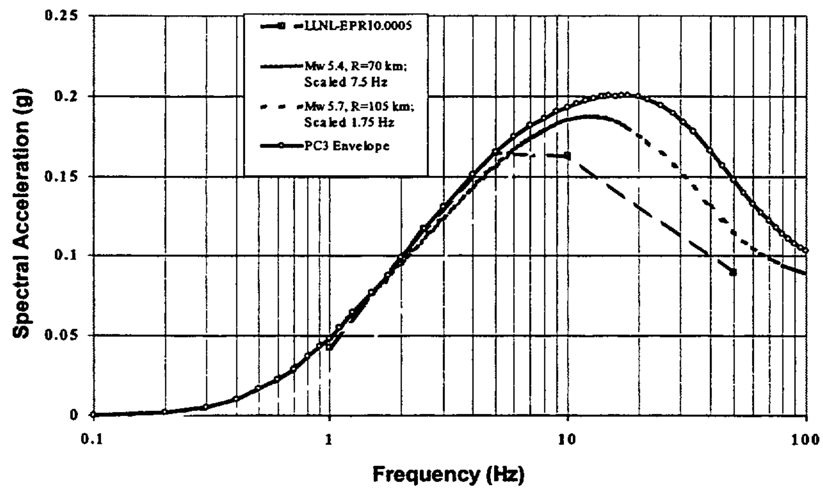
EPRI/LLNL COMBINED ROCK 5 Hz VALUE @ .0005 [PC3]
SA= 0.165g

Savannah River Site - EPRI Rock Seismic Hazard Deaggregations

5-Hz at a mean annual probability of .00016 / yr. Sa value = 0.194g

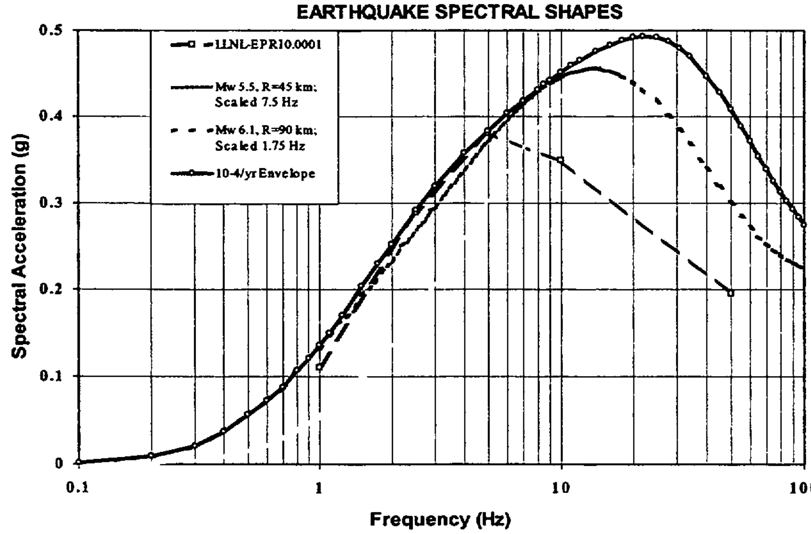


DEVELOPMENT OF PC3 PSHA ENVELOPE: SRS ROCK 5% Damping
ORIGINAL 5E-4/yr EPRI/LLNL UHS ADJUSTED USING CONTROLLING EARTHQUAKE SPECTRAL SHAPES



7

DEVELOPMENT OF PC4 PSHA ENVELOPE: SRS Rock 5% Damping
ORIGINAL 1E-4/yr EPRI/LLNL UHS ADJUSTED USING CONTROLLING EARTHQUAKE SPECTRAL SHAPES



8

DUKE COGEMA
STONE & WEBSTER

SRS Site-Specific PSHA
Development of Soil Surface Design Spectra

R. Lee
WSRC
19 September 2001

WSRC Approach to Develop Design Spectra

- Implement DOE-STD-1023 seismic design criteria
- Review and apply DOE recommended PSHA's
- Characterize SRS-wide soils and shallow bedrock
- Evaluate SRS Site Soil Response
- Make site specific adjustments to rock PSHAs to correct for SRS conditions
- Develop SRS PC-3 and PC-4 design basis
- Evaluate SRS specific soil UHS.
- Use high-gain sensors to monitor seismicity.

Scope of Spectra Development

- Smooth PC-3 and PC-4 surface spectra that could be applicable site-wide
- Appropriate for simple response analysis
- Incorporate available soil properties to about mid-1996
- Incorporate EPRI and LLNL bedrock PSHAs
- Requires review of site-specific conditions prior to site application of spectrum

Approaches to Develop SRS-Specific Design Basis

- Use SRS-specific ground motion attenuation model(s) in the conduct of the PSHA
- Evaluate PSHA for a reference rock outcrop site condition and apply mean SRS soil surface/bedrock amplification function.
- Evaluate PSHA for the reference bedrock condition and compute soil surface hazard using SRS-specific amplification functions.

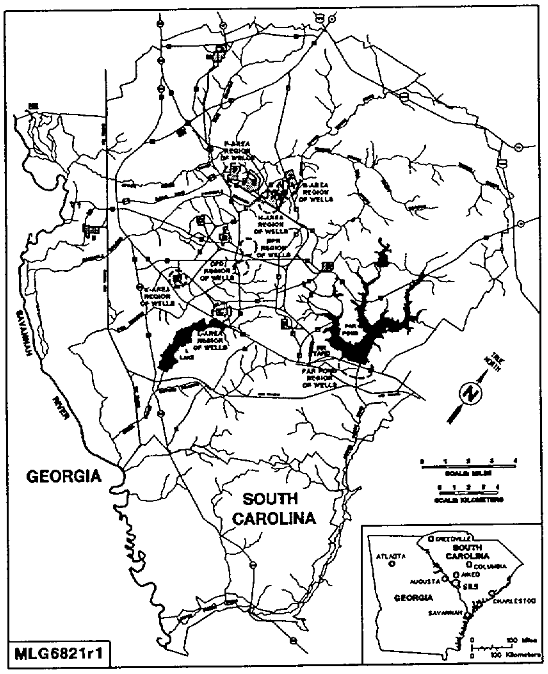
4

Evaluate SRS Response-

Site Amplification Analysis

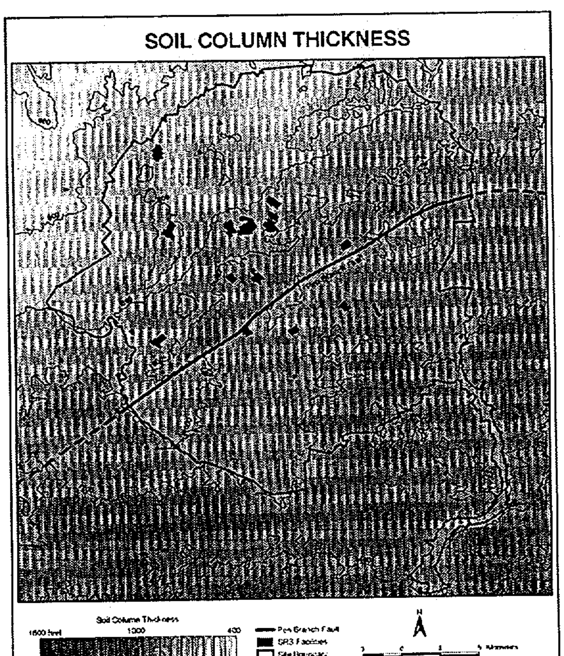
- Use large SRS geophysical and geotechnical database to establish variability in soil velocity profiles, ranges in soil column thickness and strain-dependence of soils
- Use equivalent linear analysis to handle strain-dependence of soil
- Establish frequency, magnitude and ground motion level dependent site response distributions by ranges in soil column thickness and bedrock type

5



Areas where samples used to develop SRS-specific dynamic properties were collected

6



Soil column thickness across the SRS and Pen Branch Fault (WSRC-TR-97-0085)

7

SRS Shear-Wave Model

- Database of soil velocities and dynamic properties compiled from eight areas of the SRS (176 Vs profiles)
- Data limited in some facility areas and not available outside facility areas
- Five shear-wave profiles available for soil depths > 300 ft.
- Measured soil profiles used to derive a statistical shear-wave model that can be used to generate profiles having the appearance and statistical qualities of the measured profiles (EPRI, 1993).
- Measured variability incorporated in site response.

SRS Shear-Wave Model (Cont.)

- SRS soil database combined into one "generic" model
- Randomized profiles from SRS generic model show variability similar to observed SRS profiles
- Similar analysis conducted for F-, H- and A-Areas show similar medians and sigmas as compared to "generic" model.
- Because of the similarity of the results, the "generic" model was deemed appropriate for use SRS-wide with confirmation.

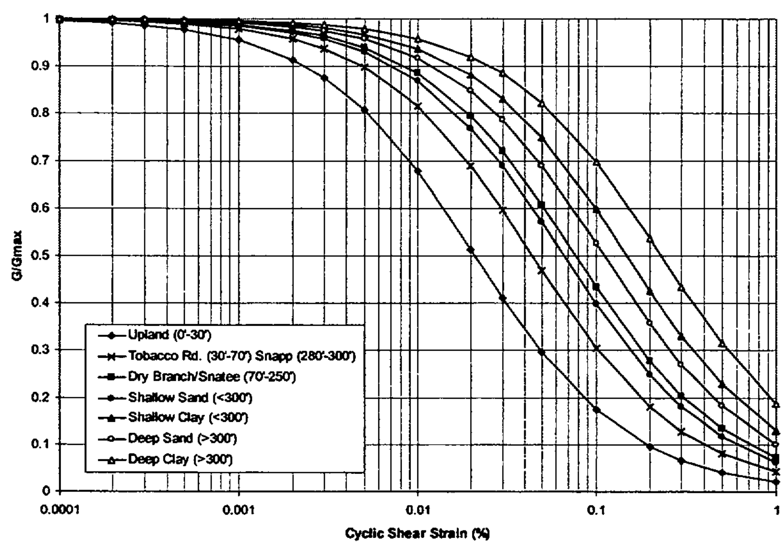
SRS Dynamic Soil Properties

- UTA employed to make dynamic property recommendations for the SRS:
  - review existing SRS dynamic property database
  - test SRS soil samples using calibrated equipment
  - construct dynamic property database and evaluate SRS soils for correlations with nonlinear dynamic properties
  - provide recommendations for dynamic soil properties
- Testing data was reviewed from 29 reports
- Dynamic property database was compiled for 8 different site areas

Dynamic Soil Properties (Cont)

- 72 resonant column (RC) and 15 torsional shear (TS) tests were completed by UTA
- RC and TS tests were completed on same samples in same device
- G/Gmax consistent between RC and TS
- Frequency dependent effects were discovered in RC damping results suggesting a high-damping bias.
- Damping recommendations based on TS data only.

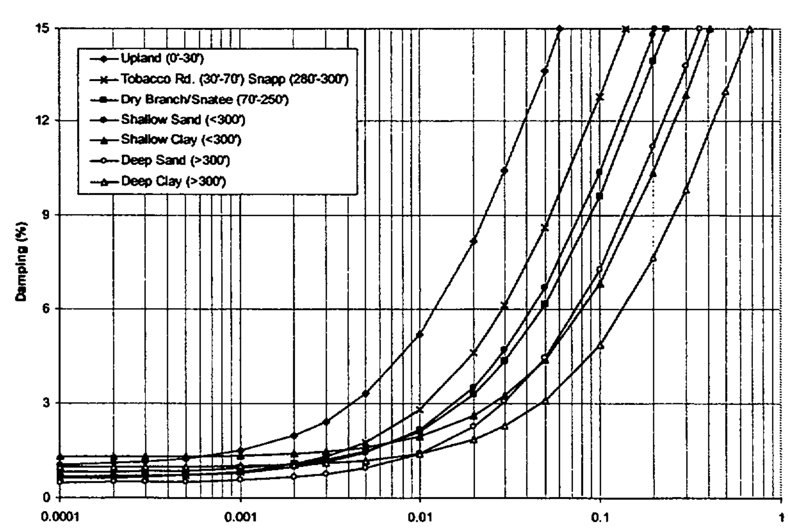
SRS Recommended G/Gmax



(from WSRC-TR-96-0062)

12

SRS Recommended Damping

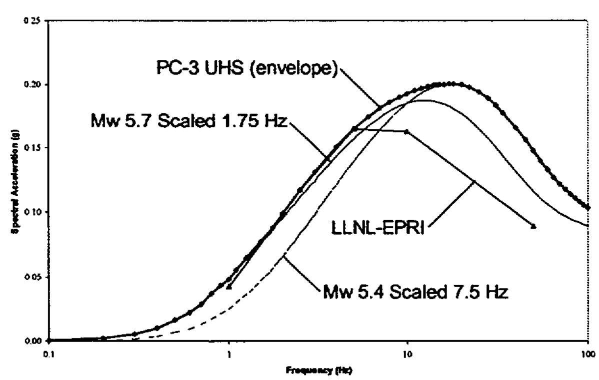


(from WSRC-TR-96-0062)

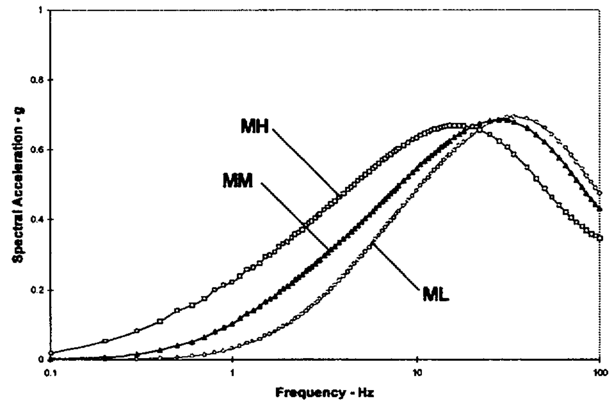
13

Development of Site Amplification Functions

- Equivalent linear model used to model site response of a given soil profile to a selected bedrock input control motion.
- Vs(h), ρ(h), $G/G_{max}(\gamma,h)$ and $D(\gamma,h)$ were randomized to match distributions observed in the field or laboratory.
- For a given bedrock control motion, a distribution on the site response is derived.
- Choice of the bedrock control motion magnitude and level of motion is selected on the basis of the ranges used in the EPRI hazard deaggregation.

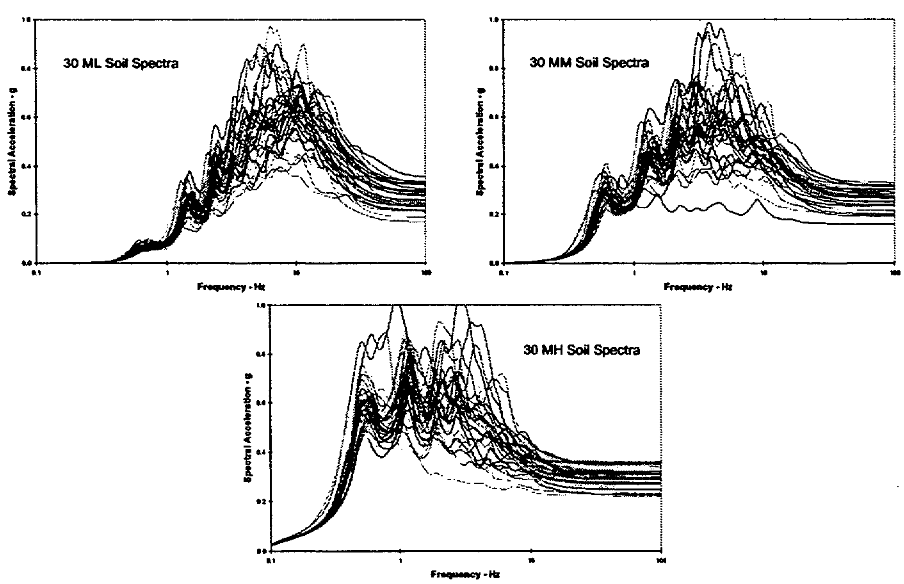


(a) SRS Broadened Rock Uniform Hazard Spectra (UHS) are the basis for generating a Soil UHS (free surface).



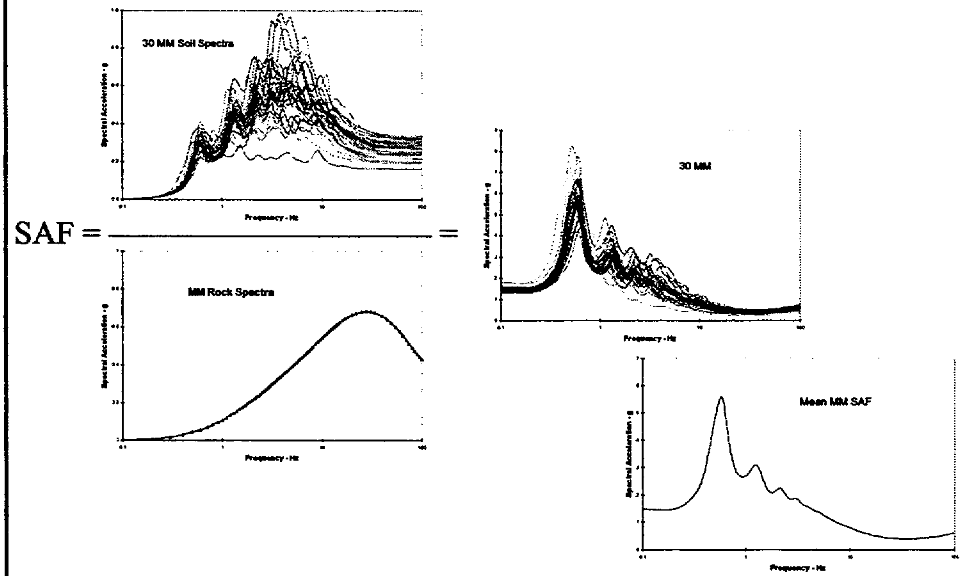
(b) Three bedrock control motion spectra representing low (ML), medium (MM), and high (MH) magnitude were generated for each suite of Peak Ground Acceleration (PGA) levels (0.05, 0.1, 0.2, 0.25, 0.3, 0.4, 0.5 and 0.75g) and each SRS bedrock type (crystalline and Triassic). The bedrock control motion PGA levels and magnitudes, are based on the EPRI de-aggregation. The distances were varied to produce the desired PGA levels.

16



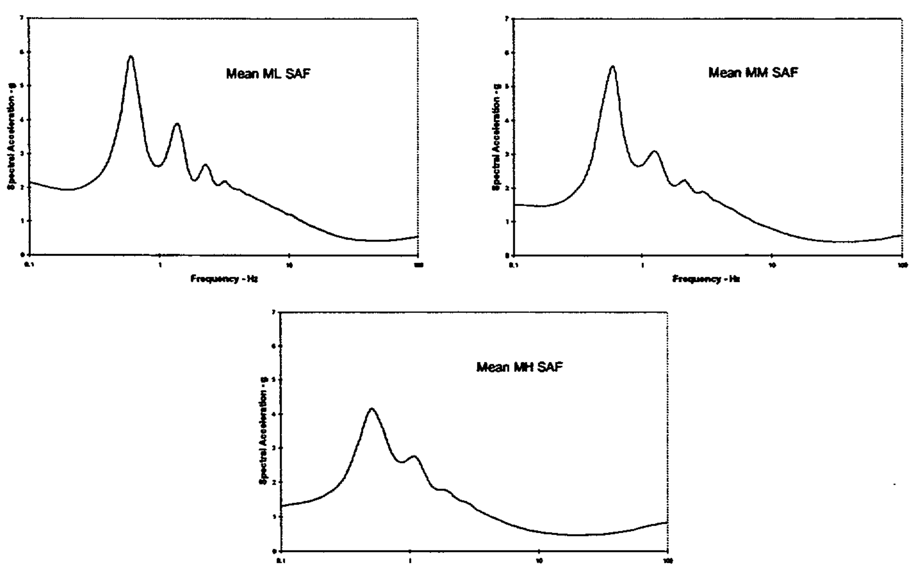
(c) Thirty convolution analyses (corresponding to 30 different soil profiles) are performed for each bedrock control motion (30 convolution analyses x 9 PGA levels x 3 magnitudes x 2 bedrock types). The convolution analyses are also performed for 3 depth ranges.

17



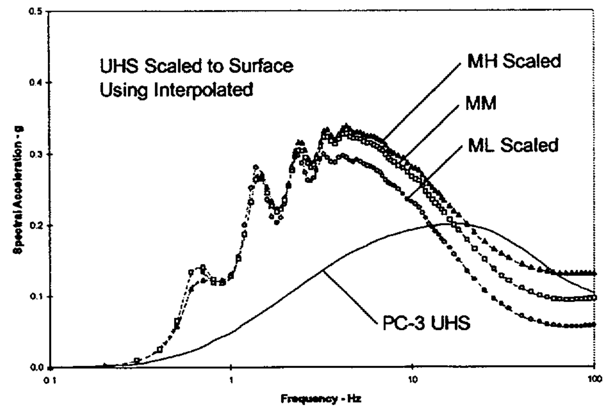
(d) Thirty Spectral Amplification Functions (SAFs) are calculated for each bedrock control motion and depth range. The 30 SAFs are averaged to get a mean SAF for each bedrock control motion, PGA level and depth range.

18

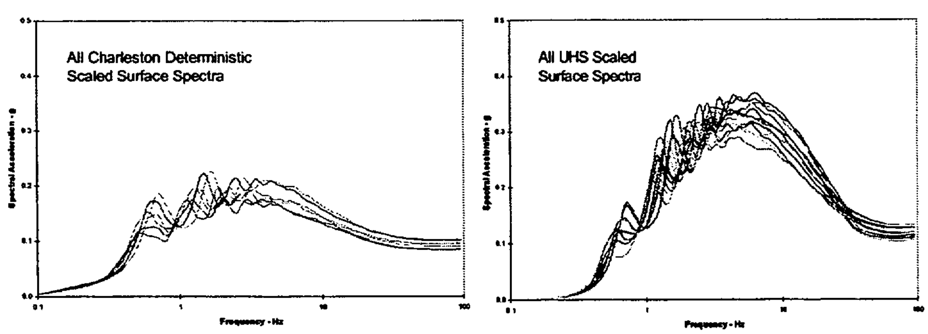


(e) Each PGA level, bedrock type and depth range has three mean SAFs representing low, medium, and high magnitude.

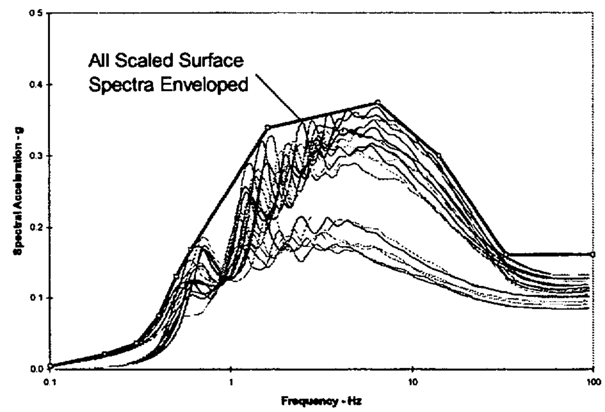
19



(f) The appropriate mean SAFs are interpolated to provide SAFs to scale the UHS to surface.



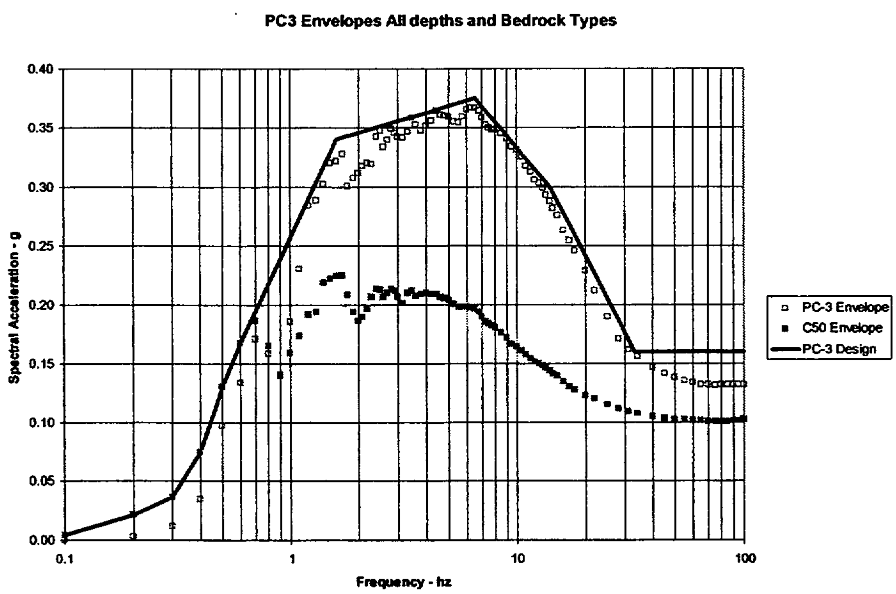
(g) The same scaling process is repeated for the Charleston deterministic check. Soil response for UHS scaling and Charleston scaling can then be compared.

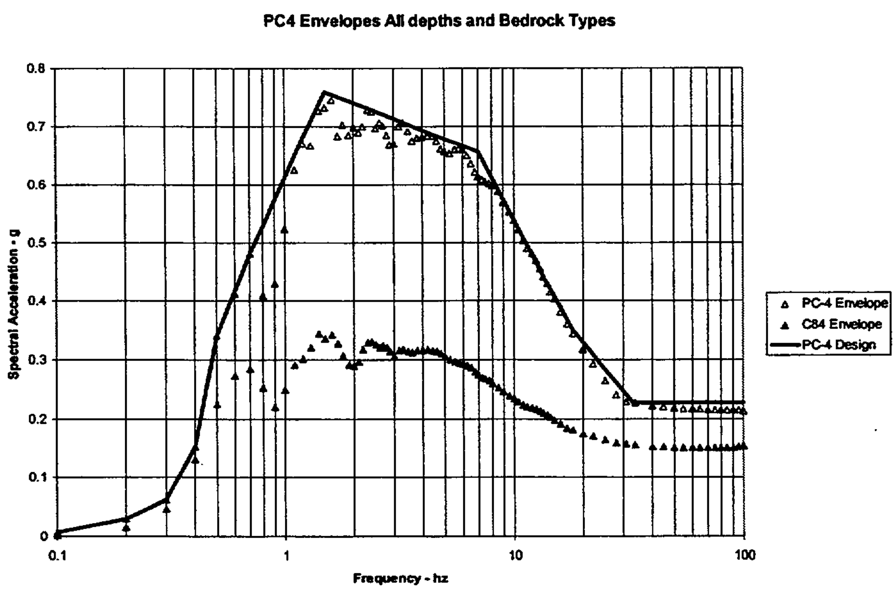


(h) The UHS and Charleston surface responses (low, medium, and high magnitude surface responses for each bedrock type and depth range) are then enveloped.

SRS Site-wide Spectra

- Historic Earthquake Check
  - Compute RVT spectrum for a repeat of Charleston earthquake (50th and 84th percentile motions)
  - Source properties: Mw 7.3; $\Delta\sigma$ = 150 bars; R = 120 km
- Charleston RVT motions use EPRI (1993) median anelastic attenuation model
- Soil, bedrock and crustal properties were varied.


PC3 Envelopes All depths and Bedrock Types
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Spectral Acceleration - g
0.1
1
10
100
Frequency - hz
PC-3 Envelope
C50 Envelope
PC-3 Design


PC4 Envelopes All depths and Bedrock Types
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Spectral Acceleration - g
0.1
1
10
100
Frequency - hz
PC-4 Envelope
C84 Envelope
PC-4 Design

Parameters Important to Site Spectra

- In order of importance
  - soil shear-wave velocity
  - bedrock shear-wave velocity (f< 2 Hz)
  - shear-wave modulus and damping (f > 10 Hz)
  - soil column thickness (f < 4 Hz)
- Other important source and path parameters
  - Charleston source distance and stress drop
  - Crustal structure
- Bedrock PSHA

26

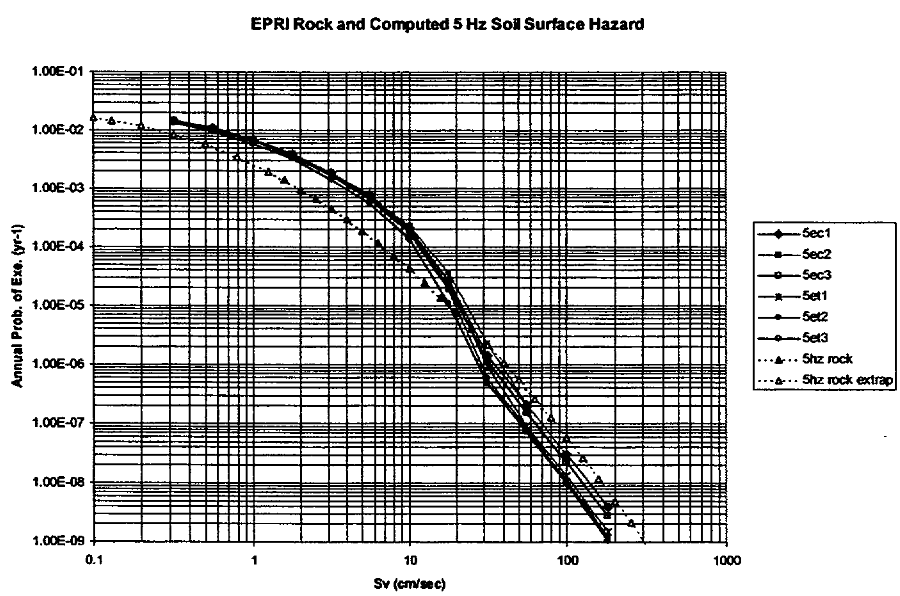
Validation of Site Response Methodology

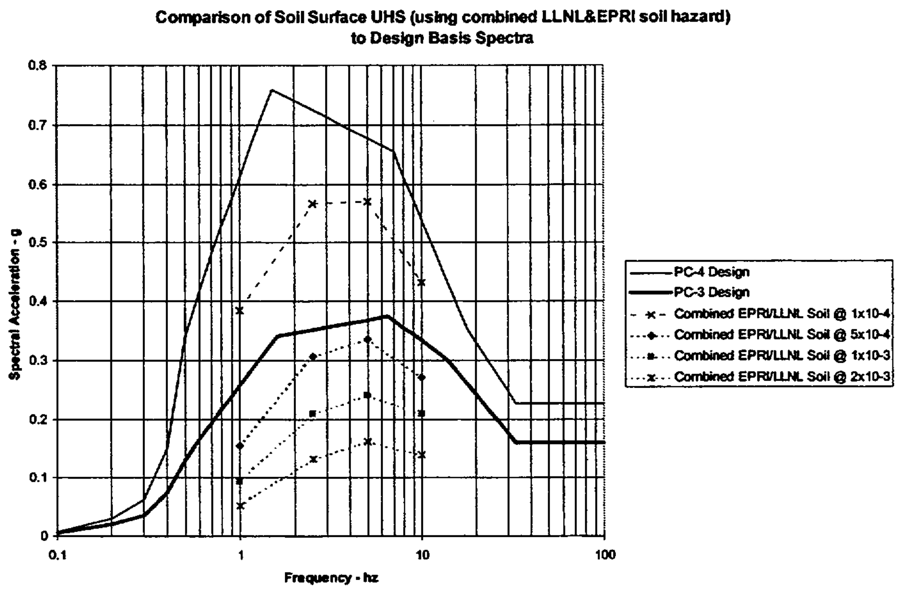
- A methodology was devised to validate the approach of scaling the bedrock UHS with a mean site amplification function to achieve a design earthquake spectrum.
- The Cornell/Bazzuro methodology was adopted to assure that a mean hazard level is achieved at the soil surface
- This method essentially allows one to compute a soil hazard curve from a bedrock hazard curve
- Confirms that the SRS PC-3 and PC-4 design spectra meet or exceed the combined EPRI and LLNL hazard goals of $5x10^{-4}$/yr and 10^{-4}/yr respectively.

27

Development of SRS-Specific Soil Surface Hazard

- For each oscillator frequency, a bedrock hazard curve and corresponding earthquake magnitude and distance deaggregation is required.
- For each level of bedrock motion (contained in the hazard curve), a magnitude dependent bedrock-to-surface soil amplification distribution function is required.
- Resulting hazard curve is SRS-specific.





30

Summary

- DOE-STD-1023 implemented at SRS using SRS-wide properties and their variability.
- Mean EPRI and LLNL bedrock PSHAs were used as well as deterministic assessments of motions for the "Charleston" earthquake.
- SRS mean soil amplification functions were used to scale bedrock results.
- Envelope of scaled bedrock results were found to be conservative using the Cornell methodology.
- Site-specific assessment required before application of PC-3 or PC-4 design spectra.

31

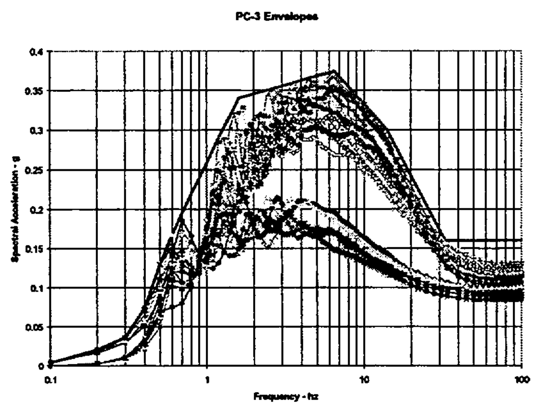
DUKE COGEMA
STONE & WEBSTER

Site PC-3 Design Spectrum Modification

B. Gutierrez
Engineering & Analysis Division, DOE-SR
19 September 2001

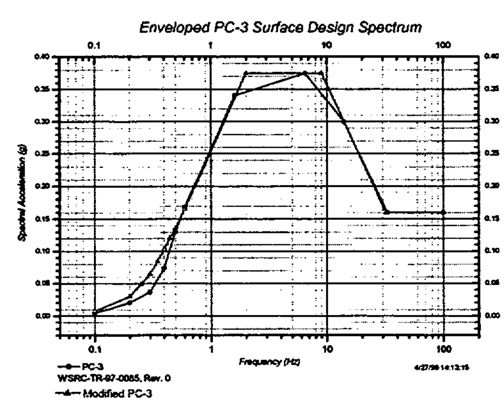
Original PC-3 Design Spectrum

- WSRC-TR-97-0085, Rev. 0
- Site Standard 01060, Rev. 3



Modified PC-3 Surface Design Spectrum

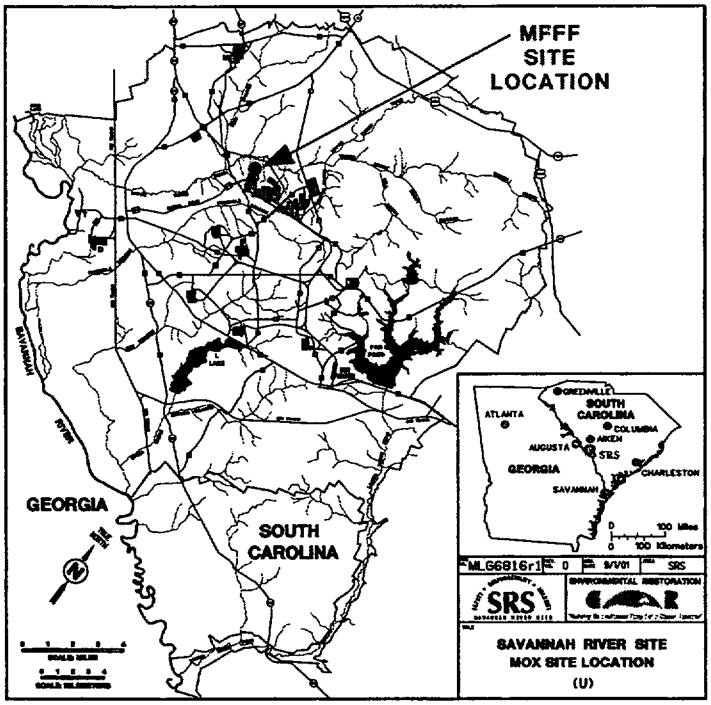
- Re-drawn surface design spectrum envelope consistent with traditional spectral shapes
- Site Standard 01060, Rev. 4



DUKE COGEMA
STONE & WEBSTER

MFFF Site Confirmation of SRS PC-3 / PC-4 Spectra

M. Lewis
WSRC
19 September 2001



2

MFFF Site Confirmation

- According to;
  - WSRC-TR-97-0085 (WSRC 1997) and site standards
- Site spectra development (WSRC 1997) based on available data through mid 1996
- Confirmation ensures site-specific conditions have been incorporated

3

MFFF Site Confirmation

- Criteria
  - Site surface topography
    - No unusual features that could affect ground motion
  - Stratigraphy
    - Ensure consistency with conditions modeled
  - Soil column thickness
    - Ensure it is within conditions modeled
  - Bedrock type
    - Ensure it is within conditions modeled

MFFF Site Topography

- Surface topography
  - The MFFF site is located on the northeast side of F area. The surface topography is consistent with the General Separations Area (GSA)
  - There are no unusual naturally (the existing fill spoil pile will be removed) occurring surface topographic conditions
  - The conditions are consistent with assumptions used in WSRC 1997 report

Stratigraphy

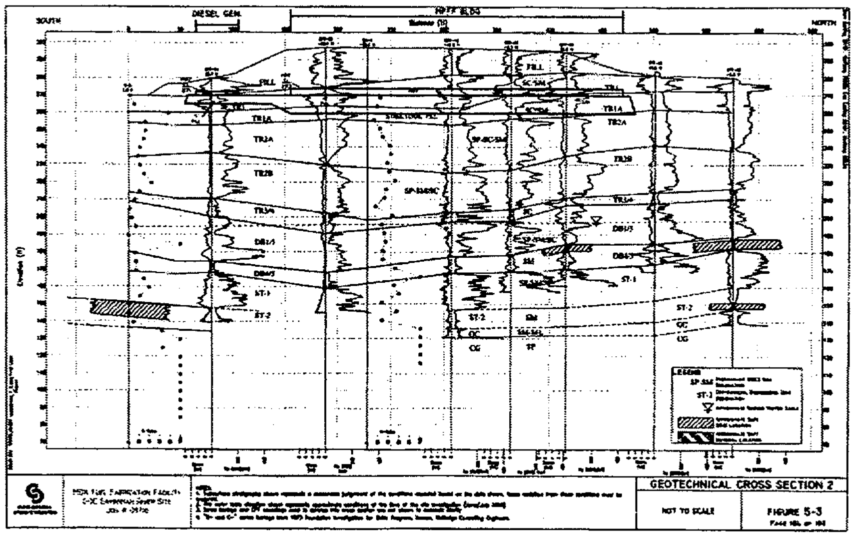
- Criteria
  - Local geologic layering
  - Dynamic properties
  - Shallow V_s profile

6

MFFF Stratigraphy

- Horizontal layering
- Sands, silty sands and clayey sands
- Thicknesses consistent across distances of interest
- Consistent with other areas of SRS

7



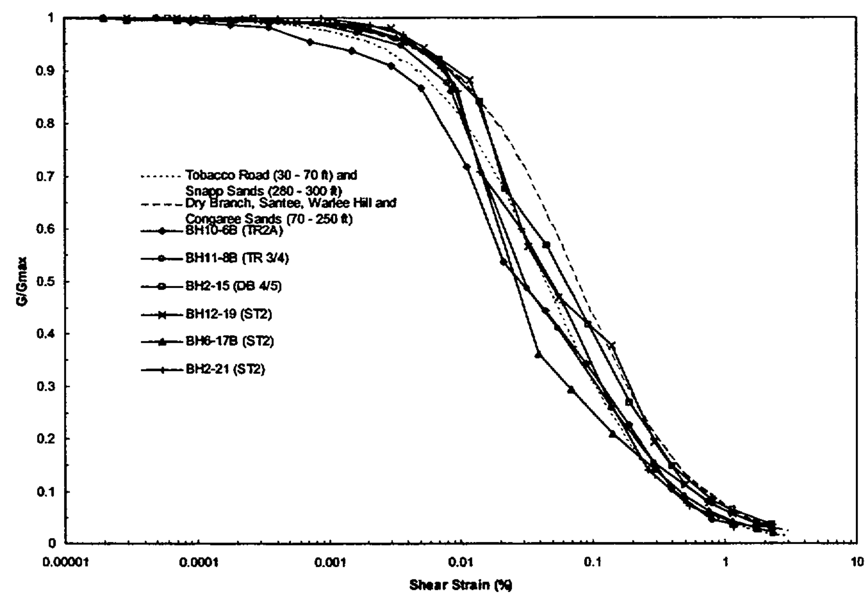
From MOX Fuel Fabrication Facility Site Geotechnical Report

8

Stratigraphy

- Dynamic properties
  - Dynamic properties are well established for SRS WSRC-TR-96-0062 (WSRC 1996)
  - The properties are linked to geologic formations (WSRC 1996)
  - Confirmatory tests were conducted by DCS
    - Modulus reduction data compares well
    - Damping is relatively high at low strain (related to testing equipment)

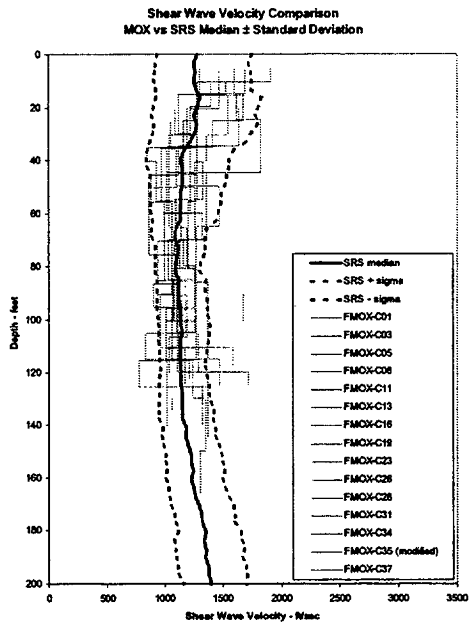
9



From MOX Fuel Fabrication Facility Site Geotechnical Report

Stratigraphy

- Shallow shear wave velocity, V_s, profile
  - MFFF velocity profiles were evaluated and compared to WSRC 1997
  - Results show excellent overall agreement
  - Results are also consistent with results in F area



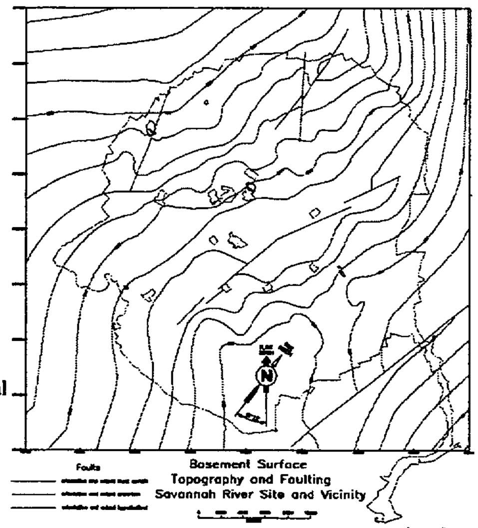
12

Soil Column Thickness

- The MFFF site is in F area within the GSA of the SRS
- Bedrock in F area is approximately 900 feet below ground surface
- MFFF falls within depth range 3 (800 to 1,000 ft) analyzed as part of WSRC 1997

13

We have numerous control points to make a basement topographical surface map. Basement rocks are the igneous, metamorphic or Triassic rocks that lie beneath our unconsolidated sediments. Regional faults are shown.



Modified from Cumbest et.al., 2000

regional overview

Bedrock Type

- Based on existing data over the SRS and within the GSA, the MFFF site lies above crystalline bedrock, which was analyzed as part of WSRC, 1997

Conclusions

- There are no topographic or subsurface features at MFFF site that could alter ground motion over the cases modeled in WSRC 1997
- The soil column thickness and bedrock type at MFFF match ranges used in WSRC 1997
- The MFFF shallow V_s are within variances modeled in WSRC 1997
- Thus, SRS sitewide PC-3 & PC-4 spectra are applicable for the MFFF site

DUKE COGEMA
STONE & WEBSTER

Selection of MFFF Seismic Design Basis

J. M. McConaghy
19 September 2001

DUKE COGEMA
STONE & WEBSTER

MFFF Site Specific Criteria

- Development of MFFF site-specific criteria align with NRC-recommended approach
  - Detailed geological, seismological and geotechnical investigations
  - PSHA
    - PC-4 target 10^{-4} mean
    - RG-1.165 target 10^{-5} median
      - based on comparison to existing reactors
      - if mean were used, would be 10^{-4}
    - PC-3 Selected to be about an order of magnitude more likely

DUKE COGEMA
STONE & WEBSTER

- Development of MFFF site-specific criteria align with NRC-recommended approach (cont)
  - Deaggregation to determine controlling earthquakes
  - Develop response spectrum shapes
  - Compare and envelope UHS spectra as applicable.

MFFF Site-Specific Criteria (cont)

DUKE COGEMA STONE & WEBSTER

- DOE practices used in developing MFFF site-specific criteria meet the intent of NRC guidance in RG-1.165
- DCS has used this MFFF site-specific criteria to select the seismic design basis for MFFF

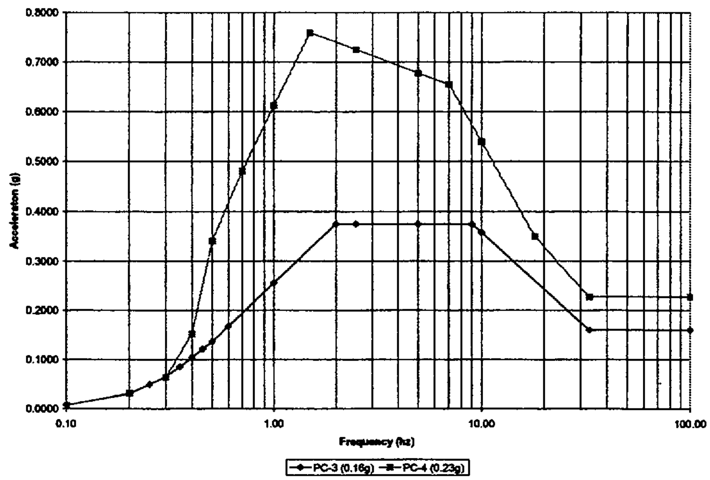
Selection of MFFF Seismic Design Basis

DUKE COGEMA STONE & WEBSTER

- MOX Standard Review Plan suggests a risk-informed approach.
- DCS observed PC-4 spectrum, applicable to reactor facilities, which MFFF is not.
- DCS selected a design spectrum somewhat higher than the 2,000-year PC-3.

DUKE COGEMA
STONE & WEBSTER

SRS Soil Surface Design Spectra



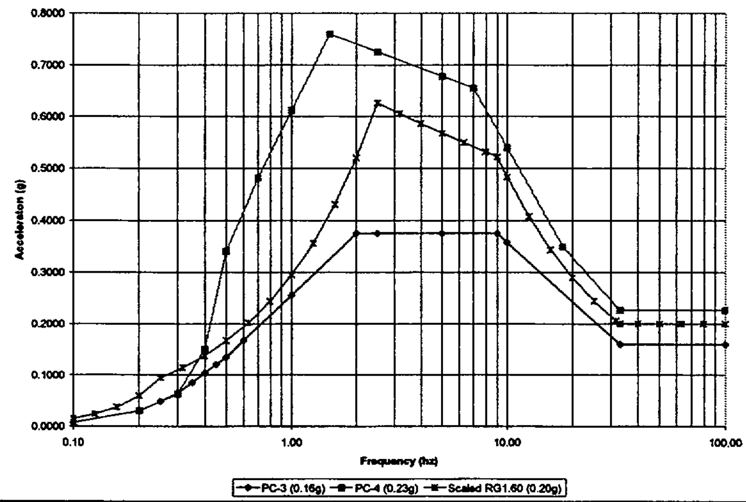
DUKE COGEMA
STONE & WEBSTER

Selection of MFFF Seismic Design Basis

- DCS selected a goal of approximately 10,000 year return period for accelerations at frequencies of practical structural interest.
- A standard Regulatory Guide 1.60 spectrum was scaled to 0.2g peak ground acceleration to meet this goal.
- The resulting spectrum is comparable to the design basis for nearby 10CFR50 facility.

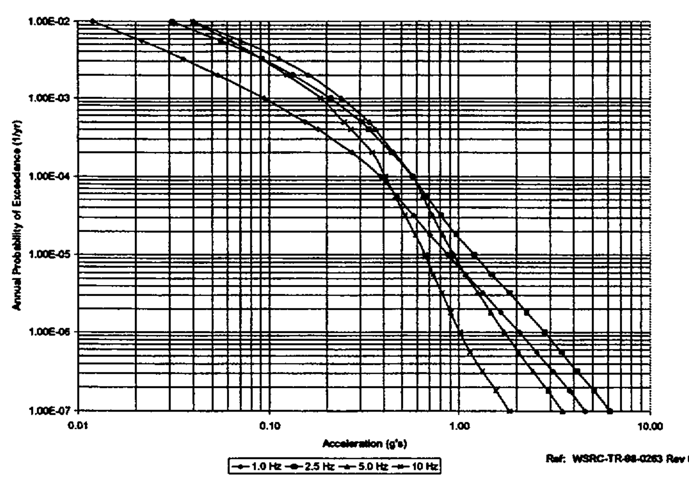
DUKE COGEMA STONE & WEBSTER

MFFF Soil Surface Spectrum Selection



DUKE COGEMA STONE & WEBSTER

SRS Soil Surface Hazard Curves



Spectral Ordinate Return Periods

DUKE COGEMA
STONE & WEBSTER

PC-3 (2,000-year) Spectrum (0.16g)

Frequency (Hz)	Sa (g)	Return (yr)
1.00	0.250	4,000
2.50	0.375	3,300
5.00	0.375	2,700
10.00	0.360	5,600

PC-4 (10,000-year) Spectrum (0.23g)

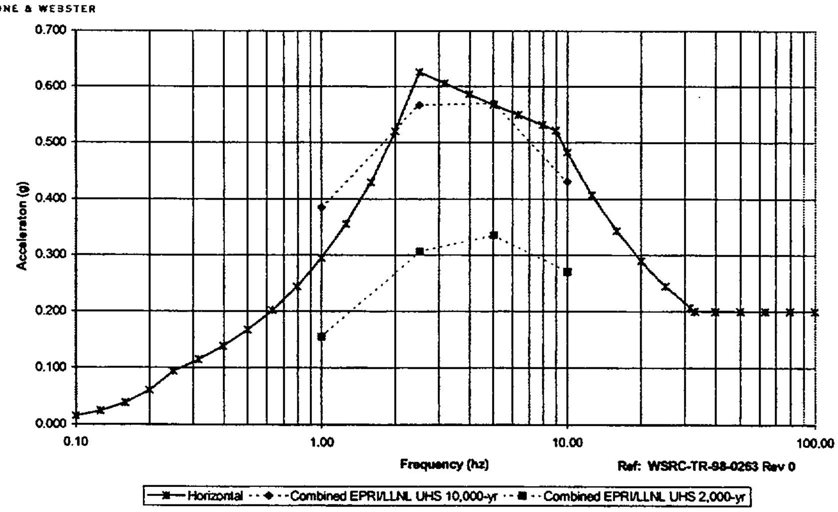
Frequency (Hz)	Sa (g)	Return (yr)
1.00	0.610	37,000
2.51	0.730	23,000
5.01	0.680	22,000
10.00	0.540	36,000

0.2g Regulatory Guide 1.60 Spectrum

Frequency (Hz)	Sa (g)	Return (yr)
1.00	0.300	6,300
2.51	0.620	14,000
5.01	0.570	10,000
10.00	0.480	22,000

Comparison to Soil Surface UHS (4 Points)

DUKE COGEMA
STONE & WEBSTER



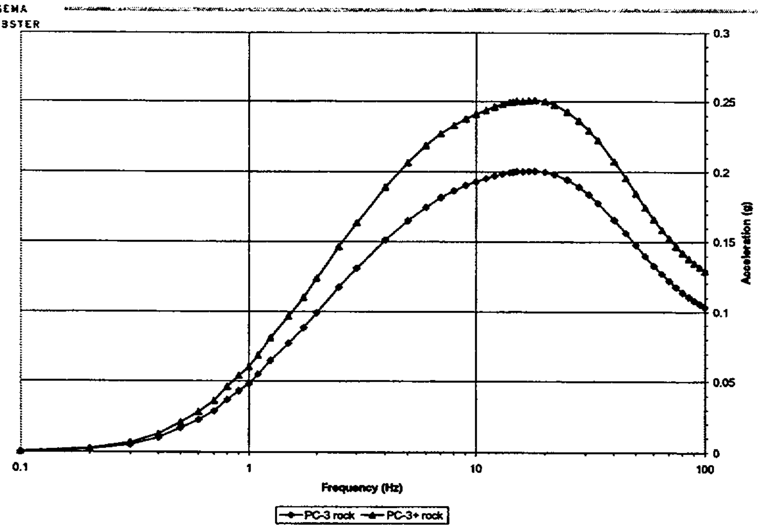
DUKE COGEMA
STONE & WEBSTER

MFFF Design Earthquake

- The technical basis for the MFFF design earthquake is the existing SRS PC-3 design spectrum.
- The design of the MFFF SSCs is based on a RG 1.60 horizontal soil surface spectrum shape scaled to 0.20g PGA.
- For soil stability analyses, bedrock motions based on the SRS PC-3 bedrock spectrum will be used, scaled so that when amplified through the site soil profile, the resulting surface ground motion will have 0.20g PGA.

DUKE COGEMA
STONE & WEBSTER

Bedrock Spectra



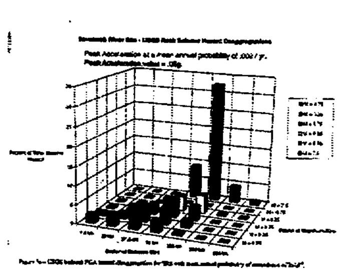
DUKE COGEMA
STONE & WEBSTER

Vertical Earthquake Component

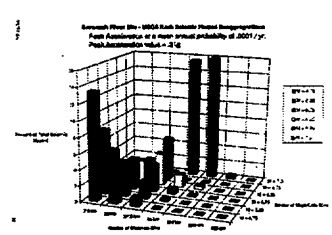
- CAR defines the vertical component as two-thirds the corresponding horizontal component.
- Review of magnitude-distance relations indicate that although the near-field earthquakes are not <u>dominant</u>, their contribution is potentially significant.

DUKE COGEMA
STONE & WEBSTER

USGS Seismic Hazard (PGA)



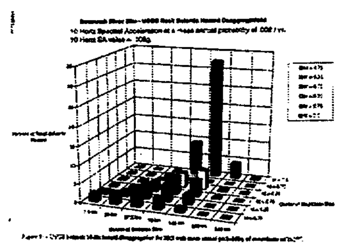
500-year



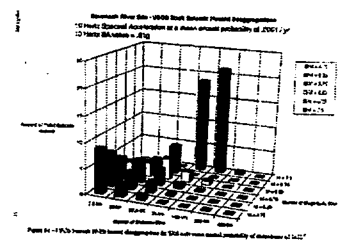
10,000-year

DUKE COGEMA STONE & WEBSTER

USGS Seismic Hazard (10-hz)



500-year



10,000-year

DUKE COGEMA STONE & WEBSTER

Vertical Earthquake Component

- DCS requested a site-specific study by WSRC.
- Results confirm that the vertical component can be expected to be greater than 2/3.
- DCS decided to increase the magnitude of the vertical spectrum component.

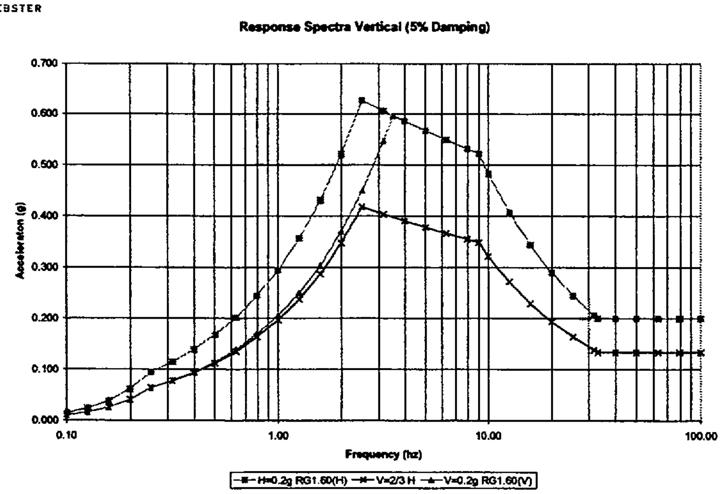
DUKE COGEMA
STONE & WEBSTER

Vertical Earthquake Component

- If near-field effects dominate, ASCE-4-98 recommends the ratio of vertical to horizontal spectral ordinates be taken as:
  - at least unity for frequencies above 5 Hz,
  - 2/3 for frequencies below 3 Hz,
  - and a transition between 3 Hz and 5 Hz.
- RG-1.60 vertical spectrum closely and conservatively approximates this.
- DCS has selected 0.2g RG-1.60 soil surface vertical spectrum for the MFFF design basis.

DUKE COGEMA
STONE & WEBSTER

Vertical Earthquake Component



MFFF Seismic Design Basis Summary

DUKE COGEMA STONE & WEBSTER

- Soil Surface Design Spectrum is selected to be 0.2g scaled RG-1.60 horizontal and vertical spectra
- For evaluation of soil stability (liquefaction and dynamic settlements), a 2,000-year UHS bedrock spectrum is scaled up to produce 0.2g PGA at the surface.

Consulting Board Endorsement

DUKE COGEMA STONE & WEBSTER

- MFFF Structural Consulting Board advises DCS in design matters.
- Members include Dr. Robert Kennedy, Dr Carl Costantino, Mr. Thomas Houston, and DCS subject matter experts
- SCB members concur that the seismic design basis selected is appropriate for MFFF.

DUKE COGEMA STONE & WEBSTER

Day 1 Summary

- SRS Site-wide criteria have been developed following practices that align with NRC expectations
- SRS Site-wide criteria also apply for the MFFF site.
- MFFF seismic design basis has been selected using SRS Site-wide criteria as a technical basis.

- Day 2 will discuss geotechnical engineering evaluations.