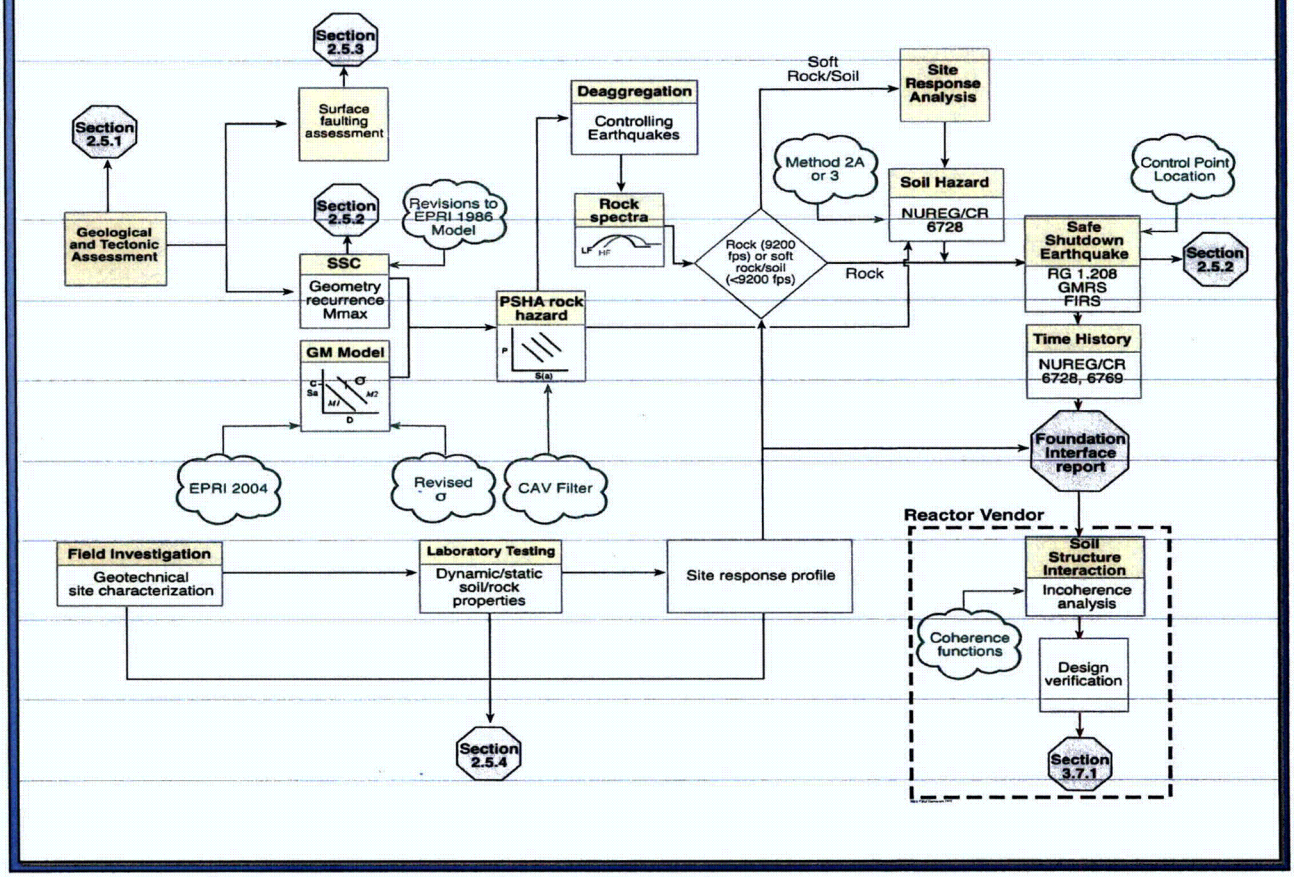
Overview of Seismic Hazard Analysis Program

Luminant Comanche Peak COLA

Dr. William Lettis
President & Senior Principal Geologist
William Lettis & Associates, Inc.

WLA

Seismic Hazard Analysis Program



Geotechnical Site Characterization

Luminant Comanche Peak COLA

Jeff Bachhuber

William Lettis & Associates, Inc.

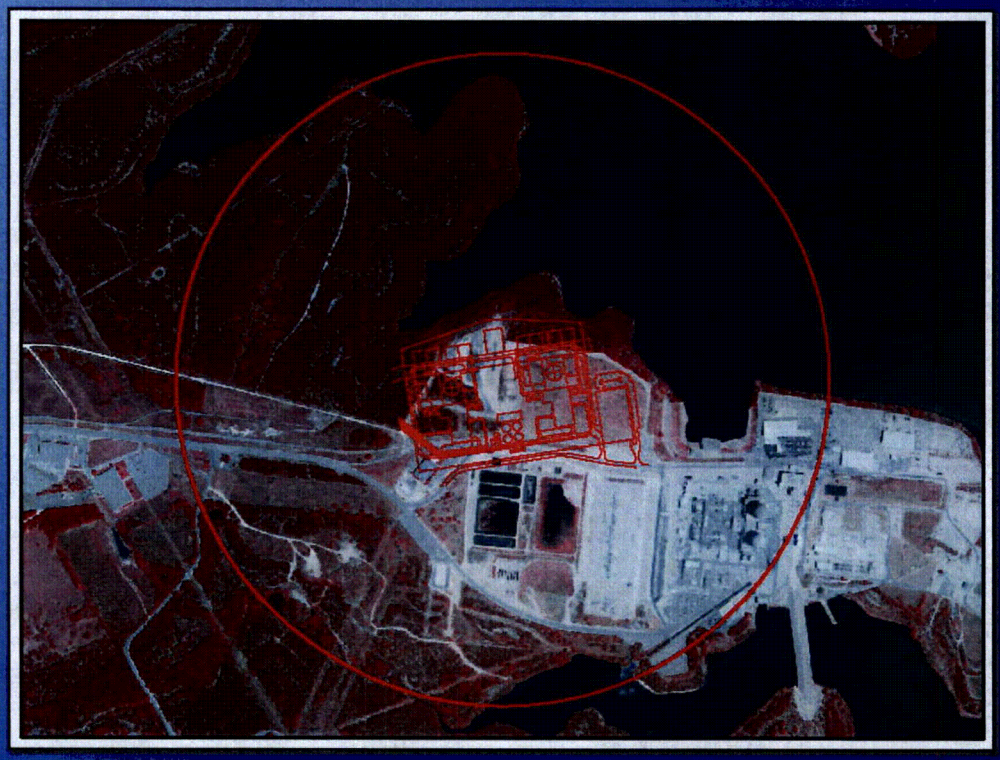
WLA

Project Status

- Site Conditions
- Geotechnical Program
  - Field Exploration
  - Laboratory Testing Program
  - Geotechnical Analysis
- Subsurface Conditions
- Geologic Mapping

WLA

0.6 Mile Imagery (1994-1997)



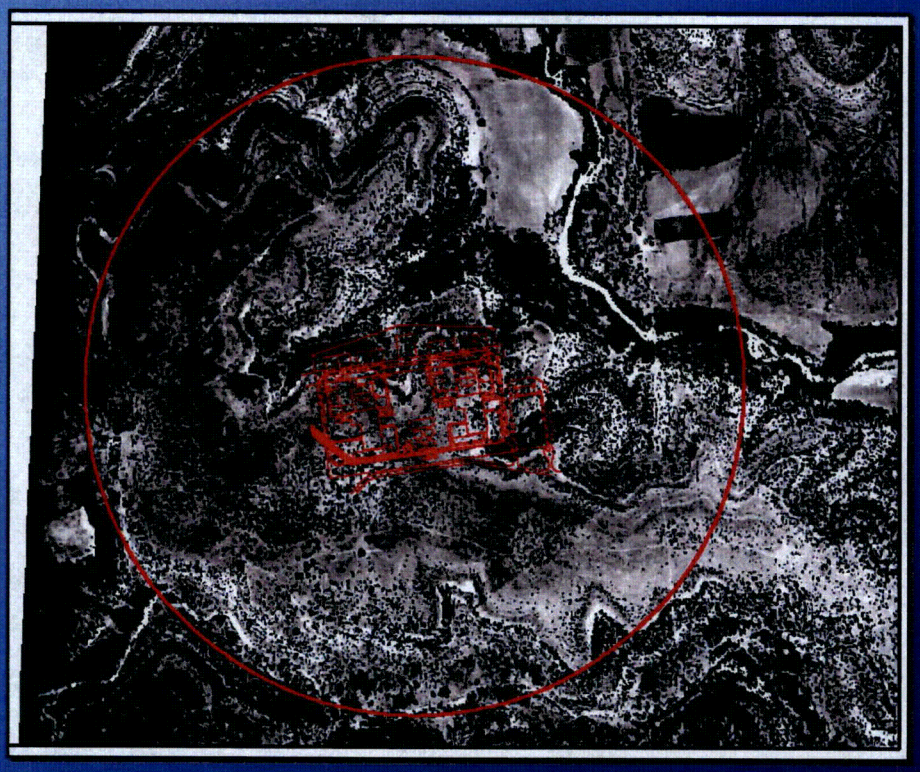
WLA

Geologic Mapping

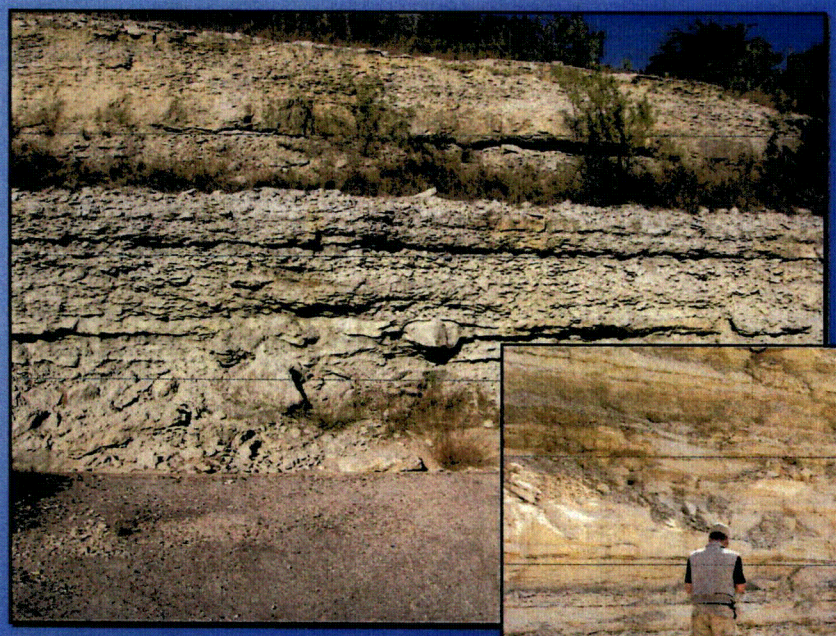
- 0.6 Mile
  - Correlation to stratigraphy noted in COLA borings and Unit 1 & 2
  - Comparison to published maps
- 5 Mile
  - Correlation to 0.6 Mile map
  - Ground check of exposed regional units
    - Discontinuities
    - Structure
    - Lithologies
    - Presence of dissolution features
- 25 Mile
  - Confirmation of regional contacts
  - Ground check of regional structural features
- 200 Mile +
  - Ground check of regional structural features

WLA

0.6 Mile Imagery (1949)



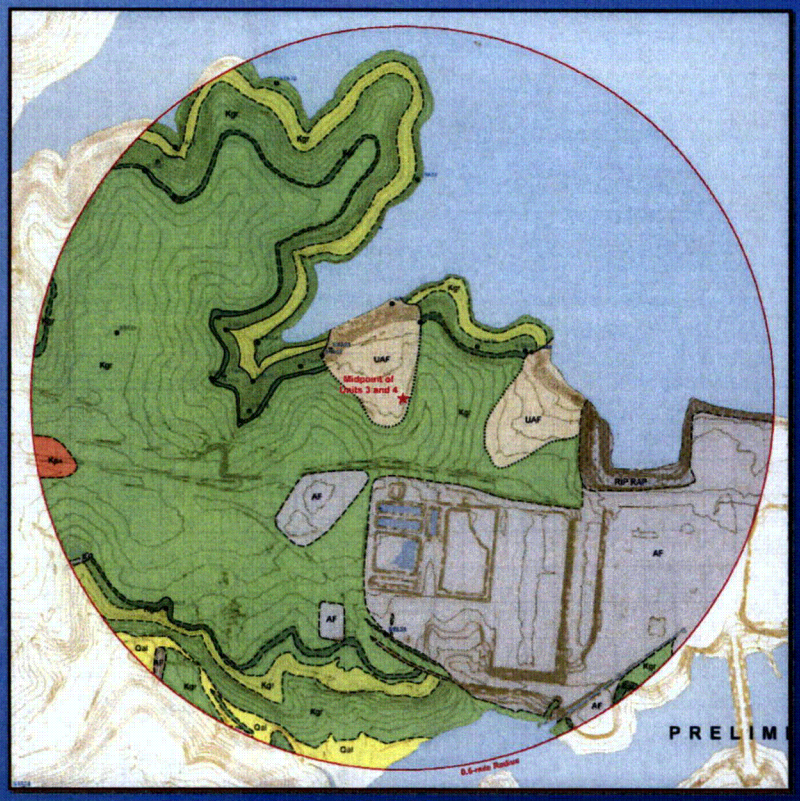
WLA



Glen Rose Exposure near Unit 1 & 2

Glen Rose Exposure ~ 5 miles from CPNPP

0.6 Mile Geologic Map



Geologic Units

- Kpx — Paluxy sandstone
- Kgr — Glen Rose Formation
  - Sparitic Wackestone
  - Wackestone
  - Shaley limestone
- UAF — Undocumented artificial fill
- AF — Artificial fill
- Qal — Quaternary alluvium

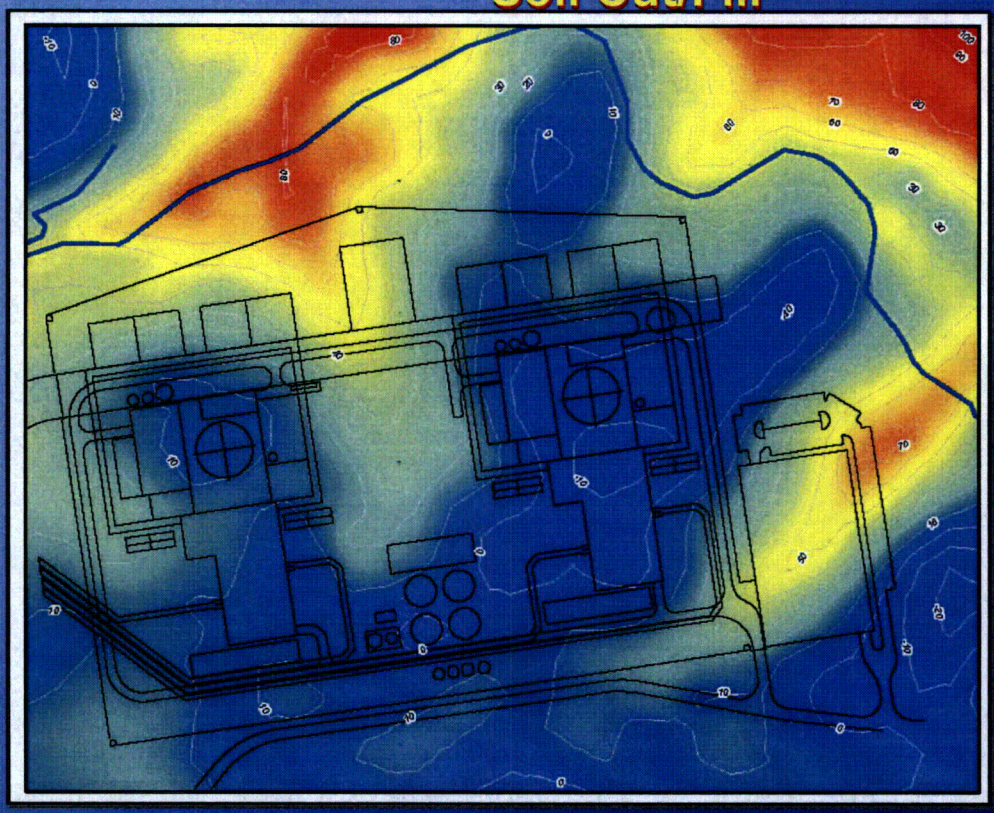
WLA

Site Conditions

- Existing General Site Elevation
- Yard Grade - 830' MSL
- Previous grading/fill activities in the area

WLA

Soil Cut/Fill



Explanation

CPNPP

Water Boundary

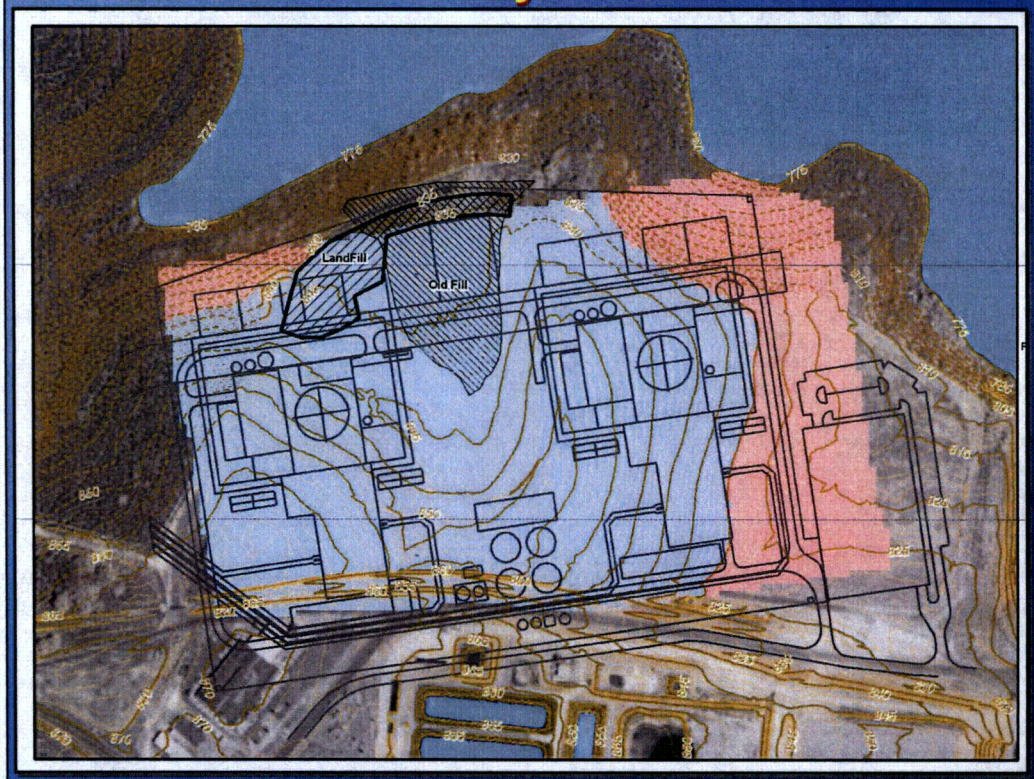
- 50 feet
- No change
- 30 feet

Cut / Fill

10 ft contour

WLA

Cut and Fill Analysis Plant Grade 830 ft MSL



CPNPP

Old Fill

Landfill

Topographic Contours

Index contours

Approximate index contours

Intermediate contours

Approximate intermediate contours

Plant grade = 830' MSL cut/fill volume

Fill = 265,212 cubic yards
555,600 square feet

Cut = 1,123,720 cubic yards
1,690,800 square feet

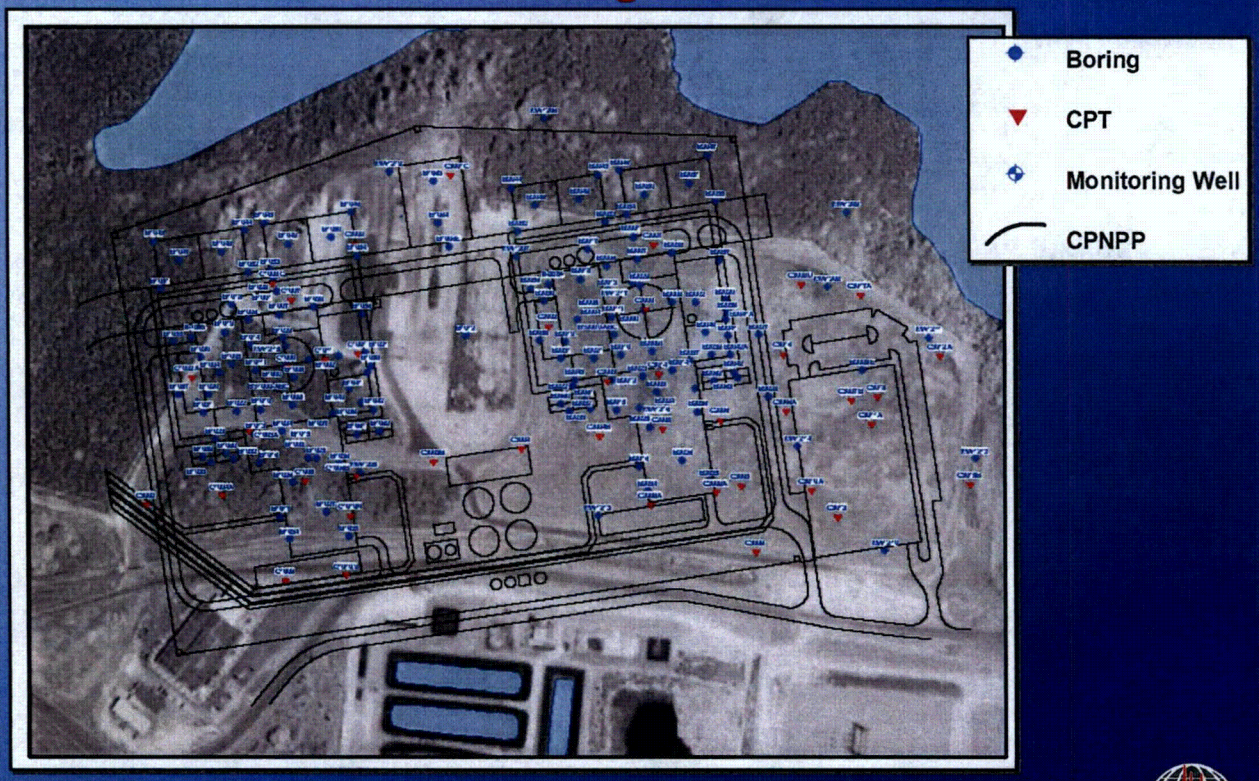
WLA

Field Exploration

- 186 Foundation Specific Borings
- 15 P-S Suspension Borings
- 2 Down-hole surveys
- 3 SASW surveys
- 7 Pressuremeter Test Borings
- 6 Packer Test Borings
- 7540' Seismic Refraction
- 3 Test Pits
- 32 Cone Penetration Test Sounding locations

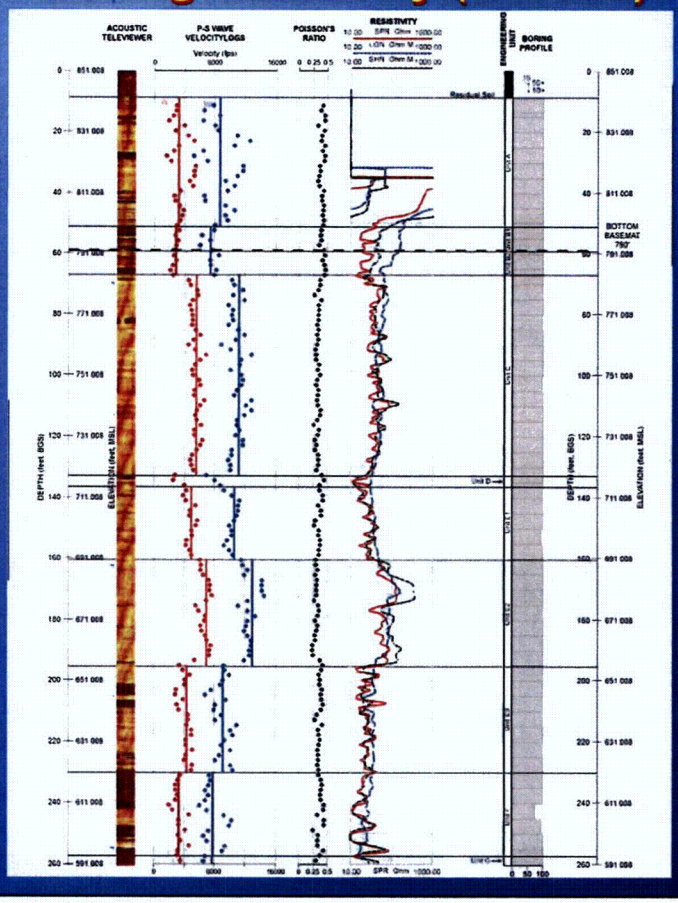
WLA

As-Built Investigation Locations

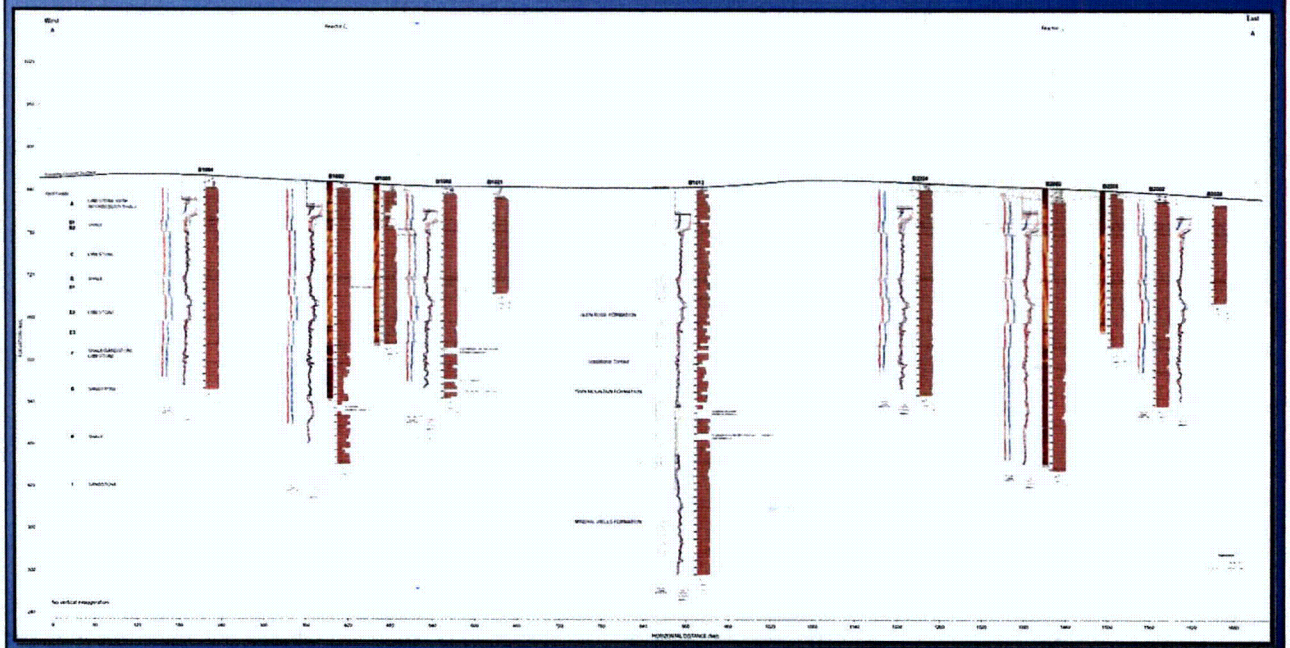


WLA

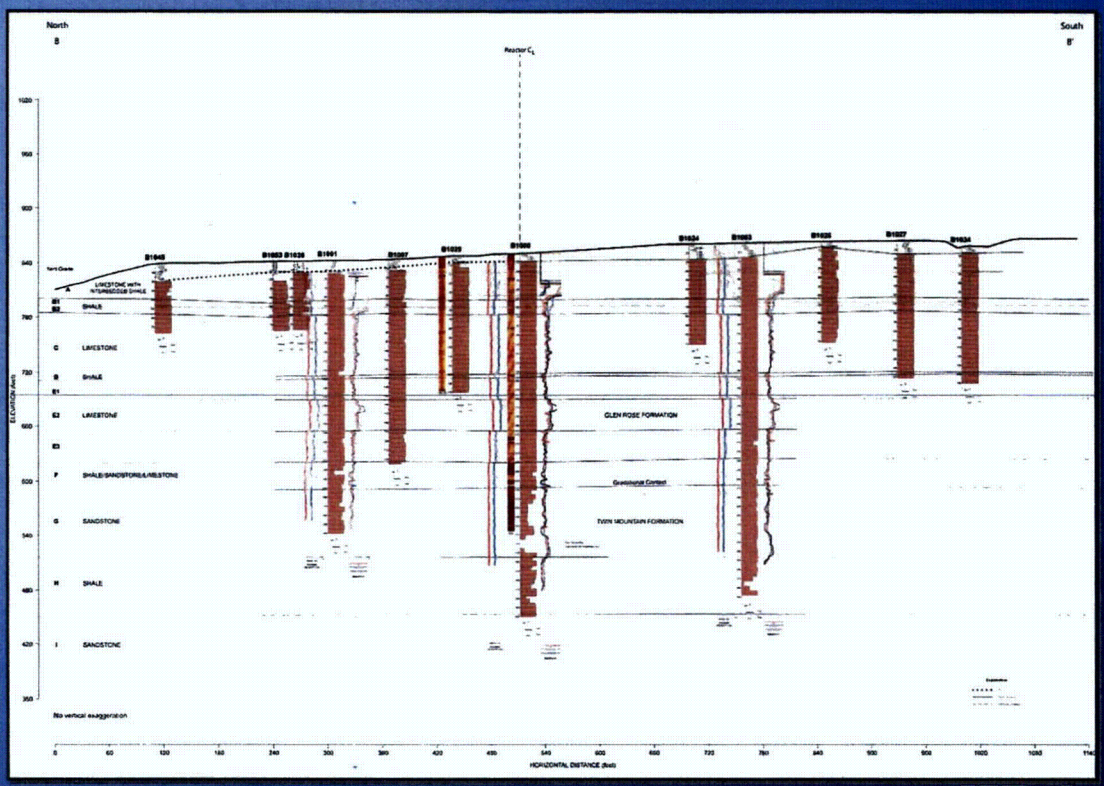
Boring Summary (B-1000)



W-E Cross Section (A-A')



N-S Cross Section (B-B')



WLA

Soil Isopach Contours and Fill Areas

WLA

Laboratory Testing Program

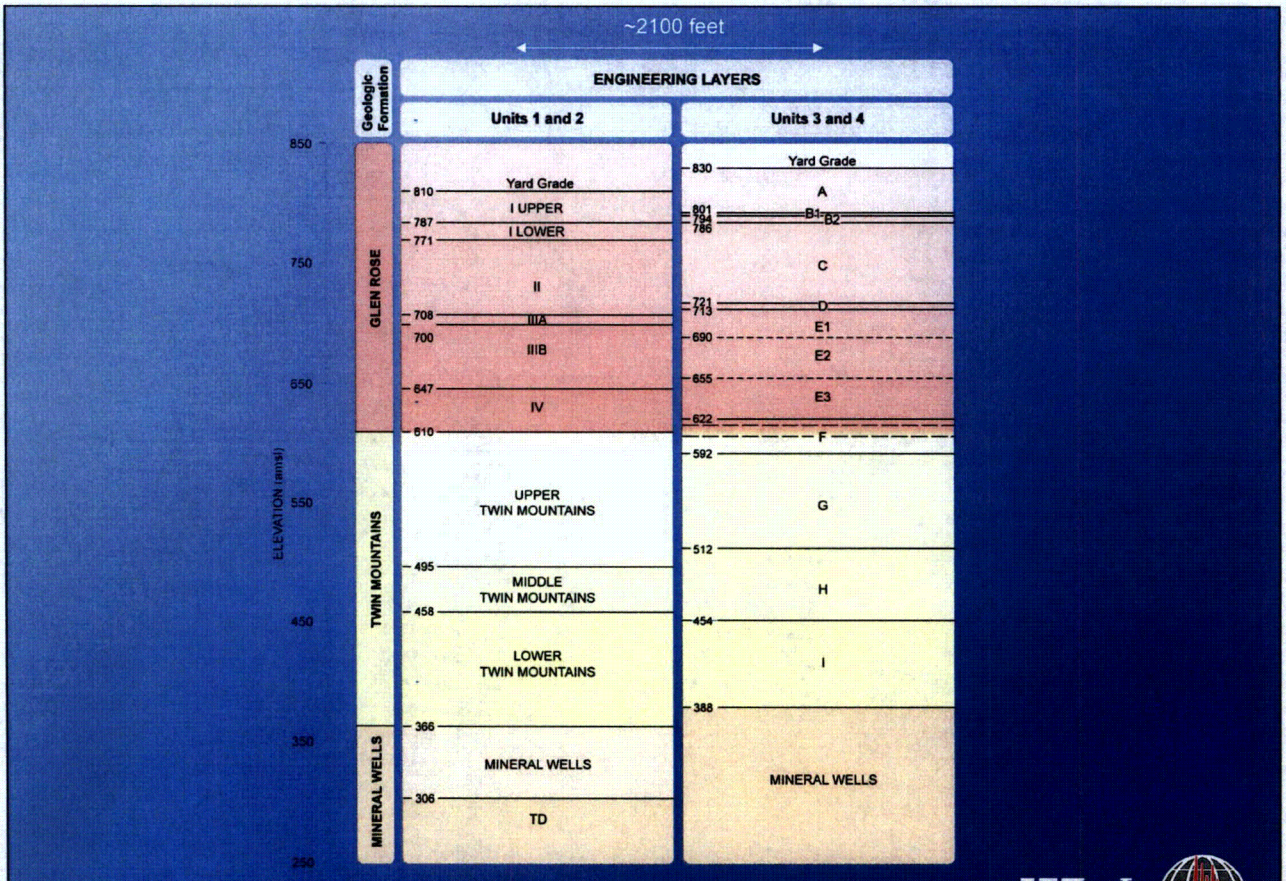
- Unconfined Compression (28)
- Unconfined Compression w Modulus & Poisson Ratio (24)
- Point Load (21)
- Pulse Velocity (78)
- Triaxial UU-1pt (4)
- Triaxial CU w Sat, w/o pp-1pt (2)
- Triaxial CU w/o pp- 1pt (18)
- Triaxial CU w/o pp- 3pt (4)
- Triaxial CU w pp- 3pt Staged (3)
- Direct Shear- 3pt (7)
- Consolidation (4)
- Swell (8)
- Atterberg Limits (7)
- Slake Durability (7)
- Moisture-Density (106)
- Specific Gravity (2)
- Calcium Carbonate (28)

Subsurface Conditions

- Presence of a Shale Unit between 800-790 (776-786) MSL
- Thick (~65), Competent Foundation Bearing Unit at ~ 782 MSL
- Uniform Stratigraphy
  - Flat uniform thickness and lithology laterally
  - Alternating limestone, shale and sandstone sequences
- High RQD Values and % Recoveries
- Limited discontinuities (joints and fractures)
- Few zones of noted dissolution
- Soft Rock Site
  - Vs (3200-6200 ft/sec)

Site Velocity Profile

- Shallow Velocity Profile
  - Velocity Measurements Techniques
    - Suspension
    - SASW
    - Down-hole
    - Cross-hole (Units 1&2)
- Deep Velocity Profile
  - Stratigraphy
  - Velocity Measurements from Regional Wells
  - Definition of Basement

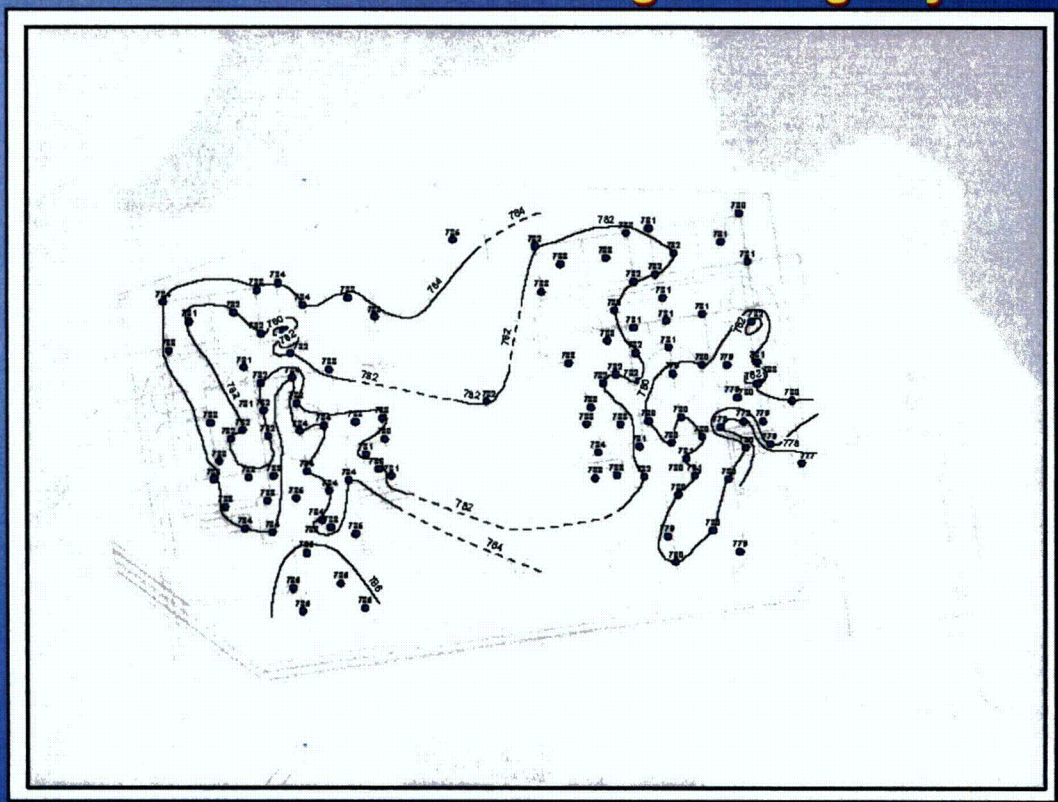


Engineering Layers

Layer	Mean Thickness (ft)	Top Elevations (MSL, ft)			
		Mean	Max	Min	Std Dev
A	35	834	858	887	12.0
B1	8	798	802	794	1.8
B2	8	790	794	786	1.8
C	65	782	786	716	1.9
D	4	717	722	713	1.4
E1	23	714	719	710	1.6
E2	35	690	692	688	1.0
E3	33	656	658	654	0.9
F	30	622	626	618	2.1
G	80	593	598	584	4.0
H	63	513	517	507	3.5
I		451	455	446	3.3

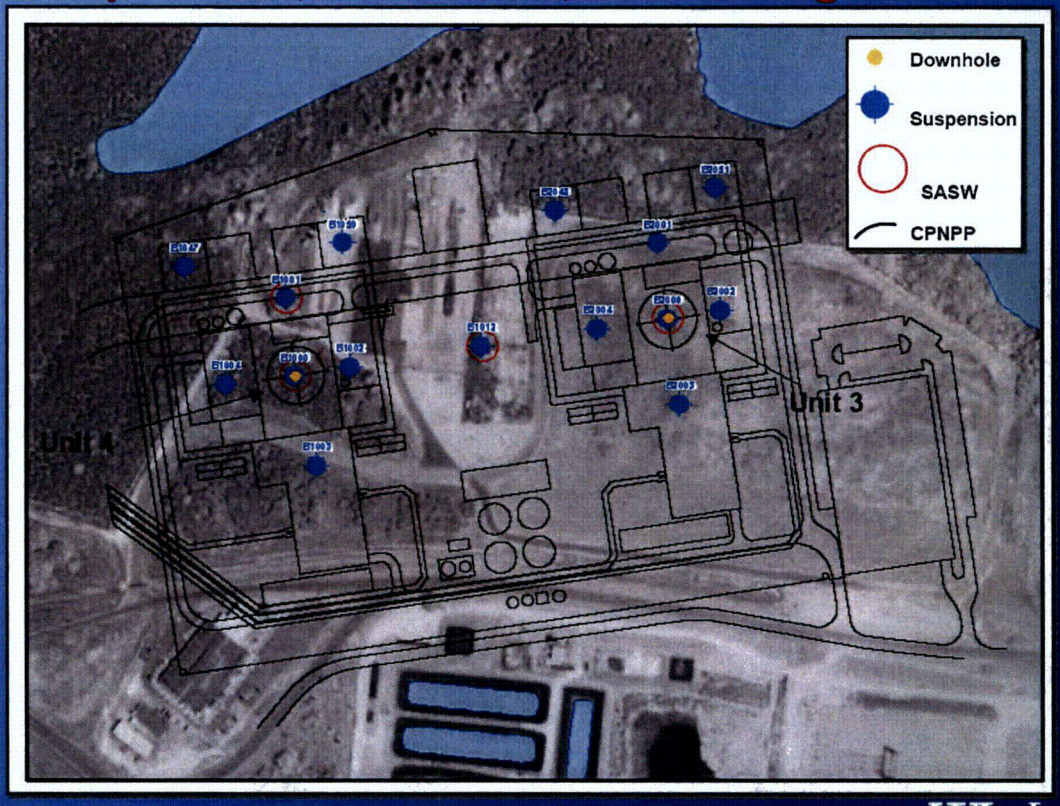
WLA

Structure Contours for Engineering Layer C



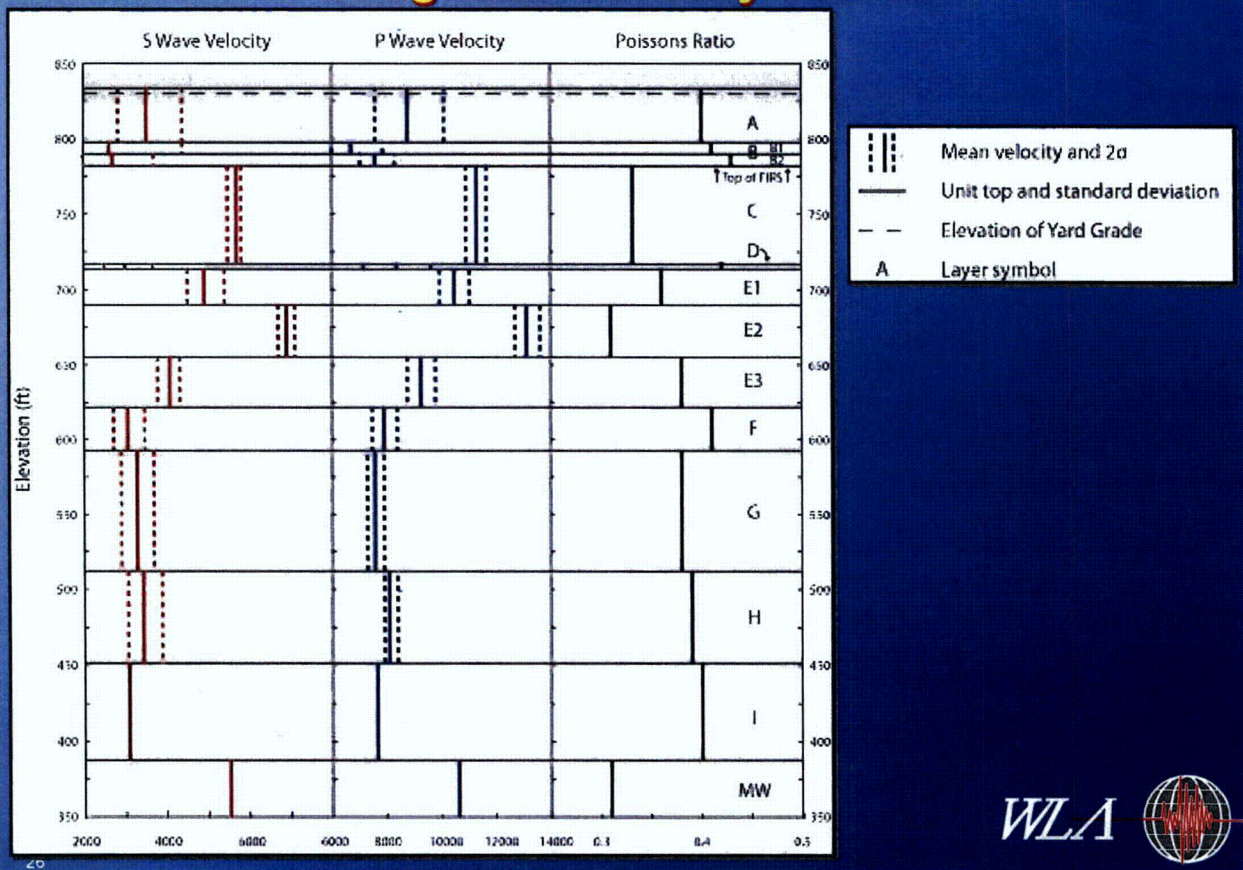
WLA

Suspension, Downhole, SASW Log Locations



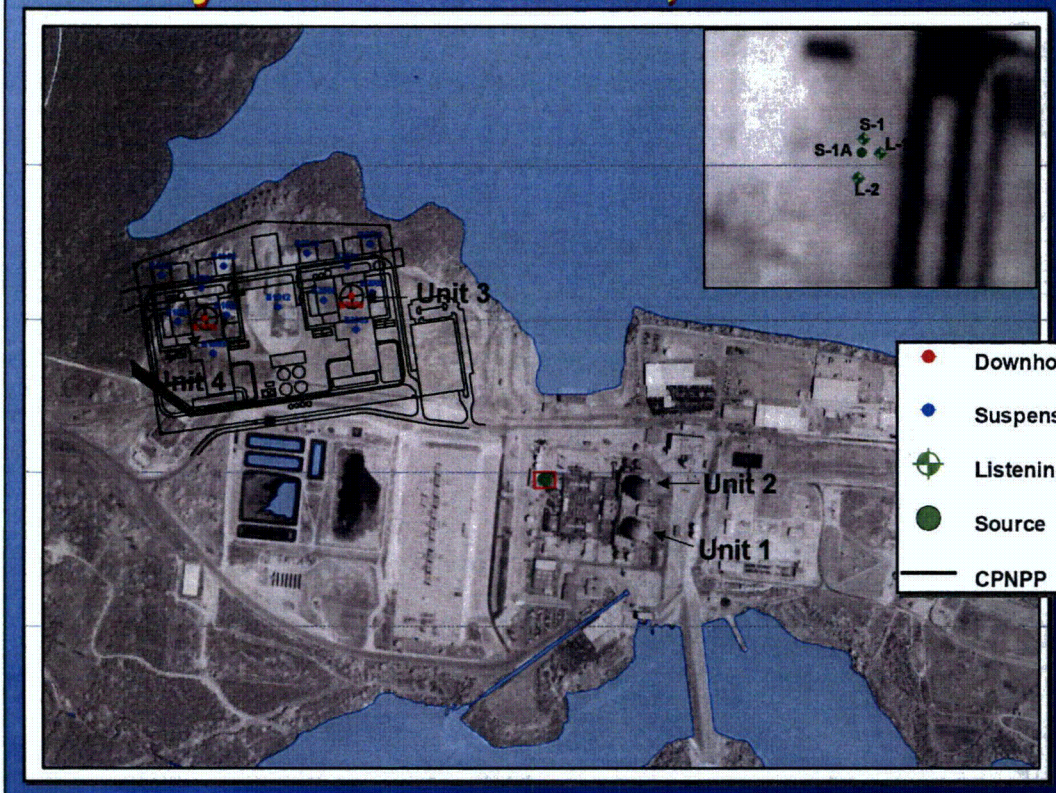
WLA

Integrated Velocity Profile



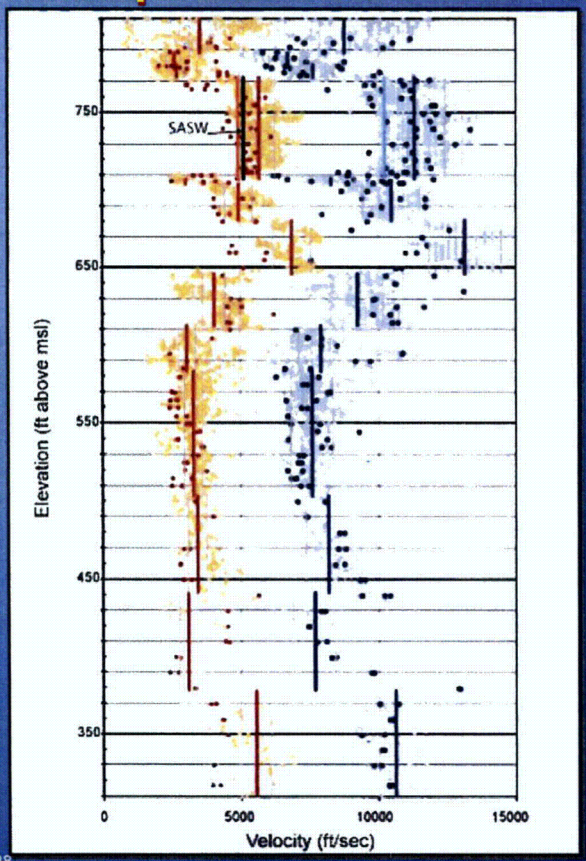
WLA

Velocity Data for Units 3&4, Cross-hole Data for 1&2



WLA

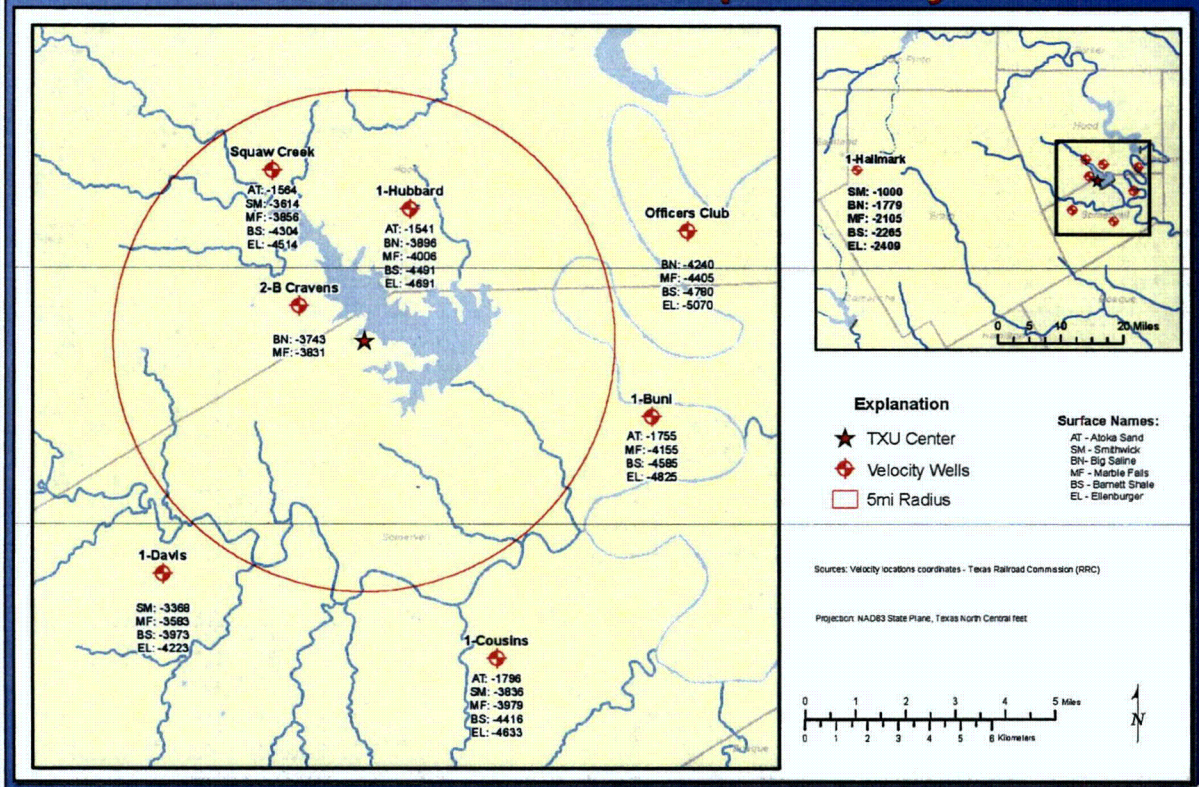
Comparison of Cross-hole Velocities Units 1 & 2



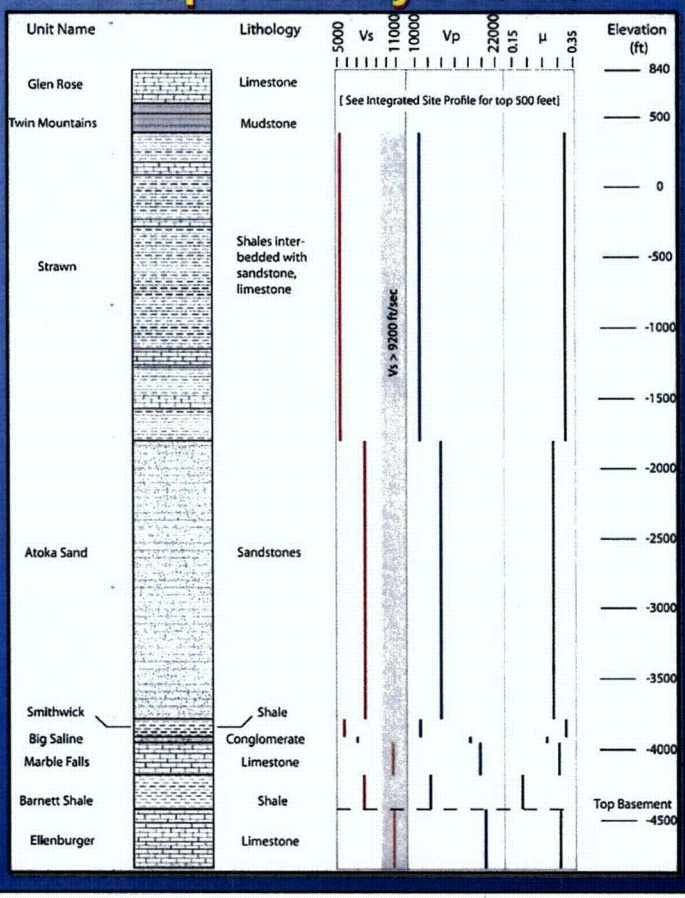
	Vs	Vp		Vs	Vp
Suspension Log			Integrated Profile		
Crosshole Data	•	•	Downhole		

WLA

Well Date Used for Deep Velocity Profile



Deep Velocity Profile

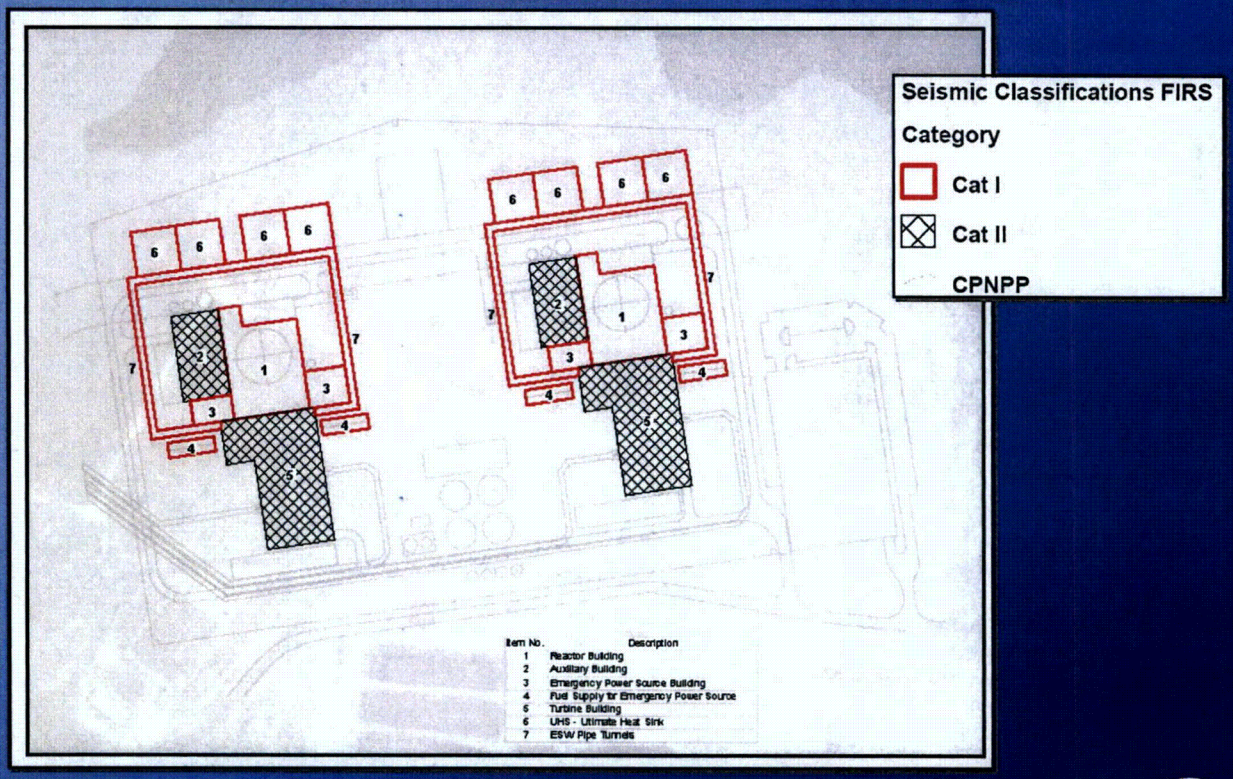


FIRS Development

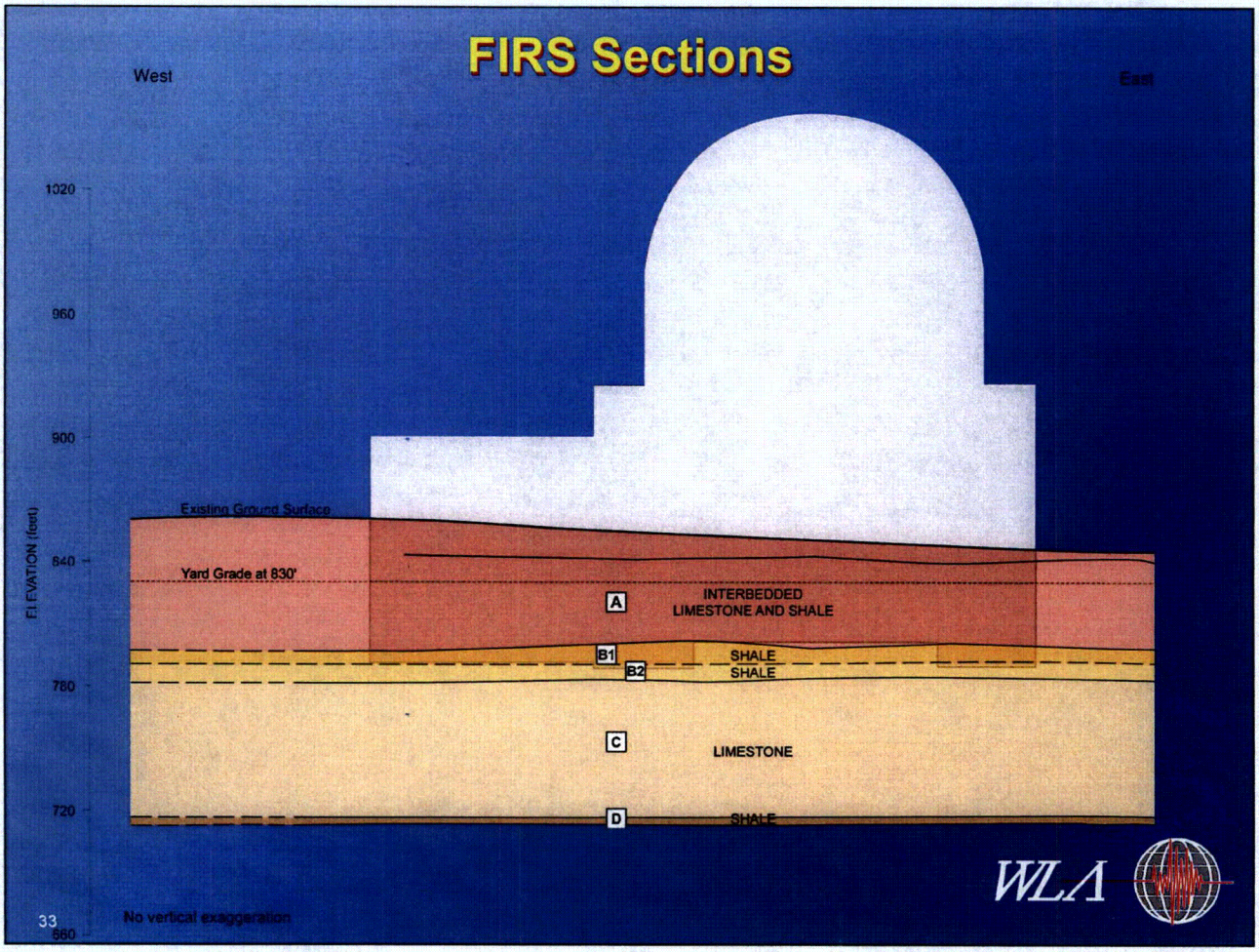
- Excavation for all Category I Structures to Remove Layer B (Shale)
- All Category I Structures to be Founded on Layer C (Limestone, Vs >5685 ft/sec) with Fill Concrete (Vs >6000 ft/sec) as required.
  - Emergency Power Source Building to be placed on ~ 16 ft of Fill Concrete
  - Duct Banks to be embedded with Structural Fill placed around structures to Yard Grade

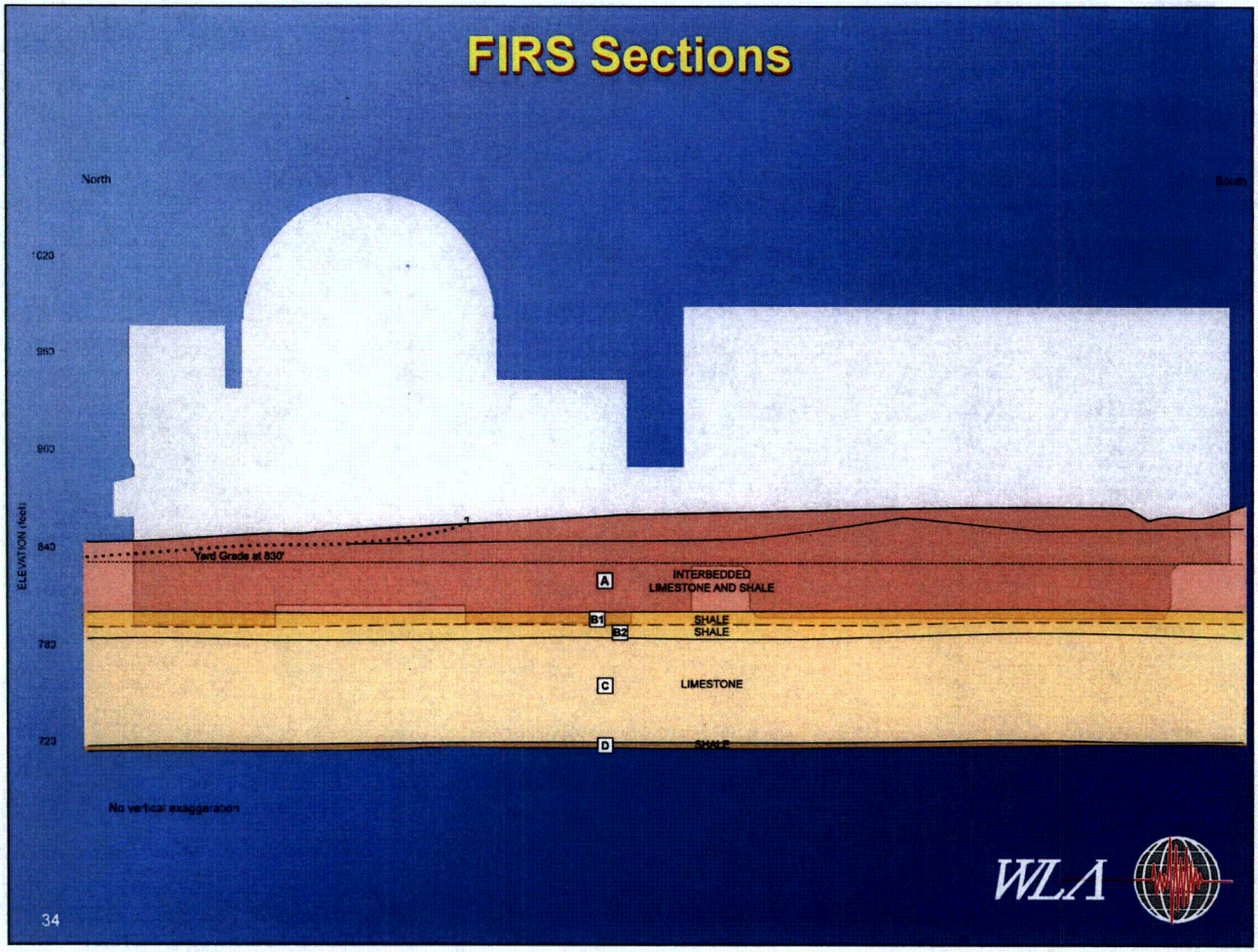
WLA

Seismic Classification for Units 3 & 4

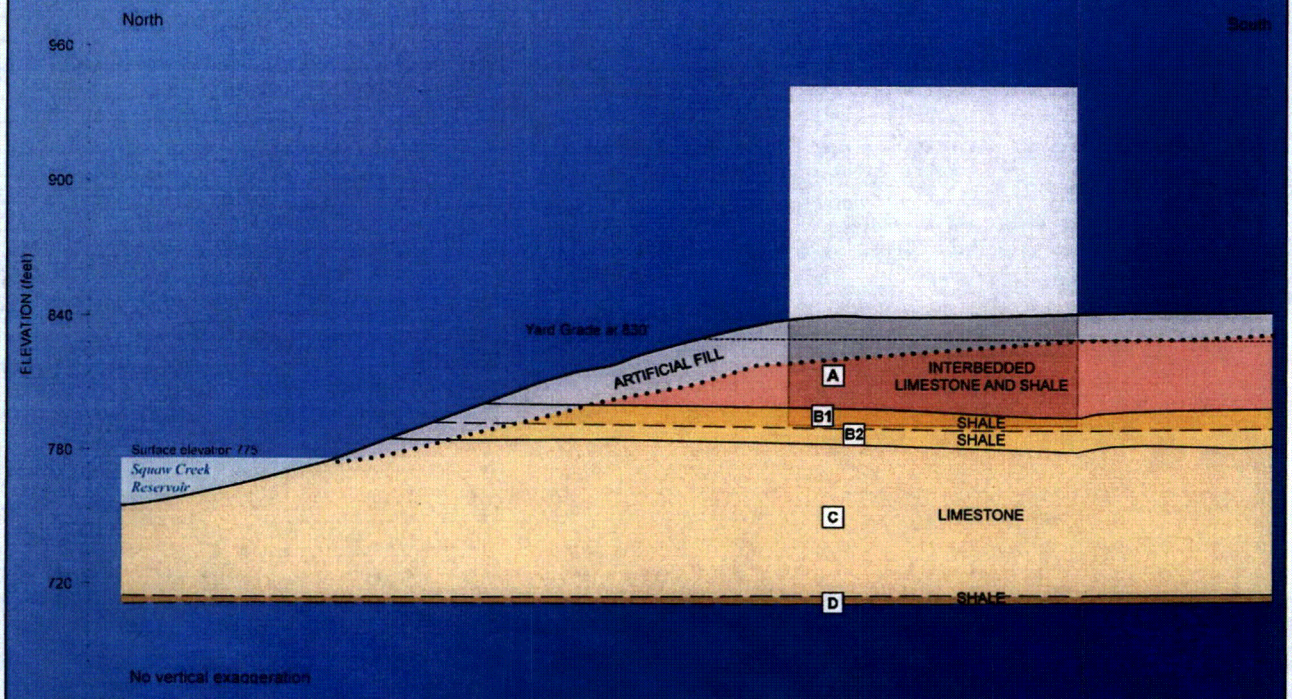


WLA


FIRS Sections
West
East
1020
960
900
840
780
720
660
ELEVATION (feet)
Existing Ground Surface
Yard Grade at 830'
A
INTERBEDDED
LIMESTONE AND SHALE
B1
SHALE
B2
SHALE
C
LIMESTONE
D
SHALE
No vertical exaggeration
33
WLA


FIRS Sections
North
South
1020
960
900
840
780
720
ELEVATION (feet)
Yard Grade at 830'
A
INTERBEDDED
LIMESTONE AND SHALE
B1
SHALE
B2
SHALE
C
LIMESTONE
D
SHALE
No vertical exaggeration
34
WLA

FIRS Sections



Summary of Geotechnical Site Characterization

- Uniform rock site with Vs 3000-7000 fps
- Competent rock foundation
  - Stable w/o significant karst or voids
  - High bearing capacity factor of safety
  - Minimal settlement
  - Linear dynamic properties

Seismic Source Characterization

Luminant Comanche Peak COLA

William Lettis
President & Senior Principal Geologist
William Lettis & Associates, Inc.

WLA

PSHA Input

- Use 1986/1989 EPRI-SOG model for Comanche Peak as base source model
- Revise existing source zones from EPRI-SOG model to reflect new (post-1986) information
- Screen for new significant seismic sources

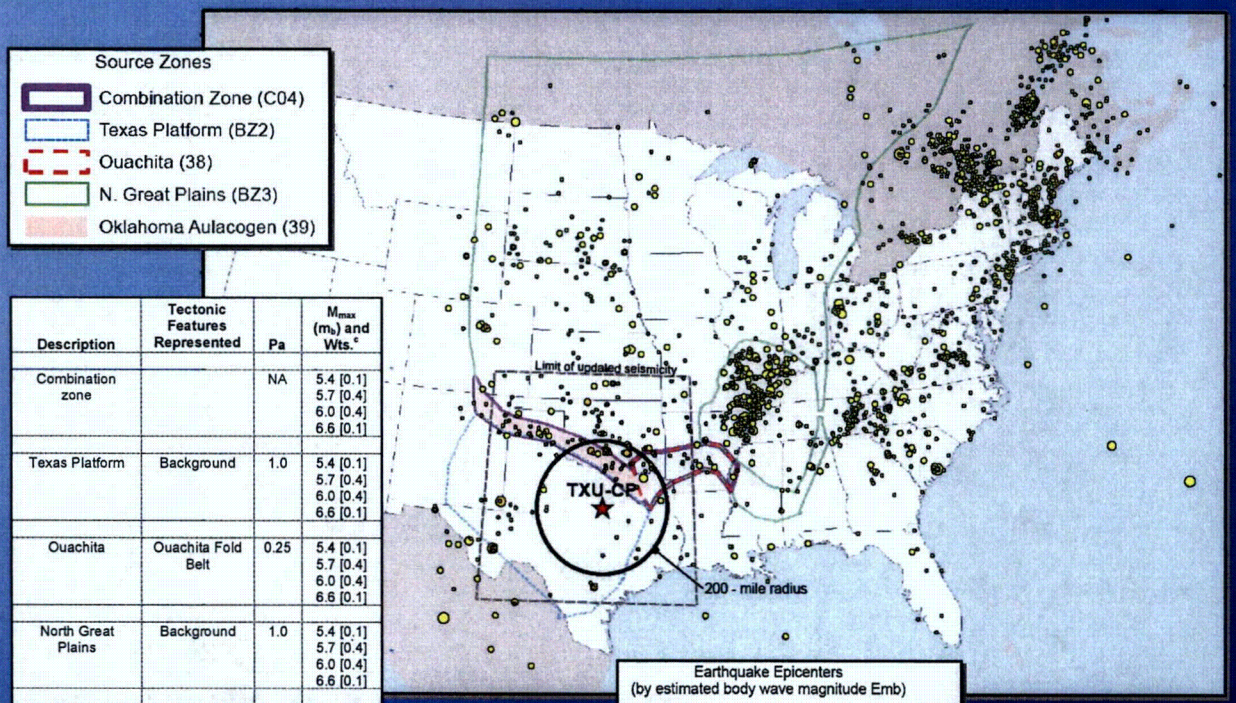
WLA

Existing EPRI-SOG Source Model for CP

Six ESTs each with unique source zones characterized by:

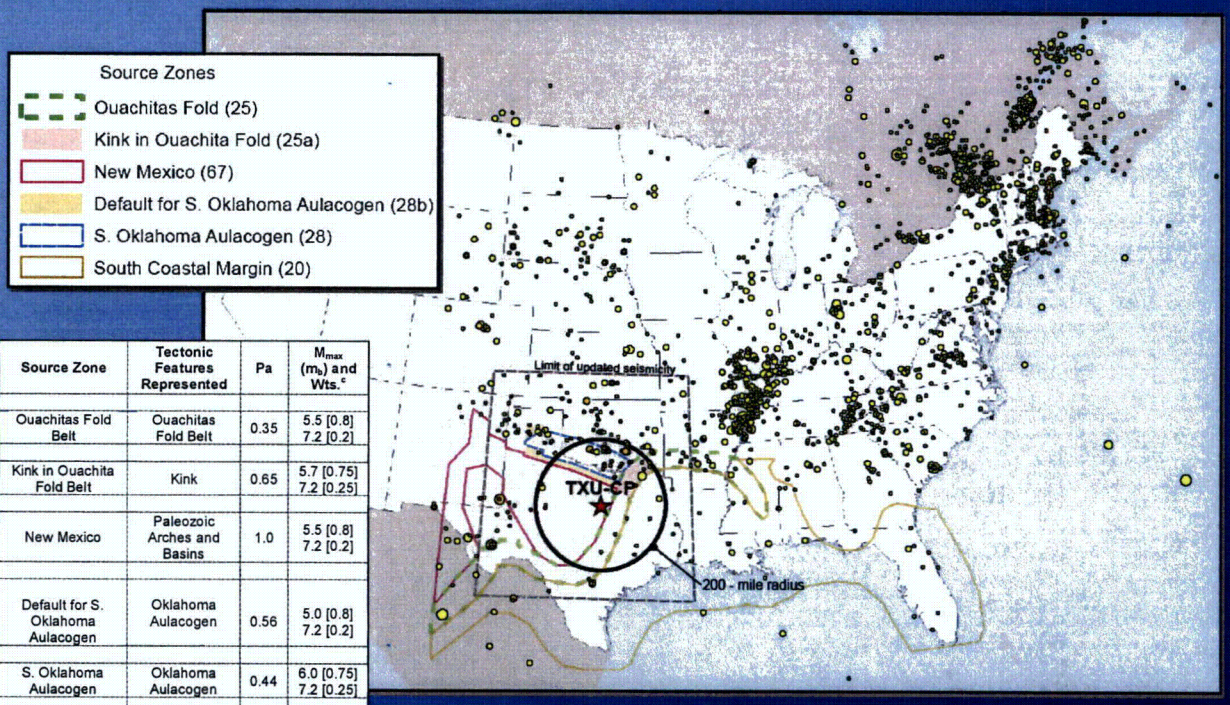
- Geometry
- Maximum magnitudes
- Probability of activity
- Recurrence parameters

Bechtel Group Source Zones



Description	Tectonic Features Represented	Pa	M_{max} (m_b) and Wts.[c]
Combination zone		NA	5.4 [0.1] 5.7 [0.4] 6.0 [0.4] 6.6 [0.1]
Texas Platform	Background	1.0	5.4 [0.1] 5.7 [0.4] 6.0 [0.4] 6.6 [0.1]
Ouachita	Ouachita Fold Belt	0.25	5.4 [0.1] 5.7 [0.4] 6.0 [0.4] 6.6 [0.1]
North Great Plains	Background	1.0	5.4 [0.1] 5.7 [0.4] 6.0 [0.4] 6.6 [0.1]
Oklahoma Aulacogen	Oklahoma Aulacogen	0.20	5.4 [0.1] 5.7 [0.4] 6.0 [0.4] 6.6 [0.1]

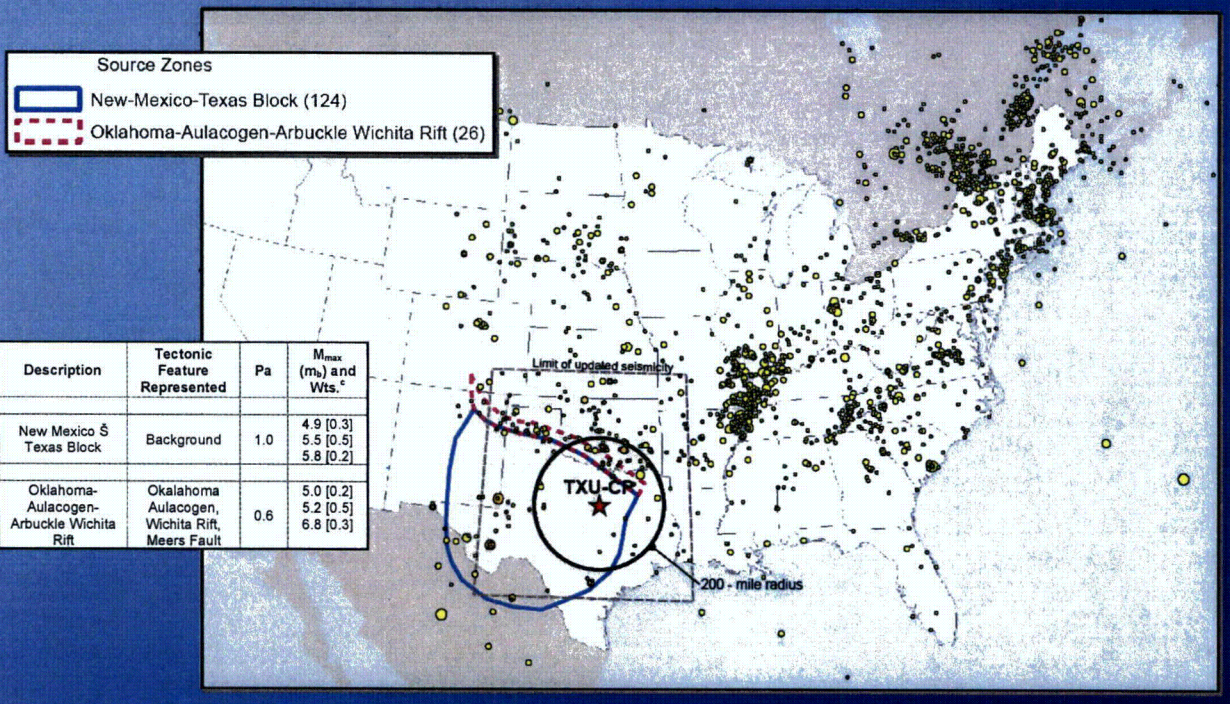
Dames & Moore Source Zones



Source Zone	Tectonic Features Represented	Pa	M_{max} (m_b) and Wts.[c]
Ouachitas Fold Belt	Ouachitas Fold Belt	0.35	5.5 [0.8] 7.2 [0.2]
Kink in Ouachita Fold Belt	Kink	0.65	5.7 [0.75] 7.2 [0.25]
New Mexico	Paleozoic Arches and Basins	1.0	5.5 [0.8] 7.2 [0.2]
Default for S. Oklahoma Aulacogen	Oklahoma Aulacogen	0.56	5.0 [0.8] 7.2 [0.2]
S. Oklahoma Aulacogen	Oklahoma Aulacogen	0.44	6.0 [0.75] 7.2 [0.25]
South Coastal Margin	Background	1.0	5.3 [0.8] 7.2 [0.2]

WLA

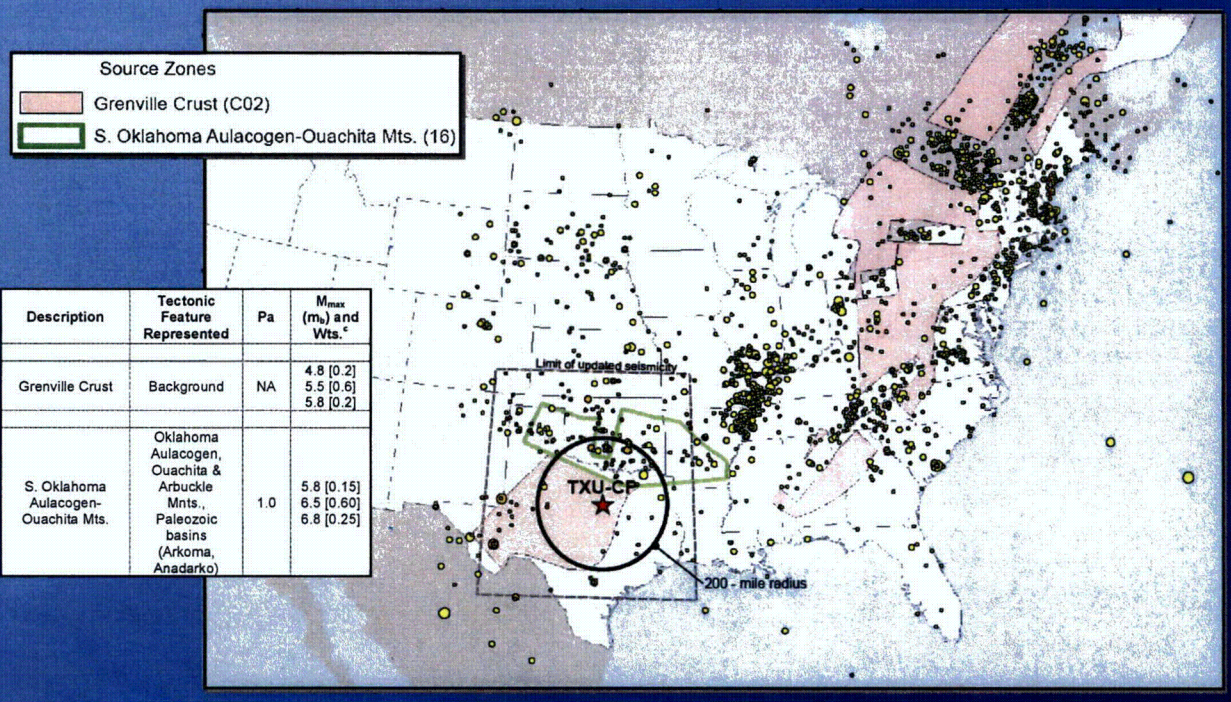
Law Engineering Source Zones



Description	Tectonic Feature Represented	Pa	M_{max} (m_b) and Wts.[c]
New Mexico Ŝ Texas Block	Background	1.0	4.9 [0.3] 5.5 [0.5] 5.8 [0.2]
Oklahoma-Aulacogen-Arbuckle Wichita Rift	Okalahoma Aulacogen, Wichita Rift, Meers Fault	0.6	5.0 [0.2] 5.2 [0.5] 6.8 [0.3]

WLA

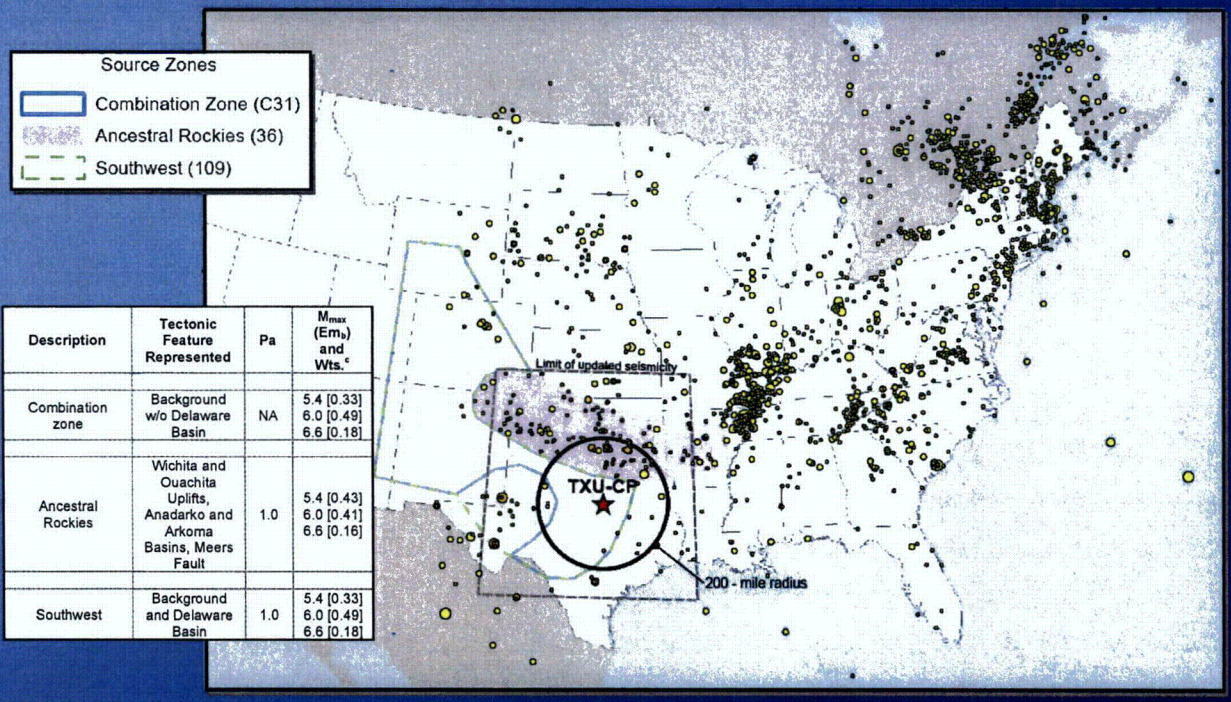
Rondout Associates Source Zones



Description	Tectonic Feature Represented	Pa	M_{max} (m_b) and Wts.[c]
Grenville Crust	Background	NA	4.8 [0.2] 5.5 [0.6] 5.8 [0.2]
S. Oklahoma Aulacogen-Ouachita Mts.	Oklahoma Aulacogen, Ouachita & Arbuckle Mnts., Paleozoic basins (Arkoma, Anadarko)	1.0	5.8 [0.15] 6.5 [0.60] 6.8 [0.25]

WLA

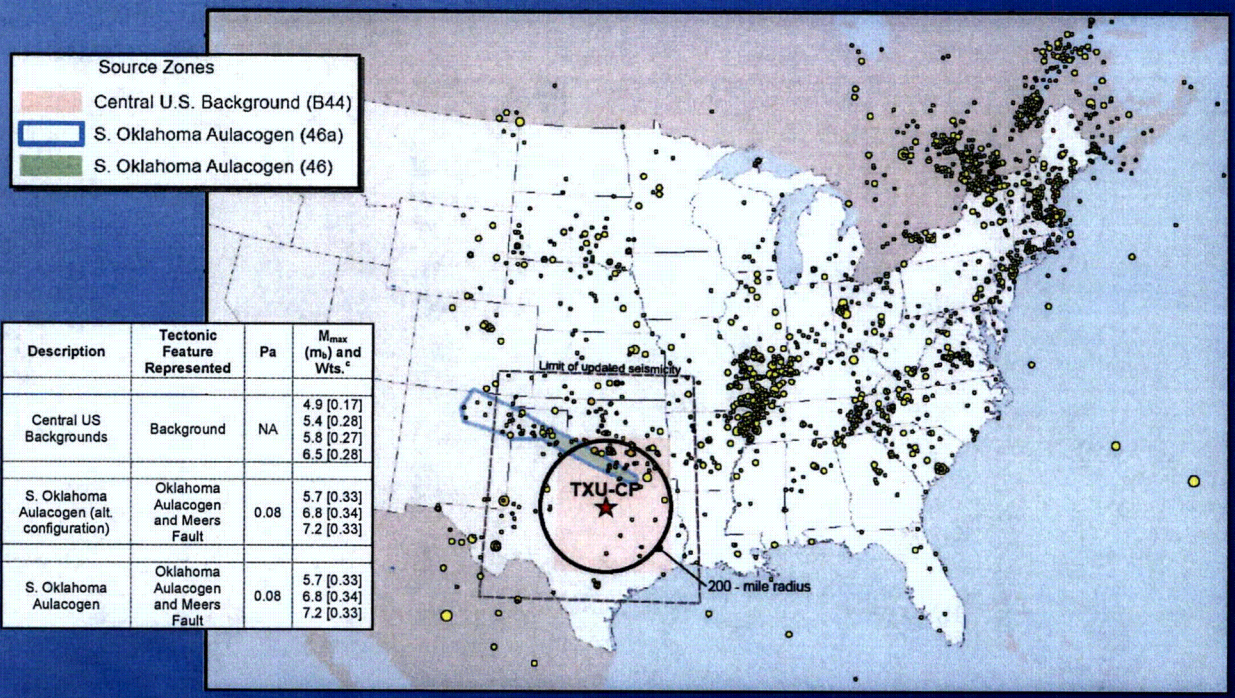
Weston Geophysical Source Zones



Description	Tectonic Feature Represented	Pa	M_{max} (Em_b) and Wts.[c]
Combination zone	Background w/o Delaware Basin	NA	5.4 [0.33] 6.0 [0.49] 6.6 [0.18]
Ancestral Rockies	Wichita and Ouachita Uplifts, Anadarko and Arkoma Basins, Meers Fault	1.0	5.4 [0.43] 6.0 [0.41] 6.6 [0.16]
Southwest	Background and Delaware Basin	1.0	5.4 [0.33] 6.0 [0.49] 6.6 [0.18]

WLA

Woodward-Clyde Source Zones



Description	Tectonic Feature Represented	Pa	M_{max} (m_b) and Wts.[c]
Central US Backgrounds	Background	NA	4.9 [0.17] 5.4 [0.28] 5.8 [0.27] 6.5 [0.28]
S. Oklahoma Aulacogen (alt. configuration)	Oklahoma Aulacogen and Meers Fault	0.08	5.7 [0.33] 6.8 [0.34] 7.2 [0.33]
S. Oklahoma Aulacogen	Oklahoma Aulacogen and Meers Fault	0.08	5.7 [0.33] 6.8 [0.34] 7.2 [0.33]

WLA

Revisions to EPRI-SOG Source Model

No new information post-dating 1986 EPRI-SOG study to suggest revisions to contributing source zone:

- Geometries
- Probabilities of activity
- Seismicity parameters (pending results of sensitivity analysis for affects of 1985-2006 seismicity)

However:

- Earthquakes in updated seismicity catalog require updates to Mmax for some source zones
- Seismicity parameters need to be calculated for some regions

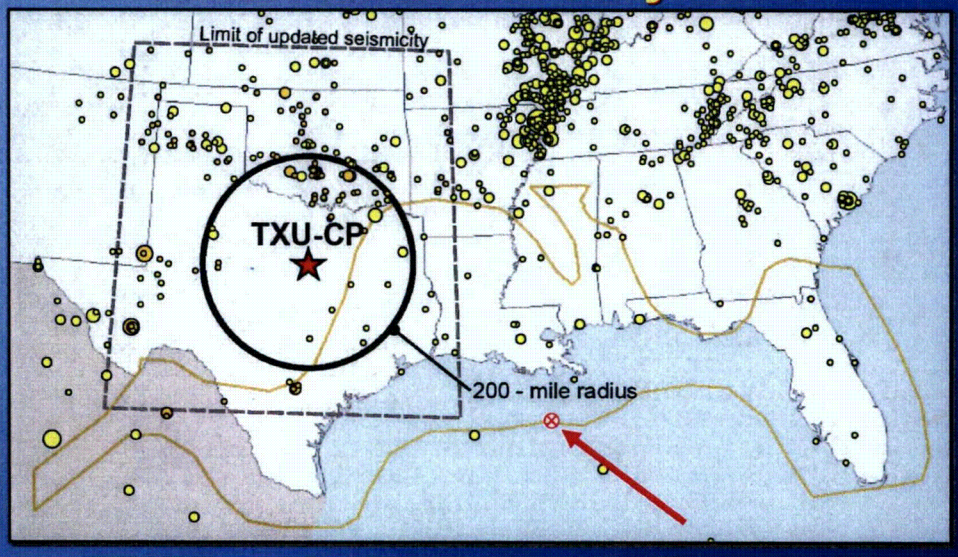
WLA

Mmax Revisions

Two earthquakes with Emb greater than the lower bound Mmax for some source zones require updating Mmax values:

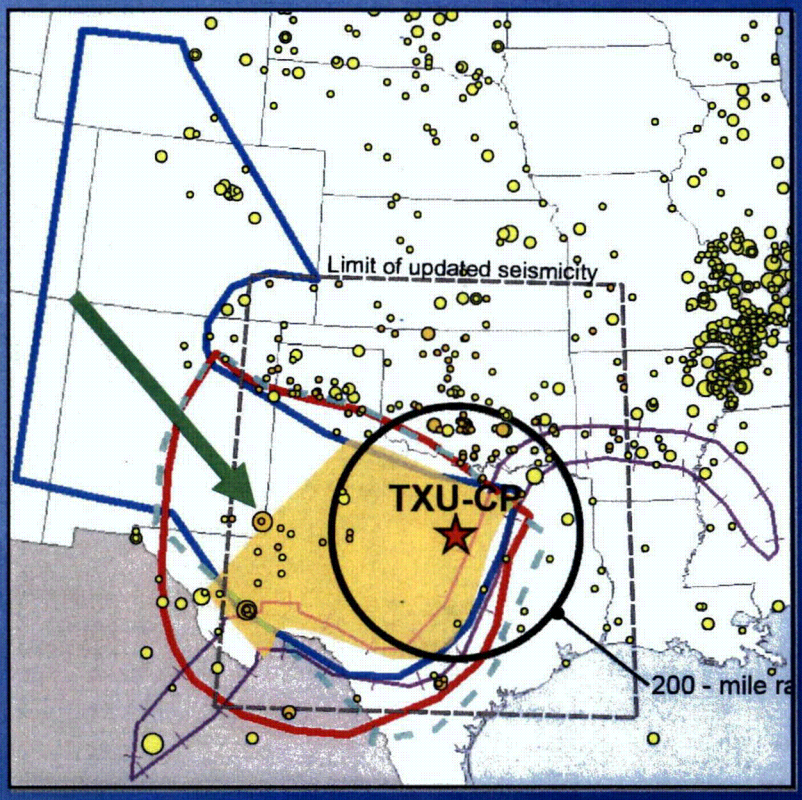
- Emb 5.5, 2 February 2006 in Gulf of Mexico
- Emb 5.0, 2 January 1992 in SE New Mexico

Emb 5.5: 2 February 2006



Source Zone	Original Mmax Distribution and Weights (EPRI, 1989)	Updated Mmax Distribution and Weights
Dames and Moore South	5.3 [0.8]	5.5 [0.8]
Coastal Margin	7.2 [0.2]	7.2 [0.2]

Emb 5.0: 2 January 1992



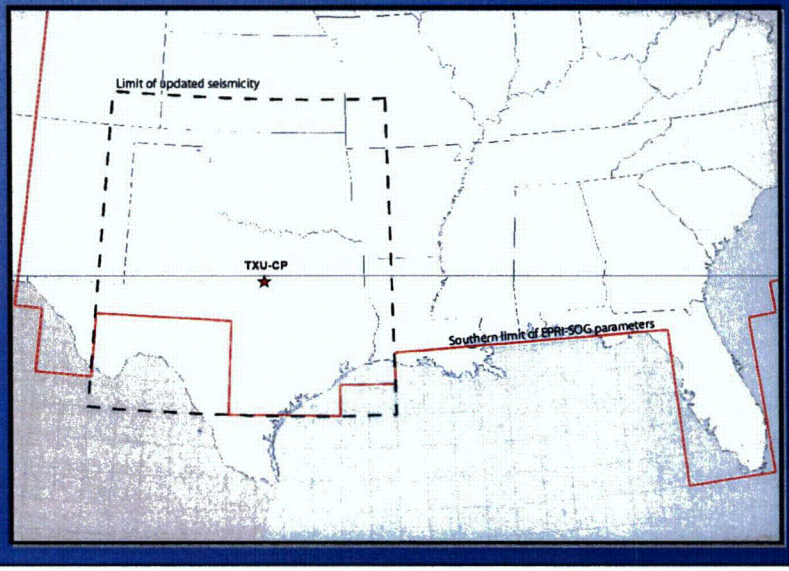
Source Zones
- Rondout - Greenville Crust (C02)
- Dames & Moore - Ouachitas Fold (25)
- Bechtel - Texas Platform (BZ2)
- Law - New Mexico-Texas Block (124)
- Weston - Southwest (109)

Source Zone	Original Mmax Distribution and Weights (EPRI, 1989)	Updated Mmax Distribution and Weights
Law New Mexico Texas Block	4.9 [0.3] 5.5 [0.5] 5.8 [0.2]	5.0 [0.3] 5.5 [0.5] 5.8 [0.2]

WLA

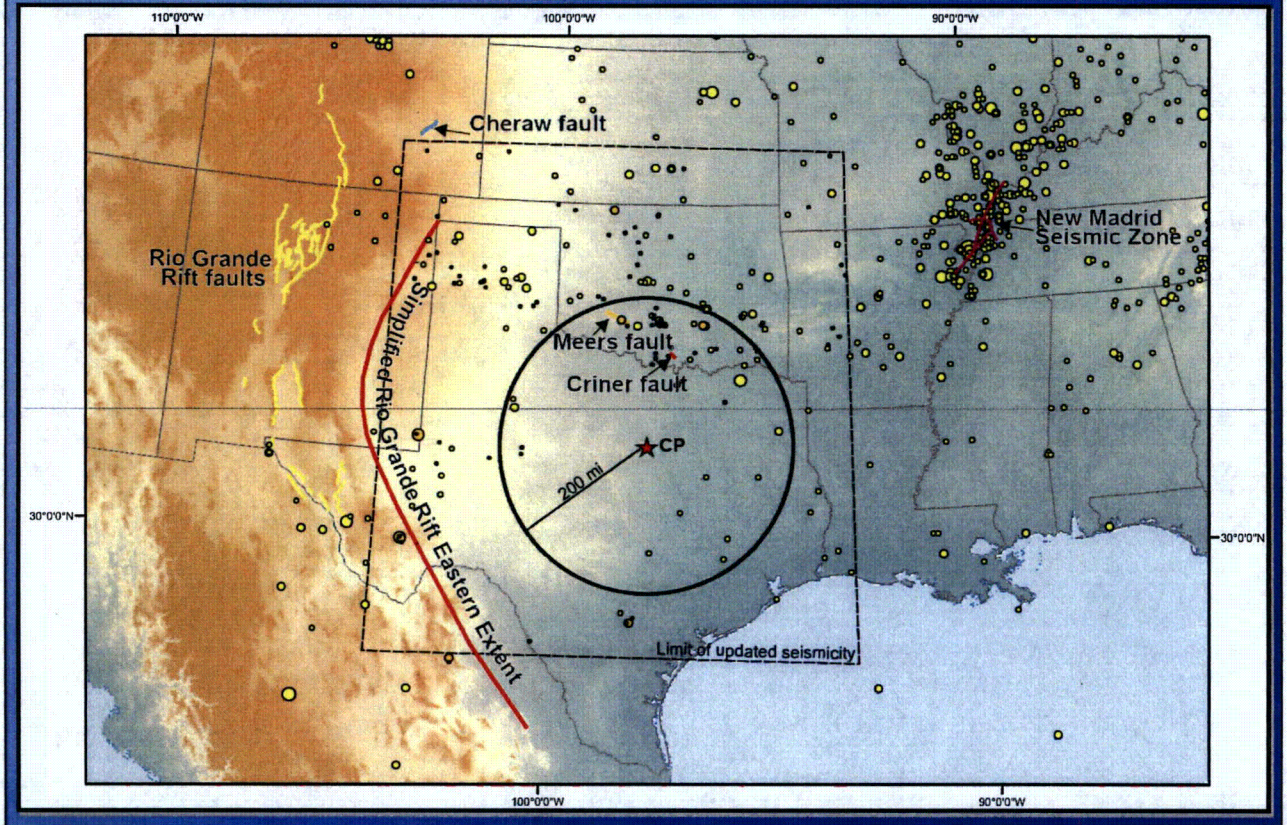
Seismicity Parameter Update

- EPRI-SOG PSHA model uses seismicity parameters defined on 1°x1° cells.
- Parameters were not calculated south of red line, so no contribution to hazard from cells south of line.
- Calculate seismicity parameters for empty 1°x1° cells within the extent of updated catalog.



WLA

New Seismic Sources for Screening Study



Rio Grande Rift

- Only explicitly considered by one EST in EPRI-SOG study
- Post EPRI-SOG studies indicate higher activity rates and larger magnitude earthquakes
- Use two complimentary models of RGR as a seismic source

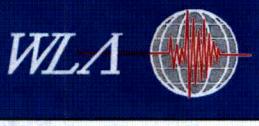
WLA

Rio Grande Rift

Model 1: 2002 USGS National Seismic Hazard Map faults for RGR representing discrete faults

Model 1: 41 faults used in USGS Seismic Hazard Maps as distinct sources.

Trace Coordinates (Lon., Lat.)	Take from Table A1
Dip, Dip Direction	90¼, NA
Recurrence Model	Characteristic Earthquake
Recurrence Rate (EQs/yr)	Use USGS defined characteristic recurrence rate
Magnitude (Mw) and weights	Use USGS defined characteristic magnitude (M_CHAR) with branches M_CHARŠ0.2 [0.2], M_CHAR [0.6], M_CHAR+0.2 [0.2]
Probability of Activity	1.0



Rio Grande Rift

Model 2: Conservative representation of the easternmost extent of RGR with seismicity parameters derived from bulk behavior of USGS parameterized faults. Source represents potential for EQs distal from identified faults

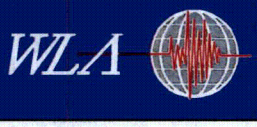
Model 2: Point source located at the closest approach of RGR morphotectonic domain as a conservation simplification of an aerial source zone.

Point location (Lon., Lat.)	(-102.671¼, 29.796¼)
Recurrence Model	Characteristic Earthquake
Return Period (yrs) and weights	14,500 [0.4], 37,500 [0.4], 119,000 [0.2]
Magnitude (Mw) and weights	6.3 [0.1], 6.65 [0.3], 6.95 [0.4], 7.3 [0.2]
Probability of Activity	1.0

Cheraw Fault

- Not considered in EPRI-SOG study
- Research post-dating EPRI-SOG has shown three surface rupturing events in past ~25 ka
- Use conservative simplification of fault as described in 2002 USGS National Seismic Hazard Maps

Recurrence Model	Characteristic Earthquake
Recurrence Rate	1.148e-4 per year
Magnitude (Mw) and weights	6.8 [0.2], 7.0 [0.6], 7.2 [0.2]
Probability of Activity	1.0



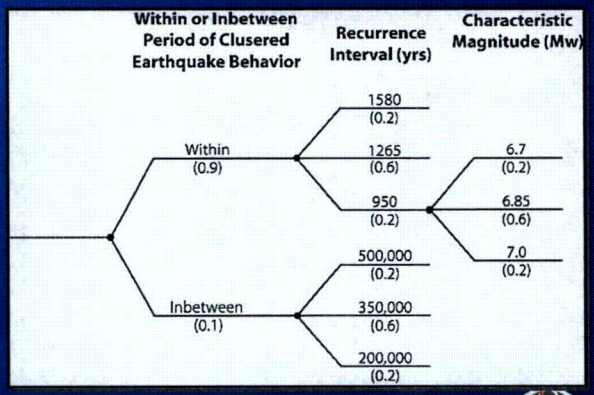
New Madrid Seismic Zone

- Not a contributor to hazard at CP in EPRI-SOG study
- Research post-dating EPRI-SOG has lead to revised maximum magnitudes, source geometry, and recurrence rates
- Use conservative simplification of model from Clinton ESP parameterization of New Madrid Seismic Zone

Meers Fault

- Identified in EPRI-SOG study as tectonic feature with non-zero probability of activity
- Post EPRI-SOG research indicates need for revision of source to account for higher recurrence rates, larger Mmax, refined location of Quaternary-active segment
- Source model based on work by Geomatrix in late 80s and early 90s

Trace Coordinates (Lon., Lat.)	(-98.64°, 34.85°), (-98.29°, 34.71°)
Dip, Dip Direction	89¼, SW
Recurrence Model	Characteristic Earthquake
Probability of Activity	1.0



WLA

Criner Fault

- Not identified as unique source by EPRI-SOG
- Research in early 1990s identified fault as potentially active
- More recent studies suggest very low probability of activity (Pa ~ 0.2
- Source may be adequately characterized by existing EPRI-SOG area source zones

WLA

Status of Ground Motion Analysis

- Screening studies in progress
  - Meers, Cheraw, RGR, NMSZ, Criner
- PSHA and site response to be completed
  - CAV filtering
  - Modified sigma

Summary of Geotechnical and Seismic Conditions

- Excellent rock site
  - Vs 3000-7000 fps
  - Uniform horizontal layering
  - Competent rock foundation
- Low seismic environment
  - Modified EPRI-SOG SSC
  - Consistent with other applicants
  - Expected GMRS < CSDRS
- Complete Application
  - Nothing deferred