




Seismic Hazard Reevaluation

June 30, 2014

DUKE ENERGY.

"One Team, One Fleet, One Company"

Participants

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Objectives

- Discuss issues resulting from the NRC’s review of BNP and RNP seismic hazard and screening reports
- Understand the reasons for the differences between the preliminary NRC and RNP GMRS
- Continue to support resolution of NRC questions and information needed for BNP and RNP

Introduction

- Duke Energy followed approved process and guidance for development of Seismic Hazard Reevaluation
- Screening determinations were performed in accordance with NRC endorsed Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic (EPRI 1025287)
- Conference call held with NRC on 6/2/14 to discuss questions regarding BNP soil failure analysis for Intake Canal and differences between NRC and RNP GMRS

Brunswick

Brunswick

- NRC Question
  - Clarify whether the submittal should cite Reference 6.6 instead of Reference 6.4 when referring to Table 7-1A or provide a description of the considerations were used for screening
- Duke Energy Response
  - The correct reference is 6.6

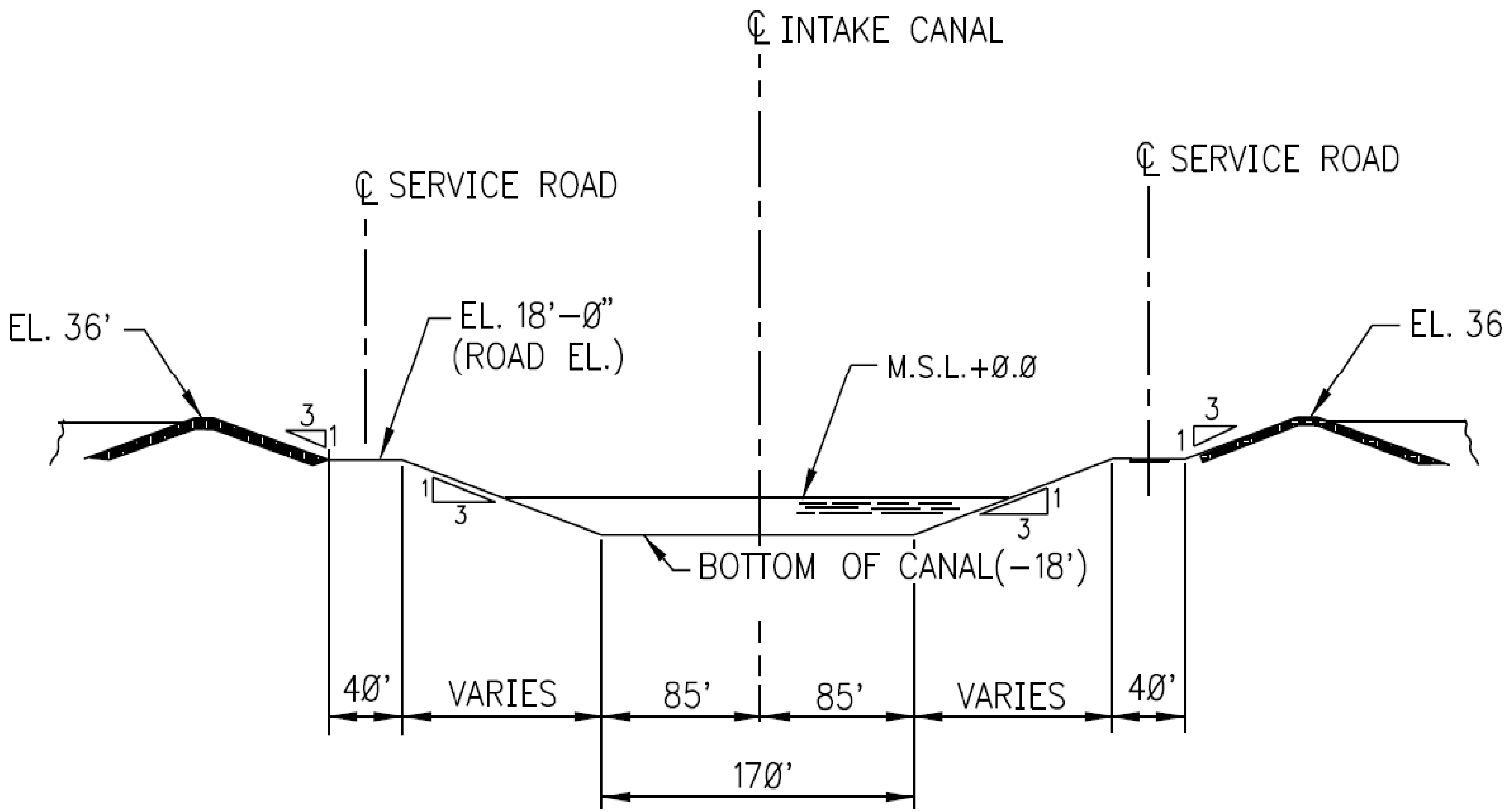
Brunswick – Intake Canal

- NRC Question
  - Describe the basis for screening out slope stability along the Intake Canal under the review level earthquake loading
- Duke Energy Response
  - Original Intake Canal design evaluation acknowledged liquefaction and slope sliding
  - The total length of the Intake Canal is 2.57 miles
  - The bottom of the Intake Canal is at elevation -18 feet, the Intake Canal bottom is 170 feet wide, and the side slopes are at a 4H:1V slope in the marsh area, and 3H:1V in the high ground area
  - Intake Canal was originally designed to provide normal cooling water loads for five (5) units

Brunswick – Intake Canal

- Duke Energy Response (cont.)
  - The Intake Canal is designed to accommodate a flow requirement of 1,390 cubic feet/second per unit
  - The maximum designed capacity of the Intake Canal is approximately 7,000 cubic feet/second
  - Intake Canal channel mean sea level (MSL) velocity for one unit operating is 0.3 feet/second (fps), and maximum low tide velocity is 0.4 fps. When two units are in operation the MSL velocity is 0.6 fps, and maximum low tide velocity is 0.8 fps
  - The maximum acceptable low water level Intake Canal velocity is limited to 1.5 fps

Brunswick – Intake Canal



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Brunswick – Intake Canal

Brunswick – Intake Canal

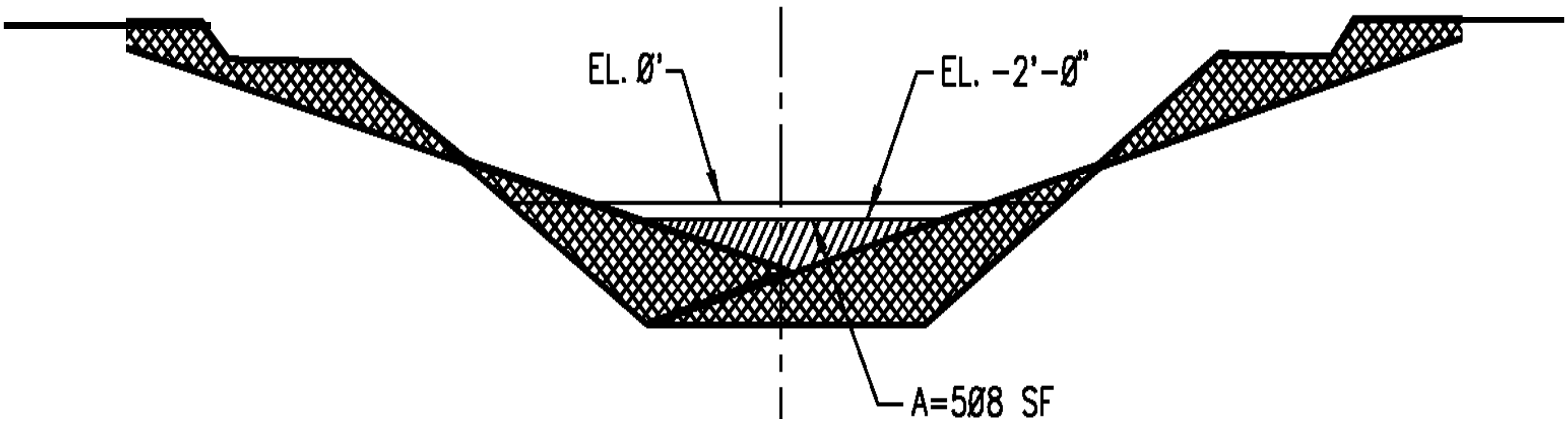
- Duke Energy Response (cont.)
  - EPRI Report NP-6041-SL, Table 7-1A, *“Relationship Between Observed Lateral Deformation During Earthquakes and Geometric Properties of Liquefied Alluvial Soils”*, presents a breakdown of consequences of liquefaction based on soil conditions and topography
  - Intake Canal slope slides similar to those presented in Table 7-1A will occur based on the canal design slope, elevation changes and susceptibility to liquefaction
  - Theoretical limit of the progressive failures was established as having a median angle of repose of 5º corresponding to a slope of approximately 12H:1V

Brunswick – Intake Canal

- Duke Energy Response (cont.)
  - Sliding at any point along the Intake Canal length, on both sides, is conservatively postulated to occur
  - Amount of material transported will not significantly impact the Intake Canal performance
  - Service Water pump capacity for ten (10) pumps for both units is 80,000 gallons per minute (gpm)
  - At a velocity of 1.5 fps, the required cross section area for 80,000 gpm is 119 square feet (ft^2). Design cross sectional area of canal at low tide is 3760 ft^2
  - Intake Canal design capacity ensures significant margin remains to provide adequate cooling water to both units

Brunswick – Intake Canal

- Duke Energy Response (cont.)



Brunswick – Conclusion

- Duke Energy performed a focused scope IPEEE per NUREG-1407 and submitted to NRC by letter dated June 30, 1995
- Duke Energy performed a full scope soil failure evaluation
- Intake Canal can accept liquefaction/slope failures without danger of loss of cooling water to the plant
- Intake Canal capacity ensures significant margin remains to provide adequate cooling water to both units

Robinson

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GMRS - Robinson

- NRC identified 5 topics which may account for the differences between RNP and NRC GMRS
  1. Thickness of alluvium at surface
  2. Shear-Wave Velocity profile for the Tuscaloosa Formation (Middendorf)
  3. Epistemic uncertainty in Shear-Wave Velocity profile
  4. Combination of EPRI soil (1993), Peninsular Range and EPRI Rock curves versus EPRI soil only curve for shear modulus and damping
  5. Review of EPRI 1021097 Earthquake Catalog for RIS Earthquakes in the Southeastern U.S. and Earthquakes in South Carolina Near the Time of the 1886 Charleston Earthquake Sequence

GMRS - Robinson

- NRC Topic 1
  - Thickness of alluvium at surface
- Duke Energy Response
  - For thickness of alluvium layer, NRC Staff used UFSAR Section 2.5.4.1 and UFSAR Figure 2.5.1-2
  - RNP also used data from UFSAR Section 2.5.4.1, UFSAR Figure 2.5.1-2, supplemented with recent site geologic profile site investigations for the Independent Spent Fuel Storage Installation (ISFSI)

GMRS - Robinson

- Duke Energy Response (cont.)
  - UFSAR Section 2.5.1.2*, "In general, the upper alluvial sands and gravels are moderately compact. Layers of compressible material occur in the upper <u>30 to 50 feet.</u>"*
  - UFSAR Section 2.5.4.1, *"The piedmont crystalline basement rock at the site is overlain with approximately 460 feet of unconsolidated coastal plain sediment. These sediments are comprised of <u>about 30 feet</u> of surface alluvium over 430 feet of the Middendorf formation."*

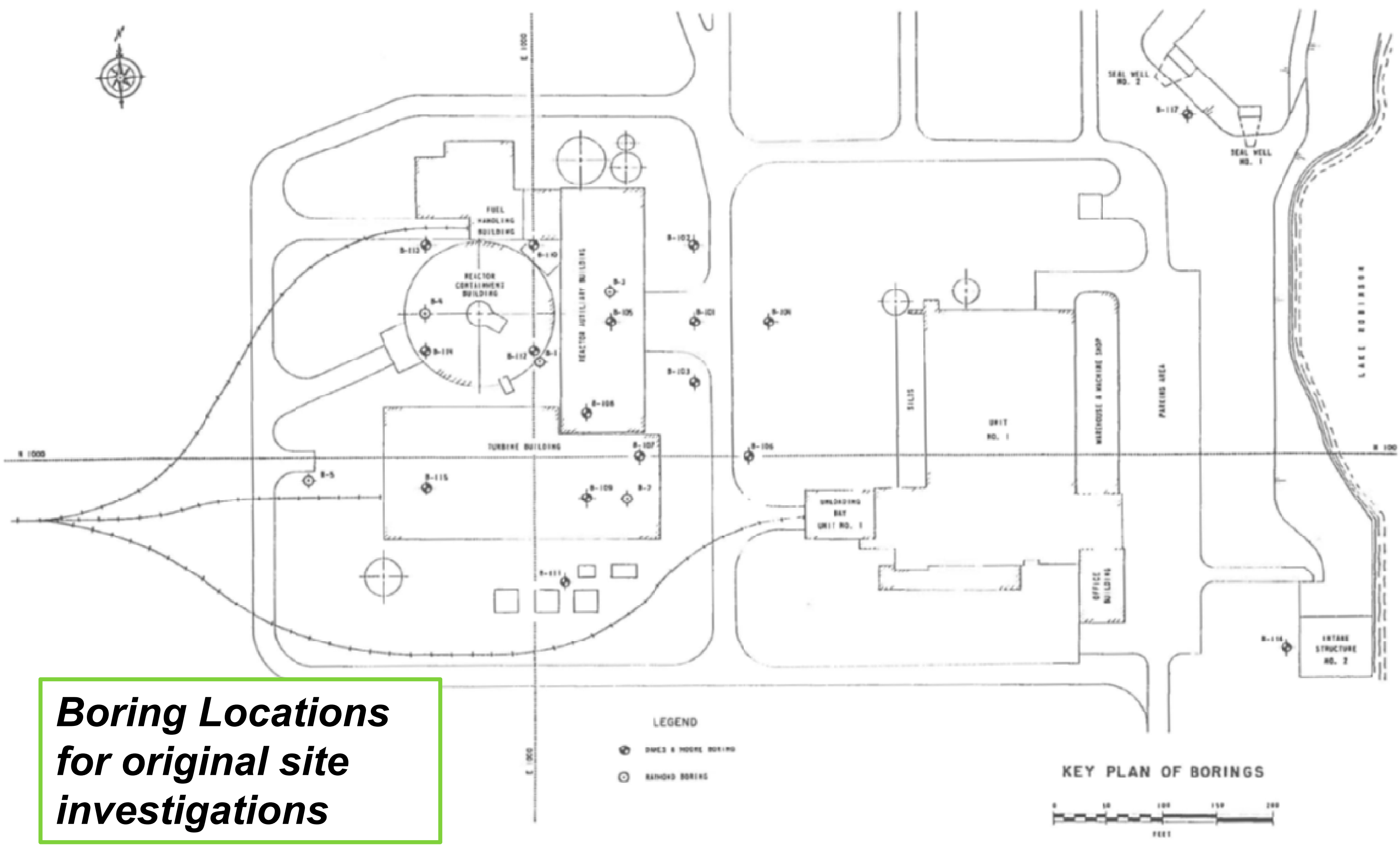
GMRS - Robinson

GEOLOGIC COLUMN

(DATA FROM RNP UFSAR, FIGURE 2.5.1-2)

Depth In Feet	LOG SYMBOLS	DESCRIPTION	COMPRESSIONAL WAVE VELOCITY (FT / SEC)	ASSUMED POISSON'S RATIO	SHEAR WAVE VELOCITY (FT / SEC)	UNIT WEIGHT (LBS/CU.FT)
0		ALLUVIUM, RECENT (SAND & GRAVELS)	1500	.33	750	125
30		MIDDENDORF, CRETACEOUS (SANDS, SILTY AND SANDY CLAY, SANDSTONE AND MUDSTONE)	7200	.33	3600	130
460		CRYSTALLINE, PRE-CAMBRIAN (GRANITE, GNEISS, PHYLLITE SCHIST	17500	.15	11200	170

GMRS - Robinson



Boring Locations for original site investigations

GMRS - Robinson

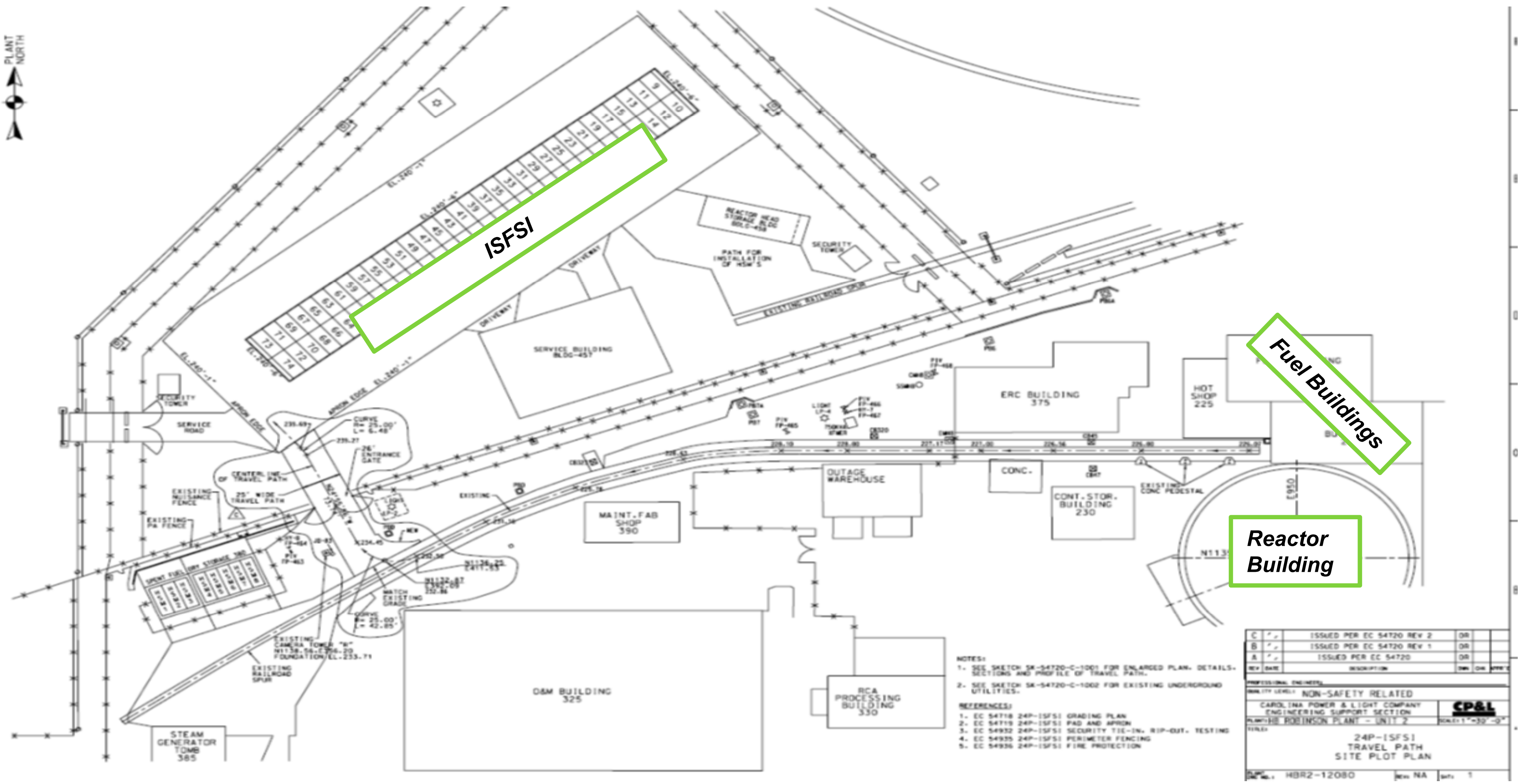
- Duke Energy Response (cont.)
  - Conclusions from the ISFSI subsurface investigation reported in the September 11, 2013 submittal (ML13312A918)
    - MACTEC suggests an adjusted value of 1000 fps for the first 70 feet of soil (measured from Elevation 240)
    - Average N-values change at approximately 70 feet depth
    - Down hole survey performed for upper 70 feet
  - Materials sampled in recent borings are consistent with the previous geologic descriptions
  - ISFSI subsurface investigations were performed close to the power block (~350 feet)

GMRS - Robinson

- Duke Energy Response (cont.)
  - The ISFSI soil investigation determined site consists of 56 feet (measured from El. 226 ft.) of recent alluvium
  - The remaining 404 feet (Cretaceous Middendorf) consists of light-colored feldspathic and slightly micaceous quartz sand interbedded with red, purple, gray, and brown silty and sandy clay. Some of the sand layers have been cemented, resulting in poorly indurated sandstones and occasional laminated mudstones. (UFSAR Section 2.5.1.1.2)
  - Regarding original plant field and laboratory investigations, UFSAR Section 3.8.5.1 states, “the soil conditions throughout the area are moderately consistent”

GMRS - Robinson

- Site map showing ISFSI relative to other safety-related structures in the power block



GMRS - Robinson

Site geologic data based on recent soil investigations for ISFSI			
Depth* Range (feet)	Soil/Rock Description	Density (PCF)	Shear-Wave Velocity (fps)
0 to 56	Recent alluvium (sand and gravel)	125	1000**
56 to 460	Cretaceous Middendorf (sands, silty, and sandy clay, sandstone and mudstone)	130	3600
> 460	Pre-Cambrian Crystalline (granite, gneiss, phyllite schist)	170	11200

* Measured from elevation 226 feet

** Original soil profile from UFSAR Figure 2.5.1-2 adjusted based on ISFSI tests

GMRS - Robinson

- NRC Topic 2
  - Shear-Wave Velocity profile for the Tuscaloosa Formation (Middendorf)
- Duke Energy Response
  - For Vs of Middendorf (Tuscaloosa) formation, NRC staff used USGS Open File Report 03-043 (Odum et. al., 2003)
  - RNP data from UFSAR Section 2.5.4.1, UFSAR Figure 2.5.1-2 based on Seismic Refraction survey Compression Wave Velocity (Vp) and assumed Poisson ratio.
  - Applied Vs of 3,600 feet/sec as average over 404 feet

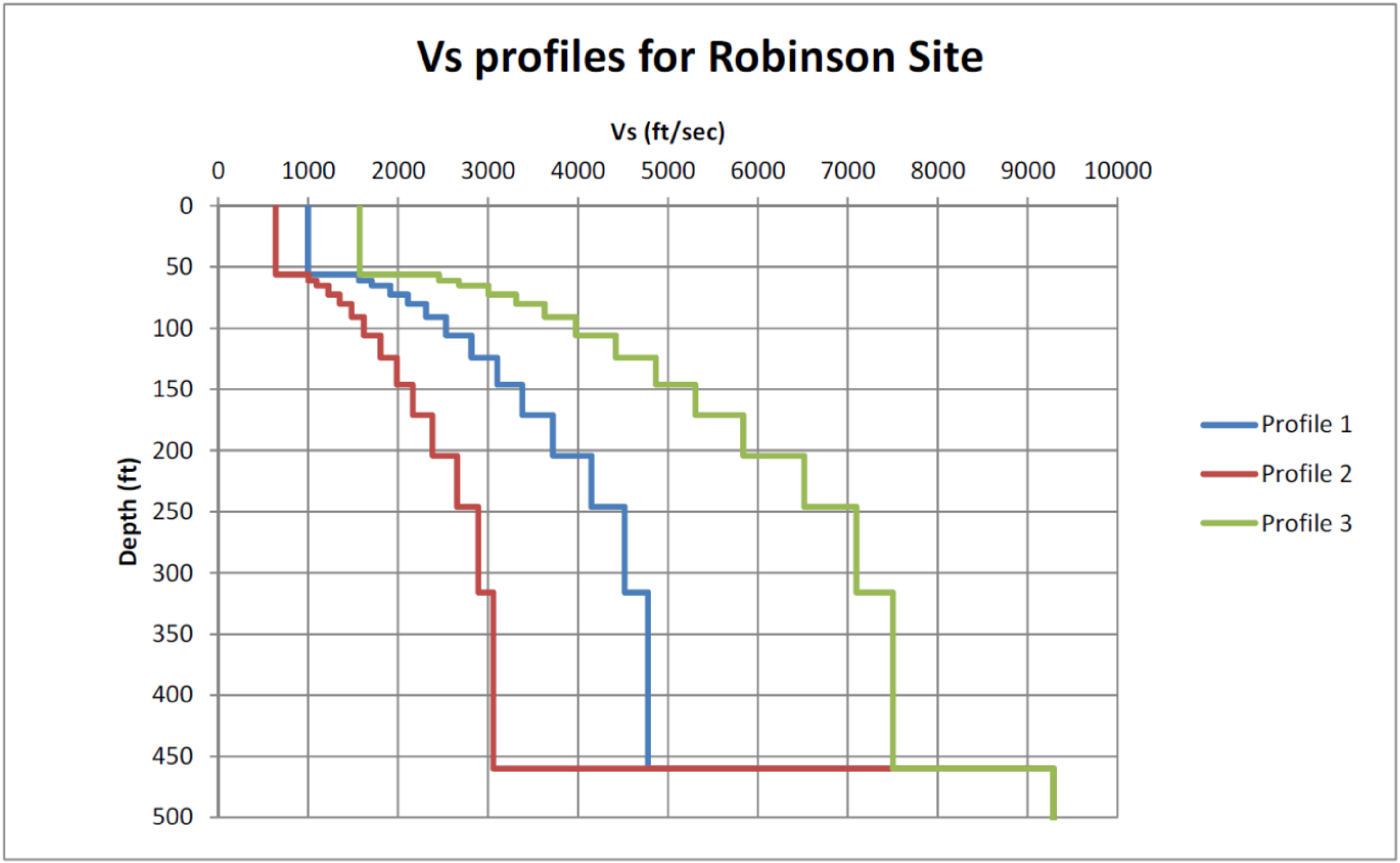
GMRS - Robinson

- Duke Energy Response (cont.)
  - Shear-Wave Velocity profile of 1,000 feet/sec for alluvium is based on testing associated with ISFSI soil exploration
  - Average Shear-Wave Velocity of 3,600 feet/sec is used for the Middendorf (Tuscaloosa) formation based on UFSAR Figure 2.5.1-2
  - Shear-Wave Velocity profile of 11,200 feet/sec for granite, gneiss, phyllite schist is based on UFSAR Figure 2.5.1-2
  - Following the SPID, the soft rock generic gradient was used for 404 feet of stiff soils and soft rock, 760 m/s Vs(30m) template
  - Adjusted to the average Vs over 404 feet of 3,600 feet/sec
  - A depth dependent velocity gradient is used to more accurately represent in-situ conditions

GMRS - Robinson

- NRC Topics 3 & 4
  - Epistemic uncertainty in Shear-Wave Velocity profile
  - Variability of dynamic material properties
- Duke Energy Response
  - No direct Vs measurement for the Middendorf
  - Followed the SPID with development of 3 base case profiles

GMRS - Robinson



GMRS - Robinson

- Duke Energy Response (cont.)
  - No recent laboratory dynamic testing
  - Following SPID, soils modeled with two sets of generic modulus reduction and hysteretic damping curves, EPRI and Peninsular Range
  - Middendorf treated alternatively as cohesionless soils or soft rock (sandstones / shales)
  - Accounted for a realistic range in response from largely linear with Peninsular Range curves throughout to significantly non-linear with EPRI (Soil and Rock) curves throughout

GMRS - Robinson

- Duke Energy Response (cont.)

Basis for estimation of total effective kappa

- Conservative (low) estimate of low strain effective kappa based on damping curves plus contribution from hard rock (0.006s)
- Average 0.012s close to SPID estimate of 0.014s based on 456 feet soil
- Total effective kappa at design loading largely controlled by damping at higher strains
- Epistemic uncertainty on total effective kappa at design levels accommodated with multiple sets of shear modulus and hysteretic damping curves

GMRS - Robinson

Velocity Profile	Kappa(s)	
	M1, M2	M3
P1	0.009	0.014
P2	0.011	0.019
P3	0.008	0.011
	Weights	
P1	0.4	
P2	0.3	
P3	0.3	
G/G_{max} and Hysteretic Damping Curves		
M1	0.3	
M2	0.3	
M3	0.3	

GMRS - Robinson

- NRC Topic 5
  - Site-Specific CEUS-SSC Catalog Review
- Duke Energy Response
  - Identification of additional reservoir induced seismicity (RIS) earthquakes in the southeastern United States
  - Locations of earthquakes in South Carolina near the time of the 1886 Charleston, South Carolina earthquake sequence
  - Site-specific correction to earthquake catalog
  - GMRS developed before and after this change and the resulting impact is shown

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Robinson - Conclusion

- RNP GMRS is developed in accordance with SPID process based on the new site geologic data from the site investigation performed for ISFSI; shear modulus and damping; and kappa values as discussed in the September 11, 2013 submittal (ML13312A918)
- The Expedited Seismic Evaluation Process (ESEP) used the maximum scale factor of 2XSSE therefore not impacted by changes to the GMRS
- Results of SPID screening process concludes the need for a seismic risk evaluation be performed for RNP
- The seismic risk evaluation is to be submitted June 30, 2017

Summary

- For both BNP and RNP, development of the March 31, 2014 submittal followed the SPID process outlined in EPRI Report 1025287, November 2012 (ML12333A170)
- BNP Intake Canal capacity ensures significant margin remains given liquefaction/slope failures without danger of loss of cooling water for both units
- Duke Energy agrees with NRC conclusion that RNP screens in as a Group 1 plant and that a seismic risk evaluation will be submitted by June 2017
- Duke Energy looks forward to continued dialog with the NRC on this important matter

Acronyms

BNP	Brunswick Nuclear Plant
CEUS	Central and Eastern United States
EPRI	Electric Power Research Institute
ESEP	Expedited Seismic Evaluation Process
ft	feet
ft^2	square feet
fps	feet/second
g	Gravity
GPM	Gallons per minute
GMRS	Ground Motion Response Spectrum
G/G_{max}	Shear Modulus Reduction
H	Horizontal
Hz	Hertz
IPEEE	Individual Pant Examination of External Events
ISFSI	Independent Spent Fuel Storage Installation
MSL	Mean Sea Level
NRC	Nuclear Regulatory Commission
PCF	pounds/cubic feet
RIS	reservoir induced seismicity
RNP	Robinson Nuclear Plant
S or sec	Seconds
SSE	Safe Shutdown Earthquake
SPID	Screening and Prioritization Implementation Details
USGS	United States Geological Survey
V	Vertical
Vp	Compression Wave Velocity
Vs	Shear-Wave Velocity
Vs(30m)	Thirty-Meter Shear-Wave Velocity