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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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REGULATORY POLICIES AND PRACTICES SUBCOMMITTEE

+ + + + +

WEDNESDAY

OCTOBER 17, 2018

+ + + + +

ROCKVILLE, MARYLAND

+ + + + +

The Subcommittee met at the Nuclear  
Regulatory Commission, Three White Flint North, Room  
1C3 & 1C5, 11601 Landsdown Street, at 1:00 p.m.,  
Walter Kirchner, Chairman, presiding.

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COMMITTEE MEMBERS:

- WALTER KIRCHNER, Chairman
- MICHAEL L. CORRADINI, Member
- RONALD G. BALLINGER, Member
- DENNIS C. BLEY, Member\*
- CHARLES H. BROWN, JR., Member
- MARGARET SZE-TAI Y. CHU, Member
- PETER RICCARDELLA, Member
- HAROLD B. RAY , Member
- MATTHEW SUNSERI, Member

DESIGNATED FEDERAL OFFICIAL:

QUYNH NGUYEN

\*Present via telephone

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Deformation

Vibratory Ground Motion

Stability of Subsurface Materials and  
Foundations and Stability of Slopes

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## P R O C E E D I N G S

12:59 p.m.

CHAIRMAN KIRCHNER: Good afternoon. You need a click to go. Okay, the meeting will now come to order. This is a meeting of the Regulatory Policies and Practices Subcommittee of the Advisory Committee on Reactor Safeguards. I am Walt Kirchner, Chairman of this Subcommittee meeting.

ACRS members in the room are, I have to take my glasses off, Charles Brown, Ron Ballinger, Harold Ray, Matt Sunseri, Pete Riccardella, Mike Corradini, and Margaret Chu. And I believe we're expecting Vesna Dimitrijevic. And also I think we have Dennis Bley on the line.

Quynh Nguyen of the ACRS staff is the Designated Federal Official for this meeting. This turns out to be the fourth meeting of this subcommittee on the topic. Today, the Subcommittee will hear from representatives of TDA and the staff regarding the following sections of the Clinch River early site permit application and the corresponding safety evaluation: geological characterization and surface deformation, 2.5.1 and 2.5.3; a vibratory ground motion, 2.5.2; and stability of subsurface materials and foundations and stabilities of slopes,

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1 that's 2.54 and 2.5.5.

2 The Subcommittee will gather information,  
3 analyze relevant issues and facts, and formulate  
4 proposed positions and actions as appropriate for  
5 deliberation by the full Committee.

6 The ACRS was established by statute and is  
7 governed by the Federal Advisory Committee Act, FACA.  
8 This means that the Committee can only speak through  
9 its published letter reports. We hold meetings to  
10 gather information to support our deliberations.  
11 Interested parties who wish to provide comments can  
12 contact our offices requesting time after the meeting  
13 announcement is published in the Federal Register.

14 That said, we also set aside some time for  
15 spur of the moment comments from members of the public  
16 attending or listening to our meetings. Written  
17 comments are also welcome. In regard to early site  
18 permits, 10 CFR 52.23 provides that the Commission  
19 shall refer a copy of the application to the ACRS, and  
20 the Committee shall report on those portions which  
21 concern safety.

22 The ACRS section of the US NRC public  
23 website provides our charter, bylaws, letter reports,  
24 and full transcripts of all full and Subcommittee  
25 meetings, including slides presented at the meetings.

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1 The rules for participation in today's meeting were  
2 previously announced in the Federal Register. We have  
3 received no written comments or requests for time to  
4 make oral statements from members of the public  
5 regarding today's meeting.

6 We have a bridge line established for  
7 interested members of the public to listen in. To  
8 preclude interruption of the meeting, the phone bridge  
9 will be placed in a listen-in mode during the  
10 presentations and Committee discussions. We will  
11 unmute the bridge line at a designated time to afford  
12 the public an opportunity to make a statement or  
13 provide comments.

14 At this time, I request that meeting  
15 attendees and participants silence their cellphones  
16 and any other electronic devices that are audible. A  
17 transcript of the meeting is being kept and will be  
18 made available as stated in the Federal Register  
19 notice. Therefore, we request that participants in  
20 this meeting use the microphones located throughout  
21 the meeting room when addressing the Subcommittee.

22 The participants should first identify  
23 themselves and speak with sufficient clarity and  
24 volume so that they may be readily heard. Make sure  
25 that the green light of the microphone is on before

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1 speaking, and off when not in use.

2 We will now proceed with the meeting, and  
3 I call upon Andy Campbell of NRO to begin. Andy.

4 MR. CAMPBELL: Good afternoon, my name is  
5 Andy Campbell, I'm the Deputy Director for the  
6 Division of Licensing, Siting, and Environmental  
7 Analysis in the Office of New Reactors. With me today  
8 are a number of staff from DLSC involved in this  
9 project, Alan Fetter, Mallecia Sutton, Garry  
10 Stirewalt, Jenise Thompson, David Heeszal, Luisette  
11 Candelario, Weijun Wang.

12 And I will let the TVA folks introduce  
13 themselves.

14 So this is the third of four Subcommittee  
15 meetings for the staff evaluation, the safety  
16 evaluation, with no open items. Let me repeat that,  
17 we have no open items.

18 First, ESP from an SMR plant design, the  
19 review has been proceeding as scheduled, and you'll  
20 hear today about the geology and ground information  
21 aspects of that safety evaluation. We look forward to  
22 continued fruitful dialog with the Advisory Committee  
23 on Reactor Safeguards as this ESP review continues  
24 moving forward.

25 And the last and final Subcommittee will

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1 be November 14, I believe. And so with the full  
2 Committee of the Advisory Committee on Reactor  
3 Safeguards scheduled for December 5.

4 And so with that full Committee meeting  
5 and any letter the Committee wishes to write, we would  
6 be closing out Phase C of our review. So with that,  
7 I'll turn it back to you. I want to thank everyone  
8 and thank the staff and thank TVA for coming in and  
9 supporting this review.

10 CHAIRMAN KIRCHNER: Thank you, Andy. So  
11 we'll turn to TVA. Ray, are you going to make the  
12 introductions, or is Wally? Go ahead, Ray.

13 MR. SCHIELE: Good afternoon, my name is  
14 Ray Schiele and I'm the Licensing Manager for the  
15 Clinch River early site permit application. I have  
16 over 44 years in the nuclear industry, including  
17 United States Navy, plant operations, and licensing.

18 TVA would like to thank Chairman Kirchner  
19 and the rest of the Subcommittee for their support in  
20 the review of this early site permit application.

21 This slide is an acknowledgment of the  
22 relationship between DOE and TVA and the associated  
23 responsibilities of that relationship.

24 Overview of TVA's mission. TVA's mission  
25 includes partnering with over 154 local power

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1 companies serving more than nine million people in a  
2 service area that covers seven states. TVA directly  
3 serves over 54 large industries and federal  
4 installations.

5 This slide is a review of our schedule  
6 thus far. The first section here we're going to talk  
7 about is the safety review. Today's meeting is the  
8 fourth of five planned Subcommittee meetings.  
9 Previous meetings included an overview of the project,  
10 sections on geography, tomography, aircraft hazards,  
11 radiological consequences of design-based accidents,  
12 emergency planning, and EPZ sizing.

13 Today, TVA will be presenting Section 2.5,  
14 geology, seismology, and geotechnical engineering.  
15 The final Subcommittee meeting, scheduled for November  
16 14, will cover Sections 2-3, meteorology; 2-4,  
17 hydrology; 11-2 and 11-3, radiological effluent  
18 releases; and 17, which is quality assurance.

19 So as you can see, we're well ahead of the  
20 proposed FSER issuance of August of '17. The  
21 Environmental Review was issued, the DEIS was issued  
22 five weeks early. The NRC is on or ahead of the  
23 published schedule for the review and disposition of  
24 DEIS comments. TVA is looking forward to an early  
25 issuance of the FEIS. And this is the basic Gantt

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1 chart for the Environmental Review.

2 The hearing. In July of 2018, the ASLB  
3 dismissed the last remained admitted contention,  
4 rejecting two new proposed contentions, and terminated  
5 the contested hearing. And this is a, just a Gantt  
6 timeline of the hearing schedule.

7 This slide illustrates the NRC and  
8 reactions related to the ESPA SSAR Section 2.5. The  
9 first pre-application audit was held in July of 2015  
10 with eight NRC staff and resulted in the  
11 identification of 68 issues that require resolution  
12 prior to application submittal. In January of 2016,  
13 there was a public meeting to discuss the disposition  
14 of those issues identified in the readiness  
15 assessment.

16 The second audit was held in May of 2017  
17 to review geology, seismology, geotechnical  
18 information in the application. The audits focused  
19 specifically on geological information, vibratory  
20 ground motion, and geotechnical engineering  
21 information. It included a site, a vicinity tour of  
22 geologic features and a review of core samples.

23 This audit identified six specific areas  
24 where supplemental information was requested.  
25 Additionally, an NRC management and geology visit was

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1 conducted in January of 2018.

2 I'd like now to introduce the presenters  
3 for today's discussion. Wally Justice, who'll be  
4 assisted by both Kevin Clahan and Janet Sowers.  
5 Wally.

6 MR. JUSTICE: Thank you, Ray. Turn to  
7 Slide 8, please. My name is Wally Justice, and I'm a  
8 mechanical engineer with 36 years of experience in the  
9 United States nuclear industry. In the commercial  
10 side, including design, construction, and operation of  
11 nuclear power plants. The last several years I had  
12 been involved in the small modular reactor technology  
13 sector, in addition to working on COLAs and ESPAs.

14 Today I'm going to give you a high level  
15 overview of the geological investigations and results  
16 provided in early site permit application for the  
17 Clinch River site. From the investigations and  
18 analysis, you will learn that the only identified  
19 geological hazard for the site is karst formations.  
20 We will have detailed discussion on the subject later  
21 in the presentation.

22 The site directly adjoins the Oak Ridge  
23 Reservation, and if you look to the right on the  
24 slide, you will see the Clinch River site, bounded by  
25 the Clinch River itself as it goes around. It looks

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1 like a small foot.

2 For Section 2.5.1, TVA followed the  
3 requirements of 10 CFR 100.23(c). The information  
4 was developed in accordance with the NRC guidance  
5 documents per Reg Guide 1.206, and NUREG-0800 standard  
6 review plans for the review of safety analysis reports  
7 for nuclear power plants was followed to produce  
8 Section 2.5.1. Next slide, please.

9 The overall geological profile for the  
10 Clinch River site area is best explained by  
11 understanding of the regional geology and relationship  
12 to the eastern United States. A total of six  
13 physiographic provinces lie within the 320 kilometer,  
14 or 200 mile, radius of the site location. The site is  
15 located in the Valley and Ridge Province, with the  
16 Appalachian Plateau Province to the west and the Blue  
17 Ridge Province to the east. Next slide.

18 Drilling down from the regional view of  
19 200 miles to the five-mile site radius from the  
20 center, the local ridges and valleys are presented in  
21 the figure. The 0.6 mile site location, also known as  
22 the one kilometer mile location, is located in the  
23 center of the figure.

24 As shown on the 200-mile radius map, the  
25 site lies within the regional stratigraphy associated

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1 with the Valley and Ridge Province of folded and  
2 faulted carbonate rocks. This consists predominantly  
3 of a sequence of Paleozoic sedimentary rocks ranging  
4 in age from Lower Cambrian to Pennsylvania,  
5 approximately 541 to 323 million years ago.

6 And this slide will reappear in today's  
7 presentation in two more instances because it contains  
8 useful information related to many of today's topics.  
9 This slide represents a one-mile cross-section of the  
10 Clinch River site. At the top of the slide, and it  
11 may be easier to see on your handouts, but you have  
12 Site A, also noted here as, excuse me, Site B, also  
13 noted as Location B, and Site, or Location A.

14 We'll be talking today about two faults,  
15 the Chestnut Ridge fault and the Copper Creek fault.  
16 You will also notice that these are the various rock  
17 formations that lie underneath the Clinch River site  
18 area. We're on a 33 degree dipping stratigraphy to  
19 the southeast, and the borings that are associated  
20 with this cross-section are located in their location  
21 of drilling, and the depths are presented.

22 CHAIRMAN KIRCHNER: Wally, would you just  
23 point out where the CRBR site was relative to A and B.

24 MR. JUSTICE: So I have a slide in a  
25 couple slides that will help you understand this a

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1 little better, but the old Clinch River Breeder  
2 Reactor excavation is actually located in the same  
3 rock formation as the Site B. And it would be out  
4 from the face of the slide you're looking at. That'll  
5 make a little more sense here in just a minute.

6 Now that we have a general idea about the  
7 location and the characteristics of the site in  
8 region, I would like to discuss some of the methods  
9 utilized to investigate and characterize the site,  
10 such as field reconnaissance activities.

11 Again, the previous Clinch River Breeder  
12 Reactor data and investigations that were done in the  
13 late 70s and early 80s, core borings that were  
14 performed, reports done for the Oak Ridge National  
15 Laboratory, karst mapping, river terrace mapping, just  
16 to name a few.

17 The picture to the right is actually a  
18 picture of the field investigation for the Copper  
19 Creek Cave, which is located approximately five miles  
20 from the site center to the northeast. Go to the next  
21 slide, please.

22 This slide's a little busy, but it depicts  
23 an example of the dates and locations for the field  
24 reconnaissance trips to investigate the relevant  
25 geological features in the site area. Much of the

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1 information I gathered was utilized in subsequent  
2 analyses and reports in determining the suitability of  
3 the site.

4 MEMBER CORADINI: Are these new, or is  
5 this from the original CRBR?

6 MR. JUSTICE: These were performed new.  
7 These were performed recently, and if you can see on  
8 the slide the dates are actually listed. They're just  
9 a little hard to see on the actual chart on the  
10 screen. That's okay.

11 We're on Slide 15 now. LiDAR data was  
12 taken for the area to ensure complete coverage of the  
13 file-mile site area. An example of the results of  
14 this effort are located on the right of the slide.  
15 The identification of karst depressions, a sink hole,  
16 and ground depressions are identified.

17 For example, Figure D, which is at the  
18 bottom right corner, shows close depressions that were  
19 identified from the LiDAR investigations.

20 MEMBER CORADINI: So remind me, these are  
21 surface depressions?

22 MR. JUSTICE: Yes, these would be surface  
23 depressions that were identified during the LiDAR  
24 investigation.

25 Okay, this is the core borings for the

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1 Clinch River Breeder Reactor Project. Again, that was  
2 in the late 70s and early 80s. And I wanted to  
3 present this. It's very busy and hard to read, but  
4 you can see this area of a lot of borings. That's the  
5 actual excavation area for the Clinch River Breeder  
6 Reactor.

7 If we go to the next slide, this shows  
8 right here is the old Clinch River Breeder Reactor  
9 footprint. So it is outlined in blue on your slide.  
10 Then there's a series of new cores that were performed  
11 associated with the current Small Modular Reactor  
12 Project. Site B is generally located in the red  
13 circle, as is Site A.

14 And just to help understand the number of  
15 borings, 76 rock core borings were performed for the  
16 Small Modular Reactor Project in present day. And  
17 there were 104 borings that were performed for the  
18 original Clinch River Breeder Reactor Project. All of  
19 this information was utilized to help us characterize  
20 the site for this early site permit application.

21 MEMBER RAY: Was there any difference in  
22 the information provided by the two eras and types of  
23 boring used and so on?

24 MR. JUSTICE: In general, they were very  
25 close in agreement with, from one era to the next.

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1 MEMBER RAY: So you didn't have some new  
2 technology that enabled you to get more information  
3 now than in the past?

4 MEMBER CORADINI: I think he was talking  
5 about old versus new, not A versus B.

6 MEMBER RAY: No, that's right, yeah.

7 MR. JUSTICE: That's correct. I  
8 understand the question you're asking is the old  
9 borings that were performed in the late 70s to support  
10 the Breeder, and then the borings that were performed  
11 in modern day, today, was there anything, any  
12 different or significant from those. And the answer  
13 to that is no.

14 MEMBER RAY: Thank you.

15 MR. JUSTICE: I would now like to turn --

16 CHAIRMAN KIRCHNER: Wally, before you go  
17 on, just --

18 MR. JUSTICE: Yes, sir.

19 CHAIRMAN KIRCHNER: I can't read it here.  
20 What's the distance between the center of B and A?

21 MR. JUSTICE: The center, the distance  
22 between B and A is approximately 600 feet.

23 CHAIRMAN KIRCHNER: Six hundred feet,  
24 okay. Two football fields. Is there a preferred site  
25 between A or B, or you were just covering all bets?

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1 MR. JUSTICE: For the application, we  
2 evaluated two specific locations on the site,  
3 specifically because you'll learn that these are in  
4 different rock members from a geologic perspective.  
5 Based on the technology that TVA may decide to select,  
6 you may need more than one location to build one or  
7 more plants. So it was decided to do two locations,  
8 and at this time there's really not a preferred  
9 location associated ---

10 (Simultaneous Speaking.)

11 CHAIRMAN KIRCHNER: So there isn't at this  
12 point.

13 MR. JUSTICE: That's correct.

14 CHAIRMAN KIRCHNER: Thank you.

15 MR. JUSTICE: So I would now like to turn,  
16 or excuse me, to introduce Kevin Clahan from Lettis  
17 Consultants International to discuss faults and sheer  
18 fracture zones for the next few slides. Kevin.

19 MR. CLAHAN: All right, thank you, Wally.  
20 It's nice to be here. My name is Kevin Clahan and I'm  
21 a professional geologist and certified engineering  
22 geologist with over 25 years of experience conducting  
23 geologic and seismic hazard studies around the world.  
24 I've worked for over 12 years now in the nuclear  
25 industry evaluating conditions at 11 different

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1 proposed or existing nuclear sites, and I've been  
2 working on the Clinch River site since 2011.

3 This slide here, can I borrow a pen?  
4 Thank you. So faults are one of the more important  
5 aspects of any site evaluation, and the assessment of  
6 that faulting. The first step in this evaluation is  
7 understanding the bedrock and Quaternary geology.

8 And so what you see here at the latitude  
9 of the Clinch River site, we have a repeated section  
10 of interbedded carbonate and shale units that are part  
11 of the Rome. You can maybe see better on, oops. The  
12 Rome, Conasauga, Knox, and Chickamauga group.

13 And so you'll see those same patterns  
14 here. We have a light tan, green, brown, pink that  
15 are repeating. At the boundary of these repeating  
16 sections are large scale thrust faults that were  
17 active during the late Paleozoic Alleghanian orogeny,  
18 which occurred some 320 to 280 million years ago.

19 And you're going to be hearing the term  
20 Alleghanian orogeny, so I just want you to understand  
21 that that was the orogeny where the plates Gondwana  
22 and Laurentia collided to form Pangaea and close the  
23 proto-Atlantic Ocean before it reopened again. So  
24 that happened about 300 million years ago.

25 MEMBER CORADINI: No test, right?

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1 MR. CLAHAN: There's no test after this.  
2 So we know that these faults have not become active or  
3 have been active in the last 276 million years, and  
4 that's due to fault gouge dating by argon-argon on the  
5 Copper Creek fault, just to the north, several miles  
6 to the north of the site here.

7 As well as a well-studied dyke system that  
8 was emplaced within the Valley and Ridge formation,  
9 which offsets these faults. And that dyke system was  
10 dated at about 200 million years, so that gives you a  
11 minimum age at least for the activity of that  
12 faulting.

13 In addition, what we did is we've mapped  
14 Quaternary river terraces upstream and downstream of  
15 the site along the Clinch River within the five-mile  
16 site radius. So we mapped from approximately here all  
17 along up to here, and mapped Quaternary fluvial  
18 terraces, plotted those terraces. And then where they  
19 projected across these particular faults, looked for  
20 any sort of deformation.

21 Some of these river terraces are on the  
22 order of several hundred thousand years old, and we  
23 saw no deformation associated with those terraces due  
24 to those faults. All right, next slide, please.

25 So while we're on the topic of faulting,

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1 a potentially related feature was described during the  
2 excavation of the Breeder Reactor. They referred to  
3 this particular feature as a shear zone, and we  
4 identified this same feature in our bore hole  
5 investigation. The two images here are a cross-  
6 section similar to what Wally showed early, our  
7 dipping stratigraphic units.

8 The shear zone, or shear fracture zone as  
9 we're referring to it, is in yellow here. And we  
10 found it in two locations, and it projects parallel to  
11 bedding and with the same dip as well.

12 The shear fracture zone itself, again, is  
13 a bedding parallel feature that's characterized by an  
14 abundance of calcite veins, stylolites, which are a  
15 result of pressure solution. These are oriented both  
16 parallel and perpendicular to bedding, as well as some  
17 slick insided fractures.

18 And what this image on the bottom right is  
19 trying to do, and it's difficult to see, but on your  
20 handouts, we give examples of those particular  
21 features. These black serrated lines here are  
22 parallel to bedding stylolites, the white blebs are  
23 veins, and then we have some normal, or perpendicular  
24 to bedding stylolites as well here. And we'll see  
25 some more of that on the next slide as well.

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1           Before we go to the next slide, let's see,  
2           I want to mention that these features sometimes  
3           truncate each other in ways which support a diagenetic  
4           or syndepositional origin, meaning they occurred  
5           during deposition and lithification of the rock. And  
6           this rock, again, is the Chickamauga group, it's on  
7           the order of 500 million years old.

8           When we see stylolites that are oriented  
9           perpendicular to bedding, we associate that with the  
10          tectonic overprinting, which I'll show you in the next  
11          slide. Again, there's no measurable displacement  
12          along this zone, and it is not visible in the ground  
13          surface. Okay, next -- oh, and I want to conclude  
14          that by saying the breeder reactor PSAR concluded that  
15          this feature is a zone of interbed slippage that  
16          occurred during the Alleghanian orogeny.

17                 MEMBER CORADINI: So may we have a minute  
18          for digression?

19                 MR. CLAHAN: Yeah.

20                 MEMBER CORADINI: You said there's no  
21          displacement, so how are you measuring displacement?  
22          Because you're looking a long time ago.

23                 MR. CLAHAN: Yes.

24                 MEMBER CORADINI: So displacement means  
25          that I'm looking for a difference in the qualitative

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1 features of the rock? I'm --

2 MR. CLAHAN: That's right. No, that's  
3 right. If there was a fault, you would see a  
4 discernable displacement of like units on either side  
5 of that particular feature. Here, we don't see any  
6 discernable offset. There's minor microfracturing of  
7 things, there's vein, there's pressure dissolution,  
8 which sort of skews the margins of contacts, but  
9 there's no through going deformation or displacement.

10 MEMBER CORADINI: But more generally since  
11 you're going, I'm going to, you're going to lose me,  
12 is it more of a qualitative judgement on your part to  
13 look for something?

14 MR. CLAHAN: No --

15 MEMBER CORADINI: In other words, if I see  
16 a fracture or if I see an opening, the measurement of  
17 the opening is not important as much as there's  
18 physically an opening that you see of like rock.

19 MR. CLAHAN: Not necessarily. When you're  
20 looking at whether or not there's active faulting or  
21 there's faulting in a general area, you're looking for  
22 that displacement. So the fracturing and the  
23 separation of rock could be completely, something  
24 completely different.

25 MEMBER CORADINI: Okay, but then let me

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1 push the point. So now I see a fracture, so how do I  
2 know how old it is? It could be a fracture from 100  
3 million years ago, 200 million years ago.

4 MR. CLAHAN: Sure.

5 MEMBER CORADINI: Twenty years ago.

6 MR. CLAHAN: It's a good question, yeah,  
7 good question. And what that ties into are these  
8 stylolites, and these are a result in carbonate rock  
9 of dissolution during deposition. And we also see a  
10 imprint of a tectonic. And so what we're doing is  
11 correlating the two different phases of stylolite  
12 formation with the deposition of the rock 500 million  
13 years ago, and then the Alleghanian orogeny 280  
14 million years ago.

15 And so all that deformation occurred  
16 within that window. Does that answer?

17 MEMBER CORADINI: Yeah.

18 MR. CLAHAN: So we can tell that age.

19 MEMBER CORADINI: The age of the fracture.

20 MR. CLAHAN: That's right.

21 MEMBER CORADINI: Okay.

22 MR. CLAHAN: Yeah, that's right.

23 CHAIRMAN KIRCHNER: Also, Kevin, so the  
24 picture on the left is the depth of the bore holes and  
25 the picture on the right has a scale of about two or

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1 three feet.

2 MR. CLAHAN: That's right.

3 CHAIRMAN KIRCHNER: All right, so what  
4 we'll see on the right is coming up on the next slide.

5 MR. CLAHAN: It is, that's right.

6 CHAIRMAN KIRCHNER: That's fine, okay.

7 MR. CLAHAN: Yes, and this is a schematic

8 --

9 CHAIRMAN KIRCHNER: Connective pieces.

10 MR. CLAHAN: This is part of one of the  
11 RAIs that we helped, sort of explained the shear  
12 fracture zone. So next slide, please. So these  
13 images show photographs of natural and modified logs  
14 that are detailing the shear fracture zone features.  
15 And one thing to notice again is the abundant veining  
16 compared to the adjacent rock. You see that in  
17 certain areas here.

18 The serrated stylolites produced by  
19 pressure solution, both parallel to bedding and  
20 perpendicular to bedding. Down here, the stylolites  
21 are listed as in purple, bedding is in yellow on this  
22 figure. So bedding again here, you can see this is a  
23 33 degree southwest dipping bedding, represented in  
24 the core. And then these are those bedding parallel  
25 stylolites that formed during syndeposition of that

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1 rock and lithification of that rock.

2 We also see stylolites that are  
3 perpendicular to the bedding here. And those give us  
4 an idea that those subvertical stylolites indicate  
5 pressure solution occurred during subhorizontal  
6 compression, which coincides with the shortening and  
7 emplacement of the Valley and Ridge thrust faults  
8 during the Alleghanian orogeny.

9 There's a lack of brittle cataclasis or  
10 fault breccia or gouge that we see associated with the  
11 Copper Creek fault, which we know to have accommodated  
12 at least 50 kilometers or so of shortening. All the  
13 faults within the Valley and Ridge have accommodated  
14 together approximately 250 kilometers of shortening  
15 during the Alleghanian orogeny. That's going to be on  
16 the test.

17 So again, these parallel stylolites  
18 occurred during bedrock formation, and they're also  
19 located throughout all the cores. All right, and so  
20 these features, again, are not fault-related, but they  
21 accommodate internal deformation of the rock and they  
22 show no discernable displacement.

23 And that's all I have. I'd like to turn  
24 it back to Walt.

25 MR. JUSTICE: Thank you, Kevin. Next

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1 slide, please.

2 Local geological hazards. NUREG-0800  
3 requires the identification of geological hazards  
4 which may affect the suitability of a site for the  
5 construction of a nuclear power plant. As I stated  
6 earlier, through our investigations, karst dissolution  
7 is the primary geologic hazard of concern for this  
8 application.

9 Janet Sowers, who is also to my right and  
10 pictured in the picture on the slide, will now take up  
11 the discussion of the topic. Janet, would you please  
12 introduce yourself.

13 MS. SOWERS: Thank you, Wally. My name is  
14 Janet Sowers and I'm a licensed professional geologist  
15 with Fugro. I received an undergraduate degree from  
16 University of Virginia and a PhD from University of  
17 California. During my 30-year career, I've worked on  
18 site characterization and geologic hazard projects for  
19 many large infrastructure projects, including six  
20 proposed or existing nuclear power projects.

21 One of my specialties and my focus for the  
22 Clinch River Project is the karst characterization and  
23 evaluation of karst hazards. Next slide.

24 So karst is a landscape with distinctive  
25 features that are formed by the slow dissolution of

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1 limestone by groundwater. The water flows through the  
2 fractures and joints, enlarging them and eventually  
3 forming an underground drainage system, and karst  
4 landscape features such as sinkholes and caves and  
5 springs and an irregular bedrock contact underneath  
6 the soil.

7 This is an example of a karst model drawn  
8 for an area, the Copper Ridge area of Oak Ridge, where  
9 the, it's underlined by thick dolomite. The rock  
10 under the hillside has a number of dissolution  
11 passages shown by yellow, in yellow. Many were formed  
12 when the rock was under the groundwater table in the  
13 phreatic zone.

14 After the erosion cut down and drained  
15 these passages, vadose zone dissolution, or  
16 dissolution above the water table, took place by  
17 descending rainwater forming vertical slots and steep  
18 passages, which may intersect the older phreatic  
19 passages.

20 Sinkholes form at the ground surface,  
21 typically where the soil over the bedrock filters down  
22 into the underground slots and passages, and then  
23 undermines the surface soil. And the surface soil  
24 then sinks or collapses to form the sinkhole. It's  
25 called a cover collapse sinkhole, and that's the most

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1 common type of sinkhole in the Valley and Ridge.

2 Springs occur where conduits discharge at  
3 the surface. In a later slide we'll show you a karst  
4 model that we've developed for the Clinch River site.  
5 This particular karst model was developed by the  
6 Tennessee Geologic Survey for the Copper Ridge area.  
7 Next slide.

8 MEMBER CORADINI: So just a cartoon, since  
9 we have the cartoon in front, so this is mainly by  
10 rainfall moving its way through the earth to the  
11 river, versus river intrusion subsurface? Or some  
12 combination of that?

13 MS. SOWERS: Let's back up for just a  
14 second, because many of the passages are phreatic,  
15 which means they were formed below the water table.  
16 Right now, they're high and dry in this model. So  
17 imagine, undo the downcutting of the Clinch River and  
18 put a lot more rock back up on top.

19 And then you're under the groundwater  
20 table, and rainwater then descends down through, and  
21 then there's groundwater circulation underneath the  
22 water table that is dissolving out these phreatic  
23 passages.

24 MEMBER CORADINI: And so this all natural.  
25 Is there any mining operations in the area that uses

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1 --

2 MS. SOWERS: No, no mining operations.  
3 And this is a very slow process.

4 MEMBER CORADINI: Okay.

5 MS. SOWERS: All right, so next one. We  
6 based our karst analysis on information from previous  
7 --

8 CHAIRMAN KIRCHNER: You said that, Janet,  
9 it was slow. Just for the record, how slow?

10 MS. SOWERS: How slow? It's slow enough  
11 that you would not notice dissolution in your lifetime  
12 or in the lifetime of the planet. We would not notice  
13 it. It's like in the order of centimeters per hundred  
14 or thousand years.

15 CHAIRMAN KIRCHNER: So if we do a good  
16 mapping of the potential site, then for the lifetime  
17 of the power plant, we would not expect one of the  
18 sinkholes to form.

19 MS. SOWERS: We would not expect  
20 additional rock dissolution that we could notice.  
21 Sinkholes are more of a surface phenomenon that  
22 involves the soil.

23 CHAIRMAN KIRCHNER: Yeah I know --

24 MS. SOWERS: So you could get, you can get  
25 sinkholes from, in the soil, during the lifetime of

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1 the plant.

2 MEMBER CORADINI: But to get to Walt's  
3 point, you've got to, once you know the shape of the  
4 geometrically.

5 MS. SOWERS: In the rock.

6 MEMBER CORADINI: You're going to be  
7 around essentially static during the life of this --

8 MS. SOWERS: Yes, the rock passages will  
9 be --

10 MEMBER CORADINI: Project.

11 MS. SOWERS: For the lifetime of the plant  
12 will be, we would consider static. Thank you for the  
13 question.

14 So we're basing our analysis on existing  
15 and new information that we develop for the project.  
16 There were many karst studies that were done at Oak  
17 Ridge on the Reservation, including an inventory of  
18 karst features and a number of groundwater studies  
19 that tracked flow of groundwater through karst  
20 passages.

21 We also looked at the Clinch River Breeder  
22 Reactor data from the 1970s and 1980s. This provided  
23 good topographic mapping of the site before  
24 development, so we could see locations of sinkholes  
25 and what the original ridges and valleys looked like.

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1 We also were able to use the detailed logging that  
2 they did of the cavities encountered in bore holes and  
3 incorporate that in with our bore hole data.

4 For this SMR project, we conducted a LiDAR  
5 mapping of karst features from the five-mile radius,  
6 which Wally showed you some examples from. And then  
7 we compiled all the core boring information from the  
8 breeder reactor and the SMR project for analysis and  
9 modeling. Next slide.

10 Here are the conclusions. I'm sorry  
11 that's such a small font, we had intended to cut out  
12 some of this. The first bullet really says that the  
13 flow in our site is strike parallel, meaning the  
14 orientation of passages goes along strike, so  
15 perpendicular to the direction of the dip.

16 And the reason that we have that at our  
17 site is that the Chickamauga Group is a interbedded  
18 sequence of limestones and silt stones and silty  
19 limestones. And dissolution is more well developed in  
20 the pure limestones, so that the orientation of karst  
21 development is parallel to strike along those more  
22 pure limestone beds and units.

23 Second bullet says that there are some low  
24 carbonate units, and they are generally silt stones.  
25 We have the Fleanor formation, on which the Breeder

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1 Reactor was built, and that would be for Site B. We  
2 also have the Blackford formation and the Bowen  
3 formation. Those are also more carbonate pure, and  
4 those units have no mapped sinkholes. And they have  
5 smaller and fewer bore hole cavities than the other  
6 units.

7           The third bullet says that based on the  
8 bore hole data, the frequency and size of cavities,  
9 generally these decreases with depth as you go down.  
10 It doesn't, we don't completely run out of cavities.  
11 There still are some in our deepest bore holes, but  
12 they're smaller. But they're there, so there are  
13 cavities beneath the water table. But in generally  
14 it's more of a surface-intensive process where we have  
15 the greater sizes and frequency of cavities closer to  
16 the ground surface.

17           The third bullet makes a point about  
18 hypogene dissolution, which we haven't introduced yet,  
19 but just to let you know. Epigenetic dissolution  
20 means that the water, rainwater comes down, it  
21 dissolves from the vadose zone, it forms the  
22 groundwater and dissolves in the phreatic zone.

23           Hypogene dissolution would be water  
24 welling up from depths below, where it may be warm, it  
25 may be super-charged with minerals. And that can

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1 often be a more aggressive dissolution and is  
2 documented in other parts of the Valley and Ridge,  
3 such as in Virginia, but not at our Clinch River site.

4 MEMBER CORADINI: Is that, you can tell  
5 that by the chemical content of the water?

6 MS. SOWERS: You can tell it by the  
7 chemistry of the water, by deposition of exotic  
8 minerals in around springs, and by the temperature of  
9 the water.

10 MEMBER CORADINI: Okay. So no possibility  
11 --

12 MS. SOWERS: No, we don't, no. Everything  
13 seems to have a meteoric signature, all the rainwater.  
14 I mean, all the spring water.

15 CHAIRMAN KIRCHNER: So Janet, since it's  
16 up there, would you just explain one more time for the  
17 quiz, phreatic versus --

18 MS. SOWERS: Vadose?

19 CHAIRMAN KIRCHNER: Where is the other?

20 MS. SOWERS: Phreatic is at and below the  
21 water table, the groundwater table. Vadose is in the  
22 unsaturated zone above. So in the vadose zone, water  
23 is generally descending along fractures, joints,  
24 bedding plains. In the phreatic zone, it's moving  
25 along whatever paths it can find.

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1           MEMBER CHU: Can I ask you a question?  
2           You, I think you said the karst located below  
3           groundwater level, am I correct or not?

4           MS. SOWERS: Karst is, happens both above  
5           and below.

6           MEMBER CHU: Above, okay. What is the  
7           most, what do you see that's closest to the surface,  
8           the location of the karst from your mapping?

9           MS. SOWERS: The sinkholes are the most,  
10          are the surficial expression of karst processes  
11          happening at depth. Sinkholes is the number one thing  
12          that we see at the surface. Springs, cave entrances,  
13          those are also things that you see at the ground  
14          surface. And those are things that we were mapping  
15          with the LiDAR.

16          MEMBER CHU: Okay.

17          MS. SOWERS: Okay, next slide. All right,  
18          as promised, here is our karst model for our site.

19          MEMBER CORADINI: Let me just ask another  
20          question. So if you know have mapped where the holes  
21          are, and you now have Site A and B and you're going to  
22          dig through it to put down a foundation for a  
23          installation, do you fill the holes, or just monitor  
24          that they're small enough that you ignore  
25          structurally, or is that not your problem?

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1 MS. SOWERS: We'll be discussing that --

2 MEMBER CORADINI: Later?

3 MS. SOWERS: In the, near the end when we  
4 talk about geotechnical engineering. But good  
5 question.

6 So here's our model, and it's a cross-  
7 section of the site, similar to what you saw before.  
8 It's a little bit more artistic, we tried to show what  
9 the bedrock, the rock types actually are. So going  
10 from the west to the east, the, here's the dolomite.  
11 And this is the Knox Group. We are not going to be  
12 building on this, this is at the northern part of the  
13 property, however.

14 And the Knox Group, like the Copper Ridge  
15 dolomite, is more intensely karstified than these  
16 other units. So we're representing the cavities with  
17 the black. Of course, it's a schematic, so nothing is  
18 implied here as far as actual locations. This is a  
19 schematic of how we think it might look.

20 There's the Knox Group, there's an  
21 unconformity between them. There was a period of  
22 erosion of the Knox before the Chickamauga was laid  
23 down. So here's the Chickamauga from here over to the  
24 Copper Creek fault over there, and our sequence of  
25 beds.

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1                   This is the siltstone, the Fleanor  
2 formation, on which the Breeder Reactor was excavated,  
3 and this is the location for our Location B. Our  
4 Location A will be over here, and one of the limestone  
5 units, it's one of the siltier ones, but it is a  
6 limestone unit, Location A, right here.

7                   So we tried to show that there are  
8 cavities generally follow bedding plains and joints,  
9 and large bedding planes and joints, and that there  
10 are more near the surface and there are still some  
11 down at depth as well. On the other side of the  
12 fault, in the Rome formation, that's a sandstone. So  
13 that is not a karst unit.

14                   And with that, I will turn it back over to  
15 Wally.

16                   MR. JUSTICE: Thank you, Janet. Next  
17 slide, please.

18                   We have discussed the Clinch River Breeder  
19 Reactor Project in this presentation, and this  
20 photograph is the completed excavation in 1983. The  
21 documented geological mapping of the excavation has  
22 been very helpful in our current site characterization  
23 efforts. This excavation is also located, as Janet  
24 said, in the same rock member, the Fleanor, as Site B  
25 that we are discussing today and in the application.

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1 Karst features identified during the  
2 excavation of the Clinch River Breeder Reactor were  
3 considered small and manageable, particularly  
4 supporting the conclusion that karst cavities are  
5 reduced in size and frequency as depth is increased.  
6 Just for your information, this excavation was  
7 approximately 483 feet long by 360 feet wide, about  
8 100 feet deep.

9 And if you look at the picture, this rock  
10 unit here is the Rockdell unit. This unit here is the  
11 Fleanor unit, and the basement of the excavation lied  
12 within the Fleanor unit. So this mapping that was  
13 performed, it was documented in some regulatory  
14 documents and some supporting reports. And again,  
15 during that excavation, they did not identify any  
16 large karst cavities as part of their mapping efforts.  
17 Next slide, please.

18 So in conclusion, for SSAR 2.5.1, active  
19 faulting is not a geological hazard for site area or  
20 the region. All identified faults are considered  
21 greater than 290 million years old. Shear fractures  
22 are not a geological hazard for the site area, as they  
23 are also greater than 290 million years old.

24 Karst conditions are identified as the  
25 potential geological hazard for the area, and the

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1 information to discuss how we will identify and  
2 mitigate in the future will be discussed in the  
3 following presentation. And we believe we've met the  
4 regulatory requirements of 10 CFR 52.17 and the  
5 guidance from Regulatory Guide 1.2.08.

6 I'll now take us to the second portion of  
7 the presentation, which is discussion on SSAR Section  
8 2.5.2, seismology. I have Ivan Wong from Lettis  
9 Consultants International on the bridge line in the  
10 event that I have a question that needs a technical  
11 answer from him, but I will start the presentation.

12 2.5.2 is there to determine the site-  
13 specific ground motion response vector, the GMRS. The  
14 GMRS is identified as a free filled horizontal and  
15 vertical ground motion response spectrum at the site,  
16 and it must satisfy the requirements of 10 CFR 100.23.

17 We developed the GMRS in accordance with  
18 NUREG-0800, we also developed the ground motions in  
19 the SSAR with implementation of the provisions in Reg  
20 Guide 1.208, the performance-based approach to define  
21 the site-specific earthquake. Next slide, please.

22 This is a plot of the Central Eastern  
23 United States Earthquake Catalog, showing the location  
24 and magnitudes of seismic activity in the central and  
25 eastern United States. This information is contained

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1 in NUREG-2115, the central eastern United States  
2 seismic source characterization for nuclear  
3 facilities. Next slide, please.

4 Within that zone, the East Tennessee  
5 Seismic Zone is defined as an area of more frequent  
6 seismic activity, although this activity is relatively  
7 small in magnitude. The source is specifically  
8 detailed in NUREG-2115 and captures the current  
9 understanding of the seismic hazard.

10 It should be noted that TVA has two plants  
11 operating within the current East Tennessee Seismic  
12 Zone, the Watts Bar Nuclear Plant, located  
13 approximately there, and the Sequoyah Nuclear Plant,  
14 which is located approximately in that location. Next  
15 slide, please.

16 I'm sorry, the Clinch River is that red  
17 arrow or red star. Just slightly outside of the  
18 Eastern Tennessee Seismic Zone.

19 MEMBER RICCARDELLA: Okay, thank you.

20 MR. JUSTICE: Next slide, please. For the  
21 ground motion response development approach, this is  
22 a very high level description of how information is  
23 utilized to develop the GMRS for the Clinch River  
24 site.

25 The rock hazard is a result of the site-

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1 specific probabilistic seismic hazard analysis, which  
2 used an updated Department of Energy, EPRI, NRC, CUS  
3 seismic source characterization models in the EPRI  
4 ground motion models. This is now the standard  
5 practice for seismic analysis post-Fukushima. Next  
6 slide, please.

7 I would like to just a brief overview of  
8 the method we used out of Reg Guide 1.208, which is  
9 known as Approach 3. It is fully probabilistic, it  
10 preserves hazard levels. The hazard at the surface is  
11 computed by integration of the hard rock hazard with  
12 the probability distribution and frequency, and this  
13 results in a complete hazard curve at the ground  
14 surface.

15 It is endorsed by NUREG-6728. And the  
16 basic steps in Approach 3 are the randomization of  
17 site-dynamic material properties, the computation of  
18 amplification factors using random vibration theory,  
19 and the full integration of mean and fractal hazard  
20 curves. Next slide, please.

21 This slide I had a presented a couple of  
22 times earlier today, but I just wanted to point out  
23 again Site A, excuse me, Site B and Site A locations.  
24 We've talked about the faults on both ends, we talked  
25 about the dipping angle. This is a one-mile

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1 representation. I would like to go to the next slide.

2 And this is a four-mile representation,  
3 which includes the Clinch River site, which is the  
4 purple box. It has the Site B profile, which is this  
5 purple location, and the Site A profile. So this a  
6 much larger map, and it is also to basement depth of  
7 approximately 12,000 feet below sea level. So this  
8 shows all of the rock units that are associated with  
9 it, and it shows their relative velocities.

10 And I believe, if you'll pardon me, I just  
11 cannot see that number. So we see that the limestone  
12 is approximately 10,500 feet per second. And the  
13 shale, the Conasauga shale, is approximately 6,000  
14 feet per second. The limestone, the Chickamauga, is  
15 also approximately 10,000 feet per second. Next  
16 slide, please.

17 Profiles were developed for both Sites A  
18 and B separately, based on the velocity shown on the  
19 cross-section you just saw, based on the particular  
20 rock members and depth. And if you compare these two,  
21 even though they're in different rock members, you  
22 notice that there's a lot of consistency in the  
23 profiles. Next slide, please.

24 The mean rock hazard curves were then  
25 developed based on that analysis. And this is the

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1 hazard at ground surface for the Clinch River site, an  
2 example. Next slide.

3 We then, from that information, developed  
4 the ground motion response specter for Site A and Site  
5 B. And then if you go the next slide. We then  
6 brought those two curves together and combined them  
7 into one overall, enveloping ground motion response  
8 specter for the Clinch River site. This is for both  
9 the horizontal and vertical ground motion response  
10 specter. Next slide.

11 The 2D sensitivity analysis was performed  
12 to determine if the dipping stratigraphy of  
13 approximately 33 degrees was fully recognized by the  
14 1D analysis or the GMRS analysis. The 2D analysis is  
15 considered a multi-dimensional approach for validation  
16 for Reg Guide 1.208.

17 The 2D-1D comparison described in the SSAR  
18 and documented in the GMRS study involved calculating  
19 the amplification for the full, two-dimensional  
20 profile compared to amplification of single, one-  
21 dimensional profiles as best estimate slices through  
22 the midpoint of Sites A and B.

23 In the site response analysis performed to  
24 develop the GMRS, the best estimate 1D profiles at  
25 Sites A and B were used along with upper and lower

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1 wrench profiles at each location for a total of six  
2 profiles and associated amplification factors.

3 The hazard was then calculated for each of  
4 the six profiles, and the hazard at Sites A and B each  
5 reflecting a wave average over best estimate and upper  
6 and lower wrench profiles. Next slide.

7 MEMBER CORADINI: Can you go back to the  
8 angle?

9 MR. JUSTICE: Back one more?

10 MEMBER CORADINI: I'm just trying to  
11 understand what was done, so maybe Slide 36? That  
12 one. So the 1D basically layers them horizontally?  
13 Not vertically, I assume. So when you say it's a 1D  
14 model, I basically take all these various rock  
15 formations with different sound speeds and just layer  
16 them one on top of the other.

17 MR. JUSTICE: That is correct.

18 MEMBER CORADINI: Okay. And the two  
19 dimensional actually captures in two dimensions the  
20 angle or feature, the angle.

21 MR. JUSTICE: Correct. And then you  
22 perform a comparison to see if the assumptions that  
23 were performed in the 1D were fully captured, based on  
24 the 2D analysis.

25 MEMBER CORADINI: Okay then, so can you go

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1 back to 40?

2 MR. JUSTICE: Slide 40?

3 MEMBER CORADINI: Yeah. So the dark blue  
4 at the bottom is 2D, everything else is 1D above it.

5 MR. JUSTICE: That's correct.

6 MEMBER CORADINI: And on the Y axis is  
7 what?

8 MR. JUSTICE: The side amplification.

9 MEMBER CORADINI: What does that mean?  
10 Can you help me there? So it's the G force times that  
11 number?

12 MR. JUSTICE: So at this frequency, this  
13 is the amplification factor associated with each  
14 frequency from the analysis.

15 MEMBER RICCARDELLA: A single degree of  
16 freedom oscillator at the --

17 MEMBER CORADINI: You need to turn  
18 something on. Higher.

19 MEMBER RICCARDELLA: A single degree of  
20 freedom oscillator at the frequency, right? And so  
21 when the two dimensional you do, you look at the  
22 vertical as well as the horizontal, is that the two  
23 dimensions?

24 MR. JUSTICE: That's correct. And you  
25 have, and we had a slight accedence at approximately

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1 two, frequency of two hertz in both cases. But that  
2 was the only place that there was any accedence  
3 associated with 2D sensitivity.

4 MEMBER RAY: I think Mike's asking  
5 amplification of what.

6 CHAIRMAN KIRCHNER: Ground motion.

7 MEMBER CORADINI: And so I've got at some  
8 depth a wiggle, and I'm wiggling it at some frequency.  
9 And then I'm looking at the surface, what that wiggle  
10 corresponds to after it's passed through all these  
11 layers of stuff.

12 MR. JUSTICE: That is correct.

13 MEMBER CORADINI: Okay, so is this, it's  
14 got to be horizontal wiggle, it can't be side to side  
15 wiggling, because one dimensionally, it doesn't --

16 MR. CLAHAN: It's vertically propagating  
17 shear waves.

18 MEMBER CORADINI: But the shear wave is a  
19 vertical propagating shear wave, so it's not, it's  
20 horizontal motion. It's vertical motion, vertical  
21 motion. It can't be horizontal motion, not with a 1D  
22 modeling.

23 MEMBER RAY: Mike, there's two dimensions  
24 in the horizontal plane.

25 MEMBER CORADINI: I know, but they have a

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1 1D model where they're leveraging rock this way, so I  
2 can't do anything here and model that. I'm only  
3 modeling wiggling that way.

4 MEMBER RAY: How much shear in the one  
5 direction? You're talking about -- yeah, yeah.

6 MEMBER CORADINI: So there's some sort of  
7 shear component perpendicular to the oscillation  
8 that's modeled in the 1D model.

9 MR. JUSTICE: So perhaps it would be best  
10 if we brought Ivan Wong from Lettis on the bridge  
11 line.

12 MEMBER CORADINI: I just want to  
13 understand all the curves. At least, so I understand  
14 it vertically, how you did the layering. I just was  
15 trying to understand the side-to-side horizontal  
16 motion.

17 MR. JUSTICE: We'll see if we can get you  
18 a little better explanation than I'm going to be able  
19 to give you on this subject. Is the bridge open where  
20 Ivan can hear me?

21 MR. WONG: Wally, I'm on the line.

22 MR. JUSTICE: Hello, Ivan. If you would  
23 be so kind as to give your background and experience  
24 and your full name, and we'll answer the question.

25 MR. WONG: Okay. My name is Ivan Wong,

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1 I'm a seismologist with Lettis Consultants  
2 International. I have 44 years of experience in  
3 seismic hazard, and I guess my most conspicuous  
4 project was I was the Project Manager for the seismic  
5 hazard evaluation of the Yucca Mountain Project for  
6 about 15 years.

7 So Wally, are we looking at the slide  
8 that's a comparison of 1D and 2D amplification  
9 factors?

10 MR. JUSTICE: That is correct, we're on  
11 Slide 40.

12 MR. WONG: Okay, so what we're showing  
13 here is the results of basically a 1D and 2D site  
14 response analysis. So we're basically showing what we  
15 call amplification factors, which compare the ground  
16 motions at the input of a soil column, versus anywhere  
17 at the top of the column.

18 So in the 1D analysis, as one of the  
19 members of the Committee mentioned, in a 1D analysis  
20 it's a, basically a layer cake profile. We're  
21 modeling vertically incident seismic shear waves, so  
22 they're vertically propagating, they go up through the  
23 column in a vertical fashion.

24 But because they are shear waves, the  
25 particle motion is horizontal. So we're looking at

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1 the horizontal motion from a vertically propagating  
2 shear wave velocity.

3 So in the 2D, we're actually modeling the  
4 dipping stratigraphy and just calculation the  
5 amplification factors of the vertically propagating  
6 through the dipping layers. And in that figure, we're  
7 just comparing the amplification factors between the  
8 1D and the 2D.

9 And as Wally has stated, the 1D  
10 amplification factors are conservative. But to the  
11 2D, and that's simply because when we did the 1D, we  
12 had multiple profiles and we included all the  
13 uncertainties. And so that compensates for any 2D  
14 effects.

15 And the other observation is because the  
16 velocities of the rock are so hard, the 2D effects are  
17 very, very small. So it's easily captured in the 1D  
18 analysis.

19 MEMBER CORADINI: So just one last  
20 question, just so I think I get it. So there's a  
21 frictional, there's an assumption of frictional  
22 between the layer cakes? In other words, if I start  
23 wiggling it horizontally, which you call a shear wave,  
24 one made up of layer X then provides a force to layer  
25 Y.

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1           But there must be a shear component at the  
2 interface between the two layers, which is the same  
3 assumed in both analyses?

4           MR. WONG: There is that particle motion,  
5 or friction as you call it. But again the velocities,  
6 because the rock is so hard, even though you're going  
7 from one rock type to another, let's say from 6,000  
8 meters per second to 10,000 meters per second, that  
9 transfer of motion is relatively small.

10           If you were in lower velocity materials,  
11 like a soil, where the velocities are on the more, on  
12 the order of a few hundred meters per second, that  
13 effect that you're talking about would be more  
14 pronounced. But there it's not.

15           MEMBER CORADINI: Okay, so really what  
16 we're seeing between the blue line, which is lower in  
17 all the other colored lines, is the effect of the  
18 angle or structure.

19           MR. WONG: Yes.

20           MEMBER CORADINI: Got it, thank you.

21           MR. WONG: Absolutely, thank you.

22           MEMBER RICCARDELLA: So, yes, another  
23 question. So in the 2D model, are you still putting  
24 in a single, one dimensional horizontal movement that  
25 just, and you're just considering the stiffness in the

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1 two different directions, that they? Or are you  
2 looking at two different, distinct directions of  
3 vibratory motion, vertical and horizontal?

4 MR. WONG: No, we're still putting in,  
5 we're still putting in, you know, vertically  
6 propagating waves. But they, we're looking at the 2D,  
7 yeah.

8 MEMBER RICCARDELLA: Yeah.

9 MR. WONG: So we're looking at them in the  
10 two dimensional sense. And we're propagating them  
11 through that 2D structure.

12 MEMBER CORADINI: But the source term is  
13 the same. I thought what was Pete was asking, the  
14 source is the same. It's still --

15 MEMBER RICCARDELLA: The driving  
16 vibration, you're just putting in horizontal motion,  
17 at various frequencies, right?

18 MR. WONG: Yes, absolutely.

19 MEMBER RICCARDELLA: Okay, thank you.

20 MR. JUSTICE: Thank you, Ivan.

21 MEMBER SUNSERI: So I have a question.  
22 Maybe you're leading us to this answering my question,  
23 and if so I can be patient and wait. But if I think  
24 about the previous presentation with the karst, and I  
25 would characterize that as blemishes near the surface,

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1 such as streams, caves, sinkholes, etc., and then I  
2 think about the proximity of the site to this Eastern  
3 Tennessee Seismic Zone, is it possible that the  
4 seismic activity could connect perforations, like  
5 peeling the postage stamp off the perforated sheet and  
6 cause problems that way?

7 I'm just trying to think of where this  
8 presentation's going to end up, what the conclusion's  
9 going to be. You understand what I'm saying?

10 So you have the karst, which at least what  
11 I'm hearing described is blemishes near the surface,  
12 or it could be anywhere, but I'm talking about the  
13 ones near the surface, the caves, the streams, the  
14 sinkholes, whatever. They're randomly distributed, I  
15 presume. And you have the site, and then the site is  
16 adjacent to this Eastern Tennessee seismic area.

17 So now you have something seismically  
18 happen. Can you connect the blemishes and cause  
19 problems that way with the surface?

20 MR. JUSTICE: So I think to try to address  
21 that question, the earthquake activity would occur  
22 deep within the, near the Precambrian basin and up.  
23 The blemishes we're talking about, the karst  
24 depressions, sinkholes, naturally forming areas such  
25 as that, are very close to the surface.

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1           From my foundation of a nuclear plant, and  
2 we will discuss some of that in the next part of the  
3 presentation, but from the depth of the foundation of  
4 the site and the anchorage of that site, you will have  
5 removed any of those considered blemishes in the area  
6 for the safety-related feature that you're putting in  
7 at the plant.

8           And perhaps, maybe we can table that a  
9 little through the next part of the presentation, and  
10 then maybe revisit your question and see if we've  
11 hopefully enlightened it or can answer it further.

12           MEMBER SUNSERI: Yeah, that's fine. I'm  
13 just trying to, you know, it's not my field, so I'm  
14 not even going to try to attempt to understand all  
15 these intermediate graphs, I just want to get from the  
16 beginning to the end kind of conclusion, right.

17           MR. JUSTICE: Understand, thank you for  
18 that. Let's go ahead and move to Slide 42, if we can.  
19 Just to conclude the seismology portion, the PSHA  
20 performed for the Clinch River site, specifically for  
21 Sites A and B, we followed 10 CFR 100.23, and we used  
22 the guidance of Reg Guide 1.208.

23           It represents the regional and local  
24 hazards and includes the local subsurface properties.  
25 And it evaluated the potential for 2D effects due to

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1 the dipping angle of 33 degrees.

2 Now I'd move to Slide 44 and discuss the  
3 remaining sections of SSAR 2.5. These would be 2.53,  
4 2.54, and 2.55. Specifically, these subsections  
5 address the following issues: potential surface  
6 deformation associated with active tectonism,  
7 including any significant neotectonic features and  
8 faults; potential surface deformation associated with  
9 non-tectonic processes, such as collapse of  
10 structures, karst collapse for instance; slope  
11 failures; and any human activity, such as mining we  
12 talked about earlier.

13 The geological, geophysical, and  
14 geotechnical information is used as a basis to  
15 evaluate the stability of subsurface materials and  
16 foundations at the Clinch River site. And the  
17 information presented in this subsection is based on  
18 the results of the site-specific subsurface  
19 evaluations that were performed at the Clinch River  
20 site. Next slide, 45.

21 For surface deformation, TVA has performed  
22 geological, seismological, and geophysical  
23 investigations and analysis for the region and site.  
24 We concluded in the application that the potential for  
25 tectonic deformation at the site is negligible.

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1 Non-tectonic karst deformation is possible  
2 with karst conditions. Detailed mapping of excavation  
3 walls and foundations will be performed during  
4 construction for a confirmation of the conclusions  
5 reached in this application. Next slide.

6 I would like to reiterate some of the  
7 investigations and activities that were performed to  
8 address the stability of subsurface materials and  
9 foundations. We've talked about the previous Clinch  
10 River Breeder Reactor Project subsurface  
11 investigations and analyses. We also did some  
12 additional work, a lot of additional work, for the  
13 current project.

14 There were 82 actual geotechnical core  
15 borings that were performed at the site. Earlier I  
16 told you there were 76 core borings. Those were rock  
17 borings, and there were six additional soil borings at  
18 the site.

19 We had test pits dug, we had groundwater  
20 observation wells. We did down hole geophysical  
21 testing in multiple borings. We did groundwater level  
22 monitoring in the observation wells, and we did  
23 laboratory testing of the boring soil and rock samples  
24 that were pulled up from the cores. These programs  
25 followed Reg Guide 1.1.32, site investigations for

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1 foundations for nuclear power plants. Next slide.

2 Engineering properties were developed to  
3 determine if the site was suitable for support of a  
4 nuclear power plant, in conjunction with Reg Guide  
5 1.132. These are just a few examples of some of those  
6 properties that were investigated. Ultimate bearing  
7 capacity, allowable bearing capacity, settlement heat  
8 analysis, and additional properties such as rock  
9 strength and others.

10 Properties were evaluated against a  
11 surrogate plant for the Clinch River site using the  
12 plant parameter envelope approach. And I believe that  
13 plant parameter envelope approach was discussed  
14 previously in an ACRS meeting, but if there are any  
15 questions on what that is, I can go back through an  
16 explanation of that effort. Okay, moving to the next  
17 slide.

18 Due to the identified geological hazard of  
19 karst dissolution, additional geotechnical studies  
20 were performed to understand the effect on nuclear  
21 safety-related foundations. We performed a PLAXIS two  
22 dimensional analysis to determine foundation  
23 acceptability. We used a large reactor foundation  
24 that we selected that a current design because enough  
25 detailed information about the four conceptual SMRs

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1 was not available the time we performed the analysis.

2 Finite element models were developed for  
3 both Site A and B. These models were done at three  
4 different embedment depths, a 40-foot embedment, a 90-  
5 foot embedment, and a 140-foot embedment.

6 MEMBER CORADINI: Where did you come up  
7 with 40, 90, 140?

8 MR. JUSTICE: They will correspond to --

9 MEMBER CORADINI: Potential.

10 MR. JUSTICE: Potential foundation levels  
11 for SMRs being considered.

12 MEMBER CORADINI: Okay. I was guessing  
13 that, I just wanted to make sure. Undefined, thank  
14 you.

15 MR. JUSTICE: You're welcome. The 40-foot  
16 embedment was actually done because the embedment  
17 depth of the design we used to, as the surrogate model  
18 for this site. The 90 and 140 more closely represent  
19 embedment depths for the current SMR designs.

20 So for each Site A and B, we did the three  
21 different embedment depths. And then, at each of  
22 those embedment depths, we then evaluated the  
23 placement of the cavity at five foot below the  
24 embedment depth and at 30 feet below the embedment  
25 depth.

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1                   And then for each of those models, we then  
2                   selected three different locations for the placement  
3                   of the cavity at those depths. It was either at the  
4                   edge of the nuclear island, at the center of the  
5                   nuclear island, or at the appropriate bedding plane  
6                   for the Site A or B. So multiple models were  
7                   performed.

8                   MEMBER CORADINI: Remind me what the  
9                   cavity is in relation to the bottom of the embedment.

10                  MR. JUSTICE: Five feet --

11                  MEMBER CORADINI: Yeah, I understand that  
12                  but --

13                  MR. JUSTICE: Or 30 feet.

14                  MEMBER CORADINI: But what do you mean by,  
15                  I don't understand what you mean by cavities.

16                  MR. JUSTICE: Karst cavity.

17                  MEMBER CORADINI: Oh, cavity, I'm sorry.

18                  MR. JUSTICE: An assumed --

19                  MEMBER CORADINI: I got it.

20                  MR. JUSTICE: Unfound, couldn't find it,  
21                  never knew it was there cavity. Hypothetical cavity.  
22                  And if we turn to the next slide --

23                  MEMBER BROWN: Before you do that.

24                  MR. JUSTICE: Yes?

25                  MEMBER BROWN: What's the basis for a

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1 large PWR being satisfactory as opposed to an SMR?

2 MR. JUSTICE: We looked at --

3 MEMBER BROWN: They are different.

4 MR. JUSTICE: They are different. You  
5 have similar building sizes in a lot of cases, even  
6 though an SMR is small. In some cases, their  
7 footprint can be almost as large as a current, modern  
8 PWR. We knew the information from the design, and we  
9 knew that that information had been previously  
10 reviewed and approved in a DCA or other method by the  
11 NRC. So the information was known and available.

12 If you'll allow me, in a couple slides, we  
13 get to do this analysis again for the technology --

14 (Simultaneous Speaking.)

15 MEMBER BROWN: I'll be happy to allow you.

16 MR. JUSTICE: Thank you.

17 MEMBER BROWN: This is not my area, just  
18 seemed to stick out, that's all. Thank you.

19 MR. JUSTICE: Our attempt at this was to  
20 do as many different scenarios as we could to fully  
21 explain the effect that an unknown cavity may have on  
22 our geology, with the best information possible at the  
23 time from the application.

24 If we go to the next slide, which should  
25 be 49, this is an example of a Site B. This is a

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1 finite element model for cavity placement for Site B,  
2 with a cavity diameter assumed of 15 feet. So the  
3 unknown cavity's 15 feet. At the center of the  
4 nuclear island, so we can see it's, if you can see my  
5 little red dot. And the foundation is at a 90-foot  
6 embedment depth.

7 So this is just an example of a sheet  
8 pulled out from the finite element analysis.

9 CHAIRMAN KIRCHNER: And the basis for 15-  
10 foot diameter is that you would probably detect  
11 anything larger than that when you do your site, final  
12 site where, before you start laying the concrete in?

13 MR. JUSTICE: That is one point, and it  
14 also corresponds to what we have found, either through  
15 the Breeder Reactor or through the investigations we  
16 did for the SMR.

17 MEMBER RICCARDELLA: Would you point to  
18 the cavity again, please?

19 MR. JUSTICE: I'm sorry, did you say the  
20 cavity?

21 MEMBER RICCARDELLA: Yeah.

22 MR. JUSTICE: Yes, it is, yeah. Sorry,  
23 this doesn't show it for some reason on that blue.

24 MEMBER RICCARDELLA: Got it.

25 MR. JUSTICE: So this again was at the

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1 center of the island. It was a 15-foot cavity placed  
2 five feet below at a 90-foot embedment depth for the  
3 rock units associated with Site B. And if we go to  
4 the next slide.

5 Just to reiterate the foundation model  
6 results, the development in the site areas is  
7 generally limited to the most markedly weather zone,  
8 okay. We've discussed that before in how karst is  
9 formed and where you find it and at what depths.

10 Typically, these are to depths less than  
11 100 feet. Seventy-five percent of reported cavities  
12 in the Site A and B borings occurred at depths less  
13 than 55 feet. And of course this material, if those  
14 sites are chosen, that material would be excavated and  
15 removed.

16 Cavity-related failure has a higher  
17 potential to occur at relatively shallow depth, less  
18 than about 30 feet. But the technologies that we are  
19 considering under this application have embedment  
20 depths between 80 and 140 feet. Precisely, they are  
21 at 86 feet and 138 feet as we move forward with the  
22 designs of these different facilities.

23 And we chose the 15-foot cavity as the  
24 terminal cavity for this analysis because it bounded  
25 the size cavities that we had found in the

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1 investigation for both the Clinch River Breeder  
2 Reactor and from the current SMR evaluations. Next  
3 slide, please.

4 Now to help with last question. So at  
5 COLA, if TVA moves forward with a COLA, the foundation  
6 performance will have to be re-evaluated based on that  
7 technology. And that technology would then have a DCA  
8 or a DCV that provides the requisite information you  
9 would need to do this type of analysis.

10 It would take into account the specific  
11 plant design, the loads, any potential ground  
12 improvement or grouting plans that may be necessary if  
13 you find --

14 MEMBER CORADINI: So grouting is what  
15 you'd stick in the hole.

16 MR. JUSTICE: So once you dig an  
17 excavation, you then do mapping and you do additional  
18 investigations to determine if in that area where our  
19 safety-related foundations are going, are there karst  
20 cavities. If you do find karst cavities, per  
21 regulatory requirements, then you come up with a  
22 grouting plan and a mitigation plan to deal with the  
23 karst cavities.

24 It is not an unusual practice, it happens  
25 in a lot of the areas where karst is normally found in

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1 the eastern United States. And there's plenty of  
2 regulatory guidance to tell you how to do that. But  
3 we won't do any of that until we have an actual  
4 technology pick for the site.

5 MEMBER RICCARDELLA: So is PLAXIS, is that  
6 a finite element computer code?

7 MR. JUSTICE: Yes. The PLAXIS analysis  
8 that was used for this is a finite element analysis  
9 model.

10 MEMBER RICCARDELLA: And what is the  
11 loading that you use, is it just the dead weight of  
12 the structure, or do you put in seismic loads as well?

13 MR. JUSTICE: It is the information, it  
14 would be the loading of the plant. It would be the  
15 footprint of the plant for a nuclear island. And it's  
16 a --

17 MEMBER RICCARDELLA: But it's just the  
18 dead weight, basically.

19 MR. JUSTICE: And footprint.

20 MEMBER RICCARDELLA: The footprint.

21 MR. JUSTICE: And footprint weight.

22 MEMBER RICCARDELLA: Oh, spread over that  
23 footprint, I assume.

24 MR. JUSTICE: Half of the building out --

25 MEMBER RICCARDELLA: But you're not

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1 looking at the effects of, for example, cavities on a  
2 seismic loading.

3 MR. JUSTICE: No, we're just, you're  
4 looking at it from the effect of, as prescribed by  
5 1.132, the effects of potential unrecognized cavities  
6 under a safety-related foundation. Can you find them,  
7 if you'd missed one, would it be okay. And if you do  
8 find them, can you mitigate them through grouting  
9 methods to shore that up.

10 MEMBER RICCARDELLA: Thank you.

11 MEMBER CORRADINI: So if one of these  
12 technologies wants to do seismic isolation, would any  
13 of this procedure change? Or that's more within the  
14 plant and the plant response to these, to this seismic  
15 source and the associated required foundation  
16 improvement.

17 MR. JUSTICE: So that would be considered  
18 in the infrastructure and seismic evaluation for the  
19 actual plant. But the characterization efforts would  
20 still be the same.

21 MEMBER CORRADINI: Okay.

22 MR. JUSTICE: As we have done for this  
23 application.

24 MEMBER CORRADINI: Thank you.

25 MR. JUSTICE: All right, I would like to

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1 now move to Slide 52, discuss a little bit of  
2 stability of slopes. Giving the existing topography,  
3 the natural topography, and the planned finish grade  
4 as described in the application. So basically it  
5 would be a flat site with no safety-related slope  
6 planned in the vicinity of safety-related structures.

7           However, the stability of slopes as  
8 identified in the application will be re-evaluated  
9 during the COLA phase based on the actual technology  
10 selected.

11           And just to note, the previous Breeder  
12 Reactor excavation experience, the reports from that  
13 are very helpful also in determining this as it goes  
14 forward in future. Last slide, please.

15           In summary, the early permit application  
16 seeks approval for the Clinch River site for potential  
17 future use of a small modular reactor technology. The  
18 Clinch River site is capable from a geologic and  
19 seismic perspective for the construction of a small  
20 modular reactor.

21           As we discussed, the potential hazard,  
22 karst, is identifiable and can be mitigated through  
23 approved regulatory processes.

24           We'd like to also state that the efforts  
25 associated with the pre-application ratings review

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1 process and the site audit and visit were very helpful  
2 in ensuring that the right level of detail and  
3 supporting information was available in the  
4 application. And I would like to thank you for your  
5 time in listening and preparing in this presentation.  
6 Thank you.

7 CHAIRMAN KIRCHNER: Let's go around the  
8 table, then. Any of the members have questions,  
9 further questions of the applicant?

10 I have one question. In the unlikely  
11 event you didn't detect a cavity, highly unlikely I  
12 would guess, but would it appreciably change, my  
13 intuition says no to this question, but would it  
14 appreciably change the seismic loading in any way?  
15 You've got pretty hard rock that you're --

16 MR. JUSTICE: No.

17 CHAIRMAN KIRCHNER: Building this plant  
18 on. So I wouldn't expect that, but that would be my  
19 question.

20 MR. JUSTICE: That, and your assumption is  
21 correct. That would not, the identification of  
22 cavities in the safety-related excavation, additional  
23 borings will be performed, additional methods of  
24 detection of cavities.

25 Let's just assume that it's a 100-foot

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1 excavation. You've now removed a 100 foot of  
2 material. You've most likely removed the vast  
3 majority of your karsistic material. But you're still  
4 going to attempt to identify everything you can in  
5 that excavation.

6 If you find a karsistic area, then you  
7 will then follow regulatory prescribed mitigation  
8 plans to fill those voids. The PLAXIS analysis is a  
9 pretty conservative view of you just somehow missed it  
10 and now you are determining what is the largest cavity  
11 that you could have that still, with the weight of the  
12 plant and the design of the plant, would not affect  
13 that safety-related foundation.

14 And again, that gets redone for this  
15 project if the project moves to a COLA phase for the  
16 specific technology that would then be picked and  
17 aligned with the COLA.

18 CHAIRMAN KIRCHNER: Thank you. Okay, with  
19 that, let's go to the staff. Andy. Or you want to  
20 break? Don't you want to go right through? Okay,  
21 let's take a break. And Qyunh will explain where the  
22 facilities are located. So we're, are we recessed or  
23 adjourned? We're recessing? Okay.

24 MR. CAMPBELL: And I'm going to let the  
25 staff sit up here for the presentation or wherever.

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1 You have a table for them, okay, great. Thank you.

2 MR. JUSTICE: We're vacating.

3 MR. NGUYEN: Okay. Dr. Kirchner, when do  
4 you want people back? Twenty-five of three? Okay, so  
5 if you need to use the facilities, go out of this  
6 room, turn a left, and keep hugging that corridor and  
7 you'll find the restrooms.

8 There is a convenience store right before  
9 the security turnstiles. I don't know what's in  
10 there, but feel free to check it out. And for the  
11 members, there's some coffee and Munchkins.

12 (Whereupon, the above-entitled matter went  
13 off the record at 2:22 p.m. and resumed at 2:35 p.m.)

14 CHAIRMAN KIRCHNER: Okay. Let's reconvene  
15 and we're going to turn to the staff.

16 Andy, are you going to make any  
17 introductions or are they going to introduce  
18 themselves?

19 MR. CAMPBELL: I will happily let them  
20 introduce themselves, but I did want to introduce Dr.  
21 Cliff Munson, who's our senior-level advisor for  
22 siting, who's joined me at the table --

23 CHAIRMAN KIRCHNER: Uh-huh.

24 MR. CAMPBELL: -- and I'll let Allen take  
25 it from there.

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1 CHAIRMAN KIRCHNER: Okay.

2 MR. CAMPBELL: And I don't have anything  
3 else to add, but this has been the culmination of a  
4 lot of outstanding effort on the part of the staff in  
5 their reviews through this whole project, and I'm  
6 going to let Allen take it from there. Thank you.

7 MR. FETTER: Yes.

8 CHAIRMAN KIRCHNER: Okay.

9 MR. FETTER: Good afternoon.

10 Everyone hear me okay?

11 Yes, I'm Allen Fetter, one of the two  
12 safety project managers on the Clinch River review.  
13 Mallecia Sutton, who is the other safety project  
14 manager, had to duck out to finish the SEs for the  
15 next ACRS meeting on the 14th.

16 So, Ms. Sutton and I will be at the table  
17 for the next ACRS meeting on SE Sections 2.3, 2.4.11  
18 and 17 on November 14th, 2018.

19 So, I've been at the NRC since 2004, and  
20 in 2009 I started working as a project manager in the  
21 Office of New Reactors.

22 Prior to taking over as safety project  
23 manager on the Clinch River ESP review in July 2015,  
24 I was an environmental project manager for the  
25 Bellefonte COL and the PSEG early site permit reviews.

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1 Today's ACRS meeting is the fourth meeting  
2 that TVA and NRC and the ACRS have had together. This  
3 is the third of four subcommittee meetings on the SEs  
4 that have been prepared for the project.

5 Today, the NRO Geoscience, Geotechnical  
6 and Engineering Branch technical reviewers, listed on  
7 this slide with their credentials, will give  
8 presentations on their safety evaluations under  
9 Section 2.5, Geology, Seismology and Geotechnical  
10 Engineering.

11 Of course you will have the opportunity to  
12 ask questions throughout the presentations and for the  
13 sections discussed today.

14 In addition to staff's review of TVA's  
15 application, staff conducted two audits, one site  
16 visit and issued three RAIs comprising ten questions  
17 to the Applicant in order to obtain additional  
18 information to support NRC's findings.

19 I will now turn it over to Dr. Gerry  
20 Stirewalt and Ms. Jenise Thompson for the first part  
21 of the presentation.

22 DR. STIREWALT: Thank you, Allen.

23 Good afternoon. I am indeed Gerry  
24 Stirewalt. What we would like to do, we'd like to  
25 discuss the pure geology pieces, 2.5.1 and 2.5.3

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1 first.

2 So, I'll start with 2.5.1, which is  
3 titled "Geologic Characterization Information." And  
4 if we could take a look at Slide 4 just as a reminder  
5 of what the SSAR includes that the Applicant prepared,  
6 2.5.1 -- again, Geologic Characterization Information  
7 is divided into two subsections.

8 2.5.1.1 relates to original geology. Let  
9 me remind you that that region is a 200-mile radius  
10 around the site.

11 The Applicant presented information on  
12 physiography, geomorphic processes, geologic history,  
13 tectonic evolutions, stratigraphy, tectonic setting,  
14 including distribution of seismicity and stress in the  
15 eastern U.S., and certainly nontectonic hazards  
16 including karst.

17 2.5.1.2 gets -- it sort of narrows down  
18 the scope of where the data was collected and  
19 evaluated. Local geology relates to site vicinity  
20 that's 25 miles, site area that's five miles, and site  
21 location, which is a 6/10th of a mile radius of the  
22 site.

23 And, again, similar things were reviewed  
24 at this scale as well; physiography, geomorphic  
25 processes, geologic history, stratigraphy, lithology,

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1 structural geology, including faults and shear-  
2 fracture zones in particular, geologic hazards,  
3 including karst, and certainly the site engineering  
4 geology piece that included potential effects of human  
5 activity.

6 Let me, in the next slide, just sort of  
7 remind you of the physiographic scene. The site is  
8 located in the valley and ridge physiographic  
9 province, and the parallel ridges in that province  
10 really developed as a result of differential  
11 weathering and erosion of the folded and faulted  
12 sedimentary rock strata that characterized that  
13 province.

14 Okay. Let's think about what the -- so,  
15 what are the key geologic features of interest here?  
16 Well, there are two. One, is the regional thrust  
17 faults; and the other is the localized shear-fracture  
18 zones.

19 Now, neither of those two features is  
20 really well-exposed at the surface in the site area.  
21 Staff are able to examine them in rock core samples  
22 that the Applicant provided during site audits and  
23 site visits and both of those features, as you have  
24 heard mentioned before, are generally parallel to  
25 bedding.

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1           Okay. So, the thrust faults are, in fact,  
2 tectonic in origin and they are regional features.  
3 The shear-fracture zones are more localized and they  
4 contain features of both a nontectonic and probable  
5 tectonic overprint origin.

6           Okay. So, the important thing that the  
7 staff really needed to focus on was determining and  
8 documenting that the thrust faults and the shear-  
9 fracture zones are, in fact, older than Quaternary --  
10 that's greater than 2.6 million years in age -- and  
11 consequently pose a negligible hazard for the site.

12           So, it was really important to confirm the  
13 ages of these features just to make certain that they  
14 didn't pose a problem.

15           Okay. Let's do a quick look at a cross-  
16 section that you've seen just to sort of show you,  
17 again, the subsurface stratigraphy, faults and shear-  
18 fracture zones.

19           This profile essentially crosses the  
20 entire site location and extends beyond. What I would  
21 like to point out to you, on this particular slide,  
22 are the Copper Creek fault that is revealed in  
23 borehole CCB2.

24           And I mention that because I'm going to  
25 take you into the field and show you what it looks

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1 like in core.

2 The other fault that actually occurs that  
3 was also mentioned, is the Chestnut Ridge fault.  
4 That's really a local fault. Has the same orientation  
5 as the regional structures, but it's really localized,  
6 but the Copper Creek certainly is very characteristic  
7 of what the regional thrust faults look like.

8 We're also going to take a look in the  
9 field -- I'm a geologist. I have to take you into the  
10 field, after all.

11 We're going to take a look at the shear-  
12 fracture zone in the Rockdell formation in borehole  
13 MP-101.

14 Now, one thing I'd like to mention, this  
15 cross-section is actually vertically exaggerated. So,  
16 the depth that you keep hearing mentioned of around 33  
17 degrees are exaggerated.

18 So, let me take you into the field really  
19 quickly, show you an exposure of the Fleanor  
20 formation. This is within the site location and, in  
21 fact, this really shows the amount and direction of  
22 the dip of bedding that is commonly seen at the site.  
23 And the bed's around 33 degrees southeast dipping  
24 towards the geologic scale that you have.

25 Okay. Let's talk about thrust faults

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1 then. Again, they are characteristic of the entire  
2 Valley and Ridge province in which the site is  
3 located. They do occur in the site area.

4 And, again, there is no surface expression  
5 of any thrust faults in the site area, so -- and  
6 although not exposed at the surface, I pointed out the  
7 Copper Creek and Chestnut Ridge faults that are  
8 located within the site location at 0.6 miles from the  
9 site.

10 During the site audits and the site visit,  
11 staff were able to examine the Copper Creek fault and  
12 core from borehole CCB2.

13 And I'm going to drag you into the field  
14 and let you take a look at that in a moment, but I  
15 just wanted to mention that the Copper Creek, although  
16 it's not exposed at the surface at the site, is very  
17 well-exposed in the site region and, again, it's  
18 typical of the orientation northeast-striking,  
19 southeast-dipping faults that characterize the entire  
20 valley and ridge.

21 Okay. Let's take a quick look again at  
22 the site area itself. That's the big red circle, and  
23 the smaller one is the site location.

24 You will note that the site is, in fact,  
25 located between two of these regional thrust faults.

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1 One is the Copper Creek; the other is the Whiteoak  
2 Mountain fault.

3 So, geometrically, what that is, you have  
4 the Whiteoak dipping beneath the site about 33  
5 degrees, again, parallel to bedding, and the fault  
6 that overlies that in that stack of units is the  
7 Copper Creek, and the site is located within that  
8 fault block in between those two structures.

9 Okay. Well, it's kind of an important  
10 thought to note we have an age date on the fault  
11 gouge. Okay. What is "fault gouge"?

12 Well, that's when you sort of are grinding  
13 the fault along the surface beneath it, you actually  
14 crush the rock and mill the rock and grind it. So,  
15 it's called cataclasis, but the point is that you  
16 develop a gouge, a pulverized rock that's sort of very  
17 characteristic and it's due to displacement, in this  
18 case, along the Copper Ridge fault.

19 That gouge has been dated at around 280  
20 million. Now, it wasn't dated at the site; it was  
21 dated at a different location, but it's the same  
22 fault.

23 Reported displacement on this fault is  
24 ranging between 7 and 31 miles, depending on where you  
25 look at it. And with this age date, again, it is

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1 clearly older than Quaternary. No question about  
2 that.

3 Well, okay. I promised you a look at  
4 stuff in the field, so let's --

5 MEMBER SUNSERI: Just a quick question.

6 DR. STIREWALT: I'm sorry. Yeah, please.

7 MEMBER SUNSERI: Can you tell me, again,  
8 what "northeast-striking and southeast-dipping" means?

9 DR. STIREWALT: I certainly can.

10 If I talked about a bed, the strike would  
11 be in this direction for this. So, it would be  
12 striking towards you and it would be dipping towards  
13 my colleagues here.

14 So, that's literally a three-dimensional  
15 orientation of that fault surface and, in fact, the  
16 bedding, because they're parallel. Good question.  
17 Thank you. Sorry, I got carried away.

18 MEMBER RICCARDELLA: And would you clarify  
19 what the 7.4 to --

20 DR. STIREWALT: Is your mic on?

21 I'm sorry, could you repeat the question?

22 MEMBER RICCARDELLA: Yeah. Would you  
23 clarify what you mean by the 12 to 50 kilometers of  
24 displacement along the fault?

25 DR. STIREWALT: Yes. That's actually

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1 measured -- a question earlier came up about how do  
2 you identify a fault? You can look at a marker that's  
3 displaced and they can determine, in the field, from  
4 field data, that that is the actual displacement --  
5 amount of displacement along this fault.

6 And, again, the movement would be like  
7 this. So, there's evidence from what they see, in the  
8 field, that it has moved somewhere between 7 and 31  
9 miles.

10 Of course, I mean, the fault doesn't go on  
11 forever. It does dies out. So, the amount of  
12 displacement will vary along it. So, a maximum of  
13 about 30 miles or so, yeah.

14 Okay. I promise to --

15 MEMBER RICCARDELLA: Sorry. So, I thought  
16 I got it, but I don't got it.

17 So, are you saying it's the length of the  
18 fault or the actual fact that it moved 31 miles?

19 I thought it was --

20 DR. STIREWALT: Yeah. The displacement is  
21 parallel to the fault surface, it's not the length.

22 MEMBER RICCARDELLA: Okay.

23 DR. STIREWALT: That is the actual  
24 displacement.

25 MEMBER RICCARDELLA: Okay.

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1 DR. STIREWALT: The actual displacement.

2 Am I clear on that?

3 MEMBER RICCARDELLA: And that took place  
4 over many years a long, long time ago, right?

5 DR. STIREWALT: Yes. Yes. Because we  
6 have this nice, little age date at around 280, so we  
7 know it's pretty old.

8 MEMBER RICCARDELLA: Yeah.

9 DR. STIREWALT: Okay. All right. I'm  
10 excited to show you what fault gouge looks like.

11 This is, again, along the Copper Creek  
12 fault. This is in borehole CCB2 that I located for  
13 you, and I hope that you can see a rather clear  
14 distinction between the gouge and between the rock  
15 that is not involved in faulting.

16 Well, what are some of the differences?  
17 Okay. Again, we know the gouge is dated at 280. And  
18 if you look at this, I mean, this is really pulverized  
19 rock.

20 In the part that's not faulted, you can  
21 see very, very well-developed bedding. You don't see  
22 anything like that here. It's totally structureless.  
23 All the original sedimentary structures that were  
24 there before the fault movement are erased, they're  
25 gone, they're pulverized.

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1           So, this, again, is a -- I think a good  
2 illustration and why you would know in the core that,  
3 gosh, I'm not looking at a normal stratigraphic  
4 sequence. Something has happened to this rock.

5           And what happened to it, in this case, is  
6 30 or so miles of displacement along the Copper Creek  
7 fault.

8           Any questions on that?

9           Okay. Well, then let's talk about the  
10 shear-fracture zones. They were of concern because we  
11 wanted to make certain that there wasn't anything  
12 related to those particular features that suggested  
13 Quaternary deformation.

14           Now, you've already heard that the shear-  
15 fracture zones at the site contain pressure solution  
16 features, namely stylolites, in two different  
17 orientations. So, two sets of these solution  
18 features. They are both parallel and perpendicular to  
19 bedding.

20           Now, those features tell us some really  
21 important stuff about the orientation of the stresses  
22 that must have influenced those shear-fracture zones.  
23 So, let me just sort of talk about that a bit.

24           The -- maybe I should qualify. The reason  
25 you can see a stylolite, and you saw them in the

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1 earlier slides -- I'm going to show you in another  
2 slide, but the reason you can actually see this little  
3 surface where the dissolution occurred, is because  
4 when you -- again, the stress itself operates  
5 perpendicular to the dissolution feature and you can  
6 actually see it because I'm dissolving a limestone.

7           You have parts, clays and things, that do  
8 not dissolve and, lo and behold, they concentrate  
9 right along that little surface so you can see -- you  
10 can see a little crinkly line that's marked by  
11 minerals that did not dissolve. And that's how --  
12 that's why you can see the stylolite.

13           Okay. The nontectonic bedding-parallel  
14 stylolites that, again, are the earliest, these formed  
15 during deposition and lithification of the sedimentary  
16 units due to the vertical overburden pressure.

17           That is to say as you're stacking --  
18 depositing this rock, stacking them one on top of the  
19 other, you develop a very thick overburden. And that  
20 overburden produces a stress that's perpendicular to  
21 bedding, just like those stylolites, and that's the  
22 source.

23           So, this is syndepositional sort of  
24 nontectonic strictly, but it occurred very, very  
25 early.

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1 All right. Now, the bedding perpendicular  
2 stylolites, which are the latest, likely formed in  
3 response to the near-horizontal stresses related to  
4 transport of the flow sheets.

5 And we know that timing is around 280  
6 million, so they're old, also, but the point is that  
7 it is a tectonic overprinting, but that tectonic  
8 overprinting is not Quaternary in age. It's also  
9 very, very old. Very, very old.

10 So, during the site audits and site  
11 visits, then, staff were able to examine the shear-  
12 fracture zone specifically on the Rockdell formation  
13 in borehole MP-101.

14 And, guess what. As you suspected, I'm  
15 going to show you that. You saw this same piece of  
16 core in something that the Applicant presented, but  
17 what I'd like to do, I just sort of blew up one part  
18 of it to sort of note that bedding is well-developed,  
19 you can see bedding surfaces; you can see these little  
20 squiggly, dark-colored lines marked by the clay that  
21 didn't dissolve that are parallel to bedding; and you  
22 can also see some that are perpendicular to bedding.

23 Now, again, since these features form  
24 essentially perpendicular to the causative stress,  
25 they must have developed at two different times. And

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1 we have the timing of the latest because of the dating  
2 on the fault motion. It's around 280 million.

3 So, again, that sort of sets the scene for  
4 the conclusions that we can make about any concerns  
5 related to tectonic features that are young Quaternary  
6 at the site.

7 If there are no questions on that picture,  
8 let's take the final slide and let's sort of address  
9 the conclusions.

10 Again, no tectonic features with the  
11 potential for adversely affecting suitability of the  
12 site occur in the site region, the site vicinity, the  
13 site area or at the site location. That is to say, no  
14 data suggests the presence of Quaternary tectonic  
15 features.

16 In fact, the primary event that's  
17 registered, which is development of the regional  
18 thrust faults, is dated around 280 million.

19 It's kind of geologically fun to think  
20 about that that actually happened when Africa was  
21 colliding with North America, growing the Appalachian  
22 Mountains to the east of this. So, it's a part of  
23 that major tectonic package, but that's exciting to a  
24 geologist anyway.

25 Okay. And, again, no field data --

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1 CHAIRMAN KIRCHNER: An earlier slide had  
2 it 280.3 or something.

3 DR. STIREWALT: Yeah. 279 --

4 CHAIRMAN KIRCHNER: So, how do you get  
5 such precision in this dating? How did they derive  
6 significant figures?

7 DR. STIREWALT: Well, it's done with  
8 radiometric dating using --

9 CHAIRMAN KIRCHNER: Okay.

10 DR. STIREWALT: -- I believe it was argon-  
11 argon in this case. And you still have that era band  
12 (phonetic) on it, but, I mean, it --

13 CHAIRMAN KIRCHNER: It's not using argon  
14 in the laboratory.

15 Is argon the element --

16 DR. STIREWALT: Yes.

17 CHAIRMAN KIRCHNER: -- just for the public  
18 record?

19 DR. STIREWALT: Yes. Yes.

20 CHAIRMAN KIRCHNER: Okay.

21 MR. FETTER: Potassium-argon, argon-argon.

22 DR. STIREWALT: Yeah. That's a good  
23 question.

24 Okay. And, again, there's no field  
25 evidence that suggests the shear-fracture zones are

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1 younger than that thrusting event which, again, really  
2 pins it as being certainly older -- certainly  
3 preQuaternary age, which was our concern.

4 Well, there's no question that karst is a  
5 primary nontectonic feature that's recognized, and  
6 that does have a potential for adversely affecting  
7 site suitability.

8 Certainly the Applicant described the  
9 geologic characteristics of the site region, site  
10 vicinity, site area, site location in full compliance  
11 with the regulatory requirements and in accordance  
12 with guidance in 1.208.

13 Are there other questions or comments or  
14 anything on this?

15 Okay. Well, that being the case, I am  
16 pleased to pass the talking baton to my colleague, Ms.  
17 Jenise Thompson, who will speak to 2.5.3; and you may  
18 be certain she is going to mention karst.

19 MS. THOMPSON: And show lots of pictures.

20 My name is Jenise Thompson. I was the  
21 primary reviewer to Section 2.5.3, Surface  
22 Deformation.

23 So, in Section 2.5.3, we focused on the  
24 information related to the assessment of both tectonic  
25 and nontectonic surface deformation and the potential

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1 for that surface deformation.

2 So, at the Clinch River site, we looked  
3 specifically at geologic features observed in the East  
4 Tennessee seismic zone and at numerous karst-related  
5 features that were observed in the site area.

6 So, for tectonic surface deformation, we  
7 looked at potential for tectonic surface deformation  
8 in the site area and concluded that there were no  
9 Quaternary age tectonic structures near the site  
10 location.

11 So, this was based on available data that  
12 showed negligible potential for surface deformation  
13 due to tectonics.

14 We also looked at river terraces. I know  
15 that the Applicant mentioned a rather extensive river  
16 terrace study that they did.

17 We observed those terraces in the field  
18 and saw no evidence of surface deformation that could  
19 be attributed to tectonics.

20 So, the staff concludes that there's no  
21 evidence of Quaternary age tectonic surface  
22 deformation at the site.

23 The relationship of potential tectonic  
24 surface deformation to observe seismicity in the East  
25 Tennessee seismic zone is undetermined.

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1           Due to carbonate rocks in the subsurface,  
2           direct observation of karst features in the field and  
3           ongoing dissolution processes in the site vicinity and  
4           interpreted cavities in the rock core, as indicated by  
5           missing segments, which I will show you, the staff  
6           concluded that karst has the potential to cause  
7           surface deformation at the Clinch River site.

8           So, you saw this picture earlier. This is  
9           the distribution of karst features in the Clinch River  
10          site area.

11          MEMBER BROWN: Could you go back a slide,  
12          please. 16. You said the relationship between the  
13          deformation and observed seismicity is undetermined.

14          That sounds not like a good conclusion.  
15          You don't know what's going on.

16          MS. THOMPSON: There are features within  
17          the site vicinity and the site region, so not within  
18          the five-mile site area, that are still under study.  
19          And there are numerous possibilities of what their  
20          origin could be, but none of them have been  
21          definitively determined to be related to seismicity in  
22          the East Tennessee seismic zone.

23          MEMBER BROWN: Does that have any meaning  
24          relative to the positioning of this plant in this  
25          location?

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1                   What's the conclusion?

2                   Is it it doesn't bother siting this  
3 particular potential plant in this region?

4                   Is that what that means?

5                   MS. THOMPSON: My colleague David will  
6 address that more in his discussion of the vibratory  
7 ground motion in Section 2.5.2.

8                   MEMBER BROWN: Okay. Well, I'm old enough  
9 I may not remember this by that time.

10                   (Laughter.)

11                   MS. THOMPSON: David will.

12                   MEMBER BROWN: Thank you.

13                   MS. THOMPSON: So, moving on to karst,  
14 each of the black dots shown here is a karst  
15 depression.

16                   So, there were approximately just under  
17 3,000 karst depressions or karst features mapped in  
18 the five-mile radius of the Clinch River site, which  
19 is that red star in the center.

20                   So, these depressions can be any number of  
21 forms. They can be swales, which are kind of a small,  
22 wet depression at the surface; a swallet, which is  
23 slightly larger and usually has some percolation or  
24 water draining in it; or sinkholes, which the  
25 Applicant showed you some great examples of, which is

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1 that surface depression which is the result of  
2 subsurface dissolution and collapse. So, that's how  
3 we can kind of see what's going on in the subsurface  
4 without digging down into the ground.

5           Something to note here, Gerry was talking  
6 about the dip of the layers. And you can see the blue  
7 dip angle -- dip symbols here showing you what  
8 direction these layers are dipping, and you'll notice  
9 that most of these depressions, these karst features  
10 are in the Knox group, which is that tan color; there  
11 are a few in the Chickamauga group, which is what's  
12 underlying the Clinch River site; and then there are  
13 just a handful in the Conasauga group, but all three  
14 of those groups are present in the subsurface because  
15 of that dip angle.

16           So, we also observed cavities in the rock  
17 core at the site that was part of the boring program.  
18 So, one interpretation of these cavities is that they  
19 may be recording the cavities that we see for karst  
20 and dissolution features.

21           So, this particular cavity was mapped here  
22 in borehole MP-418, and the cavities were of varying  
23 thicknesses.

24           In total, there were 238 cavities  
25 encountered in the boreholes of numerous, varying

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1 sizes. Anything that was more than a tenth of a foot  
2 of no recovery was mapped as a cavity in the boring  
3 logs.

4 So, they were encountered -- these  
5 cavities were encountered in all of the subsurface  
6 units that the boreholes encountered, but the size  
7 differs.

8 So, when you have the more pure carbonates  
9 of the limestone units, you would have larger and more  
10 frequent cavities. Whereas when you have the more  
11 classic units, some of the siltstones, you would have  
12 smaller and less frequent cavities.

13 So, one possible interpretation of what  
14 these cavities could be representative of is pinnacle  
15 and cutter karst -- or buried pinnacle and cutter  
16 karst.

17 And so, these are two examples of  
18 pinnacle and cutter karst that the staff observed  
19 within the five-mile site area. And pinnacle and  
20 cutter karst is the result of dissolution along joints  
21 and bedding planes and it could result in these  
22 cavities.

23 And so, on the left picture, you see my  
24 colleague's hand here and this is the joint along  
25 which you have dissolution and you end up with this

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1 larger dissolution pit.

2 The depth of this, I can stick my arm all  
3 the way in to my shoulder, and I could keep going if  
4 I had larger arms.

5 And then for -- on the lower right, this  
6 is a typical exposure of the pinnacles that you see.  
7 So, we have these high points, and then you would have  
8 the joints at the low points here, which is where you  
9 have your dissolution occurring, and it kind of looks  
10 like a jawbone in this kind of classical exposure of  
11 pinnacle and cutter karst.

12 So, some of the things that you might see  
13 in borings that would lead you to think that it would  
14 be buried pinnacle and cutter karst would be different  
15 thicknesses of soil or overburden or filled-in  
16 cavities that have kind of soil or other material that  
17 is not consistent with the subsurface layers that you  
18 would expect to see.

19 So, additional karst features that we saw,  
20 we mentioned the swales, the swallets and the  
21 sinkholes, which are additionally the surficial karst  
22 depressions that we see.

23 And I use this picture because this is the  
24 best one that I have of a clear sinkhole. So, you can  
25 see that classic karst depression and what it looks

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1 like.

2 And this is 4 1/2 miles east of the Clinch  
3 River site near the Melton Hill Dam, and the rim of  
4 this depression is generally the tree line and where  
5 this nice little house is sitting.

6 So, you would have water flow down the  
7 slope into this sinkhole here where you have ponded  
8 water, but there is active percolation. So, the  
9 presence of ponded water is generally determined on a  
10 precipitation event.

11 So, if you were to come in the middle of  
12 a drought, there wouldn't necessarily be ponded water,  
13 but this is one of the examples of many of the  
14 sinkholes that the staff went and observed at the  
15 site.

16 Another karst feature that was observed in  
17 the site area was caves, which are kind of the classic  
18 karst feature.

19 So, the Copper Ridge cave was the largest  
20 cave that the staff visited in the Clinch River site  
21 area, and this occurs in the basal unit of the Knox  
22 group, which, again, because of that dip angle of the  
23 units below the Clinch River site, the Knox group is  
24 present in the subsurface.

25 And this is a cave that occurs inside a

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1 closed basin in a hill slope. So, you have this  
2 closed depression -- that's the rim, the dotted line  
3 there -- you have a flow down into the joint, which  
4 continues here -- there's the entrance to the cave --  
5 and that line in the roof, that joint, that small  
6 break in the roof, that's where dissolution is  
7 occurring.

8 You also have dissolution along bedding  
9 planes. As you can see down here at the yellow arrow,  
10 you kind of have that dissolution where you have some  
11 units that are more prominent than others.

12 And supporting this dissolution along  
13 joints and bedding planes is that this cave follows  
14 the orientation of the joint through a 90-degree turn  
15 just inside the entrance to the cave. So, you have  
16 dissolution along the joint, and when the joint turns  
17 90 degrees, the cave follows.

18 So, given the presence of karst and the  
19 numerous karst features in the site area, the  
20 Applicant acknowledged the need to perform geologic  
21 mapping for documenting the presence or absence of  
22 karst features, faults or shear-fracture zones in  
23 plant foundation materials.

24 Accordingly, the staff identified Permit  
25 Condition 1, which is here, to allow the staff to

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1 confirm and the Applicant to verify the determinations  
2 made at the ESP stage with respect to surface  
3 deformation. And then, if necessary, to mitigate any  
4 potential hazard through the appropriate means.

5 MEMBER CORRADINI: So, they would map out  
6 where the holes are. And then if they are of a  
7 certain size, they would have to be filled or is that  
8 left to the Applicant? That's what I'm curious about.

9 MS. THOMPSON: This will be addressed at  
10 the COL stage. So, if there are -- so, they will  
11 perform the mapping and it will be made available for  
12 the staff to go into the field and examine.

13 And then if anything is identified, it  
14 will be up to the Applicant to determine an  
15 appropriate mitigation plan.

16 MEMBER CORRADINI: So, they can suggest a  
17 remedy which you can then --

18 MS. THOMPSON: Yes. And that goes to  
19 something -- the permit condition, the confirmatory  
20 activities, which would include the geologic mapping  
21 and, if necessary, the development and implementation  
22 of a mitigation plan were -- are all included as part  
23 of COL Action Item 2.5-3 in Section 2.5.4 of the ESP.

24 MEMBER CORRADINI: So, if they map out --  
25 just for example. So, for example, if they plan to

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1 have an embedment that's a hundred feet deep and so  
2 wide and so deep -- or so wide and long based on a  
3 particular design, if they map out the cavities, is  
4 there -- and they find that they have -- I'll pick a  
5 number -- ten of them three feet or less, is there  
6 some smaller -- is the size of the cavity determined  
7 on how one would remedy it or is there a prescribed  
8 approach?

9 I'm still trying to understand what this  
10 condition means other than look, see what you find and  
11 report back.

12 DR. HEESZEL: Or mitigate as needed.

13 MEMBER CORRADINI: Or mitigate as needed,  
14 but what I -- then my next question is that once they  
15 report back and they suggest a remedy, are there  
16 acceptable remedies that have been done in the past  
17 and they would just pick from those or is it quite  
18 customized to the region? That's what I'm trying to  
19 understand.

20 MEMBER RAY: Before you respond, isn't  
21 this just a carve-out from the normal scope of an ESP?  
22 In other words, it simply can't be addressed until --

23 MS. CANDELARIO: Yes.

24 MEMBER RAY: -- COL --

25 MS. CANDELARIO: It won't be addressed

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1 until COL application --

2 MEMBER RAY: There's no prescribed  
3 solution --

4 MS. CANDELARIO: Right.

5 MEMBER RAY: -- no criteria that are  
6 preestablished or anything like that.

7 MS. CANDELARIO: Right. But if they find  
8 voids on the geologic mapping phase, then the COL  
9 applicant will address that as part of COL Action Item  
10 2.5.3 which I can read.

11 And it says, an applicant for a COL or CP  
12 referencing this early site permit should design and  
13 conduct additional subsurface investigation during  
14 excavation and construction to detect cavities below  
15 the foundation elevation that could adversely affect  
16 condition performance. In addition, the Applicant  
17 should perform confirmatory drilling or borehole  
18 testing during excavation/construction to characterize  
19 the source of geophysical anomalies and to develop a  
20 grouting program with associated ITAACs when needed  
21 based on the information obtained by the geologic  
22 mapping, geophysical surveys and specific analysis to  
23 mitigate the effect of bores or cavities on foundation  
24 performance at and below the foundation level of the  
25 safety-related structure.

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1 MEMBER RAY: Okay. Thank you.

2 MS. THOMPSON: Thank you, Luisette.

3 So the staff's conclusions on the next  
4 slide are as follows: "The staff concludes that a  
5 negligible potential exists for tectonic surface  
6 deformation that could adversely affect the  
7 suitability of the Clinch River site. Staff also  
8 concludes that karst is the primary potential hazard  
9 for nontectonic surface deformation at the Clinch  
10 River site. The staff further concludes that the  
11 Applicant described the information related to the  
12 assessment of the potential for tectonic and  
13 nontectonic surface deformation in full compliance  
14 with the regulatory requirements."

15 CHAIRMAN KIRCHNER: So, this addresses  
16 what Charlie raised earlier. It just struck me, as  
17 well as him, that your Slide 16, that first bullet,  
18 that's rather a sweeping conclusion because your  
19 summary slide says that there's not a problem.

20 In other words, in 16 you say "surface  
21 deformation in this area is largely undetermined," but  
22 then you go on and draw a conclusion that says, "for  
23 this site, negligible potential exists for tectonic  
24 surface deformation." That would be adverse.

25 MS. THOMPSON: So, the statement on Slide

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1 16 is that the relationship between tectonic surface  
2 deformation and the observed seismicity in the East  
3 Tennessee seismic zone is undetermined, but that does  
4 not -- that's not in conflict with our conclusion that  
5 there's a negligible potential for tectonic surface  
6 deformation at the site.

7 And David will get a little more into the  
8 relationship in the seismicity of the East Tennessee  
9 seismic zone and how it may affect the site; but from  
10 the perspective of surface deformation and what  
11 evidence we have now and the conclusions that we have  
12 available to us, there is a negligible potential for  
13 tectonic surface deformation to affect the site.

14 CHAIRMAN KIRCHNER: Okay.

15 MEMBER BROWN: Would you say that again?  
16 There is -- did you say "negligible"?

17 MS. THOMPSON: Negligible potential --

18 MEMBER BROWN: Okay. I didn't hear you.

19 MS. THOMPSON: -- for tectonic surface  
20 deformation to affect the site.

21 The primary hazard for surface  
22 deformation, either tectonic or nontectonic, at the  
23 Clinch River site is karst.

24 MEMBER BROWN: You gave us a picture and  
25 a discussion about the cave and how it went in and it

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1 goes at right angles underground. That didn't look  
2 like a very good place to try to mount -- to put the  
3 site.

4 That's a nice example, but I'm trying to  
5 connect the dots between your example and what they  
6 reported in their writeups, in their presentation.

7 MS. THOMPSON: The cave is just under five  
8 miles east-northeast of the Clinch River site.

9 MEMBER BROWN: Okay.

10 MS. THOMPSON: And it's within the Knox  
11 group, which is in the deep subsurface at the Clinch  
12 River site.

13 So, this is the -- the cave -- the example  
14 that I used is the Copper Ridge cave and it occurs in  
15 the Copper Ridge dolomite, which is the absolute  
16 bottom layer of the Knox group.

17 Which, if you remember Gerry's slides of  
18 the borings, the deepest boring at the site, I think  
19 it just reached the top of the Knox group, which was  
20 the Newala formation, and we're talking about what's  
21 way at the bottom far below that.

22 But because of the way the faulting in the  
23 area has occurred and the exposure of the units, in  
24 some areas you have -- the Knox group has -- if you  
25 click once -- or, I'm sorry, back to the second slide,

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1 Slide 17, I think.

2 So, the Knox group is this one here. So,  
3 we're talking about the bottom unit of that. So,  
4 something that's like down over here.

5 Do you want us to go back to the picture  
6 of the --

7 MEMBER BROWN: No, that's fine.

8 MS. THOMPSON: Yeah.

9 MEMBER BROWN: You could stop on that one  
10 you were talking about, gaps. I didn't ask the  
11 question at the time. Right there -- no, not that  
12 one. It's in your presentation.

13 MS. THOMPSON: Oh, cavities.

14 MEMBER BROWN: Cavities.

15 MS. THOMPSON: Yes.

16 MEMBER BROWN: Where are the cavities?  
17 What should we look at in that picture for the  
18 cavities?

19 MS. THOMPSON: So, this is the --

20 MEMBER BROWN: Right there?

21 MS. THOMPSON: -- recovered core.

22 MEMBER BROWN: Okay.

23 MS. THOMPSON: And this here -- and I'm  
24 sorry the picture is not lighter, but this is a --  
25 basically a pool noodle that is marking no recovery.

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1                   So, it's a foam tube that's marking that  
2                   there was no rock recovered between 59 feet and I  
3                   think that's 63. So, you had about a four-foot period  
4                   of no recovery.

5                   CHAIRMAN KIRCHNER: So, meters down from  
6                   the surface where that borehole was extracted --

7                   MS. THOMPSON: Yes. So, this is the --

8                   CHAIRMAN KIRCHNER: -- that sample was  
9                   extracted.

10                  MS. THOMPSON: Yes.

11                  MEMBER BROWN: Okay.

12                  MS. THOMPSON: So, this is depth. So,  
13                  this is just an example of what we observe as a cavity  
14                  in core, what a cavity looks like when you encounter  
15                  it in a boring program.

16                  And when you open up the core box, that's  
17                  what it is. It's a piece of round foam that says, "no  
18                  recovery" on it and a boring log that documents the --

19                  MEMBER BROWN: Well, somebody put the foam  
20                  in, I guess, when they open it up, right?

21                  (Laughter.)

22                  MEMBER BROWN: I'm sorry, you got to have  
23                  humor in here somewhere. Okay. I understand what you  
24                  meant. I couldn't see that when you were talking  
25                  about it.

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1 MS. THOMPSON: Okay.

2 MEMBER BROWN: Thank you.

3 MS. THOMPSON: If there are no other  
4 questions, I'll introduce my colleague --

5 CHAIRMAN KIRCHNER: Would you -- again, a  
6 slide like this is very informative, but is it  
7 directly relevant? So, yes, you find cavities, karst  
8 you identified as a major issue.

9 Would you agree with the Applicant that  
10 most of the cavity formation is probably closer to the  
11 surface than the depth of the foundation that they  
12 plan to use for the actual site?

13 MS. THOMPSON: In general, you will have  
14 larger and more frequent cavities closer to the  
15 surface.

16 CHAIRMAN KIRCHNER: Okay. Are you going  
17 to talk to their analysis with PLAXIS?

18 MS. THOMPSON: That will be addressed by  
19 our geotechnical engineer.

20 CHAIRMAN KIRCHNER: Okay. Good. I'll  
21 wait then. Thank you.

22 MS. THOMPSON: So, I will pass the pointer  
23 on to Dr. David Heeszal for vibratory ground motion.

24 DR. HEESZEL: Good afternoon. My name is  
25 David Heeszal. I was the lead reviewer for Section

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1 2.5.2, Vibratory Ground Motion.

2 Next slide. So, some key topics of review  
3 for Section 2.5.2 was the Applicant's treatment of the  
4 Eastern Tennessee seismic zone, the Applicant's  
5 approach to developing its site response inputs, and  
6 its 2D site response sensitivity study.

7 So, the Eastern Tennessee seismic zone is  
8 a region outlined in green here of elevated seismicity  
9 rates relative to the background rate and rest of --  
10 the majority of the rest of the eastern United States.  
11 The magnitudes are quite small, magnitudes 3, there's  
12 a couple 4s.

13 These earthquakes generally occur within  
14 the basement rocks, so within the granitic bedrock  
15 beneath the sedimentary section that we spent all of  
16 this time talking about. So, they're quite deep  
17 relative to what we've been discussing previously.

18 The Eastern Tennessee seismic zone is  
19 included within NUREG-2115, the CEUS SSC. It's  
20 included both within our seismic tectonic zones and  
21 within the Mmax source zones.

22 Sensitivity studies were done at the time  
23 of the NUREG-2115 to ensure that the Eastern Tennessee  
24 seismic zone was adequately captured by the models as  
25 they were developed; however, there's been a couple of

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1 recent geologic studies that have interpreted the  
2 potential based on some trenching work and some field  
3 mapping for potentially large earthquakes, magnitude  
4 greater than 6 1/2.

5 Next slide.

6 MEMBER RICCARDELLA: Is that subsequent to  
7 NUREG-2115, that recently?

8 DR. HEESZEL: It's subsequent, yes.

9 Next slide.

10 CHAIRMAN KIRCHNER: Let's go back to that  
11 slide.

12 When you put something down like that,  
13 that, for the public, would raise questions, I would  
14 think.

15 DR. HEESZEL: Exactly. I'm going to  
16 address them.

17 CHAIRMAN KIRCHNER: So, you're going to  
18 address the --

19 DR. HEESZEL: Yeah.

20 CHAIRMAN KIRCHNER: But in terms of  
21 notwithstanding potential, but based on measurements  
22 where you have a lot of data, it seems to me, not  
23 surprisingly, it's -- and I'm not a geologist, so I  
24 may not be using correct clinical terminology, it  
25 looks like this is active, that's not surprising given

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1 the geology, but the magnitudes that have been  
2 measured are, on the average, quite low.

3 DR. HEESZEL: That's correct.

4 So, if you look at this slide here, you  
5 can't quite see the --

6 CHAIRMAN KIRCHNER: Well, we can read it  
7 from your view of --

8 DR. HEESZEL: Yeah.

9 CHAIRMAN KIRCHNER: Yes.

10 DR. HEESZEL: So, you know, there's, what,  
11 two magnitude 5 -- between 5 and 6 over here; but  
12 within the Eastern Tennessee seismic zone you're  
13 looking at 3s and 4s.

14 CHAIRMAN KIRCHNER: So, you have not -- in  
15 the past, you've never seen something six or greater?

16 DR. HEESZEL: No, not within --

17 CHAIRMAN KIRCHNER: And we make large  
18 arguments about how this is geologically aged 280  
19 million years.

20 What would -- what is the potential for  
21 newer seismic activity of such a magnitude?

22 DR. HEESZEL: Background tectonic  
23 stresses.

24 CHAIRMAN KIRCHNER: But that's true almost  
25 everywhere you have a fault and --

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1 DR. HEESZEL: And that's why Mmaxes within  
2 the entire central and eastern United States account  
3 for the potential for large earthquakes.

4 CHAIRMAN KIRCHNER: Okay. And that  
5 frequency would be what?

6 DR. HEESZEL: On the order of which  
7 frequency?

8 CHAIRMAN KIRCHNER: 6.5 or greater.

9 DR. HEESZEL: It was suggested within  
10 120,000 years, I believe.

11 CHAIRMAN KIRCHNER: 10 to the minus fifth.  
12 Okay.

13 MEMBER RAY: What did you say?

14 MEMBER RICCARDELLA: 10 to the minus 5th.

15 MEMBER RAY: Yeah. Well, I come from a  
16 different part of the country where the continued  
17 escalation of the potential doesn't seem to ever stop.

18 CHAIRMAN KIRCHNER: Yeah. That's my  
19 concern. It's kind of an open-ended item here, unless  
20 there is more explanatory information.

21 Is it speculative or is it --

22 DR. HEESZEL: The geologic studies are  
23 quite preliminary and the interpretations vary widely  
24 amongst different experts about what the source for  
25 the geologic features is.

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1 CHAIRMAN KIRCHNER: Just caution, in  
2 general, that's a declarative statement there. That's  
3 not -- that's suggestive of a much higher seismic  
4 risk.

5 DR. HEESZEL: And that's what the recent  
6 geologic study has -- that's their assertion.

7 CHAIRMAN KIRCHNER: And that recent study  
8 has been reviewed and considered as a reasonable  
9 conclusion?

10 DR. HEESZEL: It is one possible  
11 interpretation for the field notes.

12 CHAIRMAN KIRCHNER: Okay. Well, I'm  
13 just, in a different way, voicing Harold's concern  
14 that when you put that on the table, then there's the  
15 danger of ever escalating the design-basis earthquake  
16 that you're designing the plant for.

17 Okay. I've made my point. Thank you.

18 DR. HEESZEL: Next slide, please.

19 So, in response to this recent geologic  
20 data, the Applicant performed two sensitivity studies  
21 following SSHAC guidance for a Level 2 study.

22 The first study, they evaluated the  
23 Mmaxes; and then the second study, they evaluated the  
24 magnitude-frequency relations.

25 The Mmax values in NUREG-2115 encompass

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1 the proposed Mmax values developed by these -- or  
2 suggested by these recent geologic studies and, in  
3 fact, give a large amount of weight to magnitudes that  
4 are consistent or larger than what has been suggested.

5 MEMBER RICCARDELLA: But they were further  
6 away, right? As I understand, you know, the Mmaxes --  
7 the big high ones are just -- they're not specifically  
8 within the zone, are they?

9 DR. HEESZEL: Within each zone there's a  
10 set of Mmax values that are established. So, within  
11 the PEZ, the Paleozoic Extended Zone, the zone that  
12 the Clinch River site and Eastern Tennessee sit  
13 within, there is a suite of Mmaxes, a range. And that  
14 range encompasses the range that has been recently  
15 suggested.

16 In addition, the recurrence of these  
17 large-magnitude events that's in NUREG-2115, if you  
18 look at the NUREG-2115, the recurrence rates for  
19 magnitude 6 1/2 and 7s is on the order of 13,000 to  
20 88,000 here. So, again, within the same range of  
21 values as has been suggested recently.

22 And so, you know, based on the fact that  
23 the Mmax values are consistent and the frequency of  
24 recurrences is consistent, staff has concluded that  
25 NUREG-2115 adequately captures our current

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1 understanding of the seismic hazard in the Eastern  
2 Tennessee seismic zone.

3 Next slide. This slide simply shows  
4 staff's confirmatory PSHA calculations at three  
5 frequencies compared to the Applicant's. Applicant's  
6 are solid; staff's are dotted. You can see at 10 to  
7 the minus 4 and 10 to the minus 5 there's very good  
8 agreement.

9 Next slide.

10 MEMBER BALLINGER: I'd like to be a little  
11 bit more blunt.

12 DR. HEESZEL: Okay.

13 MEMBER BALLINGER: Back on Slide 26, that  
14 statement, recent geologic studies interpret --

15 MEMBER CORRADINI: Is your microphone on?

16 MEMBER BALLINGER: I did -- it's on.  
17 Okay. So, there's that statement. And then on two  
18 slides later -- no. No. Excuse me. One slide later,  
19 the bottom on, that implies to me that you folks have  
20 done a study because the recent geologic studies  
21 interpret potential for larger than 6.5. Now, you say  
22 that the staff concludes.

23 So, this study was done after 2115?

24 DR. HEESZEL: That's right.

25 MEMBER BALLINGER: So, but now you

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1 conclude that 2115 does adequately capture the events  
2 that would be greater than 6.5?

3 DR. HEESZEL: The study proposes that  
4 there is the potential for large events. Our  
5 conclusion is that the NUREG adequately captures the  
6 potential for large events.

7 MEMBER BALLINGER: Oh, okay. Okay.

8 CHAIRMAN KIRCHNER: Another way to say it  
9 would be at brackets, that potential.

10 DR. HEESZEL: But it bounds.

11 CHAIRMAN KIRCHNER: Okay.

12 MEMBER RICCARDELLA: But still I'd like to  
13 get back to this distance.

14 As I recall -- I reviewed 2115 several  
15 years ago -- the big, large-magnitude earthquakes were  
16 pretty far away from this Tennessee --

17 DR. HEESZEL: You're talking about the  
18 RMLEs like in Charleston or in --

19 MEMBER RICCARDELLA: And near Detroit. I  
20 think there was one near Detroit, right, or --

21 DR. HEESZEL: New Bridge, Charleston,  
22 Charlevoix --

23 MEMBER RICCARDELLA: Is that where these  
24 recent geologic studies are talking about or --

25 DR. HEESZEL: No. No.

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1 MEMBER RICCARDELLA: -- are they talking  
2 about right in that geologic --

3 DR. HEESZEL: Right in here. Sorry.  
4 Right in this -- I believe it is in the little box,  
5 this little black box that is barely visible.

6 MEMBER RICCARDELLA: Okay. Although, the  
7 data showed that the largest was about five, right?

8 DR. HEESZEL: Say again?

9 MEMBER RICCARDELLA: The data shows that  
10 the largest --

11 DR. HEESZEL: The seismicity data shows  
12 magnitude 5s, yeah.

13 MEMBER RICCARDELLA: Okay.

14 MEMBER RAY: Well, in all cases, we're  
15 talking about recurrence interval or probability.

16 MEMBER RICCARDELLA: Yeah.

17 MEMBER RAY: And so, there's no capping of  
18 the size that could conceivably occur. The issue is,  
19 do we have the recurrence interval of a large  
20 earthquake correct, and they're saying they think 2115  
21 still does it.

22 Okay? I mean, is that -- do you agree?

23 DR. HEESZEL: Yes.

24 MEMBER RAY: All right.

25 DR. HEESZEL: All right. Site response.

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1 So, the Clinch River site has a significant dip in the  
2 subsurface approximately 30 degrees. We've discussed  
3 it previously.

4 It has relatively high seismic velocities  
5 greater than 5,000 to greater than 10,000 feet per  
6 second.

7 Just for a reference frame, basement  
8 crystalline rock is considered about 9200 feet per  
9 second. So, you're talking about - you know, for  
10 sedimentary rock it's quite fast.

11 CHAIRMAN KIRCHNER: So, hard rocks.

12 DR. HEESZEL: Hard rocks. If you're not  
13 careful, you'll hit yourself in the head when you  
14 swing your rock hammer at it.

15 So, the Applicant developed site response  
16 inputs using three profiles in each of its two  
17 locations. And the base case profile was developed  
18 using log mean seismic velocity as a function of  
19 depth.

20 So, if you go down 50 feet, you take all  
21 of your data for 50 feet, calculate the log mean, and  
22 you calculate an upper and lower profile based on the  
23 standard deviation of that log with the statistical  
24 variation.

25 The effectiveness is obviously that if you

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1 have Unit A right next to Unit B, with the dip, you're  
2 going to smear those units together. So, you're going  
3 to discard some of your geologic information in favor  
4 of your geophysical information.

5 And so, the staff requested that the  
6 Applicant explain how the use of these multiple-phase  
7 cases accounts for the dip across the site.

8 The Applicant's response was that the  
9 smearing of the units, using their approach, is  
10 appropriate because you're maintaining both the mean  
11 and the range of values as a function of depth.

12 If you think about your plant that crosses  
13 boundaries, it's going to sense both units in  
14 accordance with how much of those units it's on top  
15 of. And so, the stratigraphic variations, the dip, is  
16 accounted for.

17 Staff performed its confirmatory site  
18 response by considering the dip explicit. So, if you  
19 think about, from left to right, you have an up  
20 section, a middle and a down section profile.

21 In addition, the staff truncated its  
22 profiles at the top of the Knox unit as it's over a  
23 kilometer thick and it has a velocity of greater than  
24 three kilometers per second. So, it's basically  
25 basement rock from a geologic -- or seismological

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1 perspective.

2 And as you'll see on the next slide,  
3 staff's overall results are consistent with the  
4 Applicant's.

5 And so, this shows staff's confirmatory  
6 GMRS in red, and the Applicant's in blue, and it's  
7 just shown for reference. And the dotted black is if  
8 you just consider the hard rock GMRS, you know, it's  
9 a hard rock site. Just make that assumption.

10 MEMBER CORRADINI: Maybe I don't  
11 understand what you mean by the staff's GMRS.

12 How did you come to that? By a separate  
13 calculation or just --

14 DR. HEESZEL: We did an independent  
15 confirmatory analysis using our base rock seismic  
16 hazard curves that I showed a few slides ago involved  
17 with site response that we developed in-house.

18 MEMBER CORRADINI: So, you used generic  
19 curves that you showed on Slide 28?

20 DR. HEESZEL: Yeah. The base rock hazard  
21 curves for the site that we developed for -- on Slide  
22 28.

23 MEMBER CORRADINI: Thank you.

24 DR. HEESZEL: And as you can see --

25 DR. MUNSON: Just to clarify, they're not

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1 generic. They are specific to that latitude and  
2 longitude, those basement rock hazard curves.

3 And then on top of that, we do the site  
4 response and develop hazard at various elevations  
5 beneath the site.

6 MEMBER CORRADINI: Okay. Thank you.

7 MEMBER RICCARDELLA: For the record, I  
8 also compared those to the new GMRS for the Sequoyah  
9 site and these are very, very close to the new --

10 DR. HEESZEL: I mean, we did a similar  
11 analysis through the 2.1 process for the other sites.

12 MEMBER RICCARDELLA: Yeah.

13 DR. HEESZEL: And, as you can see, staff  
14 and applicant's GMRSes are very similar indicating  
15 that the differences in our approach to site response  
16 are -- don't change this overall answer.

17 Next slide.

18 DR. MUNSON: Just to add one thing --  
19 David, could you go back?

20 CHAIRMAN KIRCHNER: Just state your name,  
21 please.

22 DR. MUNSON: Cliff Munson. I'm the senior-  
23 level advisor.

24 The dotted line shows that if you just  
25 treat this as a hard rock site and don't do site

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1 response at all, that's the GMRS you get.

2 So, of this wrangling about 1D versus 2D  
3 versus dipping layers, really, it doesn't have that  
4 big of an impact if you look at the dotted curve.

5 So, in the end, this is an extremely hard  
6 rock site that - the impedance contrasts are very  
7 small.

8 DR. HEESZEL: Okay. Next slide.

9 MR. CAMPBELL: And Dr. Munson is the  
10 senior-level advisor for siting for NRO.

11 MEMBER CORRADINI: Can you go back,  
12 because I wanted -- I agree with you that they don't  
13 look that different. But if I take the blue versus  
14 the dots or the red, the fact that at high frequency  
15 the Applicant's blue is a little bit lower comes from  
16 the very fact of the next slide which shows at high --  
17 what am I trying to say -- at high frequency they are  
18 slightly below the 1D.

19 What I'm trying to understand is -- I  
20 understand what you're getting at is you're saying if  
21 you just take a monolithic, hard rock site, it's close  
22 enough for government work, right?

23 But I was just trying to -- when I was  
24 asking this of the Applicant, I was trying to  
25 understand 1D versus 2D calculations and it's all at

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1 high frequency.

2 MR. CAMPBELL: "Close enough for  
3 government work" isn't the right word.

4 (Laughter.)

5 MR. CAMPBELL: Close enough for the  
6 purposes of characterizing the site for the ESP.

7 DR. MUNSON: And I think that the slight  
8 dip you see in the high frequency might be due to the  
9 Applicant using a slightly higher damping.

10 DR. HEESZEL: Slightly higher damping and  
11 differences in interpolation algorithms, you know.

12 MEMBER RICCARDELLA: Because my  
13 understanding is the Applicant used 1D analysis.

14 DR. HEESZEL: Yes.

15 (Simultaneous speaking.)

16 MEMBER RICCARDELLA: He just did the 2D  
17 for comparison to show that the 1D was conservative.

18 DR. HEESZEL: Next slide. So, the  
19 Applicant, as we've discussed, has performed a 2D site  
20 response sensitivity study due to the relatively high  
21 dip in the subsurface.

22 Reg Guide 1.208 specifically called out  
23 this potentiality if there's a complicated subsurface  
24 structure, a multidimensional approach may be  
25 necessary.

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1           In response to that, the Applicant  
2 developed this 2D analysis. Initially, the 2D  
3 analysis compared -- so, the blue line to a suite of  
4 lines that were developed using the same inputs that  
5 were developed for the 2D response, staff requested  
6 that they compare to the 1D response used for the  
7 licensing basis.

8           And the result is this graph here on the  
9 right, which satisfied staff's concern that the 2D  
10 results account for -- or the 1D results, excuse me,  
11 account for 2D structure using the site response  
12 inputs that are used in the GMRS development.

13           Next slide. So, staff's conclusions. The  
14 Applicant provided thorough characterization of the  
15 seismic sources surrounding the site as required by 10  
16 CFR 100.23.

17           The Applicant adequately addressed the  
18 uncertainties inherent in that characterization  
19 through the use of a PSHA, and the PSHA follows  
20 guidance provided in Reg Guide 1.208.

21           Finally, the Applicant's GMRS adequately  
22 represents the regional and local seismic hazards and  
23 accurately includes the effects of the local site  
24 subsurface properties.

25           If there are no additional questions, I

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1 will pass the baton to my colleague Luisette  
2 Candelario.

3 MEMBER RICCARDELLA: Is it the  
4 anticipation that in addition to designing this GMRS  
5 that at COL time there will also be a seismic PRA  
6 considering all frequencies?

7 I mean, at some point I would assume  
8 there'd be -- or a seismic margins analysis?

9 DR. HEESZEL: That is part of the Part 52  
10 process.

11 MEMBER CORRADINI: But I want to make sure  
12 that I understood it could be either. It wouldn't  
13 have to be a probabilistic seismic analysis, it could  
14 be a --

15 MEMBER RICCARDELLA: SMA.

16 MEMBER CORRADINI: What is --

17 MEMBER RICCARDELLA: Seismic margins  
18 analysis.

19 MEMBER CORRADINI: Seismic margin  
20 analysis.

21 DR. MUNSON: Now, before fuel loading,  
22 they have to do a seismic PRA. A seismic margin is  
23 done for the design certification, but for the site-  
24 specific COL before fuel loading, once they receive  
25 license, they have to do a seismic PRA.

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1 MEMBER RICCARDELLA: Okay. Thank you.

2 MEMBER CORRADINI: Thanks for the  
3 clarification.

4 MS. CANDELARIO: Thank you, Dr. Heeszal,  
5 and good afternoon.

6 My name is LUISSETTE Candelario, and I was  
7 one of the technical reviewers for Section 2.5.4,  
8 Stability of Subsurface Materials and Foundations, and  
9 Section 2.5.5, which is Slope Stability Analysis.

10 My colleague, Dr. Weijun Wang in the  
11 audience, was also involved in the review of these  
12 sections.

13 This slide presents a summary of SAR  
14 Section 2.5.4 and the key areas reviewed by the staff.  
15 SAR Section 2.5.4 present the individual properties of  
16 subsurface materials and evaluation of stability of  
17 subsurface materials and foundation at the site.

18 SAR Section 2.5.4 includes the staff  
19 review of the Applicant field and laboratory  
20 investigations data and associated assumptions and  
21 calculations used to determine the geotechnical  
22 properties of materials at the site.

23 The staff also review the relationship of  
24 foundations and underlying materials, descriptions of  
25 your physical investigation performed at the site and

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1 the result of same.

2 The excavation and backfill, groundwater  
3 conditions, response of soil and -- dynamic loading,  
4 liquefaction potential and stability of foundations.

5 SAR Section 2.5.4 also includes 16 COL  
6 action items and one permit condition, which I will  
7 explain in detail in the upcoming slides.

8 In order to provide sufficient  
9 geotechnical information of the site without having a  
10 specific design, the Applicant provided a surrogate  
11 design in its application.

12 The surrogate plant approach covered a set  
13 of bounding parameters also known as the plant  
14 parameter envelope or PPE.

15 Under the PPE approach, the resulting ESP  
16 will be applicable for a range of reactor designs if  
17 the relevant design parameters falls into the PPE.

18 Section 2.5.4, PPE site characteristic,  
19 includes a minimum bedding capacity of 110 kips per  
20 square foot, a minimum shear-wave velocity of 4,650  
21 feet per second, no liquefaction, and the deepest  
22 foundation embedment depth of 138 feet from the  
23 finished grade.

24 This slide present a site layout and a  
25 boring location plan at the Clinch River site. The

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1 figure provides the bounding power block area  
2 associated with the plant parameter envelope.

3 The Clinch River site subsurface  
4 investigation included 82 borings with depth of about  
5 20 feet to 540 feet.

6 Seven of the borings were drilled at  
7 inclinations between 25 and 29 degrees from the  
8 vertical.

9 The Applicant performed three test pits,  
10 44 observation wells, two surface geophysical tests,  
11 and rock pressuremeter tests in two borings. The  
12 Applicant performed downhole geophysical tests in 28  
13 borings.

14 Next slide. This slide shows a cross-  
15 section of a bedrock structure and the stratigraphic  
16 unit of the site underneath the power block area.

17 The area bounded by the green lines shows  
18 the -- foundation level that the Applicant considered  
19 for the power block area.

20 The Applicant considered foundation  
21 embedment depth of 80 feet and 138 feet below plant  
22 grade. Bedrock is encountered approximately between  
23 20 and 30 feet below the existing ground surface.

24 The average of the existing site elevation  
25 in the power block area is about 810 feet. The

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1 Applicant use a finish plan rate elevation of 821 feet  
2 from the power block area -- for the power block area.

3 The groundwater generally occurs at depths  
4 ranging from near surface to approximately 25 feet.  
5 The average dip of the bedding plane is about 33  
6 degrees southeast, and, as you can see, it doesn't  
7 change considerably between layers.

8 Because of this dipping bed at the site,  
9 various stratigraphic units may be exposed at the  
10 foundation level at different locations within the  
11 power block area.

12 The implications of this geologic feature  
13 for the evaluation of bedding capacity and sediment  
14 will be explained in the upcoming slides.

15 Next slide. One of the key review topics  
16 of interest is the assessment of the effect of  
17 underground voids on foundation stability.

18 As Jenise and Gerry point out, karst  
19 exists at the Clinch River site and the underground  
20 voids may adversely affect the foundation stability.

21 The Applicant site investigation provided  
22 preliminary information on void distribution and size.  
23 The Applicant data shows that cavities are present in  
24 all stratigraphic unit of the site, but are more  
25 predominant in the Rockdell Formation and Eidson

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1 Member.

2           These cavities ranges from one feet to  
3 about 17 feet in height and includes open and clay-  
4 filled voids and are predominantly found within the  
5 first hundred feet from the ground surface.

6           The staff review the Applicant's PLAXIS 2D  
7 finite element analysis that assess the effect of  
8 postulated underground voids on foundation stability  
9 at the Clinch River site.

10           The staff review of the analysis focus on  
11 assessing the suitability of the site related to the  
12 critical size of a cavity that can affect foundation  
13 stability.

14           The 2D finite element model consider  
15 actual site conditions based on information obtained  
16 from the site investigation.

17           The diameter of the maximum void was  
18 assumed based on boring data, and the length of the  
19 void was conservatively assumed to be infinity.

20           Locations of the maximum voids were  
21 assumed at the most critical locations where the  
22 materials is the weakest and stress induced by  
23 structures is the highest.

24           Next slide. Another key review topic of  
25 interest is the foundation stability analysis with

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1 inclined strata.

2 The Clinch River site consists of multiple  
3 incline layers of various rock formation with possible  
4 weakened interfaces between the formations.

5 The staff review the Applicant's multiple  
6 traditional methods and finite element method used to  
7 assess foundation stability at the Clinch River site.

8 The Applicant used different traditional  
9 methods to obtain a range of calculated values and to  
10 identify which method is more suitable for the site.

11 The staff noted that traditional methods  
12 for the evaluation of foundation stability, such as  
13 bedding capacity and sediment, are based on  
14 assumptions of flat layers, either half-space  
15 (phonetic) uniform material, or layered uniform  
16 material. Therefore, the suitability of the  
17 traditional methods needed to be evaluated.

18 As such, the Applicant developed a two-  
19 dimensional finite element model to estimate the  
20 bedding capacity and sediment. The analysis modeled  
21 the actual site geologic conditions based on the site  
22 investigation data.

23 The staff concludes that the traditional  
24 method's results are in good agreement with those  
25 obtained from the finite element model and that the

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1 selected PPE values related to the site stability  
2 analysis are appropriate.

3 The staff identifies COL Action Item 2.5-  
4 12 through 2.5-14 for the COL or CP applicant to  
5 address the foundation stability of the site once a  
6 reactor technology and a specific location and extent  
7 of the seismic category I structure is identified.

8 Next slide. The Applicant used a PPE  
9 instead of a specific plant design. As such, seismic  
10 category I structures for the proposed site are not  
11 identified and the specific location and extent of the  
12 structure is not known at the ESP stage.

13 As such, the staff identify COL Action  
14 Item 2.5-1 through 2.5-16 that specifies that the  
15 reactor technology and site location-specific actions  
16 needed to be addressed by the COL or CP applicant when  
17 referencing this ESP.

18 Those COL action items are related to the  
19 following site characteristics: Site geologic  
20 features, properties of subsurface materials,  
21 excavation and backfill, groundwater conditions,  
22 static and dynamic stability, design criteria, and  
23 techniques to improve subsurface conditions.

24 The staff identified permit condition two,  
25 to ensure that the material above elevation 741 feet

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1 in areas where safety-related structure would be  
2 located are removed to minimize the adverse effect of  
3 discontinuities, weather and shear-fracture zones, and  
4 karst features on the stability of subsurface  
5 materials and foundations.

6 And that additional geotechnical  
7 investigations are performed at the excavation level  
8 to identify any potential geologic features that may  
9 adversely impact the stability of subsurface materials  
10 and foundations.

11 MEMBER CORRADINI: I want to make sure I  
12 understand this condition. So, this says that  
13 regardless of the design chosen, if it's chosen for  
14 this area, they have to excavate down to 741 feet,  
15 which is how much above the surface?

16 MS. CANDELARIO: 80 feet is the shallowest  
17 embedment considered by the Applicant.

18 MEMBER CORRADINI: Thank you. At least?

19 MS. CANDELARIO: At least.

20 The staff concludes that the Applicant  
21 adequately determined the site-specific engineering  
22 properties of subsurface materials underlying the  
23 Clinch River site and conducted sufficient evaluation  
24 of the stability of subsurface materials and  
25 foundations based on the result of field and

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1 laboratory tests and the state-of-the-art methodology  
2 and in accordance with Regulatory Guides 1.1-32, 1.1-  
3 38 and 1.1-98.

4 The staff concludes that the Applicant  
5 meets the requirements of 10 CFR Part 52.17(a)(1)(vi)  
6 and 10 CFR Part 100.23(c) for this ESP application  
7 regarding the stability of subsurface materials and  
8 foundations.

9 Any questions?

10 (No questions.)

11 MS. CANDELARIO: So, Sections 2.5.5  
12 discuss the stability of slopes. Next slide. The NRC  
13 staff reviewed SSAR Section 2.5.5 which provide  
14 general descriptions of site related to slope  
15 stability analysis.

16 There are no existing slope on the site at  
17 this time, either natural or manmade, that could  
18 affect the stability of the site.

19 The Applicant deferred the actual slope  
20 stability analysis to the COL or CP application. In  
21 order to address the need for future slope stability  
22 analysis, the staff identified COL Action Item 2.5-15,  
23 which specifies that an applicant for a COL or CP  
24 application that references these early site permit  
25 should perform a slope stability analysis of any

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1 safety-related slopes, including dams and dikes,  
2 consistent with the selected reactor technology.

3 Next slide. The staff conclude that the  
4 Applicant provided unnecessary information on site  
5 topography and geologic characteristic and adequately  
6 described the slope's characteristic at the site.

7 The staff conclude that the SSAR Section  
8 2.5.5 is adequate and acceptable because it meets  
9 applicable requirements of 10 CFR Part 50 Appendix S,  
10 10 CFR Part 52.17(a)(1)(vi) and 10 CFR Part 100.23.

11 Any questions?

12 CHAIRMAN KIRCHNER: Questions? Members?

13 (No questions.)

14 CHAIRMAN KIRCHNER: Well, I think we  
15 should now turn to any members of the public who wish  
16 to make a comment.

17 Anyone present in the audience?

18 (No questions.)

19 CHAIRMAN KIRCHNER: Can we now turn to our  
20 phone connection, please.

21 OPERATOR: The conference is now in talk  
22 mode.

23 CHAIRMAN KIRCHNER: If there are any  
24 members listening in who wish to make a comment,  
25 please identify yourself and make your comment.

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1 (No comments.)

2 CHAIRMAN KIRCHNER: Hearing none --

3 MEMBER BLEY: You said members?

4 CHAIRMAN KIRCHNER: Oh, excuse me, Dennis.

5 That sounds like a familiar voice. Please go ahead.

6 MEMBER BLEY: Okay. Well, I assume you're  
7 doing our round now and --

8 CHAIRMAN KIRCHNER: Yes.

9 MEMBER BLEY: (Telephonic interference)  
10 presentation revises the questions, but I don't have  
11 anything to add.

12 CHAIRMAN KIRCHNER: Thank you, Dennis.

13 Members?

14 (No questions.)

15 CHAIRMAN KIRCHNER: Let me then thank both  
16 the Applicant and the staff for very good  
17 presentations. And with that, we are adjourned.

18 (Whereupon, the above-entitled matter went  
19 off the record at 3:51 p.m.)

20

21

22

23

24

25



Clinch River  
Early Site Permit  
Part 2, SSAR Section 2.5

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Advisory Committee on Reactor Safeguards

Committee Meeting

Presented by

Ray Schiele, Licensing

Wally Justice, Engineering

October 17, 2018

# Acknowledgement and Disclaimer

Acknowledgment: "This material is based upon work supported by the Department of Energy under Award Number DE-NE0008336."

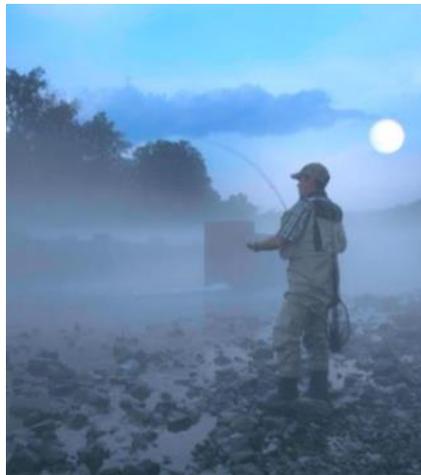
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# TVA's Mission

Serving the people of the Tennessee Valley to make life better.



Energy



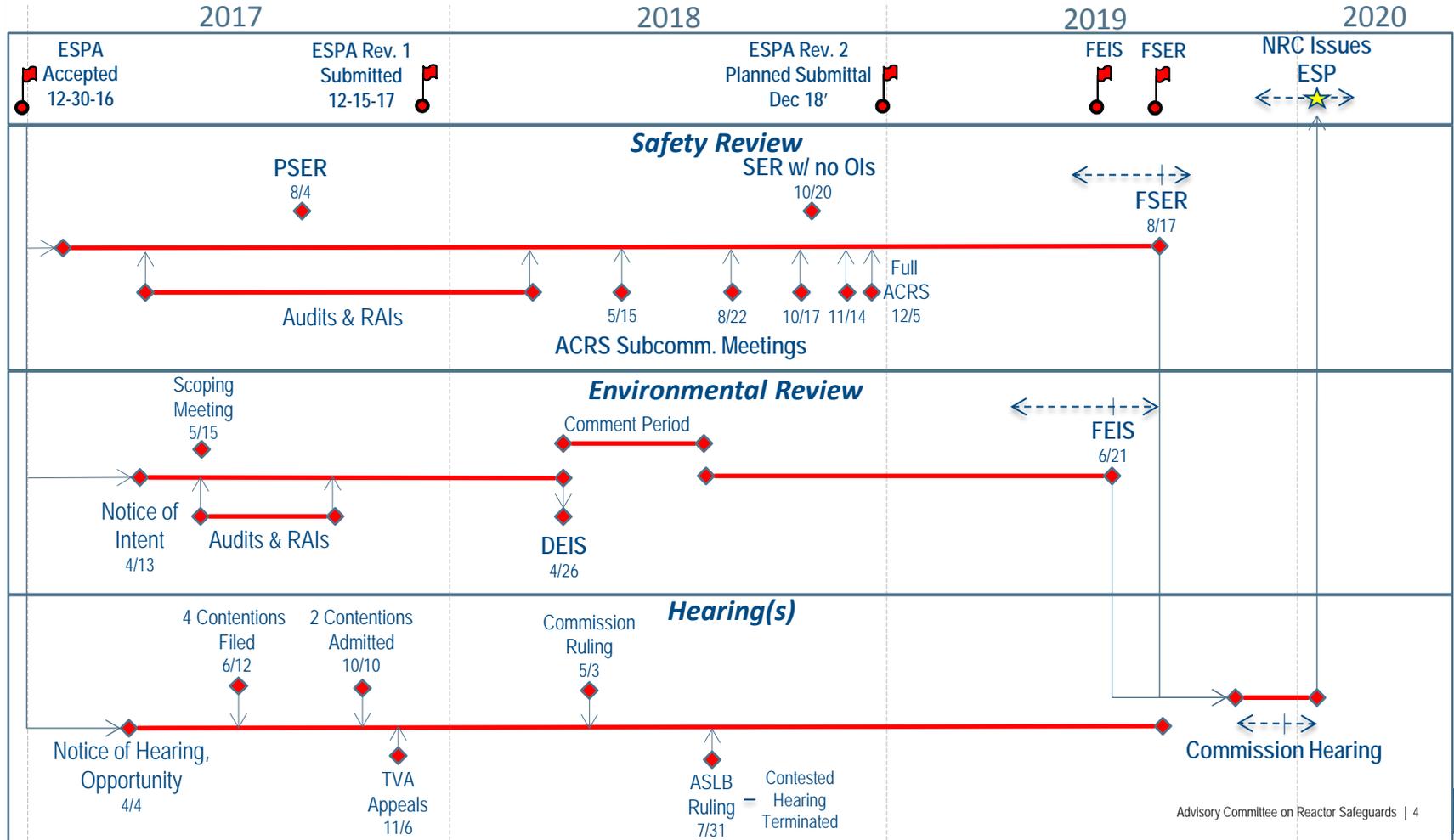
Environment



Economic Development

Partner with **154** local power companies, to serve more than **9 million** customers in parts of **seven states**. Directly serve **54** large industries and federal installations.

# NRC Review of ESPA



# Key NRC Interactions Related to ESPA SSAR Section 2.5

Two audits and one management/geologist visit were conducted to review the geology, seismology, and geotechnical information in the ESPA

- Pre-Application Readiness Assessment – September 15-17, 2015
  - 68 specific actions identified for resolution prior to application submittal
  - January 13, 2016 Public Meeting to discuss TVA's incorporation of issues in the application
- Audit – May 8-9, 2017
  - Office discussion
    - General presentation of the Clinch River site
    - Discussion and response to specific NRC Audit Information Needs regarding Geologic Information, Vibratory Ground Motion, and Geotechnical Engineering
  - Site Tour
    - Tour site and site vicinity geologic features
    - Review core samples
    - 6 specific areas where supplemental info was requested (part of RAIs)
- Management Visit – January 30-31, 2018
  - Office discussion
  - Site Tour

# Presentation Outline

## Part 2, Site Safety Analysis Report (SSAR), Section 2.5, Geology, Seismology, and Geotechnical Engineering:

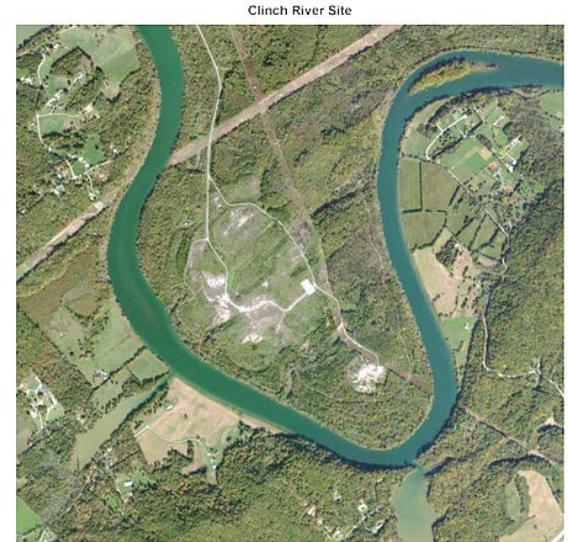
- Geology – Wally Justice, SMR Engineering ,Kevin Clahan, LCI, Janet Sowers, Fugro
- Seismology – Wally Justice
- Geotechnical Engineering – Wally Justice

# ESPA Part 2, SSAR Section 2.5 Geology

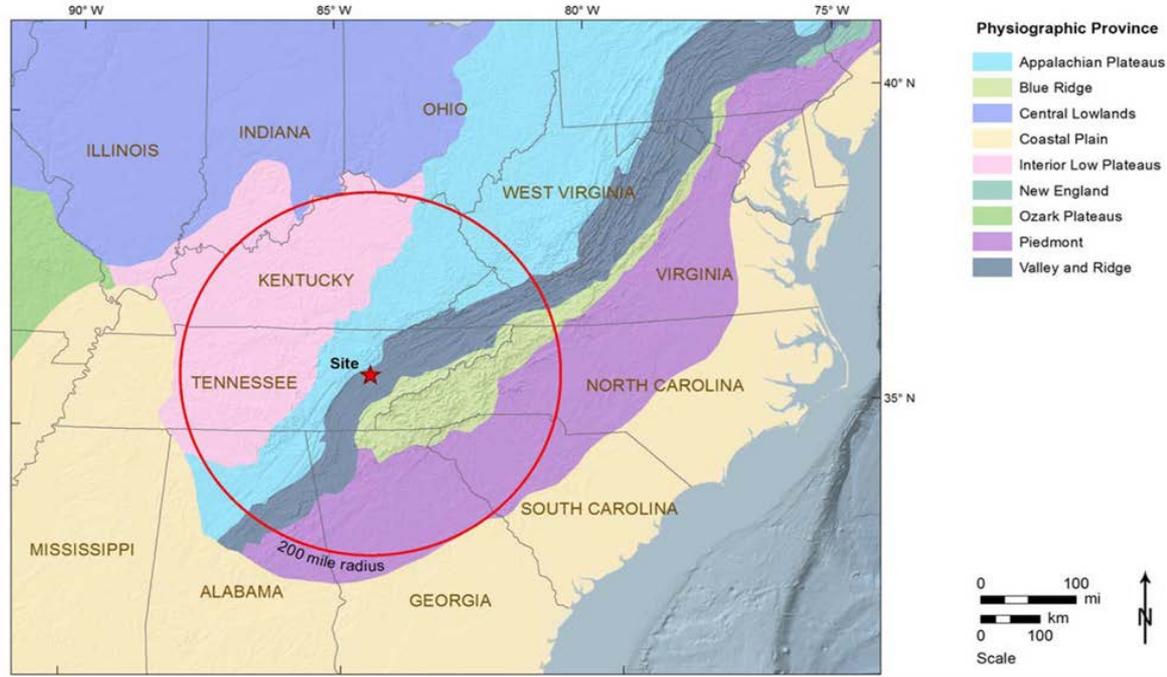
# SSAR Section 2.5 - Geology

The geological and seismological information presented in this subsection 2.5.1 was developed from a review of previous reports for the proposed Clinch River Breeder Reactor, published geologic literature, and interpretations of data obtained as part of the surface and subsurface field investigations.

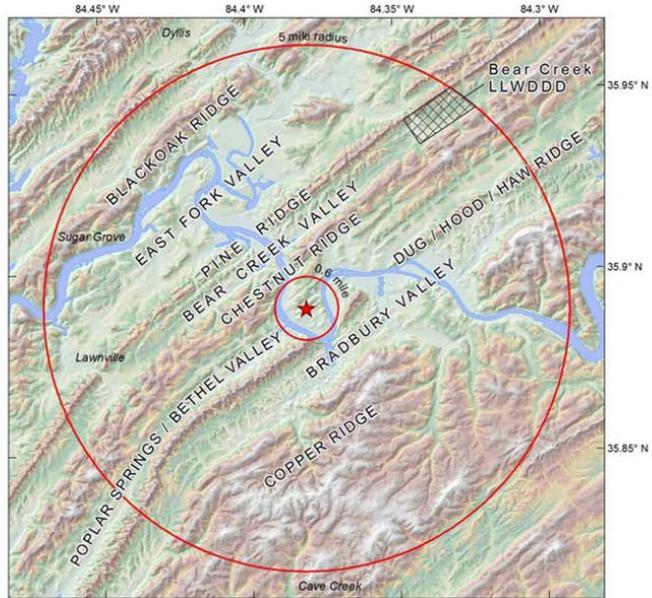
- Complies with the requirements of 10 CFR 100.23(c).
- The geological information was developed in accordance with NRC guidance documents Regulatory Guide (RG) 1.206
- NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition, Section 2.5.1, provides guidance for the development of Subsection 2.5.1.



# Clinch River Site Regional Description

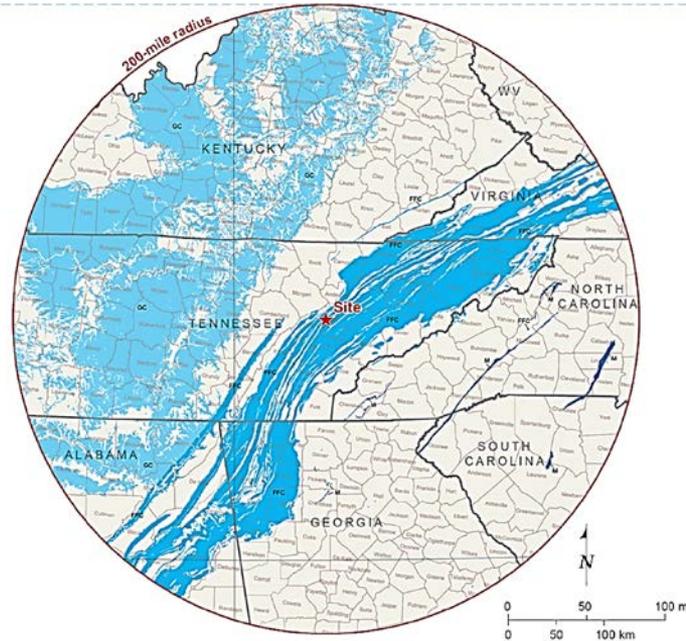


# Local Physiography



Bedrock physiography is characterized by a well-developed valley and ridge system.

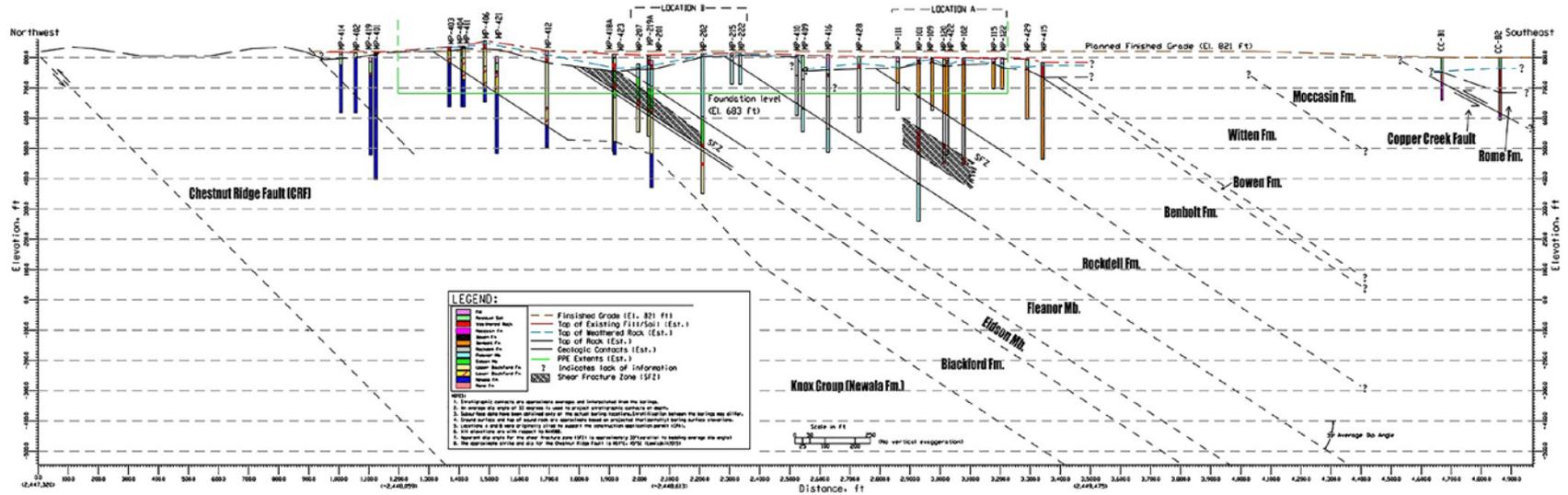
# Regional Distribution of Carbonate Rocks



## Description of Map Units

- GC** Gently folded and flat-lying carbonate rocks: indurated limestone and dolomite that has not been strongly deformed. Predominantly found in interior plateaus and lowlands. Dissolution may produce solution, collapse, and cover-collapse sinkholes. Where carbonates are thick and extensive, cave systems may be long and complex. Where thin and interbedded with non-carbonates, caves are small and short. Geometry of cave passage patterns often shows stratigraphic and bedding-plane control often resulting in branchwork caves. (Reference 2.5.1-35)
- FFC** Folded, faulted carbonate rocks: limestone and dolomite in areas flanking and in orogenic zones. May be intensely folded and faulted, commonly well jointed, commonly with cleavage. These rocks are located in the Valley and Ridge Province on this map and most are Paleozoic in age. Dissolution may produce solution, collapse, and cover-collapse sinkholes. Caves range from small and simple to long and complex systems. Geometry of cave passage patterns tend to show at least some structural control producing network caves. (Reference 2.5.1-35)
- M** Marbles and metalimestones: highly deformed carbonate rocks, usually found in long, thin, linear belts or pods. Mapped areas are often exaggerated as these rocks are usually mapped with associated, non-soluble metamorphic rocks. Dissolution may result in solution, collapse, and cover-collapse sinkholes and small, short caves.

# Geological Cross Section of Clinch River Site

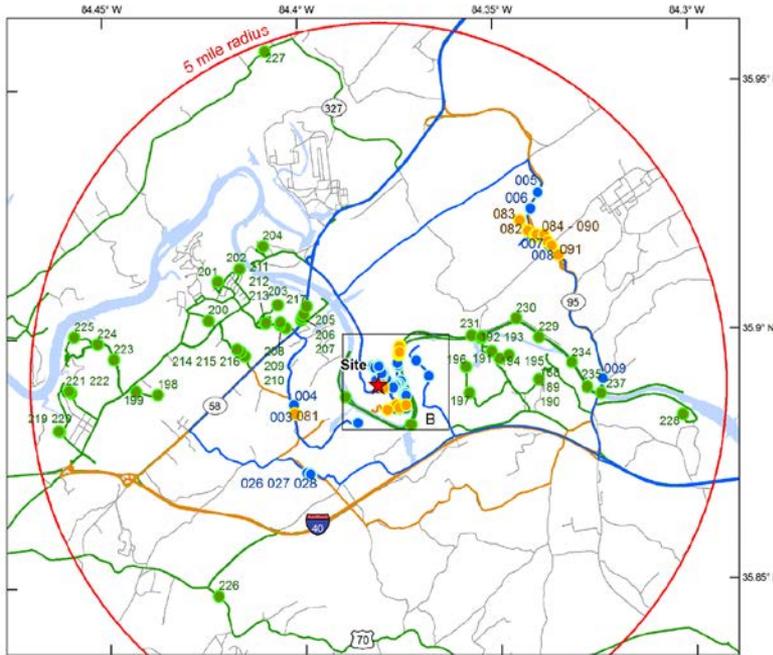


# Field and Data Investigations

- Field Reconnaissance
- Geomorphic analyses/LiDar digital elevation data
- Previous Clinch River Breeder Reactor data and investigations (70's -80's)
- Core Borings
- Oak Ridge National Laboratory reports
- Geologic publications
- Karst mapping
- River-terrace mapping



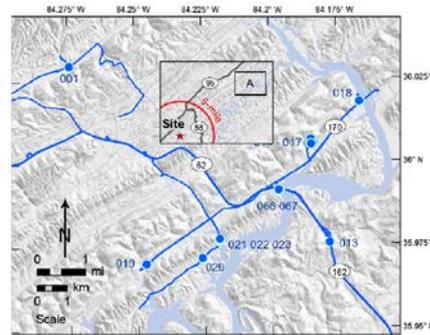
# Field Reconnaissance Waypoints – Regional and Site Area



## GPS Logs

### Waypoints and Tracks

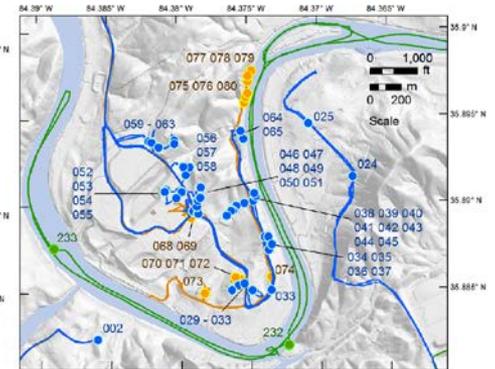
- Recon 1 July 22-25, 2013
- Recon 2 September 3-6, 2013
- Recon 3 November 12-15, 2013



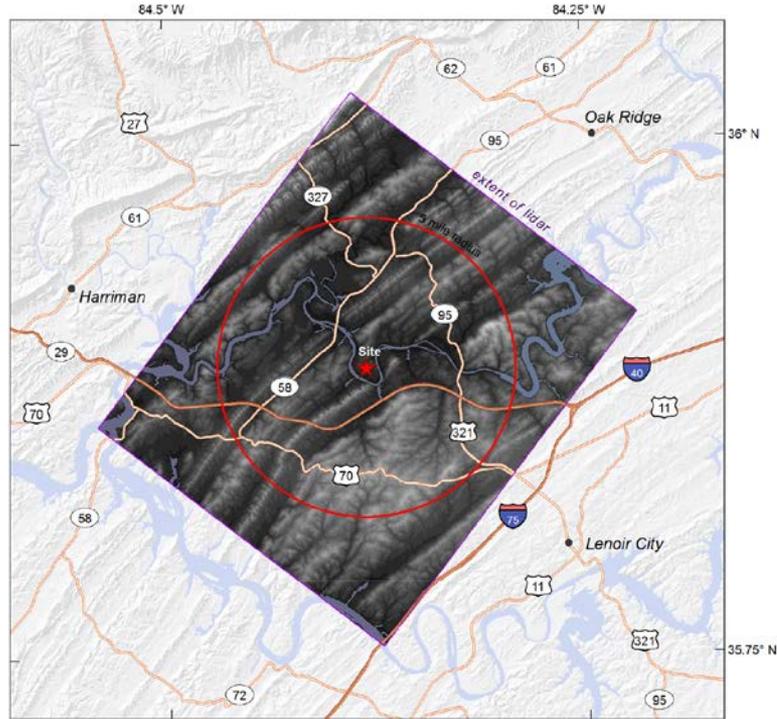
## GPS Logs

### Waypoints and Tracks

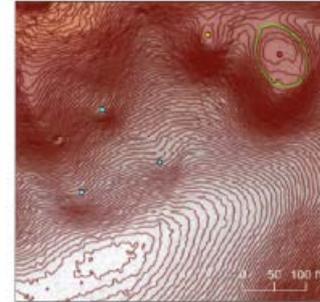
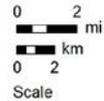
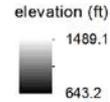
- Recon 1 July 22-25, 2013
- Recon 2 September 3-6, 2013
- Recon 3 November 12-15, 2013



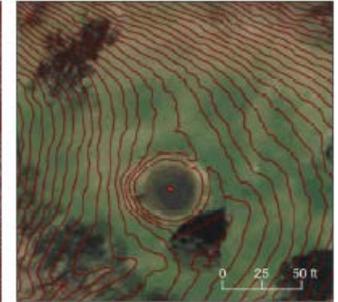
# LiDAR Digital Elevation Model Coverage



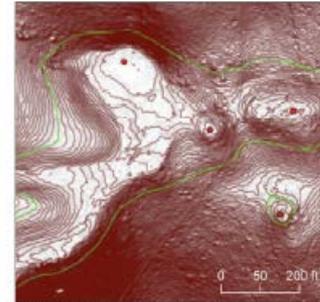
## Project Lidar DEM



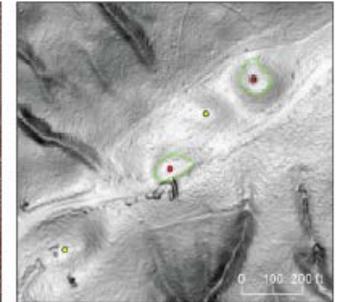
A. Karst depressions on a hillside with 1-foot contours and color ramp DEM



B. Water-filled sinkhole in an open field with 1-foot contours on 2013 aerial photography



C. Multiple sinks within a larger closed depression with 1-foot contours

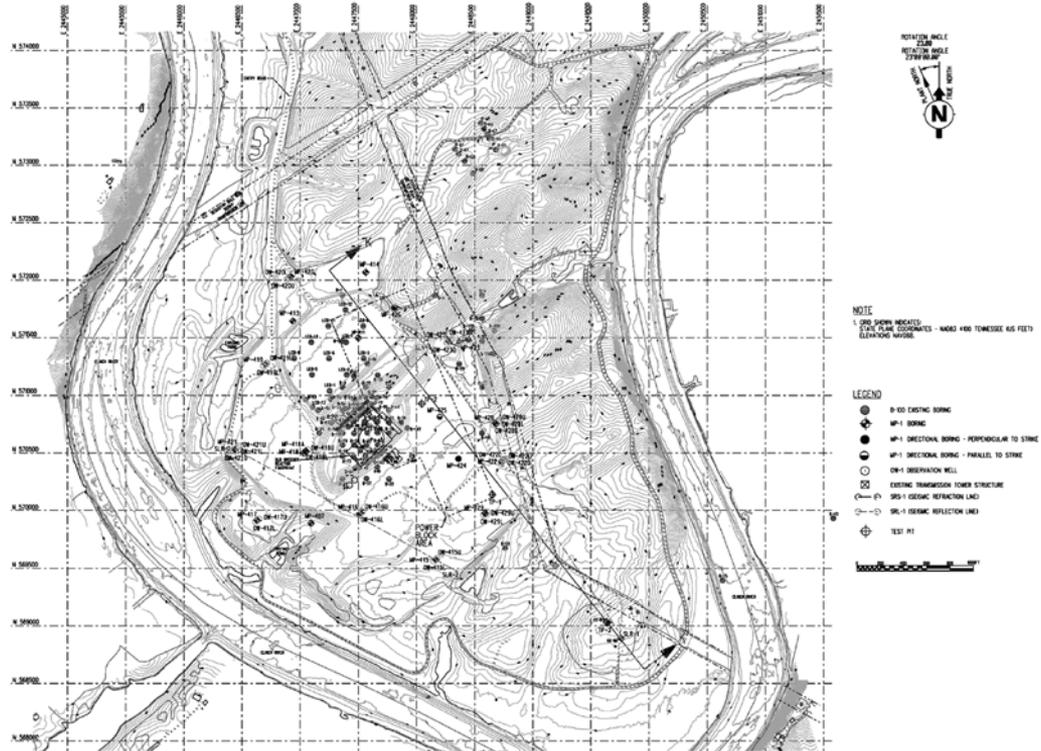


D. Depressions on ridge top, hillshade DEM

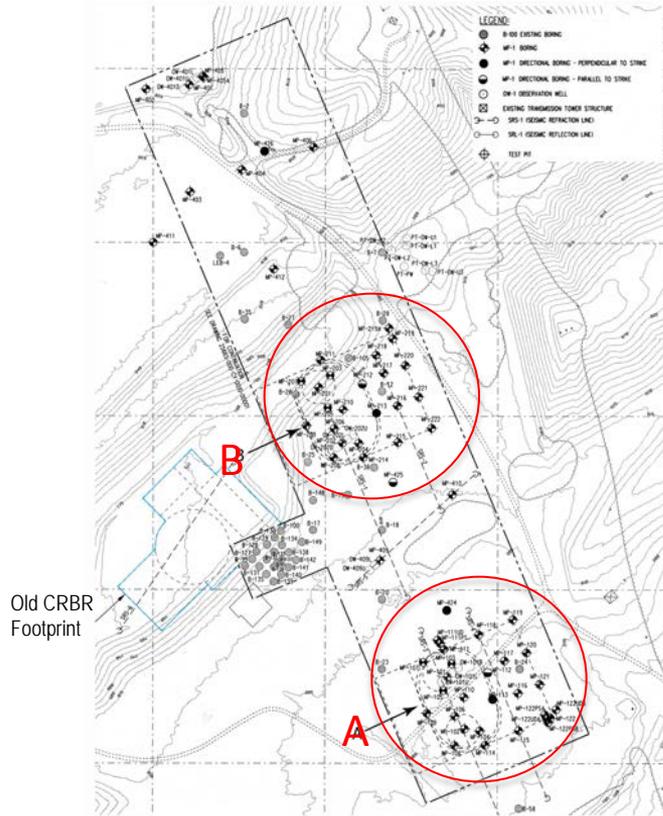
### Explanation

- Center of closed depressions 2-foot depth and 100-square-foot area
- Two-sided depression
- Extent of closed depression
- Three-sided depression
- Shallow depression

# Core Borings of CRBR Project



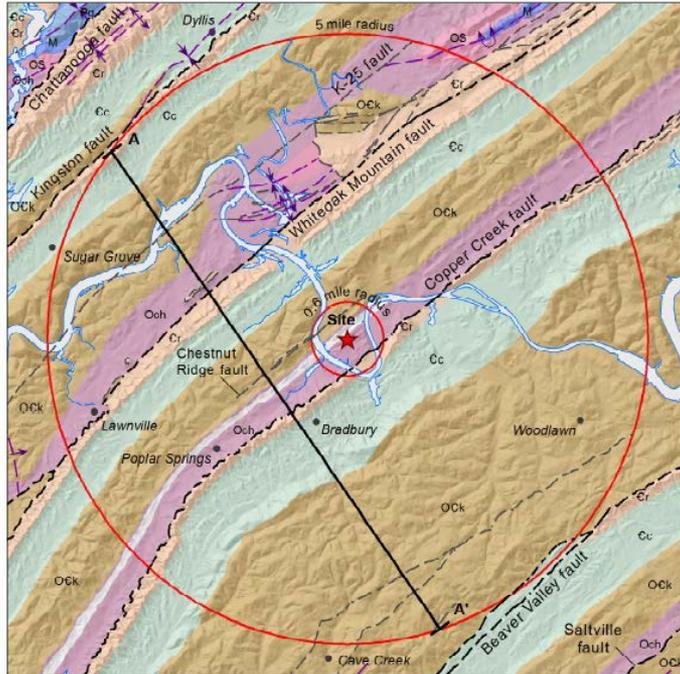
# Borehole Locations at Site A and B



## Core Borings

- 76 rock borings performed for the SMR project
- 104 borings performed for the Clinch River Breeder Reactor Project

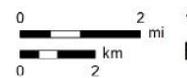
# Faults



## Groups

<span style="background-color: #4a7ebb; color: white; padding: 2px;">Pg</span>	Gizzard Group
<span style="background-color: #4a7ebb; color: white; padding: 2px;">M</span>	Mississippian
<span style="background-color: #c0504d; color: white; padding: 2px;">OS</span>	Ordovician-Silurian
<span style="background-color: #e08080; color: white; padding: 2px;">Och</span>	Chickamauga Group
<span style="background-color: #f0e68c; color: white; padding: 2px;">Ock</span>	Knox Group
<span style="background-color: #c0e0c0; color: white; padding: 2px;">Co</span>	Conasauga Group
<span style="background-color: #d2b48c; color: white; padding: 2px;">Cr</span>	Rome Formation

	Fault
	Anticline
	Syncline
	Overturned syncline

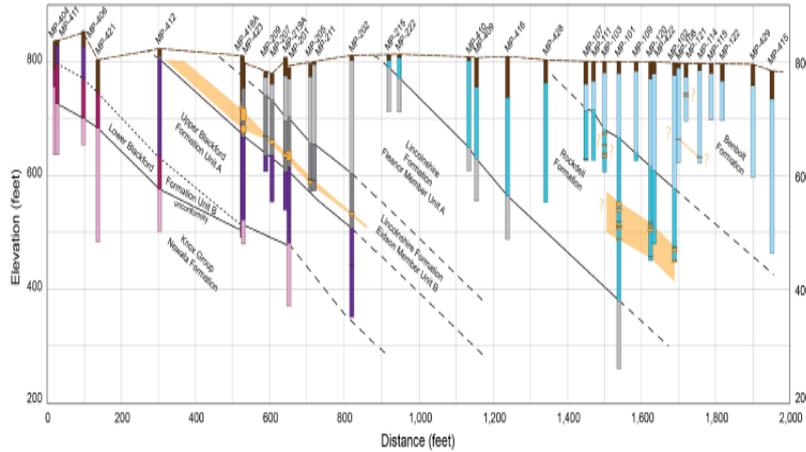


Two Faults traverse the Clinch River Site Location

- Copper Creek Fault
- Chestnut Ridge Fault

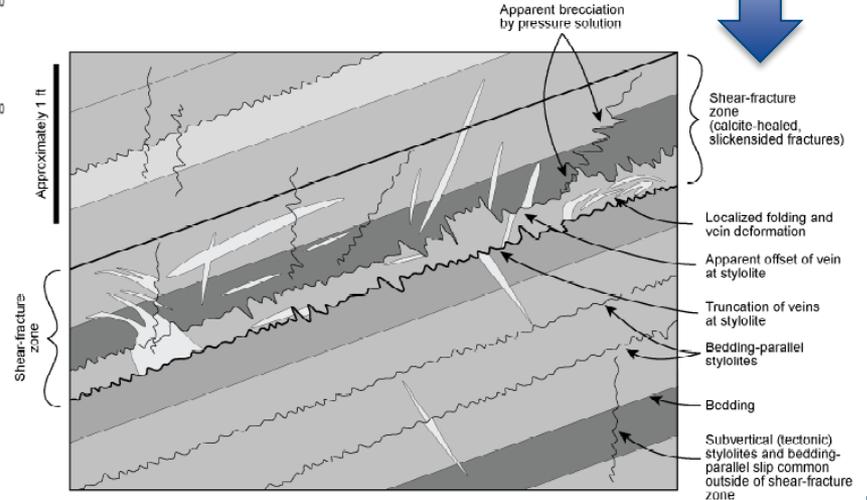
*No evidence of deformation within the Quaternary time period*

# Shear Fracture Zone

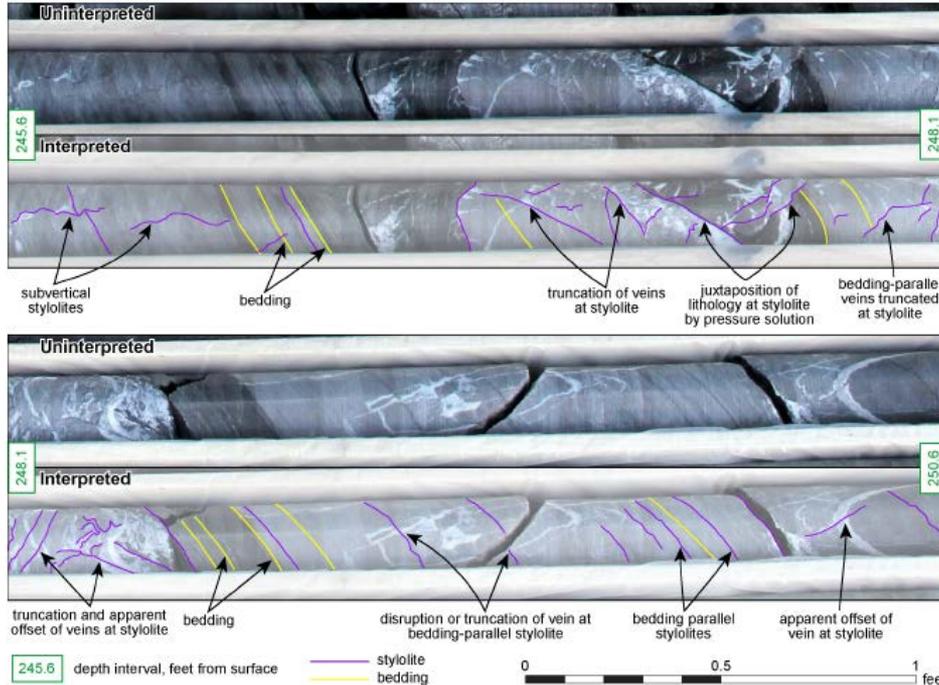


Cross-section through Shear-Fracture Zones

Schematic diagram of relationship between Bedding, Stylolites, and Shear-Fracture Zones



# Shear Fracture Zone Core Boring Photograph



Photograph of Boring MP-101

- Shear-Fracture Zone is very small
- Not a fault breccia
- Resulted from strain relief during the Alleghanian orogeny

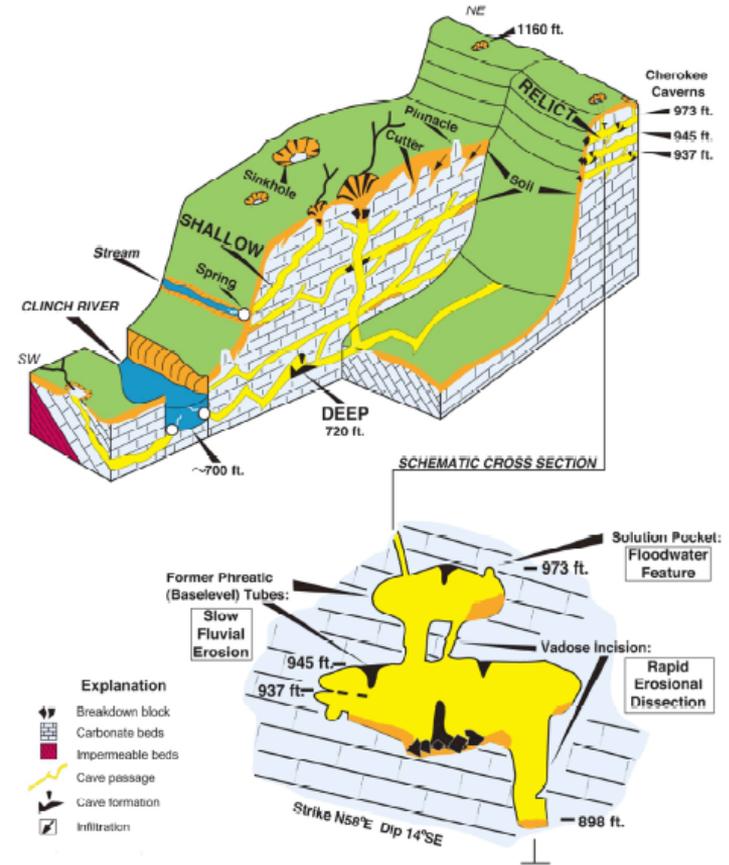
# Local Geologic Hazards

- Karst features and active processes are common throughout the site
- Sinkholes, springs, underground drainage and irregular soil-bedrock contact
- Karst conditions are the primary geologic hazard of concern for this application



# Karst Model Example

- In summary, karst models show that dissolution occurs in a variety of hydrogeologic settings.
- Epigenetic dissolution, by descending and circulating meteoric water, can occur in the vadose zone, in the shallow phreatic zone, and in the deep phreatic zone.
- A karst model for the CRN Site, informed by the above discussions, is shown on a following slide.



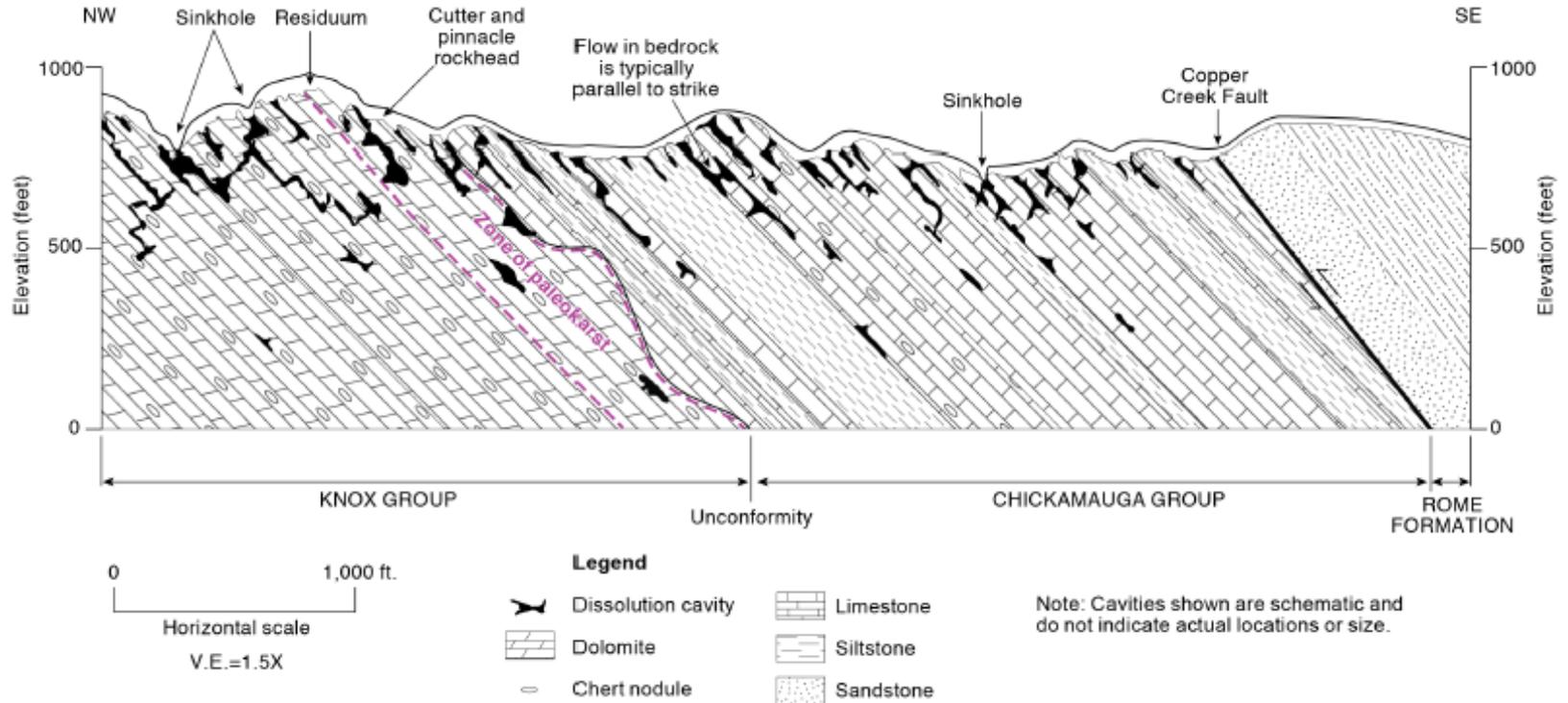
# Karst-related studies

- Multiple karst studies performed for the Oak Ridge Reservation were utilized, including karst inventories and ground water flow testing
- Karst studies performed for the Clinch River Breeder Reactor Project were utilized, including information from core borings
- Recent studies included LiDAR mapping of karst features, compilation of core boring information, analysis and modeling

# Karst Study Conclusions

- The dominant orientation of phreatic dissolution pathways is strike-parallel. Groundwater flow is constrained by low-carbonate units, resulting in strike-parallel drainage systems
- The Fleanor, Blackford, and Bowen formations, the most carbonate-poor units in the Chickamauga Group, have no mapped sinkholes and smaller and fewer borehole cavities than other units.
- Borehole data show that subsurface dissolution is most intense near the surface and decreases steadily with depth. Small numbers of cavities are observed below the water table indicating deep phreatic dissolution has occurred. This is consistent with observations of decreased fracturing frequency and groundwater flowrates with depth in the ORR studies
- Direct evidence of hypogene dissolution processes is not documented at the CR Site or within the ORR. Most evidence is consistent with dissolution by epigenetic processes in the vadose and phreatic zones. This evidence includes the decrease in frequency of fractures and dissolution cavities with depth in boreholes

# Karst Model of the Clinch River Site



# Clinch River Breeder Reactor Excavation Mapping circa 1983

- The excavation mapping report concluded that the site was suitable for development of the proposed facility or other industrial facilities based on the character of the rock exposed. NUREG -0968
- The planned foundation level of the CRBRP, 714 ft MSL, was below the zone of weathered siltstone observed in the excavation, and the limestone at that elevation was found to be hard and sound. No cavities were described on the floor of the excavation.



# Geologic Investigation Conclusion

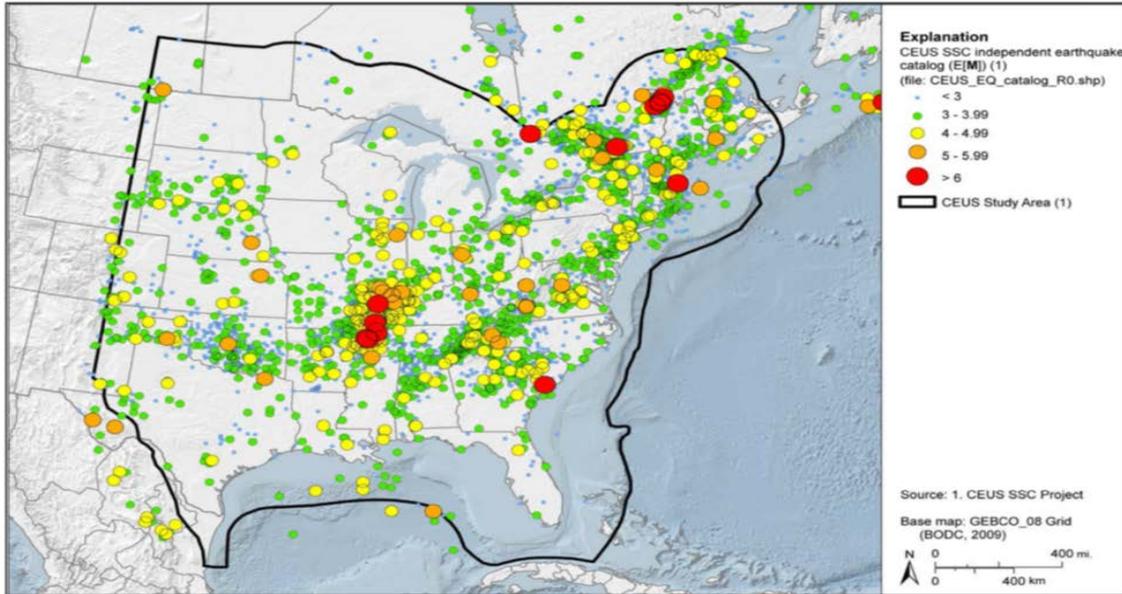
- Active faulting is not a geological hazard for the site area
- Shear fractures are not a geological hazard for the site area
- Karst conditions are identified as the potential geologic hazard for the site area
- Met regulatory requirements of 10CFR52.17 and the guidance from Regulatory Guide 1.208

# ESPA Part 2, SSAR Section 2.5 Seismology

# SSAR Section 2.5 - Seismology

- The purpose of Subsection 2.5.2 is to determine the site-specific ground motion response spectrum (GMRS). The GMRS is defined as the free-field horizontal and vertical ground motion response spectra at the site and must satisfy the requirements of 10 CFR 100.23.
- The GMRS was developed with consideration of the guidance provided in NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants
- Development of the ground motions for the SSAR begins with implementation of the provisions of RG 1.208, A Performance-Based Approach to Define the Site-Specific Earthquake. This regulatory guide describes acceptable methods to conduct geological, seismological, and geophysical investigations of the CRN Site and region around the site, identify and characterize seismic sources, perform a probabilistic seismic hazards analysis (PSHA), perform site response analysis, and determine the Ground Motion Response Spectra (GMRS) using a performance-based approach.

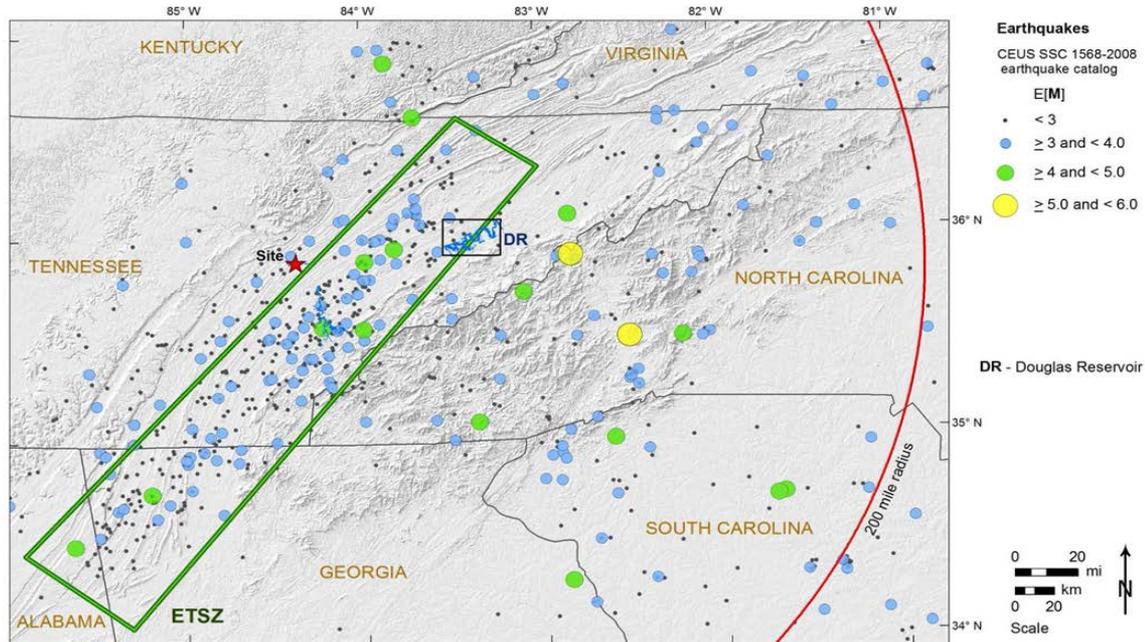
# Seismicity



Plot of Regional Seismicity from the Central Eastern United States (CEUS) SSC Earthquake Catalog (2009)

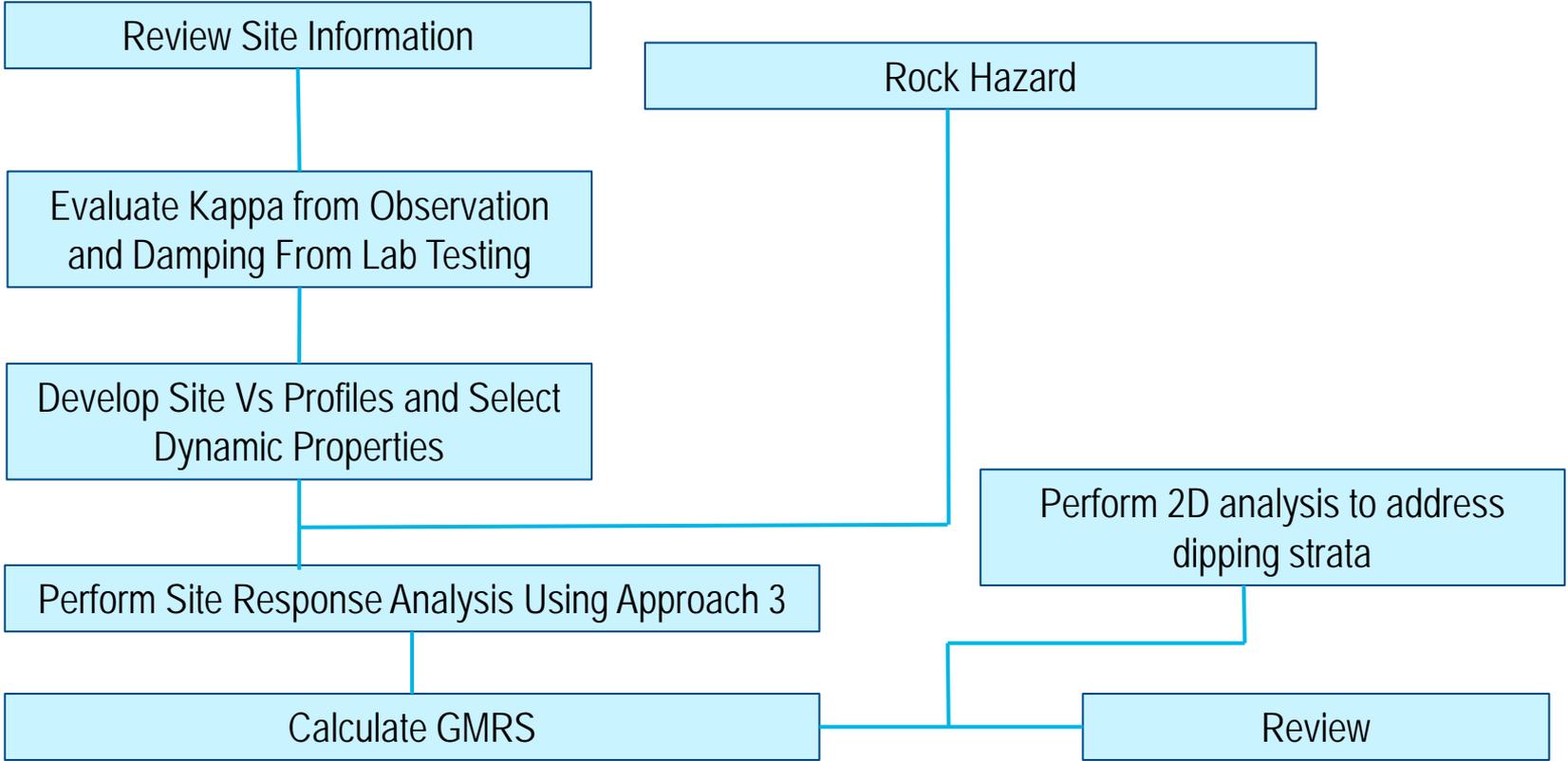
Application was based on 2012 data update

# Seismicity



East Tennessee  
Seismic Zone  
Geometry  
(As Defined by  
USGS)

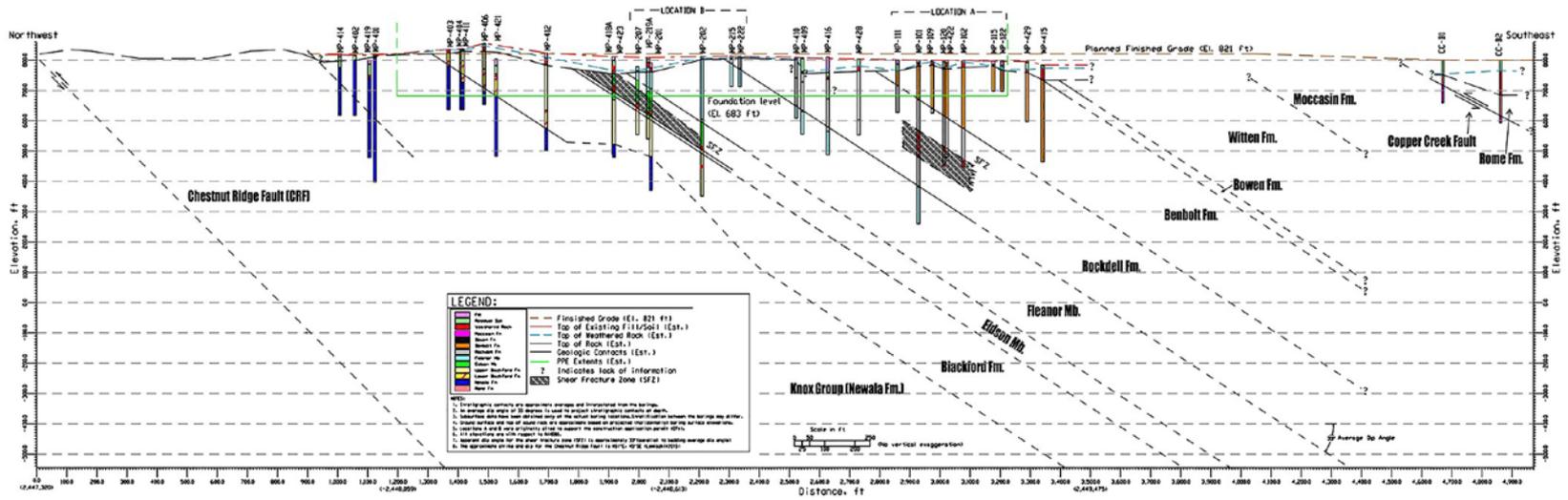
# GMRS Development - Approach



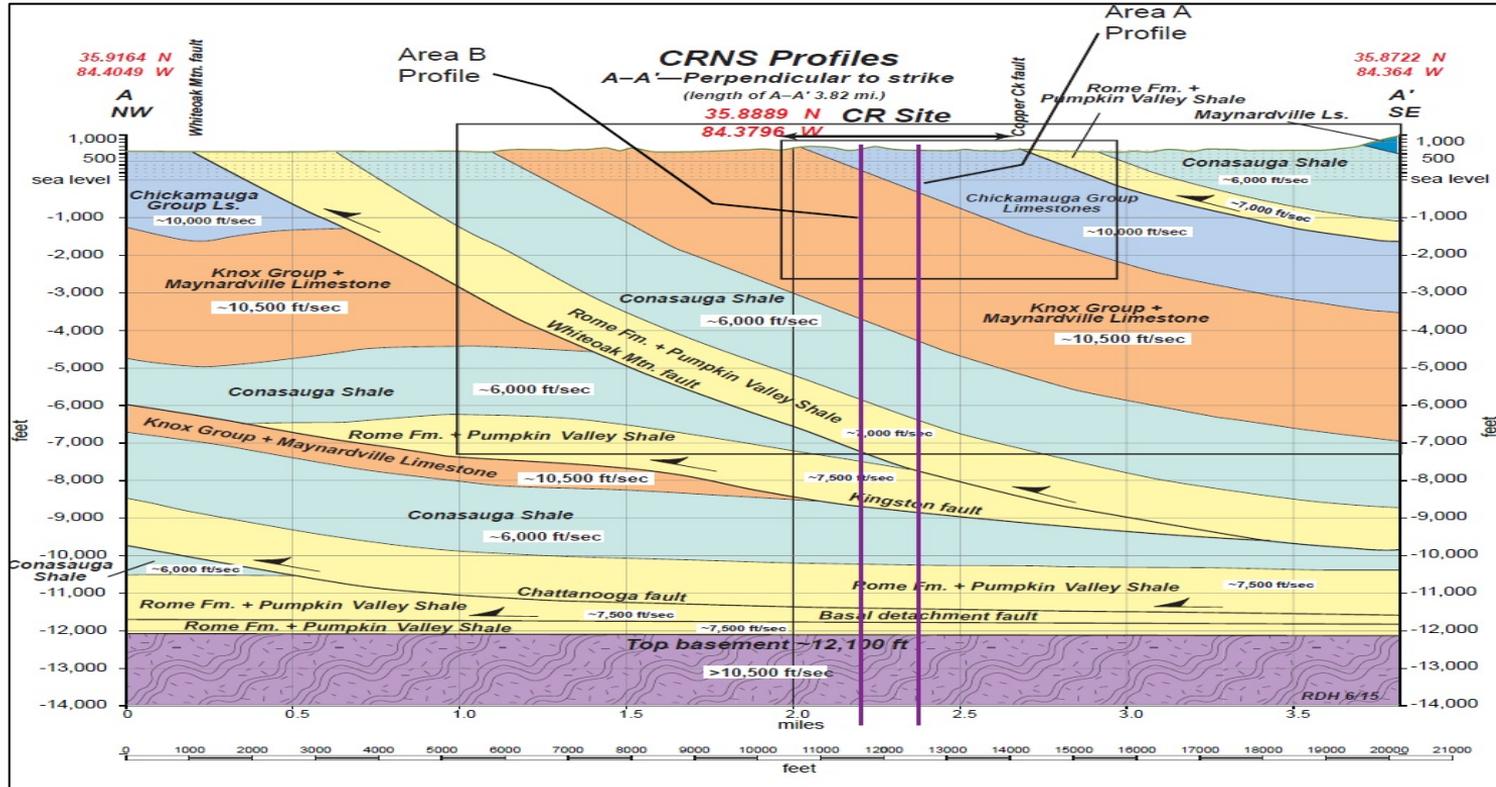
# RG 1.208 Approach 3 Description

- Approach 3
  - Fully Probabilistic
    - > Preserves Hazard Levels
    - > Hazard at Surface computed by integration of Hard Rock Hazard with probability distribution of frequency and strain dependent factors
    - > Results in complete hazard curve at ground surface.
  
  - Endorsed by NUREG CR/6728: Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-Consistent Ground Motion Spectra Guidelines
  
  - Basic Steps in Approach 3
    - > Randomization of site dynamic material properties
    - > Computation of amplification factors using Random Vibration Theory
    - > Full Integration of mean and fractile hazard curves

# Geologic Cross-Section Showing Borehole Locations and VS Profiles

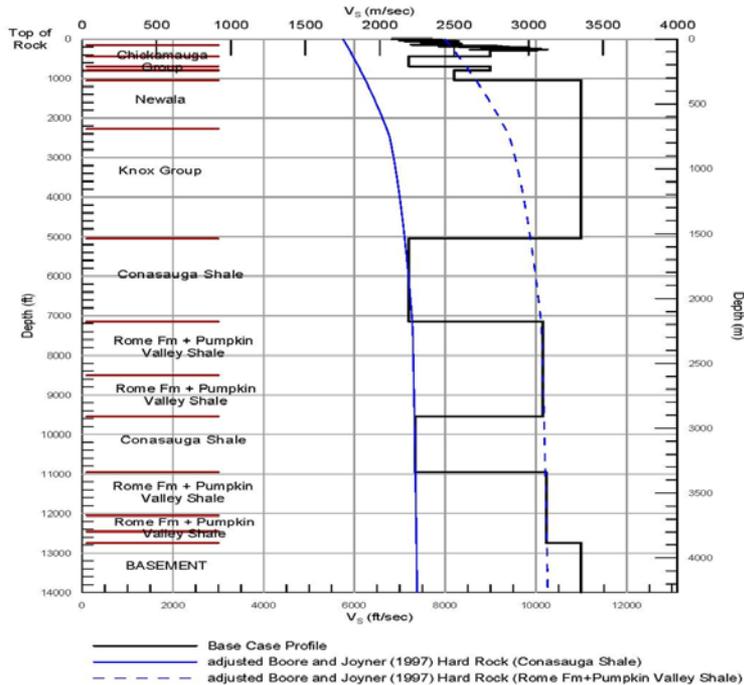


# Geological Cross-Section with $V_s$ Profiles

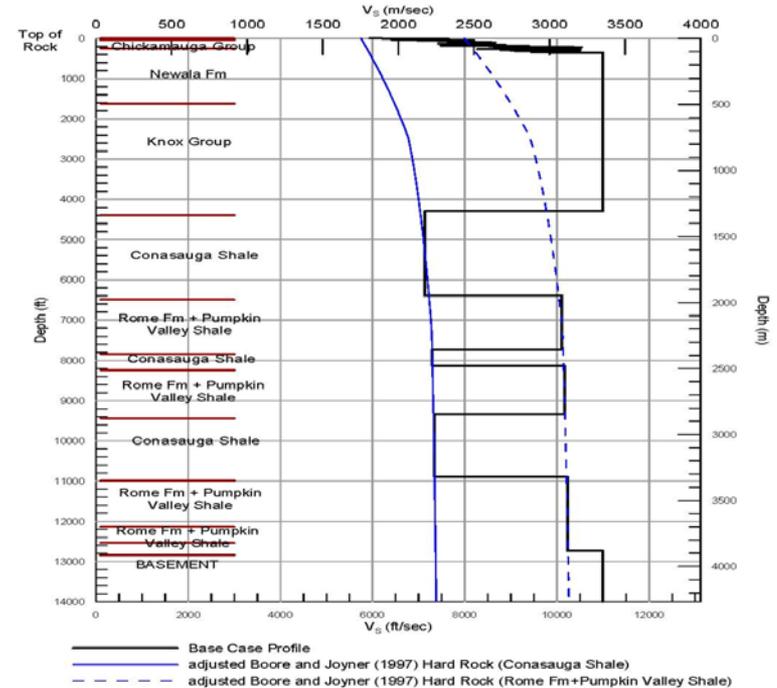


# V<sub>s</sub> Profiles for Site A and B

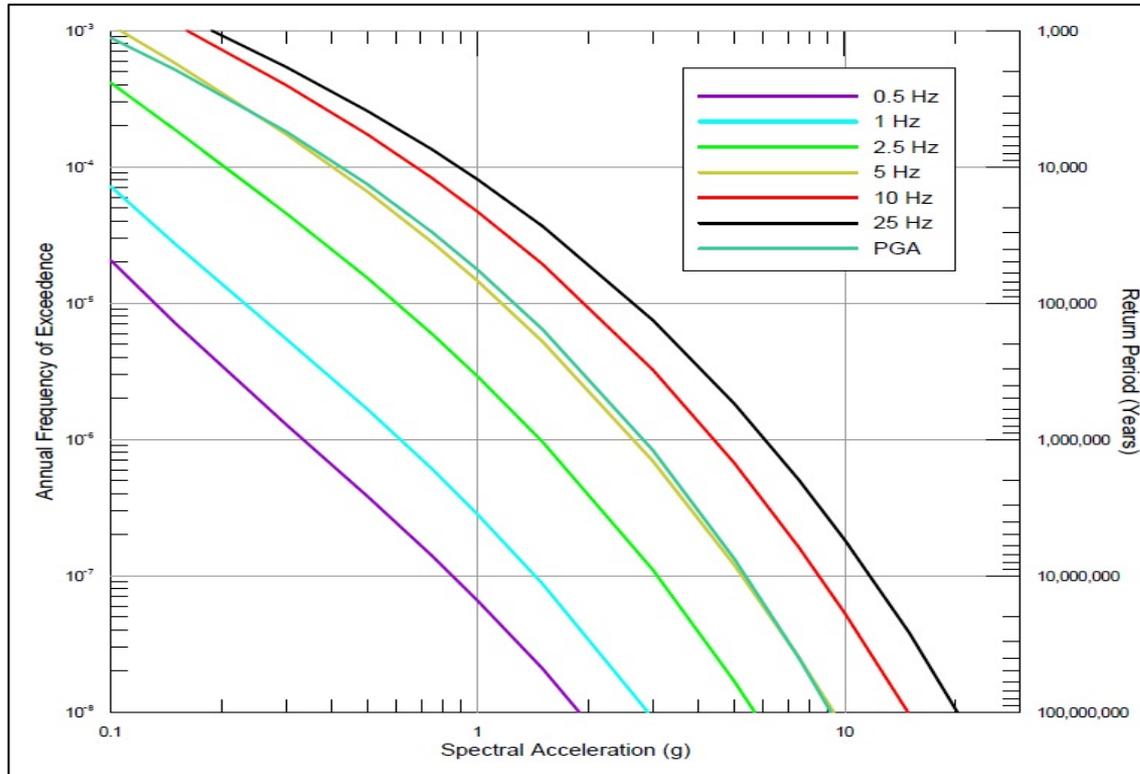
## Geologic and Velocity Profiles for Site A



## Geologic and Velocity Profiles for Site B

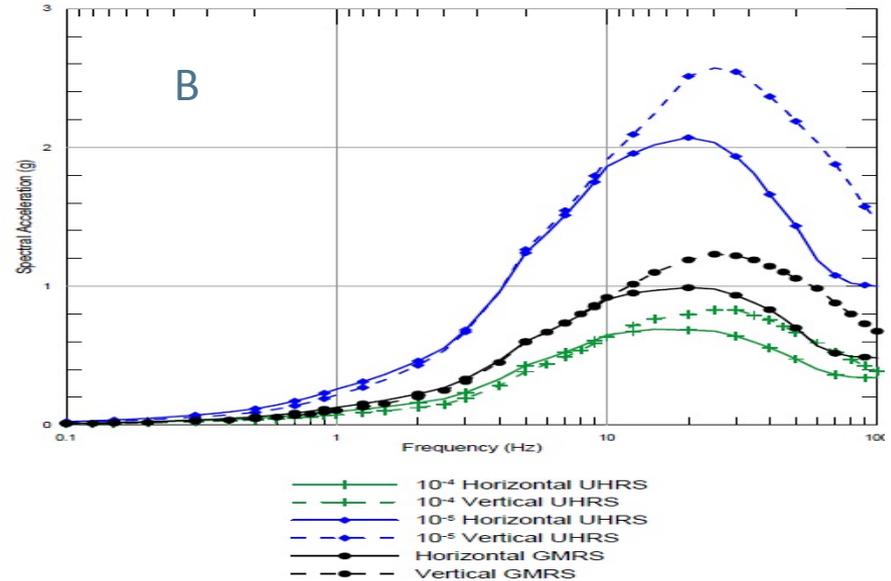
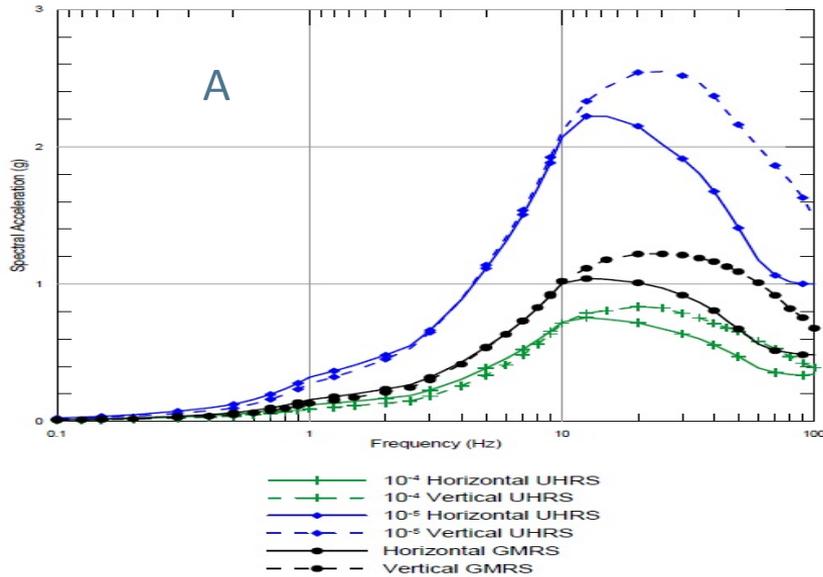


# GMRS Development – Hazard at Ground Surface

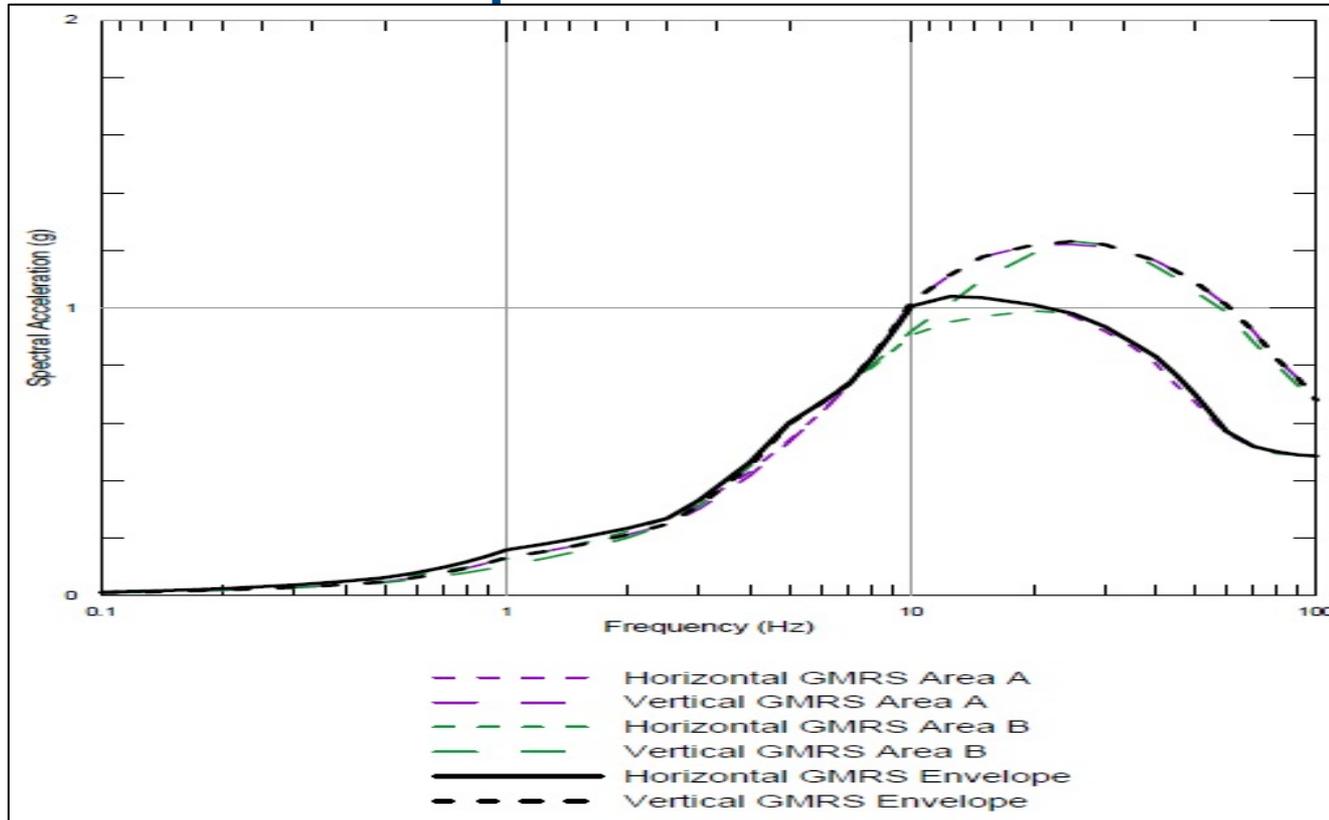


Mean Hazard at ground surface for the range of frequencies

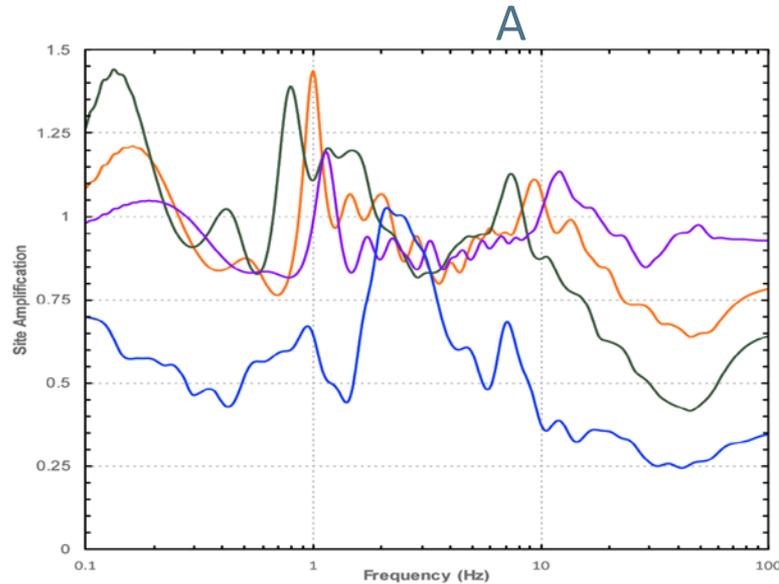
# GMRS Development Area A and B



# GMRS Envelope

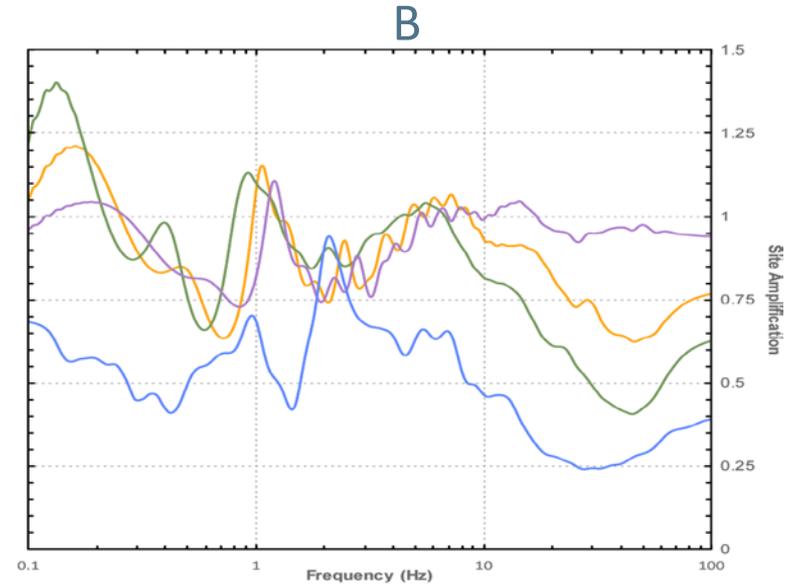


# Comparison of the 2D and the 1D RVT Amp Factors (all basecase profiles)



**LEGEND**

- Amplification, 1D, Median, Base Case Profile
- Amplification, 1D, Lower Range, Base Case Profile
- Amplification, 1D, Upper Range, Base Case Profile
- Amplification, 2D, 1 Sample, Base Case Profile (K & O smoothing)



**LEGEND**

- Amplification, 1D, Median, Base Case Profile
- Amplification, 1D, Lower Range, Base Case Profile
- Amplification, 1D, Upper Range, Base Case Profile
- Amplification, 2D, 1 Sample, Base Case Profile (K & O smoothing)

# 2D vs 1D Comparison

- The Random Vibration Theory (RVT) 1D amplification factors used to calculate the GMRS significantly exceed the 2D amplification factors (smoothed) for the single time-domain sensitivity calculation across the full frequency range except at one frequency.
- 2D effects are not expected at the site because of the high shear wave velocity ( $V_s$ ) of the underlying rock and the small impedance contrasts between rock layers.
- The use of multiple basecase velocity profiles in calculating the GMRS are expected to accommodate any potential 2D effects.

# Seismology Conclusions

- The Probabilistic Seismic Hazard Analysis performed for the Clinch River Site, specifically Sites A and B, :
  - Followed 10 CFR 100.23 and the guidance of RG 1.208
  - Represents the regional and local hazards
  - Includes the local subsurface properties
  - Evaluated the potential for 2D effects due to dipping angle

ESPA Part 2,  
SSAR Section 2.5  
Geotechnical Engineering

# SSAR Section 2.5 - Geotechnical Engineering

Information presented within these subsections 2.5.3, 2.5.4, and 2.5.5 has been developed in accordance with RG 1.208 and is intended to demonstrate compliance with 10 CFR 100.23, Geologic and Seismic Siting Criteria

- Specifically, this subsection addresses the following issues: Potential surface deformation associated with active tectonism, including any significant neotectonic features (faults). Potential surface deformation associated with non-tectonic processes such as collapse structures (karst collapse), slope failures, and anthropogenic deformation (e.g., mine collapse).
- This geological, geophysical and geotechnical information is used as a basis to evaluate the stability of subsurface materials and foundations at the CRN Site.
- The information presented in this subsection is based on the results of the site-specific subsurface investigation performed at the Clinch River Nuclear Site.

# Surface Deformation

- TVA performed geological, seismological and geophysical investigations and analysis for the region and the site
- TVA concluded in the application that the potential for tectonic deformation at the site is negligible
- Non-tectonic deformation is possible with karst conditions
- Detailed mapping of excavation walls and foundations will be performed during construction for a confirmation of the conclusions reached in the application

# Stability of Subsurface Materials and Foundations

- CRBRP subsurface investigations
- Clinch River site subsurface investigations:
  - 82 geotechnical core borings (includes 6 soil borings)
  - 3 test pits
  - 44 observation wells
  - Seismic reflection and refraction tests
  - Downhole geophysical testing in 28 borings
  - Field permeability and pumping tests
  - Groundwater level monitoring in the observation wells
  - Rock pressure meter tests in two borings
  - Laboratory testing of boring soil and rock samples
- These programs followed RG 1.132, Site Investigations for Foundations of Nuclear Power Plants

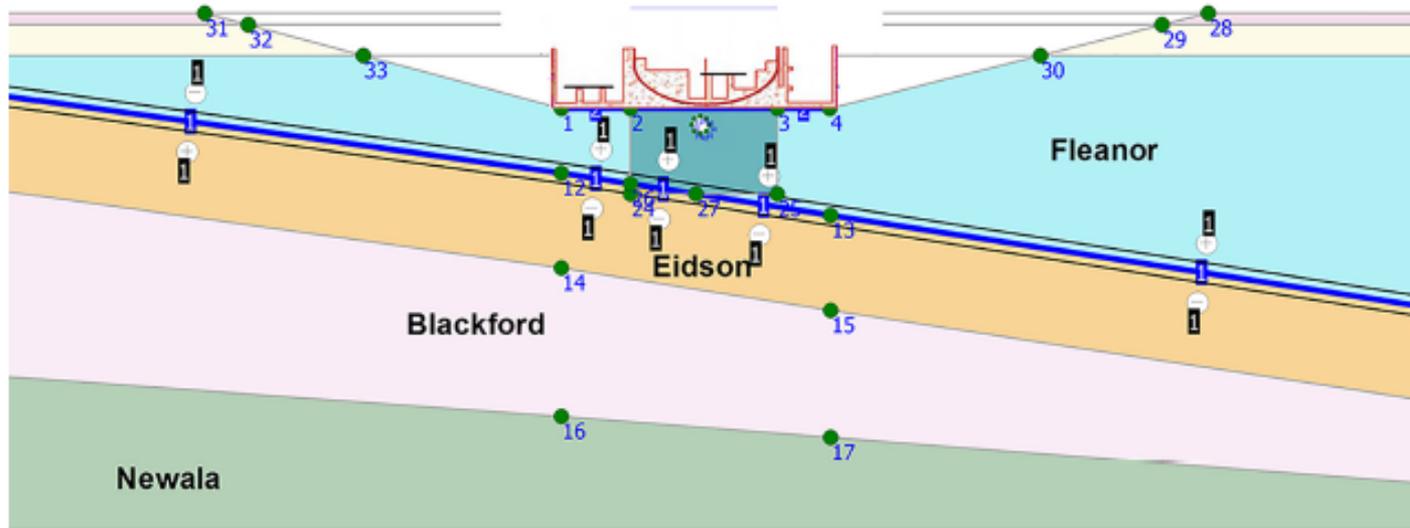
# Engineering Properties

- Ultimate Bearing Capacity
- Allowable Bearing Capacity
- Settlement and Heave Analysis
- Additional engineering properties were also developed per regulatory requirements

# Foundation Assessment Model for Karst Voids

- A PLAXIS 2D analysis was performed to demonstrate foundation acceptability
- A large PWR foundation was selected due to limited design information available for the SMRs considered in the Plant Parameter Envelope
- Finite Element Models were developed for both Site A and B
- Three embedment depths (40 ft, 90 ft and 140 ft) were evaluated
- Two different cavity depths below the foundation level were evaluated (5 ft and 30 ft) for each embedment depth
- Additionally, three locations for cavity placement were also evaluated for each of the above cases:
  - At the edge of the Nuclear Island (for tipping)
  - At the center of the Nuclear Island
  - Along the appropriate bedding plane for the Site

# PLAXIS Model Example



Note: Reference 2.5.4-59 Figure 2-29  
Cavity Diameter: 15 ft  
Embedment Depth: 90 ft  
Cavity Depth: 5 ft Below Foundation  
Cavity Location: Center of Common Basemat  
Interface Elements at Formation Contact

# Foundation Model Results

- Approximately 99 percent of the cavities observed in Site A and B borings are significantly less than 11 ft in inferred height.
- Cavity development in CRN Site areas is generally limited to the most markedly weathered zone immediately below ground surface, to depths less than 100 ft; 75 percent of reported cavities in Site A and B borings occur at depths less than 55 ft which will consequently be excavated to the embedment depths of 80-140ft. Depending on the technology selected.
- Cavity-related failure has a higher potential to occur at relatively shallow depth, less than about 30 ft. Given that foundation embedment depths are deeper than 30 ft and that the 15 ft critical cavity diameter determined by PLAXIS 2D modeling is significantly larger than the 11 ft height that bounds 99 percent of the cavities observed in CRN Site borings, Sites A and B are suitable for SMR foundation.

# Foundation Model Results (continued)

- At COLA, foundation performance will be re-evaluated on selection of a final technology, taking into account specific plant design, specific plant loads, and any potential ground improvement or grouting plans.
- Final foundation locations will also be re-evaluated using specific plant information.

# Stability of Slopes

- Given the existing topography, the natural topography and the planned finished grade, a flat site with no safety-related slope is planned in the vicinity of safety-related structures.
- The stability of slopes will be evaluated during the COLA phase once a reactor technology has been selected.

# Summary

- The efforts associated with the Pre-Application Readiness Review and the site audit and visit were very helpful in ensuring that the right level of detail and supporting information was available in the Application
- The Clinch River Site is capable from a geologic and seismic perspective for the construction of a Small Modular Reactor
- The potential geological hazard, karst, is identifiable and can be mitigated through approved regulatory processes.



## Advisory Committee on Reactor Safeguards

# Presentation to the ACRS Subcommittee

## **Safety Review of the Clinch River Nuclear (CRN) Site, Early Site Permit Application**

### **Chapter 2, Section 2.5: Geology, Seismology, and Geotechnical Engineering**

October 17, 2018

#### **Technical Reviewers from NRO/DLSE/RGS**

Gerry Stirewalt, Ph.D., P.G., C.E.G.

Jenise Thompson, M.S., PMP

David Heeszal, Ph.D.

Luisette Candelario, M.E

Weijun Wang, Ph.D., P.E.

# CRN Site Audits and Site Visit

- **July 17 & 18, 2013 - Site Audit:** Staff visited the proposed site before the ESP application was submitted to observe the initial field activities being conducted by the applicant for collecting subsurface geotechnical and geologic data (Report ML13210A3070).
- **May 8 & 9, 2017 - Site Audit:** Staff visited the proposed site to discuss information derived from the continuing geologic, seismic, geophysical, and geotechnical investigations being conducted by the applicant for characterizing the site (Report ML17223A428).
- **January 30 & 31, 2018 - Site Visit:** Staff visited the proposed site to confirm the applicant's interpretations regarding faults, shear-fracture zones, and karst features (Report ML18220A749).

# **Section 2.5.1 - Geologic Characterization Information**

# **Section 2.5.3 - Surface Deformation**

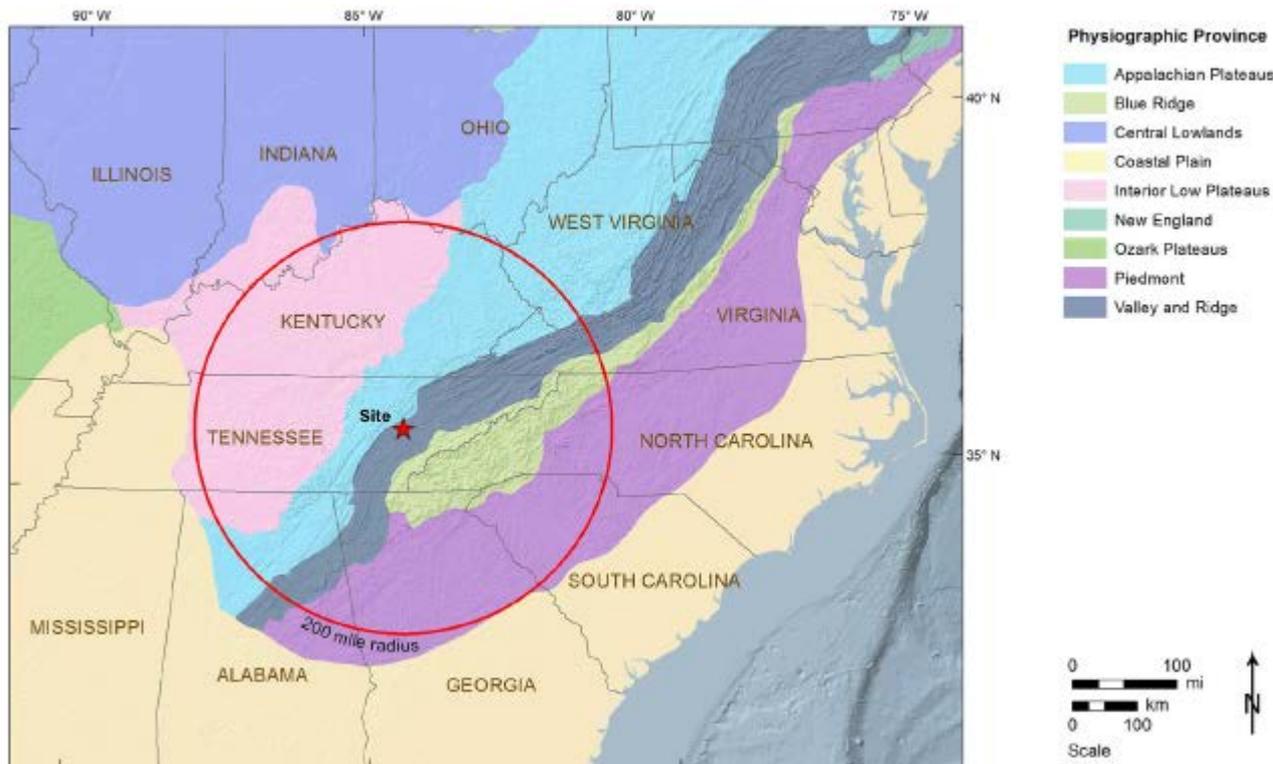
# Content of CRN Site ESP SSAR

## Section 2.5.1

### Section 2.5.1 - Geologic Characterization Information

- 2.5.1.1 - Regional Geology within 320 km (200 mi) of the site: Physiography and geomorphic processes, geologic history and tectonic evolution, stratigraphy, tectonic setting (including distribution of seismicity and stress in the eastern U.S.), and non-tectonic geologic hazards (including karst).
- 2.5.1.2 - Local Geology within 40 km (25 mi), 8 km (5 mi), and 1 km (0.6 mi) of the site: Physiography and geomorphic processes, geologic history, stratigraphy and lithology, structural geology (including faults and shear-fracture zones), geologic hazards (including karst), and site engineering geology (including potential effects of human activities).

# Physiographic Provinces in the CRN Site Region



Parallel ridges and valleys of the Valley and Ridge province developed as a result of differential weathering and erosion of folded and faulted sedimentary rock units that occur in the province.

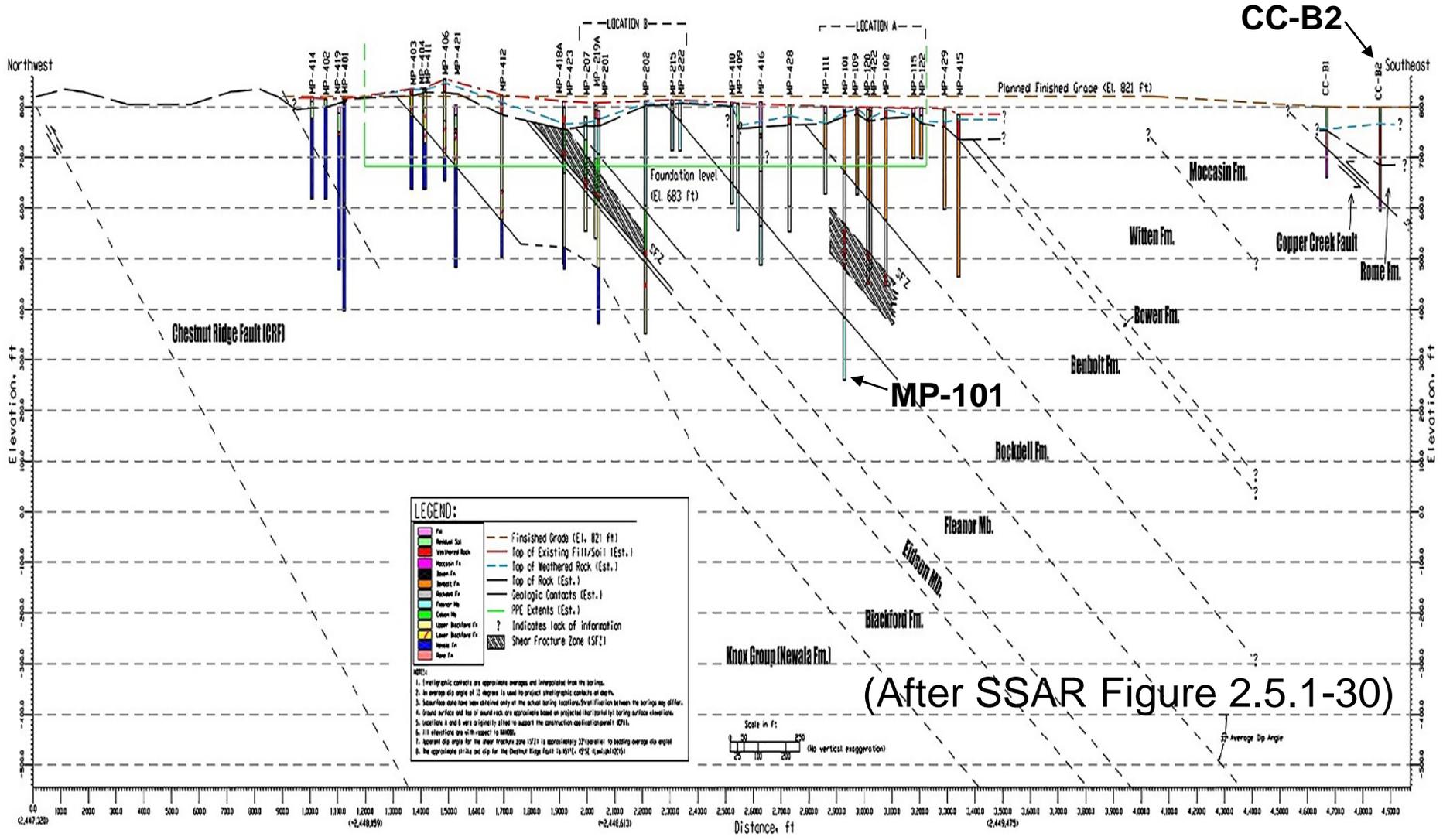
(Reproduced from SSAR Figure 2.5.1-1)

# Key Geologic Features of Interest for Section 2.5.1

## Regional Thrust Faults and Localized Shear-Fracture Zones

- Neither of these features is well-exposed at the surface at the site. Staff examined them in rock core samples provided by the applicant during the site audits and site visit. Both features are generally parallel to bedding
- Thrust faults are tectonic in origin and regional structures. Shear-fracture zones are more localized and contain features of both non-tectonic and probable tectonic origin
- Staff focused on documenting that the thrust faults and the shear-fracture zones are older than Quaternary (i.e., > 2.6 Ma in age) and, consequently, pose negligible hazard for the site.

# CRN Site Subsurface Stratigraphy, Faults, and Shear-Fracture Zones



# Carbonate Strata Examined by Staff during the 01/2018 Site Visit

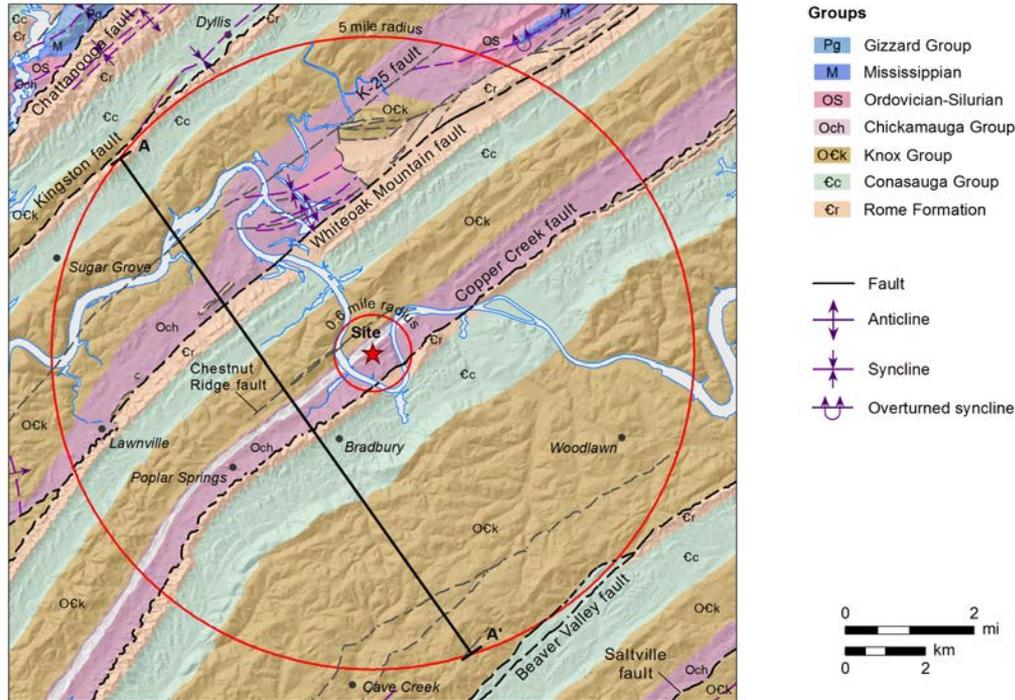


Exposure of the Fleanor Formation at the site location showing amount and direction of dip of bedding commonly seen at the CRN Site (i.e., about 33 degrees southeast).

# Thrust Faults

- Thrust faults are characteristic of the Valley and Ridge Province in which the site is located and do occur in the site area. There is no surface expression of any thrust faults in the site area.
- Although not exposed at the surface, the Copper Creek and Chestnut Ridge faults are located within 1 km (0.6 mi) of the site.
- During the site audits and site visit, staff examined the Copper Creek Fault in core from Borehole CC-B2. We will look at the subsurface expression of the fault in that borehole!

# Geologic Map Showing Locations of Thrust Faults in the Site Area



(Reproduced from SSAR Figure 2.5.1-34)

Fault gouge produced by crushing and grinding of rock units due to displacement along the Copper Creek Fault is dated at **279.5 +/- 11.3 Ma**. Reported displacement along the fault is 12-50 km (7.4-31 mi).

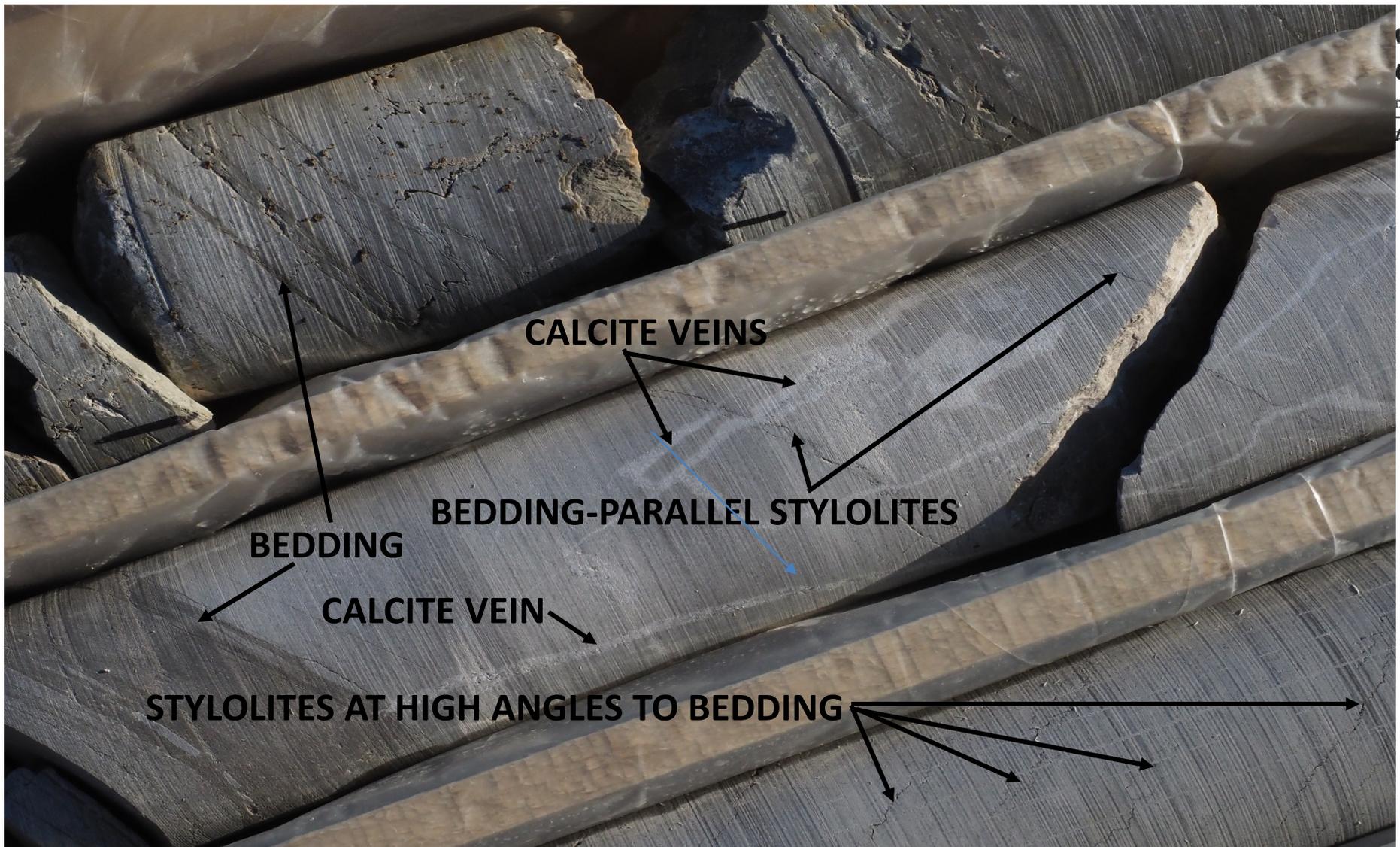
Note that the site lies between the northeast-striking, southeast-dipping Copper Creek and Whiteoak Mountain thrust faults.



Fault gouge marking the Copper Creek Fault in Borehole CC-B2. Note the clear distinction between the gouge, dated at ~280 Ma, and intact rock. (G. Stirewalt image, January 2018)

# Shear-Fracture Zones

- Shear-fracture zones at the site contain pressure solution features (stylolites) oriented parallel and perpendicular to bedding. These features tell a story about orientation of stresses that affected the shear-fracture zones.
- Non-tectonic bedding-parallel stylolites (earliest) formed during deposition and lithification of sedimentary units due to vertical overburden pressures. Bedding-perpendicular stylolites (latest) likely formed in response to near-horizontal stresses related to transport of thrust sheets (~280 Ma) and suggest tectonic overprinting.
- During the site audits and site visit, staff examined the shear-fracture zone that occurs in the Rockdell Formation in core from Borehole MP-101.



Shear-fracture zone penetrated in borehole MP-101. The stylolites must have developed at two different times because they form essentially perpendicular to the causative stress. (G. Stirewalt image, January 2018)

# Staff's Conclusions for CRN ESP SSAR Section 2.5.1

- No tectonic features with the potential for adversely affecting suitability of the site occur in the site region, site vicinity, site area or at the site location (i.e., no data suggest the presence of Quaternary tectonic features). The primary tectonic event registered in the rock units, regional thrust faults, is dated at ~280 Ma. No field evidence suggests the shear-fracture zones are younger than that event.
- Karst is the primary non-tectonic feature with the potential to adversely affect suitability of the site.
- The applicant described geologic characteristics of the site region, site vicinity, site area and site location in SSAR Section 2.5.1 in full compliance with regulatory requirements in 10 CFR 52.17(a)(1)(vi) and 10 CFR 100.23(c) and in accordance with guidance in RG 1.208.

# **Content of CRN ESP SSAR**

## **Section 2.5.3**

### **Section 2.5.3 - Surface Deformation**

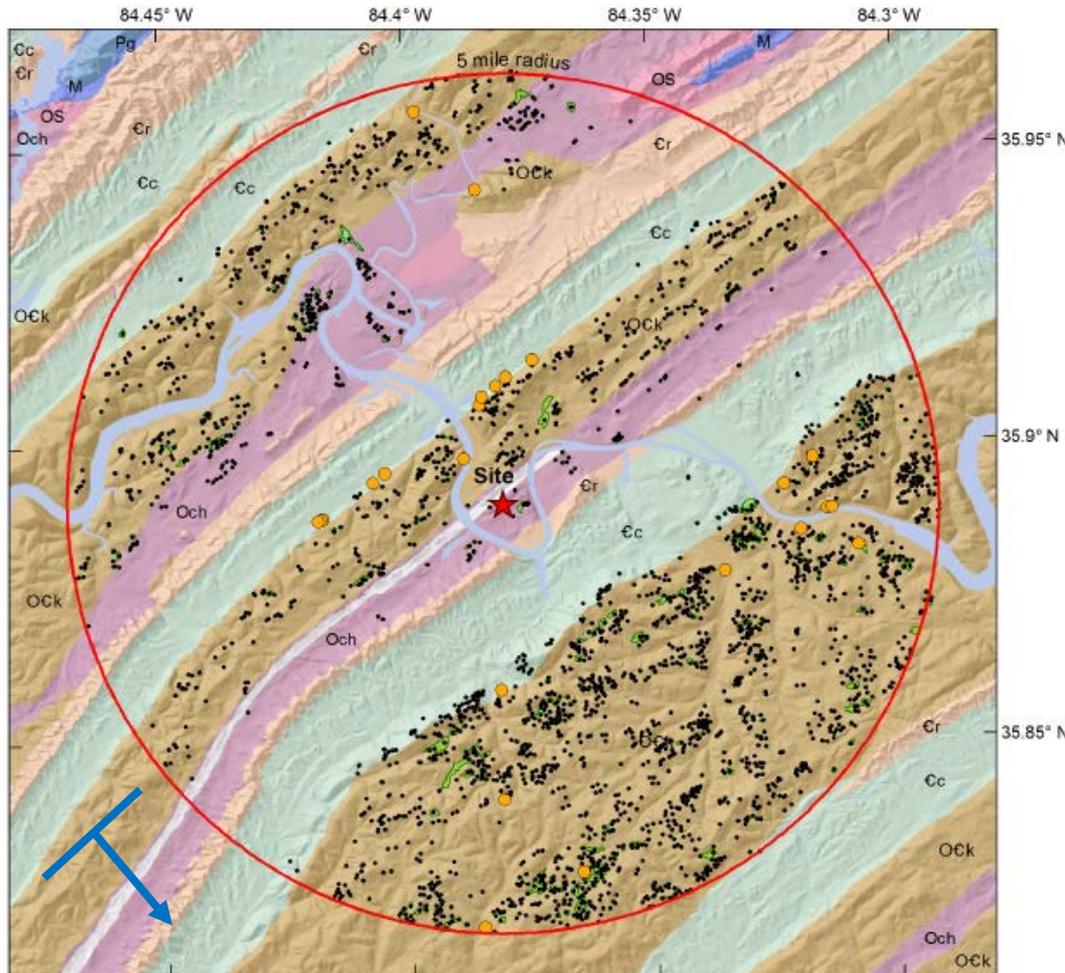
- 2.5.3.1 through 2.5.3.8 - Information related to assessment of features that might indicate a potential for tectonic (including geologic features observed in the East Tennessee Seismic Zone) and non-tectonic (i.e., specifically karst-related features) surface deformation at the site.

# Key Review Topics of Interest for Section 2.5.3

The staff reviewed the following key topics for the potential for tectonic and non-tectonic surface deformation at the CRN site.

- The relationship of potential tectonic surface deformation to observed seismicity in the East Tennessee Seismic Zone is undetermined.
- Due to carbonate rocks in the subsurface, direct observation of karst features and ongoing dissolution processes in site vicinity, and interpreted cavities in core as indicated by missing segments, karst has the potential to cause surface deformation at the CRN Site

# Distribution of mapped karst features in the CRN site area



- Groups**
- Pg Gizzard Group
  - M Mississippian
  - OS Ordovician-Silurian
  - Och Chickamauga Group
  - OCK Knox Group
  - Cc Conasauga Group
  - Cr Rome Formation
  - Cave
  - Karst depression

**Swale:** small wet depression  
**Swallet:** slightly larger depression through which water drains  
**Sinkhole:** surface depression as a result of subsurface collapse due to dissolution

# Cavities in core from borings



Interpreted cavities of varying thicknesses recorded in numerous boreholes.

# Pinnacle and cutter surficial karst features



Dissolution features along joints and bedding planes resulting in cavities in the exposed rock

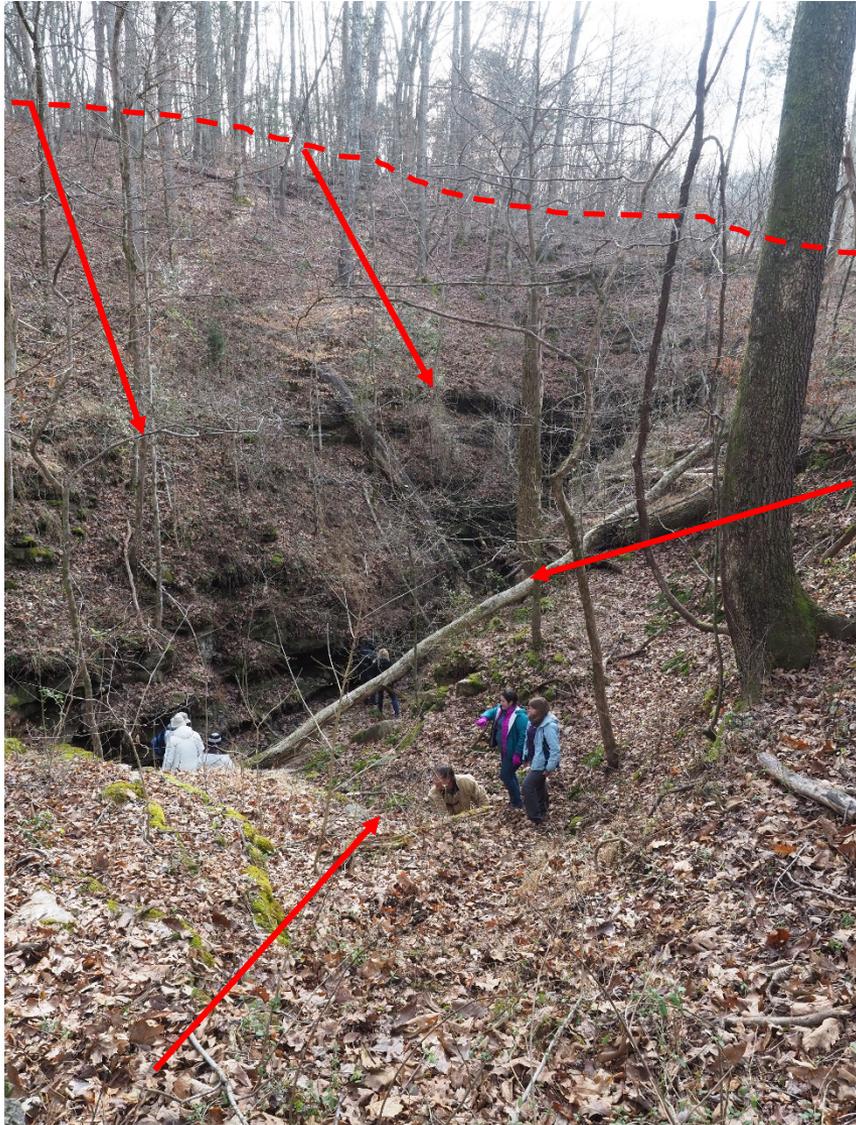


# Swales, swallets, and sinkholes as surficial karst features



Sinkhole within the site area with steep slope and ponded water

# Entrance to Copper Ridge Cave



Copper Ridge Cave is the largest cave the staff visited in the Clinch River site area

Drainage flows into the cave entrance from the surrounding depression with dissolution along joints and bedding planes, including a 90-degree turn



October 17, 2018

# Geologic Mapping Permit Condition

In SSAR Section 2.5.1.2.6.10, the applicant acknowledged the need to perform detailed geologic mapping for documenting the presence or absence of karst features, faults, or shear-fracture zones in plant foundation materials. To address this need, the staff identified Permit Condition 1 in SER Section 2.5.3.5 as stated below:

- The applicant for a combined license (COL) or a construction permit (CP) that references this early site permit (ESP) shall perform detailed geologic mapping of excavations for safety-related engineered structures; examine and evaluate geologic features discovered in those excavations; and notify the Director of the Office of New Reactors, or the Director's designee, once excavations for safety-related structures are open for examination by NRC staff.

# Staff's Conclusions for CRN ESP SSAR Section 2.5.3

- Negligible potential exists for tectonic surface deformation that could adversely affect suitability of the CRN Site. Karst is the primary potential hazard for non-tectonic surface deformation at the CRN Site.
- The applicant described information related to assessment of features that might have a potential for producing tectonic and non-tectonic surface deformation at the site in SSAR Section 2.5.3 in full compliance with regulatory requirements in 10 CFR 52.17(a)(1)(vi) and 10 CFR 100.23(d) and in accordance with guidance in RG 1.208.

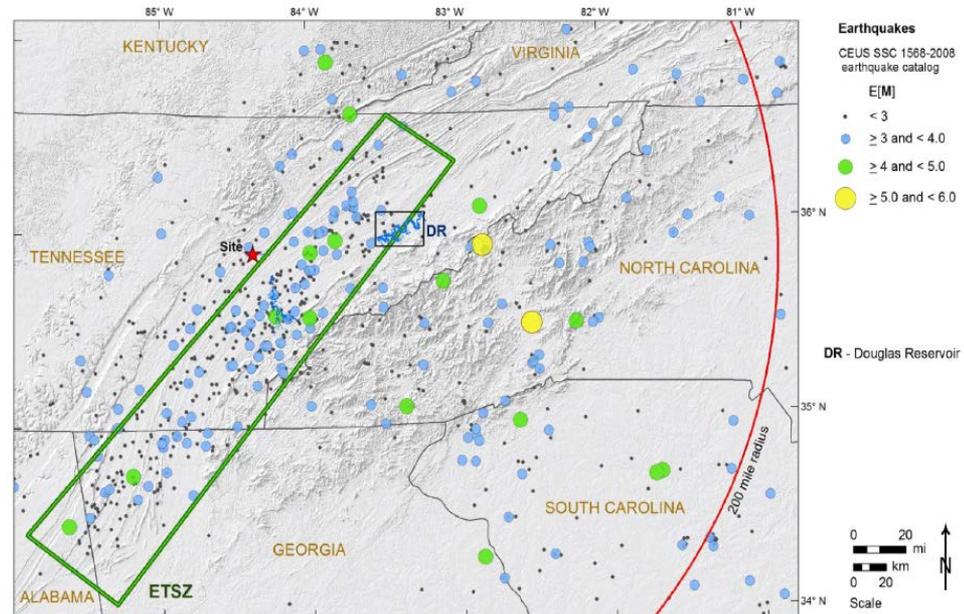
# Section 2.5.2 – Vibratory Ground Motion

## Key Review Topics of Interest for Section 2.5.2

- Treatment of Eastern Tennessee Seismic Zone
- Approach to developing site-response analysis
- Development of 2-D site response analysis

# Treatment of Eastern Tennessee Seismic Zone (ETSZ)

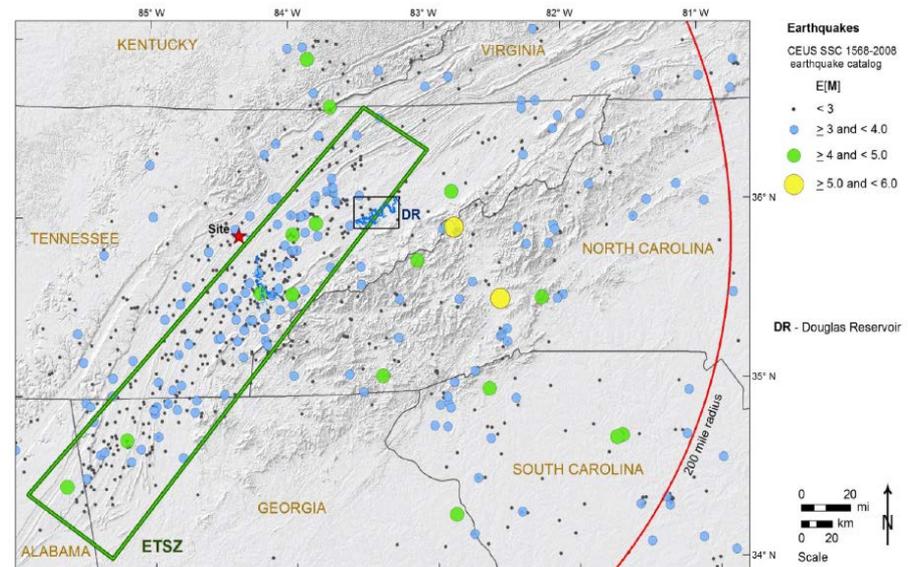
- ETSZ is region of elevated seismicity rates.
  - Small magnitude earthquakes
  - Occur within basement rocks below sedimentary section
- Included in NUREG-2115 within seismotectonic and  $M_{\max}$  source zones
  - Sensitivity studies done during study to ensure that source zones adequately capture seismicity in ETSZ
- Recent geologic studies interpret potential for larger ( $M \geq 6.5$ ) earthquakes



SSAR Figure 2.5.2-26

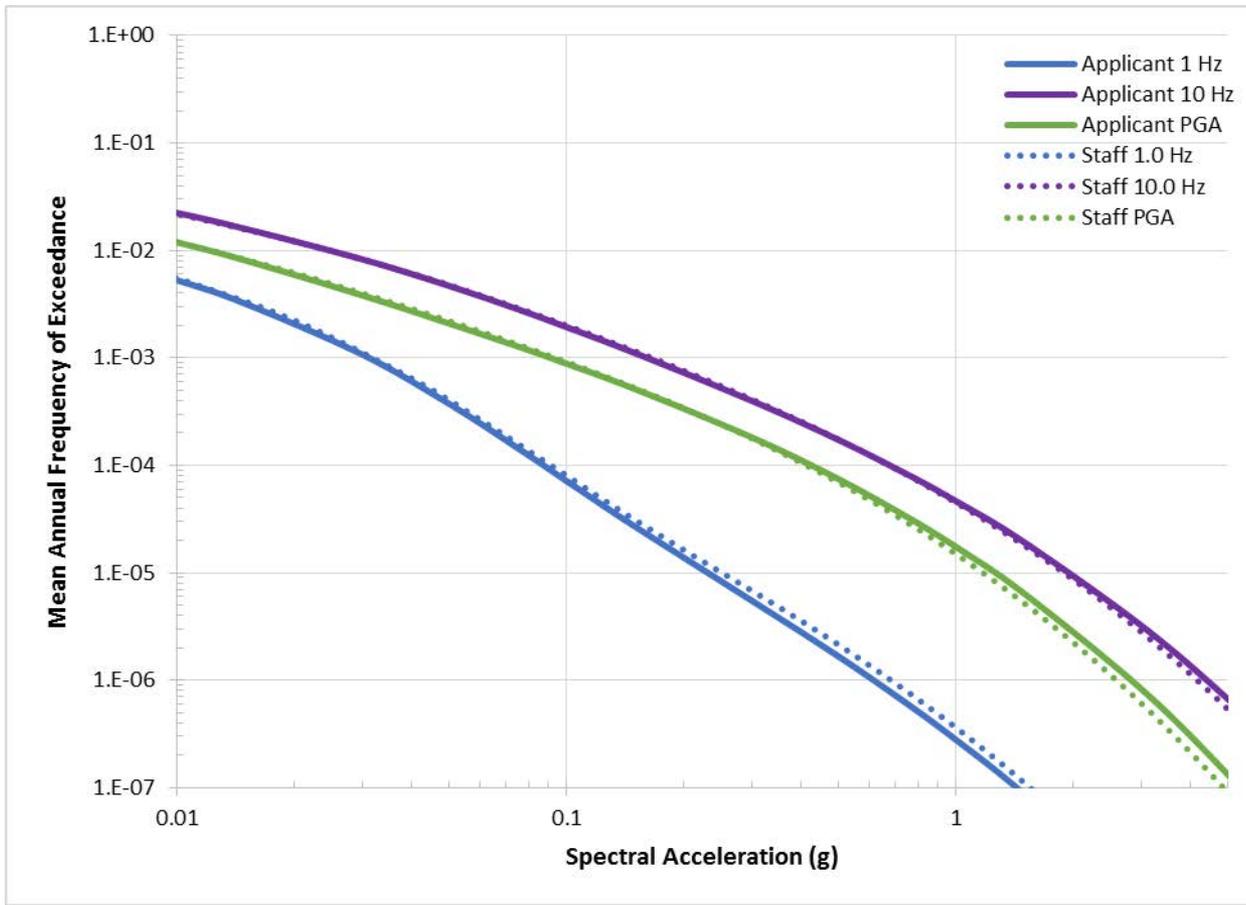
# Treatment of Eastern Tennessee Seismic Zone

- Applicant performed two sensitivity studies following SSHAC guidance for Level II study
  - Evaluate  $M_{max}$
  - Evaluate Magnitude-Frequency relations
- $M_{max}$  values in NUREG-2115 encompass proposed  $M_{max}$  developed using new data
- Recurrence of large magnitude events in NUREG-2115 consistent with proposed values in new geologic studies
- Staff concludes that NUREG-2115 adequately captures current understanding of seismic hazard in the Eastern Tennessee Seismic Zone



SSAR Figure 2.5.2-26

# Probabilistic Seismic Hazard Analysis (PSHA) Confirmatory Calculations

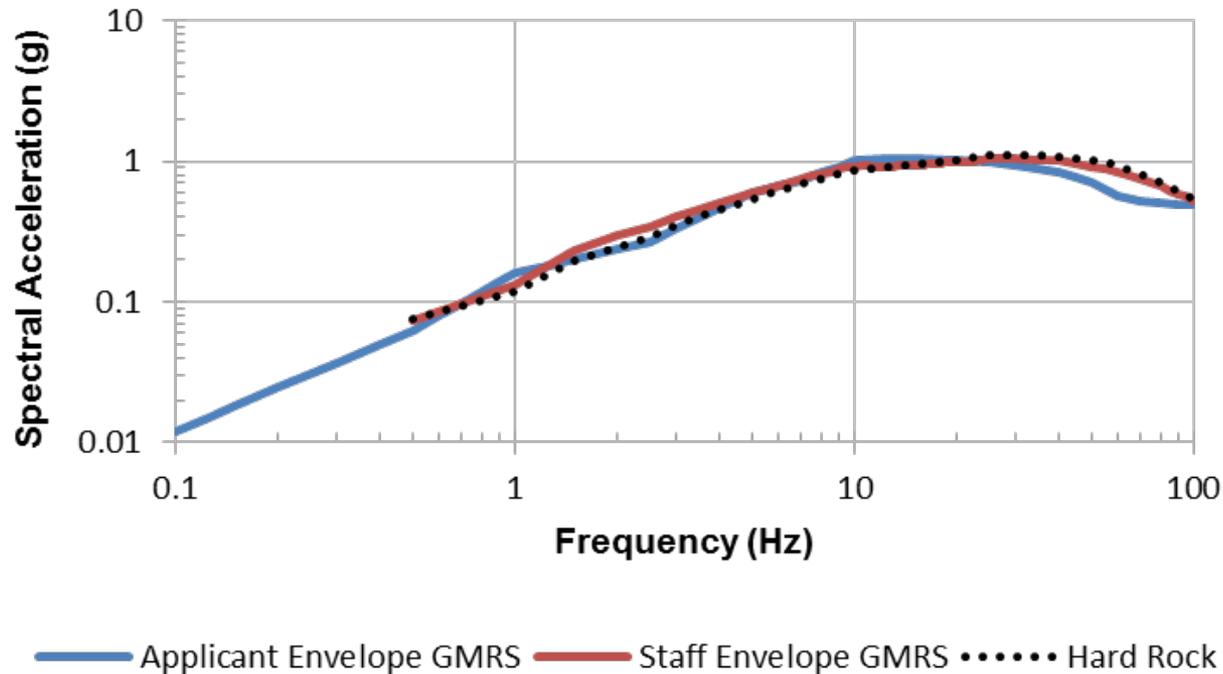


Staff independently calculated seismic hazard curves at the Clinch River site. Comparisons show that the seismic hazard curves are in good agreement at the annual frequency of exceedances of interest:  $10^{-4}$ ,  $10^{-5}$ , and  $10^{-6}$ .

# Approach to Site Response Inputs

- Clinch River site has significantly dipping rock layers
  - Approximately 30 degrees
- High seismic velocities
  - 5,000 to >10,000 fps
- Applicant developed site response inputs using
  - 3 profiles for each location
  - Log mean seismic velocity as function of depth as base case
  - Upper and lower case using log standard deviation
  - Effect of smearing geologic units together
- Staff requested that applicant explain how the use of multiple base cases accurately accounts for dip across site
- Applicant responded the smearing of units is appropriate because mean and range of values at a specific depth is maintained, implicitly accounting for stratigraphic variations.
- Staff performed confirmatory site response considering dip explicitly (i.e. upsection; middle; and downsection profiles)
- Staff truncated profiles at the top of the Knox Group due to thickness and velocity of layer
- Staff's results are consistent with applicant's

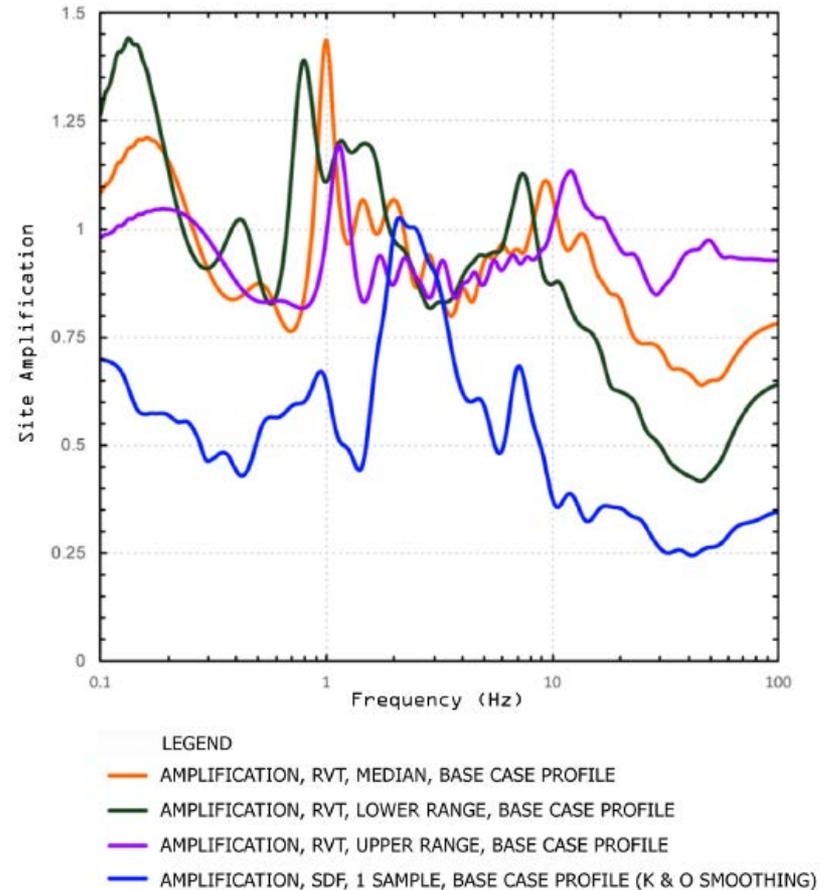
# Ground Motion Response Spectrum (GMRS) Confirmatory Analysis



Staff developed alternative input parameters for site response analysis. Staff independently calculated site response and developed a site ground motion response spectrum (GMRS) based on its preferred inputs. Site GMRS developed by staff is consistent with that developed by the applicant.

# 2-D Site Response

- Clinch River site has significantly dipping (>30 degrees) rock layers in subsurface
- RG 1.208 states that for sites with complicated subsurface structure, a multi-dimensional approach to site response may be necessary
- Applicant developed a 2-D site response analysis and compared amplification functions to 1-D results developed using 2-D inputs
- Staff requested that applicant compare 2-D results to 1-D results used in developing GMRS
- Applicant's 2-D results compare favorably with 1-D results, satisfying staff's concern



SSAR Figure 2.5.2-108

# Staff Conclusions - Section 2.5.2

- The applicant provided a thorough characterization of the seismic sources surrounding the site, as required by 10 CFR 100.23
- The applicant adequately addressed the uncertainties inherent in the characterization of these seismic sources through a PSHA, and its PSHA follows the guidance provided in RG 1.208
- Applicant's GMRS adequately represents the regional and local seismic hazards and accurately includes the effects of the local site subsurface properties

## Section 2.5.4 - Stability of Subsurface Materials and Foundations

# Summary of CRN ESP SSAR

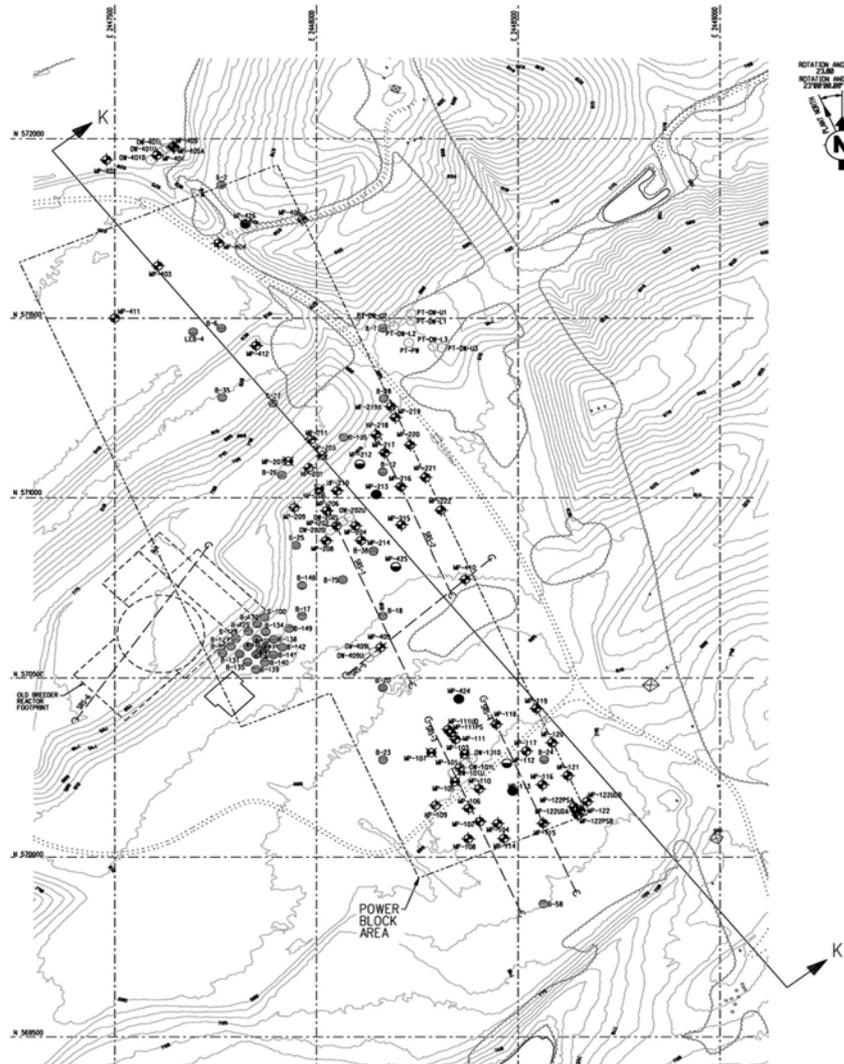
## Section 2.5.4

- SSAR Section 2.5.4 presents the engineering properties of subsurface materials, and evaluation of stability of subsurface materials and foundations at the CRN Site.
- SER Section 2.5.4 includes:
  - ♦ The staff's evaluation of engineering properties of subsurface materials; foundation interfaces; geophysical surveys; excavation and backfill; groundwater conditions; response of soil and rock dynamic loading; liquefaction potential; stability of foundations
  - ♦ 16 COL Action Items
  - ♦ 1 Permit Condition

# Plant Parameter Envelope

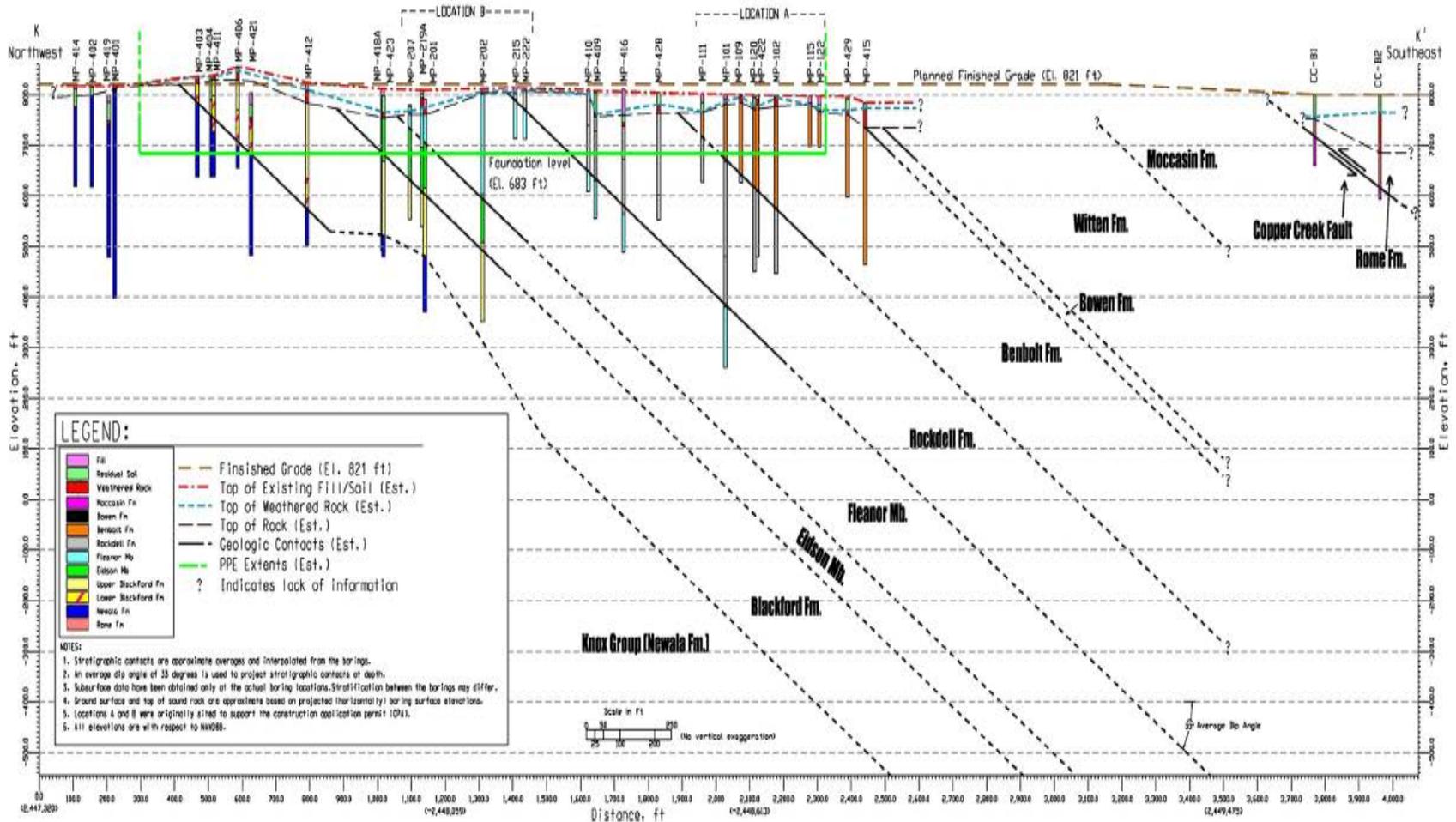
- In order to provide sufficient geotechnical information at the site without having a specific design, the applicant provided a surrogate design in its application. The surrogate plant approach covers a set of bounding parameters: the plant parameter envelope (PPE).
- Under the PPE approach, the resulting ESP will be applicable for a range of reactor designs if their relevant design parameters fall into the PPE.

# CRN ESP Site Exploration



**Boring Location Plan at the CRN Site**  
(Reproduced from SSAR Figure 2.5.4.)

# Site Stratigraphy



**Geotechnical Cross-Section of the Stratigraphy of the Power Block Area (Reproduced from SSAR Figure 2.5.4-1)**

# Key Review Topics of Interest for Section 2.5.4

## Assessment of the Effects of Underground Voids on Foundation Stability

- Karst exists at the CRN Site and the underground voids may adversely affect the foundation stability.
- The applicant's site investigation for the ESP application provided preliminary information on void distribution and size.
- The staff reviewed the applicant's PLAXIS 2-D Finite Element (FE) model that assessed the effects of postulated underground voids on foundation stability at the CRN Site.
- The staff concludes that the applicant conducted an appropriate preliminary evaluation to determine potential karstic cavity impacts on the foundations.
- This analysis should be site location and technology specific, therefore the staff identified COL Action Item 2.5-2 which establishes that a future applicant referencing this ESP should reevaluate the potential of karstic cavity impacts, within the zone of influence of the foundation under all design loading conditions, on foundation stabilities for safety-related structures.

# Key Review Topics of Interest for Section 2.5.4

## Foundation Stability Analysis for CRN Site with Inclined Strata

- The CRN Site consists of multiple inclined layers of various rock formations with possible weakened interfaces between the formations.
- The staff reviewed the applicant's multiple traditional methods and Finite Element (FE) methods used to assess foundation stability at the CRN Site.
- The staff concludes that the traditional methods results are in good agreement with those obtained from the finite element model and that the selected PPE values related to the site stability analyses are appropriate.
- The staff identified COL Action Items 2.5-12 through 2.5-14 for the COL or CP applicant to address the foundation stability of the site once a reactor technology and the specific location and extent of Seismic Category 1 structures is identified.

# COL Action Items

COL Action Items 2.5-1 through 2.5-16 pertain to reactor technology and site location specific actions that need to be addressed by the COL or CP applicant when referencing this ESP. Those COL Action Items are related to the following site characteristics:

- Site Geologic Features
- Properties of Subsurface materials
- Excavation and backfill
- Groundwater condition
- Static and dynamic stability
- Design criteria
- Techniques to Improve Subsurface Conditions

# Permit Condition

The site investigation data shows that the discontinuities, shear fractures zones, and weathered fracture zones typically exist within weathered rock in the uppermost 30.5 m (100 ft), where most of the cavities are encountered at the CRN Site. The rock mass characterization described in the application is mainly for bedrock stratigraphic units below 24.4 m (80 ft) (El. 225.9 m (741 ft) NAVD88), the staff identified **Permit Condition 2** in SER Section 2.5.4.5 as stated below:

An applicant for a combined license (COL) or a construction permit (CP) that references this early site permit shall remove the material above El. 225.9 m (741 ft) NAVD 88 in areas where safety-related structures will be located, to minimize the adverse effects of discontinuities, weathered and shear-fracture zones, and karst features on the stability of subsurface materials and foundations. The applicant shall also perform additional geotechnical investigations, in accordance with RG 1.132, at the excavation level to identify any potential geologic features that may adversely impact the stability of subsurface materials and foundations.

# Staff Conclusions – Section 2.5.4

- The applicant adequately determined the site-specific engineering properties of the subsurface materials underlying the CRN Site, and conducted sufficient evaluation of the stability of subsurface materials and foundations, based on the results of field and laboratory tests and the state of the art methodology, and in accordance with RG 1.132, RG 1.138, and RG 1.198.
- The staff concludes that the applicant meets the requirements of 10 CFR Part 52.17(a)(1)(vi) and 10 CFR Part 100.23(c) for this ESP application regarding the stability of subsurface materials and foundations.

## Section 2.5.5 - Stability of Slopes

## Section 2.5.5- Stability of Slopes

- The NRC staff reviewed SSAR Section 2.5.5, which provides general description of the site related to slope stability analysis.
- There are no existing slopes on the site at this time, either natural or manmade, that could affect the stability of the site.
- The applicant deferred the actual slope stability analysis to the COL or CP application.
- To address the need for future slope stability analyses, the staff identified COL Action Item 2.5-17 as stated below:

An applicant for a COL or CP application that references this early site permit should perform a slope stability analysis of any safety-related slopes, including dams and dikes, consistent with the selected reactor technology.

# Staff Conclusions – Section 2.5.5

- The applicant provided necessary information on site topography and geologic characteristics, and adequately described the slope characteristics at the site.
- The staff concludes that the SSAR Section 2.5.5 is adequate and acceptable because it meets applicable requirements of 10 CFR Part 50, Appendix S, 10 CFR Part 52.17(a)(1)(vi) and 10 CFR Part 100.23.