Attachment 18
NRC3-10-0006

Response to RAI Letter No. 17
(eRAI Tracking No. 4007)

RAI Question No. 02.05.01-30

02.05.01-30

FSAR Section 2.5.1.2.5 discusses the probability of karst features in the Fermi site location with respect to existing karst features in similar rock found in northwestern Ohio. The FSAR states that the probability for karst in the Fermi site location is low based on the fact that the Bass Islands Group is covered by more than 6m (20 ft) of till and lacustrine deposits. The FSAR references conclusions made by Davies et al in FSAR Reference 2.5.1-388 and also states that karst features within Silurian-age units in northwestern Ohio are "large enough to cause engineering problems." Please provide additional justification for making the conclusion that the probability of karst in the Fermi site location is low and include a description of how the overlying sediments contribute to the formation of karst features at depth and any additional supporting information or references used in making the conclusion that the probability of karst is low due to the thickness of overlying deposits.

Response

Fermi 3 FSAR Section 2.5.1.1.5 states the following:

> Karst related problems in the (320-km [200-mi] radius) site region are associated with fissures, tubes and caves that are generally less than 300-m (1000-ft) long developed in flat lying carbonate rocks (Figure 2.5.1-228; Reference 2.5.1-388). In northwestern Ohio and adjacent Indiana and southeastern Michigan, karst occurs in Silurian-age limestones and dolomites. In northwestern Ohio areas where the carbonate rocks are covered by less than 6 m (20 ft) of glacial deposits have karst features large enough to cause engineering problems. Some caves with generally less than 1,000 ft of passages are present in northwestern Ohio. Evaporative karst (karst in halite or gypsum deposits) occurs in the central portion of the Michigan basin. (Reference 2.5.1-388)

Fermi 3 FSAR Section 2.5.1.2.5 states the following:

> The National Atlas Map showing the Engineering Aspects of Karst indicates the site vicinity, site area, and site location are in an area that can have fissures, tubes, and caves up to 300-m (1,000-ft) long below at least 3 m (10 ft) of noncarbonate overburden (Figure 2.5.1-228) (Reference 2.5.1-388). Davies et al. (Reference 2.5.1-388) emphasize that active karst in adjacent areas of northwestern Ohio occurs in areas where the noncarbonate overburden is less than 6-m (20-ft) thick. In the 1-km (0.6-mi) radius site location, the combined thickness of the till and lacustrine deposits is over 6 m (20 ft), indicating that the probability for karst is low.

The statement at the end of the paragraph from FSAR Section 2.5.1.2.5 repeated above is applying the observations from FSAR Reference 2.5.1-388 to the conditions present within the 1-km (0.6-mi) radius site location. The exact text from FSAR Reference 2.5.1-388 referenced in FSAR Section 2.5.1.2.5 reads as follows:

> "The Silurian limestones and dolomites (Niagaran) of northwestern Ohio and adjacent Indiana are buried beneath glacial drift. Only in northwestern Ohio, where the glacial deposits are less than 20 ft (6 m) thick, are there karst features large enough to cause problems in engineering geology."

Regarding the impact of glacial activities on karst, FSAR Reference 2.5.1-388 states the following:

> "Caves and related solution features are common in most carbonate and gypsum terrains in the United States, except in the area formerly covered by Pleistocene ice sheets (Davies and LeGrand, 1972). The southward advance of these ice sheets covered New England, New York, northeastern and northwestern Pennsylvania, most of the States bordering the Great Lakes, and much of the area north of the Missouri River. Karst features in the formerly glaciated area are covered by glacial drift, and most caves and fissure openings have been eroded away or filled. The caves and open fissures that remain generally have less than 1,000 ft (300 m) each of passages large enough to be traversed by humans."

The information presented in Reference 2.5.1-388 indicates that karst formation is less likely in areas that have been formerly covered by ice sheets that are therefore covered by glacial drift.

Additional information that supports the justification for making the conclusion that the probability of karst at the Fermi 3 site location is low is as follows:

- The subsurface investigation at the Fermi 3 site did not identify large voids in the Bass Islands and Salina group bedrock. The largest voids encountered during the Fermi 3 subsurface investigation were up to 0.46 m (1.5 feet) in Salina Group Unit F (FSAR Section 2.5.1.2.3.1.1). FSAR Section 2.5.1.2.3.1 provides the following discussion regarding core loss, voids, cavities, and tool drops during the borings for the subsurface investigation at Fermi 3 for Salina Unit E, Salina Unit F, and the Bass Islands Group are as follows:

  > Salina Unit E: "An analysis of boring logs was conducted regarding core loss, and voids, cavities, and tool drops that occurred during the Fermi 3 subsurface investigation. The analysis included comparing available boring logs, photos of the core recovered, caliper and gamma logs, and downhole televiewer logs to determine an explanation of conditions that were encountered. The analysis indicated that two cavities were encountered in the layers of vuggy dolomite and limestone near the top of the unit. The largest cavity was 0.3 m (1 ft) thick vertically, and shows on the optical televiewer log as a possible opening along bedding that appeared to be clay filled. The other cavity was a 0.06 m (0.2 ft) opening along bedding that showed evidence of water movement. The depths of the vuggy dolomite and limestone varied from 75 to 78 m (245 to 255 ft) below ground surface. Most of the vugs were clay filled. Core loss was determined to be due to either soft weathered rock that washed away during drilling, or when

harder layers became stuck in the core barrel and ground the softer or fractured rock."

Salina Unit F: "An analysis of boring logs was conducted regarding core loss, voids, cavities, and tool drops that occurred during drilling of Unit F. The approach used was the same for Unit E. Two cavities were encountered in the layers of vuggy dolomite and limestone near the top of the Salina Group Unit F. The optical televiewer images of one of the voids indicated that the northern wall of the boring was open to a depth of about 0.33-m (13 in) and had a vertical height of about 0.46 m (1.5 ft). The other void was reported as a drilling tool drop of about 0.06 m (2.5 in) and optical televiewer logs were not preformed on this boring. Based upon the core photos, the possible void is a soft zone along bedding. Other core loses were determined to be due to soft weathered rock that washed away during drilling, poorly indurated sediments that washed away, or when harder layers became stuck in the core barrel and ground the softer or fractured rock. The origin of the poorly indurated sediments is unclear, but possible explanations are provided in Subsection 2.5.1.2.3.1.2.1."

Bass Islands Group: "An analysis of boring logs was conducted regarding core loss, voids, cavities, and tool drops that were encountered during drilling in the Bass Islands Group. The analysis approach was the same as used for Salina Group Units E and F. The analysis indicated that cavities or voids were limited to a depth of 23.8 m (78 ft) below ground surface. The cavities or voids encountered were narrow, generally 3 cm (0.1 ft) along fractures. The open fractures are most likely formed during the unloading of the rock after the glaciers retreated. Some of the voids were filled with clay that appeared to be transported into the fracture. Core losses appear to be caused by fractured rock blocking off the core barrel and grinding away the rock. Some of the core loss was due to weathered clayey or shaley seams being washed away during drilling."

- During November and December 2009, Denniston Quarry near Monroe, Michigan was visited. No large voids or open caves were observed: however, caves completely filled with breccia, stratified sediments, and poorly indurated rocks were observed in the quarry walls. FSAR Section 2.5.1.2.3.1.2.1 discussed observations from the subsurface investigation at the Fermi 3 site regarding breccia and poorly indurated sediments identified in core recovered from the borings as repeated here:

  "The Fermi 3 subsurface investigation encountered brecciated dolomite, and breccia within Salina Group Unit F and the Bass Islands Group. Poorly indurated sediments were encountered within Salina Group Unit F and at the top of Salina Group Unit E.

  A breccia is a rock comprised of angular gravel and larger clasts (fragments). The clasts can be loose, in a matrix of finer-grained materials, or cemented or partially cemented with calcite, dolomite, quartz or other minerals. A brecciated dolomite is a dolomite that has been fractured, but the asperities (openings normal to the fracture plane) of the fractures are relatively small. The fracture asperities can be unfilled, filled with fine-grained material that washed in or filled with minerals that precipitated from groundwater.

Indurated sediments are those that have hardened into rock. Poorly indurated sediments are weak sediments that have not completely hardened.

Breccias were encountered in the Bass Islands Group and in Salina Group Unit F during the Fermi 3 subsurface investigation. In the Bass Islands Group, the breccias were comprised of clasts of dolomite from the Bass Islands Group with a matrix consisting of indurated fine-grained fragments of Bass Islands Group sediments or cemented with precipitated calcite and anhydrite. The breccias in the Bass Islands Group were healed and younger fractures split clasts and matrix within the breccias.

In Salina Group Unit F the breccias are comprised of clasts of dolomite, limestone, shale, and claystone from the Salina Group in a matrix of claystone or mineral precipitates. The breccias in the Salina Group Unit F range from indurated to poorly indurated. Typically, the matrix of the poorly indurated breccias consists of weak to extremely weak claystone with properties comparable to soil. Percent recoveries from core runs were low in borings in the Salina Group Unit F and the upper portion of Unit E.

Optical televiewer and natural gamma logs indicated that sediments were present in Units E and F. Caliper logs within low recovery zones have measured increased borehole diameters, indicating that the sides of the borings probably collapsed during and after drilling. The materials visible in the optical televiewer logs within the enlarged portions of Salina Group Units E and F appear to be shales, claystones, and sand layers with thin beds of dolomite. In several borings loose clays and sands were recovered, and these were probably poorly indurated material that was weakened during drilling."

- No halite (salt) beds and minimal anhydrite beds were encountered during the subsurface investigation or are reported in the site vicinity. Regarding the halite, the following is indicated in FSAR Section 2.5.1.2.3.1.1:

  "In the center of the Michigan basin the Salina Group contains economic halite (salt) beds. The site area however, is located in a region with no halite in the Salina and Bass Islands Groups (Reference 2.5.1-393). The Fermi 3 subsurface investigation and the site investigation for Fermi 2 (Reference 2.5.1-221) did not encounter any halite beds."

Regarding halite and anhydrite, the following is indicated in FSAR Section 2.5.1.2.5:

> "Subsection 2.5.1.2.3.1.2.1 discussed breccias and soft zones and potential explanations for their presence at the site. The formation of paleokarst was indicated as a possible reason for breccias and soft zones, with paleokarst episodes related to the dissolution of evaporate minerals, primarily halite and gypsum (Reference 2.5.1-392; Reference 2.5.1-397). Since no halite exists at the site and only minor amounts (nodule fillings and beds less than 3 cm [0.1 ft]) of gypsum and anhydrite exist in the Bass Islands Group and in Salina Group Unit F, the potential for modern evaporite karst is small."

- The lack of sinkholes within the 8-km (5-mi) radius site area is also an indication of a lack of karst activity in the area of Fermi 3. FSAR Section 2.5.1.2.5 states the following:

> "Several sinkholes have been mapped in southwestern and southern Monroe County (Bedford, Whiteford, and Ida Townships). At least seven sinkholes are located in Devonian-age Detroit River group, which is outside the 8-km (5-mi) radius site area. Two sinkholes are in the Bass Islands Group. No sinkholes are in the (8-km [5-mi] radius) site area. (Reference 2.5.1-419; Reference 2.5.1-389; Reference 2.5.1-420)"

The information obtained from literature, and the findings during the subsurface investigation and the inspection of the Denniston Quarry support the contention that there is currently no evidence of karst activity at or in the area of the Fermi 3 site, and that the potential for modern karst is small.

Proposed COLA Revision

A proposed markup to revise FSAR Section 2.5.1.2.5 is attached.

Markup of Detroit Edison COLA
(following 2 pages)

The following markup represents how Detroit Edison intends to reflect this RAI response in a future submittal of the Fermi 3 COLA. However, the same COLA content may be impacted by revisions to the ESBWR DCD, responses to other COLA RAIs, other COLA changes, plant design changes, editorial or typographical corrections, etc. As a result, the final COLA content that appears in a future submittal may be different than presented here.

is from 1.2 to 6 m (2 to 10 ft). A minor set of joints trend from N54° to 72° E and dips from 30° to 60° to the northwest. Generally, these joints vary in length from 0.6 to 3.0 m (1 to 5 ft) but some are as much as 9.1 m (30 ft) long. Joints of the minor set are more irregular than the major set. Some minor joints terminate against major joints. Bedding plane joints, which undulate but are essentially horizontal, are spaced from 15 cm (6 in) to 1.2 m (2 ft) apart. These joints are generally tight but occasionally have minor openings which are often clay filled. (Reference 2.5.1-417)

During the Fermi 3 subsurface investigation jointing was observed throughout the Bass Islands Group and Salina Group Unit F. The joints encountered are opening-mode fractures. The joint density in the Bass Islands Group and Salina Group Unit F varies from isolated joints to groups of closely spaced joints referred to on the logs as highly fractured zones. The existence of joints and fracture zones is confirmed on the optical televiewer logs; however, the field boring logs have more joints and fracture zones possibly indicating mechanical breaking of the core during the drilling process. The orientations vary from horizontal to vertical with near horizontal and near vertical fractures dominating. The joint apertures were from tight or hairline up to several inches. Some joints were filled with anhydrite, calcite, or clay while others had no filling. A small percentage of joints have weathering along the joint walls or display minor dissolution (solutioning). Below Salina Group Unit F, the joint density decreases, and joints are rare in Salina Group Units C and B, but mineral (anhydrite) filled joints are present even in the deepest formations.

Joint orientations vary from horizontal to vertical, with near horizontal and near vertical joints dominating. Optical televiewer logging completed for the Fermi 3 project determined the presence of low angle (< 45°) bedding planes, low angle fractures (< 45°), and high angle fractures (> 45°). The dominant strike orientations of the bedding planes are north-northeast and west-northwest. The dominant strike orientations of all fracture planes are north-northwest and west-northwest. (Reference 2.5.1-418)

2.5.1.2.5 Site Geologic Hazard Evaluation

This section covers the non-seismic geologic hazards in the 40-km (25-mi) radius site vicinity including landslides and karst. The Landslide Overview Map of the conterminous United States (Figure 2.5.1-227) indicates the site vicinity, site area, and site location are in a region of moderate landslide susceptibility. The susceptibility is based on the presence of lacustrine deposits (lake beds). The (8-km [5-mi] radius) site area has a maximum relief of 10.7 m (35 ft) (Subsection 2.5.1.2.1) and is best described as relatively flat with no steep slopes. The lacustrine deposits in the (1-km [0.6-mi] radius) site location are up to 3-m (9-ft) thick. The natural slopes are probably not landslide prone; however, the stability of the lacustrine deposits should be considered in excavation design (Reference 2.5.1-387).

The National Atlas Map showing the Engineering Aspects of Karst indicates the site vicinity, site area, and site location are in an area that can have fissures, tubes, and caves up to 300-m (1,000-ft) long below at least 3 m (10 ft) of noncarbonate overburden (Figure 2.5.1-228) (Reference 2.5.1-388). Davies et al. (Reference 2.5.1-388) emphasize that active karst in adjacent areas of northwestern Ohio occurs in areas where the noncarbonate overburden is less than 6-m (20-ft) thick. In the 1-km (0.6-mi) radius site location, the combined thickness of the till and lacustrine deposits is over 6 m (20 ft), indicating that the probability for karst is low.

Several sinkholes have been mapped in southwestern and southern Monroe County (Bedford, Whiteford, and Ida Townships). At least seven sinkholes are located in Devonian-age Detroit River group, which is outside the 8-km (5-mi) radius site area. Two sinkholes are in the Bass Islands Group. No sinkholes are in the (8-km [5-mi] radius) site area. (Reference 2.5.1-419; Reference 2.5.1-389; Reference 2.5.1-420)

Subsection 2.5.1.2.3.1.2.1 discussed breccias and soft zones and potential explanations for their presence at the site. The formation of paleokarst was indicated as a possible reason for breccias and soft zones, with paleokarst episodes related to the dissolution of evaporite minerals, primarily halite and gypsum (Reference 2.5.1-392; Reference 2.5.1-397). Since no halite exists at the site (Section 2.5.1.2.3.1.1) and only minor amounts (nodule fillings and beds less than 3 cm [0.1 ft]) of gypsum and anhydrite exist in the Bass Islands Group and in Salina Group Unit F, the potential for ~~modern~~ evaporite karst is small.

The presence of voids was evaluated and discussed in Subsection 2.5.1.2.3 for applicable stratigraphic units.

Attachment 19
NRC3-10-0006

Response to RAI Letter No. 1
(eRAI Tracking No. 3918)

RAI Question No. 02.05.02-02

RAI 02.05.02-02

FSAR Section 2.5.2.4 includes an update of the EPRI SOG seismic source parameters (specifically, maximum magnitudes) based on the latest earthquake information. Please explain why the maximum magnitudes for the Bechtel BZ3 source were updated but the Law Engineering source114 maximum magnitudes were not updated. Please provide a detailed description of the SSHAC procedure used in revising the EPRI/SOG seismic source parameters, including the maximum magnitude, probability of activity and others. Describe how you integrated expert opinions, especially conflicting opinions, and how you incorporated the informed community consensus into the revised seismic source model. In addition, discuss how you applied regional paleoseismic data to the source updates.

Response

Attached summary Figures 1 – 12 illustrate the source parameters that were updated based on the new information. The responses to these various requests are provided below.

"Please explain why the maximum magnitudes for the Bechtel BZ3 source were updated but the Law Engineering source 114 maximum magnitudes were not updated."

A consistent approach was used to update both source zones. In each case, the maximum magnitude probability distribution that the EPRI-SOG teams had assigned to their sources was updated using earthquake catalogs with additional prehistoric events that were based on paleoseismic evidence. Results of paleoliquefaction studies conducted in the CEUS subsequent to the EPRI-SOG study were considered and used in the seismic source characterization update for the Fermi 3 site. A summary is provided below of how new information on prehistoric earthquakes from these paleoseismic studies was incorporated into the PSHA. The explanation of the difference in the updates for Bechtel Source BEC-BZ3 compared to Law Engineering Source LAW-114 is as follows.

All of the EPRI-SOG teams included source zones that encompass the more concentrated seismicity that is observed in southern Illinois and southern Indiana (Figures 1, 3, 5, 7, 9, and 11). This region of the southern Illinois basin is characterized by persistent, scattered seismicity that includes several moderate historical earthquakes. Investigation of paleoliquefaction features at several sites also indicates that multiple earthquakes have occurred in the region with magnitudes significantly larger than those historical events. Mapping and dating of liquefaction features throughout most of the southern Illinois basin and in parts of Indiana, Illinois, and Missouri have identified at least eight latest Pleistocene and Holocene earthquakes having estimated moment magnitudes of **M** ~ 6 to ~ 7.8 (FSAR References 2.5.1-350, 2.5.1-370, 2.5.1-371, 2.5.1-372, 2.5.1-373, 2.5.1-374). With the exception of the Springfield paleoevent, the other postulated energy centers for these prehistoric earthquakes (shown on FSAR Figure 2.5.1-207) are encompassed by alternative configurations used by the EPRI-SOG teams to characterize the Wabash Valley region and the surrounding, more seismically active regions of southern Illinois and Indiana. As noted in Figures 1 – 12, the maximum magnitude probability distribution

for the Wabash Valley zones was updated based on the estimated size of the Vincennes earthquake that occurred approximately 6,000 years before present (BP) (FSAR References 2.5.1-371 and 2.5.1-372).

The postulated Springfield energy center, which is located just beyond the limits of most of the Wabash Valley and Southern Illinois zones, was included in larger background zones used by four of the EPRI-SOG teams (Bechtel, Law Engineering, Rondout, and Weston Geophysical) to characterize the surrounding craton areas. As noted in FSAR Section 2.5.2.4.1.3, the ESP application prepared for Exelon Generation Company in 2006 (Reference 2.5.2-254) updated a number of the EPRI-SOG source zones to account for the occurrence of a prehistoric earthquake near Springfield, Illinois, having an estimated moment magnitude of **M** ~ 6.5. Following this approach, the maximum magnitude distribution for Bechtel Source BEC-BZ3, a background source (Northern Great Plains Region) that also covers an extensive area in the central United States, was updated based on the estimated size and location of the Springfield paleoevent. The background zone contains ten individual seismic source zones, many of which are located more than 320 km (200 mi.) from the site. The maximum magnitude probability distribution for Law Engineering Source LAW-116, Rondout Source RND-52, and Weston Source WGG-105 also were updated based on the Springfield paleoevent.

Law Engineering Source LAW-114 (Wisconsin Block) lies north of the region in Illinois and Indiana where evidence for moderate- to large-magnitude prehistoric earthquakes has been identified from paleoliquefaction studies (e.g., FSAR References 2.5.1-350, 2.5.1-370, 2.5.1-371, 2.5.1-372, 2.5.1-373, and 2.5.1-374). The Law Engineering team differentiated this zone from the regions in central and southern Illinois based in part on differences in the crust as inferred from gravity and magnetic trends, quoting:

> "The Wisconsin Block is defined by the magnetic and gravity trends that are approximately concentric around the north end of the large gravity high that defines the Mississippi Embayment. The northern boundary of the block follows the Midcontinent Rift System from Iowa northeast to Lake Superior and from there southeast down the continuation of the rift (Mid-Michigan Rift System) into Michigan. The southern boundary is along the southernmost concentric trend in the magnetic and gravity data as interpreted by Hatcher and Zietz (1984)." (2.5.2-236)

Evidence for prehistoric earthquakes based on paleoseismic evidence has not been reported for the Law Engineering Source LAW-114 zone. There also have been no recent moderate- or large-magnitude earthquakes within the Law Engineering Source LAW-114 zone that would result in an update to the maximum magnitude distribution following the approach used by the Law Engineering team.

"Please provide a detailed description of the SSHAC procedure used in revising the EPRI/SOG seismic source parameters, including the maximum magnitude, probability of activity and others."

SSHAC guidance outlines appropriate methods to use for quantifying uncertainty in evaluations of seismic hazard (2.5.2-260). The Fermi 3 PSHA was conducted as a Senior Seismic Hazard Analysis Committee (SSHAC) Level 2 update to a SSHAC Level 4 study. In this context the seismic source characterization relied primarily on the assessments made by the six EPRI-SOG expert teams. These assessments were updated when new information would change an interpretation made by the EPRI-SOG expert teams. The EPRI-SOG expert teams used information on the size of the largest earthquake known to have occurred in a source zone as one of the factors that influenced their assessment of maximum magnitude. Since the assessments of the EPRI-SOG teams were completed, the results of paleoearthquake research have produced new information on the size of earthquakes that have occurred in the recent geologic past. In a number of cases, this research has identified larger events than were previously observed in specific source zones. The maximum magnitude distributions in specific source zones were updated to reflect this recent information.

For Level 1, 2, and 3 studies, SSHAC directs the Technical Integrator (TI) to communicate with regional experts to understand the technical positions taken by various proponents of particular hypotheses. By this means, the knowledge and uncertainties of the larger informed technical community are captured. For the Fermi 3 PSHA, this guidance was followed by reviewing published literature, available unpublished reports, and documents pertinent to seismic source characterization, and by contacting researchers familiar with the seismic sources that could potentially affect the Fermi 3 site. Attached Table 1 summarizes communications with various researchers contacted during the Fermi 3 COLA study.

Input parameters developed by the EPRI-SOG teams were reviewed and some values were updated based on this new information. Figures 1 – 12 illustrate where new information was used to update parameters for different source zones for each of the six EPRI-SOG teams. On Figures 2, 4, 6, 8, 10, and 12, the seismic sources for each team are provided. In column four of the tables in Figures 2, 4, 6, 8, 10, and 12, the EPRI 1989 maximum magnitude distribution for the Fermi 3 site is provided, while in the last column of the tables, the updated maximum magnitude distribution used in the PSHA for Fermi 3 is provided.

As described in the FSAR Section 2.5.2.4.1, based on review of new geological, geophysical, and seismological information, the EPRI-SOG source models were modified for the Fermi 3 COLA as follows:

- Fault sources were added for repeated large-magnitude earthquakes in the New Madrid Seismic Zone (NMSZ) (FSAR Section 2.5.2.4.1.1).

- The maximum magnitude distribution for the Wabash Valley – Southern Illinois source zone(s) (WVSZ) was revised (FSAR Section 2.5.2.4.1.2).

- The maximum magnitude distribution for selected EPRI-SOG team sources was updated based on updated earthquake catalog events (FSAR Section 2.5.2.4.1.3).

- The maximum magnitude distributions for local EPRI-SOG sources were updated to account for recent or recently discovered earthquakes in those source zones (see the above discussion of the Springfield earthquake).

Three fault sources are included in the updated characterization of the central fault system of the NMSZ: (1) the New Madrid South (NS) fault, (2) the New Madrid North (NN), and (3) the Reelfoot fault (RF). The most significant updates of source parameters for the NMSZ since the 1986 EPRI-SOG study stem from the results of paleoliquefaction studies; these are the reduction in the mean recurrence interval to approximately 500 years, and consideration of clustered event sequences. Recent estimates of maximum magnitude for the NMSZ have generally been within the range of $m_b \sim 7.2$ to ~ 7.9 that was used by the EPRI-SOG teams.

The most significant update of source parameters for the WVSZ since the EPRI-SOG 1986 study is the estimate for maximum magnitude. The estimated magnitude for the largest identified paleoearthquakes in the WVSZ (**M** ~ 7.5) is at the upper end of the EPRI-SOG earth science team composite assessment for the WVSZ sources.

Finally, the updated earthquake catalog was used to obtain the largest earthquake observed in each of the EPRI-SOG seismic sources. The 1986 m_b 5.0 and the 1998 m_b 5.2 earthquakes in Ohio are larger than the minimum maximum magnitude assigned by the Law Engineering team to their Source LAW-112 and by the Woodward-Clyde team to their background source for the Fermi 3 site. Accordingly, the maximum magnitude distributions for these two sources were modified to account for these post–EPRI-SOG earthquakes using the approach applied by each team for assessing maximum magnitude.

In the case of the Dames & Moore Source DAM-08, the occurrence of the 1986 m_b 5.0 and the 1998 m_b 5.2 earthquakes in Ohio was the basis for increasing the probability of activity from 0.08 to 1.0.

Table 1
Resource Experts Contacted

Contact	Affiliation	Expertise	SSC Issues
Mark Baranoski	Ohio Division of Geological Survey	Basement structures	Evidence for reactivation of basement faults
Glenn Larsen	Ohio Division of Geological Survey	Geologic Structures	Identification and characterization of regional faults
Rick Pavey	Ohio Division of Geological Survey	Quaternary Geology	Information on Evidence for Quaternary faulting, pop-up structures

Table 1
Resource Experts Contacted

Contact	Affiliation	Expertise	SSC Issues
E. Mac Swinford	Ohio Division of Geological Survey	Division Assistant Chief	Referral to appropriate staff
Erick Venteris	Ohio Division of Geological Survey	Paleoliquefaction	Assessment of existing paleoliquefaction study results for identifying prehistoric earthquakes
Donovan Powers	Ohio Division of Geological Survey	GIS datasets	Obtaining digital datasets
John Esch	Michigan DEQ	Geologic Structures	Identification and characterization of faults in Michigan
Raymond Vurginovich	Michigan DEQ	Geologic Mapping and Well Database	Data compilation for source characterization
Ron Elowski	Michigan DEQ	Geologic Mapping and Well Database	Data compilation for source characterization
Steve Wilson	Michigan DEQ	Geologic Mapping	Data compilation for source characterization
Larry Organek	Michigan DEQ	Well database	Primary data for evaluating deformation history for subsurface faults in site vicinity
Roger Nelson	Michigan DEQ	Well database	Primary data for evaluating deformation history for subsurface faults in site vicinity
John Rupp	Indiana Geological Survey	Geologic Structures-Paleoliquefaction Studies in Indiana	Identification and characterization of regional faults
Mary Parke	Indiana Geological Survey	Seismic Hazard Studies in Indiana	Identification and characterization of regional faults
Terry Carter	Ontario Geological Survey	Structures defined from Oil and Gas	Identification and characterization of regional fault and subsurface faults in site vicinity
Desmond Rainford	Ontario Geological Survey	Datasets in Ontario	Data compilation for source characterization
James Boyd	Ontario Geological Survey	GIS datasets	Data compilation for source characterization

Table 1
Resource Experts Contacted

Contact	Affiliation	Expertise	SSC Issues
Thomas Hoane	Michigan Basin Geological Society	MBGS Publications	Data compilation for source characterization
Viki Bankey	USGS	Regional Magnetic Data	Data compilation for source characterization
Kaz Fujita	Michigan State University	Seismicity in Michigan	Data compilation for source characterization
Stephen Halchuck	Geological Survey of Canada	Seismicity	Data compilation for source characterization
John Adams	Geological Survey of Canada	Seismicity	Data compilation for source characterization
Steve Obermeier	USGS	Paleoliquefaction	Primary researcher for paleoliquefaction studies in Anna, Ohio and NE Ohio regions
Margaret Hopper	USGS	Seismicity	Data compilation for source characterization
Rich Harrison	USGS	Seismic Hazards	Data compilation – paleoliquefaction data sets
Bill Harrison	Western Michigan University	Geologic Structures	Data compilation for source characterization

Abbreviations:
SSC = Seismic Source Characterization
DEQ = Department of Environmental Quality
MBGS = Michigan Basin Geological Society
USGS = U.S. Geological Survey

"Describe how you integrated expert opinions, especially conflicting opinions, and how you incorporated the informed community consensus into the revised seismic source model."
The principal area of controversy that affects the hazard at the Fermi 3 site is with regard to the size of New Madrid source zone earthquakes. The 1811-1812 New Madrid earthquakes represent the largest historical events in the CEUS and are among the largest events in the worldwide database for stable continental region earthquakes. In the CEUS, estimates of magnitude for prehistoric earthquakes based on paleoliquefaction results are tied in part to the magnitude-bound curve developed most recently by Olson et al. (Reference 1).

Publications over the past decade, in addition to recent communications with researchers, indicate that there still remains uncertainty and differing views within the research community about the size and location of the 1811-1812 earthquakes. The maximum magnitude distribution used to characterize the central fault system of NMSZ for this study was initially developed by Exelon Generation Company, LLC (EGC) Early Site Permit (ESP) application for the Clinton, Illinois, site (2.5.2-243). In order to incorporate the then current perspectives of knowledgeable researchers who had published very different estimates of the size of the 1811-1812 earthquakes, based on evaluation of intensity data and other geologic information, three individuals were contacted to discuss their current preferred values and reasons for the discrepancies among the various researchers using similar intensity data sets (written communications from Dr. S. Hough, August 22, 2004 [Reference 2]; Dr. W. Bakun, August 15, 2004 [Reference 3]; and Dr. A. Johnston, August 31, 2004 [Reference 4]).

The following is a summary of these differing opinions and the approach used to integrate the values into a composite distribution for the size of the earthquakes presented in FSAR Table 2.5.2-207 as outlined in FSAR Reference 2.5.2-253:

> "Bakun and Hopper (2004) [Reference 5] provide preferred estimates of the locations and moment magnitudes and their uncertainties for the three largest events in the 1811-1812 sequence near New Madrid. Their preferred intensity magnitude $\mathbf{M}_I$, which is their preferred estimate of **M**, is 7.6 (6.8 to 7.9 at the 95% confidence interval) for the 16 December 1811 event (NM1), 7.5 (6.8 to 7.8 at the 95% confidence interval) for the 23 January 1812 event (NM2), and 7.8 (7.0 to 8.1 at the 95% confidence interval) for the 7 February 1812 event (NM3). The intensity magnitude $\mathbf{M}_I$ is the mean of the intensity magnitudes estimated from individual MMI assignments. In their analysis, Bakun and Hopper (2004 [Reference 5]) consider two alternative eastern North America (ENA) intensity attenuation models, which they refer to as models 1 and 3. As indicated in the table below [attached Table 2 excerpt from FSAR Reference 2.5.2-253], these two models give significantly different results for larger-magnitude earthquakes. Bakun and Hopper (2004 [Reference 5]) state that because these models are empirical relations based almost exclusively on **M** < 6 calibration events, "There is no way to confidently predict which relation better represents the MMI-distance data for **M** 7 earthquakes in ENA" (p. 66). They present arguments supporting their preference for model 3, but do not discount the results based on model 1.
>
> Dr. Susan Hough (personal communication, 22 August, 2004) [Reference 2] believes that there are insufficient data regarding the calibration of ENA earthquakes larger than **M** > 7 to rely strictly on ENA models as was done in the Bakun and Hopper (2004). She offers arguments to support **M** 7.6 (the size of the 2003 Bhuj earthquake) as a reasonable upper bound for the largest of the earthquakes in the 1811-1812 New Madrid earthquake sequence, which is more consistent with the estimates cited in Hough et al. (2000 [FSAR Reference 2.5.1-360]) and Mueller et al. (2004 [Reference 6]).
>
> Mueller et al. (2004) use instrumentally recorded aftershock locations and models of elastic stress change to develop a kinematically consistent rupture scenario for the main shock earthquakes of the 1811-1812 New Madrid sequence. In general, the estimated magnitudes for NM1 and NM3 used in their analysis (**M** = 7.3 and **M** = 7.5, respectively) are consistent with those previously published by Hough et al. (2000). Their results suggest that the main shock events NM1 and NM3 occurred on two contiguous faults, the strike-slip Cottonwood Grove fault and the Reelfoot thrust fault, respectively. The locations of the NM1 and NM3 events on the Cottonwood Grove and Reelfoot faults,

respectively, are relatively well constrained. In contrast to the earlier Hough et al. (2000 [FSAR Reference 2.5.1-360]) study that located the NM2 earthquake on the New Madrid north fault, they suggest a more northerly location for the NM2 event, possibly as much as 200 km to the north in the Wabash Valley of southern Indiana and Illinois. Using Bakun and Wentworth's (1997 [Reference 7]) method, Mueller et al. (2004) obtain an optimal location for the NM2 main shock at 88.43°W, 36.95°N, and a magnitude of 6.8. They note that the location is not well northeast of the optimal location. Mueller et al. (2004) conclude that the three events on the contiguous faults increased stress near fault intersections and end points, in areas where present-day microearthquakes have been interpreted as evidence of primary main shock rupture. They note that their interpretation is consistent with established magnitude/fault area results, and do not require exceptionally large fault areas or stress drop values for the New Madrid main shocks.

With respect to the location of the NM2 event, Bakun and Hopper (2004) also discuss the paucity of MMI assignments available for this earthquake to the west of the NMSZ and the resulting uncertainty in its location. They note that the two MMI sites closest to the NMSZ provide nearly all of the control on the location of this event, and that based on these two sites, a location northeast of their preferred site would be indicated. However, they conclude that the lack of 1811-1812 liquefaction observations in western Kentucky, southern Illinois, and southern Indiana preclude an NM2 location in those areas. Bakun and Hopper (2004) follow Johnston and Schweig (1996) FSAR Reference 2.5.2-305] in selecting a preferred location on the New Madrid north fault.

S. Obermeier confirmed the statement regarding the absence of liquefaction features in the Wabash Valley region that would support the more northerly location preferred by Mueller et al. (2004) (Dr. Steve Obermeier, personal communication, 24 August 2004 [Reference 8]). He noted that he had looked specifically in the area cited in the Yearby Land account that was cited by Mueller et al. (2004 [Reference 6]) and observed evidence for only small sand blows and dune sands, but did not see features of the size and origin described in that account. Finally, recently, Dr. Arch Johnston (personal communication, 31 August 2004 [Reference 4]) indicates that the estimates of Johnston (1996) (FSAR Reference 2.5.2-248) are likely to be high by about 0.2 to 0.3 magnitude units. Dr. Johnston indicates that he is working on developing revised estimates for a forthcoming paper."

FSAR Tables 2.5.2-207 and 2.5.2-208 show the magnitude comparisons of the New Madrid earthquakes and the suggested revision to the magnitude assessments for large-magnitude New Madrid events based on this new information. The weighting approach used for the EGC-ESP study (FSAR Reference 2.5.2-253) outlined below was adopted for the Fermi 3 study.

- "Equal weight (1/3) is be given to estimates based on Bakun and Hopper (2004 [Reference 5]) and Hough et al. (2000 [FSAR Reference 2.5.1-360])/Mueller et al. (2004 [Reference 6]) and the Johnston (personal communication, August 31, 2004 [Reference 4]) revisions to Johnston (1996 [FSAR Reference 2.5.2-248]).

- For the Bakun and Hopper (2004 [Reference 5]) estimate, we consider results from using both intensity attenuation relations (models 1 and 3). Based on Bakun and Hopper's preference for model 3, we assign weights of 0.75 to model 3 and 0.25 to model 1.

- In the case of the Hough et al. (2000 [FSAR Reference 2.5.1-360])/Mueller et al. (2004 Reference 6]) estimates and the Johnston (personal communication, August 31, 2004 [Reference 4]) estimates, we assign equal weight to the range of preferred values given for each earthquake.

The resulting characteristic magnitude distribution for each of the three faults is given in the following table [attached Table 2 excerpt from FSAR Reference 2.5.2-253]. Rupture sets 1 and 2 correspond to the revised Johnston (2004) estimates, rupture sets 3 and 4 correspond to the Bakun and Hopper (2004 [Reference 5]) estimates, and rupture sets 5 and 6 correspond to the Hough et al. (2000 [FSAR Reference 2.5.1-360]) estimates."

Table 2
(Excerpt From FSAR Reference 2.5.2-253)

TABLE 2.5.1-1-1

MAGNITUDE COMPARISONS FOR NEW MADRID 1811-1812 EARTHQUAKE SEQUENCE

Study	NM1	NM2	NM3
Johnston (1996)	M 8.1 +/- 0.3	M 7.8 +/- 0.3	M 8.0 +/- 0.3
Hough et al. (2000)	M 7.2 to 7.3	M ~7.0[1] (located on the New Madrid north fault)	M 7.4 to 7.5
Mueller and Pujol (2001)	-	-	M 7.2 to 7.4 (preferred M 7.2 to 7.3)
Bakun and Hopper (2004)	M_I 7.6 (M 7.2 to 7.9) (preferred model 3)	M_I 7.5 (M 7.1 to 7.8) (preferred model 3)	M_I 7.8 (M 7.4 to 8.1) (preferred model 3)
	M_I 7.2 (M 6.8 to 7.9) (model 1)	M_I 7.2 (M 6.8 to 7.8) (model 1)	M_I 7.4 (M 7.0 to 8.1) (model 1)
Mueller et al. (2004)	M 7.3	M 6.8 (located within the Wabash Valley of southern Illinois/ southern Indiana)	M 7.5
Johnston (personal communication, 31 August 2004)	M 7.8-7.9	M 7.5-7.6	M 7.7-7.8

[1] The estimated location and magnitude of this earthquake are revised in Mueller et al. (2004).

References

1. Olson, S.M., Green, R.A., and Obermeier, S.F., 2005b, Revised magnitude bound relation for the Wabash Valley seismic zone of the central United States: *Seismological Research Letters*, v. 76, no. 6, pp. 756-771.
2. Hough, S., Personal communication, 22 August 2004.
3. Bakun, W.H., Personal communication, 15 August 2004.
4. Johnston, A.C., Personal communication, 31 August 2004.
5. Bakun, W.H., and M.G. Hopper, "Magnitudes and Locations of the 1811-1812 New Madrid, Missouri, and the 1886 Charleston, South Carolina, Earthquakes." *Bulletin of the Seismological Society of America*, Vol. 94, No. 1, pp. 64-75, 2004.
6. Mueller, K., S. E. Hough, and R. Bilham, "Analysing the 1811-1812 New Madrid earthquakes with recent instrumentally recorded aftershocks." *Nature.* Vol. 429, pp. 284-288, 2004.
7. Bakun, W.H., and C.M. Wentworth, "Estimating Earthquake Location and Magnitude From Seismic Intensity Data." *Bulletin of the Seismological Society of America*, Vol. 87, pp. 1502-1521, 1997.
8. Obermeier, S., Personal communication, 24 August 2004.

In addition, discuss how you applied regional paleoseismic data to the source updates.

There is no regional paleoseismic database that provides uniform coverage of the entire CEUS. The most detailed paleoliquefaction investigations have been conducted in regions that have experienced a large-magnitude historical earthquake (e.g., New Madrid seismic zone, Missouri; and Charleston, South Carolina) or in areas of elevated seismicity (e.g., the Wabash Valley and adjoining regions of southern Illinois, southern Indiana, and southeastern Missouri; North Anna, Ohio, and northeastern Ohio). Where results have documented the occurrence of moderate- to large-magnitude earthquakes, this information has been applied to update the source(s) where those events occurred.

In some instances, paleoliquefaction studies have not yielded conclusive evidence to demonstrate the occurrence of moderate-to large-magnitude prehistoric earthquakes or to preclude such events over a period of time that would be significant to seismic source characterization. For example, paleoliquefaction surveys were conducted along rivers in both the Anna, Ohio, and northeastern Ohio regions. The results of these studies, which are outlined in the Responses to RAI 02.05.01-14 and RAI 02.05.01-10, did not identify paleoliquefaction features. The findings in the North Anna region suggested that earthquakes greater than **M** ~ 7 likely had not occurred in the past several thousand years, but the scarcity of outcrops was not sufficient to preclude moderate-magnitude events (FSAR Reference 2.5.1-350). The negative findings in these regions cannot be reliably incorporated into the seismic source characterization as there are a number of factors that could lead to an incomplete record, including the lack of susceptible deposits or conditions favorable for the formation and preservation of paleoliquefaction, the scarcity of adequate outcrops to identify paleoliquefaction, and the young age of many of the sediments exposed along the surveyed streams.

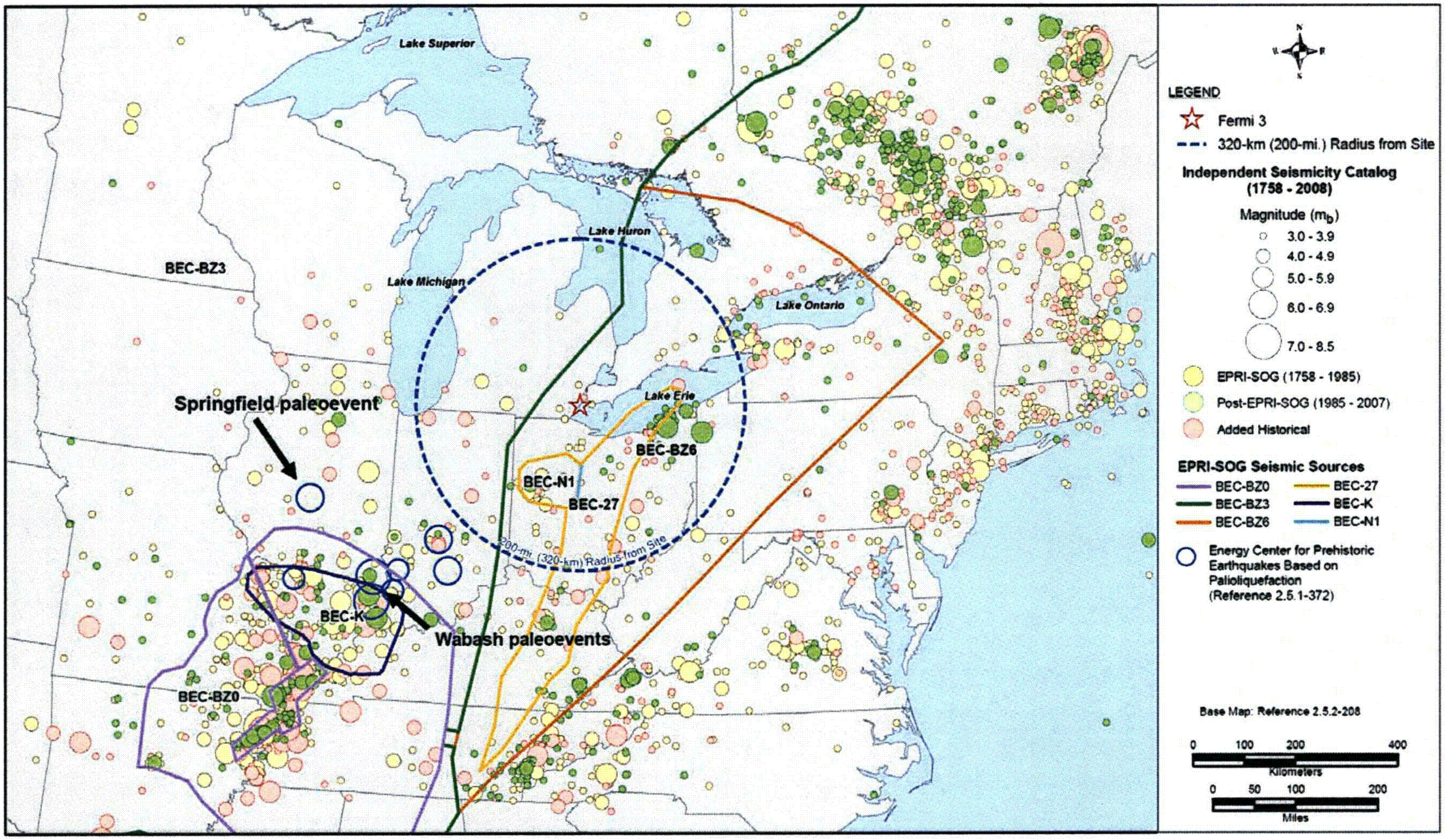

Figure 1 – Map Showing Modified Bechtel Sources

Table 2.5.2-201 Bechtel Team Seismic Sources

Source	P*	Closest Distance to Fermi 3 Site (km)	EPRI (1989) Maximum Magnitude Distribution for Fermi 3 Site (m_b)	Maximum Magnitude Distribution Used in PSHA for Fermi 3 Site (m_b)
New Madrid Region (BEC-BZ0)	1	484.1	5.7 (0.10), 6.0 (0.40), 6.3 (0.40), 6.6 (0.10)	**M** 7.0 (0.1), **M** 7.3 (0.4), **M** 7.5 (0.4), **M** 7.8 (0.1)
Northern Great Plains Region (BEC-BZ3)	1	67.6	5.4 (0.10), 5.7 (0.40), 6.0 (0.40), 6.6 (0.10)	**M** 5.75 (0.02), **M** 6 (0.02), **M** 6.25 (0.16), **M** 6.5 (0.3), **M** 6.75 (0.26), **M** 7 (0.15), **M** 7.25 (0.07), **M** 7.5 (0.02)
Southern Eastern Craton Region (BEC-BZ6)	1	0	5.4 (0.10), 5.7 (0.40), 6.0 (0.40), 6.6 (0.10)	5.4 (0.10), 5.7 (0.40), 6.0 (0.40), 6.6 (0.10)
Frankfort-Bucyrus (BEC-27)	0.12	80.2	5.4 (0.10), 5.7 (0.40), 6.0 (0.40), 6.6 (0.10)	5.4 (0.10), 5.7 (0.40), 6.0 (0.40), 6.6 (0.10)
Southern Illinois Region (BEC-K)	1	521.3	6.0 (0.10), 6.3 (0.40), 6.6 (0.50)	**M** 7.0 (0.1), **M** 7.3 (0.4), **M** 7.5 (0.4), **M** 7.8 (0.1)
Anna, Ohio, Area (BEC-N1)	0.6	98.1	5.4 (0.10), 5.7 (0.40), 6.0 (0.40), 6.6 (0.10)	5.4 (0.10), 5.7 (0.40), 6.0 (0.40), 6.6 (0.10)

Springfield paleoevent

Wabash paleoevents

Notes:

P* = the probability that the source is included in the hazard model.
M = moment magnitude
(Weight) = relative contribution of the source

Figure 2 – Updates to Bechtel Team Seismic Sources

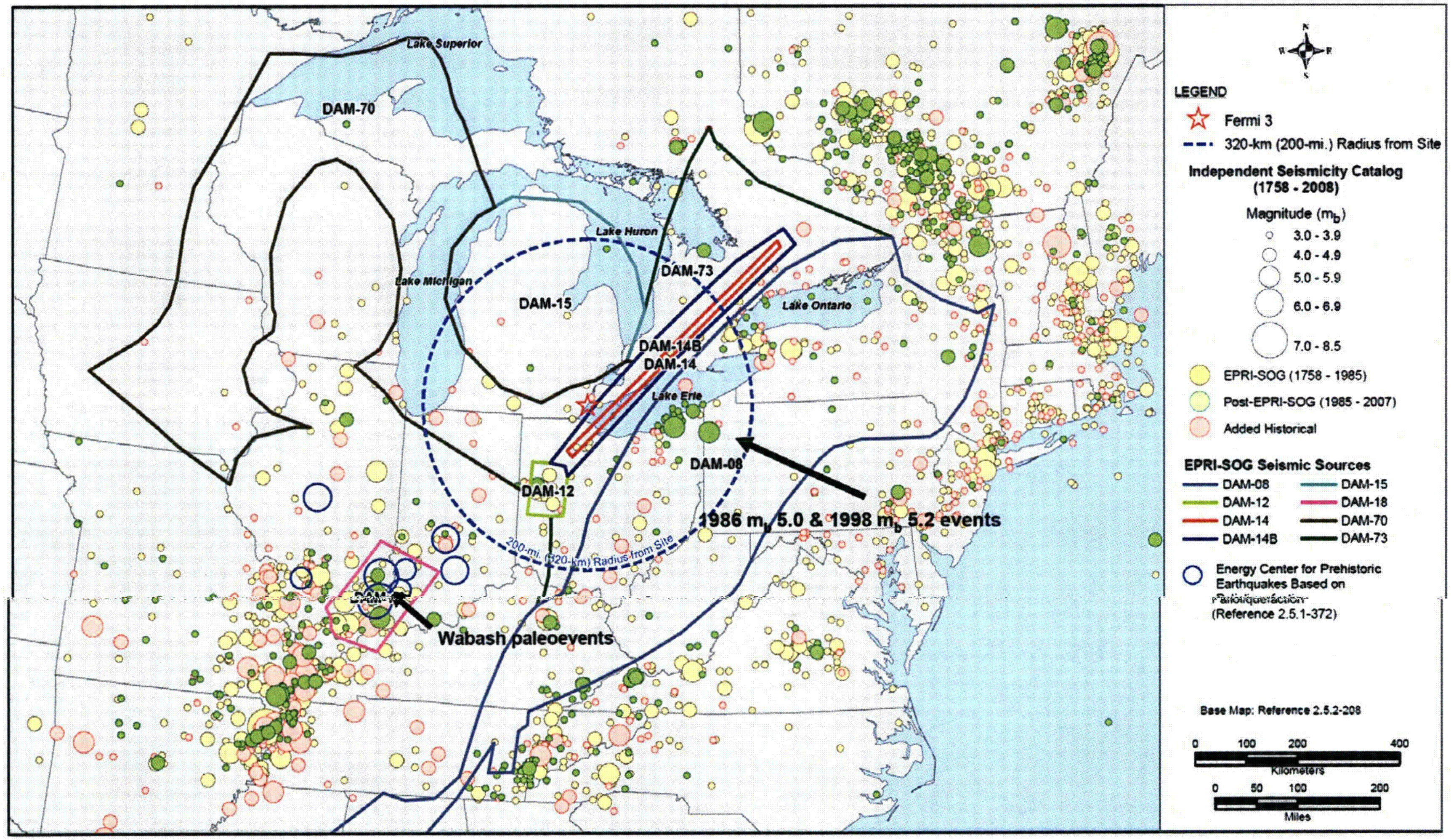

Figure 3 – Map Showing Modified Dames & Moore Sources

Table 2.5.2-202 Dames & Moore Team Seismic Sources

Source	P*	Closest Distance to Fermi 3 Site (km)	EPRI (1989) Maximum Magnitude Distribution for Fermi 3 Site (m_b)	Maximum Magnitude Distribution Used in PSHA for Fermi 3 Site (m_b)
Eastern Marginal Basin (DAM-8)	0.08[a]	106.3	5.6 (0.80), 7.2 (0.20)	5.6 (0.80), 7.2 (0.20)
Anna, Ohio (DAM-12)	1	127.7	6.8 (0.75), 7.2 (0.25)	6.8 (0.75), 7.2 (0.25)
Findlay Arch/Algonquin Axis (DAM-14 and DAM-14B)	1 (0.25 for 14, 0.75 for 14B)	35.6 for 14 12.1 for 14B	5.5 (0.75), 7.2 (0.25) for 14, 5.4 (0.80), 7.2 (0.20) for 14B	5.5 (0.75), 7.2 (0.25) for 14, 5.4 (0.80), 7.2 (0.20) for 14B
Michigan Basin (DAM-15)	1	42.1	5.3 (0.80), 7.2, (0.20)	5.3 (0.80), 7.2, (0.20)
Southern Illinois/Southern Indiana/Fairfield Basin (DAM-18)	1	436.1	6.6 (0.75), 7.2 (0.25)	**M** 7.0 (0.1), **M** 7.3 (0.4), **M** 7.5 (0.4), **M** 7.8 (0.1)
Wisconsin-Michigan Block (DAM-70)	1	0	5.1 (0.80), 7.2 (0.20)	5.1 (0.80), 7.2 (0.20)
Southern Canada Province (DAM-73)	1	66.1	5.3 (0.80), 7.2 (0.20)	5.3 (0.80), 7.2 (0.20)

1986 mb 5.0 & 1998 mb 5.2 events

Wabash paleoevents

Notes:

a. modified to 1 for Fermi 3 PSHA
P* = the probability that the source is included in the hazard model.
M = moment magnitude
(Weight) = relative contribution of the source

Figure 4 – Updates to Dames & Moore Team Seismic Sources

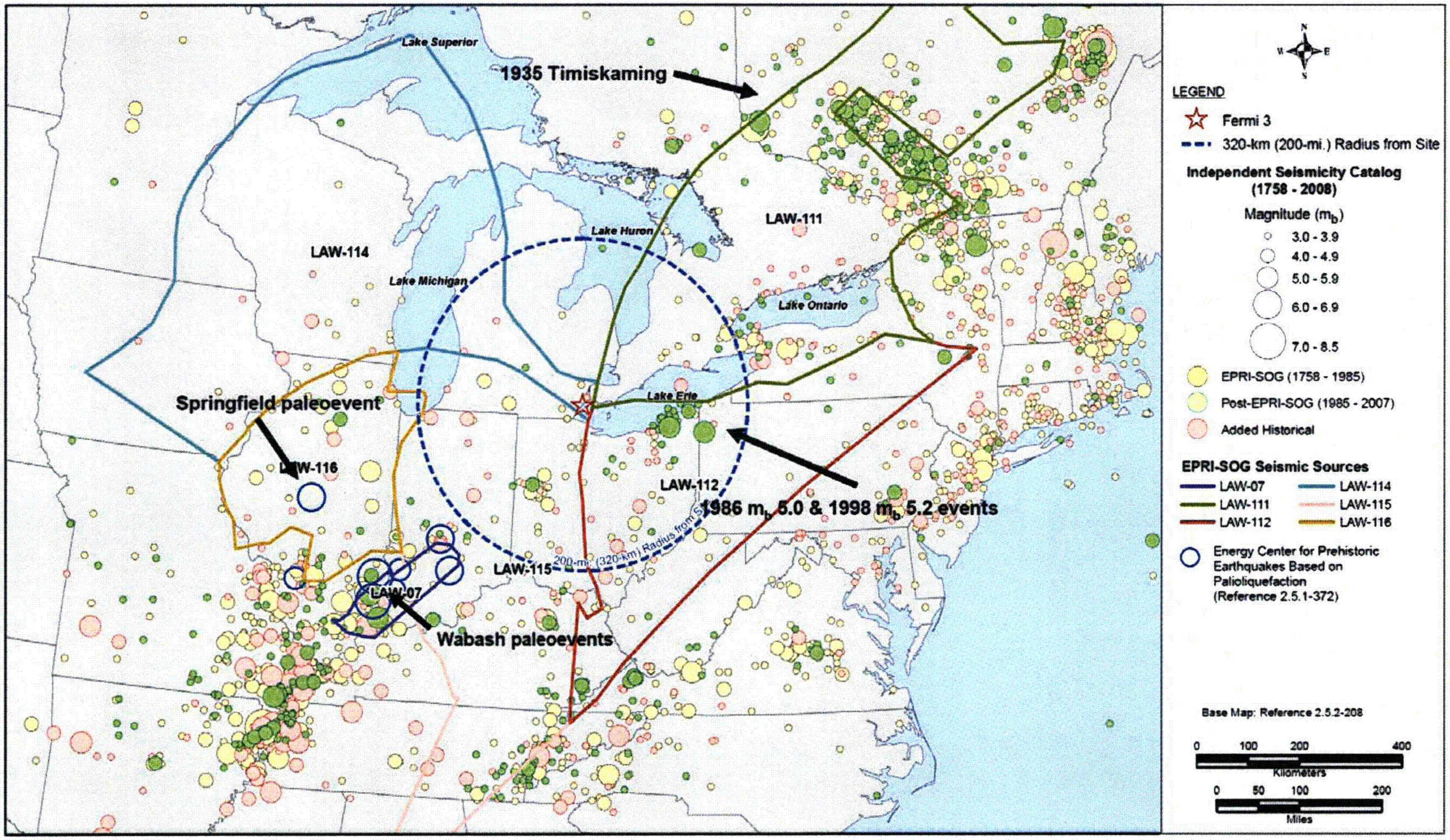

Figure 5 – Map Showing Modified Law Engineering Sources

Table 2.5.2-203 Law Engineering Team Seismic Sources

Source	P*	Closest Distance to Fermi 3 Site (km)	EPRI (1989) Maximum Magnitude Distribution for Fermi 3 Site (m_b)	Maximum Magnitude Distribution Used in PSHA for Fermi 3 Site (m_b)
Wabash Valley Arm (LAW-07)	1	374.5	5.5 (0.2), 6.0 (0.5), 6.8 (0.3)	**M** 7.0 (0.1), **M** 7.3 (0.4), **M** 7.5 (0.4), **M** 7.8 (0.1)
111 Laurentian (LAW-111)	1	19.7	5.5 (0.5), 6.0 (0.5)	5.5 (0.5), 6.2 (0.5)
Ohio-Pennsylvania Block (LAW-112)	1	19.9	4.6 (0.2), 5.1 (0.5), 5.5 (0.3)	5.0 (0.5), 5.5 (0.5)
Wisconsin Block (LAW-114)	1	0	4.6 (0.2), 5.1 (0.5), 5.5 (0.3)	4.6 (0.2), 5.1 (0.5), 5.5 (0.3)
Indiana Block (LAW-115)	1	17.4	5.2 (0.5), 5.5 (0.5)	5.2 (0.5), 5.5 (0.5)
Illinois Block (LAW-116)	1	303.6	5.2 (0.5), 5.5 (0.5)	**M** 5.75 (0.02), **M** 6 (0.02), **M** 6.25 (0.16), **M** 6.5 (0.3), **M** 6.75 (0.26), **M** 7 (0.15), **M** 7.25 (0.07), **M** 7.5 (0.02)

Annotations:

Wabash paleoevents (→ Wabash Valley Arm, PSHA distribution)

1935 Timiskaming (→ 111 Laurentian, PSHA distribution)

1986 mb 5.0 & 1998 mb 5.2 events (→ Ohio-Pennsylvania Block, PSHA distribution)

Added to EPRI (1989) set (→ Illinois Block (LAW-116))

Springfield paleoevent (→ Illinois Block, PSHA distribution)

Notes:

P* = the probability that the source is included in the hazard model.
M = moment magnitude
(Weight) = relative contribution of the source

Figure 6 – Updates to Law Engineering Team Seismic Sources

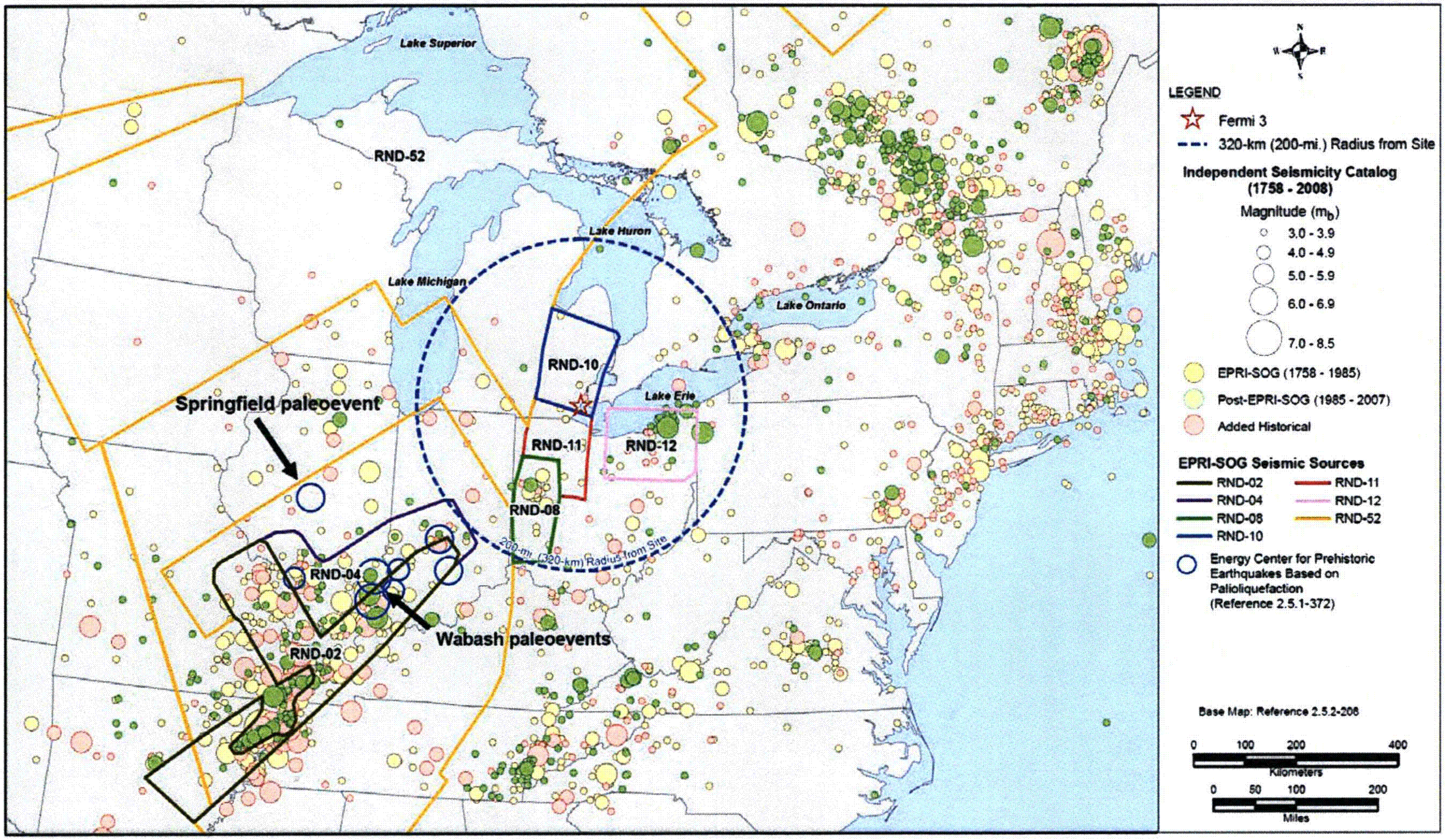

Figure 7 – Map Showing Modified Rondout Sources

Table 2.5.2-204 Rondout Team Seismic Sources

Wabash paleoevents

Added to EPRI (1989) set

Springfield paleoevent

Source	P*	Closest Distance to Fermi 3 Site (km)	EPRI (1989) Maximum Magnitude Distribution for Fermi 3 Site (m_b)	Maximum Magnitude Distribution Used in PSHA for Fermi 3 Site (m_b)
New Madrid Rift Complex (RND-2)	1	366.8	~~6.6 (0.30), 6.8 (0.60),~~ 7.0 (0.10)	**M** 7.0 (0.1), **M** 7.3 (0.4), **M** 7.5 (0.4), **M** 7.8 (0.1)
Southern Illinois and Indiana (RND-4)	1	310.8	~~6.6 (0.30), 6.8 (0.60),~~ 7.0 (0.10)	**M** 7.0 (0.1), **M** 7.3 (0.4), **M** 7.5 (0.4), **M** 7.8 (0.1)
Anna, Ohio (RND-8)	1	116.8	5.8 (0.15), 6.5 (0.60), 6.8 (0.25)	5.8 (0.15), 6.5 (0.60), 6.8 (0.25)
Southeast Michigan (RND-10)	0.95	0	5.8 (0.15), 6.5 (0.60), 6.8 (0.25)	5.8 (0.15), 6.5 (0.60), 6.8 (0.25)
Northwestern Ohio (RND-11)	0.87	14.9	5.2 (0.30), 6.3 (0.55), 6.5 (0.15)	5.2 (0.30), 6.3 (0.55), 6.5 (0.15)
Cleveland, Ohio (RND-12)	0.78	53.0	5.2 (0.30), 6.3 (0.55), 6.5 (0.15)	5.2 (0.30), 6.3 (0.55), 6.5 (0.15)
Pre-Grenville Precambrian Craton (RND-52)	1	89.5	4.8 (0.20), 5.5 (0.60), 5.8 (0.20)	**M** 5.75 (0.02), **M** 6 (0.02), **M** 6.25 (0.16), **M** 6.5 (0.3), **M** 6.75 (0.26), **M** 7 (0.15), **M** 7.25 (0.07), **M** 7.5 (0.02)

Notes:

P* = the probability that the source is included in the hazard model.
M = moment magnitude
(Weight) = relative contribution of the source

Figure 8 – Updates to Rondout Team Seismic Sources

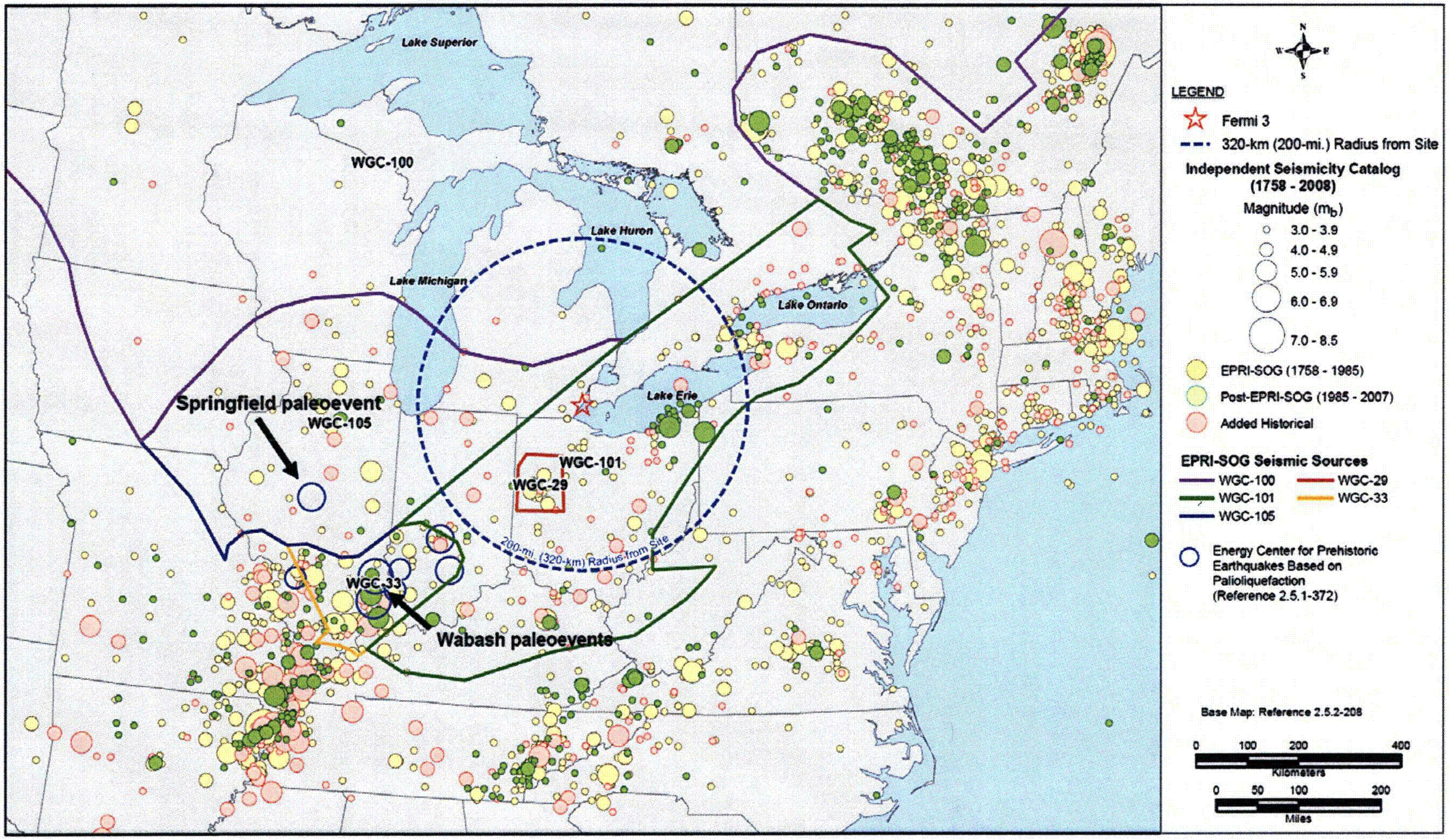

Figure 9 – Map Showing Modified Weston Geophysical Sources

Table 2.5.2-205 Weston Geophysical Team Seismic Sources

Wabash paleoevents → (Indiana Arm (WGC-33), Maximum Magnitude Distribution Used in PSHA)

Springfield paleoevent → (North Central (WGC-105), Maximum Magnitude Distribution Used in PSHA)

Source	P*	Closest Distance to Fermi 3 Site (km)	EPRI (1989) Maximum Magnitude Distribution for Fermi 3 Site (m_b)	Maximum Magnitude Distribution Used in PSHA for Fermi 3 Site (m_b)
Anna, Ohio (WGC-29)	0.93	107.5	5.4 (0.19), 6.0 (0.68), 6.6 (0.13)	5.4 (0.19), 6.0 (0.68), 6.6 (0.13)
Indiana Arm (WGC-33)	1	361.8	6.0 (0.68), 6.6 (0.27), 7.2 (0.05)	**M** 7.0 (0.1), **M** 7.3 (0.4), **M** 7.5 (0.4), **M** 7.8 (0.1)
Northern Interior (WGC-100)	1	99.2	5.4 (0.62), 6.0 (0.29), 6.6 (0.09)	5.4 (0.62), 6.0 (0.29), 6.6 (0.09)
Southern Ontario–Ohio-Indiana (WGC-101)	1	0	5.4 (0.19), 6.0 (0.68), 6.6 (0.13)	5.4 (0.19), 6.0 (0.68), 6.6 (0.13)
North Central (WGC-105)	1	44.9	5.4 (0.80), 6.0 (0.14), 6.6 (0.06)	**M** 5.75 (0.02), **M** 6 (0.02), **M** 6.25 (0.16), **M** 6.5 (0.3), **M** 6.75 (0.26), **M** 7 (0.15), **M** 7.25 (0.07), **M** 7.5 (0.02)

Notes:

P* = the probability that the source is included in the hazard model.
M = moment magnitude
(Weight) = relative contribution of the source

Figure 10 – Updates to Weston Geophysical Team Seismic Sources

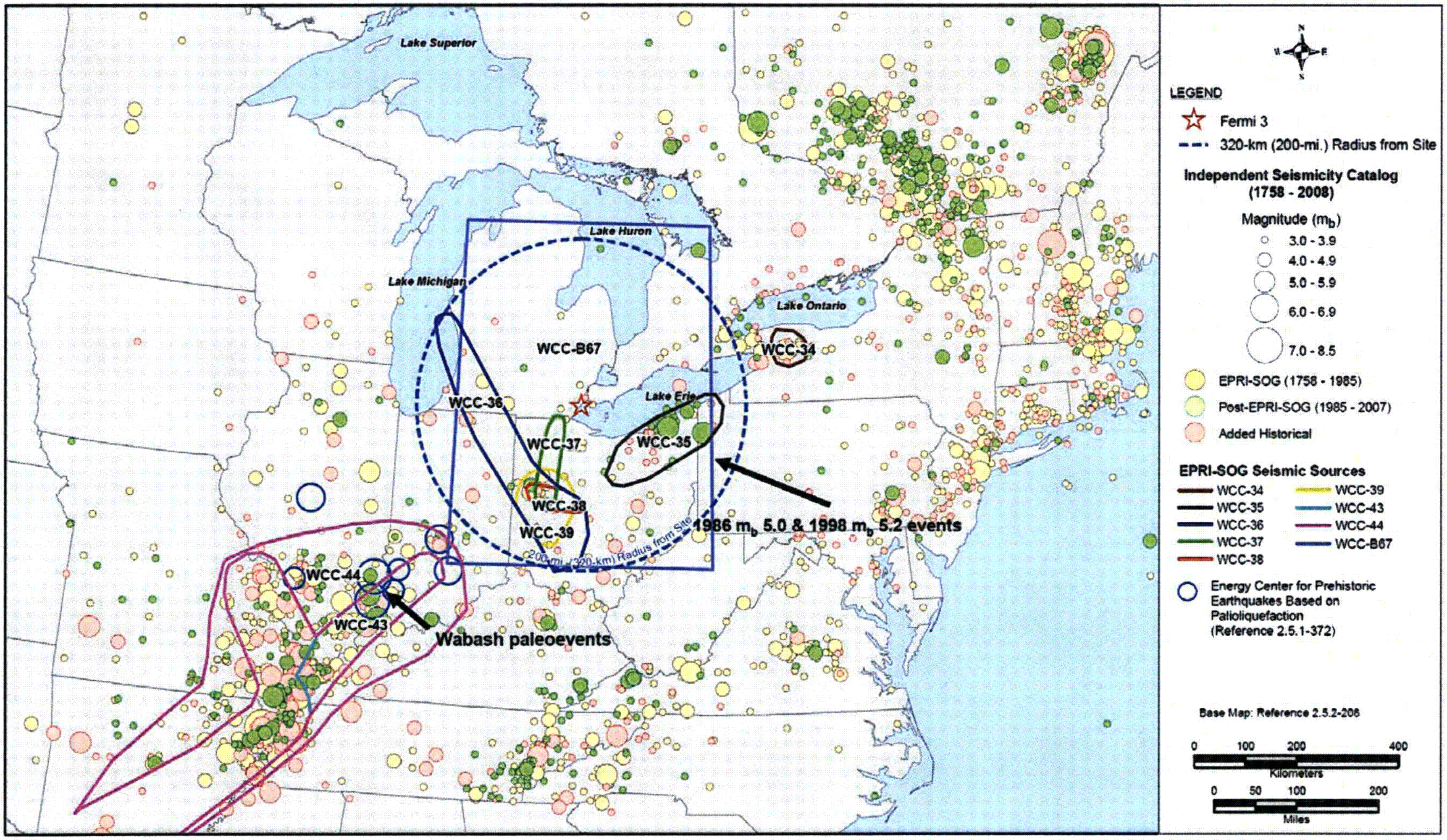

Figure 11 – Map Showing Modified Woodward-Clyde Sources

Table 2.5.2-206 Woodward-Clyde Team Seismic Sources

Added to EPRI (1989) set → Attica, NY Intersection (WCC-34)

Wabash paleoevents → Southern Indiana Arm (WCC-43)

1986 m_b 5.0 & 1998 m_b 5.2 events → Background Zone 67 (WCC-B67)

Source	P*	Closest Distance to Fermi 3 Site (km)	EPRI (1989) Maximum Magnitude Distribution for Fermi 3 Site (m_b)	Maximum Magnitude Distribution Used in PSHA for Fermi 3 Site (m_b)
Attica, NY Intersection (WCC-34)	1	381.9	5.6 (0.33), 6.3 (0.34), 7.4 (0.33)	5.6 (0.33), 6.3 (0.34), 7.4 (0.33)
Northeastern Ohio Gravity Source (WCC-35) and NOTA	0.548	107.4	5.3 (0.33), 6.0 (0.34), 6.8 (0.33)	5.3 (0.33), 6.0 (0.34), 6.8 (0.33)
Michigan-Ohio Geophysical Anomaly (WCC-36)	0.090	135.0	5.6 (0.33), 6.5 (0.34), 7.1 (0.33)	5.6 (0.33), 6.5 (0.34), 7.1 (0.33)
Bowling Green–Auglaize Fault System (WCC-37)	0.072	43.3	5.6 (0.33), 6.5 (0.34), 7.2 (0.33)	5.6 (0.33), 6.5 (0.34), 7.2 (0.33)
Champaign-Anna Fault System (WCC-38)	0.065	169.5	5.7 (0.33), 6.8 (0.34), 7.6 (0.33)	5.7 (0.33), 6.8 (0.34), 7.6 (0.33)
Anna, Ohio Geophysical Intersection (WCC-39) and NOTA	0.773	138.5	5.5 (0.33), 6.5 (0.34), 7.3 (0.33)	5.5 (0.33), 6.5 (0.34), 7.3 (0.33)
Southern Indiana Arm (WCC-43)	1	408.1	5.8 (0.33), 6.3 (0.34), 7.4 (0.33)	**M** 7.0 (0.1), **M** 7.3 (0.4), **M** 7.5 (0.4), **M** 7.8 (0.1)
New Madrid Loading Volume (WCC-44)	1	369.4	5.6 (0.33), 6.3 (0.34), 6.9 (0.33)	**M** 7.0 (0.1), **M** 7.3 (0.4), **M** 7.5 (0.4), **M** 7.8 (0.1)
Background Zone 67 (WCC-B67)	1	0	4.9 (0.17), 5.4 (0.28), 5.8 (0.27), 6.5 (0.28)	5.0 (0.17), 5.4 (0.28), 5.8 (0.27), 6.5 (0.28)

Notes:

NOTA = none of the above zone, a source with the same geometry.
P* = the probability that the source is included in the hazard model.
M = moment magnitude
(Weight) = relative contribution of the source

Figure 12 – Updates to Woodward-Clyde Team Seismic Sources

Proposed COLA Revision

None

Attachment 20
NRC3-10-0006

Response to RAI Letter No. 17
(eRAI Tracking No. 4006)

RAI Question No. 02.05.02-09

RAI 02.05.02-09

FSAR Section 2.5.2.1.2 states that the Fermi 3 site experienced a Modified Mercalli Intensity (MMI) IV-V during the January 31, 1986 Lake County, Ohio earthquake (mb 5.0), and experienced an MMI III during the July 12, 1986, Anna seismic zone earthquake (mb 4.5). Please provide basic observation information related to the local MMI estimation and if available, seismic instrument recordings from those earthquakes at or near the site.

Response

Fermi 3 FSAR, Revision 1, Section 2.5.2.1.2, states:

> **"January 31, 1986**
>
> As discussed in Subsection 2.5.1.1.4.3.3.1, the largest historic event in the northeastern Ohio seismic zone was the January 31, 1986, magnitude (m_b) 5.0 event located about 40 km (24.4 mi.) east of Cleveland in southern Lake County, Ohio, and about 17 km (10.4 mi.) south of the Perry Nuclear Power Plant (Reference 2.5.2-224). This earthquake was located 175 km (108 mi.) from the site. The earthquake produced Modified Mercalli intensity (MMI) VI to VII at distances of 15 km (9 mi.) from the epicenter and short-duration high accelerations of 0.18 g at the Perry plant (Reference 2.5.2-224). The Fermi 3 site experienced Modified Mercalli Intensity (MMI) IV–V during this event (Reference 2.5.2-228). Thirteen aftershocks were detected by April 15, 1986, with magnitudes ranging from 0.5 to 2.5 and focal depths ranging from 2 to 6 km (1.2 to 3.7 mi.) (Reference 2.5.2-224). Although these events were within 12 km (7.4 mi.) of a deep waste disposal injection well, Nicholson et al. (Reference 2.5.2-224) argue a natural origin for the earthquakes.
>
> **July 12, 1986**
>
> The July 12, 1986, event near the town of St. Marys in Auglaize County was the largest earthquake to occur in the Anna seismic zone since 1937 (Reference 2.5.2-226). This earthquake was located 184 km (114.3 mi.) from the site. Schwartz and Christensen (Reference 2.5.2-223) determined a hypocenter of 5 km (3 mi.) for the magnitude (m_b) 4.5 event and a focal mechanism (strike = 25°, dip = 90°, rake = 175°) representing mostly strike-slip with a small oblique component approximately parallel to the Anna-Champaign fault and a nearly horizontal P axis oriented east-northeast. The earthquake produced an MMI V1 event (Reference 2.5.2-226). The Fermi 3 site experienced approximately MMI III during this event (Reference 2.5.2-229)."

The statement that the January 31, 1986, earthquake produced Modified Mercalli Intensity (MMI) IV-V shaking at the Fermi 3 site is based on an isoseismal map presented by Hansen (FSAR Reference 2.5.1-228) as shown on Figure 1. The statement that the July 12, 1986, earthquake produced MMI III shaking at the Fermi 3 site is also based on an isoseismal map presented by Hansen (FSAR Reference 2.5.1-229) as shown on Figure 2. These two isoseismal maps were taken from Stover and Brewer (Reference 1), which include the locations of felt reports for both events, as determined from surveys. Attached Figures 3 and 4 contain Stover and Brewer's (Reference 1) original isoseismal maps with intensity data for the January 31 and July 12, 1986, earthquakes, respectively. Felt earthquake intensity reports are plotted as a Roman numeral of the intensity, and earthquakes reported not to have been felt are plotted as an open circle. A felt report for the town of Monroe, Michigan, provides evidence for MMI IV shaking during the January 31, 1986, earthquake. The closest felt reports to the Fermi 3 site during the July 12, 1986, earthquake indicate that the event was not felt; however intensity III reports were obtained from the towns of Dundee and Gross Ile, located 31.5 km (19.6 mi) and 21 km (13 mi), respectively, from the Fermi 3 site. The Earthquake Intensity Database maintained by NOAA does not contain intensity data for Michigan after 1983 (Reference 2).

Strong-motion recordings were not identified for the January 31, 1986, and July 12, 1986, events near the Fermi 3 site. Stover and Brewer (Reference 1) do not list accelerometer data for these two events. Three strong-motion stations maintained by the National Strong-Motion Program (Reference 3) located within the site region in Dayton, Ohio, Erie, Pennsylvania, and Marion, Indiana, have been in operation since 1973 (Reference 4). There are no strong motion records available for the site vicinity.

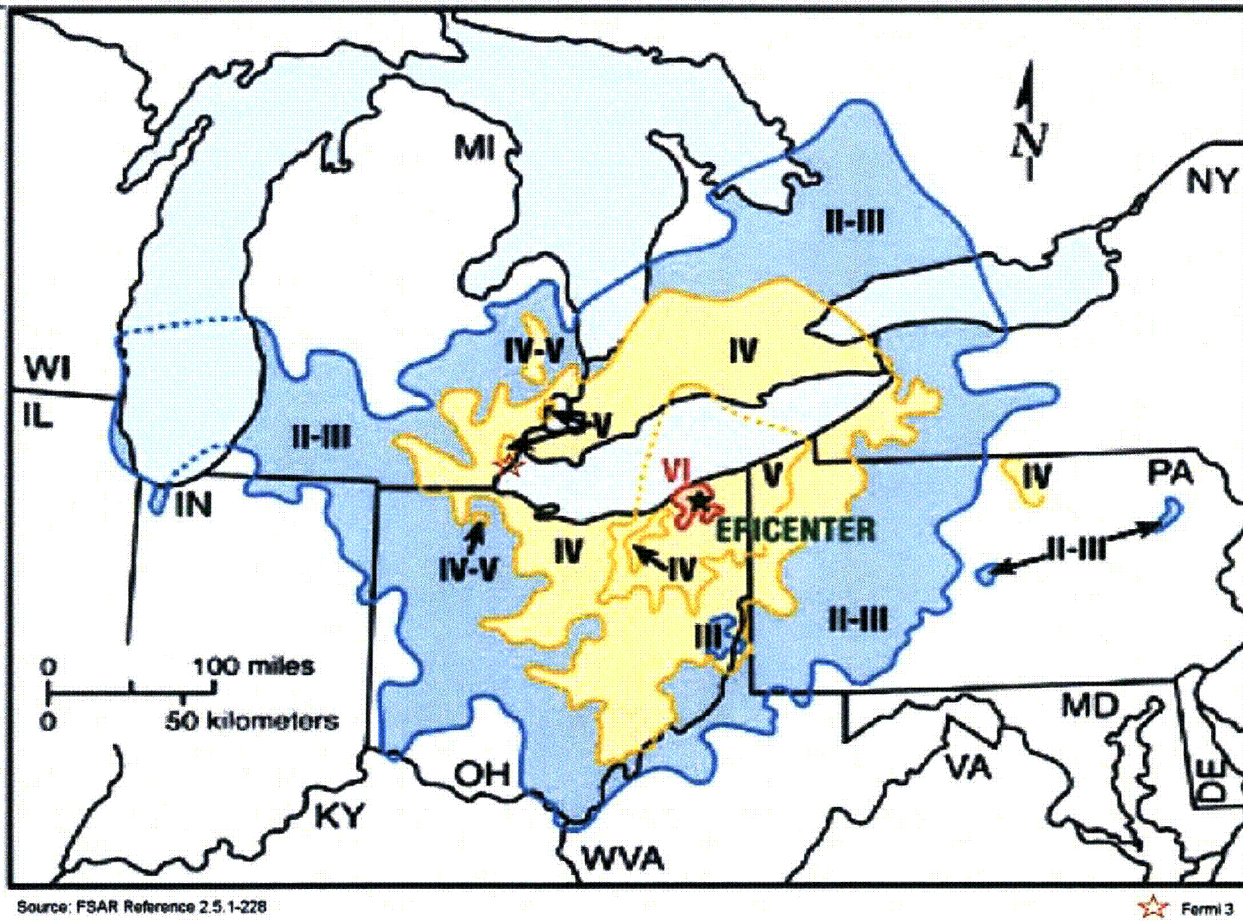

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Figure 1 – Isoseismal Map of the January 31, 1986, Earthquake (FSAR Reference 2.5.1-228).

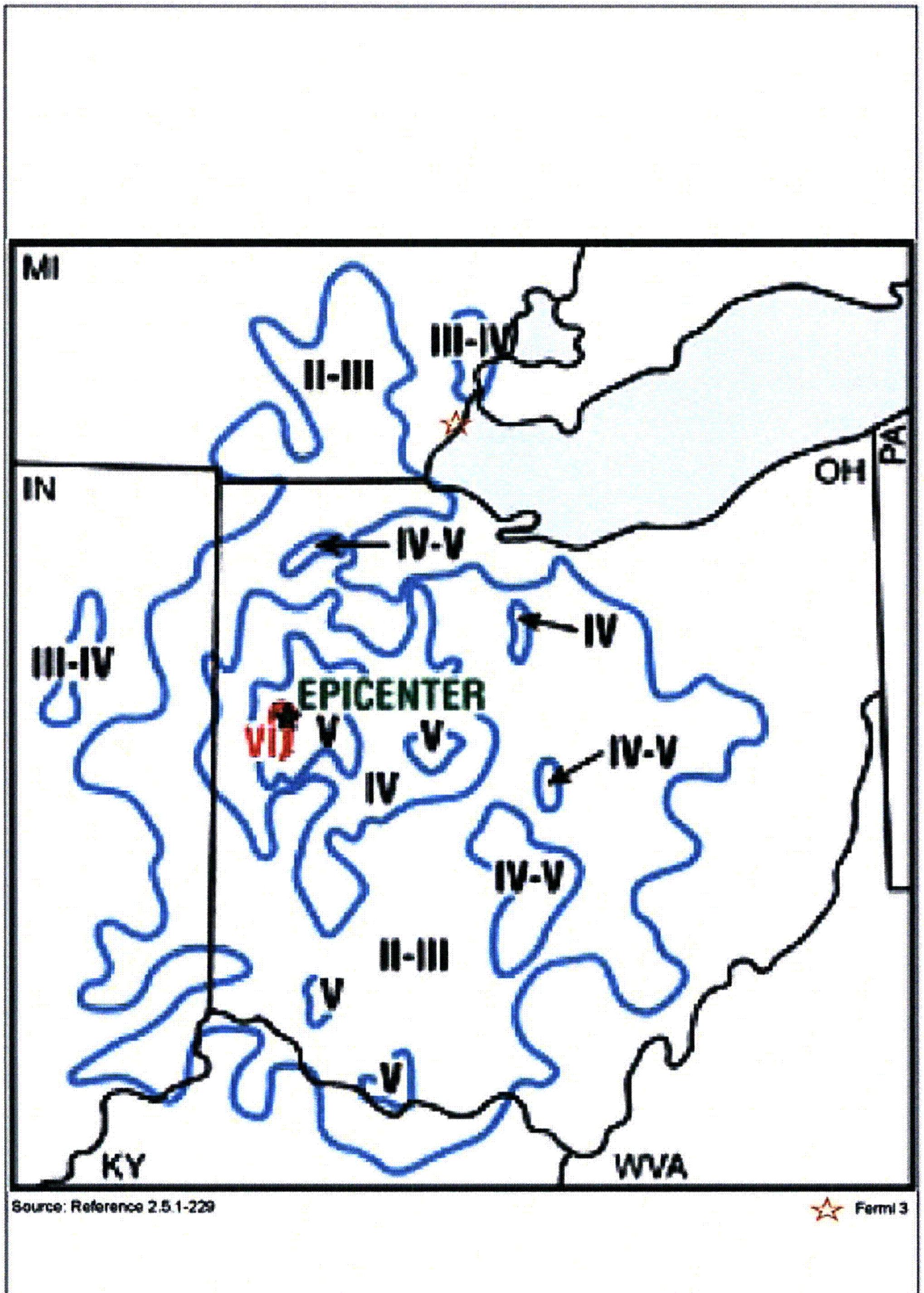

Figure 2 – Isoseismal Map of the July 12, 1986, Earthquake (FSAR Reference 2.5.1-229).

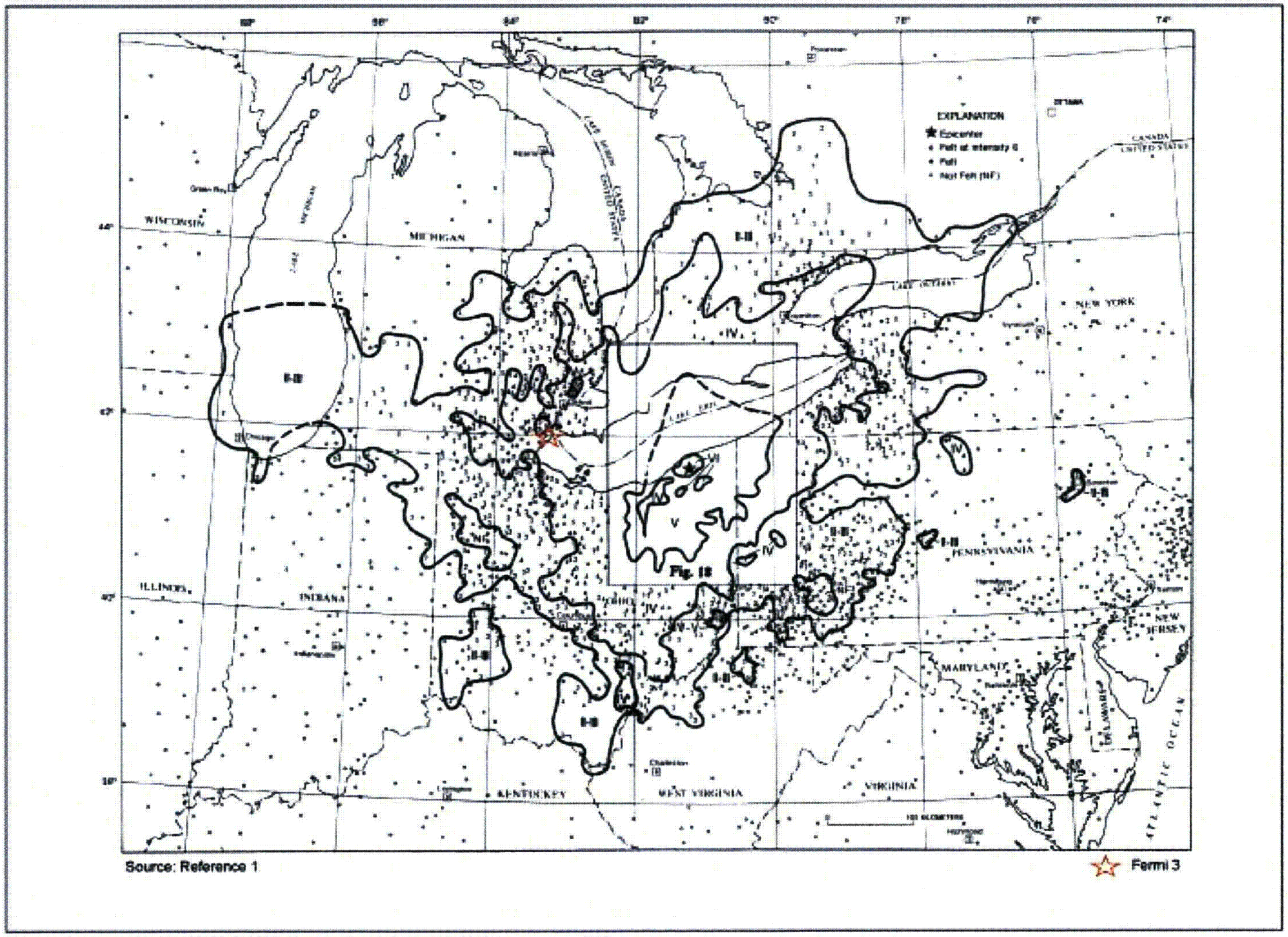

Figure 3 – Isoseismal Map of the January 31, 1986, Earthquake (Reference 1).

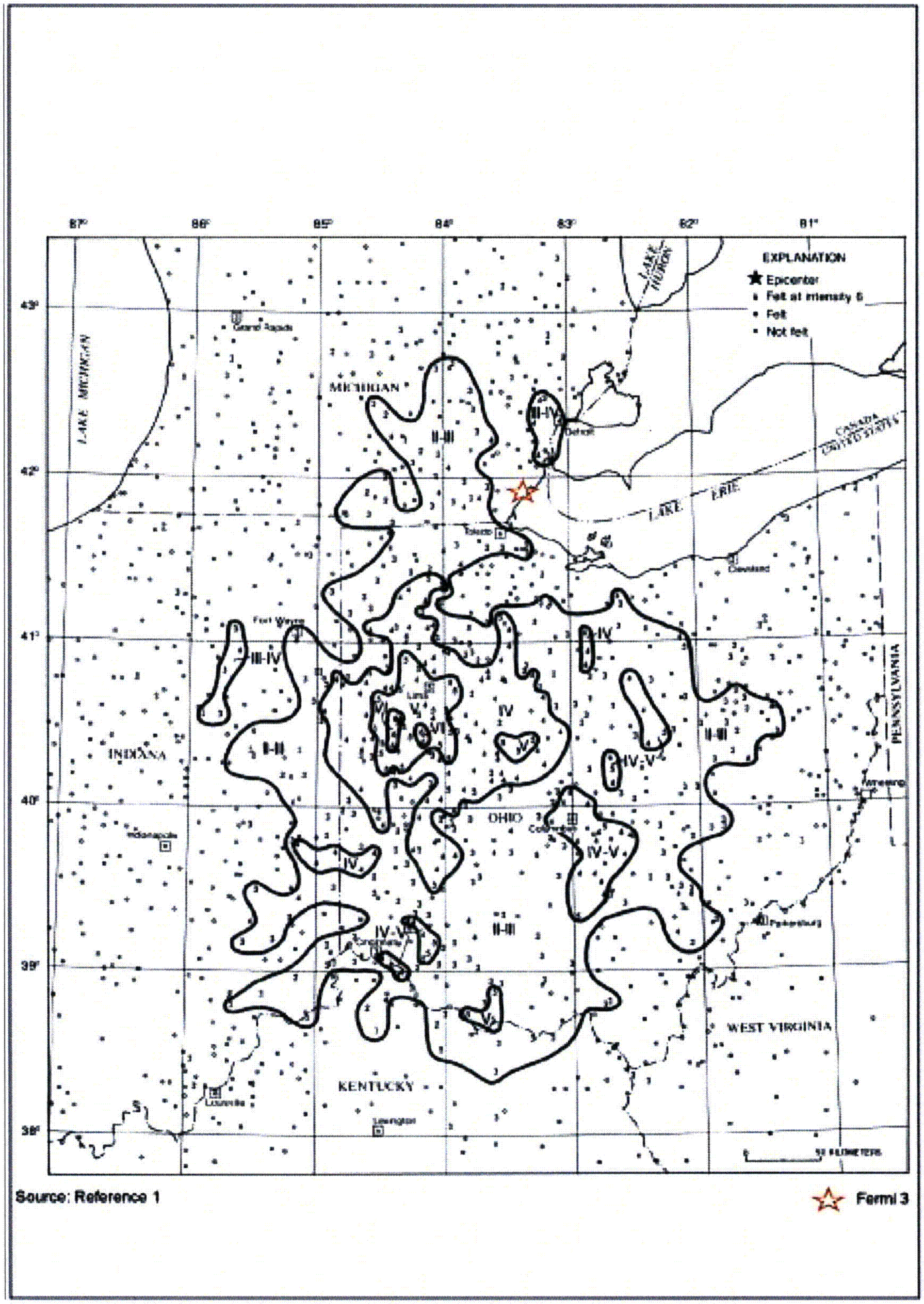

Figure 4 – Isoseismal Map of the July 12, 1986, Earthquake (Reference 1).

References

1. Stover, C.W., and Brewer, L.R., "United States Earthquakes, 1986," U.S. Geological Survey Bulletin 2089, 1994.

2. NOAA Earthquake Intensity Database, http://www.ngdc.noaa.gov/hazard/int_srch.shtml#city.

3. National Strong-Motion Program, Station List, http://nsmp.wr.usgs.gov/stations.html.

4. E-mail between Erol Kalkan (USGS) and Laura Glaser (AMEC Geomatrix), January 12, 2010.

Proposed COLA Revision

None.

Attachment 21
NRC3-10-0006

Response to RAI Letter No. 22
(eRAI Tracking No. 3937)

RAI Question No. 02.05.01-10

RAI 02.05.01-10

FSAR Section 2.5.1.1.4.3.3.1 does not discuss liquefaction studies within the Northeast Ohio seismic zone. However, Crone and Wheeler (FSAR Reference 2.5.1–316) cite Obermeier for his examination of streambanks for liquefaction features in the Northeast Ohio seismic zone. Paleoliquefaction investigations are relevant to evaluating the potential for magnitude 6 or larger earthquakes that may have occurred within the Northeast Ohio seismic zone. Given the proximity of the Northeast Ohio seismic zone to the Fermi site, an earthquake of magnitude 6 or larger may impact the seismic hazard at the Fermi site. Therefore, please include a description of any paleoseismic investigations conducted in the Northeast Ohio seismic zone including the locations investigated and the level of detail of the investigations.

Response

In a 1995 National Earthquake Hazards Reduction Program (NEHRP) annual summary report, Obermeier (Reference 2.5.1-482) discussed the results of a paleoseismic liquefaction field study along two of the larger drainages in northeast Ohio: the Grand River and the Cuyahoga River. Approximately 25 km (7.6 mi.) of stream banks along each river were searched and no evidence of liquefaction was observed along either transect. Conditions and ages of the sediment encountered along each of these rivers as noted by Obermeier (Reference 2.5.1-482) were summarized in the report, as follows.

- Radiocarbon data from along the Grand River show that many of the exposures searched are at least 2,000 years old. Many others are probably mid-Holocene in age, based on depth and severity of weathering. A few scattered sites are earliest Holocene in age. Liquefaction susceptibility at many of the sites examined is at least moderate.
- Numerous exposures along the Cuyahoga River are at least a few thousand years in age, and scattered exposures are up to 8,000 years old, based on radiocarbon data. Conditions are very good for forming liquefaction effects at many places.

Additional documentation of the 1995 paleoliquefaction field search in northeast Ohio, which focused on the vicinity of the nuclear power plant near Perry, Ohio, was provided to the U.S. Nuclear Regulatory Commission (NRC) in a letter report submitted to Dr. Andrew Murphy by Dr. Obermeier on May 23, 1996 (Reference 2.5.1-483). A copy of this letter report and additional notes on communications with Dr. Obermeier were made available to this project by Dr. Russell Wheeler, U.S. Geological Survey, on November 17, 2009. Figure 1 shows the locations of the rivers searched as described in the letter report to the NRC. Table 1 summarizes the conditions (liquefaction susceptibility and estimated ages of sediments) and observations at various localities within the study area.

Based on these observations, Dr. Obermeier made the following conclusions:

- The lack of suitable exposures within 20 km (12 mi)of the nuclear power plant at Perry, Ohio, precludes definitive statements as to whether there has been strong seismic shaking for most of Holocene time.
- The lack of exposures with liquefiable sediment more than a few thousand years old, within 20 to 25 km (12 to 16 mi) of the plant, precludes any statement concerning whether there could have been strong shaking at the plant locale from even moderate-sized earthquakes (M ~ 6) occurring more than a few thousand years ago.
- The lack of liquefaction features in latest Pleistocene sediment (moderate to high liquefaction susceptibility through time) in the Pit-CL locality does not provide sufficient data to make a statement on seismic shaking at a distance of 32 km (20 mi) from the Perry nuclear power plant.

Dr. Obermeier noted in the letter report that perennial streams flowing subparallel and through a beach ridge/sand dune complex within 2 to 6 km (1 to 4 mi) inland from the shore (identified from examination of the Soil Survey Report of Lake County) might offer the possibility of a field setting where liquefaction features could have developed for much of Holocene time. These streams were not searched during the 1995 study or in any subsequent studies by Obermeier.

Erik Venteris (Ohio Geological Survey), who as a graduate student worked with Dr. Obermeier on the paleoliquefaction studies in northeast Ohio, was contacted to determine whether additional work had been done since the studies in 1995. He indicated that he has not done any additional paleoliquefaction reconnaissance in the area since the 1995 study. Based on a thorough literature search, no additional paleoliquefaction studies have been done in the area since the 1995 studies.

References

2.5.1-482 Obermeier, S., "Paleoseismic Liquefaction Studies—Central and Eastern US," USGS Annual Report, Volume 37, 1995, accessed in 1998 at http://erp-web.er.usgs.gov/reports/VOL37/CU/obermeier.htm, paper copy provided by Russ Wheeler on November 17, 2009.

2.5.1-483 Obermeier, S., "Summary of 1995 Paleoliquefaction Field Search in the Vicinity of Perry, Ohio," Letter submitted to Dr. Andrew Murphy, U.S. Nuclear Regulatory Commission, 10 pp., May 23, 1996.

Table 1. Summary of paleoliquefaction study areas of Obermeier (1995) in northeast Ohio

Stream	Reconaissance Area	Approx. Stream Length	Location Along Stream	Geology	Liquefaction Susceptibility	Age of Deposits	Conclusions Regarding Strong Ground Shaking
Grand River	GR-A	4 km	Swine Creek at intersection with SR 87 beyond confluence with Grand River	Clean liquefiable sand (inferred from augering) capped by clay-rich sediments	High	Base of clay-rich cap at two localities 4,690 and 13,780 radiocarbon yr before present (BP)	Unlikely that area has experienced strong ground shaking during the past 4,000 years
Grand River	GR-B	3 km	From Montgomery Road to Johnson Road	Not specified	Uncertain	Not provided	
Grand River	GR-C	3 km	Shaffer Road to Footville-Richmond Road	3-5 m (9.8 to 16.4 ft.)thick clay-rich cap over thick, clean sand	High	Base of clay-rich cap 2,080 to 2,230 radiocarbon yr BP	Unlikely that area has experienced strong ground shaking during the past 2,000 years
Grand River	GR-D	3 km	Sweitzer Road to Cork-Cold Springs Road	Clay-rich cap over local clean sands (no sand identified by augering)	High in places	Base of clay-rich cap 1,000 to 3,000 yr BP based on degree of weathering	
Grand River	GR-E	3 km	Lampson Road to Sexton Road	Clay-rich deposits to at least 8 ft depth, shallow bedrock	Low	Clay-rich cap 1,000 to 2,000 yr BP based on degree of weathering	
Grand River	GR-F	4 km	Blair Road to Madison Avenue	Clay-rich cap over clean sand, shallow depth to bedrock	Low	Clay-rich cap less than 1,000 yr BP based on degree of weathering	
Grand River	GR-G	3.5 km	"V" in "River" on topographic map to bridge at SR 535	Upstream area: clay-rich cap over clean sand downstream area: clay-rich cap with some local sand	Low within past several thousand years based on water table	Upstream area: clay-rich cap more than several thousand yr BP based on degree of weathering downstream area: clay-rich cap less than 1,000 yr BP based on degree of weathering	Unlikely that area has experienced strong ground shaking during the past few thousand years

Trumbull Creek	TR-A	1.5 km	Riverdale to confluence with Grand River	Clay-rich cap over local sand	High to low	Clay-rich cap more than several thousand years BP based on degree of weathering	Unlikely that area has experienced strong ground shaking during the past few thousand years
Cuyahoga River	CUY-A	16 km	Boston Mills to Rockside Road	Clay-rich cap over liquefiable sand	High	Oldest clay-rich cap 4,000 radiocarbon yr BP to 710 yr BP	Area has not experienced strong ground shaking during the past 500-1,000 years and probably not during the past 4,000 years
Cuyahoga River	CUY-B	5 km	Bridge at SR 87 to 5 km downstream	Not specified—exposure only at bridge	Uncertain	Not provided	
Near Tributary to Phelps Creek	PIT-CL	400 m	Sand pit on SR 534 just north of Ashtabula-Trumbull county line	Glaciofluvial sand with low-permeability cap	High to moderate—lack of weathering suggests a shallow groundwater table through Holocene time	Uncertain	Unlikely that area has experienced strong ground shaking through all or most of Holocene time
Streams unsuitable for paleoliquefaction studies							
Chagrin River							
East Branch Chagrin River							
Most of the east-west portion of the Grand River downstream from Mechanicsville							
Big Creek							
Paine Creek							
Mill Creek							
Rock Creek							
Lake Erie shoreline exposures between Ashtabula and the mouth of the Chagrin River were examined and found to be too clay-rich to be susceptible to liquefaction.							
Abandoned sand pits in beach sands and dune deposits formed during high levels of ancient Lake Erie were examined. The water table was very deep in all pits, and no suitable exposures were found that contained liquefiable deposits.							

Note: The field survey was conducted from a canoe at a time when the seasonal water table was extraordinarily low because of a prolonged drought; therefore, any paleoliquefaction features should have been conspicuous.

Figures

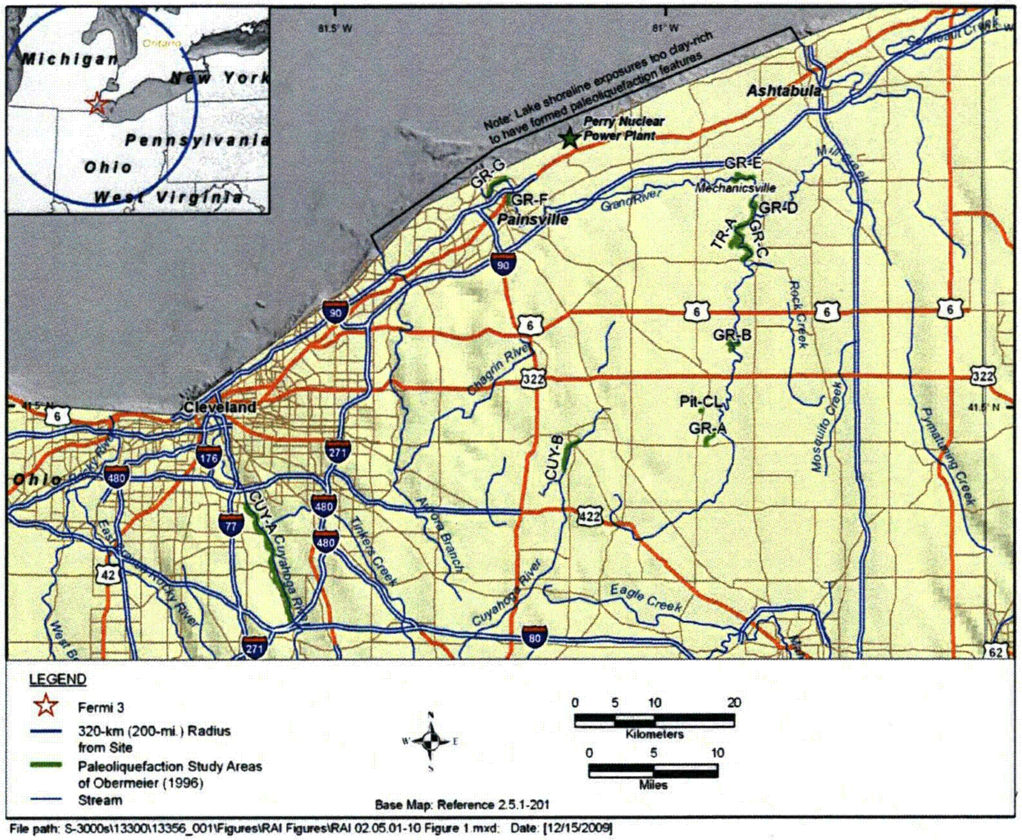

Figure 1. Paleoliquefaction study areas of Obermeier (1995) in northeast Ohio.

Proposed COLA Revision

Revisions to Section 2.5.1.1.4.3.3.1 to discuss the results of paleoliquefaction studies conducted in the Northeast Ohio seismic zone region are provided with the Response to RAI 02.05.01-28.

Attachment 22
NRC3-10-0006

Response to RAI Letter No. 16
(eRAI Tracking No. 3917)

RAI Question No. 02.05.03-03

RAI 02.05.03-03

FSAR Section 2.5.3.2.1 briefly discusses Quaternary stratigraphy based on FSAR Section 2.5.1 but does not report details of observations that bear on the deformation or lack of deformation of Quaternary deposits as revealed in stratigraphic exposures. Please describe any observations of the stratigraphy (from pits, trenches, boreholes, or natural exposures) that help constrain postglacial deformation in the site vicinity, especially with respect to the lacustrine deposits. In addition, please provide any relevant figures to help document your observations and conclusions regarding the Quaternary deposits surrounding the Fermi site.

Response

Quaternary surficial geologic units exposed in the Fermi 3 site vicinity (40 km [25 mi.] radius) consist primarily of till of Wisconsinan age overlain by a thin mantle of lacustrine and eolian sands or locally thicker beach–dune ridge deposits formed along late glacial lake shorelines (FSAR Figure 2.5.1-231). Publications and reports describing glacial lake deposits and shoreline features (e.g., References 2.5.1-297 and 2.5.1-391), as well as electronic data for Quaternary map units (e.g., References 2.5.1-450, 2.5.1-451, and 2.5.1-452) and soil maps (Reference 2.5.1-405), were compiled and reviewed, providing key data sets for evaluating the surficial stratigraphy and geomorphology in the site vicinity. Field and aerial reconnaissances were conducted in 2007 and 2009 to further evaluate the stratigraphy in the site vicinity. The reconnaissance routes and key field stop localities are shown on Figure 1.

Localities where good exposures of Quaternary stratigraphic relationships were clearly observed are few. As illustrated in the photographs of the lacustrine/till plain that is present throughout the majority of the site vicinity (Figures 2 and 3), there is very little relief, and stream incision by the smaller drainages is minimal. This is especially the case for streams cutting across the lacustrine/till plain below the Lake Grassmere lake level (approximately elevation 195 m [640 ft]). Stream incision along even major streams like the Raisin River, as observed in the vicinity of Dundee, Michigan (Field Reconnaissance GPS Stops GMX-15 and GMX-17) (Figure 1), is limited. The Raisin River is incised approximately 1.5 m (4.9 ft) below the lacustrine/till plain at elevation 181.2 m (594 ft) and 3.2 m (10.5 ft) below the slightly higher terrace surface at elevation 183 m (600 ft). An exposure of till at an elevation of about 181 m (594 ft) that was observed at stream level at Field Reconnaissance GPS Stop GMX-30 suggests that Stoney Creek has not incised significantly into bedrock below the till. Deposits of younger alluvium are not well exposed due to the vegetation along stream banks.

Other streams such as Swan Creek also show limited incision. At B&V Field Stop C (at an elevation of approximately 182 m [597 ft]), the present channel of Swan Creek is approximately 2 m (6.6 ft) below the general elevation of the lacustrine/till plain

(Figure 4). The present meandering channel is incised about 0.6 m (2 ft) into a low, broad floodplain of young alluvium mapped as the Sloan soil series.

Maps showing the thickness of unconsolidated sediment and top of bedrock inferred from a review of 2,500 well logs and test boring data suggest that significant incision is present only in the lower reaches of the major drainages (Reference 2.5.1-389) (Figures 5 and 6). Sand ridges are primary depositional features that have been used to define the location and elevation of paleoshorelines (strandlines) associated with late glacial lakes in the site vicinity (References 2.5.1-297 and 2.5.1-391) (Figure 7). Additional discussion of the geomorphic expression of the strandline features that define the paleoshorelines is provided in the Response to RAI 02.05.03-06. These features have varying geomorphic expression, from discontinuous, thin, patchy layers (Figure 3), to low ridges of sand (Figure 8)), to better-defined slope breaks associated with sand ridges at or just below the Lundy strandline (Figure 9) and older, higher lake levels (Lakes Maumee and Arkona). The thicker sand bodies, which are described in the literature (References 2.5.1-488 and 2.5.1-490), are well expressed geomorphically and have been differentiated by geologic and soils mapping units (References 2.5.1-451 and 2.5.1-405).

Denniston Quarry Exposures

Initial observations in 2007, as well as in October 2009 at the Denniston Quarry (16 km [10 mi.] southwest of the Fermi 3 site), identified exposures of sand overlying till (Field Reconnaissance GPS Stop GMX 31 and B&V Field Stop B) (Figure 1). In December 2009 a detailed study was conducted at Denniston Quarry to evaluate deformed bedrock in the Silurian Bass Islands Group observed in the quarry. This study allowed for mapping of the entire sequence of Quaternary sediments and associated surface soils (Figure 2.5.1-258) overlying the Silurian Bass Islands Group bedrock exposed in the quarry (Reference 2.5.1-498). Three backhoe excavations in the Quaternary deposits at the quarry provided over 244 m (800 ft) of continuous lateral exposure of Quaternary deposits (Figure 2.5.1-258).

A major objective of the Denniston Quarry study was to document evidence for the presence or absence of deformation in the Quaternary deposits overlying deformation features identified in the underlying bedrock. A detailed report (Reference 2.5.1-498) discussing the study and its findings is provided in the response to RAI 2.5.1-29, which includes a detailed discussion of the material encountered during the excavations. The Denniston Quarry report concludes that there is no indication of deformation associated with tectonic activity or paleokarst features within the lacustrine sand or underlying till identified at the quarry. Proposed FSAR text updates for Quaternary stratigraphy observations at Denniston Quarry for Section 2.5.1 are provided with this response.

Attachment 22 to
NRC3-10-0006
Page 4

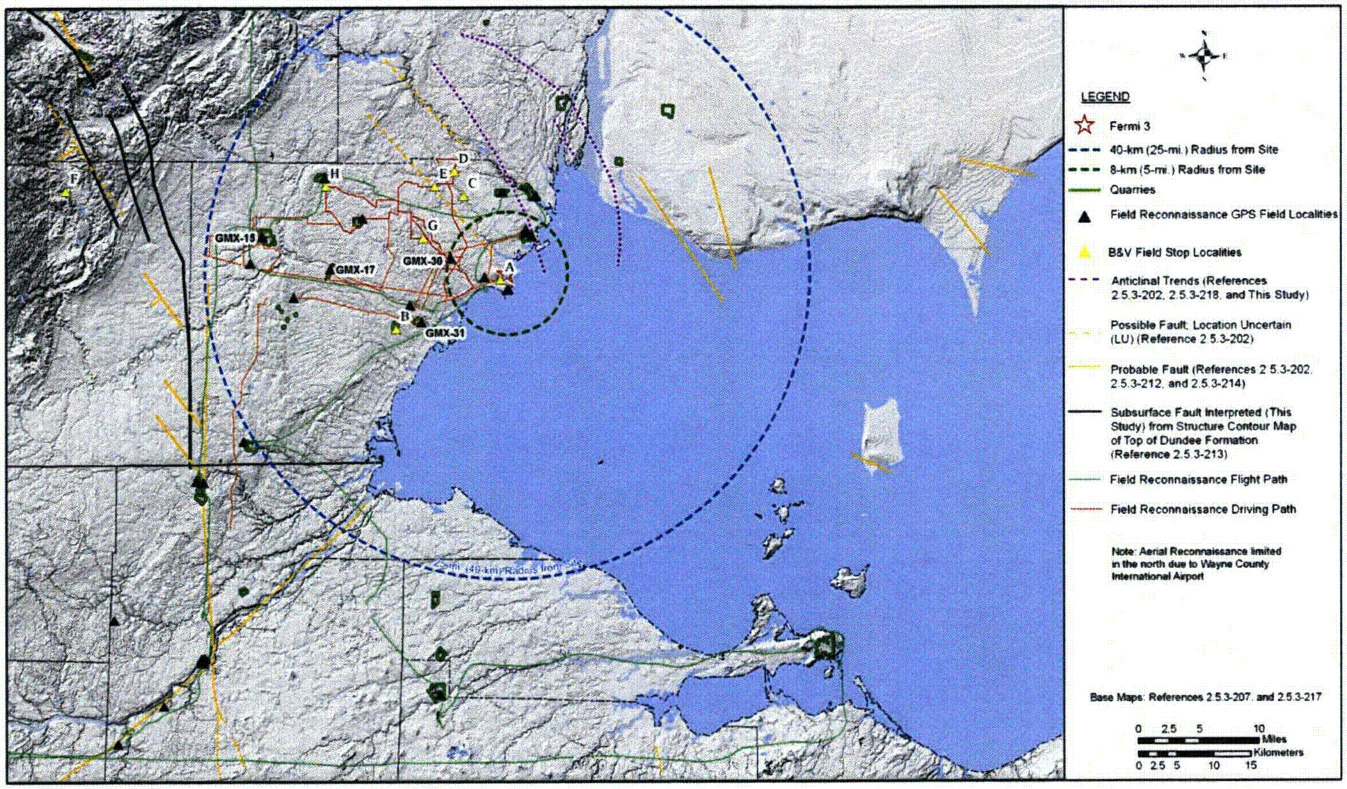

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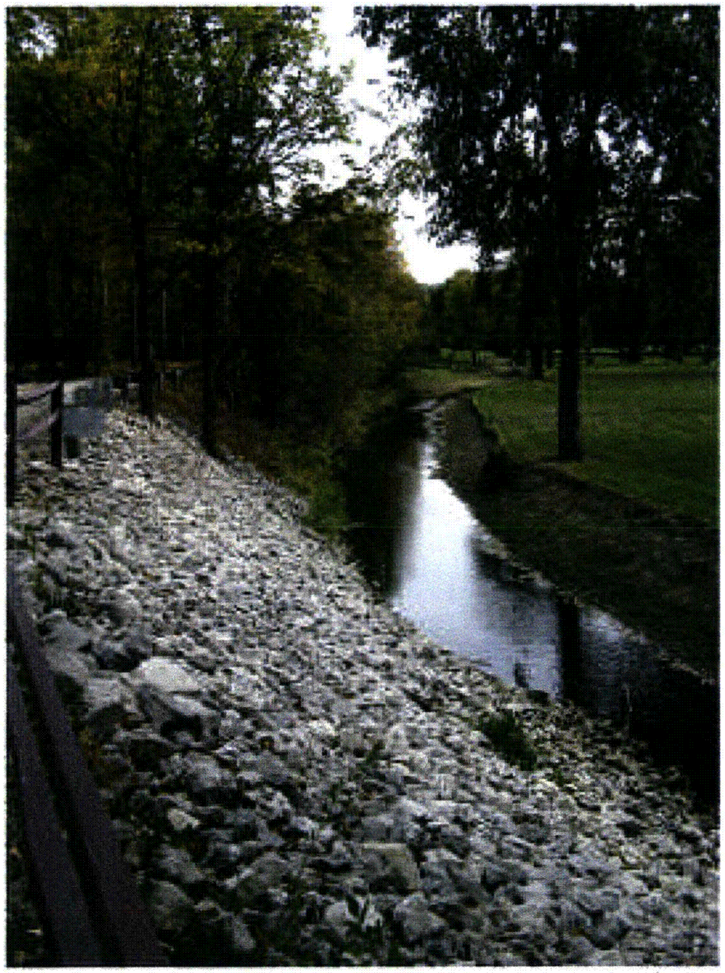
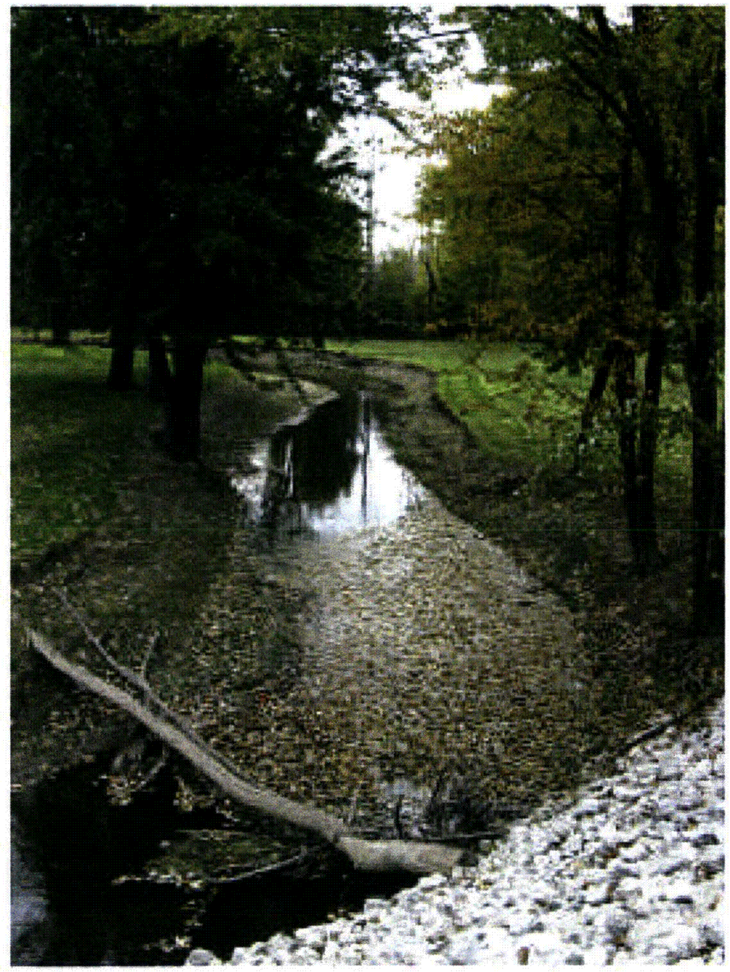
Figure 1. Map Showing the Aerial and Field Reconnaissance Routes and Key Field Localities

Figure 2. Photograph Showing the Lacustrine/Till Plain in the Vicinity of the Fermi 3 Site (view is to the southeast).

Figure 3. Photograph Showing Sand Deposits (tan-colored area) Marking a Subtle Paleoshoreline Feature on the Lacustrine/Till Plain Surface



a) View to the southeast subparallel to trend of Swan Creek



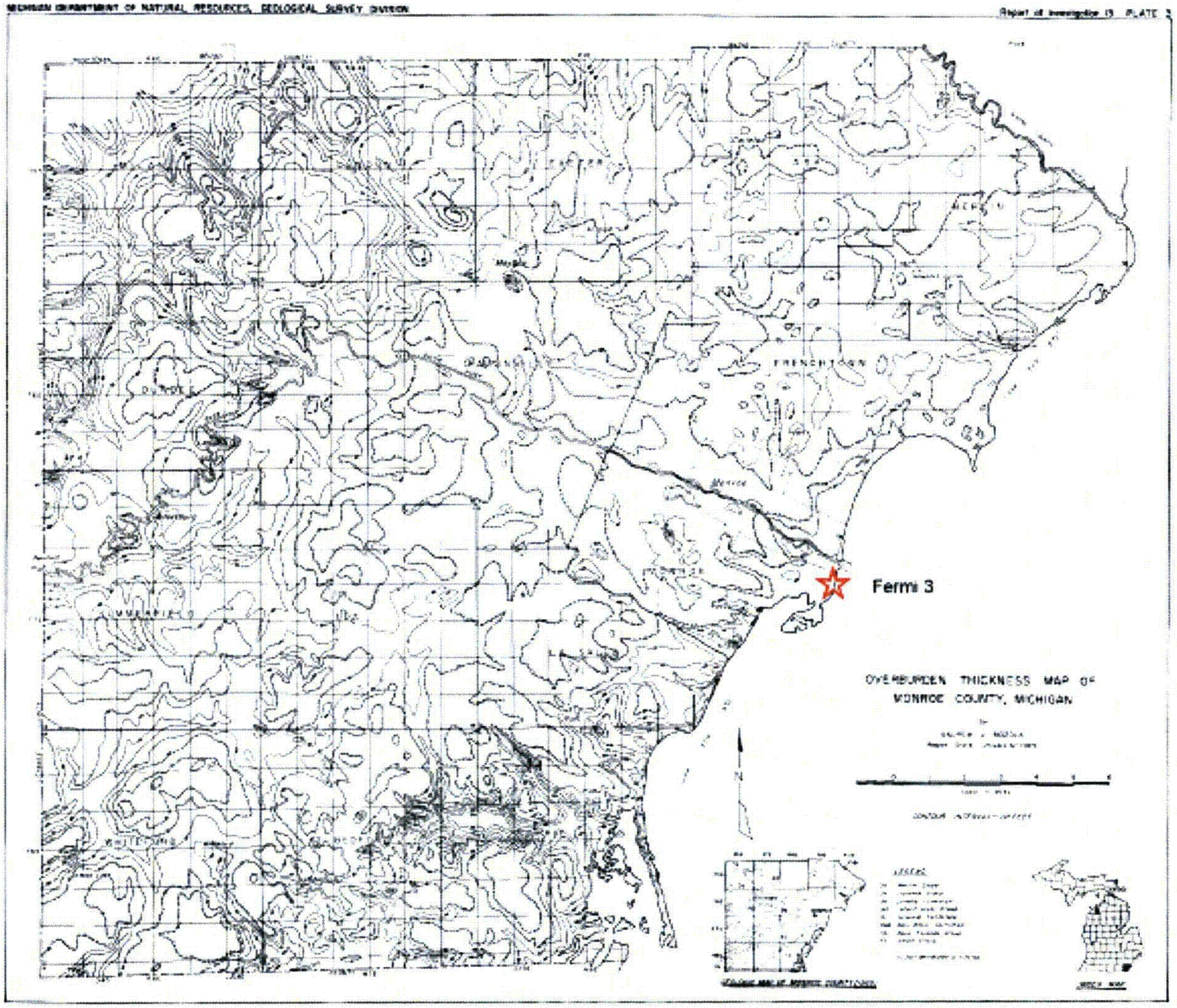
b) View to the southwest across modern floodplain at Swan Creek

Figure 4. Photographs Showing (a) the Present Channel of Swan Creek Incised Below the General Level of the Lacustrine Plain (Road Level), and (b) the Exposure of Alluvium Underlying Broad Modern Floodplain of Swan Creek

a) View to the southeast subparallel to trend of Swan Creek

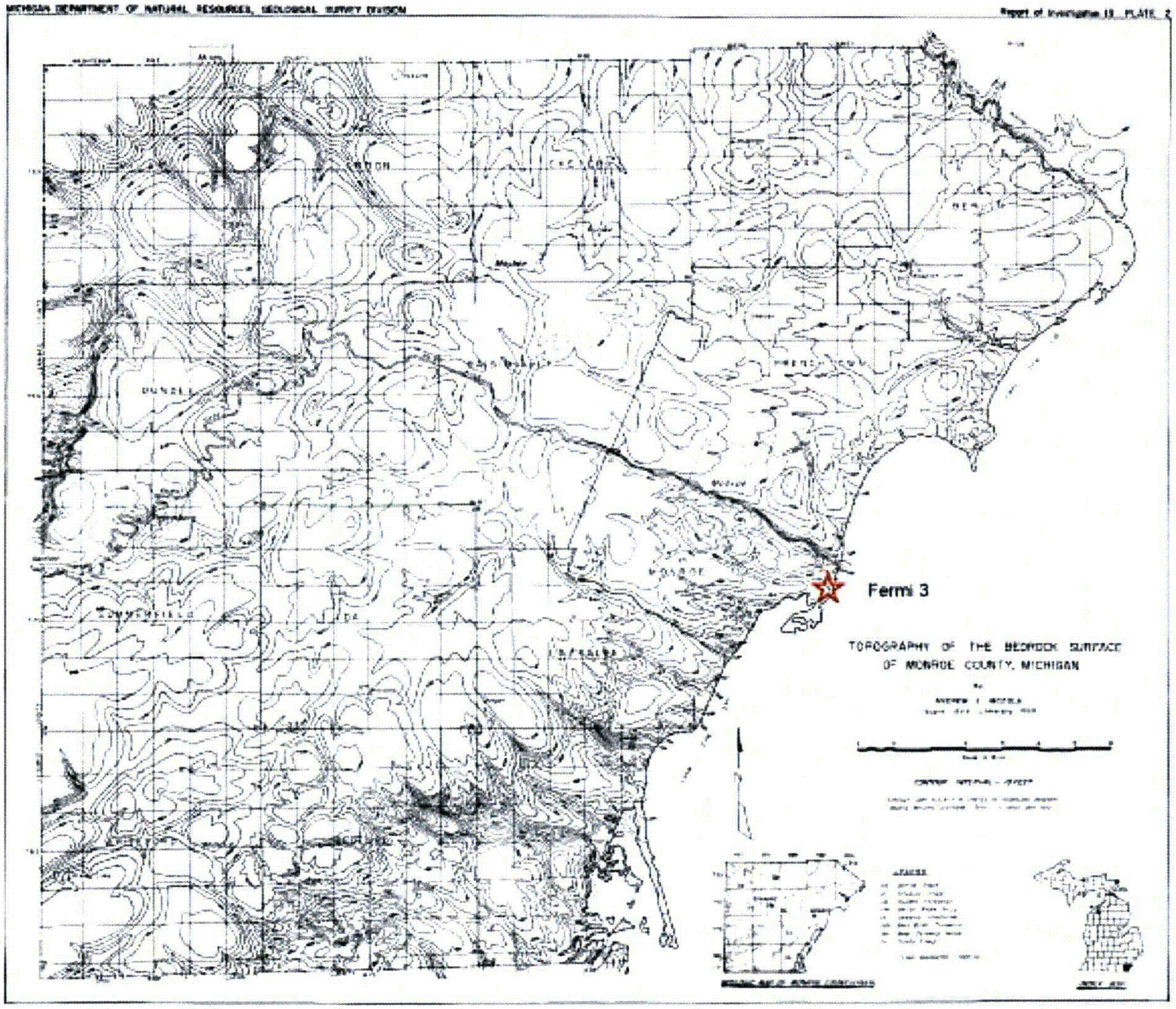
b) View to the southwest across modern floodplain at Swan Creek

Figure 4. Photographs Showing (a) the Present Channel of Swan Creek Incised Below the General Level of the Lacustrine Plain (Road Level), and (b) the Exposure of Alluvium Underlying Broad Modern Floodplain of Swan Creek



Source: Reference 2.5.1-389

Figure 5. Map Showing Inferred Thickness of Unconsolidated Sediment in Monroe County



Source: Reference 2.5.1-389

Figure 6. Map Showing Inferred Top of Bedrock in Monroe County

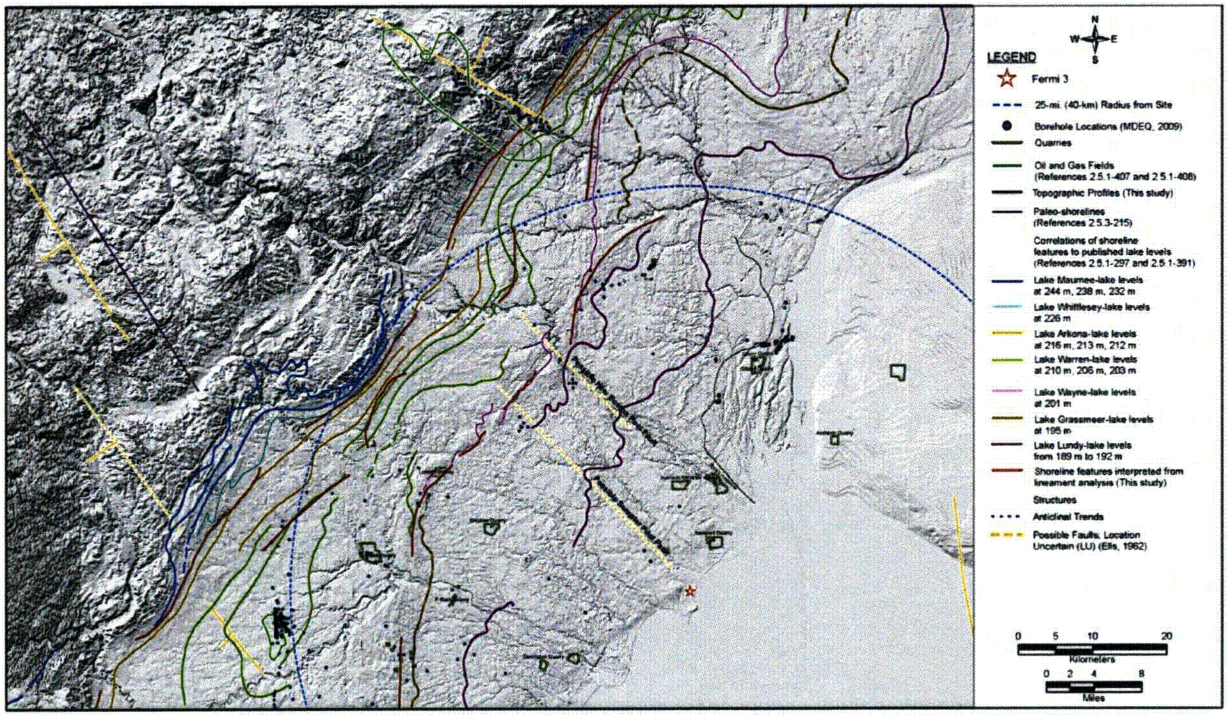


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Figure 7. Paleoshorelines and Structural Features in the Vicinity of the Fermi 3 Site

Figure 8. Photograph Showing Low Beach Ridge Topography (in foreground of photograph)

a) Geomorphic Expression (Subtle break in slope across road) of Beach Ridge Just Below the Lundy Shoreline at Field Stop G

b) Sand Ridge Deposits at Field Stop D

Figure 9. Photographs Showing (a) Geomorphic Expression (subtle break in slope across the road) of Beach Ridge Just Below the Lundy Shoreline at Field Stop G, and (b) nearby Sand Ridge Deposits at Field Stop D.

Proposed COLA Revision

Proposed markups to revise FSAR Sections 2.5.1.2.3.2.2 and 2.5.1.2.3.2.3 are attached. The response to RAI 2.5.3-7 provides proposed FSAR text markups addressing deformation of Quaternary deposits.

Markup of Detroit Edison COLA
(following 13 pages)

The following markup represents how Detroit Edison intends to reflect this RAI response in a future submittal of the Fermi 3 COLA. However, the same COLA content may be impacted by revisions to the ESBWR DCD, responses to other COLA RAIs, other COLA changes, plant design changes, editorial or typographical corrections, etc. As a result, the final COLA content that appears in a future submittal may be different than presented here.

Limestone, the Traverse Group, and Antrim Shale. These units are not discussed because they are in the western portion of the site vicinity and are generally covered in Subsection 2.5.1.1.3.2.3 Kaskaskia cratonic sequence.

Add Insert #1 here

2.5.1.2.3.2.3

~~2.5.1.2.3.2~~ **Quaternary Stratigraphy of the Site Location**

This section concentrates on the Quaternary units encountered as part of the Fermi 3 subsurface investigation including, listed from oldest to youngest, glacial till, lacustrine deposits, and fill.

2.5.1.2.3.2.3.1

~~2.5.1.2.3.2.1~~ **Glacial Till**

Glacial till predominantly overlies the top of bedrock (Bass Islands Group) over the entire (1-km [0.6-mi] radius) site location. At the top of bedrock, there is often sand or gravel that may represent weathered bedrock. To the west and northwest of the Fermi 3 site near borings MW-381 and MW-393 (Figure 2.5.1-235), the glacial till is immediately below the top soil. Throughout the remainder of the site location the glacial till is overlain by lacustrine deposits. The glacial till ranges from 1.8- to 5.8-m (6- to 19-ft) thick. The glacial till is subdivided into an upper and lower unit based on color. The composition of the glacial till is comprised of predominantly of fines with variable amounts of sand, and gravel, with cobbles.

The lower glacial till is a gray to dark gray, lean clay with sand or gravel (CL), silt with sand or gravel (ML), or clayey graded gravel (GC). The individual boring logs from the Fermi 3 subsurface investigation show that the glacial till is homogeneous; however, variations in glacial till composition between borings in the Fermi 3 subsurface investigation indicates some heterogeneity in the lower glacial till across the site.

The upper glacial till is brown to grayish brown, lean clay with sand or a trace of gravel (CL). The Fermi 3 subsurface investigation did not attempt to determine the age or correlation of these glacial tills to the Quaternary stratigraphy presented in Subsection 2.5.1.1.2.3.4.

2.5.1.2.3.2.3.2

~~2.5.1.2.3.2.2~~ **Lacustrine Deposits**

Quaternary lacustrine (lake) deposits overlie the glacial till except near borings MW-381 and MW-393 (Figure 2.5.1-235). The thickness of the lacustrine deposits ranges from 0 to 2.7 m (0 to 8.7 ft). The lacustrine deposits are laminated gray, dark gray, and reddish brown lean clay (CL) and fat clay (CH). In some areas the lacustrine deposits are overlain by a

Insert #1

2.5.1.2.3.2.2 **Quaternary Deposits and Soils in the Site Vicinity**

The thickness of unconsolidated sediment overlying bedrock in Monroe County varies from a few centimeters to more than 46 m (150 ft). In general, the sediments are less than 15 m (50 ft) over most of the area. The thickest deposits are associated with well-defined valleys carved into the rock surface, particularly in the southeastern, western, and northwestern townships in the county. (Reference 2.5.1-389).

2.5.1.2.3.2.2.1 **Glacial Deposits**

The oldest Quaternary material identified in the site vicinity is till that directly overlies Paleozoic bedrock and is overlain by a thin mantle of lacustrine and shoreline deposits. Compilation and review of over 2,500 soil test borings, water well logs, and oil and gas records show that the bedrock surface in Monroe County appears to be nearly everywhere overlain by till described as an unstratified stiff, blue-gray clay admixed with varying proportions of silt, sand, pebbles, and cobbles (Reference 2.5.1-389).

Only limited exposures of the till units were observed during the field reconnaissance. The best exposures of till were observed in Quaternary excavations completed at the Denniston Quarry approximately 16 km (10 mi) southwest of the Fermi 3 site (Reference 2.5.1-498) (Figure 2.5.1-258). Two till units, an upper brown till and a lower gray till, were well exposed in these excavations (Figures 2.5.1-260, 2.5.1-261, and 2.5.1-262). Both till units, which are very compact and hard, are silt and clay rich. The tills are sparsely pebbly, and cobbles and boulders are rare, except for basal clast pavements. The brown till is sandier, especially in the upper parts of the unit, and locally exhibits a fissile or subhorizontal blocky structural fabric. The underlying gray till generally has fewer gravel clasts, with the exception of some cobbles and boulders that are present in the basal part of the unit. In the Denniston Quarry exposures, the lower till unit locally includes larger boulders and blocks of the underlying Bass Islands Group bedrock. The more abundant, larger blocks appear to be localized in the vicinity of the nearby paleokarst features and are likely due to the plucking of more easily eroded bedrock in these zones by the overriding glacier. Larger blocks of bedrock would tend to be deposited close to their source.

In the Denniston Quarry excavations, the two till units are separated by a clast pavement and locally by possible glaciofluvial sediments in poorly defined channels at the base of the brown till (Figure 2.5.1-260). Clast pavements are common at the base of fine-grained glacial till associated with the late Pleistocene Laurentide ice sheet (Reference 2.5.1-491; Reference 2.5.1-492). The clast pavement observed at the Denniston Quarry is typical of clast pavements described in the literature in that it consists of a layer of rounded-to-subrounded cobbles and small boulders, generally one clast thick, with individual clasts separated from each other by enclosing sediment. Settling of clasts through low-strength, fine-grained deforming subglacial sediment, followed by clast abrasion by overriding deforming sediment analogous to a debris flow, is suggested by Clark (Reference 2.5.1-491) as a formative mechanism for explaining the observed characteristics of such clast pavements. Hicock (Reference 2.5.1-492) notes that subglacial processes, including lodgment, deformation, meltout, and erosion, are probably all end-members in a continuum of pavement-forming processes.

The exact ages of the till units in the site vicinity are unknown. As discussed in Subsection 2.5.1.2.3.2.3, an upper brown and lower gray till also were identified from boring samples at the Fermi 3 site. Both till units are assumed to be Woodfordian in age (MIS 2), based on the location and geomorphic position of the till units relative to late Wisconsinan end and ground moraines (FSAR Figure 2.5.1-205), the presence of calcareous material in the less-weathered or oxidized parent material of both units, and the lack of buried soils between the two units to indicate significant periods of subaerial exposure. It is not certain whether the two units are significantly different in age or whether the brown color of the upper till unit is primarily due to oxidation of the upper part of a till related to a single glacial advance, as has been noted in Ohio till units (Reference 2.5.1-220).

The available data do not permit a conclusive correlation of the till units to substages within the Woodfordian. The uniform, clayey texture of the lower gray till unit suggests that it may have formed as the glacier advanced across lacustrine sediments (possibly sediments deposited in Lake Everett formed during the Erie Interstadial between about 16 and 15.5 ka (FSAR Figure 2.5.1-234). The clay-rich character of the till, however, is similar to that of the Hiram Till mapped throughout northeastern Ohio, which was deposited prior to 14,050 years ago, probably 17,000 years ago (Reference 2.5.1-220). Slightly older tills deposited by different lobes of ice recognized locally in northeastern Ohio, such as the Lavery Till, which is assumed to be about 19,000 years old, also have a similar color and texture. The differing texture and color of the two till units exposed in the Denniston quarry excavations, as well as the clast pavement between the two till units, suggest a change in the provenance of the overriding ice sheet lobe or a change in the subglacial dynamics, but do not provide proof of an interval of deglaciation.

2.5.1.2.3.2.2.2 **Lacustrine and Beach Ridge Deposits**

Lacustrine and shoreline deposits overlying the till units observed in the site vicinity vary in thickness from less than a meter to several meters in the high beach–dune ridge complexes. The deposits include laminated silt and clay and finely bedded, fine- to moderate-grained sand that appears to have been deposited in lacustrine or beach environments (Figure 2.5.1-259), and more massive, thicker sands and gravels deposited as beach ridges or in deltas formed at the mouths of larger drainages.

2.5.1.2.3.2.2.3 **Fluvial Deposits**

Recent alluvium occurs along the major stream valleys. Streams have not deeply incised into the till and underlying bedrock throughout most of the lacustrine/till plain. For example, the Raisin River, one of the larger streams near the site is only incised about 1.5 to 3.2 m (4.9 to 10.5 ft) below the lacustrine/till plain surface along portions of the drainage upstream of Monroe, Michigan. Deeper incision into bedrock only occurs in the lower reaches. The greatest incision occurs in the southern part of the site vicinity where the thickness of sediments in valleys appears to be as much as 25 m (80 ft). (Reference 2.5.1-389)

2.5.1.2.3.2.2.4 **Soil Maps**

The general soil map for Monroe County shows that majority of the lacustrine/till plain that is present in the site vicinity (40-km [25-mi] radius) is underlain by soils of the Pewamo-Selfridge-Blount and Hoytville-Nappanee associations (FSAR Reference 2.5.1-405). These nearly level, very poorly drained to somewhat poorly drained, silty, loamy, and sandy soils formed on till plains, ground moraines, and lake plains. Thicker sandy soils (the Oakville-Tedrow-Granby association) are formed in the glacial outwash plains and delta complexes in the western part of the site vicinity. The floodplains of rivers and streams incised into the lacustrine-till plain are mapped as the Sloan or Ceresco soil series. The Sloan series consists of very poorly drained, moderately or moderately slowly permeable soils formed in waterworked loamy material. The Ceresco series consists of somewhat poorly drained, moderately or moderately rapidly permeable soils on incised floodplains of rivers and large streams. These soils have a coarse-textured B horizon; the underlying parent material is described as fine sandy loam, sandy loam, or silt loam.

thin layer of peat or organic soil. At Fermi 2 and Fermi 3 the top of the lacustrine deposits may have been removed and replaced with fill described in Subsection ~~2.5.1.2.3.2.3~~ 2.5.1.2.3.2.3.3. The lacustrine deposits are the sediments from lakes that covered the site area after the glaciers receded (Subsection 2.5.1.2.3.4.4).

~~2.5.1.2.3.2.3~~ 2.5.1.2.3.2.3.3 Fill

During the construction of existing Fermi 1 and Fermi 2, a lagoon at the site was filled with a variety of materials including gravel/cobble fill, some of the fill material came from an onsite quarry in the Bass Islands Group (Reference 2.5.1-221). In the immediate location of Fermi 3, this fill is classified as cobbles, well graded gravel (GW), poorly graded gravel (GP), well graded gravel with silt (GW-GM), and boulders.

To the east and west of the gravel/cobble fill, some finer-grained fills were encountered during the Fermi 3 subsurface investigation in the following areas:

- At boring MW-386, lean clays with sand and gravel (CL) were encountered. This is near Fermi 1. (Figure 2.5.1-235)
- At borings MW-383 and MW-384, predominantly lean clay fill with sand (CL) and gravel was encountered. Borings MW-383 and MW-384 are located south and southwest of Fermi 3 (Figure 2.5.1-235).

~~2.5.1.2.3.3~~ 2.5.1.2.3.2.3.4 Soils of Site ~~Area~~ Location

~~The distribution of surficial deposits and landforms within the site vicinity (25-mi [40-km] radius) is shown on . The site area (8-km [5-mi] radius) is located in a glaciolacustrine section on the western edge of Lake Erie (Figure 2.5.1-244).~~

Soils in the site location (1-km [0.6-mi] radius from the site) include the Lenawee ponded and Lenawee–Del Rey associations. The Lenawee ponded association consists of nearly level, very poorly drained silty soils on lake plains near Lake Erie and adjacent to large rivers. In some places it is formed on sand deposits in beach areas. The Lenawee-Del Rey association consists of nearly level, somewhat poorly drained silty soils formed on lake plains. (Reference 2.5.1-404)

Detailed soil units within the Lenawee ponded and Lenawee–Del Rey associations are shown on Figure 2.5.1-245 (Reference 2.5.1-405) and include Lenawee silty clay loam, ponded; Blount loam; Del Rey silt loam;

Fulton silty clay loam; Milton clay loam; beaches; Toledo silty clay loam; aquents and pits; and urban land (Reference 2.5.1-404). The Lenawee silty clay loam, ponded, is dark grayish brown and is formed on lake plains; approximately 5 percent of mapped areas include beach sand. It is a nearly level, poorly drained soil in flat areas and drainageways. The Del Rey silt loam is formed in loamy and clayey lacustrine deposits on lake plains and is nearly level and somewhat poorly drained. Its substratum extends to 150 cm (60 in) and is mottled silty clay loam with thin, very fine sand layers. The Toledo silty clay loam is a nearly level, very poorly drained soil in low areas and natural drainageways that is formed in clayey, calcareous lacustrine sediments in lake plains. The Blount loam, on 0 to 3 percent slopes is a nearly flat, somewhat poorly drained soil on upland flats, formed on water-reworked glacial till plains. The Fulton silty clay loam on 0 to 3 percent slopes is a nearly level, somewhat poorly drained soil on slight rises and knolls that is formed in clayey and calcareous lacustrine deposits. The Milton clay loam on 2 to 6 percent slopes is a moderately deep, gently sloping, well-drained soil on knolls. It is formed in loamy, calcareous glacial till underlain by limestone. Some well-drained sandy soils over clayey soils are included in this unit. (Reference 2.5.1-405)

-grained

In addition to soil units, the following deposits are shown on Figure 2.5.1-245. Beach sands thicker than 1.5 m (5 ft) from Lake Erie are shown as beaches. Aquents are nearly level and consist of poorly drained soils that have had 20 to 60 cm (8 to 24 in) of soil material removed. Aquents also include low, wet areas that have been filled with nonsoil material and then covered with soil material. The Pits-Aquents complex consists of open excavations and pits, the bottoms of which are nearly level aquent soils. Urban land includes level areas covered by streets, parking lots, buildings, and other structures that obscure or alter the soils to the point that identification is not feasible. (Reference 2.5.1-405)

2.5.1.2.4 Structural Geology of Site Vicinity (25-mi [40-km] Radius)

As discussed in Subsection 2.5.1.1.4 the site lies within a tectonically stable continental region of the North American Craton. Precambrian and Paleozoic structures are present in the site vicinity, but as noted below there is no evidence that these structures are capable tectonic sources.

2.5.1-444 National Geophysical Data Center, National Oceanic and Atmospheric Administration (NOAA), "2-Minute Gridded Global Relief Data (ETOPO2v2) June, 2006," Bathymetric Data, http://www.ngdc.noaa.gov/mgg/fliers/01mgg04.html, accessed 1 January 2007.

2.5.1-445 Tennessee Valley Authority, "Application for a Combined License (COL) for Two Westinghouse Advance Passive 1000 (AP1000) Pressurized Water Reactors (PWRs) Designated as Bellefonte Nuclear Station Units 3 & 4," date of application submittal October 30, 2007.

2.5.1-446 Indiana Geological Survey, "Structural Features of Indiana (Indiana Geological Survey, Line Shapefile," 2002. http://129.79.145.7/arcims/statewide_mxd/dload_page/geology.html, accessed 2 June 2008.

2.5.1-447 Taylor, K.B., R.B. Herrmann, M.W. Hamburger, G.L. Pavlis, A. Johnston, C. Langer, and C. Lam, "The Southeastern Illinois Earthquake of 10 June 1987," *Seismological Research Letters*, Volume 60, No. 3, pp. 101-110, July – September 1989.

2.5.1-448 Slucher, E.R., E.M. Swinford, G.E. Larson, and D.M. Powers, "Bedrock Geologic Map of Ohio," Ohio Geological Survey, Map BG-1, version 6.0, scale 1:500,000, 2006.

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2.5.1-450 Pavey, R.R., R.P. Goldthwait, C.S. Brockman, D.N. Hull, E.M. Swinford, and R.G. Van Horn, "Quaternary Geology of Ohio," Ohio Geological Survey, Map M-2, 1:500,000-scale map and 1:250,000-scale GIS files, 1999.

2.5.1-451 Michigan Department of Natural Resources, "Quaternary Geology of Michigan," Edition 2.0, digital map, 1998.

2.5.1-452 Ontario Geological Survey, "Quaternary Geology, Seamless Coverage of the Province of Ontario," Data Set 14, 1997.

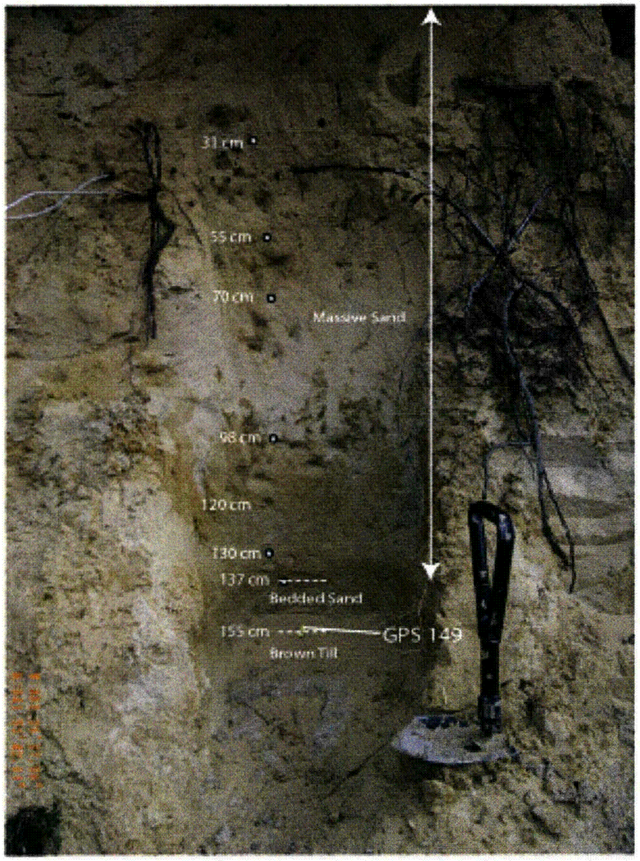
Add Insert #2 here

Insert #2

2.5.1-488	Leverett, F.B., "Correlation of Beaches with Moraines in the Huron and Erie Basins," *American Journal of Science*, Vol. 237, pp. 456-475, 1939.
2.5.1-490	Leverett, F., and Taylor, F.B., "The Pleistocene of Indiana and Michigan and the History of the Great Lakes," U.S. Geological Survey Monograph 53, 529 pp., 1915.
2.5.1-491	Clark, P.U., "Striated Clast Pavements: Products of Deforming Subglacial Sediment?," *Geology*, Vol. 19, pp. 530-533, 1991.
2.5.1-492	Hicock, S.R., "On Subglacial Stone Pavements in Till," *The Journal of Geology*, Vol. 99, No. 4, pp. 607-619, 1991.
2.5.1-498	Black & Veatch letter to Detroit Edison Company, "Denniston Quarry Investigation Technical Memorandum," Letter No. BVDE2-2010-0038, February 4, 2010.

Figure 2.5.1-258 Denniston Quarry: Quaternary Excavations, Soil Profile Locations and Mapped Soil Units

Figure 2.5.1-259 Denniston Quarry: Soil Profile SP-1 in Quaternary Excavation QE1



Photograph showing SP-1 soil horizon boundaries (designated by depth).

SP-1

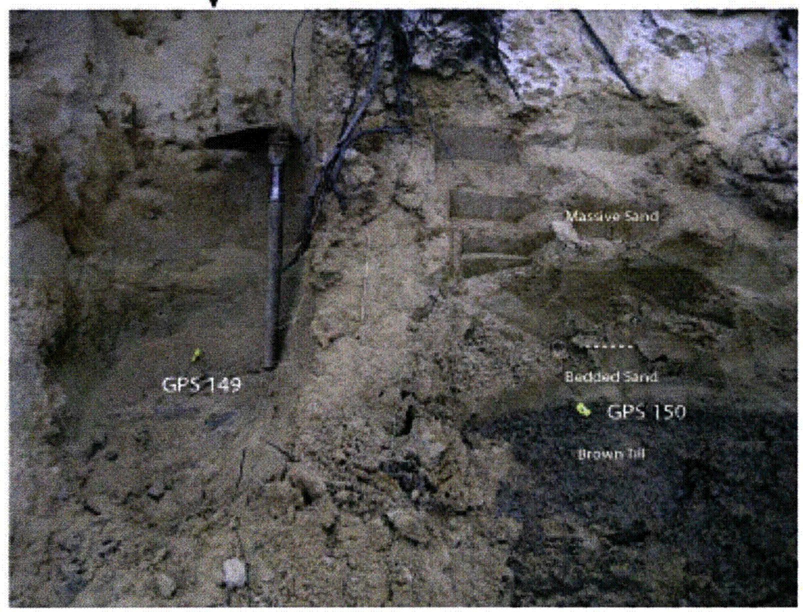
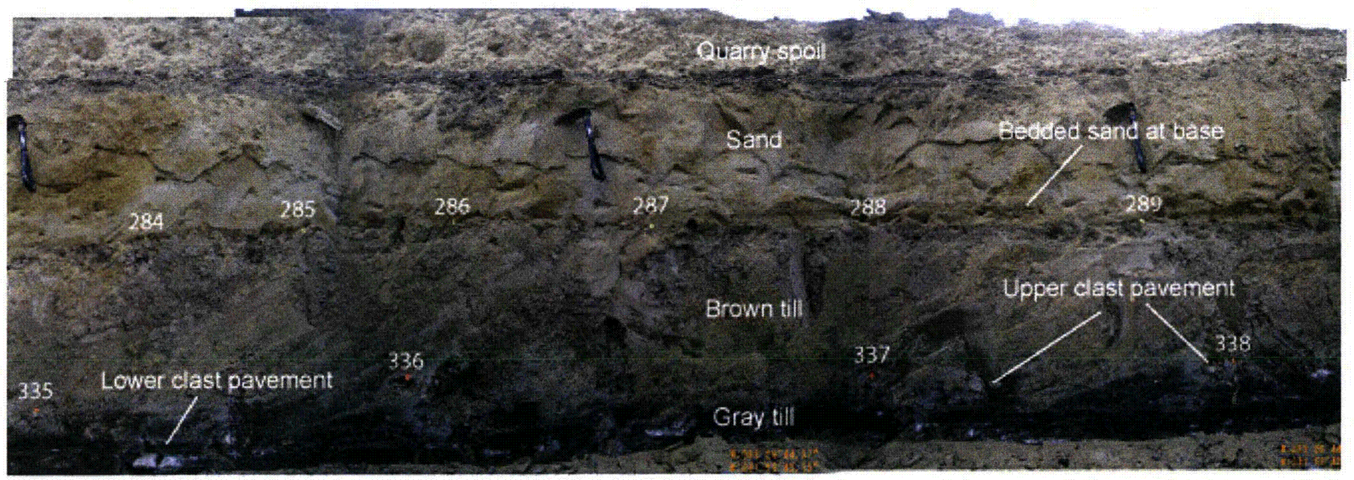


Figure 2.5.1-260 Denniston Quarry: Stratigraphy Exposed in Quaternary Excavation QE-2



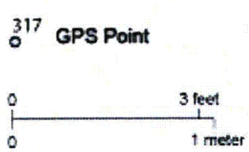


Figure 2.5.1-261 Denniston Quarry: Quaternary Excavation QE-3 and Soil Profiles SP-2 and SP-3

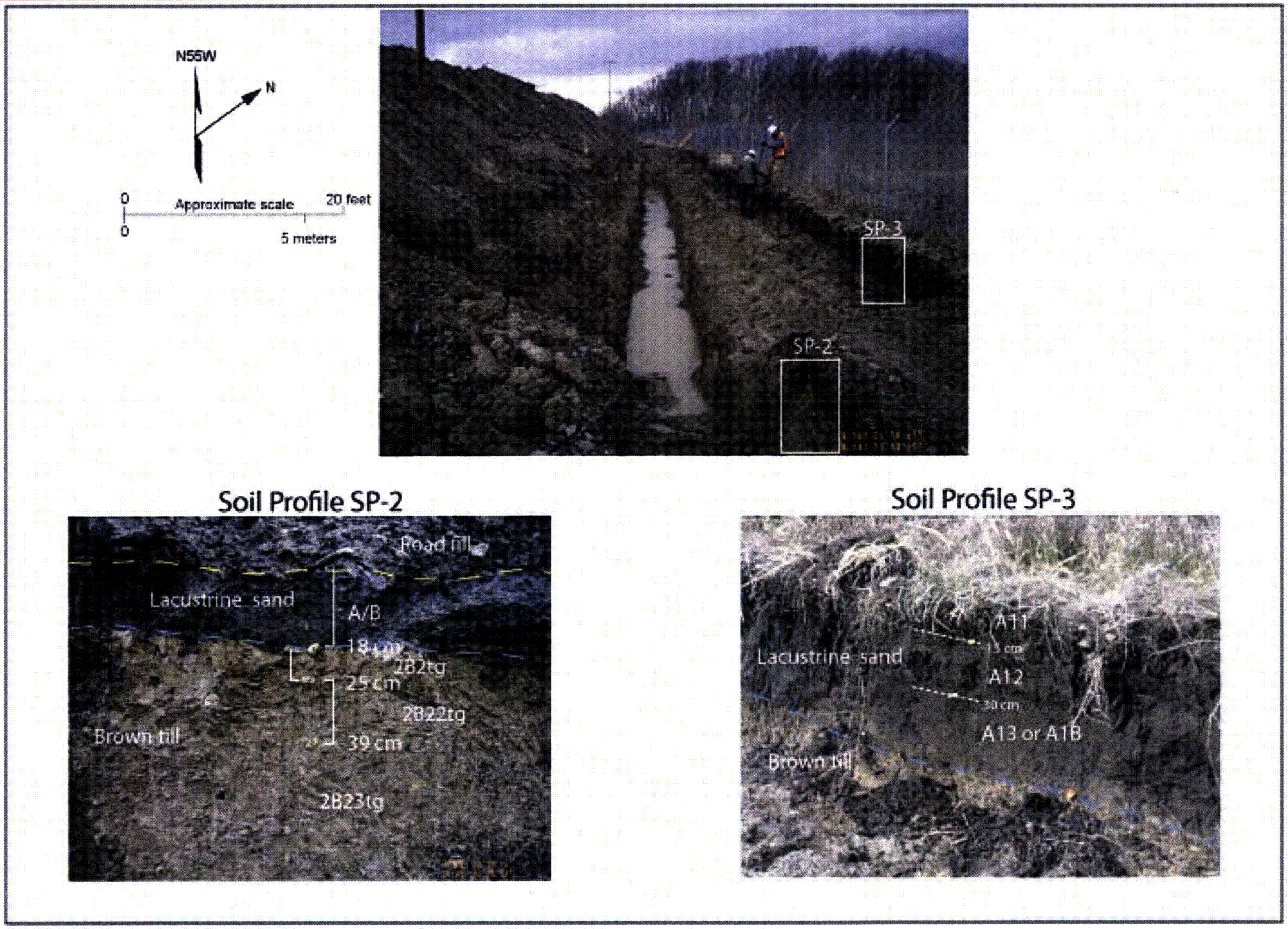


Figure 2.5.1-262 Denniston Quarry: North Wall of Quaternary Excavation QE-3

Attachment 23
NRC3-10-0006

Response to RAI Letter No. 16
(eRAI Tracking No. 3917)

RAI Question No. 02.05.03-04

RAI 02.05.03-04

FSAR Section 2.5.3.2.3 indicates that a lineament analysis was conducted for the site vicinity using a USGS 10-m DEM (Digital Elevation Model). However, the FSAR also states that "Given the low strain rates in the site region, the young surficial and near surface deposits are unsuitable for detecting long-term neotectonic strain deformation." If this is the case, then please discuss the vertical resolution of the USGS 10-m DEM and whether it is appropriate to base a negative conclusion on this dataset. Also, please discuss the availability of LiDAR high-resolution topographic datasets for the site vicinity and how these data might be used for a more detailed analysis of possible postglacial surface deformation.

Response

No LiDAR data were identified for the Fermi 3 site vicinity during the initial studies conducted for the COL application. Additional research has identified LiDAR data for the site vicinity in a narrow band along the shoreline of Lake Erie (Reference 1); however, this data reportedly extends generally only 750 m inland and up to 1,500 m over the water and would not be sufficient for evaluating geomorphic features for the site vicinity. LiDAR data was collected for Washtenaw and Wayne counties in April 2009 and is currently being processed, with reported availability in 2010 (Reference 2). These data may be useful for evaluation geomorphic features in the site vicinity. Therefore, the USGS 10-meter Digital Elevation Model (DEM) is currently the highest-resolution topographic data set available for the site vicinity.

Reference 3 addresses the vertical accuracy of the USGS 10-meter DEM, also known as the National Elevation Dataset (NED). The vertical accuracy of the NED was evaluated by comparing it to more than 13,000 very high accuracy geodetic control points across the United States. The geodetic control points are used by the National Geodetic Survey (NGS) for gravity and geoid modeling. Details regarding the evaluation of vertical accuracy are provided in Reference 3.

The overall absolute vertical accuracy expressed as the root mean square error (RMSE) was calculated to be 2.44 meters. The NED absolute vertical accuracy errors appear to be truly random with respect to different types of terrain across the data set (Reference 3). The analysis of relative vertical accuracy, which compares the difference in elevation of pairs of points within the NED data set was characterized using the same set of reference geodetic points as was used in determining the absolute vertical accuracy. The relative vertical accuracy was calculated to be 1.64 meters (Reference 3).

The objective of the lineament analysis conducted for the DTE COLA study was to identify linear anomalies in the topography that may have developed in response to surface or near-surface tectonic deformation. Evaluation of the USGS 10-m DEM enabled identification of linear features, which could be related to features on the topographic maps and in some cases in the field. These features did not match known or postulated faults. It is expected that surface rupture along a fault would result in a zone of weakened or disrupted material that would provide a pathway for water movement that would be expressed by differential erosion or vegetation anomalies that would extend along much or all of the surface rupture. Neither were observed along the length of the postulated faults in the site vicinity.

References

1) NOAA Coastal Services Center Coastal LIDAR Web page, http://www.csc.noaa.gov/digitalcoast/data/coastallidar/download.html, accessed January 11, 2010.
2) Telephone Conversation Record with Nate Arnold, Washtenaw County GIS, December 16, 2009.
3) Gesch, D.B., 2007, Chapter 4 – The National Elevation Dataset, in Maune, D., ed., Digital Elevation Model Technologies and Applications: The DEM Users Manual, 2nd Edition: Bethesda, Maryland, American Society for Photogrammetry and Remote Sensing, pp. 99-118.

Proposed COLA Revision

None

Attachment 24
NRC3-10-0006

Response to RAI Letter No. 16
(eRAI Tracking No. 3917)

RAI Question No. 02.05.03-05

RAI 02.05.03-05

The Fermi site is located on the western shore of Lake Erie, and several faults and folds discussed in the FSAR trend directly into the lake. However, the FSAR does not address if there are any high-resolution bathymetric data or seismic-reflection data that might better characterize the presence or absence of young tectonic deformation in the site region. Please discuss any relevant marine seismic and bathymetric data for Lake Erie in the context of placing limits on recent tectonic deformation in the site region.

Response

This response describes interpretations of bathymetric and high-resolution seismic reflection survey studies in the western basin of Lake Erie, a portion of which lies within the site vicinity (FSAR Figure 2.5.1-230).

Bathymetric Data

A project conducted jointly by the U.S. National Oceanic and Atmospheric Administration (NOAA) and the Canadian Hydrographic Service developed bathymetry at one-meter contour intervals for all of Lake Erie and Lake Saint Clair. This bathymetry data, which is the highest-resolution data available for Lake Erie, was used in the characterization of the Fermi 3 site (Reference 2.5.1-444). Interpretations of lake-floor topography and lake-floor features identified and mapped using this bathymetry data are described by Holcombe et al. (Reference 2.5.1-472), Holcombe et al. (Reference 2.5.1-487), Holcombe et al. (Reference 2.5.1-494), and National Geophysical Data Center (Reference 2.5.1-495).

Lake Erie occupies three basins that increase in depth from west to east. Away from the shore zone the three basins are broadly bowl-shaped, with the lake-bottom surface extending smoothly from nearshore down to greater depths. The bowl shape is inferred to be the result of postglacial deposition and sediment-smoothing in response to a gyre of water circulation in each basin, or progressive shoreline modifications in the zone of Holocene rising lake levels. The sediment-smoothing has diminished or eliminated surface relief formed during the last glaciation. (Reference 2.5.1-495)

The western Erie basin extends to depths of 10 to 11 m (33 to 36 ft), the central Erie basin extends to depths of 24 to 25 m (79 to 82 ft), and the eastern Erie basin extends to depths exceeding 40 m (131 ft). A map of western Lake Erie showing major geomorphic features is shown on Figure 2.5.1-263 . The key geomorphic observations of Holcombe et al. (Reference 2.5.1-472) regarding the lake-floor geomorphology of the western basin of Lake Erie, which are supplemented by additional, more recent interpretation (Reference 2.5.1-495), are as follows:

- The islands and reefs bordering and lying within the western basin have bedrock cores that are erosional remnants of the more resistant Upper Silurian and Lower Devonian dolomites and limestones.

- Overdeepened channels between the islands have been sites of postglacial nondeposition, and probably erosion, due to intense wind-driven water circulation through these restricted passages. The deepest channel depth is the 19-m (62-ft) Starve Island Deep located between the southernmost Bass Island and Marblehead Peninsula.
- The Pelee-Lorain Ridge is interpreted as a late Wisconsinan end moraine upon which sand deposits have been concentrated. This feature is probably associated with a re-advance of the retreating Wisconsinan ice sheet, and probably correlates with the proglacial Lake Maumee II.
- The Point Pelee Fan is a fan-shaped delta-like body of sediment that crests at 11 to 12 m (36 to 39 ft) below the present lake level. The fan extends to the east of Point Pelee Ridge, downslope to a depth of at least 18 m (59 ft), and as far south as Pelee-Lorain Ridge. The fan is believed to have been principally formed at the time when the lake level was about 10 to 15 m (33 to 49 ft) lower than at present, prior to deposition of the shallower 3,500-years before present (BP) to present sands on the Point Pelee Ridge.
- If the Point Pelee Fan is a relict shoreline feature, it may be a former shoreline delta of the Detroit River that formed following the opening of the Port Huron outlet about 4,000 years BP (Figure 1). During this time the newly formed Detroit River was eroding its channel and bringing a heavy load of sediment into Lake Erie. An alternative interpretation for formation of the Point Pelee Fan is that strong west-to-east currents have swept around the end of the Point Pelee Ridge and carried sediments eastward.
- Sands being deposited in the main postglacial channel of the Detroit River, about the same time as or soon after the Port Huron outlet first opened up, filled the channel and spilled over into a large part of the western basin, mostly eliminating topographic expression of the channel. Location of the main Detroit River Channel may have coincided with a trough in the till surface extending through the western basin as shown by Hobson et al. (Reference 2.5.1-496).
- A fan-shaped sediment accumulation occurs off the Maumee River, which has been a significant deposition site for fluvial sediments brought into Lake Erie following glaciation and at present. The fan probably began forming at its present location only after the most recent rise of Lake Erie into this area. Two sand spits resulting from converging net longshore transport of sand and gravel along the lake shores toward Maumee Bay partially enclose the bay and control the position of the Maumee River Channel.
- Surficial sediments underlying the western basin are described as unconsolidated muds with a high water content.
- Channels underlying the main shipping lanes have been excavated by propeller wash where ship traffic increases speed, resulting in resuspension of bottom sediments. Dumpsites for dredge spoils excavated from channels are expressed in the bathymetry by a distinctive hummocky pattern in two areas (one north of the Toledo dredged channel and one west of the dredged west outer channel of the Detroit River).

High-Resolution Seismic Surveys

High-resolution seismic survey studies in the western basin of Lake Erie are presented in Hobson et al. (Reference 2.5.1-496) and Carter et al. (Reference 2.5.1-497).

Hobson et al. (Reference 2.5.1-496) present the results of a high-resolution seismic survey covering the entire western basin of Lake Erie. This study, which was conducted by the Geological Survey of Canada in cooperation with the Ohio Geological Survey, collected 1,309 km (814 mi.) of continuous seismic data using a high-resolution boomer source. The survey was successful in meeting its objectives of mapping bedrock topography, sediment thickness, and stratification in the western basin and adjacent parts of the central basin of Lake Erie. Record quality was poor in the area offshore of the Detroit River and Maumee River mouth as well as in some small interior areas of the western basin. Hobson et al. (Reference 2.5.1-496) attribute the loss of information to attenuation by gaseous bubbles in the sediment, to sand bodies, or to buried peat deposits.

The results of the study are presented in a series of figures, including ones showing seismic data quality and track chart (Figure 2); elevation of top of till (Figure 3); thickness of unconsolidated sediment overlying bedrock (Figure 4), bedrock surface topography (Figure 5); and inferred preglacial drainage (Figure 6). Information from all wells bored for oil and gas exploration in the Canadian offshore region, as well as extensive borings by the coauthors of the paper, was used to develop Figures 3 ,4, and 5. Maximum bedrock relief is 67 m (220 ft), and sediment thickness ranges from zero to 36.6 m (120 ft). The major areas of high relief (Point Pelee and the Bass Islands) are clearly related to erosion-resistant rock formations.

The only horizon that could be traced over significant areas in the western basin was inferred to represent the top of till (Figure 3). This surface reflects the general pattern of late glacial and postglacial drainage during low level phases of Lake Erie. Over the greater part of the survey area, the combined results of glacial and lacustrine processes have been one of deposition that filled pre-existing lows, and topographic smoothing.

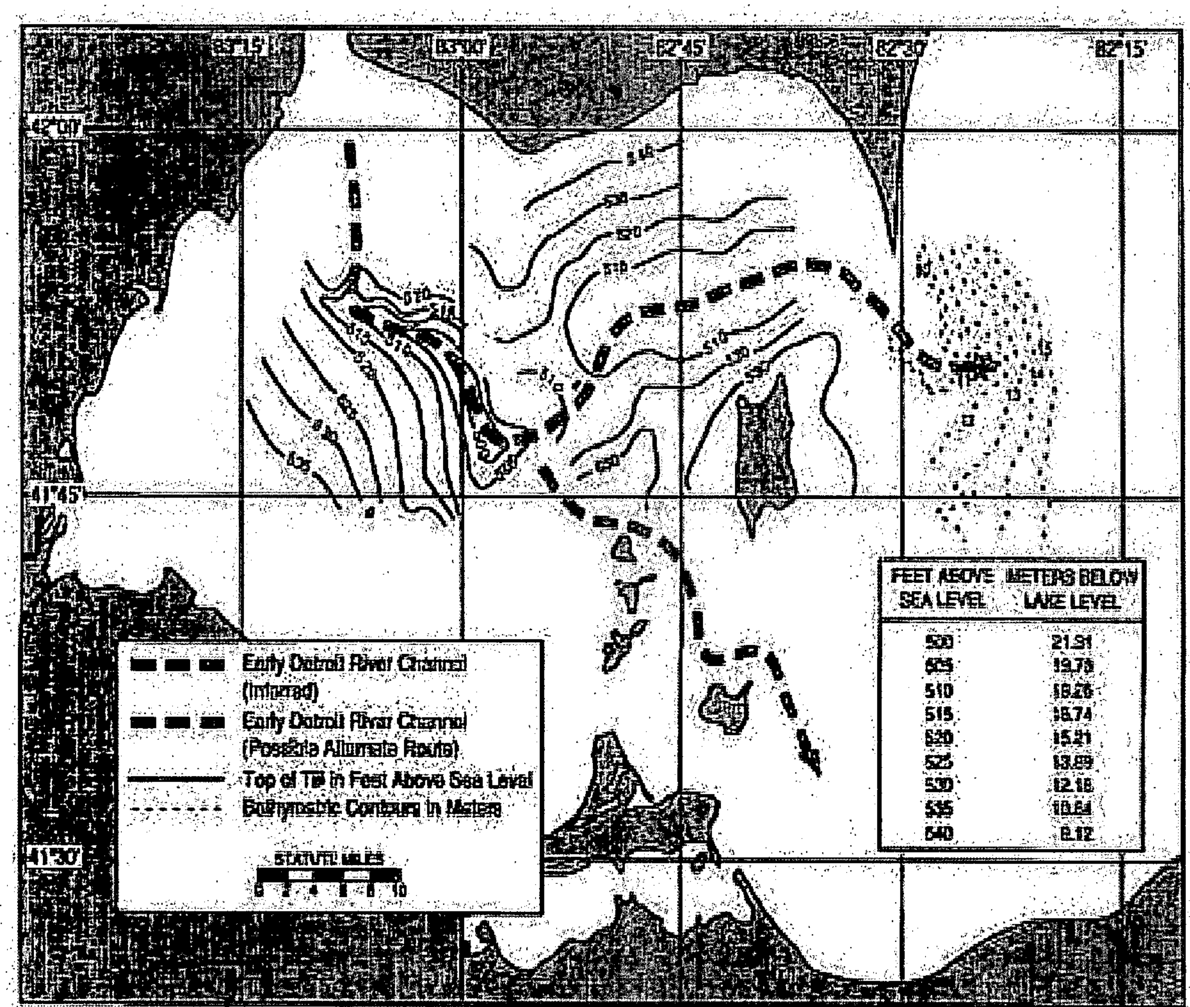
An eastward-flowing preglacial drainage system shown on Figure 6 was inferred from the thickness of unconsolidated sediment (Figure 4) and resulting bedrock topography map (Figure 5). This interpretation is based on assumptions that ice scour probably deepened the valleys preferentially and created closed depressions, without significantly altering the drainage divides, and that no significant differential earth movements have occurred since preglacial time. Hobson et al. (Reference 2.5.1-496) conclude that the drainage pattern appears to be a subsequent stream system that developed by headward erosion along the strike of weak bedrock zones of arched, northward-plunging Paleozoic strata in the Findley arch.

Carter et al. (Reference 2.5.1-497) present the results of a survey conducted of the southern part of the Ohio waters of Lake Erie between Conneaut and Marblehead (east of the Fermi 3 site vicinity boundary). Primary data from this study consists of 576 km (175.6 mi.) of seismic reflection trackline profiles taken in 1977and 58 vibracores ranging from 0.7 to 6.1 m (2.3 to 20 ft) deep taken in 1978. The study identified sand, muddy sand, sandy mud, and mud as the four principal postglacial deposits that commonly overlie lakeward rock and till. Combined postglacial deposit thicknesses range from zero to 22 m (zero to 72 ft) and, like the underlying till, thicken lakeward. The deposits record the following sequence of events: (1) deposition of till on an irregular, erosional shale surface; (2) eastward retreat of the last Wisconsinan glacier from the Erie basin; (3) drainage of a lake ponded west of the retreating glacier and subaerial erosion to form stream channels; (4) isostatic rebound of the outlet that led to rise in lake level with associated erosion and deposition along the expanding lakeshore, which tended to smooth the till surface; (5) early postglacial (Holocene) deposition in a complex of fluvial, deltaic, and lacustrine environments; and (6) modern lacustrine mud deposition over these early Holocene deposits. (Reference 2.5.1-497). .

Assessment of Recent Tectonic Deformation

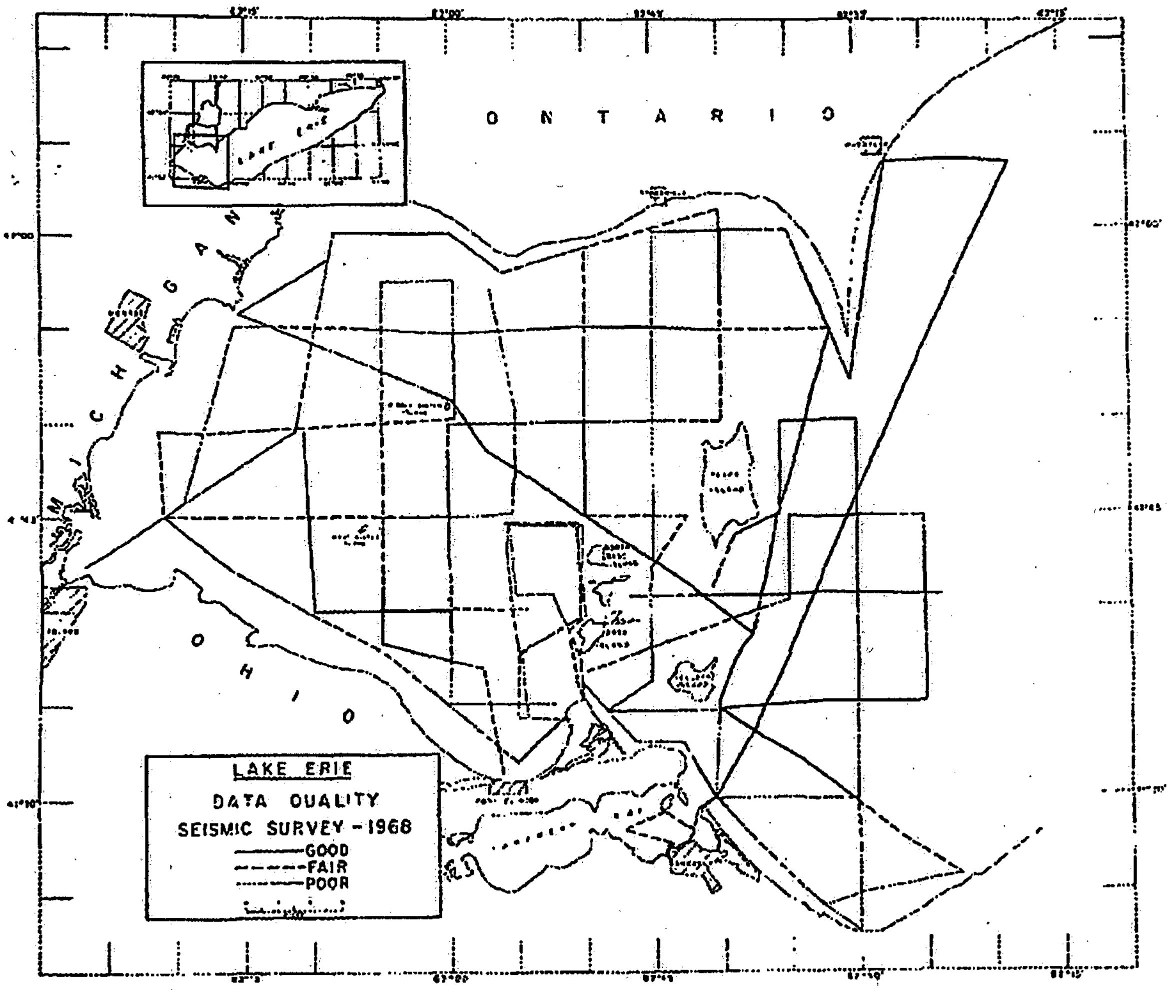
The present topography of the western Lake Erie basin and lake-floor features have been interpreted as representing the combined results of glacial and lacustrine processes in latest Pleistocene to Holocene time that have resulted in deposition filled preexisting lows, and topographic smoothing. None of the features identified in the most recent bathymetry or interpretations of the preglacial drainage pattern have been interpreted as tectonic in origin or suggestive of tectonic activity. The most prominent linear features in the western basin are anthropogenic in origin, due to shipping and dredging activities.

Figure 1 Possible Early Holocene Position of Former Detroit River Channel and Fan in Western Lake Erie



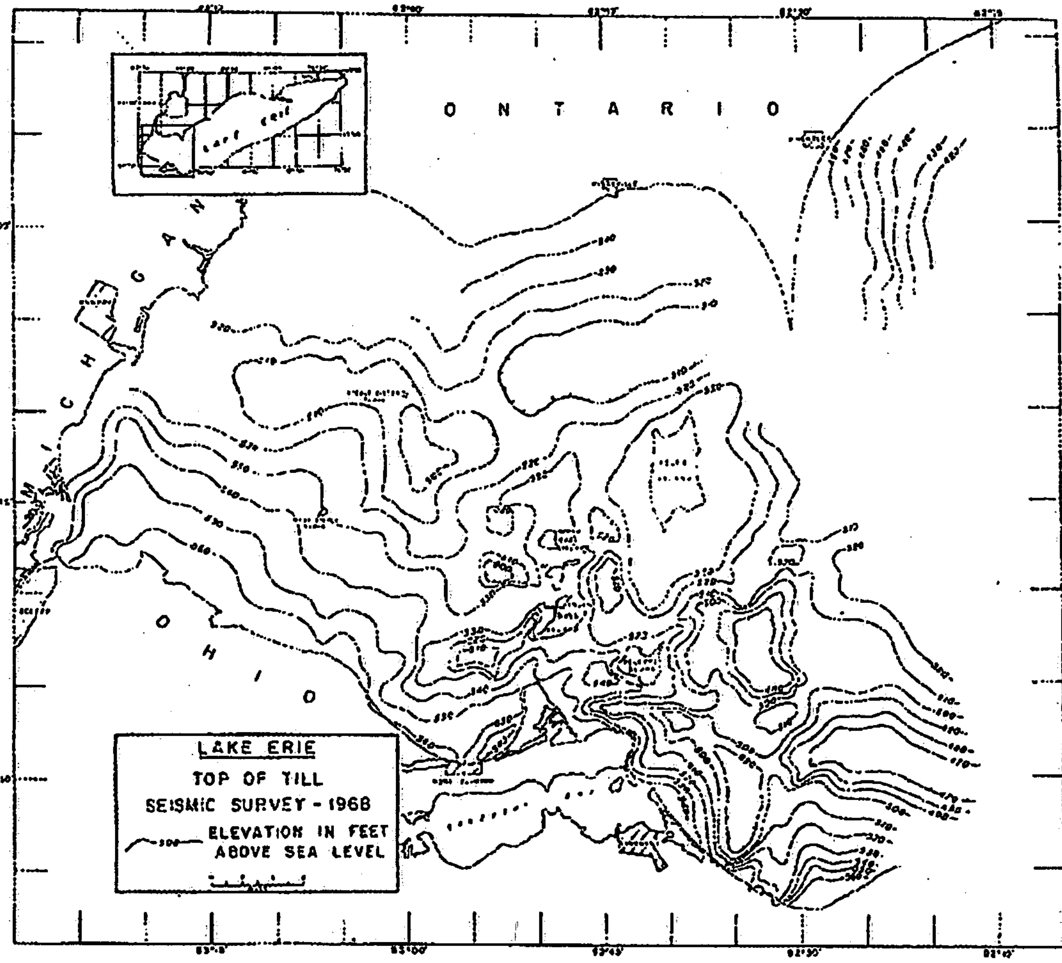
Source Reference 2.5.1-472

Figure 2 Seismic Data Quality and Track Chart, Western Lake Erie



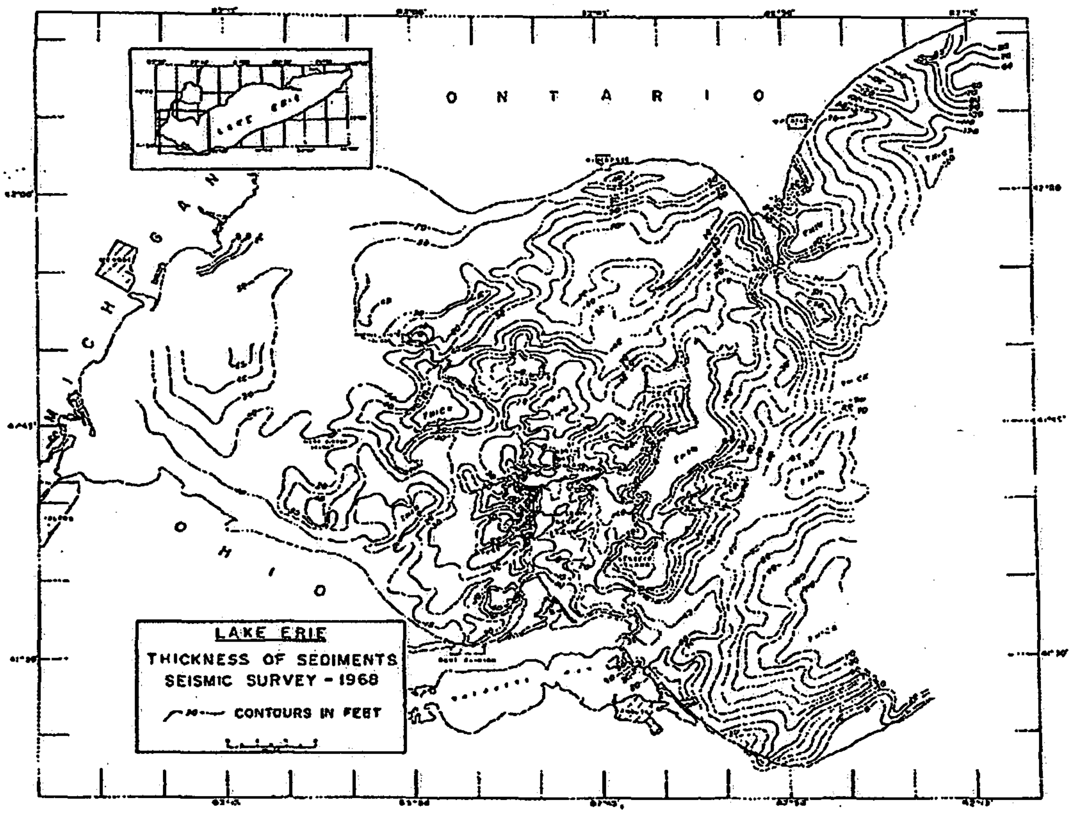
Source Reference 2.5.1-496

Figure 3 Elevation of Top of Till Underlying Western Lake Erie



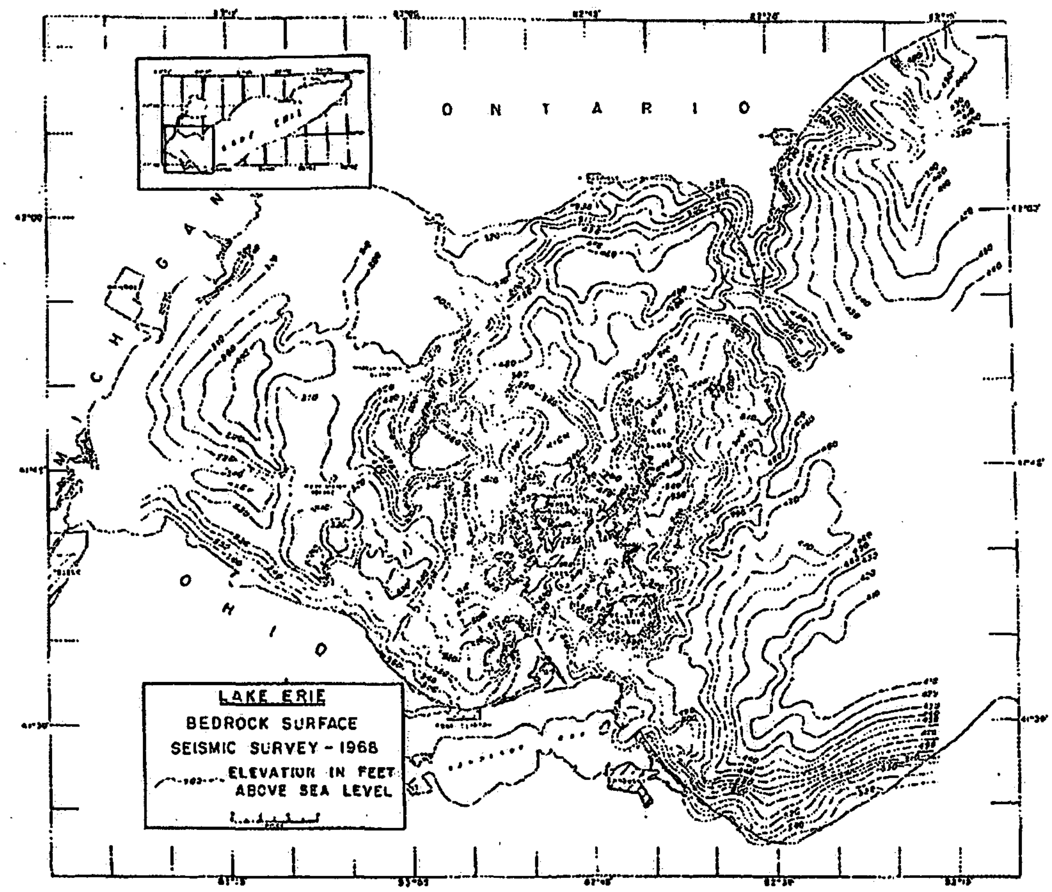
Source Reference 2.5.1-496

Figure 4 Thickness of Unconsolidated Sediments Overlying Bedrock, Western Lake Erie



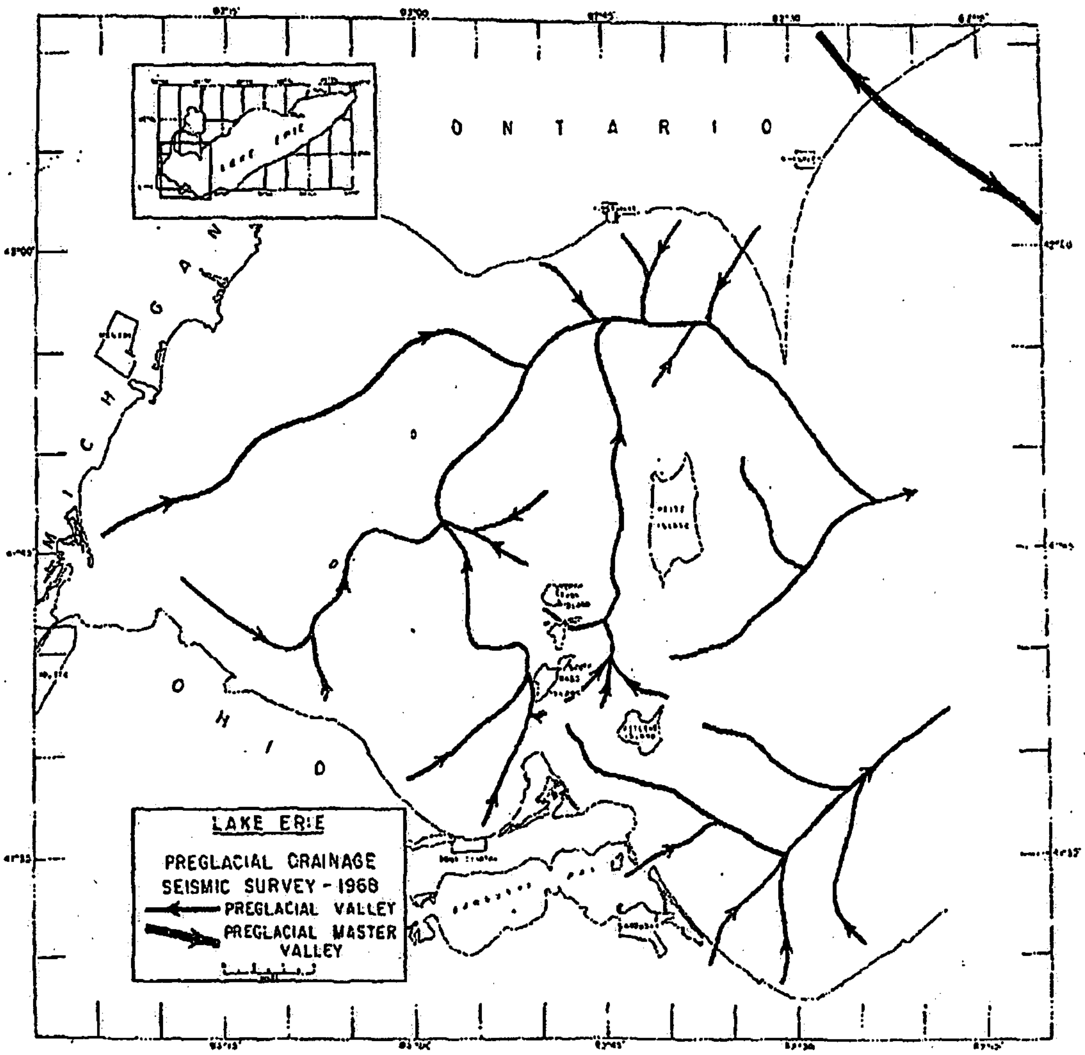
Source Reference 4.5.1-496

Figure 5 Bedrock Topography, Western Lake Erie



Source Reference 4.5.1-496

Figure 6 Inferred Preglacial Drainage, Western Lake Erie



Source Reference 4.5.1-496

Proposed COLA Revision

Proposed markups to revise FSAR Sections 2.5.1.1.1.1 and 2.5.1.2.1 are attached.

Markup of Detroit Edison COLA
(following 10 pages)

The following markup represents how Detroit Edison intends to reflect this RAI response in a future submittal of the Fermi 3 COLA. However, the same COLA content may be impacted by revisions to the ESBWR DCD, responses to other COLA RAIs, other COLA changes, plant design changes, editorial or typographical corrections, etc. As a result, the final COLA content that appears in a future submittal may be different than presented here.

respectively. The site is located within the Central Stable Region tectonic province of the North American continent (Reference 2.5.1-212). Some regional faulting and seismic activity is known, but the region is characteristically one of relative stability. The site is located on the southeast side of the Michigan basin on the northwest flank of the Findlay arch (Figure 2.5.1-208, Reference 2.5.1-213). There are no known surface faults within 40 km (25 mi) of the site and there are no capable tectonic sources as defined by Regulatory Guide 1.206 within 320 km (200 mi) of the site. Pleistocene deposits of glacial and glaciolacustrine origin underlay the site area and are underlain by Paleozoic sedimentary rocks. Approximately 945 m (3100 ft) of Paleozoic sedimentary rocks are present in the site area and overlie the Precambrian basement. The underlying basement rocks within the region reflect a history of continental collisions, accretion, and periods of rifting. The Fermi 3 site is located near the boundaries between several different basement crustal provinces (Reference 2.5.1-210; Reference 2.5.1-214; Reference 2.5.1-211; Reference 2.5.1-215; Reference 2.5.1-216; Reference 2.5.1-217). The key aspects of the regional geology of the site are presented to provide the framework for an evaluation of the geologic and seismologic hazards as outlined in subsequent subsections.

2.5.1.1.1 Regional Physiography and Geomorphology

The Fermi 3 site is located in the northern portion of the Midwestern United States in the Eastern Lake section of the Central Lowlands physiographic province (Figure 2.5.1-202) (Reference 2.5.1-203; Reference 2.5.1-204). The (320-km [200-mi] radius) site region of Fermi 3 encompasses portions of two other physiographic provinces: Appalachian Plateaus and St. Lawrence Lowlands. The St. Lawrence physiographic province is located in adjacent southern Ontario, Canada. The physiographic provinces within the site region are described as follows.

2.5.1.1.1.1 Central Lowlands Physiographic Province

The Central Lowland physiographic province is generally located in the northern Midwest but also extends through Oklahoma into north-central Texas (Figure 2.5.1-202) (Reference 2.5.1-203). The Central Lowlands physiographic province is subdivided into eight sections. The Eastern Lake and Till Plains sections are located in the (320-km [200-mi] radius) site region and Fermi 3 is located within the Eastern Lake section.

The Eastern Lake section is characterized by glacial landforms, including end moraines, ground moraines, outwash plains, kames, eskers, and drumlins, and by beach and lacustrine deposits formed during the lake level fluctuations of the Great Lakes (Reference 2.5.1-218; Subsection 2.5.1.1.2.3.4.4). The ground surface is relatively flat with relief up to 7.6 m (25 ft) (Reference 2.5.1-219). The glacial sediments were deposited on a dissected bedrock topography with cuestas and valleys (Reference 2.5.1-218; Reference 2.5.1-220). The bedrock is exposed locally and consists of relatively flat-lying bedrock of Silurian to Jurassic rocks (Figure 2.5.1-204).

Fermi 3 is located on a lake plain formed during the high-water stages of Lake Erie (see Subsection 2.5.1.1.2.3.4.4). There is little topographic relief on the lake plain, which results in poor surface drainage. The lake plain has been dissected by eastward-flowing creeks and rivers. The relief on the lake plain within the vicinity of the project area is approximately 7.6 m (25 ft) (Reference 2.5.1-221).

The Till Plains section is characterized by flat to gently rolling glacial landforms including end moraines, ground moraines, recessional moraines, and outwash plains, along with some isolated lacustrine deposits adjacent to the boundary with the Eastern Lake section (Reference 2.5.1-219). The local relief is up to 76 m (250 ft). Bedrock is exposed locally and is relatively flat-lying. (Reference 2.5.1-219) The glacial deposits were deposited on a dissected bedrock surface with buried stream valleys. The bedrock surface tends to be gently rolling with well-developed valley systems. (Reference 2.5.1-220) The Till Plains section is differentiated by having greater relief and fewer lacustrine deposits than the Eastern Lake section (Reference 2.5.1-219).

Add Insert #1 here

2.5.1.1.1.2 Appalachian Plateaus Physiographic Province

The Appalachian Plateaus physiographic province is located to the southeast of Fermi 3 and the Central Lowlands physiographic province (Figure 2.5.1-202). The Appalachian Plateau physiographic province is subdivided into seven sections, two sections, Kanawha and Southern New York sections, are within the (320-km [200-mi] radius) site region.

The Kanawha section is characterized as a dissected plateau with broad valleys containing outwash and lacustrine deposits of Pleistocene Age. The local relief ranges up to 244 m (800 ft) (Reference 2.5.1-219). The section is underlain by flat-lying to broadly folded Paleozoic sediments of

Insert #1

Lake Erie occupies three basins that increase in depth from west to east. Away from the shore zone the three basins are broadly bowl-shaped, with the lake-bottom surface depths extending smoothly from nearshore down to greater depths. The bowl shape is inferred to be the result of postglacial deposition and sediment-smoothing in response to a gyre of water circulation in each basin, or progressive shoreline modifications in the zone of Holocene rising lake levels. The sediment-smoothing has diminished or eliminated surface relief formed during the last glaciation. (Reference 2.5.1-495)

The western Erie basin extends to depths of 10 to 11 m (33 to 36 ft), the central Erie basin extends to depths of 24 to 25 m (79 to 82 ft), and the eastern Erie basin extends to depths exceeding 40 m (131 ft). Maps of western and eastern Lake Erie showing major geomorphic features are shown on Figures 2.5.1-263 and 2.5.1-264, respectively.

the site vicinity applies to the site area and the site location unless specifically discussed. Where information is presented for the site area, it applies to the site location unless specifically discussed.

2.5.1.2.1 Site Physiography and Geomorphology

Fermi 3 is located in the Eastern Lake section of the Central Lowlands physiographic province, and the (40-km [25-mi] radius) site vicinity includes the St. Lawrence Lowlands physiographic province in Canada (Figure 2.5.1-202). Subsection 2.5.1.1.1.1 and Subsection 2.5.1.1.1.3 cover the overall details of the Central Lowlands and the St. Lawrence Lowlands physiographic provinces, respectively. The St. Clair clay plain is the subdivision of the St. Lawrence Lowlands physiographic province that is in the site vicinity. The St. Clair clay plain is described as a region of low relief with elevations ranging from 175 to 213 m (575 to 700 ft) and is developed on clay tills that are thinly covered with lacustrine deposits. (Reference 2.5.1-222) In adjacent Ohio, the subdivision of the Eastern Lake section is called the Maumee Lake plains and is described by Brockman (Reference 2.5.1-219) as a "flat-lying Ice-Age lake basin...slightly dissected by modern streams; elevation 174 to 243 m (570 to 800 ft); very low relief (1.5 m[5 ft])." The surface materials In the Maumee Lake plains include silt, clay and clayey glacial till that overlie Silurian carbonate rocks and shales (Reference 2.5.1-220). The 8-km (5-mi) radius site area is entirely within the Eastern Lake section of the Central Lowlands physiographic province (Reference 2.5.1-218). The 1:24,000 scale U.S. Geological Survey topographic maps for Monroe County show the site area is relatively flat with minor incision (< 15 ft) by east-flowing streams and elevations range from 174 to 185 m (570 ft to 605 ft). Within the 1-km (0.6-mi) radius site location, data from the Fermi 3 subsurface investigation encountered lacustrine deposits over glacial till and the U.S. Geological Survey topographic maps indicate an elevation range from 173 to 180 m (570 to 590 ft) (Figure 2.5.1-229).

Add Insert #2 here

2.5.1.2.2 Site Geologic History

The (40-km [25-mi] radius) site vicinity for Fermi 3 is located within the North America Craton. The site vicinity is located on the west flank of the Findlay arch at the margin of the Michigan basin (Figure 2.5.1-208 and Figure 2.5.1-218). The regional geologic history of the Precambrian is covered in Subsection 2.5.1.1.2.1 and Subsection 2.5.1.1.2.2. No surface exposures of Precambrian rocks exist in the site vicinity (Figure

Insert #2

In the western Lake Erie basin, which includes much of the eastern site vicinity, geomorphic features have been identified and characterized using both recent bathymetry and previous results of high-resolution seismic survey studies (References 2.5.1-472, 2.5.1-487, 2.5.1-494, 2.5.1-495, 2.5.1-496, and 2.5.1-497).

The key geomorphic observations of Holcombe et al. (Reference 2.5.1-472) regarding the lake-floor geomorphology of the western basin of Lake Erie, which are supplemented by additional, more recent interpretation (Reference 2.5.1-495), are as follows:

- The islands and reefs bordering and lying within the western basin have bedrock cores that are erosional remnants of the more resistant Upper Silurian and Lower Devonian dolomites and limestones.
- Overdeepened channels between the islands have been sites of postglacial nondeposition, and probably erosion, due to intense wind-driven water circulation through these restricted passages. The deepest channel depth is the 19-m (62-ft) Starve Island Deep located between the southernmost Bass Island and Marblehead Peninsula.
- The Pelee-Lorain Ridge is interpreted as a late Wisconsinan end moraine upon which sand deposits have been concentrated. This feature is probably associated with a re-advance of the retreating Wisconsin ice sheet, and probably correlates with the proglacial Lake Maumee II.
- The Point Pelee Fan is a fan-shaped delta-like body of sediment that crests at 11 to 12 m (36 to 39 ft) below the present lake level. The fan extends to the east of Point Pelee Ridge, downslope to a depth of at least 18 m (59 ft), and as far south as Pelee-Lorain Ridge. The fan is believed to have been principally formed at the time when the lake level was about 10 to 15 m (33 to 49 ft) lower than at present, prior to deposition of the shallower 3,500 years BP to present sands on the Point Pelee Ridge.
- If the Point Pelee fan is a relict shoreline feature, it may be a former shoreline delta of the Detroit River that formed following the opening of the Port Huron outlet about 4,000 years BP. During this time the newly formed Detroit River was eroding its channel and bringing a heavy load of sediment into Lake Erie. An alternative interpretation for formation of the Point Pelee Fan is that strong west-to-east currents have swept around the end of the Point Pelee Ridge and carried sediments eastward.
- Sands being deposited in the main postglacial channel of the Detroit River about the same time as or soon after the Port Huron outlet first opened up filled the channel and spilled over into a large part of the western basin, mostly eliminating topographic expression of the channel. Location of the main Detroit River Channel may have coincided with a trough in the till surface extending through the western basin as shown by Hobson et al. (Reference 2.5.1-496).
- A fan-shaped sediment accumulation occurs off the Maumee River, which has been a significant deposition site for fluvial sediments brought into Lake Erie following glaciation and at present. The fan probably began forming at its present location only after the most recent rise of Lake Erie into this area. Two sand spits resulting from converging net longshore transport of sand and gravel along the lake shores toward Maumee Bay partially enclose the bay and control the position of the Maumee River Channel.

- Surficial sediments underlying the western basin are described as unconsolidated muds with a high fluid content.
- Channels underlying the main shipping lanes have been excavated by propeller wash where ship traffic increases speed, resulting in resuspension of bottom sediments. Dumpsites for dredge spoils excavated from channels are expressed in the bathymetry by a distinctive hummocky pattern in two areas (one north of the Toledo dredged channel and one west of the dredged west outer channel of the Detroit River).

2.5.1-444 National Geophysical Data Center, National Oceanic and Atmospheric Administration (NOAA), "2-Minute Gridded Global Relief Data (ETOPO2v2) June, 2006," Bathymetric Data, http://www.ngdc.noaa.gov/mgg/fliers/01mgg04.html, accessed 1 January 2007.

2.5.1-445 Tennessee Valley Authority, "Application for a Combined License (COL) for Two Westinghouse Advance Passive 1000 (AP1000) Pressurized Water Reactors (PWRs) Designated as Bellefonte Nuclear Station Units 3 & 4," date of application submittal October 30, 2007.

2.5.1-446 Indiana Geological Survey, "Structural Features of Indiana (Indiana Geological Survey, Line Shapefile," 2002. http://129.79.145.7/arcims/statewide_mxd/dload_page/geology.html, accessed 2 June 2008.

2.5.1-447 Taylor, K.B., R.B. Herrmann, M.W. Hamburger, G.L. Pavlis, A. Johnston, C. Langer, and C. Lam, "The Southeastern Illinois Earthquake of 10 June 1987," *Seismological Research Letters*, Volume 60, No. 3, pp. 101-110, July – September 1989.

2.5.1-448 Slucher, E.R., E.M. Swinford, G.E. Larson, and D.M. Powers, "Bedrock Geologic Map of Ohio," Ohio Geological Survey, Map BG-1, version 6.0, scale 1:500,000, 2006.

2.5.1-449 Armstrong, D.K., and J.E.P. Dodge, "Paleozoic Geology of Southern Ontario," Ontario Geological Survey, Miscellaneous Release — Data 219, 2007.

2.5.1-450 Pavey, R.R., R.P. Goldthwait, C.S. Brockman, D.N. Hull, E.M. Swinford, and R.G. Van Horn, "Quaternary Geology of Ohio," Ohio Geological Survey, Map M-2, 1:500,000-scale map and 1:250,000-scale GIS files, 1999.

2.5.1-451 Michigan Department of Natural Resources, "Quaternary Geology of Michigan," Edition 2.0, digital map, 1998.

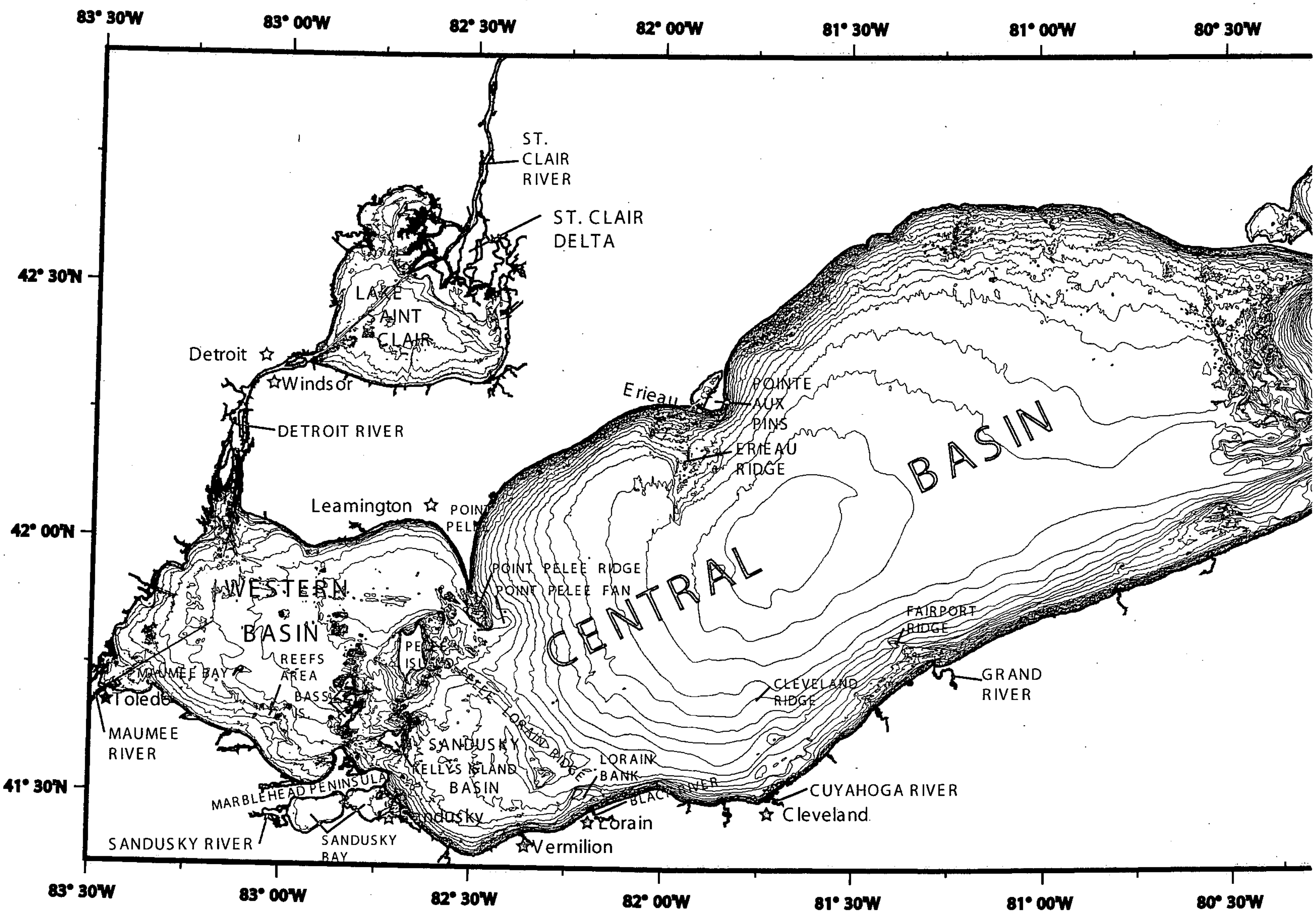
2.5.1-452 Ontario Geological Survey, "Quaternary Geology, Seamless Coverage of the Province of Ontario," Data Set 14, 1997.

Add Insert #3 here

Insert #3

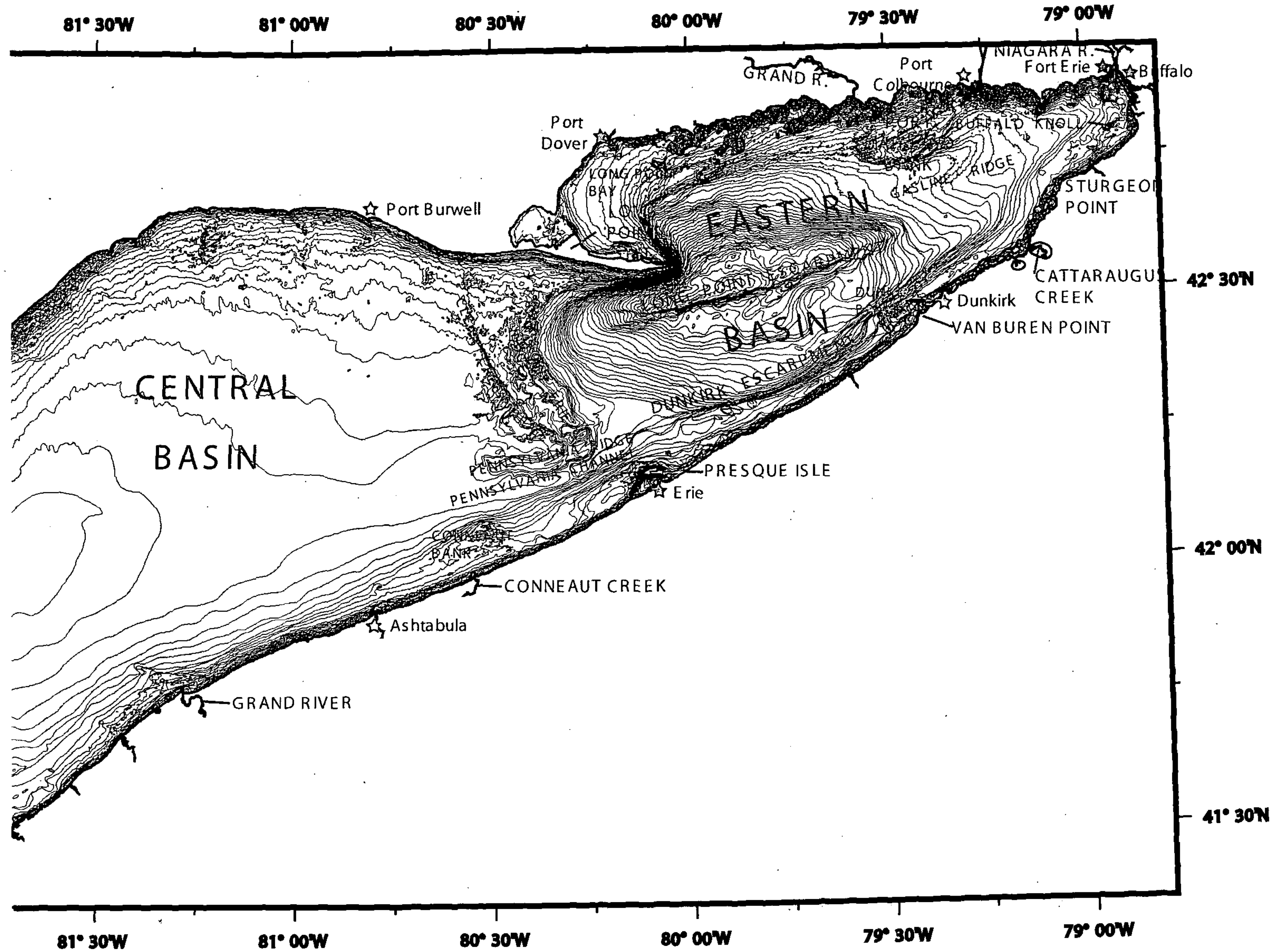
2.5.1-494	Holcombe, T.L., Taylor, L.A., Warren, J.S., Vincent, P.A., Reid, D.F., and Herdendorf, C.E., "Lake-floor Geomorphology of Lake Erie," National Environmental Satellite, Data, and Information Service, NATIONAL GEOPHYSICAL DATA CENTER, World Data Center A for Marine Geology and Geophysics Research Publication RP-3, 26 pp plus 8 plates and 9 figures, 2005.
2.5.1-495	National Geophysical Data Center, Great Lakes Data Rescue Project – Lake Erie and Lake Saint Clair Bathymetry, "Lake Erie and Lake Saint Clair Geomorphology," http://www.ngdc.noaa.gov/mgg/greatlakes/lakeerie_cdrom/html/e_gmorph.htm.
2.5.1-496	Hobson, G. D., Herdendorf, C.E., and Lewis, F.M., "High Resolution Reflection Seismic Survey in Western Lake Erie," Proceedings of the 12th Conference on Great Lakes Research," pp. 210-224, 1969.
2.5.1-497	Carter, C. H., Williams, S., Fuller, J.A., and Meisburger, E.P., "Regional Geology of the Southern Lake Erie (Ohio) Bottom: A Seismic Reflection and Vibracore Study," U.S. Corps of Engineers Coastal Research Center, Miscellaneous Report No. 82-15, 1982.

Figure 2.5.1-263 Index Map of Western Lake Erie Showing Names of Geographic Features



Source: Reference 2.5.1-494

Figure 2.5.1-264 Index Map of Eastern Lake Erie Showing Names of Geographic Features



Source: Reference 2.5.1-494

Attachment 25
NRC3-10-0006

Response to RAI Letter No. 16
(eRAI Tracking No. 3917)

RAI Question No. 02.05.03-06

RAI 02.05.03-06

FSAR Section 2.5.3.2.3 refers to FSAR Figure 2.5.3–201 and states that paleo-shoreline features in the site vicinity cross possible fault trends with no apparent disruption. Please indicate the resolution of this observation and whether it was based on field or map analyses. The FSAR does not address whether shoreline-elevation data in the site vicinity record possible deformation over a broader area. Please provide a discussion of this topic and, if tilting is evident, whether it can be attributed solely to glacial isostatic adjustments or whether it may suggest diffuse tectonic deformation. If appropriate, please include a figure showing elevation changes along paleo-shorelines identified in FSAR Figure 2.5.3–201 (in particular, n1 and n3).

Response

Strandlines and related features (e.g., wave-cut bluffs, beach ridges) are key geomorphic features that record the cumulative latest Pleistocene and Holocene history of vertical deformation in the Fermi 3 site region. On a regional basis these features show warping and uplift that reflect glacial and postglacial isostatic adjustments. Figures that illustrate the pattern of uplift (FSAR Figures 2.5.1-251 and 2.5.1-252 included in the Response to RAI 02.05.01-03) and further discussion of differential vertical uplift due to rebound and subsidence (related to collapse of the glacial forebulge) in the site region (320-km [200-mi.] wide radius) are provided in the Response to RAI 02.05.01-3. This response herein discusses (1) the glacial lake strandlines and related geomorphic features in the site vicinity and (2) constraints on the amount and location of vertical deformation of the strandline features based on analysis of the available USGS 10-m digital elevation model (DEM) data.

Glacial Lake Strandlines and Related Geomorphic Features

Early detailed mapping of beaches and correlative moraines in southeast Michigan is summarized by Leverett and Taylor (Reference 2.5.1-490), who described recognized "hinge lines" between areas or "zones of horizontality" (to the south) and tilted or warped areas (to the north), and later by Leverett (Reference 2.5.1-488). The site vicinity lies southwest of the mapped hinge lines for the late glacial (about 13 –12 ka) shorelines in the "zone of horizontality" where previous mapping would suggest there has not been differential vertical deformation of the paleo-shorelines (FSAR Figures 2.5.1-251 and 2.5.1-252 included in the Response to RAI 02.05.01-03).

The Quaternary surficial map shown on FSAR Figure 2.5.1-231 shows the locations of previously mapped latest Pleistocene and Holocene shorelines within the site vicinity. The paleo-shorelines (also referred to as relict shorelines) are defined based on various geomorphic features, including wave-cut cliffs and terraces, beach ridges, and delta deposits (References 2.5.1-488 and 2.5.1-490). The term "strandline" (the line of intersection of the slope of a terrace and that of a cliff) can also describe the location of the shoreline associated with these geomorphic features (Reference 2.5.1-489).

For northeastern Ohio, Totten (Reference 2.5.1-489) identifies three prominent wave-cut cliffs (or sets of cliffs) and terraces south of Lake Erie; on each terrace there are two to six beach ridges (FSAR Figure 2.5.1-255). The most prominent beach ridges recognized south of Lake Erie, from highest to lowest, are Lake Maumee I, II, III; Lake Whittlesey; Lake Arkona I, II, III; Lake Warren I, II, III; Lake Wayne; Lake Grassmere; and Lake Lundy. Totten (Reference 2.5.1-489) observes that the wave-cut strandlines do not occur at exactly the same elevations as the beach ridges. Although the cliff and terrace features have been identified with the associated beaches, these erosional forms are earlier than the beaches that are in front or upon them. Totten (Reference 2.5.1-489) therefore gives the cliffs and terraces separate designations of Upper, Middle, and Lower, with the former names of Lake Maumee, Lake Whittlesey, and Lake Warren, respectively, in parentheses.

Totten (Reference 2.5.1-489) concludes that in earlier episodes, prior to the most recent Late Wisconsinan (Woodfordian) ice advance, the major activity was wave erosion, forming cliffs and terraces as the modern lake is doing. At the various lake levels following the Woodfordian glaciation, the major activity was the deposition of beach and dune ridges, rather than cliff and terrace cutting. Calkin and Feenstra (Reference 2.5.1-297) believe that some segments of the deglacial Great Lakes shore features may be associated with relict or re-excavated wave-cut terraces and bluffs as Totten believes, but suggests that for at least the Whittlesey shoreline, the entire set of features (wave-cut terraces in bedrock and drift, 5 – 8 m [16 – 26 ft] below Whittlesey storm beach crests) is related to a single lake phase.

Based on geomorphic position and elevation, the mapped paleo-shorelines in the site vicinity are correlated with glacial and postglacial lake levels that postdate the most recent major glacial advance approximately 14,800 years before present (BP) (Reference 2.5.1-294) as described by Eschman and Karrow (Reference 2.5.1-391) and Calkin and Feenstra (Reference 2.5.1-297) (FSAR Figure 2.5.1-256). A topographic profile illustrating the morphology of the paleo-shoreline features near the Fermi 3 site vicinity is shown on FSAR Figure 2.5.1-257. In the following descriptions of the lake levels, the elevations represent averages of the paleo-shorelines, which have been differentially upwarped north of Cleveland, Ohio, and Detroit, Michigan, by glacial isostatic adjustment along an apparent maximum uplift trend of 020 to 030 degrees (Reference 2.5.1-297). The following descriptions are based on Calkin and Feenstra (Reference 2.5.1-297) unless noted otherwise.

Lake Maumee—Three distinct lake levels, stabilized at average elevations of 244 m (800 ft), 238 m (780 ft), and 232 m (760 ft), are referred to as Maumee I, Maumee III, and Maumee II, respectively. Leverett and Taylor (Reference 2.5.1-490) suggested that the lowest phase preceded and was submerged by the Middle Maumee phase. More recent mapping suggests that the Lowest Maumee level was either reoccupied after the Middle phase or may actually have been third rather than second in the sequence (References 2.5.1-297 and 2.5.1-489).

Lake Arkona—Beaches of glacial Lake Arkona in the Lake Erie basin occur at 216 m (710 ft) or as much as 9 m (30 ft) below those of the younger Lake Whittlesey. Drainage of Lake Arkona is postulated to have been marked by distinct intervals of outlet erosion, or by isostatic and climatic events combined during more uniform downcutting of the outlet to produce three lake levels. Three beaches at 216 m (710 ft), 213 m (700 ft), and 212 m (695 ft) are referred to as Highest (Arkona I), Middle (Arkona II), and Lowest (Arkona III), respectively. Strands south of the Port Huron area in Michigan showed evidence of erosion and modification by Whittlesey waters. The highest of the Arkona strands in this area was noted to be gravelly and barely recognizable. Deltaic sediments associated with the Arkona extend out from the general line of the shoreline (Reference 2.5.1-490). Arkona shore features in Ontario and in northern Ohio are locally gravelly, discontinuous, poorly developed, and lack good beach ridge form. An age of 13,600 ± 500 years BP for a sample from a lagoon deposit near Cleveland, Ohio, at 210 m (690 ft) may date Lowest Lake Arkona. The lagoon deposits are overlain by probably deeper water sediments assigned to Lake Whittlesey.

Lake Whittlesey—The Lake Whittlesey strands are among the strongest and best developed in the Great Lakes region. A number of radiocarbon ages closely bracket the inception of Lake Whittlesey at about 13,000 years BP during the Port Huron re-advance, following the post-Arkona low lake phase (Lake Ypsilanti) at the end of the Mackinaw Interstade. In the Lake Erie basin, waters that rose to form Lake Whittlesey at about 226 m (740 ft) submerged the Lake Arkona strands. Leverett (Reference 2.5.1-488) states that the Whittlesey beach is between elevations 224 and 227 m (735 and 745 ft) in the untilted part in northern Ohio and southeastern Michigan. In the Michigan portion of the Lake Erie basin the strand is nearly continuous. The Whittlesey strand occurs nearly everywhere as a strong single ridge or bluff.

Lakes Warren and Wayne—Glacial Lake Warren developed in the Lake Erie and Lake Huron basins as the ice margin retreated from the outermost Port Huron Moraine to allow Lake Whittlesey to drain along the ice margin into the Saginaw Bay area of the Lake Huron basin (FSAR Figure 2.5.1-232). Highest Lake Warren (Warren I) is at about 209 – 210 m (686 – 689 ft) in elevation. Lowest Warren (Warren III) existed at about 203 – 204 m (666 – 669 ft). A commonly weaker intermediate level (Middle Warren or Warren II) at about 206 m (675 ft) is represented locally. (References 2.5.1-297 and 2.5.1-391) Totten (Reference 2.5.1-489) reports an age of 13,050 ± 100 BP (ISGS-437) for wood collected from an organic horizon beneath basal Warren I (Middle Warren) beach gravel in northeastern Ohio. Several published dates between 12,100 and 12,000 BP from post-Warren sediments yield minimum ages for this lake.

The Lake Warren beaches contrast with those of Lake Whittlesey in that they are sandier and less gravelly. The beaches occur as multiple ridges. Less commonly, Warren strands are represented by wave-cut landforms. As a group, the Warren strands are strongly developed and easily traced throughout the basin. Leverett (Reference 2.5.1-488) notes that the Upper Warren beach is associated with a large sandy delta of the Raisin River in eastern Lenawee County, Michigan, and that it varies greatly in geomorphic expression, being weak where there were wide shallows in front of it.

Ice-margin retreat during the Warren phase is postulated to have allowed for eastward drainage from Lake Wayne. Leverett (Reference 2.5.1-488) cites evidence for submergence and modification of the Wayne shoreline by later stages of Lake Warren. Referring to mapping of shoreline features in northeastern Ohio, Totten (Reference 2.5.1-489) does not preclude the possibility of fluctuating lake levels, but concludes that the ridges on the south shore of Lake Erie in that area are progressively younger at lower elevations. Leverett (Reference 2.5.1-488) describes multiple ridges of similar height that stand 1 – 1.5 m (3 – 5 ft) above the intervening areas at the general elevation of Lake Wayne. It is further noted by Leverett that the sandy belt in which the Wayne beach developed is up to 5 – 8 km (3 – 5 mi.) wide or more in places with the beach near its outer border. The Wayne phase may have been followed by a brief period of even lower lake level when waters in the Lake Erie basin were lowered to levels below the Niagara Escarpment (Reference 2.5.1-297).

Lake Grassmere and Lake Lundy Glacial Lake Phases—The drop in the lake level from Lowest Warren to nonglacial early Lake Erie was marked by brief pauses that are represented by generally weak and very discontinuous shore features. These features have been assigned, on the basis of their relative positions below Lake Warren strands, to the following lake phases of successively younger age: Lake Grassmere at 195 m (640 ft) and Lake Lundy at 189 – 192m (620 – 630 ft). The dashed line for Lake Grassmere shown on FSAR Figure 2.5.1-257 represents the published lake elevation, while the band width associated with Lake Grassmere indicates the range of closely related flat surfaces identified from the DEM data. Beaches that are projected to the Lake Grassmere and Lake Lundy levels generally are sandy, have a relief of less than 1 – 2 m, and are discontinuous. Thus these strandlines have been mapped only locally. Some of the identified beach ridges are probably offshore bars formed in earlier lakes and some may be windblown sand.

Post–Lake Lundy Lake Levels—Subsiding waters in the northeastern Lake Erie basin lowered lake levels below the Niagara Escarpment about 12,400 years BP. This marked the formation of nonglacial early Lake Erie at 40 m (131 ft) below the present level (Reference 2.5.1-297). Glacioisostatic uplift, with the modulating effect of changes of inflow from the upper Great Lakes, raised lake levels from an initial two- or three-basin early Lake Erie phase to an integrated lake within 4 m of the present level by 3,400 years BP (Reference 2.5.1-487).

Analysis of the Available USGS 10-meter DEM Data

The USGS 10-m DEM data was used to evaluate whether there was evidence for vertical deformation of latest Pleistocene paleo-shoreline features across the site vicinity. A series of maps highlighting different contour interval ranges (2 m and 0.5 m) (Figures 1 and 2, and FSAR Figures 2.5.3-210 and 2.5.3-213), as well as a series of topographic profiles (Figure 3, FSAR Figures 2.5.3-211, 2.5.3-212, 2.5.3-214, 2.5.1-256, and 2.5.1-257) was developed from the DEM to evaluate the continuity and variability of paleo-shoreline features across the site vicinity and mapped locations of the Sumpter Pool and New Boston Pool possible faults.

Comparison of the mapped shorelines to the contour intervals derived from the USGS 10-m DEM shows that the elevation along individual mapped shorelines may vary as much as 3 to 4 m (Figures 1 and 2). This variability is not unexpected given that the shorelines were mapped based on a variety of features, some erosional (e.g., wave-cut bluffs) and some depositional (e.g., crests of sand ridges) and compiled on topographic maps that were available at that time. The mapped shorelines, however, generally lie within the range of elevations described in the published literature. This is illustrated in the topographic profiles that show where the mapped shorelines lie relative to the published elevation range of features associated with the different glacial lake levels. Shoreline features (n1, n2, and n3) (FSAR Figure 2.5.3-201) identified in the lineament analysis are more consistent along their mapped lengths and correlate to the Lake Wayne strandline (n1), Lake Warren I and II strandlines (n2), and the Whittlesey strandline or highest Arkona strandline (n3). The elevations of specific features associated with mapped shorelines (e.g., the top of apparent deltas formed at the intersection of major drainages and the highest Arkona shoreline, which are all at consistent elevations of 216 – 218 m) indicate the absence of significant vertical deformation across the site vicinity (FSAR Figures 2.5.3-210, 2.5.3-211 and 2.5.3-212). Geomorphic surfaces associated with the Arkona deltas, and the Warren and younger strandlines that formed at progressively lower levels are most easily correlated across the site vicinity.

Evidence for the absence of tilting and/or localized differential vertical movement across possible faults mapped in the site vicinity also is illustrated by FSAR Figures 2.5.3-213 and 2.5.3-214. The locations of topographic profiles on opposite sides of the Sumpter Pool and New Boston Pool possible faults are shown on FSAR Figure 2.5.3-213, with the topographic profiles shown on FSAR Figure 2.5.3-214. The topographic profiles in FSAR Figure 2.5.3-214 show three surfaces associated with the Grassmere Lake level (approximately 195 m). The elevations of the three surfaces are indicated on FSAR Figure 2.5.3-213 in pink for elevations 193.6 – 194 m in white for elevations 194.6 – 194 m, and in black for elevations 196.1 – 196.5 m, with these surfaces separated by slight risers (blue intervals). The brown band in FSAR Figure 2.5.3-214 corresponds to the range in estimated elevations from 193.6 to 196.5 m for the Grassmere Lake levels. The three surfaces identified on the topographic profiles; all lie within the brown band representing the estimated elevation range of Grassmere Lake (FSAR Figure 2.5.3-214).

The profiles allow for additional comparison of the morphology and relative elevations of shoreline features across mapped structures in the site vicinity. The profiles further illustrate that although the single line shown for the individual shorelines may not consistently follow the same feature, the morphology of the features associated with the mapped shorelines is similar, and that these features occur at similar elevations across the mapped structures (FSAR Figures 2.5.3-211, 2.5.3-212, and 2.5.3-214).

The resolution of this data with respect to constraining vertical deformation was discussed in the Response to RAI 02.05.03-04 and is further considered in this response.

As noted in the Response to RAI 02.05.03-04, although the *absolute* vertical accuracy of a point within the USGS data may be on the order of a few meters, the *average relative* vertical accuracy of point pairs is 1.64 m (5 ft). It is reasonable to assume that the relative accuracy of a number of points along a transect or topographic profile would be greater, i.e., the accuracy between points would be less than 1.64 m (5 ft). The contour interval maps and the topographic profiles used in this analysis do not show systematic patterns of deformation. Relict shoreline features associated with the Arkona, Lake Warren, and Grassmere lake levels appear to be at the same elevations within less than 1.0 – 1.5 m (3 - 5 ft) across the study area. The morphology of three horizontal surfaces in the range of 193.5 – 196.5 m (635 – 645 ft) associated with the Lake Grassmere lake level shown on FSAR Figure 2.5.3-214 shows evidence of no deformation or tilting of these surfaces across the Sumpter Pool and New Boston Pool possible faults within a resolution of 0.5 – 1.0 m (1.6 –3.3 ft).

In summary, early observations of the lack of tilting or deformation of the latest Pleistocene paleo-shorelines in the "zone of horizontality" in southeastern Michigan is confirmed by analysis of the USGS 10-m DEM data. The analysis of the data outlined in this response further confirms the results of the lineament analysis presented in the FSAR that concluded there is evidence of no deformation of latest Pleistocene (approximately 13 – 12 ka) shoreline features across the New Boston and Sumpter Pool possible faults.

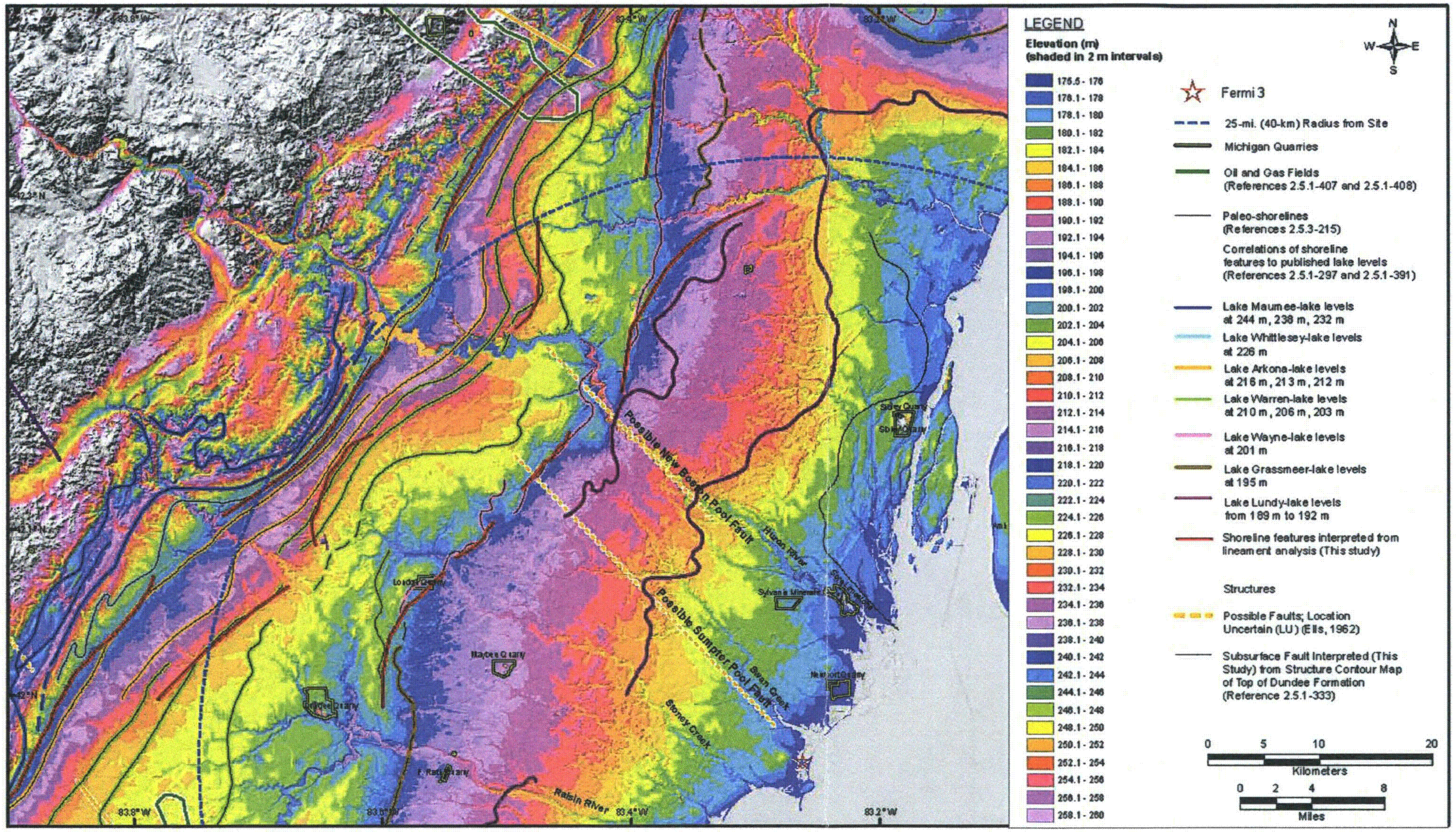


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Figure 1 Colored Contour Interval Map (2-m Intervals) Showing Locations of Previously Mapped Paleo-shorelines

Attachment 25 to
NRC3-10-0006
Page 9

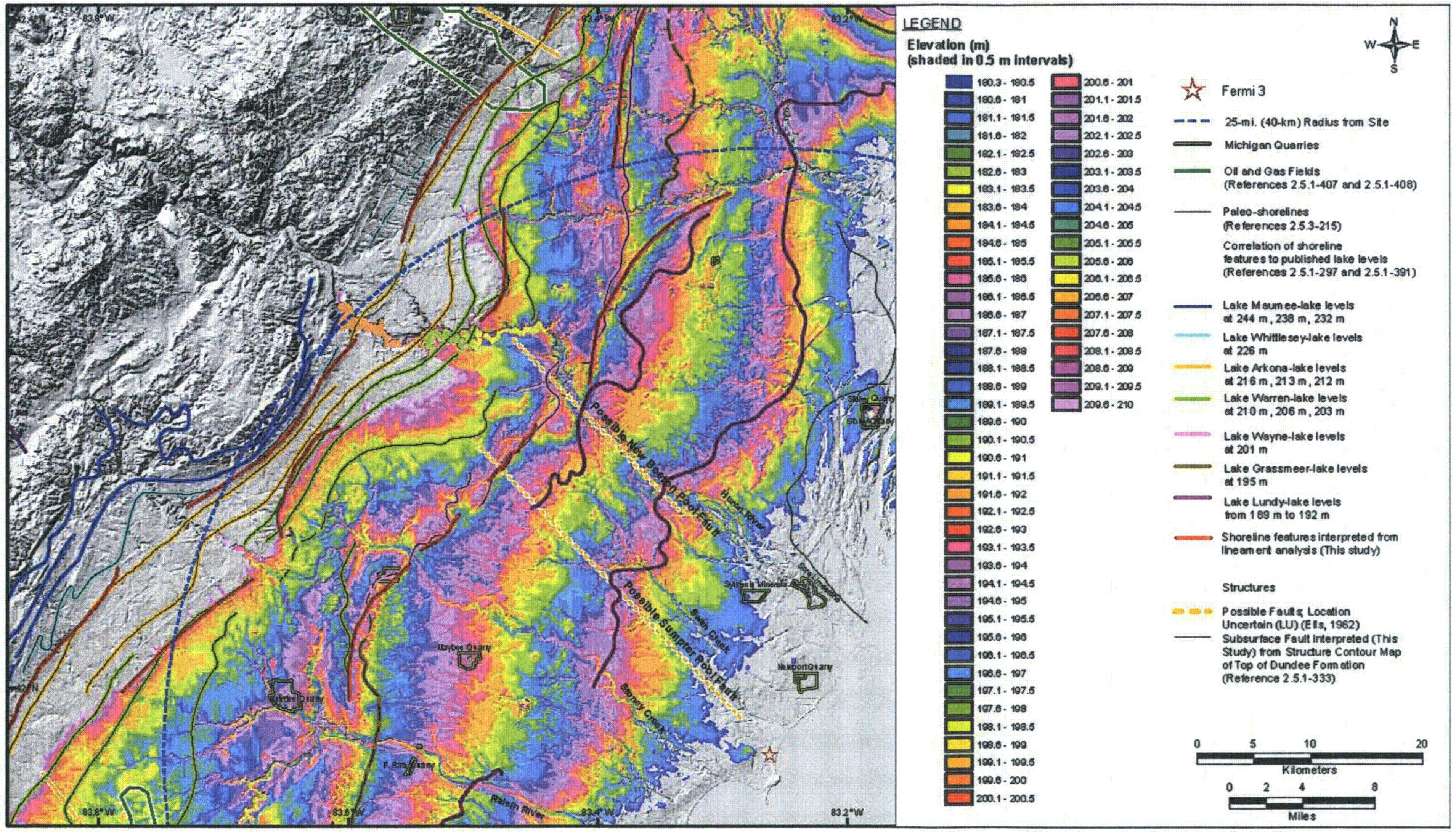

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Figure 2 Colored Contour Interval Map (0.5-m Intervals) Showing locations of Previously Mapped Paleo-shorelines at Elevations Below 210 m

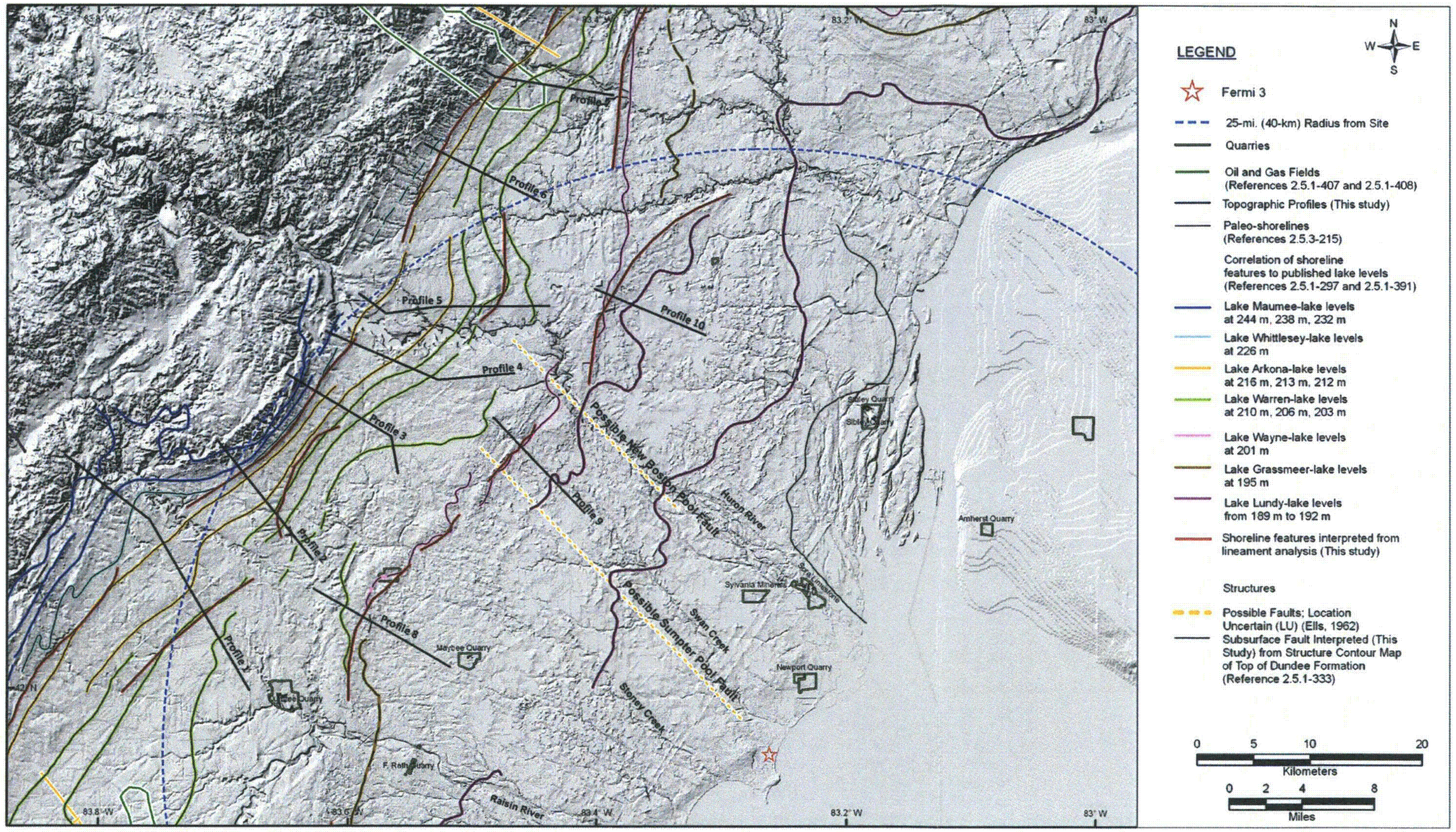

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Figure 3 Map Showing the Locations of Topographic Profiles Relative to Mapped Paleo-shorelines

Proposed COLA Revision

Proposed markups to revise FSAR Sections 2.5.1.2.3, 2.5.1.2.3.1, 2.5.1.2.3.2 are attached.

Proposed markups to revise FSAR Sections 2.5.3 are provided as an attachment to the response to RAI 02.05.03-07

Markup of Detroit Edison COLA
(following 20 pages)

The following markup represents how Detroit Edison intends to reflect this RAI response in a future submittal of the Fermi 3 COLA. However, the same COLA content may be impacted by revisions to the ESBWR DCD, responses to other COLA RAIs, other COLA changes, plant design changes, editorial or typographical corrections, etc. As a result, the final COLA content that appears in a future submittal may be different than presented here.

Figure 2.5.1-234f) and younger lakes have surface expression continuity and preserved landforms that document the rebound history of the area. The Michigan Peninsula has valleys that were lake outlets (Imlay Channel and Grand River Valley in Michigan and the Glacial Grand Valley that allowed the waters of Glacial Lake Arkona, which extended east from the Saginaw lowland into the Lake Erie basin, to drain west to the Michigan basin) (Reference 2.5.1-263) (Figure 2.5.1-234e and Figure 2.5.1-234f).

Advance of ice during the Port Huron Stade, which did not enter the site vicinity, still affected the site region. It created higher lake levels (Subsection 2.5.1.1.2.3.4.4), and proglacial lakes transgressed the site area. Deposits of Glacial Lakes Whittlesey and Warren, dated as 13,000 and 12,800 years BP, form the bulk of the glacial-age sediments deposited in the site vicinity (Reference 2.5.1-297) (Figure 2.5.1-234h and Figure 2.5.1-234i). Minor fluctuations of lake level as recently as 7,500 years BP could have reworked older sediments (Reference 2.5.1-272) (Figure 2.5.1-235). Glacial Lake Whittlesey's beaches, with 3 to 5 m (10 to 16 ft) of relief in western Ohio, are nearly continuous and include gravels as well as sand (Reference 2.5.1-297). The younger beaches are sandy, may have multiple ridges, and have been windblown (Reference 2.5.1-297) and are difficult to trace through southeastern Michigan (Reference 2.5.1-391). A lower Lake Warren level, sometimes called Lake Wayne, is named for the broad, flat-topped sandy ridge that may be a modified beach that passes through Wayne, Michigan, 28 km (17.4 mi) west of Detroit (Reference 2.5.1-391).

2.5.1.2.3 Site Stratigraphy

Add Insert #1 here

~~The stratigraphy of the (40-km [25-mi] radius) site vicinity, the 8-km (5-mi radius) site area and the 1-km (0.6-mi radius) site location is roughly equivalent to the stratigraphy of the (320-km [200-mi] radius) site region (Subsection 2.5.1.1.3.2) except for the effects on deposition caused by the proximity of the site to the Findlay arch. For a portion of the Paleozoic, the Findlay arch was a positive topographic feature (higher than the surrounding surfaces). The top of the arch was one of the last areas flooded during a transgression and the first area exposed during a regression. Because the depositional interval on the arch was shorter, the geologic units deposited on the arch were thinner than those in the center of the basin, and the duration of the period of erosion on the arch will be longer (Reference 2.5.1-325; Reference 2.5.1-276). Exposure of~~

~~soluble units (salt, gypsum, and carbonates) to fresh surface water and groundwater leads to the formation of karst and the removal of these units (Reference 2.5.1-392). This section will concentrate on the stratigraphy of the (8-km [5-mi] radius) site area and (1-km [0.6-mi] radius) site location as determined from the Fermi 3 subsurface investigation. The section will be subdivided into sections on Paleozoic bedrock, Quaternary deposits, and contains a description of the soils in the (8-km [5-mi] radius) site area.~~

The subsurface investigation conducted for Fermi 3 is discussed in Subsection 2.5.4. Figure 2.5.1-235 and Figure 2.5.1-236 show the locations of borings drilled for the COL application. The boring logs are included in Appendix 2.5DD. To aid in understanding the (1 km [0.6-mi] radius) site location stratigraphy, geologic cross sections through the site are included on Figure 2.5.1-237, Figure 2.5.1-238, Figure 2.5.1-239, and Figure 2.5.1-240. The locations of the geologic cross sections are shown on Figure 2.5.1-235 and Figure 2.5.1-236.

Add Insert #2 here

2.5.1.2.3.1 Paleozoic Stratigraphy of the Site Area

Three Paleozoic units are mapped at the surface in the (8-km [5-mi] radius) site area including the Silurian Bass Islands Group, the Devonian Garden Islands Formation and Sylvania Sandstone (Figure 2.5.1-241). East of Fermi 3, below the sediments of Lake Erie, the Fermi 2 subsurface investigation encountered the Silurian Salina Group at the top of bedrock (Reference 2.5.1-221). The Devonian-age units are not exposed at the surface in the (1-km [0.6-mi] radius) site location (Figure 2.5.1-241). The oldest geologic unit encountered in the Fermi 3 subsurface investigation was the Silurian Salina Group. This subsection covers in greater detail the geologic units in the site area and site location. Geologic units older than the Silurian Salina Group are briefly discussed in Subsection 2.5.1.1.3.2.

2.5.1.2.3.1.1 Silurian Salina Group

The Silurian Salina Group is within the Tippecanoe II cratonic sequence (Reference 2.5.1-275). The Salina Group overlays the dolomites and reef facies of the Silurian Guelph Dolomite of the Niagara group and is overlain by the Silurian Bass Islands Group (Figure 2.5.1-217). The Salina group in the center of the Michigan basin is subdivided into seven units labeled A through G. Unit A has been subdivided into 4 additional

Insert #1

The following subsections provide a summary of stratigraphy in the Fermi 3 site vicinity (40-km [25-mi.] radius) and site area (8-km [5-mi.] radius). The information presented is based on a review of geologic literature, communications with geologists and other researchers who are familiar with previous studies in the site area, and geotechnical and geologic field investigations conducted at and in the vicinity of the Fermi 3 site.

Insert #2

The Paleozoic stratigraphy of the (40-km [25-mi] radius) site vicinity, the 8-km (5-mi radius) site area and the 1-km (0.6-mi radius) site location is roughly equivalent to the stratigraphy of the (320-km [200-mi] radius) site region (Subsection 2.5.1.1.3.2) except for the effects on deposition caused by the proximity of the site to the Findlay arch. For a portion of the Paleozoic, the Findlay arch was a positive topographic feature (higher than the surrounding surfaces). The top of the arch was one of the last areas flooded during a transgression and the first area exposed during a regression. Because the depositional interval on the arch was shorter, the geologic units deposited on the arch were thinner than those in the center of the basin, and the duration of the period of erosion on the arch will be longer (Reference 2.5.1-325; Reference 2.5.1-276). Exposure of soluble units (salt, gypsum, and carbonates) to fresh surface water and groundwater leads to the formation of karst and the removal of these units (Reference 2.5.1-392). This section will concentrate on the stratigraphy of the (8-km [5-mi] radius) site area and (1-km [0.6-mi] radius) site location as determined from the Fermi 3 subsurface investigation.

Limestone, the Traverse Group, and Antrim Shale. These units are not discussed because they are in the western portion of the site vicinity and are generally covered in Subsection 2.5.1.1.3.2.3 Kaskaskia cratonic sequence.

Add Insert #3 here

2.5.1.2.3.2.3

~~2.5.1.2.3.2~~ Quaternary Stratigraphy of the Site Location

This section concentrates on the Quaternary units encountered as part of the Fermi 3 subsurface investigation including, listed from oldest to youngest, glacial till, lacustrine deposits, and fill.

2.5.1.2.3.2.3.1

~~2.5.1.2.3.2.1~~ Glacial Till

Glacial till predominantly overlies the top of bedrock (Bass Islands Group) over the entire (1-km [0.6-mi] radius) site location. At the top of bedrock, there is often sand or gravel that may represent weathered bedrock. To the west and northwest of the Fermi 3 site near borings MW-381 and MW-393 (Figure 2.5.1-235), the glacial till is immediately below the top soil. Throughout the remainder of the site location the glacial till is overlain by lacustrine deposits. The glacial till ranges from 1.8- to 5.8-m (6- to 19-ft) thick. The glacial till is subdivided into an upper and lower unit based on color. The composition of the glacial till is comprised of predominantly of fines with variable amounts of sand, and gravel, with cobbles.

The lower glacial till is a gray to dark gray, lean clay with sand or gravel (CL), silt with sand or gravel (ML), or clayey graded gravel (GC). The individual boring logs from the Fermi 3 subsurface investigation show that the glacial till is homogeneous; however, variations in glacial till composition between borings in the Fermi 3 subsurface investigation indicates some heterogeneity in the lower glacial till across the site.

The upper glacial till is brown to grayish brown, lean clay with sand or a trace of gravel (CL). The Fermi 3 subsurface investigation did not attempt to determine the age or correlation of these glacial tills to the Quaternary stratigraphy presented in Subsection 2.5.1.1.2.3.4.

2.5.1.2.3.2.3.2

~~2.5.1.2.3.2.2~~ Lacustrine Deposits

Quaternary lacustrine (lake) deposits overlie the glacial till except near borings MW-381 and MW-393 (Figure 2.5.1-235). The thickness of the lacustrine deposits ranges from 0 to 2.7 m (0 to 8.7 ft). The lacustrine deposits are laminated gray, dark gray, and reddish brown lean clay (CL) and fat clay (CH). In some areas the lacustrine deposits are overlain by a thin layer of peat or organic soil. At Fermi 2 and Fermi 3 the top of the lacustrine deposits may have been removed and replaced with fill described in Subsection ~~2.5.1.2.3.2.3~~. The lacustrine deposits are the sediments from lakes that covered the site area after the glaciers receded (Subsection 2.5.1.1.2.3.4.4).

2.5.1.2.3.2.3.3

~~2.5.1.2.3.2.3~~ **Fill**

2.5.1.2.3.2.3.3

During the construction of existing Fermi 1 and Fermi 2, a lagoon at the site was filled with a variety of materials including gravel/cobble fill, some of the fill material came from an onsite quarry in the Bass Islands Group (Reference 2.5.1-221). In the immediate location of Fermi 3, this fill is classified as cobbles, well graded gravel (GW), poorly graded gravel (GP), well graded gravel with silt (GW-GM), and boulders.

To the east and west of the gravel/cobble fill, some finer-grained fills were encountered during the Fermi 3 subsurface investigation in the following areas:

- At boring MW-386, lean clays with sand and gravel (CL) were encountered. This is near Fermi 1. (Figure 2.5.1-235)
- At borings MW-383 and MW-384, predominantly lean clay fill with sand (CL) and gravel was encountered. Borings MW-383 and MW-384 are located south and southwest of Fermi 3 (Figure 2.5.1-235).

2.5.1.2.3.3 **Soils of Site Area**

The distribution of surficial deposits and landforms within the site vicinity (25-mi [40-km] radius) is shown on . The site area (8-km [5-mi] radius) is located in a glaciolacustrine section on the western edge of Lake Erie (Figure 2.5.1-244).

Soils in the site location (1-km [0.6-mi] radius from the site) include the Lenawee ponded and Lenawee–Del Rey associations. The Lenawee ponded association consists of nearly level, very poorly drained silty soils on lake plains near Lake Erie and adjacent to large rivers. In some places it is formed on sand deposits in beach areas. The Lenawee-Del Rey association consists of nearly level, somewhat poorly drained silty soils formed on lake plains. (Reference 2.5.1-404)

Detailed soil units within the Lenawee ponded and Lenawee–Del Rey associations are shown on Figure 2.5.1-245 (Reference 2.5.1-405) and include Lenawee silty clay loam, ponded; Blount loam; Del Rey silt loam;

Insert #3

2.5.1.2.3.2 **Quaternary Stratigraphy and Geomorphology**

Quaternary surficial geologic units exposed in the site vicinity (40-km [25-mi.] radius) consist primarily of till of Wisconsinan age overlain by a thin mantle of lacustrine and eolian sands or locally thicker beach-dune ridge deposits formed along late-glacial lake shorelines. Alluvium is present along the larger drainages that are incised into the lacustrine/till plain that is present throughout the site vicinity.

The distribution of surficial deposits and landforms within the site vicinity (40-km [25-mi.] radius) is shown on Figure 2.5.1-231. The site area (8-km [5-mi.] radius) is located in a glaciolacustrine section on the western edge of Lake Erie (Figure 2.5.1-244). The following subsections discuss the glacial and postglacial lake strandlines and related geomorphic features (Subsection 2.5.1.2.3.2.1), Quaternary deposits and soils in the site vicinity and site area (Subsection 2.5.1.2.3.2.2), and Quaternary stratigraphy of the site location (Subsection 2.5.1.2.3.2.3).

2.5.1.2.3.2.1 **Glacial Lake Strandlines and Related Geomorphic Features**

The Quaternary surficial map shown on Figure 2.5.1-231 shows a number of previously mapped latest Pleistocene and Holocene shorelines within the site vicinity. The paleo-shorelines (also referred to as relict shorelines) are defined based on various geomorphic features, including wave-cut cliffs and terraces, beach ridges, and delta deposits (References 2.5.1-488, 2.5.1-490). The term strandline (the line of intersection of the slope of a terrace and that of a cliff) can also describe the location of the shoreline associated with these geomorphic features (Reference 2.5.1-489).

Early mapping of beaches and correlative moraines in the Huron and Erie basins was summarized by Leverett and Taylor (Reference 2.5.1-490), who recognized “hinge lines” between untilted areas (to the south) and tilted or warped areas (to the north) (see discussion of shoreline deformation patterns in Subsection 2.5.1.1.4.1.1). The site vicinity lies southwest of the mapped hinge lines for the late glacial shorelines in the “zone of horizontality” where previous mapping would suggest there has not been differential vertical deformation of the paleo-shorelines (Figures 2.5.1-251 and 2.5.1-252). Leverett (Reference 2.5.1-488) discusses the strandline features associated with Lakes Maumee, Arkona, Whittlesey, and Wayne in the southeastern part of Michigan.

For northeastern Ohio, Totten (Reference 2.5.1-489) identifies three prominent wave-cut cliffs (or sets of cliffs) and terraces south of Lake Erie; on each terrace there are two to six beach ridges (Figure 2.5.1-255). The most prominent beach ridges recognized south of Lake Erie, from highest to lowest, are Maumee I, II, III; Whittlesey; Arkona I, II, III; Warren I, II, III; Wayne; Grassmere; and Lundy. Totten (Reference 2.5.1-489) notes that the wave-cut strandlines do not occur at exactly the same elevations as the beach ridges. However, the Maumee, Whittlesey, and Warren beach ridges in northeast Ohio occur at the top of prominent cliffs; consequently the cliff and overlying ridge share a common frontal slope and are considered a single feature. Although the cliff and terrace features have been identified with the associated beaches, these erosional forms are earlier than the beaches that are in front or upon them. Totten (Reference 2.5.1-489) therefore gives the cliffs and terraces separate designations of Upper, Middle, and Lower, with the former names of Maumee, Whittlesey, and Warren, respectively, in parentheses.

Totten (Reference 2.5.1-489) concludes that in earlier episodes prior to the most recent late Wisconsinan (Woodfordian) ice advance, the major activity was wave erosion, forming cliffs and terraces as the modern lake is doing. At the various lake levels following the Woodfordian glaciation, the major activity was the deposition of beach and dune ridges, rather than cliff and terrace cutting. Calkin and Feenstra (Reference 2.5.1-297) agree with Totten (Reference 2.5.1-489) that some segments of the deglacial Great Lakes shore features may be associated with relict or re-excavated wave-cut terraces and bluffs, but suggest that for at least the Whittlesey shoreline, the entire set of features (wave-cut terraces in bedrock and drift, 5 – 8 m [16 – 26 ft] below Whittlesey storm beach crests) is related to a single lake phase. Calkin and Feenstra (Reference 2.5.1-297) acknowledge, however, that current erosion rates observed along the Lake Erie coast would be too slow to explain the very wide, buried terraces described by Totten (References 2.5.1-489).

Based on geomorphic position and elevation, the mapped paleo-shorelines in the site vicinity are correlated to glacial and postglacial lake levels that postdate the most recent major glacial advance approximately 14,800 years BP (Reference 2.5.1-294) as described by Eschman and Karrow (Reference 2.5.1-391) and Calkin and Feenstra (Reference 2.5.1-297) (Figure 2.5.1-256). A topographic profile illustrating the morphology of the paleo-shoreline features near the Fermi 3 site vicinity is shown on Figure 2.5.1-257. In the following descriptions of the lake levels, the elevations represent averages of the shorelines, which have been differentially upwarped north of Cleveland, Ohio, and Detroit, Michigan, by glacial isostatic adjustment along an apparent maximum uplift trend of 020 to 030 degrees (Reference 2.5.1-297). The following descriptions are based on Calkin and Feenstra (Reference 2.5.1-297) unless noted otherwise.

2.5.1.2.3.2.1.1 Lake Maumee

Three distinct lake levels, stabilized at average elevations of 244 m (800 ft), 238 m (780 ft), and 232 m (760 ft), are referred to as Maumee I, Maumee III, and Maumee II, respectively. Leverett and Taylor (Reference 2.5.1-490) suggested that the lowest phase preceded and was submerged by the Middle Maumee phase. More recent mapping suggests that the Lowest Maumee level was either reoccupied after the Middle phase or may actually have been third rather than second in the sequence (References 2.5.1-297 and 2.5.1-489).

2.5.1.2.3.2.1.2 Lake Arkona

Beaches of glacial Lake Arkona in the Lake Erie basin occur at 216 m (710 ft) or as much as 9 m below those of the younger Lake Whittlesey. Drainage of Lake Arkona is postulated to have been marked by distinct intervals of outlet erosion, or isostatic and climatic events combined during more uniform downcutting of the outlet to produce three lake levels. Three beaches at 216 m (710 ft), 213 m (700 ft), and 212 m (695 ft) are referred to as Highest (Arkona I), Middle (Arkona II), and Lowest (Arkona III), respectively. Strands south of the Port Huron area in Michigan showed evidence of erosion and modification by Whittlesey waters. The highest of the Arkona strands in this area was noted to be gravelly and barely recognizable. Deltaic sediments associated with the Arkona extend out from the general line of the shoreline (Reference 2.5.1-490). Arkona shore features in Ontario and in northern Ohio are locally gravelly, discontinuous, poorly developed, and lack good beach ridge form. An age of 13,600 ± 500 BP for a lagoon deposit near Cleveland, Ohio, at 210 m (690 ft) may date Lowest Lake Arkona. The lagoon deposits are overlain by probably deeper water sediments assigned to Lake Whittlesey.

2.5.1.2.3.2.1.3 Lake Whittlesey

The Lake Whittlesey strands are among the strongest and best developed in the Great Lakes region. A number of radiocarbon ages closely bracket the inception of Lake Whittlesey at about 13,000 years BP during the Port Huron readvance, following the post-Arkona low lake phase (Lake Ypsilanti) at the end of the Mackinaw Interstade. In the Lake Erie basin, waters that rose to form Lake Whittlesey at about 226 m (740 ft) submerged the Lake Arkona strands. Leverett (Reference 2.5.1-488) states that the Whittlesey beach is between elevations 224 and 227 m (735 and 745 ft) in the untilted part in northern Ohio and southeastern Michigan. In the Michigan portion of the Lake Erie basin the strand is nearly continuous. The Whittlesey strand occurs nearly everywhere as a strong single ridge or bluff.

2.5.1.2.3.2.1.4 Lakes Warren and Wayne

Glacial Lake Warren developed in the Lake Erie and Lake Huron basins as the ice margin retreated from the outermost Port Huron Moraine to allow Lake Whittlesey to drain along the ice margin into the Saginaw Bay area of the Lake Huron basin (Figure 2.5.1-232). Highest Lake Warren (Warren I) is at about 209 – 210 m (686 – 689 ft) in elevation. Lowest Warren (Warren III) existed at about 203 – 204 m (666 – 669 ft). A commonly weaker intermediate level (Middle Warren or Warren II) at about 206 m (675 ft) is represented locally. (References 2.5.1-297 and 2.5.1-391) Totten (Reference 2.5.1-489) reports an age of 13,050 ± 100 BP (ISGS-437) for wood collected from an organic horizon beneath basal Warren I (Middle Warren) beach gravel in northeastern Ohio. Several published dates between 12,100 and 12,000 BP from post-Warren sediments yield minimum ages for this lake.

The Lake Warren beaches contrast with those of Lake Whittlesey in that they are sandier and less gravelly. The beaches occur as multiple ridges. Less commonly, Warren strands are represented by wave-cut landforms. As a group, the Warren strands are strongly developed and easily traced throughout the basin. Leverett (Reference 2.5.1-488) notes that the Upper Warren beach is associated with a large sandy delta of the Raisin River in eastern Lenawee County, Michigan, and that it varies greatly in geomorphic expression, being weak where there were wide shallows in front of it.

Ice-margin retreat during the Warren phase is postulated to have allowed for eastward drainage from Lake Wayne. Leverett (Reference 2.5.1-488) cites evidence for submergence and modification of the Wayne shoreline by later stages of Lake Warren. Referring to mapping of shoreline features in northeastern Ohio, Totten (Reference 2.5.1-489) does not preclude the possibility of fluctuating lake levels, but concludes that the ridges on the south shore of Lake Erie in that area are progressively younger at lower elevations. Leverett (Reference 2.5.1-488) describes multiple ridges of similar height that stand 1 – 1.5 m (3 – 5 ft) above the intervening areas at the general elevation of Lake Wayne. It is further noted by Leverett that the sandy belt in which the Wayne beach developed is up to 5 – 8 km (3 – 5 mi.) wide or more in places, with the beach near its outer border. The Wayne phase may have been followed by a brief period of even lower lake level when waters in the Lake Erie basin were lowered to levels below the Niagara Escarpment (Reference 2.5.1-297).

2.5.1.2.3.2.1.5 Lake Grassmere and Lake Lundy Glacial Lake Phases

The drop in the lake level from Lowest Warren to nonglacial early Lake Erie was marked by brief pauses that are in turn now represented by generally weak and very discontinuous shore features. These features have been assigned, on the basis of their relative positions below Lake Warren strands, to the following lake phases of successively younger age: Lake Grassmere at 195 m (640 ft) and Lake Lundy at 189 – 192m (620 – 630 ft). The dashed line for Lake Grassmere shown on Figure 2.5.1-257 represents the published lake elevation, while the band width associated with Lake Grassmere indicates the range of closely related flat surfaces identified from the DEM data. Beaches that are projected to the Lake Grassmere and Lake Lundy levels generally are sandy, have a relief of less than 1 – 2 m, and are discontinuous. Thus these strandlines have been mapped only locally. Some of the identified beach ridges are probably offshore bars formed in earlier lakes and some may be wind-blown sand.

2.5.1.2.3.2.1.6 Post-Lake Lundy Lake Levels

Subsiding waters in the northeastern Lake Erie basin lowered lake levels below the Niagara Escarpment about 12,400 years BP. This marked the formation of nonglacial early Lake Erie at 40 m (131 ft) below present level (Reference 2.5.1-297). Glacioisostatic uplift, with the modulating effect of changes of inflow discharge from the upper Great Lakes, raised lake levels from an initial two- or three-basin early Lake Erie phase to an integrated lake within 4 m (13 ft) of the present level by 3,400 years BP (Reference 2.5.1-487).

2.5.1-444 National Geophysical Data Center, National Oceanic and Atmospheric Administration (NOAA), "2-Minute Gridded Global Relief Data (ETOPO2v2) June, 2006," Bathymetric Data, http://www.ngdc.noaa.gov/mgg/fliers/01mgg04.html, accessed 1 January 2007.

2.5.1-445 Tennessee Valley Authority, "Application for a Combined License (COL) for Two Westinghouse Advance Passive 1000 (AP1000) Pressurized Water Reactors (PWRs) Designated as Bellefonte Nuclear Station Units 3 & 4," date of application submittal October 30, 2007.

2.5.1-446 Indiana Geological Survey, "Structural Features of Indiana (Indiana Geological Survey, Line Shapefile," 2002. http://129.79.145.7/arcims/statewide_mxd/dload_page/geology.html, accessed 2 June 2008.

2.5.1-447 Taylor, K.B., R.B. Herrmann, M.W. Hamburger, G.L. Pavlis, A. Johnston, C. Langer, and C. Lam, "The Southeastern Illinois Earthquake of 10 June 1987," *Seismological Research Letters*, Volume 60, No. 3, pp. 101-110, July – September 1989.

2.5.1-448 Slucher, E.R., E.M. Swinford, G.E. Larson, and D.M. Powers, "Bedrock Geologic Map of Ohio," Ohio Geological Survey, Map BG-1, version 6.0, scale 1:500,000, 2006.

2.5.1-449 Armstrong, D.K., and J.E.P. Dodge, "Paleozoic Geology of Southern Ontario," Ontario Geological Survey, Miscellaneous Release — Data 219, 2007.

2.5.1-450 Pavey, R.R., R.P. Goldthwait, C.S. Brockman, D.N. Hull, E.M. Swinford, and R.G. Van Horn, "Quaternary Geology of Ohio," Ohio Geological Survey, Map M-2, 1:500,000-scale map and 1:250,000-scale GIS files, 1999.

2.5.1-451 Michigan Department of Natural Resources, "Quaternary Geology of Michigan," Edition 2.0, digital map, 1998.

2.5.1-452 Ontario Geological Survey, "Quaternary Geology, Seamless Coverage of the Province of Ontario," Data Set 14, 1997.

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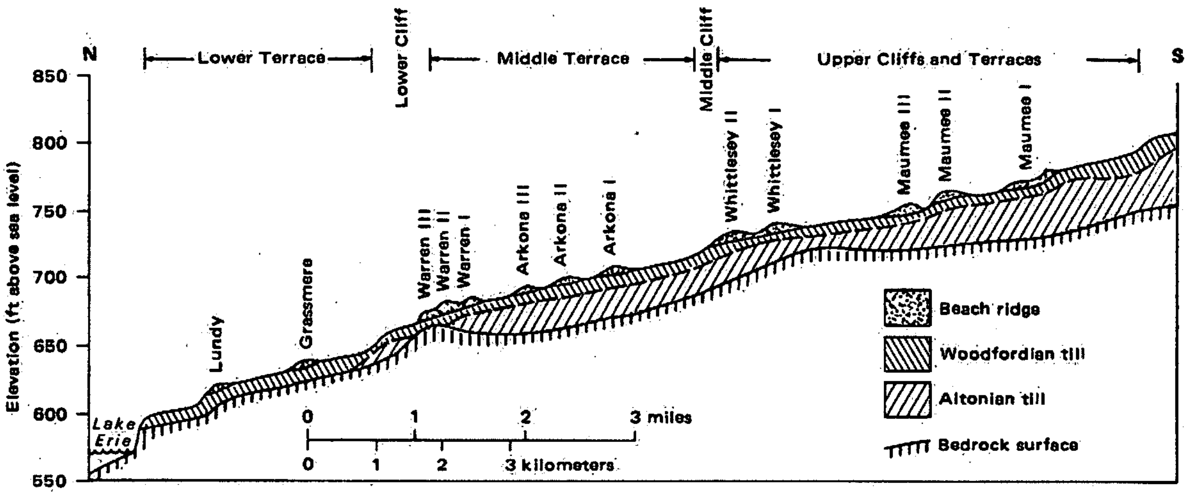
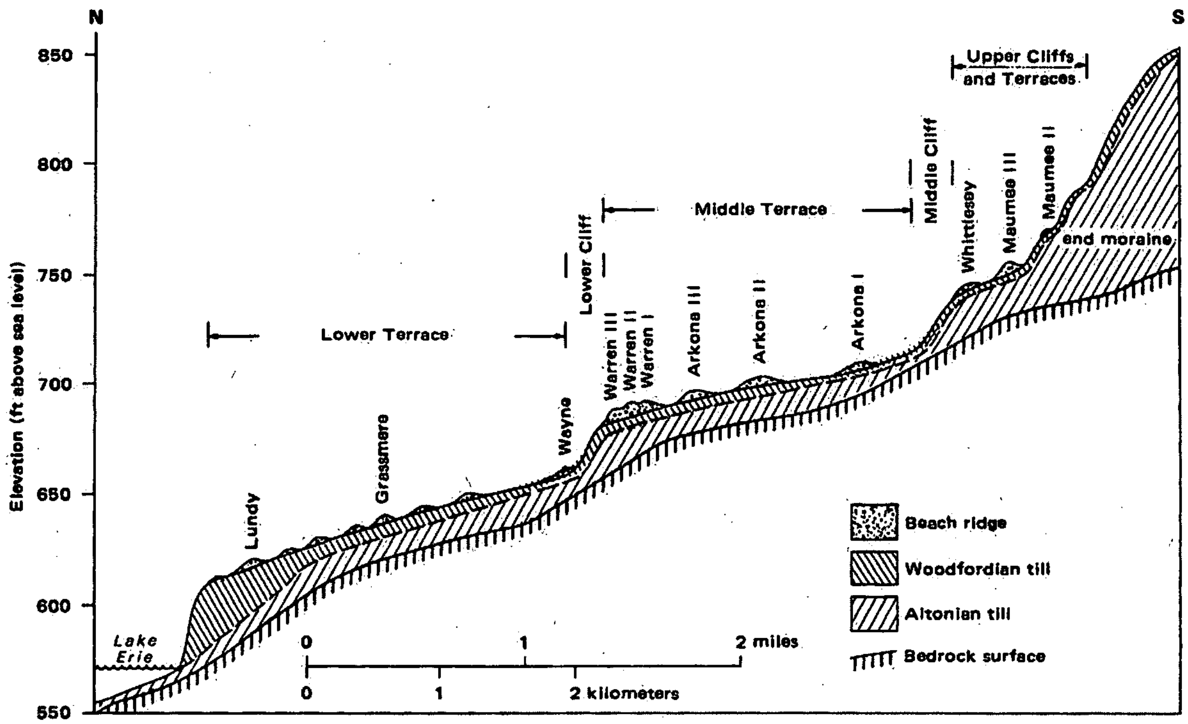
Insert #4

2.5.1-488	Leverett, F.B., "Correlation of Beaches with Moraines in the Huron and Erie Basins," American Journal of Science, Vol. 237, pp. 456-475, 1939.
2.5.1-489	Totten, S.M., "Pleistocene Beaches and Strandlines Bordering Lake Erie," in White, G.W., "Glacial Geology of Northeastern Ohio," State of Ohio Department of Natural Resources Division of Geological Survey, Bulletin 68, pp. 52-60, 1982.
2.5.1-490	Leverett, F., and Taylor, F.B., "The Pleistocene of Indiana and Michigan and the History of the Great Lakes," U.S. Geological Survey Monograph 53, 529 pp., 1915.

Figure 2.5.1-255 Composite Cross Sections of Strandlines in Northern Ohio



Composite cross section of strandlines south of Lake Erie in Lorain and western Cuyahoga Counties.



Composite cross section of strandlines south of Lake Erie in Lake and Ashtabula Counties.

Note. Three features are evident: (1) cliffs and terraces cut into bedrock; (2) cliffs and terraces cut into Altonian till (early Wisconsinan in age) and later mantled with Woodfordian till (late Wisconsinan in age); and (3) beach ridges on terraces.

Source: Reference 2.5.1-489

Figure 2.5.1-256 Paleo-shorelines and Structural Features in the Vicinity of Fermi 3 Site

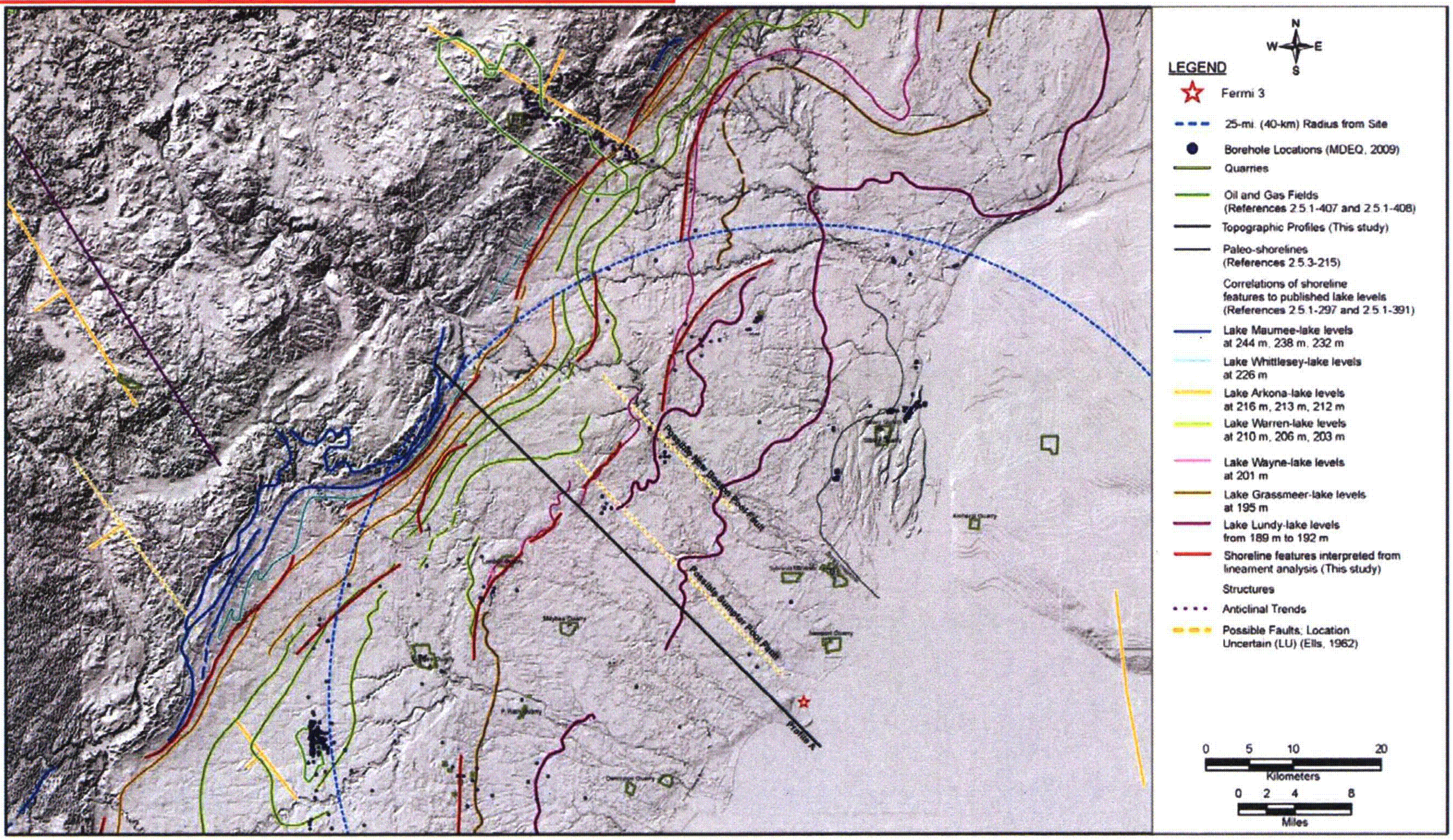


Figure 2.5.1-257 Topographic Profile AA′ Relative to Published Elevations of Mapped Paleo-shoreline Features

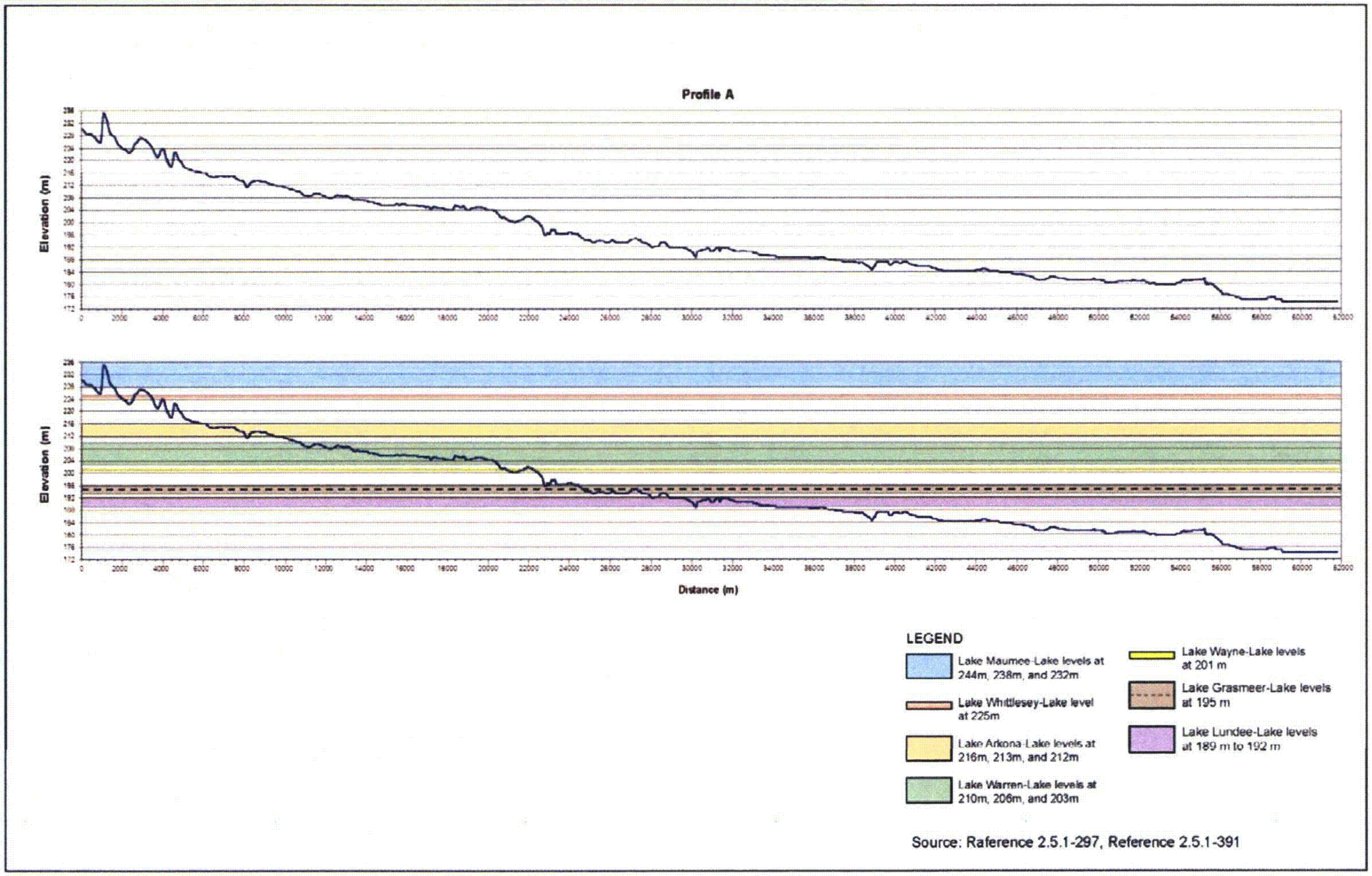


Figure 2.5.3-210 Colored Contour Interval (0.5-m Increments) Map Highlighting Surfaces Associated with the Arkona Lake Level (Elevation 212 –216 m)

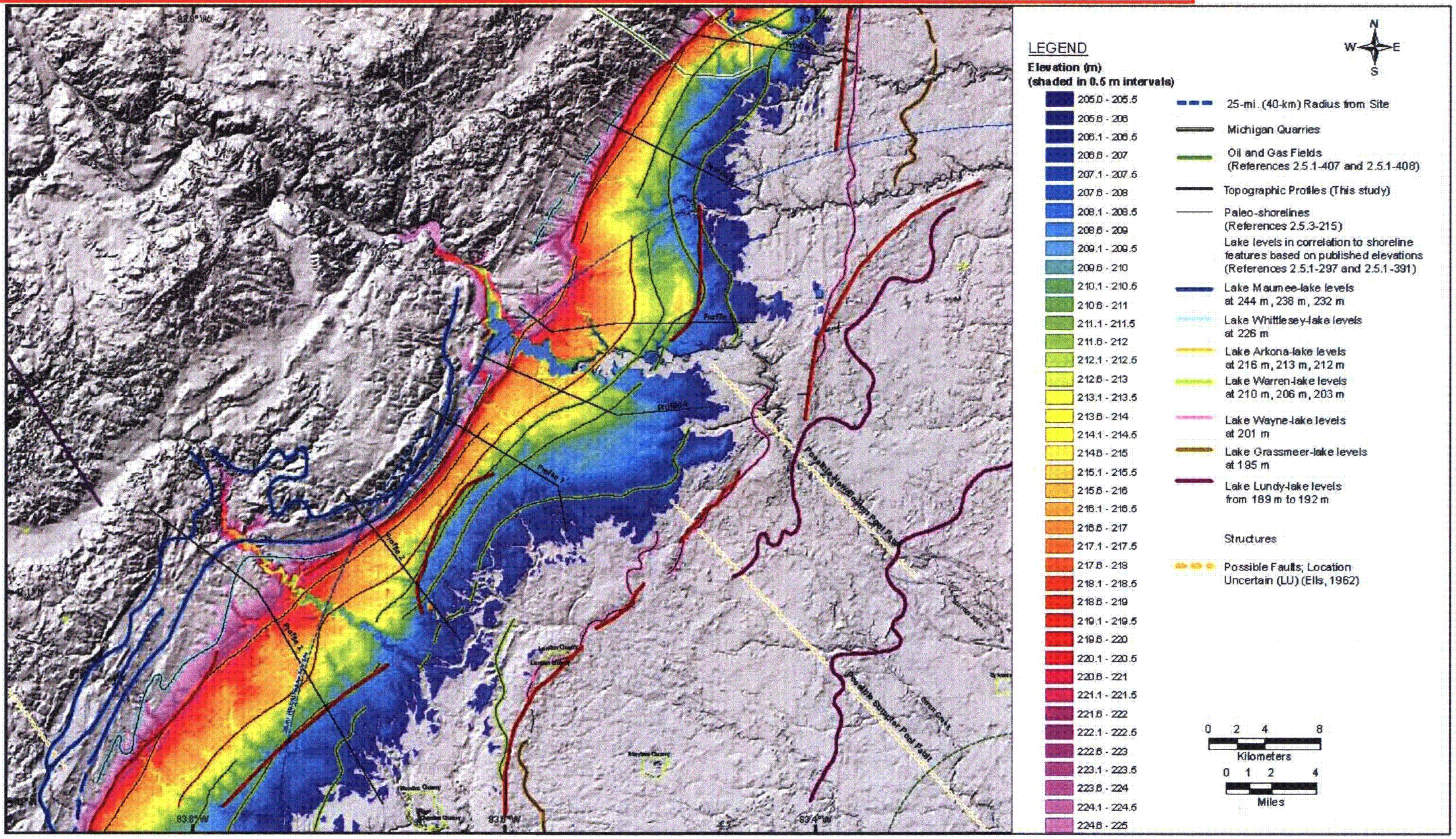


Figure 2.5.3-211 Topographic Profiles 1, 2, 3, and 5 Across the Sumpter Pool Possible Fault

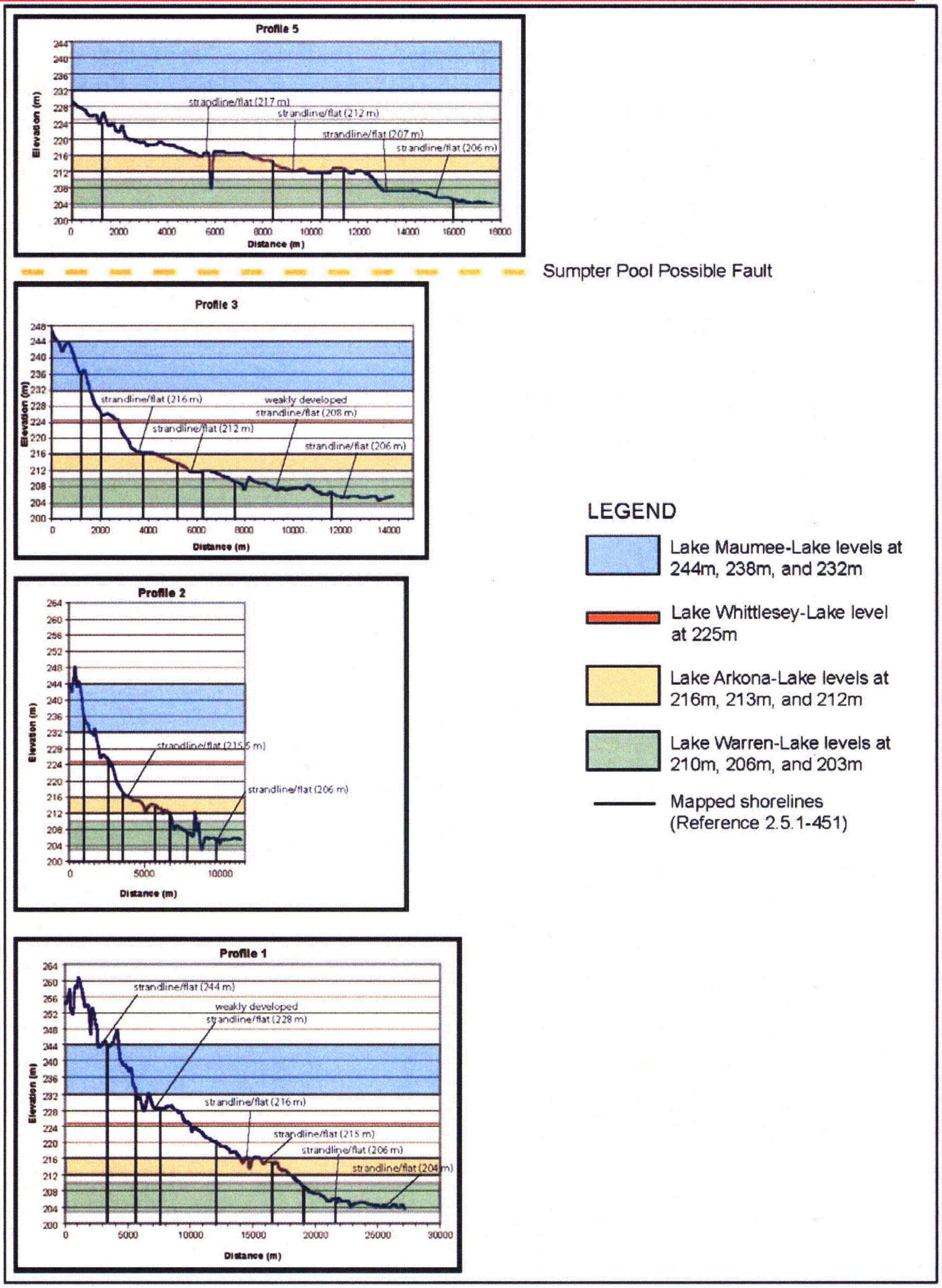


Figure 2.5.3-212 Topographic Profiles 4, 6, and 7 Across the Boston Pool Possible Fault

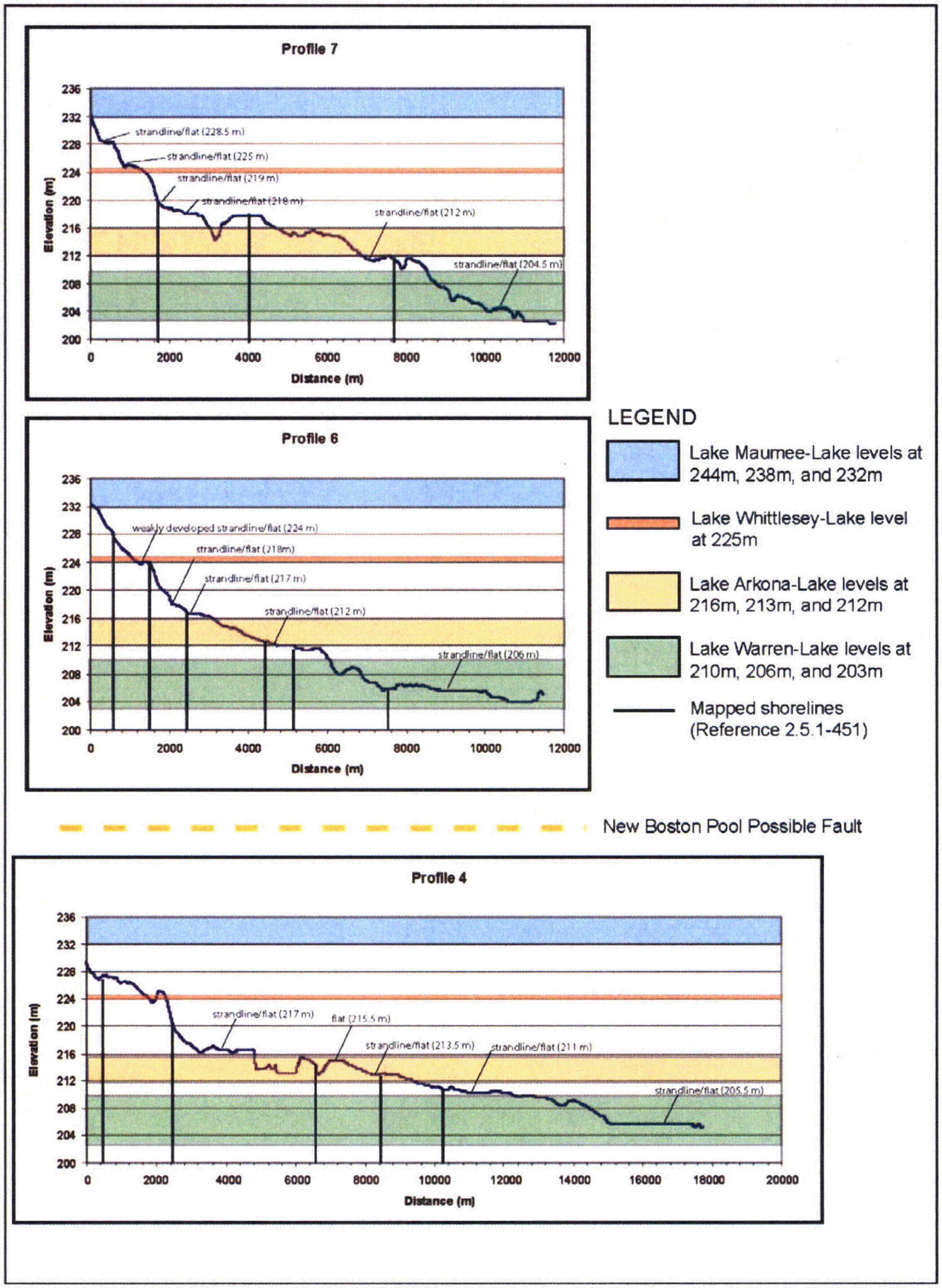


Figure 2.5.3-213 Colored Contour Interval (0.5-m Increments) Map Highlighting Surfaces Associated with the Lake Grassmere Lake Level (Elevation 195 m)

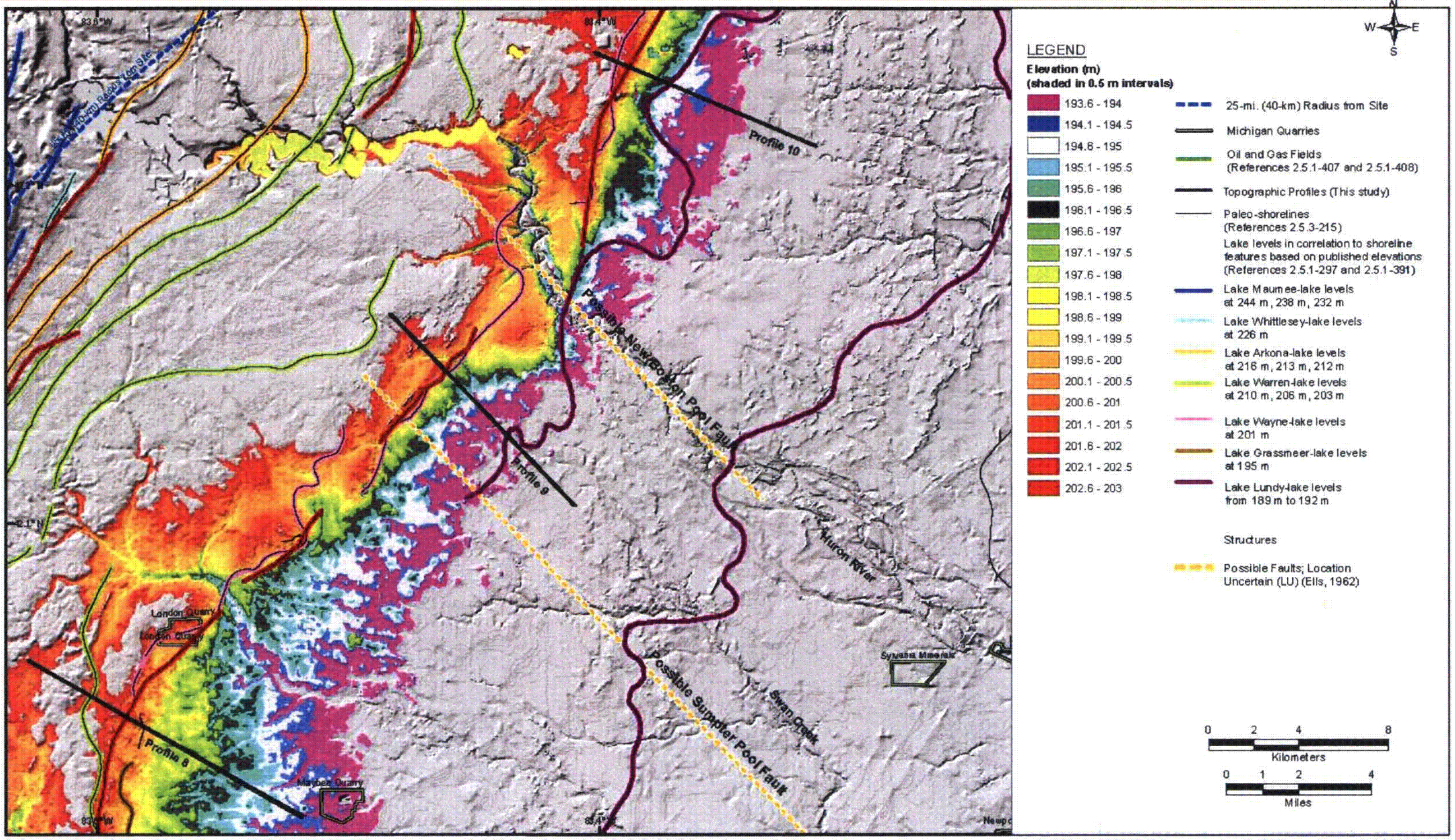


Figure 2.5.3-214 Topographic Profiles 8, 9, and 10 across the New Boston Pool and Sumpter Pool Possible Faults