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AUTH.NAME AUTHOR AFFILIATION
RHODE,G.K. Niagara Mohawk Power Corp.
RECIP.NAME RECIPIENT AFFILIATION
RUBENSTEIN,L.S. Assistant Director for Reactor Systems

SUBJECT: Forwards final responses to geologic info Requests Q361.1, .2,.13,.14 & .24 per 791001 request.

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	GEOSCIEN BR	09	4	4	HYD/GEO ENG BR		1	1
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	KIRKWOOD	29	1	1	MPA		1	0
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NIAGARA MOHAWK

NIAGARA MOHAWK POWER CORPORATION/300 ERIE BOULEVARD WEST, SYRACUSE, N.Y. 13202/TELEPHONE (315) 474-1511

June 10, 1980

Mr. L. S. Rubenstein, Acting Chief
Light Water Reactors Branch No. 4
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Rubenstein:

Re: Nine Mile Point Unit 2
Docket No. 50-410

Attached are the responses to geologic information Requests Q361.1, 361.2, 361.13, 361.14 and 361.24 for Nine Mile Point Unit 2. This completes our response to all requests for information contained in your October 1, 1979 letter.

Very truly yours,

NIAGARA MOHAWK POWER CORPORATION

Gerald K. Rhode
Vice President
System Project Management

PEF:jk
Attachment (25)

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Q361.1 Either additional evidence, re-analysis, or discussion is needed to clarify your position that the thrust faults mapped in the heater bay and radwaste buildings and the intake shaft are not capable within the meaning of Appendix A 10 CFR Part 100 and are instead old faults which have had minor postglacial adjustments. The last paragraph on page 3-15 of Volume I describes four lines of evidence from which the age of these structures can be inferred:

a. The presence of glacio-lacustrine clay within one of the low angle thrust faults is used to argue that the fault pre-dates glacial Lake Iroquois. Elsewhere in the report (Executive Summary, page 3-2) it is stated that these clays are contorted, suggesting the possibility of minor adjustments during the latest Pleistocene or Holocene. Another interpretation of equal likelihood is that the deposition of these clays within the fault and their subsequent deformation is related to the soil mechanics as a result of impoundment and rapid drawdown of Lake Iroquois during Late Pleistocene and Early Holocene. Based on your detailed observations made during mapping of this fault, provide data and discuss the various ways that the deformation features in the lake bed clays could have developed considering the geologic events that have taken place in this region. What is the most probable cause of these features? Provide the basis for your response.

b. The second line of evidence cited for the age of these structures is experimental data which indicate that a high confining pressure is necessary for a fault to transect thin-bedded strata at angles of 15° to 25°. A personal communication with Donath is cited. Provide the data that supports this conclusion.

c. The third line of evidence stated on page 3-15 is that the sinusoidal forms of folds in the heater bay and radwaste areas suggest higher stress magnitudes and confining pressures that were necessary for buckling on the Cooling Tower fault. It is also stated that dilation does not appear to be associated with these structures as is the case with the Cooling Tower fault. Provide the references and other data that support the interpretation that greater confining pressures were present during formation of these structures than during last movement along the Cooling Tower fault. One

possible argument that should be considered is that the presence of glacio-lacustrine clay within one of the faults is evidence for dilation. Provide additional support for the interpretation that dilatant fractures are not in the heater bay and radwaste area.

d. A fourth line of evidence given is that the necessary stress orientation for causing most of the geologic structures in the main power block island are probably similar in orientation to those responsible for the development of the regional fracture pattern that is believed to have occurred during the Late Paleozoic. However, the current stress regime at this location, based on in situ measurements made during this investigation, are relatively high and also commensurate with the orientations, attitudes and sense of last movements along the thrust faults in the heater bay, radwaste building and the intake shaft. Expand your discussion of the origin of these features including all the data that indicate age and causes of the deformation. Perform an analysis to assess whether or not current existing stresses in the vicinity of Unit 2 will produce adjustment-type movements on the low angle thrust faults. Among the factors to be considered in this analysis are: orientations and magnitudes of stresses, pore pressures, swelling characteristics of bedrock, and effective stresses normal to the fault plane.

<u>RESPONSE</u> Since the completion of the April 1978 report, "Nine Mile Point Nuclear Station Unit 2 - Geologic Investigation" (hereafter referred to as NMPC, 1978), additional data have been obtained from further excavations onsite. This excavation exposed the low-angle faults in the area of the proposed Radwaste Building and in the Intake Shaft.

On August 14, 1979, a bedrock exploratory trench 50 feet long and 10 feet wide was commenced in the North Radwaste Trench. Extending from elevation 231 to elevation 214, this trench was cut as an attempt to determine the depth of extent of the discontinuity in the Radwaste Trench. Consequently, it was discovered that the discontinuity was more extensive than expected. The Nuclear Regulatory Commission was thereby notified of this fact and a visit to the Nine Mile Point Unit 2 site by representatives of the Commission occurred on October 10, 1979. As a result of the Commission's site visit, it was agreed that a report with analysis and discussions would be submitted at a later date.

Since the October 10, 1979 meeting, a considerable amount of additional information has been obtained with respect to both the Radwaste Fault (Heater Bay Fault) and the Intake Shaft faults. The following additional studies were performed:

1. A line of eight vertical borings were drilled along the dip of the Radwaste Structure beginning just east of the Radwaste trench. The bedrock core was logged in detail and a television camera survey was conducted in the borings.

2. Four additional vertical overcore borings were drilled to determine the in situ stress conditions. These borings extend from just east of the reactor excavation to east of the east property line.

3. A detailed investigation was made of the clays encountered in the bedrock of the Radwaste Structure. Evaluations of the age of the clay (including pollen analysis and Carbon-14 dating) as well as the relationship of this age relative to bedrock movements were performed.

In this response, items a. through d. will be addressed in light of the additional data obtained by mapping, drilling, sampling and/or laboratory analysis. A discussion of the significance of the Radwaste Structure is discussed as item e..

a) Relationship of Clay to Faults and Bedrock Mass

From the observations made during mapping in the North Radwaste Trench, unconsolidated clay, both unlaminated and laminated, has been identified within the bedrock mass. The clay was found to be deposited principally upon parting planes coincident with bedding, as well as locally within gently dipping to vertical fractures. Where some of the inclined shear fractures contained breccia and sandy gouge, pockets of both types of clay were also observed locally. Samples of these clays were analyzed in the laboratory. Several types of tests were made, such as:

- ° analysis of pollen spectra and spores
- ° analysis of mineralogic composition
- ° analysis of grain-size distribution

Furthermore, Drs. D.R. Coates, L.A. Sirkin and T.L. Péwé examined the clays in the trench. From the results of the analyses and the site inspections, it seems clear that the laminated clay is glaciolacustrine in origin (Lake Iroquois) and is of Late Wisconsinan age (approxi-

mately 12,000 to 10,000 years B.P.). These additional observations and interpretations are in accordance with those made earlier (NMPC, 1978).

The glaciolacustrine clays exhibit numerous indications of deformation in the Radwaste exposures. The number and type of deformational structures in the clays are more complex than that reported previously (NMPC, 1978; Volume I). They consist mostly of folds and crenulations characteristic of internal heterogeneous strain caused mainly by plastic flowage of the clay during deformation. Dislocations of the laminae were locally observed within the clay layers. Moreover, it was not uncommon to find non-crenulated clay with laminae parallel to the bedding surface of the bedrock, but at various inclinations reflecting the geometry of the folds in the bedrock within the Radwaste fault zone.

As suggested in the question, the origin of these deformational features can be interpreted in various ways. One interpretation is that the clay was deposited after bedrock movement and the clay deformation is gravitationally induced penecontemporaneous sliding (that is, not related to movement of the bedrock). On the other hand, it has been interpreted that the clay was deformed in response to bedrock movement at a time subsequent to the deposition of the clay. In order to evaluate which interpretation is the most probable, Dr. T.L. Péwé was contacted to comment on the origin of the deformational features. Dr. Péwé made two site visits and reviewed the data developed from extensive investigations of the North Radwaste Trench. He concluded that the clays were deposited after the formation of the buckle and therefore, in essence, adopted the latter proposed interpretation (that is: the clay post dates bedrock movement). Dr. Péwé's specific conclusions are:

"1. The grey and tan slightly plastic clayey silts fills voids in the bedrock associated with a low angle thrust fault exposed in Radwaste Trench.

2. The clayey silt originated from the overlying glaciolacustrine deposits of Lake Iroquois that formerly overlay the site.

3. The clayey silt is therefore late Wisconsinan in age, 10,000-13,500 years BP.

4. During deposition of the clay by small vertical and horizontal water currents in the bedrock, as well as settling from non-moving groundwater, the fine-grained sediment layers were minutely

deformed by slumping and plastic deformation of the water-saturated sediments and perhaps by some liquefaction. These structures are syn-depositional and post-depositional and are similar to those reported in glaciolacustrine sediments in many places in the world.

5. Because the deformed structures in the clay are syndepositional and because it can be shown that the clay layers in places overlie without disturbance the deformed broken bedrock structures and sharp broken edges of the sandstone layers, I believe the clay post dates the bedrock deformation."

b. <u>Fault Intersection with Thin-Bedded Strata</u>

At the time of the 1978 report, only the intake shaft itself provided a clear exposure of the low-angle faults cross-cutting thin-bedded strata at angles of 15 degrees to 25 degrees. That interpretation was based upon an existing exposure of very limited extent. Nevertheless, since then, the east-dipping fault in the shaft has been further exposed by excavation for the east Lake Water Tunnel. Based upon the observations recorded during the mapping of this new exposure, it was seen that only locally thin-bedded strata are cross-cut at such angles by the discontinuity. Elsewhere along the exposure, the structure follows the bedding plane contacts between lithologies of different composition and strength. By comparison, similar observations from mapping of the bedrock slot in the Radwaste Trench are in accordance with those from the tunnel. Presently, it is clear that the structural geometry of the low-angle faults at the site is profoundly influenced by the bedding plane anisotropy of the rock mass.

During March 1980, eight vertical borings were drilled. This line of borings extended approximately 850 feet east from the Radwaste Trench and parallel to the dip direction of the Radwaste structure. The borehole depths ranged from 100 to 300 feet. Evidence was obtained from the extracted rock core which indicates that the Radwaste "fault" is not simply a single discontinuity. Instead, there is a "stack" of at least three zones of discontinuity characterized by evidence of bedding plane slip, low-angle shear fracture, and local folds in the bedrock. The lowest of these three structures occurs at a depth of approximately 70 feet from the bedrock surface. At depths below these three zones, there are additional occurrences of breccia along bedding and gently inclined shear fractures with slickensides. The lateral continuity of these lowest features has not been clearly established from the results of these boreholes. Nevertheless, it is important to

note that the three abovementioned discontinuities (including the one mapped in the Radwaste Trench) appear to pass eastward into bedding planes, and cannot be traced as discrete discontinuities beyond approximately 150 feet to the east of the Radwaste Trench.

Together, the above data strongly suggest that the final depths of these structures must be influenced by the pronounced anisotropy of the bedrock. Such anisotropy is manifested in part by the influence of bedding planes on the geometry of these low-angle discontinuities, and this is indicative of low vertical confining pressure at the time of their development.

c. Dilation and the Low-Angle Faults

The most recent exposures of the Radwaste Fault have revealed evidence that both the bedrock mass and the stratigraphic section do indeed exhibit dilation. Locally, where the bedrock has been folded and/or brecciated, voids and open fracture planes are common.

Various displacements have been observed to be caused by shear dislocation and folding. Typically the vertical component of displacement is more consistent than the horizontal component, and is approximately 1.5 to 2.0 feet.

At this time, there seems to be reliable, but indirect, evidence of dilation in a vertical plane of the stratigraphic section penetrated by the boreholes drilled east of the Radwaste Trench. This is based upon correlation of lithologies and the site stratigraphic section in the closely spaced boreholes. From the Radwaste Trench to a point 120 feet east-southeast, where the discontinuities pass into bedding planes, both the Transition Zone of the Oswego Sandstone Formation and Unit A of the Pulaski Formation seem to thicken toward the west approximately 1.5 feet. This agrees well with actual observed dilation in the trench.

On the basis of the observations set forth in a. of this response, and the foregoing observations, it is clear that dilation of the bedrock mass is associated with deformation by the low-angle faults at the Unit 2 site. The complete extent of dilation, however, is not known. Nevertheless, dilation to depths of 250 feet, and possibly greater, is suspected from the occurrence of laminated clay on parting planes parallel to the bedding as recovered in the rock cores from the line of boreholes just described. Laboratory analysis of this clay from elevations below 214 feet (North Radwaste Trench) has been completed, and it appears reasonable to interpret that the clay is of similar age and origin as the clay in the trench.

d. <u>Age of Development and Stability of the Low-Angle Faults</u>

The response in b. above, points to the likelihood of a relatively near-surface origin for the low-angle faults, that is, under relatively low vertical confining pressure. The geometry of these structures, moreover, indicates that the maximum principal effective stress extant when these features were formed was horizontal or nearly so. The data presented from the studies of epigenetic mineralization of joints and the Cooling Tower Fault (NMPC, Volume I, 1978), as well as our analysis of the mechanism of formation of these structures (NMPC, Volumes I and III, 1978), demonstrate that high overburden pressure existed when the joints were formed. The newly acquired data clearly indicate that the development of the Radwaste and Intake Shaft faults cannot be attributed to conditions that existed during the time of development of the jointing and strike-slip movement at the Unit 2 site. Instead, the data indicate that the Radwaste and related structures were formed after the normal faults when the confining pressure was reduced considerably.

Ongoing study of the Radwaste and Intake Shaft faults has shown that calcite minerals are present along shear planes and on some open vertical fractures within the zone of deformation. These minerals are deformed. To date, studies of this mineralization indicate that all of the calcite occurring on the low-angle structures is younger than the latest stage of epigenetic calcite previously reported from the site. This statement is based upon the following lines of evidence:

(1) fluid inclusion temperatures of less than 40 degrees centigrade

(2) very low fluid inclusion salinity of approximately five percent by weight NaCL indicating freshwater is contained within the inclusions.

(3) two ^{14}C age determinations on deformed calcite yielding

   a) greater than 36,000 years before present
   b) 14,180 $\pm$ 550 years before present

(4) isotopic ratios ^{13}C and ^{18}O indicating low burial depths and freshwater crystallization of calcite.

The stress tensor determined from strain-relief measurements in the Intake Shaft (NMPC, Vol. III, 1978) is commensurate with the orientation and sense of the slip vector indicated by the displacements identified along the Radwaste Fault and the east-dipping shaft fault. The stability of these faults has been evaluated as shown on Figure 361.1-1. For two cases (Table 3-18, Vol. III, NMPC, 1978) the normal stress and shear stress on the faults and on bedding were resolved from the three principal stresses, and the results are tabulated for each case (Figure 361.1-1).

Comparison of the computed values of shear stress with the shear strength for the east-dipping inclined faults reveals they are approximately equal if friction and cohesion parameters from laboratory testing are applied to analysis of the entire fault as a hypothetical, idealized plane. The irregular geometry of the fault (ranging in dip from 0 to 50 degrees) and the asperities on the fault plane contribute to the stability of the faults.

e. <u>Significance of the Radwaste Structure</u>

Because of the complexities of the Radwaste Structure, Dr. Shaïler Philbrick and Dr. Richard Jahns were contacted to review the geologic program and comment on the genesis and stability of the Radwaste Structure. Over a period of approximately five months, Drs. Philbrick and Jahns reviewed the data and analysis and concluded that:

"1. The structure was initially developed in pre-Holocene time, and in the Illinoian time interval between 500,000 and 140,000 years before the present with glacial erosion of rock and consequent reduction of vertical confining pressure. That at least most of its movement occurred in pre-Holocene time is indicated by the partial infilling of structurally-formed openings by silts that are about 11,000 years old.

2. Initial formation of the structure probably was abrupt, with displacements at a given place relatively large at first and attenuating with time.

3. Movements along the structure probably occured during Pleistocene time, as prompted by episodes of glacial loading and unloading.

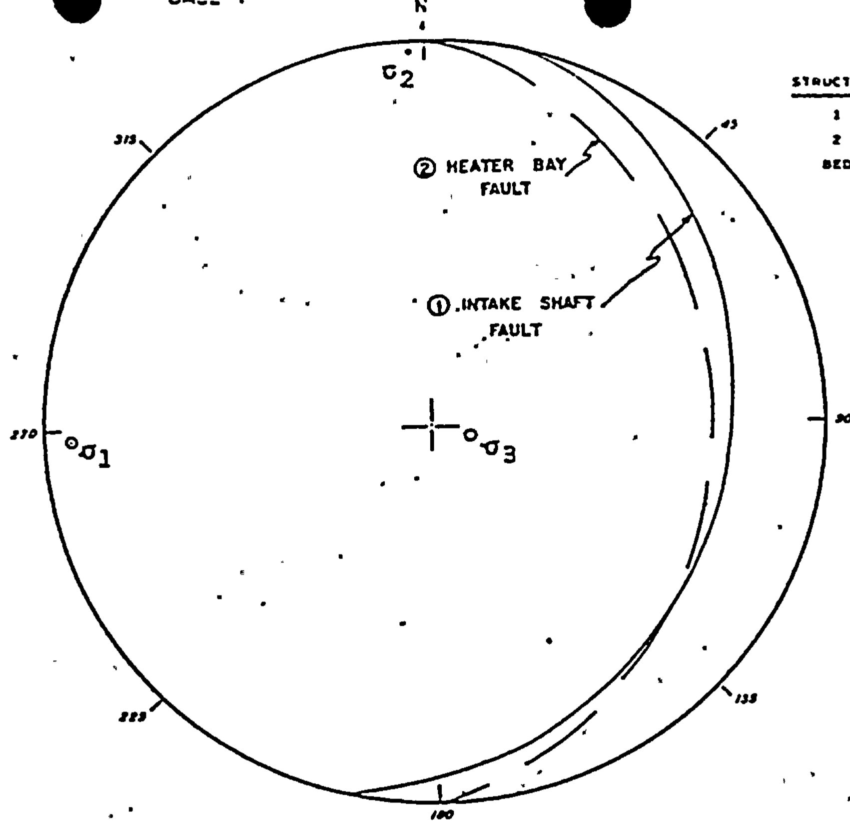
4. Post-Pleistocene (Holocene) movements have been small if they have occurred at all. It cannot be demonstrated that no Holocene movements have occurred, as no reference features (e.g. dated infilling sediments) extend entirely across the zones of disturbance.

5. Future movements along the structure are not likely to occur. Further relief of the limited amounts of strain now in the rocks will be distributed in the affected ground as dilation and small movements along fractures and bedding surfaces. The Radwaste Structure is so nearly dead at present levels of exposure that its participation in such future movements would amount to no more than a small fraction of inch ($\leq 1/4$ inch).

6. The Radwaste Structure is not seismotectonic."

Based on these conclusions it was judged that movements of the Radwaste Structure (if any) would be of no consequence to the operation of the plant.

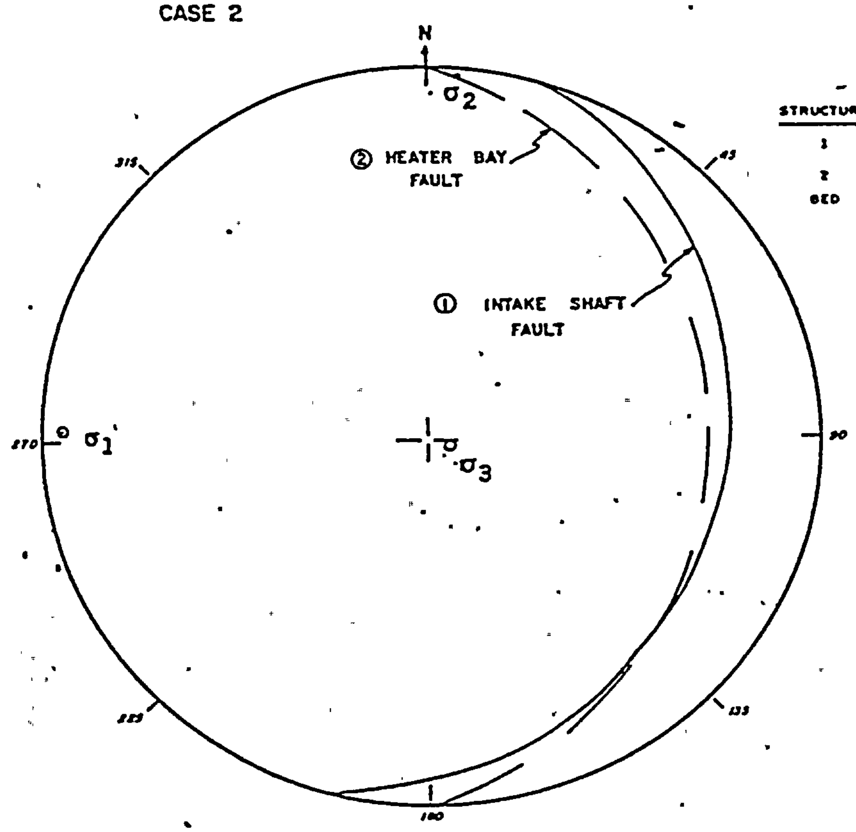
CASE 1



CASE 1

STRUCTURE	σ_n	τ	PSI
1	807	410	σ_1 = 1165
2	960	437	σ_2 = 806
BED.	249	111	σ_3 = 233
			ELEV. 141

CASE 2



CASE 2

STRUCTURE	σ_n	τ	PSI
1	592	514	σ_1 = 1520
2	706	572	σ_2 = 463
BED	308	106	σ_3 = 298
			ELEV. 141

LOWER HEMISPHERE EQUAL AREA PROJECTIONS

SHOWING RELATION, OF PRINCIPAL STRESS ORIENTATIONS TO EAST-DIPPING THRUST FAULTS*

* NOTES:

1. BEDDING IS ASSUMED TO BE HORIZONTAL
2. PRINCIPAL STRESS MAGNITUDES AND ORIENTATIONS ARE FROM TABLE 3-18, VOL. III OF 1978 DAMES & MOORE REPORT

NINE MILE POINT NUCLEAR STATION
UNIT 2
NIAGARA MOHAWK POWER CORP.

FIGURE 361.1-1

Q361.2 Based on a telephone conversation conducted on March 14, 1979 between representatives of Niagara Mohawk Corporation and its geotechnical consultants, Dames & Moore, Inc., and the NRC, it is our understanding that you have elected to support the concept that the faults in the power block area are not tectonic faults in the sense of Appendix A, 10 CFR Part 100, and that last adjustments on them are related to deglaciation phenomena and the rock mechanics properties that characterize the upper 200 feet of site bedrock. In the subject report you have attempted to define the rock mechanics characteristics in detail and apparently have developed design criteria believed to be conservative. These criteria are not in the report. The assumptions that were used to develop these criteria are not identified in the report. If the intended course of action is to show that the plant is designed to withstand minor adjustments in rock, provide the geotechnical assumptions, and rock mechanics criteria that are to be utilized in the design of all Category I structures. Discuss how these values were selected from the data presented in the report. Additionally, there appears to be a gap of information linking the investigation results and analyses presented in the report and the decision to accommodate any potential rock movements in the structure design rather than to demonstrate that no rock movement is likely during the life of the plant. Please provide a complete and detailed discussion of the rationale that led from conclusions arrived at during the investigation to the decision to modify the design of the relevant structures. What design and construction measures will be taken to accommodate the high lateral bedrock stresses imposed on the cooling water tunnels?

RESPONSE Summary of Site Conditions and Design Approach

As stated in the question, any possible future movements at the site are related to the release of in situ stresses and the physical properties of the rock, and are not in response to the type of tectonic activity considered in 10 CFR 100 Appendix A. However, for purposes of this response, it is useful to define the nature of possible future movements in order that the design criteria that have (and will be) developed, will be more easily presented.

Basically, the geotechnical conditions considered at the site are:

1. In situ stress, magnitude and rate of change;

2. Rock lithology;
3. Ground water fluctuations.

Stress levels, ranging from very low magnitude (in both tension and compression) for minor principal stresses to as high as 2700 pounds per square inch for the major principal stress were measured in the original overcore holes (NMPC, 1978). Some evidence of the possibility of in situ stress induced movements were noted at the site (see response to Question 361.4) and have been documented in the region, primarily west of Rochester, N.Y. (Rose 1951; Hogg 1959; Lee & Lo 1976; and Bowen 1976, for example). In addition to measuring in situ stresses in relation to various geological features and the free field, the effects of residual stress on the onsite rocks were investigated during the studies of the Cooling Tower Fault (NMPC, 1978). Subsequently, laboratory tests were performed to investigate the possibility of volumetric changes of the rock under a variety of moisture conditions and confining pressures (Franklin Trow Associates Ltd., 1978).

As a result of the various studies at the site, and of the regional setting, it was decided to consider "rock squeeze" in the design of Category I structures at the site. In this instance, the term "rock squeeze" incorporates several possible causes and effects. These include:

1. Essentially elastic movement of excavation walls or floors, immediately after construction;

2. Long term movement of excavation walls as a result of stress release and viscoelasticity of the rock;

3. Shrinkage or swell of rock units as a result of moisture changes caused by excavation and/or water level changes, and as influenced by stress levels;

4. Movement along broken bedding planes as a result of past or current changes of in situ stress.

These various factors can be operating in concert or separately, and the previous and current studies have considered this possibility. A number of approaches have been taken to provide appropriate yet conservative design criteria. Initially, a study of the magnitude of rock squeeze movements measured in the Upstate, New York region was undertaken. These data were compared with available onsite survey measurements

and observations at the site (see response to Question 361.4). More precise measurement devices were installed at the site (see response to Question 361.5). A finite element model of the main excavation was developed and laboratory test results were employed to estimate the magnitude of possible future movements which could result from excavation caused stress release and changes in the water table. Additionally, ongoing studies of the possibility of, or magnitude of, future movements along the Radwaste structure and the Intake Shaft thrust faults (see NMPC, 1978 for location and nomenclature) are underway (see responses to Questions 361.25) and Q361.1)

Development of Design Criteria

Early in the studies of the geologic structure exposed during site excavation, the literature available (to the year 1976) was reviewed and a number of individuals knowledgeable of the regional effects of rock squeeze were interviewed. References used in that study are noted with an asterik in the bibliography to this response.

In summary, the results of the available regional information indicate: that a near-surface stress field of 1000 to 2000 pounds per square inch has been measured in the region. Movements in excavations (buckling of excavation bottoms and the inward movement of excavation walls) apparently occur within the same region. Wall movement is generally less than about three inches (nominally 0.1 to 3 inches) with a maximum closure of eleven inches referenced by Rose (1951) in the Rochester Shale, near Lockport, New York. Wall closures have been recorded as time-dependent phenomenon, having cyclical reversals of strain but apparently continuing a non-linear movement as long as measurements have been taken (over seventy years in one instance) (Bowen, et al, 1976).

All known effects of damage to structures by rock squeeze were some distance away from the site area and onsite survey data indicated that little to no excavation induced movements (within the accuracy of the surveying system) were noted. Nevertheless, it was decided that all walls of Category I structures would be isolated from rock by six inches, a value greater than the maximum closure experienced in the region and many times the average of typical movement. Implementation of this design recommendation is discussed in the responses to Questions 361.3, 361.20 and 361.21.

A single wall (12-line wall) had been poured against rock prior to the aforedescribed review of the

regional data. Therefore, a detailed mathematical analysis of the potential for movement of the excavation walls was undertaken to develop criteria to be used in the design. Two models were analyzed, a "large" plain strain model and a "small" model in both plain strain and plain stress conditions. All were finite element models.

The time-dependent behavior of the site rock was attributed (for this portion of the evaluation of rock squeeze effects) to the relief of in situ stress due to excavation, stress change in rocks caused by any imposed structural loads, and the availability of ground water leading to changes in rock moisture content. Laboratory test results on the rock core specimens extracted at the site (NMPC, 1978 and Franklin Trow Associates Ltd., 1978) have indicated that the swell/shrinkage phenomenon of the site rock is primarily due to hydration. As a result of the manner of testing, (that is, free swell and odeometer ring swell tests), the results will inevitably include creep deformation as well. These tests indicated that the time-dependent behavior of the finer grained site rocks is subject to the availability of water at the site, and the release of in situ stresses by excavation.

In performing this analysis, it was assumed that the major causes of future rock wall movement would result from dewatering during construction and a subsequent return of the ground water to normal conditions. These sequences were included in the analysis which treated the actual or planned construction program.

For the 12-line wall analysis, a uniform stress pattern was assumed throughout the depth of the reactor excavation. A constant major principal compressive stress of 1200 pounds per square inch, oriented in an east-west direction, and a minor principal compressive stress of 400 pounds per square inch, in a north-south direction was assumed. This stress pattern represents stress values slightly larger than the average values measured in situ (NMPC, 1978) at the depths represented by the model.

For this analysis, the in situ rocks were assumed to be linear elastic and cross-anisotropic (Duncan & Goodman, 1968).

For the purposes of this model, elastic properties of the rock were reduced from these estimated values for the intact cores to account for the presence of

bedding planes and other discontinuities. The modulus values used in the analysis of each stratum consider: 1) intact core elastic properties; 2) stratum lithology; and, 3) the rock mass effects. To investigate the effects of bedding slippage (the bedding planes are more deformable than the intact rock), a number of horizontal planes with linear elasto-plastic shear resistance were incorporated into the model. To define the strength properties of intact and broken bedding planes, core samples were tested in direct shear (Franklin Trow Associates, Ltd., 1978).

The performance of rock cores were investigated under varying moisture and confinement conditions (Franklin Trow Associates, Ltd., 1978 and NMPC, 1978). On the basis of the test data, the following conclusions were reached:

1. The swell strain rates decrease with an increase of the first stress invariant.

2. The swell and shrinkage strain rates in the vertical direction are higher than those in the horizontal direction.

3. Swell deformation does not occur beyond a limiting value for the first stress invariant.

4. Shrinkage occurs when the humidity of the environment is less than 100 percent.

5. There is a limiting value to both horizontal and vertical shrinkage.

6. The onsite rocks, after reintroduction of water following dehydration, swell at an accelerated rate until a "normal" 100 percent humidity swell strain rate is achieved. That is, the rock recovers whatever the swelling magnitude that would have occurred between the initiation of stress relief and dehydration and completion of the dehydration period essentially as if the rock had not been subject to drying.

Utilizing the available data, a finite element model, as previously discussed, was used to develop the sequence of vertical and horizontal rock movements behind 12-line wall. The results of these analyses were incorporated in analytical models of the 12-line wall.

__Q361.13__ A very specific investigation and evaluation of geologic structures on the site has been carried out, however, there is an apparent gap between consideration of these structures and their relationship to geologic structures in the immediate area around the site. For example, a very significant structure was discovered after completion of your study and investigated on the New Haven site a few miles to the east. Expand your evaluation of geologic structures on site to include a consideration of the relationship between those structures and other known structures around the site.

__Q361.14__ As a result of the staff's review of geologic investigations performed by other utilities in the area (FitzPatrick fault investigation and the New Haven PSAR) subsequent to most of your work at Nine Mile Point, we find several differences of interpretation regarding the geologic and tectonic history at the site. These conflicts of opinion include: the difference in stratigraphic interpretations of the Oswego and Pulaski formations between the Nine Mile Point and New Haven sites; the conflicting opinions regarding the age of normal faulting in the region; the differences in magnitudes and orientations of the maximum compressive stress measured at the Nine Mile Point site as opposed to measurements taken at the New Haven site. Re-evaluate the subregional tectonics in light of the new information to determine whether or not it alters your earlier conclusions. Discuss this re-analysis and provide the bases for conclusions made. Are these differences of opinion significant with respect to the safety of the Nine Mile Point site? Discuss why or why not.

__RESPONSE__ It is our belief that the answers required for questions Q361.13 and Q361.14 involve a significant amount of overlapping discussion. Hence, these questions are answered below as one unified response which addresses the points of concern in both questions. Item __5.__ provides a summary of the conclusions regarding the significance of the Demster Structural Zone to the safety of the Nine Mile Point Site.

1. __Stresses__

The differences in the magnitudes and orientations of the maximum compressive stress measured at both sites are more apparent than real and do not constitute a significant conflict of opinion. The strain-relief measurements at the New Haven site were made at relatively shallow depths (maximum depth 50.5 feet).

These measurements were conducted approximately one and a half miles from a prominent deformable boundary: the Demster Structural Zone. Based upon the strain-relief measurements and the stress-distribution analysis performed for the Nine Mile Point site, it is evident that the magnitude and orientation of stress at a specific location are strongly influenced by proximity to the bedrock surface and to geologic structures.

An average of the readings at shallower depths at Nine Mile Point (less than 45 feet) was not markedly different (about 100 pounds per square inch in magnitude than the New Haven data if the "free field" data (Boring OC-1) at Nine Mile Point are excluded. Thus, the overcore results of the two sites are similar if one considers proximity to possible local perturbations of any regional stress field and depth below present grade.

2. Stratigraphic Subdivision

As a part of the effort to reconcile the conflicts of opinion, the rock cores from the borings drilled at and near the New Haven site have been examined. On the basis of this examination, it is evident that the New Haven and Nine Mile Point stratigraphic columns are identical. At each site, the column has been subdivided into correlative units. These units at both sites are also identical; there is a difference in the stratigraphic nomenclature employed. Plate 361.14-1 identifies the specific correlations between the two different terminologies used. It should be noted that the stratigraphic subdivision (that is, the placement of the unit boundaries) is identical. The identification of the Oswego/Pulaski interface at the Nine Mile Point site is in accordance with the stratigraphic identification of this interface in the excavations of the James A. FitzPatrick site by Professor Newton E. Chute, an expert in the stratigraphy of upstate New York (Power Authority of the State of New York, 1967, as referenced on p. 9-6 of Volume I of the NMPC 1978 report). The differences of the usage of the stratigraphic terminology have no bearing whatsoever on the safety of the nuclear facilities located at the Nine Mile Point site.

3. Age and Significance of Normal Faulting

During the investigation at Nine Mile Point, Dames & Moore recognized the occurrence of conjugate normal faults, namely the Cooling Tower Fault and the Barge Slip Fault. The investigators at the New Haven site have identified local normal fault displacements within the Demster Structural Zone. Dames & Moore's examination of the rock cores from borings drilled within this zone revealed the existence of a shear

fabric suggestive of normal faults. It is not known if the formation of these normal displacements corresponds to a distinct extensional tectonic event, or instead represents a secondary response during the development of the Demster Structural Zone. The mere occurrence of these displacements and fabric does not demonstrate that they are of the same origin for both sites. Nevertheless, it is clear that the faults at each site are mineralized, and their mineral assemblages are similar, also yielding identical spectra of homogenization temperatures. These facts indicate that normal faulting probably occurred in correlative geologic time.

At Nine Mile Point, there is a definite relationship between the structural fabric associated with the normal faults, and evidence of a major geochemical change during crystallization of the calcite minerals on the faults exhibited by the transformation from sulfide to goethite at decreasing temperatures. This transformation represents a change from reducing conditions to oxidizing conditions caused by the influx of convective, air-saturated ground waters. Dr. Barnes (NMPC, 1978) emphasized that the change, more importantly than the distribution of homogenization temperatures, must be regarded as a "time-line", and was of regional extent because it is also recorded in the mineral data from the New Haven site.

It is felt that the regional environmental change to oxidizing conditions corresponds to the cessation of the tendency for the northern Appalachian Basin to subside. The history of sedimentation in this region records the fact that sedimentation ceased in conjunction with the late stages of mountain building processes (that is, the end of large-scale crustal shortening) in the Appalachian geosyncline in the site area during late Paleozoic time. It is also well documented in the literature that the region around the site was subjected to extension in Mesozoic time as evidenced by the occurrence of ultramafic dikes that intruded the crust in the area of the Finger Lakes and Syracuse. On these bases, it has been interpreted (Volume I, NMPC 1978 report), that "deformational events" D_3 and D_4 represent normal faulting at Nine Mile Point, and that the age of the normal faults is late Paleozoic to Mesozoic. Furthermore, the data from both the structural fabric and the studies of mineralization from the Demster Structural Zone are in remarkable accordance with those from Nine Mile Point, and imply a similar age for the normal faulting at the New Haven site. The fact that the ages of normal faulting at Nine

Mile Point and New Haven are interpreted to be similar is not viewed to be of safety significance to the nuclear facilities at Nine Mile Point.

4. Character of Regional Tectonic Environment

On the basis of (a) the traditional understanding of tectonics of the Northern Appalachian Basin and (b) the inferred Paleozoic age for the last movement along the Demster Structural Zone, the New York State Electric and Gas, Preliminary Safety Analysis Report implies that the Demster Structural Zone resulted from orogenic shortening. As such, the structure would be categorized as a product of "thin-skinned" tectonics. The development of the structure was postulated to be accompanied with the development of conjugate shear fractures whose acute bisectrix is nearly perpendicular to the trend of the Demster Structural Zone. It is understood that normal faulting, as a discrete tectonic event, was not recognized as being expressed at the New Haven site area. The normal fault fabric discussed in the New Haven Preliminary Safety Analysis Report was perceived to be a local expression of relaxation of compressive, fold-forming forces.

In contrast to this interpretation, the tectonic development of the area was characterized in the Nine Mile Point report (NMPC, 1978) as follows:

"In the geological past the area of this province was not subjected to large-scale and orogenic, tectonic processes. Evidently, only [differential] vertical movements were the dominant crustal processes operative within this [region]. These vertical movements have resulted in the accumulation of an early through late Paleozoic sequence of sediments in the basin, diagenesis and lithification of these sediments, and their subsequent uplift and erosion."

The conjugate shear fractures and the small-scale strike-slip faults in Ordovician rocks near the Nine Mile Point site bear characteristics which indicate their development was <u>not</u> in response to major crustal shortening; however, the Demster Structural Zone displays a considerable amount of shortening. Hence, the interpretation linking both elements to a common origin is at variance with the original understanding and expectations.

The foregoing discrepancies prompted a re-assessment, of the existing data base. This re-assessment included examination of the rock cores extracted from borings drilled during the New Haven investigations, examination of geophysical data consisting of aeromagnetic and gravity maps of central New York State, and the profiles of several portable magnetometer surveys across the Demster Structural Zone. Additionally, new data by Forsyth (in press) and Diment, et al (1980) was reviewed.

The examination of the New Haven rock cores revealed that there are at least three distinct types of deformational fabric. They include:

1. Extensive and densely clustered faults that are presently lithified or incorporated into the rock mass;

2. Well developed breccias that are healed by cementation which, in places, consisted of prominent veins of epigenetic mineralization;

3. Open-work breccia without cementation or any mineralization.

These observations suggest a relatively long span (that is, a span of one million years or more) of activity along the Demster Structural Zone. Of particular importance was the occurrence of the extensive deformation (as identified in 1 above) on both sides of, and immediately adjacent to, the Demster Structural Zone. These geologic features indicate that deformation occurred at a time when the sediment was not as highly indurated as it is at the present time. Under those conditions, it is unlikely that the sediment could transmit any strains applied along a vertical boundary over a great distance. Instead, in order to explain the occurrence of these small faults, it is necessary to assume that the deformation was initiated by the dislocation of a horizontal boundary, and this dislocation must have been situated beneath the zone of deformed sediment. Furthermore, because the features in 2. and 3. above were also observed at the same locations, the possibility that the Demster Structural Zone is a drape fold developed over a step-like displacement(s) in the basement, rather than an epidermal fold or fold complex whose development was related to orogenic shortening, seems to be a logical explanation.

To investigate this possibility, the geophysical data were examined. Typically a step-like displacement in the basement rock beneath a veneer of sedimentary rock would be manifested in the data as a pronounced geo-

magnetic and gravimetric gradient. It was expected that such a gradient should be recognizable across the trend of the Demster Structural Zone if this zone were indeed a basement rooted feature. A prominent anomalous gradient, expressed by the aeromagnetic map of Central New York State, was identified as occurring in the near vicinity of the location of the Demster Structural Zone. This gradient is pronounced, especially to the northeast of the New Haven site and supports the possibility of a basement relationship. A Bouger gravity anomaly is likewise aligned with a northeast projection of the Demster Zone.

Dr. Forsyth (in press) postulates the existence of a very fundamental tectonic division, one which is based upon contrasting compositions of supracrustal rocks. Within the Precambrian basement complex, there seems to be a trough, trending northeast and southwest, of metamorphosed volcanic rocks which are bordered on the east side by a massif of acidic basement rocks of the Adirondack Mountains. The boundary between the trough and the massif is the Colton-Carthage Mylonite Zone and its northward continuation through Ottawa, Canada. The southward projection of this feature, according to Dr. Forsyth, is aligned with the Demster Struetual Zone. This information further strengthens the argument that the Demster Structural Zone can be linked to an old basement discontinuity.

A recent publication by Diment (1980) and others of the United States Geological Survey reports a series of northwest trending lineaments defined by offsets of the pervasive northeast-southwest gravity anomalies in New York and Pennsylvania. In their paper, they speculate upon the nature of these offsetting trends suggesting that they may be rooted in the basement, but are of uncertain nature(s). They further hint that there may be some, as yet not understood, relationship to the distribution of historic seismicity. The Nine Mile Point and New Haven sites are situated between lines F and X of their Figure 2 and the F lineament appears to transect the Colton-Carthage discontinuity. The interior of this structural "block" has a very low level of seismicity compared to the regions northeast of Line F. The significance of this information cannot be known without an understanding of the geologic reason for this geophysical anomaly.

It is difficult to evaluate the relationships between the geologic structures at Nine Mile Point and the Demster Structural Zone because of the uncertainties regarding the history of development and movements

along the Demster Structural Zone. However, certain characterizations and comparisons can be made.

a. Based on geophysical anomalies and deformational features associated with it, the Demster Structural Zone may have initially formed as a response of weakly lithified sediments to basement-originated adjustments. These lithified faults were rarely observed at Nine Mile Point.

b. The distribution of the homogenization temperatures of fluid inclusions indicate an overlap in terms of both time and structural activity between the Demster Structural Zone and the Cooling Tower Fault.

c. The obvious differences in amount of stratigraphic displacement and width of the zone of cataclasis between the Demster Structural Zone and the structures at Nine Mile Point indicate a significant difference in scale. The structures at Nine Mile Point are interpreted to be a part of the smaller scale structural fabric of the area, formed as a secondary response to differential movements within the northern Appalachian Basin. The Demster on the the other hand, is more properly classified as a primary structural feature of regional extent.

d. Evidence of post-glacial movement was observed above the Cooling Tower Fault at Nine Mile Point The trenches excavated across the Demster Structural Zone revealed no deformation of glacial and glaciolacustrine sediment.

5. <u>Conclusions Regarding the Significance of the Differences of Opinion with Respect to the Safety of Nine Mile Point</u>.

a. The apparent differences in results of stress measurements probably reflect local perturbations and differences in measurement depths. This does not, in our opinion, constitute a significant difference with respect to the safety of the Nine Mile Point site.

b. The differences in the usage of stratigraphic terminology have no bearing on the safety of the nuclear facilities at Nine Mile Point.

c. The ages of normal faulting at Nine Mile Point and New Haven are similar. There is

some difference of opinion regarding the exact age of the normal faulting; however, the most recent age proposed is Mesozoic. This makes the documented normal faulting at least 65 million years old, and, in our judgement these differences of opinion should not be regarded as significant to the safety of Nine Mile Point.

d. Based on the data presented by New York State Electric and Gas in their Preliminary Safety Analysis Report, particularly their conclusions regarding the lack of evidence of deformation in the glacial deposits and the non-capability of the Demster Structural Zone, it is our opinion that there is no reason to regard the Demster as significant to the safety of the Nine Mile Point site.

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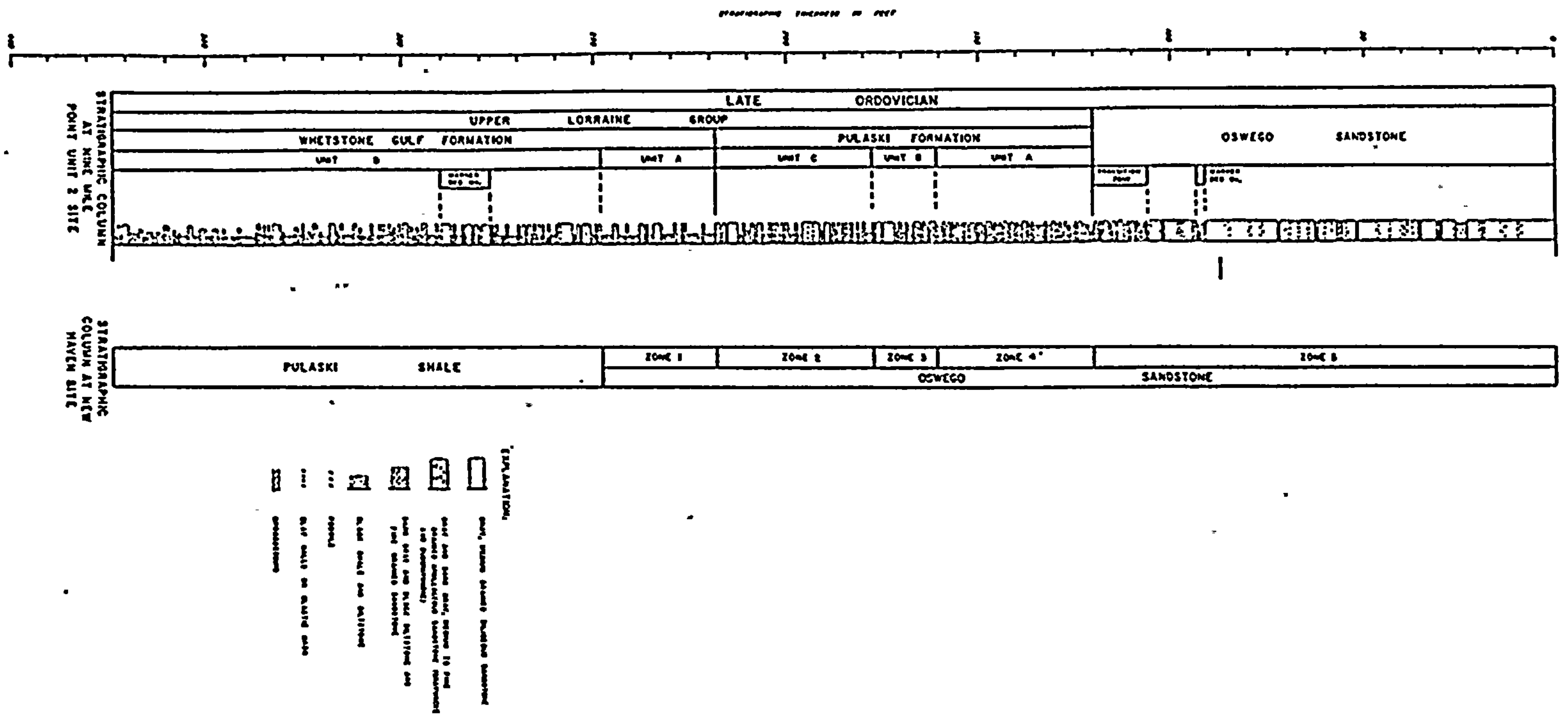
NINE MILE POINT NUCLEAR STATION
UNIT 2
NIAGARA MOHAWK POWER CORP.



Q361.24 One of the conceivable hazards that should be thoroughly considered is that a new pop-up may develop somewhere at the plant site. Since these features are widely considered to develop from stress relief, it is important to know about how much load removal would trigger one. Therefore, extend (a) the theoretical buckling concept, and (b) all available experience in the region to estimate the rock load just sufficient to prevent a buckle from forming in laterally stressed virgin ground.

RESPONSE Perhaps the best known and most widely applied buckling equations are those derived by Euler. Euler's equations are applicable to elastic layers which are weightless and frictionless and the problem is restricted to one of static instability which is independent of time. The equations are based upon the internal resistance to bending of the layer.

More recent discussions of buckling instability of elastic layers have been presented by Biot (1961) and Currie, Patnode, and Trump (1962). Biot (1957, 1961, 1964a, 1965b) and Remberg (1959, 1960, 1961b, 1963b, 1964b) have investigated the problems of the deformation of layered viscous materials.

Euler's treatment of the problem is adequate for engineering practice. Without many difficulties, it is possible to expand Euler's equation to account for body weight of a layer which is caused to buckle. In this context the buckling analyses becomes a complex problem which is governed by many parameters. Included are:

1) Young's Modulus;
2) in situ stress;
3) slenderness ratio ($L/_t$ ratio)
4) unit weight of the layer
5) thickness of indivudal beds
6) imperfections within the layer (initial inclination); and,
7) pore pressure

One of the paramters controlling the buckling instability is excavation-related load removal. This parameter may be of critical importance but only in cases where other process-controlling parameters are satisfied. The latter parameters vary greatly from one site to another, making each site unique with respect to the buckling potential. Moreover, as demonstrated at the Nine Mile Point site, the buckling controlling parameters may vary greatly across the specific site and from one rock formation to the other. Thus, extrapolation of experience from one site to another may prove to be

uncertain.. This extrapolation can only be made in light of the buckling controlling parameters. As a rule the parameters were not quantified at the sites where buckling have been triggered by excavations.

In order to proceed with the buckling analysis at a specific site it is necessary to know some characteristics of the in situ conditions. These characteristics encompass a wide spectrum of parameters, including the following:

1. dimensions of excavations - these will set a maximum value of L/t ratio;

2. thickness of individual beds;

3. in situ stress conditions and its lateral and downward consistency;

4. structural and sedimentological imperfections (will determine value of θ);

5. pore pressure (gas and water); and

6. Young's modulus.

With reference to the Nine Mile Point Unit 2 site, it is possible to assign a range of values for these parameters. The following ranges are considered to be reasonable:

1. Dimensions of excavations - vary from several feet to approximately 200 feet, measured in the direction of the maximum horizontal stress.

2. Thickness of individual layers - varies depending upon stratigraphic position. Within the marine section of the Pulaski Formation, which the majority of excavations penetrate , the representative thickness varies from .5 foot to 1.0 foot.

3. In situ stress - greatly variable depending upon depth and location with respect to a local geologic structure. At depths greater than 200 feet a value of stress equal to approximately 3000 pounds per square inch is considered to be representative. At shallower depths the stress varies from approximately -200 pounds per square inch to about 1000 pounds per square inch.

4. Structural and sedimentological imperfections - greatly variable, locally may exceed 2°00'. Assumption of an average value of θ=0°30' is considered reasonable.

5. Pore pressure - bouyancy effect equal to 40 percent of the unit body weight plus 10 percent gas pressure.

6. Young's modulus for the rock mass $E=1x10^6$ pounds per square inch to $2x10^6$ pounds per square inch.

Considering the above parameters and Euler's buckling relationships, it can be concluded that for in situ stress levels ranging from 1000 pounds per square inch to 2000 pounds per square inch occurrence of buckling is only possible if:

1. thickness of layers is smaller than 12 inches;

2. θ is greater than 0°30';

3. pore pressure exceeds zero (normal water table is reinstated after completion of construction); and

4. length of excavations is such that forming folds can attain slenderness ratio approximately equal to 100:1.

Additionally, the stress conditions must be adequate to overcome shear resistance to lateral movement of the layer involved in buckling and thus allow for the occurrence of flexural slip folding.

Information presently available indicates that the foregoing conditions would be met at Nine Mile Point only at depths below the foundation depth of the Unit 2 power complex and several thousands of feet south and east of the Unit 2 reactor excavations.

Recently performed in situ strain relief measurements at the site demonstrated that bedrock stresses at the location of Unit 2 power complex are relatively low. The low value of bedrock stress resulted from "Rad-waste-type bedrock behavior" in the past. The measurements revealed that at depths less than 100 feet the greatest horizontal stress is substantially lower than 1000 pounds per square inch. From Euler's buckling relationships, it can be concluded that buckling is not a conceivable phenomenon that can develop under Category I structures whose excavation depth is less than 100 feet. This includes all Category I structures.

At a depth of about 100 feet the measured stress is equal to approximately 1000 pounds per square inch. The average thickness of individual beds is equal to approximately 12 inches. Considering this in light

of the Euler buckling concept, it can be concluded that buckling of strata below 100 feet is only possible if the pore pressure is equal to 80 to 90 percent of the body weight of the founding stratum. The above conclusions were derived assuming complete removal of overburden.

Placement of relatively small loads (for example 12 to 24 inches of material whose unit weight is equal to 0.058 pounds per cubic inch) from engineered structures results in greatly improving the situation and eliminating the buckling problem in cases of significant pore pressure. Further improvement of the situation is evident when one considers significant bending resistance of the foundation slabs.

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