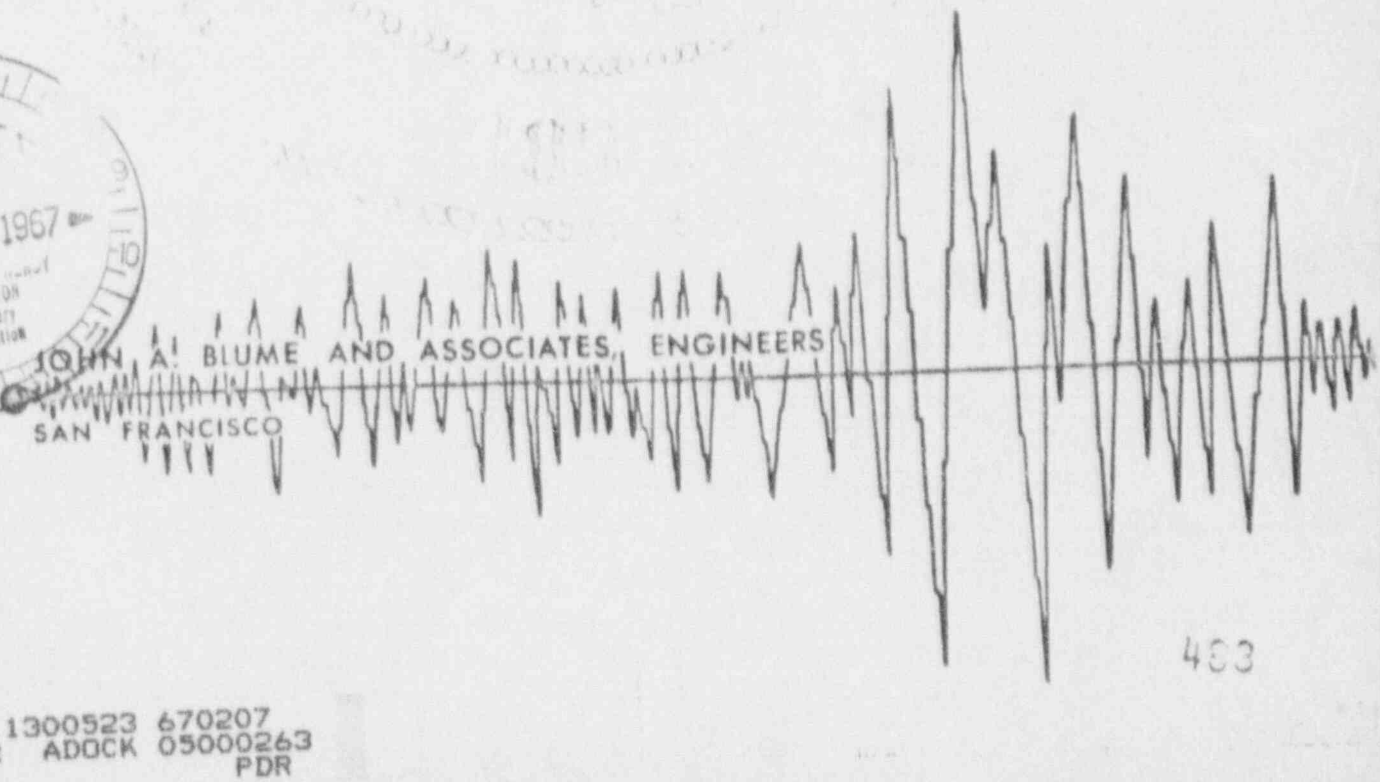
GENERAL ELECTRIC COMPANY
ATOMIC POWER EQUIPMENT DEPARTMENT

MONTICELLO NUCLEAR GENERATION PLANT

RECOMMENDED EARTHQUAKE CRITERIA



JOHN A. BLUME AND ASSOCIATES, ENGINEERS
SAN FRANCISCO

JOHN A. BLUME & ASSOCIATES, ENGINEERS
612 HOWARD STREET • SAN FRANCISCO, CALIFORNIA 94105 • (415) 397-2525

January 24, 1967

General Electric Company
Atomic Power Equipment Dept.
175 Curtner Street
San Jose, California 95103

Attention: Mr. R. B. Gile
MC-750

SUBJECT: Earthquake Design Criteria for the Monticello Nuclear Generation Plant

Gentlemen:

Reference is made to our report on the earthquake design criteria for the subject project dated July 15, 1966. In this report we recommended that Type 2 structures be designed for a minimum horizontal coefficient of 0.10.

We have reviewed this requirement on the basis of values recommended by the Uniform Building Code, and it is our opinion that the appropriate coefficient for Type 2 structures should be 0.05. Our recommendation for a one-third allowable increase in basic stress still applies.

Very truly yours,

JOHN A. BLUME & ASSOCIATES, ENGINEERS

E. J. Keith

E. J. Keith
Assistant Vice President

EJK/hp

JOHN A. BLUME & ASSOCIATES, ENGINEERS
612 HOWARD STREET • SAN FRANCISCO, CALIFORNIA 94105 • (415) 397-2525

JOHN A. BLUME
J. P. NICOLETTI
H. J. SEXTON
R. L. SHARPE
D. M. TEIXEIRA

July 15, 1966

General Electric Company
175 Curtner Street
San Jose, California

Attention: Mr. R. B. Gile

Subject: Earthquake Design Criteria for the Monticello Nuclear Generation Plant

Gentlemen:

Transmitted herewith is our recommended earthquake design criteria for the subject project.

Since not all field data have yet been made available it will be necessary that we review the findings presented herein. We do not however, expect drastic changes in these criteria.

Very truly yours,

JOHN A. BLUME & ASSOCIATES, ENGINEEFS

H. J. Sexton

H. J. Sexton,
Vice President and Chief Engineer

PRELIMINARY EARTHQUAKE DESIGN CRITERIA

FOR THE

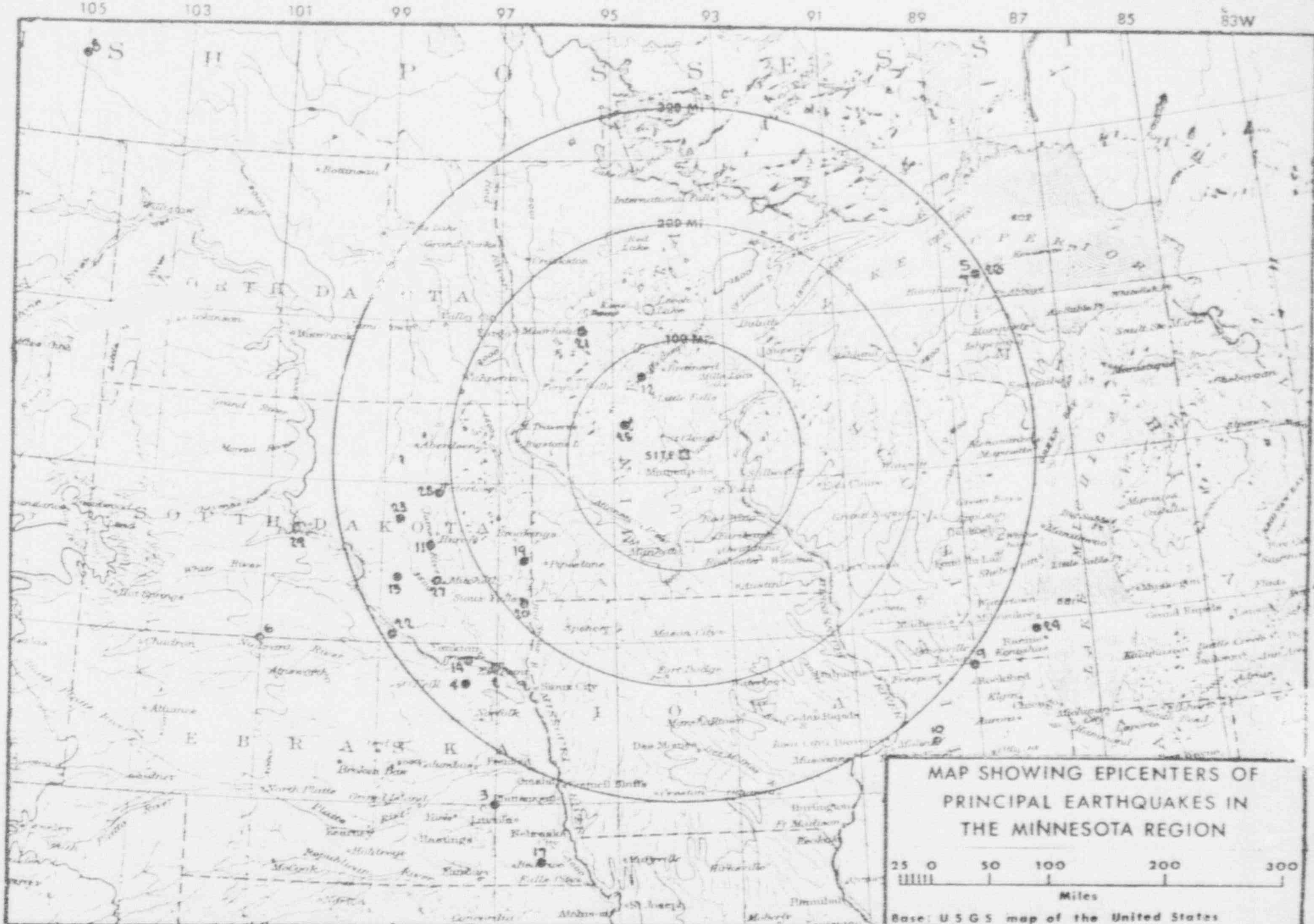
MONTICELLO NUCLEAR GENERATION PLANT

NEAR

MONTICELLO, MINNESOTA

This report is based on preliminary geologic and soil data furnished by Dames and Moore, foundation engineers, and the assumption that the reactor-building is founded in a 15-foot layer of stiff clay immediately above sandstone. When final earth science reports are available this report will be reviewed and revised if necessary.

The proposed site is located near the right bank of the Mississippi River in Wright County, Minnesota at about latitude 45° 20' North and Longitude 93° 50' West, approximately 30 miles northwest of Minneapolis.


105
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85
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100 Mi
SITE
International Falls
Duluth
Minneapolis
Sioux Falls
Sioux City
Des Moines
Omaha
MAP SHOWING EPICENTERS OF
PRINCIPAL EARTHQUAKES IN
THE MINNESOTA REGION
25 0 50 100 200 300
Miles
Base: U S G S map of the United States

PLATE 1

GEOLOGY

Regional Geology - The basement rocks of Minnesota, some as old as Precambrian, generally are covered by Pleistocene glacial debris and younger alluvial deposits. Volcanic rocks occur in some areas. Sediments of these types rest on glacially-carved bedrock of sandstone and shale in turn underlain by weathered granite rocks. The bedrock surface slopes east to southeast.

The Minnesota area here discussed is part of a deep, southerly-trending trough in which were deposited sediments and volcanics during later Precambrian and Paleozoic time. Paleozoic rocks are exposed in the southern part of the trough and, in the Minneapolis-St. Paul area, form an artesian basin.

Regional Faulting - The results of regional geophysical surveys indicate that a major fault system of Precambrian age may be present in the region. Displacements of thousands of feet are believed to have occurred on the faults in Precambrian time and displacements of lesser magnitude in Paleozoic time. There is no evidence of faulting in the last few million years.

Two lobes of ice, both of the Wisconsin glacial stage, advanced [illegible] the region, the older from the Lake Superior area and the other [illegible] the sou[illegible]west. Both left terminal moraines, the moraines of the [illegible] of the lobes being immediately south of the present-day Mississ- [illegible]ver.

The depths of stream channels cut in the area in pre-glaciation time not only may be greater than that of the Mississippi River, but they also bear no directional relationship to present-day channel. The locating of these old channels is hindered by lack of bore-hole information.

Site Geology - Decomposed igneous rocks of Precambrian age lie at a depth of about 70 feet at the site. These rocks are overlain by 10 to 15 feet of sandstone which, although in places weathered and friable, is in general moderately well cemented. The sandstone is in turn overlain by approximately 50 feet of glacial and alluvial debris consisting of sands and gravels. In the reactor-building area, the sandstone is overlain by clay of variable thickness. It is not presently known whether or not the building will be founded in this clay.

Borings and well information in the vicinity of Monticello - about 2-3/4 miles east of the site - indicate that that locality is underlain by 150 to 200 feet of unconsolidated alluvium and glacial drift which in turn overlie sandstone and shale; granite at that locality lies at a depth greater than 500 feet. The indication is therefore, that the rock and soil units at the site slope eastward toward the sedimentary basin and its artesian ground-water aquifers

SEISMOLOGY

Seismic History - Table A numerically lists the earthquakes in the general region in and around Minnesota. Those more applicable to the site are plotted on Plate I. The earliest earthquake on record occurred in 1860 in central Minnesota, thus the record here is for only some ninety years. During that period the historical earthquakes have had little effect at the proposed site.

Faulting in Area - The nearest known or inferred fault - the Douglas Fault - is 23 miles southeast of the site (Plate 2). According to referenced geological information, there is no indication that faulting has affected the area of the site in the last few million years. The major fault system of Precambrian age, which is associated with the Precambrian structural trough, is also seen on Plate 2. Major movements of thousands of feet along this system appear to have been restricted to Precambrian time, with minor displacements having occurred during the Paleozoic. Faulting within recent geologic time is not in evidence.

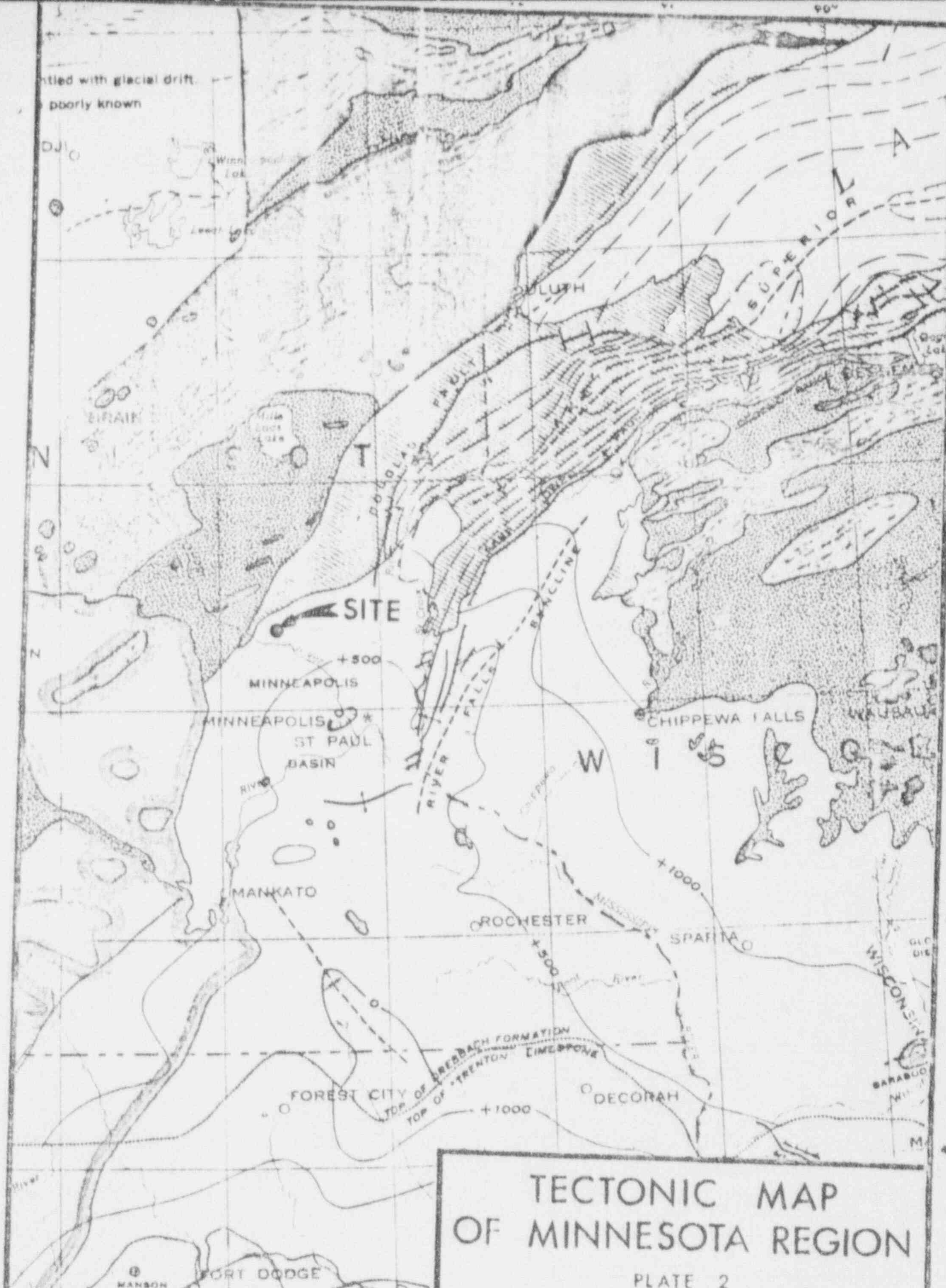
Richter's Seismic Regionalization Map (Plate A, Appendix) shows the area of the site in a probable maximum intensity of VIII, Modified Mercalli. This intensity has been based on the area's relationship to the Canadian shield. Stable shields in other continents are usually fringed by belts of moderate seismicity, with occasionally large earthquakes. Historically, this area is too young to prove or disprove such seismic activity.

The Coast and Geodetic Survey's Seismic Probability Map of the United States (Plate B in Appendix) assigns the area to Zone 0 - no damage.

It is our opinion that neither the regionalization nor the probability map is satisfactory in determining a proper seismic factor if considered alone. Each, however, is based on judgment and fact which, when weighed with other data, become more meaningful. In the case at hand, the assignment of an VIII as the largest probable intensity for general area must be tempered by the fact that the intensity at or near the sandstone will be much less than that experienced in areas of less competent material, where invariably the maximum damage is sustained.

Earthquakes can and do occur in this region away from faults, and probably result from residual stresses due to recent glaciers. A quake similar to Nos. 12 and 24 was postulated near the site and using the dynamic response data obtained insitu, the Taft earthquake of July 21, 1952

North 69 West component with an applied factor of 0.33 was selected as best representative for the design earthquake. Plate 3 shows single-mass spectra when averaged. Recommended design criteria follow which utilize this earthquake record.



TECTONIC MAP OF MINNESOTA REGION

PLATE 2

Base: USGS and AAPG

RECOMMENDED EARTHQUAKE DESIGN PROCEDURES

For purposes of design, structures (buildings or equipment) are divided into two classes:

Type I. Those structures whose failure may damage vital equipment and thus might cause a nuclear incident.

Type II. Those structures whose failure could cause no nuclear incident.

Recommended Procedures for Type I Structures and Equipment

1. For structures or equipment founded directly on soil, a structural design shall first be executed based on estimated seismic shears, moments, and displacements. The structures thus designed shall then be subjected to a dynamic analysis using the spectra on Plate 3 and damping values from Table 1. Sufficient modes shall be included to assure participation of all modes having a period greater than 0.08 second. A vertical ground acceleration of two-thirds the horizontal ground acceleration shall be applied to the structure and resulting stresses due to horizontal and vertical accelerations shall be considered to act simultaneously and shall be added directly. When combined with stresses from operating conditions, the resulting stresses shall comply with applicable codes without the usual fractional increase for short-term loading. The final design shall be reviewed for compliance with local requirements. If computerized methods of dynamic analysis are used, the mathematical model may be subjected to an excursion through the Taft earthquake of July 21, 1952 North 69 West component with an applied factor of 0.33. After this has been satisfied, the structure shall be examined under values of twice those given in Plate 3 or a dynamic excursion through the Taft earthquake of July 21, 1952 North 69 West component, with an applied factor of 0.66. As before, horizontal and vertical seismic components shall be considered with other appropriate loads, but in this case vertical ground accelerations shall be 0.08g. Under this loading condition there shall be no failure that could cause injury or prevent a safe shutdown during or after the earthquake.

2. Structures or equipment supported in or on other structures or equipment are placed into three categories based on their natural frequency and the predominant frequency of the supporting structure:

(1) Rigid category: $\frac{f_m}{f} > 2.0$

(2) Resonance category: $0.7 < \frac{f_m}{f} < 2.0$

(3) Flexible category: $\frac{f_m}{f} < 0.7$

Where:

fm is the natural frequency of the mechanical structure or equipment, and f is a predominant frequency of supporting structure at the location of installation.

(1) For Rigid Category: Because of the high frequency, the design shall be based on an acceleration corresponding to the maximum acceleration experienced by the supporting structure at the location of equipment support.

(2) For Resonance Category: Elimination of resonance phenomena is one of the principles of the design. In order to eliminate resonance vibration some modification of the natural frequency of the supporting structure may be required. In case the resonance vibration cannot be avoided, prevention of large amplitudes by means of damping devices is required or dynamic design considering resonance vibration is required. In case the mass of the object is such as to produce an "Appendage" condition with large deflections and accelerations, a thorough dynamic study will be performed. Should the restriction of vibration be enough to make the object rigid, examination for rigid category is also required.

(3) For Flexible Category: Those items which are designated as flexible will be designed using induced accelerations corresponding with their frequencies. Careful examinations will be made concerning objects coming into contact because of excessive displacements.

3. For structures and equipment too complex for direct analytical procedures, vibration tests should be performed to establish the earthquake-resistant capabilities.

TABLE 1

RECOMMENDED DAMPING VALUES

Item	Percent Critical Damping
Reactor-building (massive construction with many cross walls and equipment and providing only secondary containment	5.0
Thin-shell and prestressed concrete structures	2.0
Steel structures	2.0
Vital piping systems	0.5
Ground rocking modes of vibration	10.0

Recommended Procedures For Type II Structures and Equipment

It is recommended that Type II structures and equipment be designed on basis of a minimum seismic horizontal coefficient of 0.10 with a one-third allowable increase in basic stress. Allowable increase in soil stresses if any, must be taken from recommendations of the Soils Engineer. All equipment should be so bolted or fastened that its displacement will not occur if friction is non existent.

JOHN A. BLUME & ASSOCIATES, ENGINEERS

RESPONSE ACCELERATION SPECTRA

FOR THE

MONTICELLO NUCLEAR GENERATION PLANT

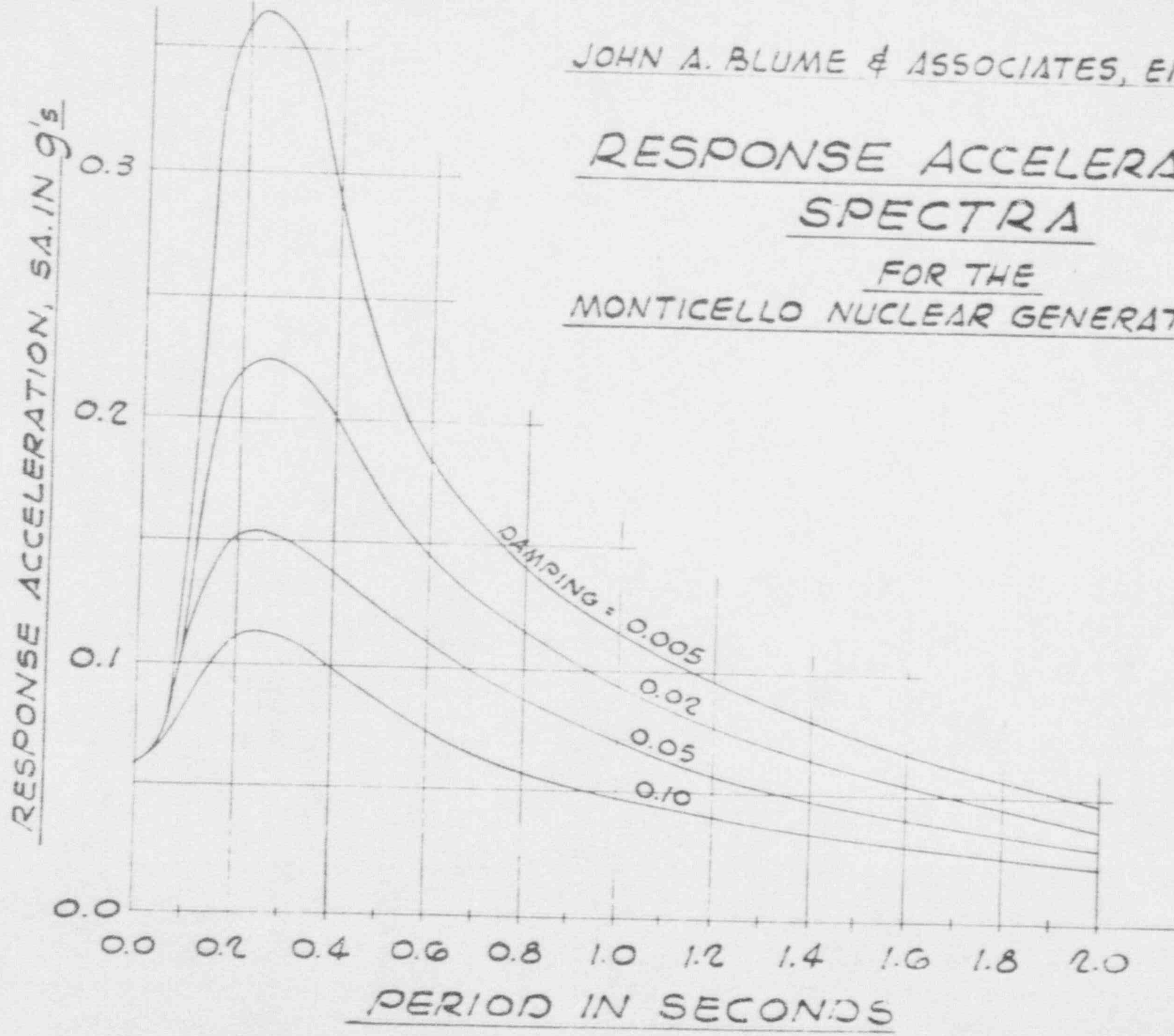


PLATE 3

REFERENCES

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2. Dames and Moore, Report - Dynamic Response Data Investigation Monticello, Proposed Nuclear Plant for the Northern States Power Company, July 7, 1966.
3. Monticello Soil Boring Data, Sheets 1, 2 & 3, Northern States Power Company, February 17, 1966.
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5. Heck, N.H., Earthquake History of the United States, U.S.Coast and Geodetic Survey, 1956 revised.
6. Richter, C.F., Seismic Regionalization, Bulletin of the Seismological Society of America, Vol. 49, No. 2, April, 1959.
7. Building Design in Canada 1965 associate committee on the National Building Code, National Research Council, Ottawa, Canada
8. Blume, John A., Earthquake Ground Motion and Engineering Procedures for Important Installation Near Active Faults, Third World Conference on Earthquake Engineering, 1965.
9. Wiggins, John H., Jr., Effect of Site Conditions on Earthquake Intensity, ASCE, Vol. 90 No. ST2, Part 1 (1964).
10. Hershberger, John, A Comparison of Earthquake Acceleration with Intensity Ratings, Bulletin of the Seismological Society of America, Vol. 46, 1956.
11. Seed, H.B., Soil Strength During Earthquakes, Second World Earthquake Conference, Tokyo, 1960.

APPENDIX

TABLE A

SEISMIC HISTORY OF THE REGION

No.	Date	Location: Place	N.Lat	W.Long	Intensity (M.M.)	Remarks
						* Indicates epicenter not plotted on map
*1	1860	Central Minn.	-	-	Unknown	
2	10/9/1872	Sioux City, Iowa	42.7	97.0	V	Felt over 3,000 square miles.
3	11/15/1877	East Neb.	41.0	97.0	VII	Felt over 140,000 square miles.
4	7/28/1902	East Neb.	42.5	97.5	V	Felt over 35,000 square miles.
5	7/26/1905	Calumet, Mich.	47.3	88.4	VII	Felt over 16,000 square miles.
6	5/9/1906	Washabaugh County, S. D.	43.0	101.0	VI	Felt over 8,000 square miles.
7	5/26/1906	Keewenaw Peninsula, Michigan	47.3	88.4	VIII	Felt over 1,000 square miles.
8	5/15/1909	Canada, felt to South	50.0	105.00	VIII	Felt over 500,000 square miles.
9	5/26/1909	Dixon, Ill.	42.5	89.0	VII	Felt over 40,000 square miles.
10	10/22/1909	Sterling, Ill.	41.6	89.8	IV-V	
11	6/2/1911	South Dak.	44.2	98.2	V	Felt over 40,000 square miles.
12	9/3/19/7	Minnesota	46.3	94.5	VI	Felt over 10,000 square miles.
*13	2/38/1925	Canada	48.2	70.8	VIII	Felt over 2,000,000 square miles.
14	10/6/1929	Yankton, S.D.	42.8	97.4	V (est.)	
15	1/17/1931	White Lake, S.D.	43.8	98.7	V (est.)	
*16	11/12/1934	Rock Island & Moline, Ill. Davenport, Iowa	41.4	90.5	V	
17	3/1/1935	Eastern Neb.	40.3	96.[illegible]	VI	Felt over 50,000 square miles.
*18	11/1/1935	Canada	46.8	79.1	IX & over	Felt over 1,000,000 square miles, felt in Minn.

No.	Date	Location			Intensity (M.M.)	Remarks
		Place	N.Lat	W.Long		
19	11/1/1935	Egan, S.D.	44.0	96.6	V (est.)	
20	10/1/1938	Sioux Falls, S.D.	43.5	96.6	V	Felt over 3,000 square miles.
21	1/28/1939	Detroit Lake, Minn.	46.9	95.5	V (est.)	
22	6/10/1939	Fairfax, S.D.	43.1	98.8	VI (est.)	
23	7/23/1946	Wessington, S.D.	44.5	98.7	VI (est.)	
24	5/6/1947	Milwaukee Area	42.9	87.9	VII	Felt Sheboygon to Kenosha.
25	2/15/1950	Alexandria, Minn.	45.7	94.8	V-VI(est.)	
26	1/6/1955	Hancock, Mich.	47.3	88.4	V	
27	12/3/1957	Mitchell, S.D.	43.8	98.0	V	
28	1/12/1959	Doland, S.D.	44.9	98.0	V	
29	12/31/1961	W.Pierre, S.D.	44.4	100.5	VI	

TABLE 2

MODIFIED MERCALLI INTENSITY SCALE OF 1931

(Abridged)

I. Not felt except by a very few under especially favorable circumstances.

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated.

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed, walls make creaking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.

V. Felt by nearly everyone, many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.

VI. Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbs persons driving motor cars.

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.

XI. Few, if any (masonry), structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipe lines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

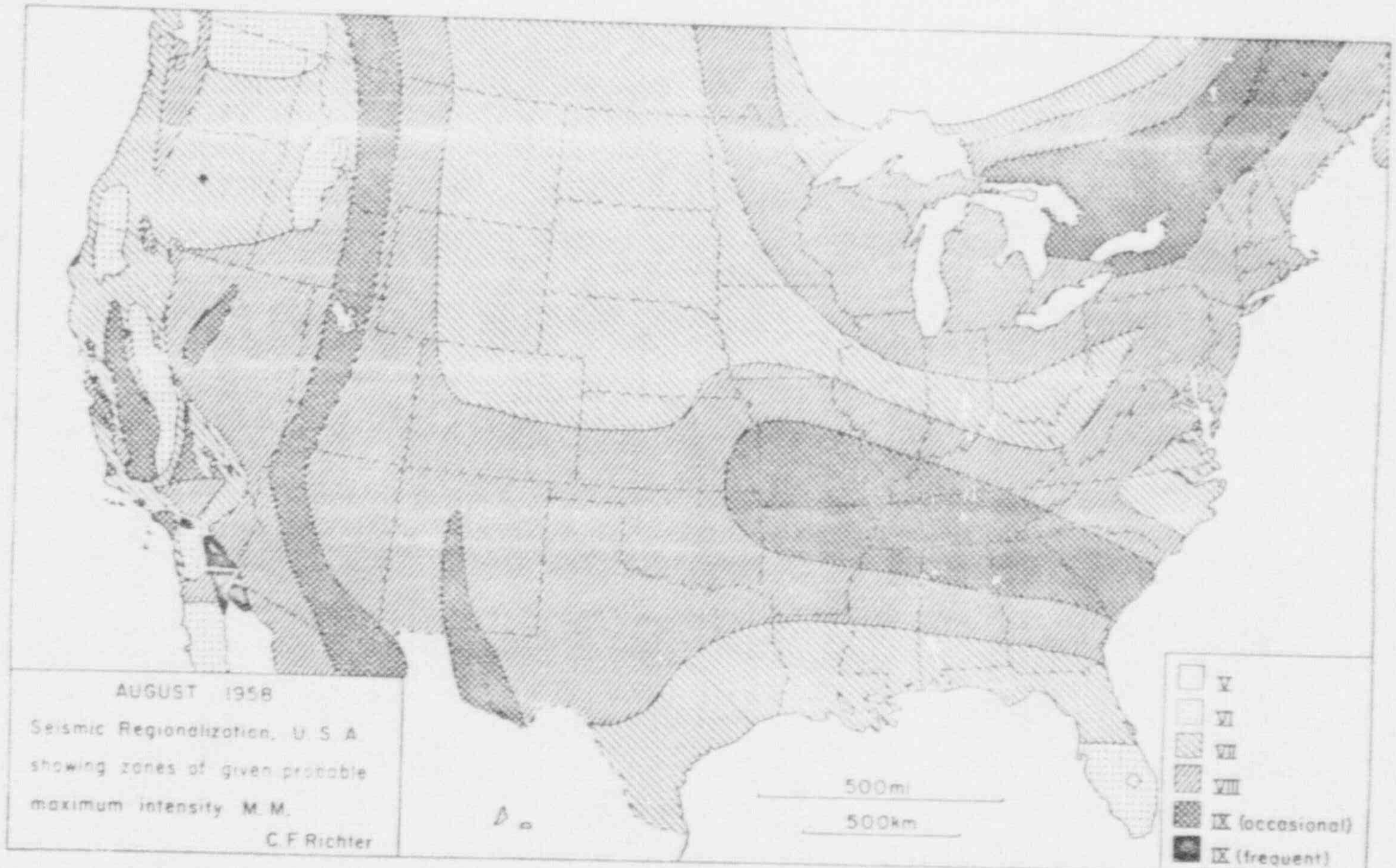
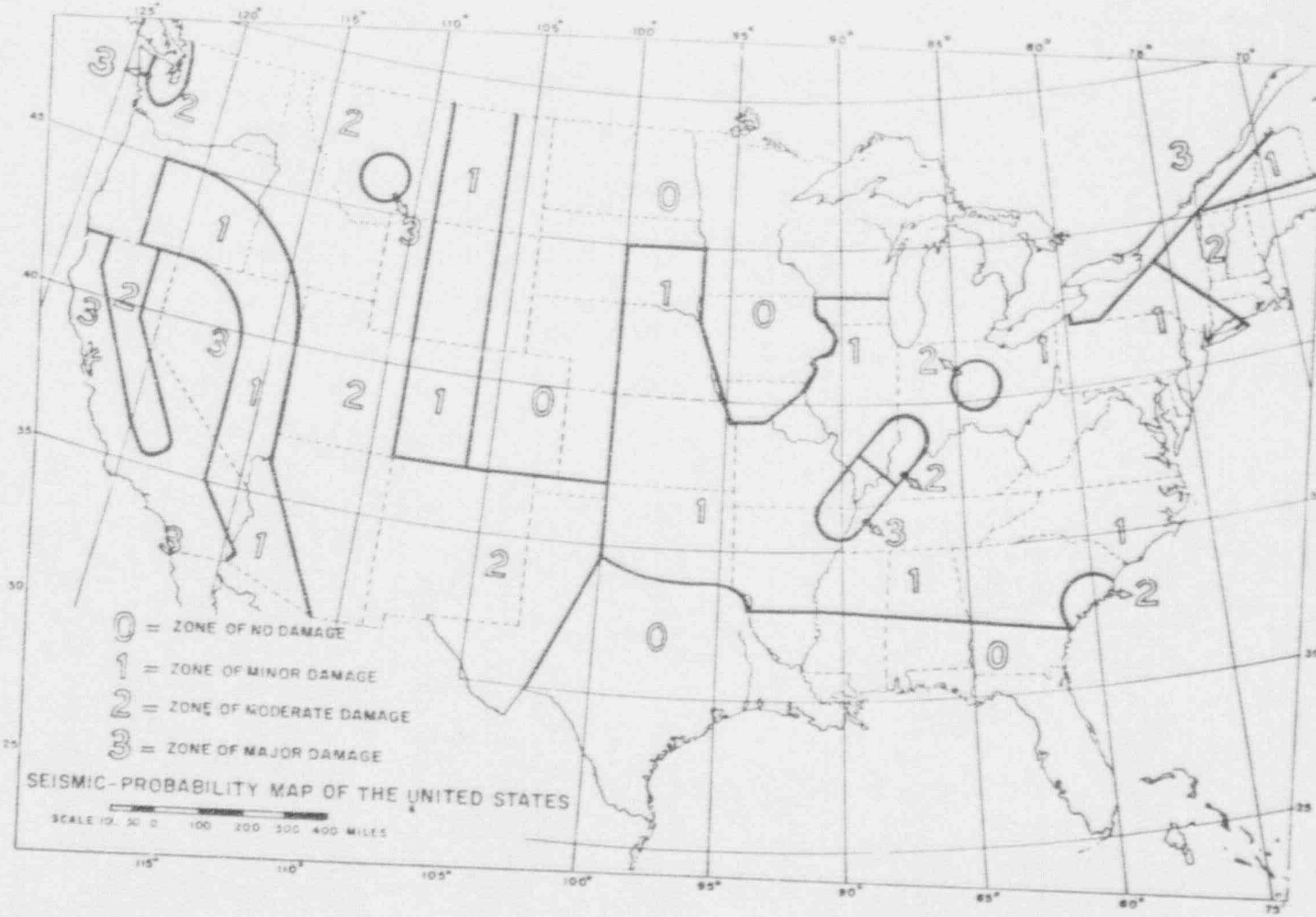

AUGUST 1958
Seismic Regionalization, U. S. A.
showing zones of given probable
maximum intensity M. M.
C. F. Richter
500mi
500km
V
VI
VII
VIII
IX (occasional)
IX (frequent)

PLATE A



From U.S. Coast and Geodetic Survey

PLATE B

309 ... ST JACKSON BOULEVARD · CHICAGO, ILLINOIS 60606 · 312 ...
PARTNERS JAMES D. THOMPSON · GEORGE ...

October 17, 1966

Bechtel Corporation
P.O. Box 3965
San Francisco, California 94119

Attention: Mr. G. L. Parkinson,
Project Engineer

Gentlemen:

Seventh Supplement
Report of Foundation Investigation
Proposed Nuclear Power Plant-Unit Number 1
Monticello, Minnesota
For Northern States Power Company

This letter presents our opinions and data pertinent to questions asked by the Bechtel Corporation concerning dewatering operations to be performed at the site of the Proposed Nuclear Power Plant-Unit Number 1 in Monticello, Minnesota. We understand that the main dewatering system will consist of large diameter wells installed around the periphery of the proposed construction and penetrating into the underlying sandstone formation. The following questions regarding dewatering operations were asked:

1 - Will the dewatering operations at the site affect the performance of privately owned wells existing near the site? We understand that the dewatering system is designed to remove 400 gallons per minute during low water conditions and up to 3,500 gallons per minute during high water conditions (A high water level assumed at Elevation 916 is anticipated during flooding of the Mississippi River.) The dewatering system is designed for a maximum capacity of 6,000 gallons per minute.

2 - Will limiting the solids content in the ground water removed from the site by the dewatering system to ten parts per million (10 ppm.) be sufficient to prevent detrimental loss of ground in the vicinity of the excavation?

3 - Will the ground water removed from the site by the dewatering system be suitable for use in concrete mixing operations and usable for plant sanitary and drinking purposes?

Based on our knowledge of the subsurface conditions in the vicinity of the site, we estimate that, during high water conditions, the zone of influence of ground water drawdown in the vicinity of the site will be on the order of 2,000 feet or less. Hence, wells located 2,000 feet or more from the proposed excavation should not experience measurable drawdown in their normal water levels. Due to the variability of subsurface permeability characteristics, our estimate of the zone of influence is considered subject to some uncertainty. We therefore recommend that pumping and drawdown data obtained during test pumping operations at the site be provided to us so that we may review and modify our conclusions if necessary.

It is our opinion that limiting the solids content in the ground water removed from the site to ten parts per million will be sufficient to prevent detrimental loss of ground within the construction area. We recommend that the contractor be required to provide substantiating data throughout the dewatering program to verify that the solids content of the pumped water does not exceed the limiting value.

If the total solids content of the water to be removed from the excavation is limited to ten parts per million, the water will not contain an amount of total solids which would preclude its use for concrete mixing and for plant sanitary and drinking purposes. wever, we recommend that samples of the ground water be obtained and subjected to laboratory chemical analyses to insure that its chemical composition is suitable for these purposes.

We trust that this supplement provides the information required at this time. It is requested that this letter be bound with and become a part of the subject report.

Yours very truly,

DAMES & MOORE

William G. Paratore

George D. Leal

GDL:WGP:mf
Twenty Copies Submitted

[illegible]

300 WEST JACKS[illegible] BOULEVARD · CHICAGO, [illegible] 60606 · 312 [illegible]

PARTNERS: JAM[illegible] THOMPS[illegible] · GEOR[illegible] D. LEAL

October 7, 1966

Bechtel Corporation
P.O. Box 3965
San Francisco, California 94119

Attention: Mr. G. L. Parkinson, Project Engineer

Gentlemen:

Sixth Supplement
Report of Foundation Investigation
Proposed Nuclear Power Plant - Unit Number 1
Monticello, Minnesota
For the Northern States Power Company

This letter presents estimated maximum settlements for the Reactor Building, the Turbine Generator Building, and the Intake Structure assuming bearing pressures imposed on the underlying soils equal to one-third the ultimate bearing capacity of the soils underlying each unit. We are also providing the estimated maximum settlement for the Reactor Building assuming a bearing pressure imposed to the underlying soils equal to one-fifth the ultimate bearing capacity of the soils underlying the Reactor Building. The ultimate bearing capacity of the soils underlying each unit were presented to you in our Second Supplement, dated August 16, 1966.

Presented below are the estimated maximum settlements for the units assuming that the installation of foundations for the units are in accordance with the recommendations provided in previous reports.

UNIT	FOUNDATION DIMENSIONS (FEET X FEET)	FOUNDATION ELEVATION (FEET)	FOUNDATION BEARING PRESSURE (LBS./SQ.FT.)	ESTIMATED MAXIMUM SETTLEMENT (INCHES)
Reactor Building	138 X 138	890	16,700	1/2*
Reactor Building	138 X 138	890	10,000	1/4*
Turbine Building	110 X 238	905	10,000	1 1/4
Intake Structure	80 X 90	893	10,000	1

* Assumes that stiff to hard clay underlying the foundation will be removed and replaced with granular fill material compacted to 100 percent of maximum density as determined by the American Association of State Highway Officials Test Designation T 180-57.

We trust that this supplement provides the information which you require at this time. It is requested that this letter be bound with and become a part of the subject report.

Yours very truly,

DAMES & MOORE

George D. Leal

George D. Leal

GDL:WGP:mf
Twenty Copies Submitted

309 WEST JACKSON BOU[illegible]VARD · CH[illegible]GO, ILLIN[illegible] [illegible] · 3[illegible]-[illegible]22-1772
PARTNERS JAMES [illegible] · GEORGE D. [illegible]AL

September 30, 1966

Bechtel Corporation
P.O. Box 3965
San Francisco, California 94119

Attention: Mr. G. L. Parkinson,
Project Engineer

Gentlemen:

Fifth Supplement
Report of Foundation Investigation
Proposed Nuclear Power Plant-Unit Number 1
Monticello, Minnesota
For Northern States Power Company

This letter presents dynamic response data for the foundation material which will immediately underlie the Reactor Building at the site of the Proposed Nuclear Power Plant-Unit Number 1 to be constructed in Monticello, Minnesota for Northern States Power Company.

We recommended in previous reports that the stiff silty clay layer which would be present below the mat foundation of the Reactor Building be removed and replaced with compacted granular fill. It was further recommended that the granular fill be compacted to a dry density of at least 100 percent of the maximum dry density as determined by the American Association of State Highway Officials T 180-57 Method of Compaction. We understand that our recommendations will be utilized and that the clean granular soils obtained from the excavating operations will be used as fill material below the Reactor Building. It is anticipated that the fill material will consist of a medium sand with some gravel.

We present below dynamic response data for a medium sand with some gravel compacted to 100 percent of the maximum dry density as determined by the American Association of State Highway Officials T 180-57 Method of Compaction:

REPRESENTATIVE PHYSICAL CHARACTERISTICS FOR COMPACTED MEDIUM SAND WITH SOME GRAVEL:

Compressional Wave Velocity (V_c) Feet Per Second	2,000
Shear Wave Velocity (V_s) Feet Per Second	1,000
Poisson's Ratio (σ) Dimensionless	0.33
Modulus of Elasticity (E) Pounds Per Square Inch	78,500
Shear Modulus (G) Pounds Per Square Inch	29,500
Density (γ) Pounds Per Cubic Foot	135

Should you have any questions regarding the information contained herein, please contact us. It is requested that this letter be bound with and become a part of the subject report.

Respectfully submitted,

DAMES & MOORE

George D. Leal by WGP

George D. Leal

GDL:WGP:mf
Twenty Copies Submitted

[illegible] WEST [illegible] CHICAGO, ILLINOIS [illegible]
PARTNERS JAMES [illegible] • GEORGE [illegible]

September 20, 1966

Bechtel Corporation
P.O. Box 3965
San Francisco, California 94119

Attention: Mr. G. L. Parkinson,
Project Engineer

Gentlemen:

Fourth Supplement
Report of Foundation Investigation
Proposed Nuclear Power Plant - Unit Number 1
Monticello, Minnesota
For the Northern States Power Company

This letter report presents recommendations regarding the location of low capacity plant sanitary water wells. We understand that two - 100 gallon per minute water wells will be installed; however, both wells will not operate at the same time. One of the two wells will act as a reserve well.

It is our opinion that the wells should be located a sufficient distance from the plant structures such that if accidential spillage of effluents occurs at the plant, the effluents would not contaminate the wells. Based on our knowledge of the subsurface conditions in the vicinity of the site, and the results of engineering studies regarding the drawdown characteristics related to the subsurface conditions for a 100 gallon per minute well, we recommended that the wells be located upstream (west) and a minimum distance of 300 feet from the plant site. It is our opinion that a well located at the recommended minimum distance will not cause subsidence to occur in the vicinity of the proposed plant area.

We hope that the information contained in this supplement is that which you require. It is requested that this supplement be bound with our report of foundation investigation and previous supplements and become a part thereof.

Yours very truly,

DAMES & MOORE

George D. Leal

George D. Leal

GDL:WGP:mf
Twenty Copies Submitted

cc: (5) Northern States Power Company
414 Nicollet Avenue
Minneapolis, Minnesota 55401

Attention: Mr. Arthur V. Dienhart,
Manager of Engineering

[illegible] JACKSON BOULEVARD • CHICAGO, [illegible] 922-[illegible]
PARTNERS JAMES B. THOMPSON • GEORGE D. [illegible]

September 14 1966

Bechtel Corporation
P.O. Box 3965
San Francisco, California 94119

Attention: Mr. G. L. Parkinson,
Project Engineer

Gentlemen:

Third Supplement
Report of Foundation Investigation
Proposed Nuclear Power Plant - Unit Number 1
Monticello, Minnesota
<u>For the Northern States Power Company</u>

This letter presents recommendations regarding methods for restricting the swelling of the silty clay layer which will be exposed during the excavation operations to be performed along the common boundary between the Reactor Building and the Turbine Generator Building. We understand that it is desired to complete the earthwork operations during fall of 1966 such that the construction of the proposed nuclear facility may be started early in 1967. The foundation grade in the Turbine Generator Building area will be established at elevation 906 and in the Reactor Building area at elevation 890.

In previous reports submitted, we indicated that a stiff to hard silty clay layer is present near the proposed foundation grades. This layer is subject to swelling should a source of water be present for the silty clay to absorb. We recommended that a minimum confining soil pressure on the order of 600 pounds per square foot be provided over the silty clay layer in order to restrict swelling. It was recommended that the initial excavation be discontinued, prior to the flooding of the excavation, at elevation 905. However, the discontinuation of the excavation at elevation 905 will delay the construction of the Reactor Building. Therefore, in order to attain the final grades in the Reactor Building and Turbine Generator Building areas in fall of 1966, certain procedures will be required to restrict swelling of the exposed silty clay layer. We have evaluated the problems associated with exposing the silty clay and it is our opinion that one of the following three methods should be considered to restrict the swelling of the exposed silty clay layer along the common boundary between these buildings:

1 - A temporary berm fill, approximately ten feet in height, could be placed on top of the exposed silty clay layer along the common boundary subsequent to the completion of the earthwork operations and prior to flooding the excavation during the winter months. This temporary berm will provide the minimum recommended confining pressure and could be removed in the spring of 1967, after the excavation is dewatered.

2 - A continuous dewatering operation can be maintained subsequent to the completion of the earthwork operations throughout the winter months and until the substructures are completed. The continuous dewatering operation would remove the water source and thereby prevent swelling.

3 - The silty clay layer could be entirely removed from under the Turbine Generator Building and replaced with compacted granular fill.

We have discussed the earthwork operations with a representative of the Griffin Well Point Corporation. It was his opinion that a two stage dewatering system will be required for the Reactor Building in order to complete the earthwork operations in this area. We were informed that the lower level of well points could be installed along the bank of the excavation near the common boundary between the Reactor Building and the Turbine Building and that these well points could be buried within the berm fill. The lower well point system could be shut-off subsequent to the placement of the berm fill, allowing the excavation to be flooded, and then re-started during spring 1967 to dewater the Reactor Building area.

Preliminary cost data regarding the operation of the well point system should it be continually operated, or discontinued over the winter months, were provided to us by the Griffin Well Point Corporation representative. These cost data are presented below:

Operation of well point system during the winter months ....$13,000 Per Month

Dismantling of pumps, and discontinuation of dewatering during the winter, with well points being left in place .... $1,000 Per Month

We trust that this supplement provides you with the information required at this time. It is requested that this supplement be bound with our report of foundation investigation and our previous supplements and become a part thereof.

Yours very truly,

DAMES & MOORE

George D. Leal

George D. Leal

GDL:WGP:mf
20 Copies Submitted

August 16, 1966

Bechtel Corporation
P.O. Box 3965
San Francisco, California 94119

Attention: Mr. G. L. Parkinson,
Project Engineer

Gentlemen:

Second Supplement
Report of Foundation Investigation
Proposed Nuclear Power Plant-Unit Number 1
Monticello, Minnesota
For the Northern States Power Company

This letter presents information supplementary to that presented in our Report of Foundation Investigation dated July 27, 1966, and our Supplement dated August 5, 1966.

We have evaluated the ultimate bearing capacity of the bearing materials which will support the various major units of the Proposed Nuclear Power Plant. The following bearing capacities can be developed for mat foundations of the dimensions indicated below, provided that installation of foundations is accomplished in accordance with the recommendations presented in our report and supplement:

UNIT	FOUNDATION DIMENSIONS, FEET X FEET	FOUNDATION ELEVATION, FEET	ULTIMATE BEARING CAPACITY LBS./SQ.FT.
Reactor Building	138 X 138	890	50,000*
Turbine Building	110 X 238	905	30,000
Intake Structure	80 X 90	893	30,000

* Assumes that stiff to hard clay underlying the foundation will be removed and replaced with granular fill material compacted to 100 percent of maximum density as determined by the American Association of State Highway Officials Test Designation T 180-57.

The above bearing capacities are ultimate values and suitable factors of safety should be applied. It is our opinion that a factor of safety of 3 is satisfactory for dead plus live loads, and that a factor of safety on the order of 2.5 is satisfactory for dead, live and seismic loads. Settlement limitations may impose more severe restrictions on the choice of a suitable bearing capacity for the various structures.

We trust that this supplement provides the information you require at this time. It is requested that this supplement be bound with our Report of Foundation Investigation and previous supplement and become a part thereof.

Yours very truly,

DAMES & MOORE

George D Leal

George D. Leal

GDL:mf
Twenty Copies Submitted

309 WEST JACKSON BOULEVARD • CHICAGO, ILLINOIS 60606 • 312-
PARTNERS: JAMES D. THOMPSON • GEORGE D. LEAL

August 5, 1966

Bechtel Corporation
P. O. Box 3965
San Francisco, California 94119

Attention: Mr. G. L. Parkinson,
Project Engineer

Gentlemen:

Supplement
Report of Foundation Investigation
Proposed Nuclear Power Plant - Unit Number 1
Monticello, Minnesota
For the Northern States Power Company

INTRODUCTION:

This letter report presents data supplementary to that presented in our "Report of Foundation Investigation, Proposed Nuclear Power Plant - Unit Number 1, Monticello, Minnesota, For the Northern States Power Company" submitted on July 27, 1966. We understand that the Reactor Building may be deepened and that the base of the mat foundation for this building may be established at elevation 890. Recommendations presented in subsequent sections of this report will consider that the bottom of the mat foundation will be established at elevation 890.

PROPOSED REACTOR BUILDING:

Foundation Design Data - It is our opinion that the Proposed Reactor Building may be earth supported on a mat-type foundation established at elevation 890 provided that the variable thickness stiff to hard silty clay layer which would be present below the mat foundation is excavated and replaced with compacted granular fill. Should the silty clay layer be left in-place, the mat foundation for the Reactor Building would settle non-uniformly. The upper surface of the silty clay layer presently ranges from approximately elevation 889 to 895 and the lower surface ranges from elevation 884 to 889. Therefore, approximately six feet of over-excavation will be required. If the silty clay layer is removed and replaced with compacted granular fill, it is our opinion that the soils and rock which will underlie the Reactor Building can safely support a mat foundation imposing pressures of 8,500 pounds per square foot.

Additional earthwork operations which will be required below elevation 890 will include the excavating of in-place soils and the placement of compacted granular fill material. In order to remove all the silty clay, excavations will extend to approximately elevation 884. We recommend that the entire area beneath the Reactor Building be excavated to elevation 884. Excavations extending below elevation 890 will penetrate the silty clay layer along the east, west and south sides of the Reactor Building and will penetrate silty clay, sands and silt-sand mixtures along the north side of the building. We recommend that the banks of the excavations which extend below elevation 890 be constructed on a slope of one and one-half vertical to one horizonal. We further recommend that the toe of the slope, at elevation 884, be constructed approximately five feet from the outer edge of the proposed mat foundation.

Dewatering by a well-point system will be required to accomplish the excavation to elevation 884. Dewatering procedures discussed in our original report will be applicable for the deeper excavation.

The clean granular soils obtained from the major excavating operation above elevation 890 may be utilized as fill material in the overexcavated area between elevations 884 and 890. All fill placed below the Reactor Building should be compacted to a dry density of at least 100 percent of the maximum dry density as [illegible] by the American Association of Highway Officials T180-57 Method of [illegible]. The fill material should be placed in the dry and in lifts approximately six to eight inches in loose thickness and each lift should be uniformly compacted in accordance with the above recommended criteria.

Settlement analyses have been performed assuming that the Proposed Reactor Building will be earth supported on a mat foundation established at elevation 890 and will be immediately underlain by compacted granular fill. The Reactor Building will impose a dead plus live load pressure of 6,500 pounds per square foot on the underlying soils. We do not anticipate that the foundation pressures from the Turbine Generator Building will significantly influence the settlement of the Reactor Building. Our engineering analyses indicate that the earth supported mat foundation will undergo essentially a uniform total settlement on the order of one-eighth of an inch or less. The Reactor Building will be essentially underlain by granular soils which will consolidate during the initial application of the load. During earthquake loading, we anticipate negligible additional settlement.

The lowering of the Reactor Building foundation from the previously planned elevation 898 to the presently planned elevation 890 will reduce the influence of the foundation pressures of this building on the settlement behavior of the adjacent Turbine Generator Building. It is estimated that the Turbine Generator Building established at elevation 905 on an earth supported mat foundation imposing a dead plus live load of 3,500 pounds per square foot on the underlying soil wil undergo an essentially uniform total settlement on the order of one-quarter inch or less. During earthquake loading, we estimate that an additional settlement on the order of one-sixteenth of an inch or less could occur due to consolidation of the granular soils which underlie the mat foundation. The earthquake loading will be of such short duration that no consolidation of the silty clay layer is anticipated.

The north wall of the Reactor Building will be subjected to the horizontal components of the adjacent Turbine Generator foundation load plus the lateral pressures due to fill and water. We present on Plate 1 the magnitude and distribution of the horizontal components of the foundation load of the Turbine Generator Building plus the lateral pressures due to fill and water.

RESULTS OF CONSOLIDATION TESTS:

Several consolidation tests were performed on representative undisturbed samples of the various foundation soils which will underlie the proposed structures. At the time of submission of our original report, the consolidation tests had not been completed. These tests have since been completed, and we present on Plates 2, 3 and 4 the results of the consolidation tests. These tests were performed in accordance with the method described on Plate 6, Method of Performing Consolidation Tests. Additional descriptions of the procedures used are presented on Plates 2, 3 and 4.

In order to evaluate the swell characteristics of the stiff to hard silty clay, we performed loading tests to approximate the field conditions which will be imposed on the silty clay layer. The results of these loading tests are presented on Plate 4.

POSSIBLE WELL LOCATION:

It has been requested that we comment on possible locations for water wells to be installed within the plant area. The ground water gradient in the vicinity is relatively flat, shallow ground water moves generally toward the Mississippi River in the immediate vicinity of the proposed plant, and deep ground water moves broadly toward the southeast in the river sediments overlying the site.

Ground water in the vicinity of the plant may be developed from either the Mississippi River sediments, predominantly sand with gravel, or from the underlying sandstone formation. Wells penetrating either of these aquifers will cause localized cone-shaped depressions in the ground water table. It is anticipated that the area in the immediate vicinity of these wells may undergo some surface subsidence due to the increase in intergranular soil stress caused by the lowering of the water table. The depressed water table will also cause a localized ground water gradient toward the wells.

Because the ground water gradient will be directed toward the wells, the wells should be located a sufficient distance from the plant structures such that local subsidence will not affect plant operations and, if accidental spillage of effluents occurs at the plant, the effluents would follow the natural ground water gradient rather than flowing toward the wells.

In view of the above, we suggest that plant water wells be installed a substantial distance upstream from the plant structures. It is recommended that a test well be installed upstream from the plant to determine draw-down characteristics, and to evaluate water quality and yield potential of the well.

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The following Plates are attached and complete this supplement:

Plate 1 - Lateral Pressure Design Data

Plate 2 - Consolidation Test Data

Plate 3 - Consolidation Test Data

Plate 4 - Consolidation Test Data

Plate 5 - Consolidation Test Data

Plate 6 - Method of Performing Consolidation Tests

Respectfully submitted,

DAMES & MOORE

William G. Paratore

William G. Paratore
Project Manager

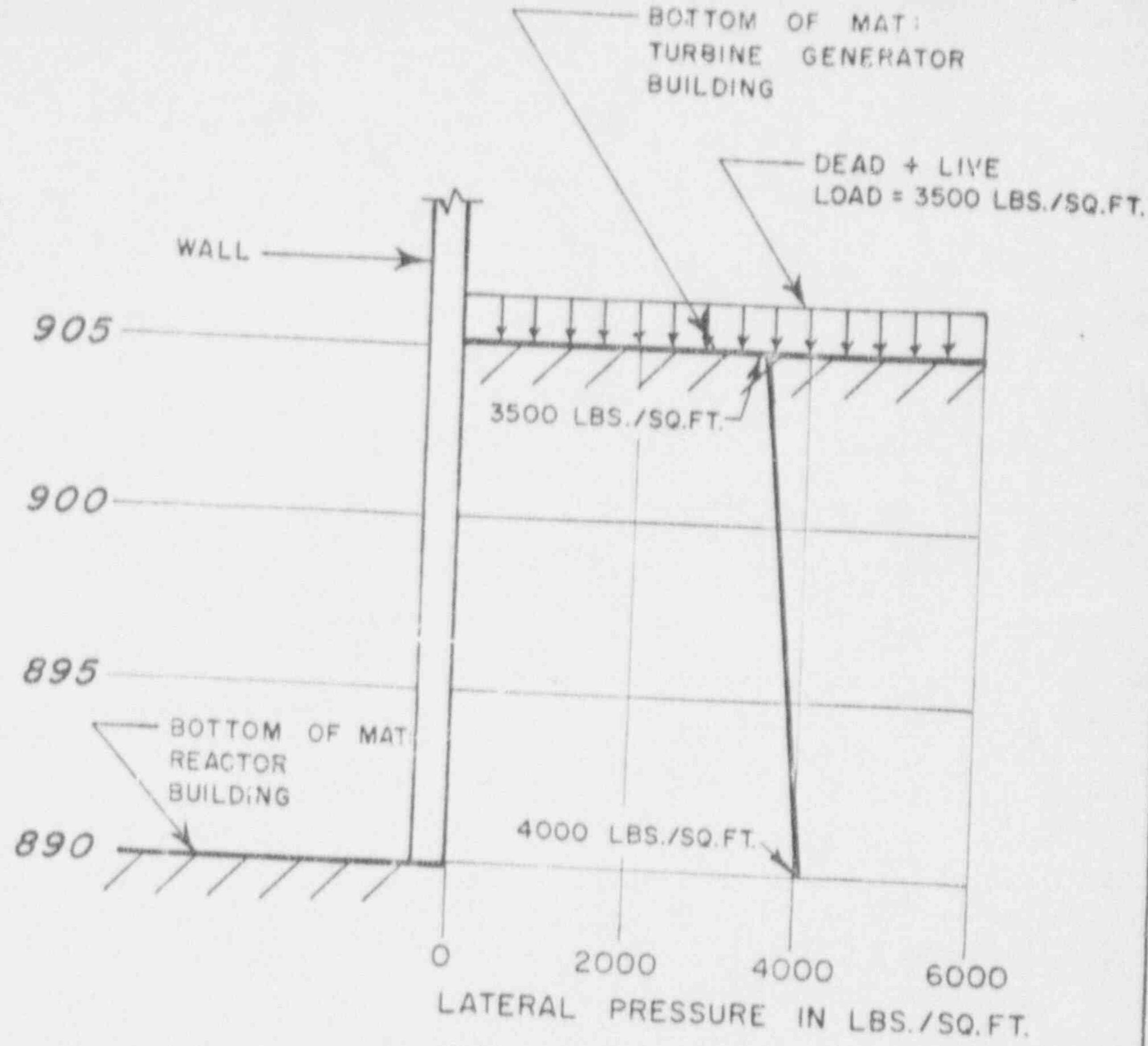
I hereby certify that this supplementary report was prepared under my direct supervision and that I am a duly registered professional engineer under the laws of the State of Minnesota. It is requested that this report be bound with and become a part of our Report of Foundation Investigation dated July 27, 1966.

George D Leal

George D. Leal
Registration Number 8131
August 5, 1966

GDL:WGP:dh

20 copies submitted



NOTES:

1) ELEVATIONS REFER TO MEAN SEA LEVEL DATUM.

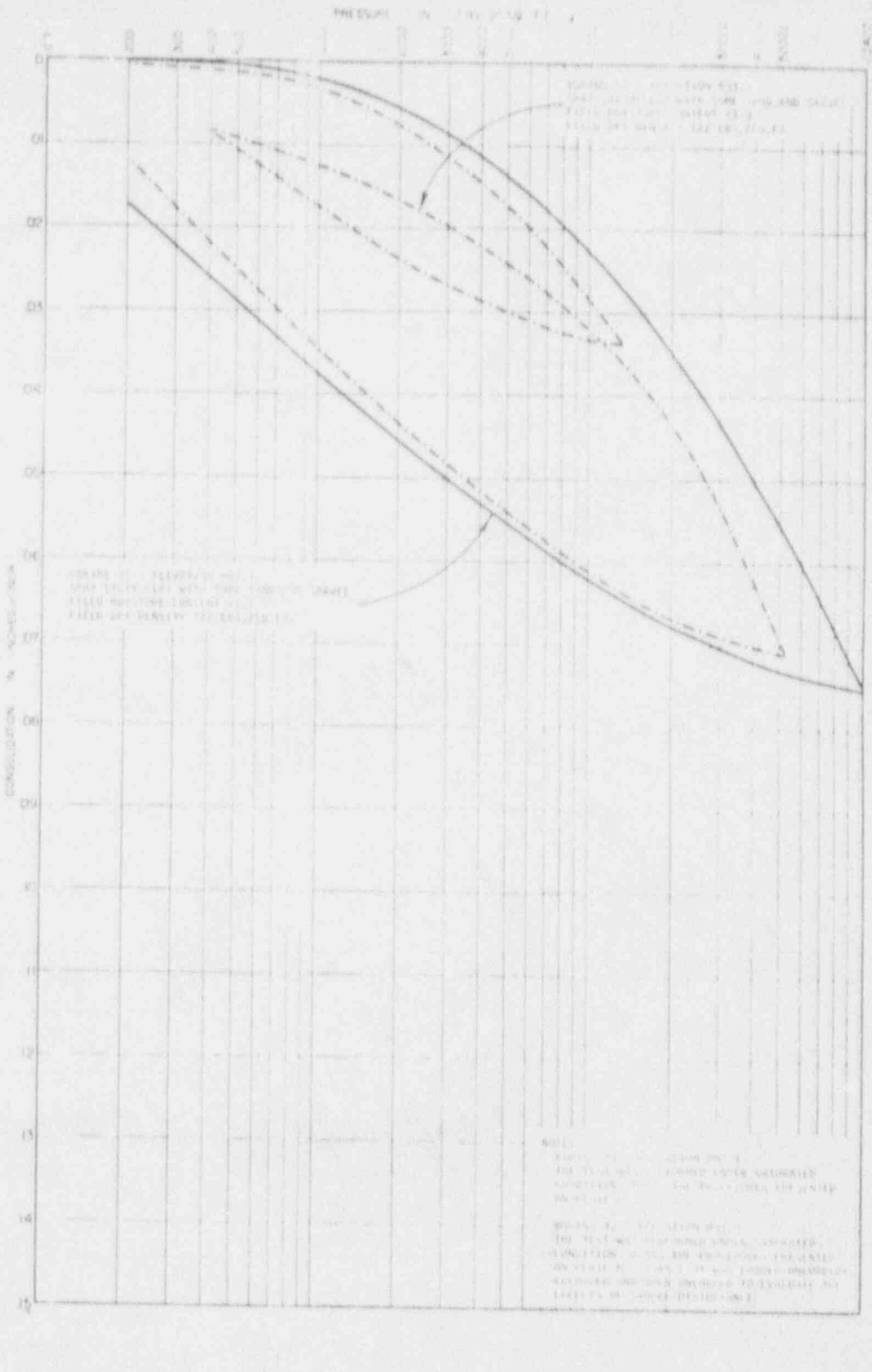
2) LATERAL PRESSURES SHOWN ABOVE ARE THE SUM OF THE PRESSURES DUE TO SOIL, WATER AND THE DEAD AND LIVE LOADS IMPOSED BY THE TURBINE GENERATOR BUILDING.

LATERAL PRESSURE DESIGN DATA
FOR NORTH WALL OF REACTOR BUILDING

REVISIONS BY ____ DATE ____

BY ____ DATE ____ CHECKED BY ____ FILE ____

DAMES & MOORE



CONSOLIDATION TEST DATA

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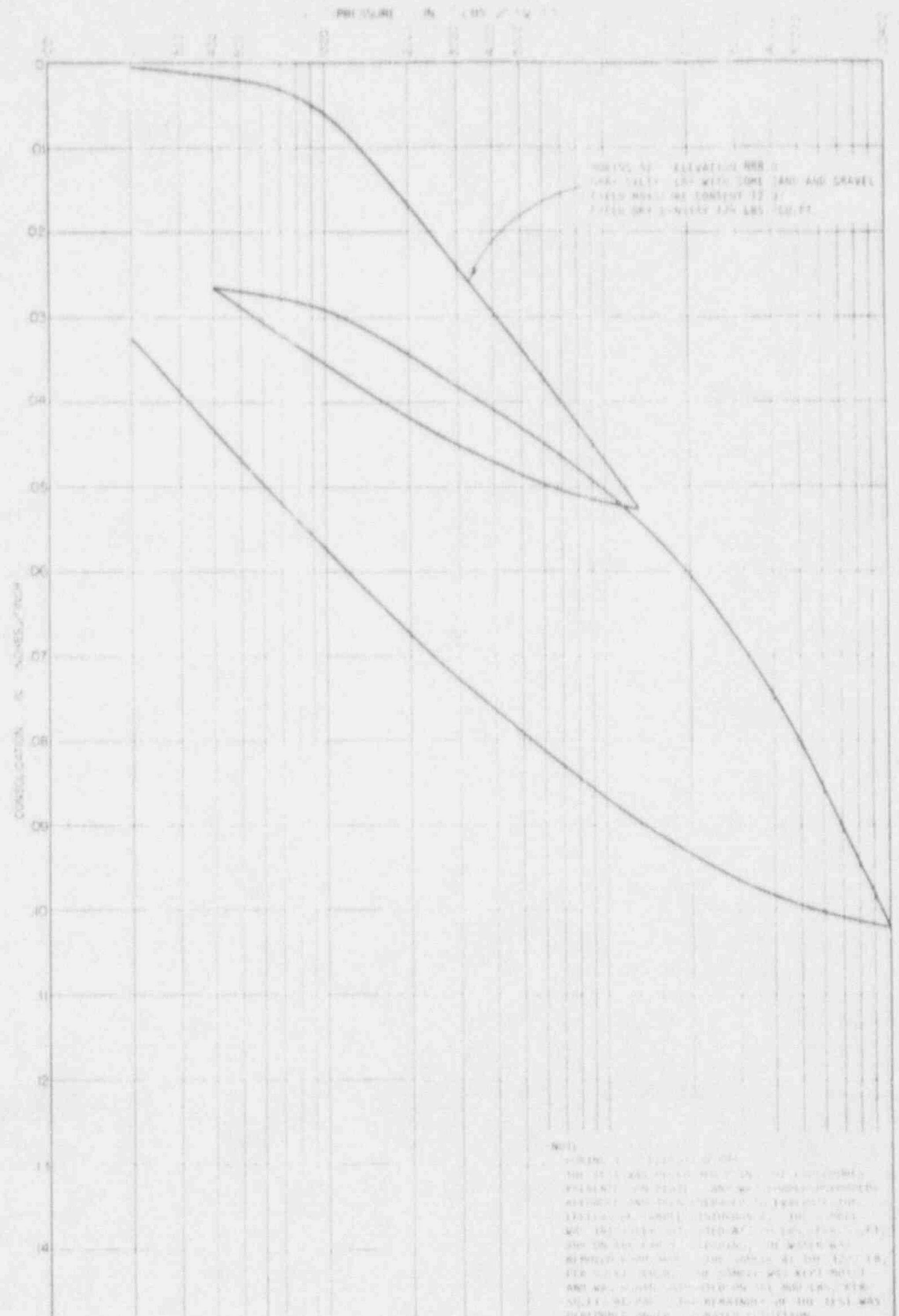
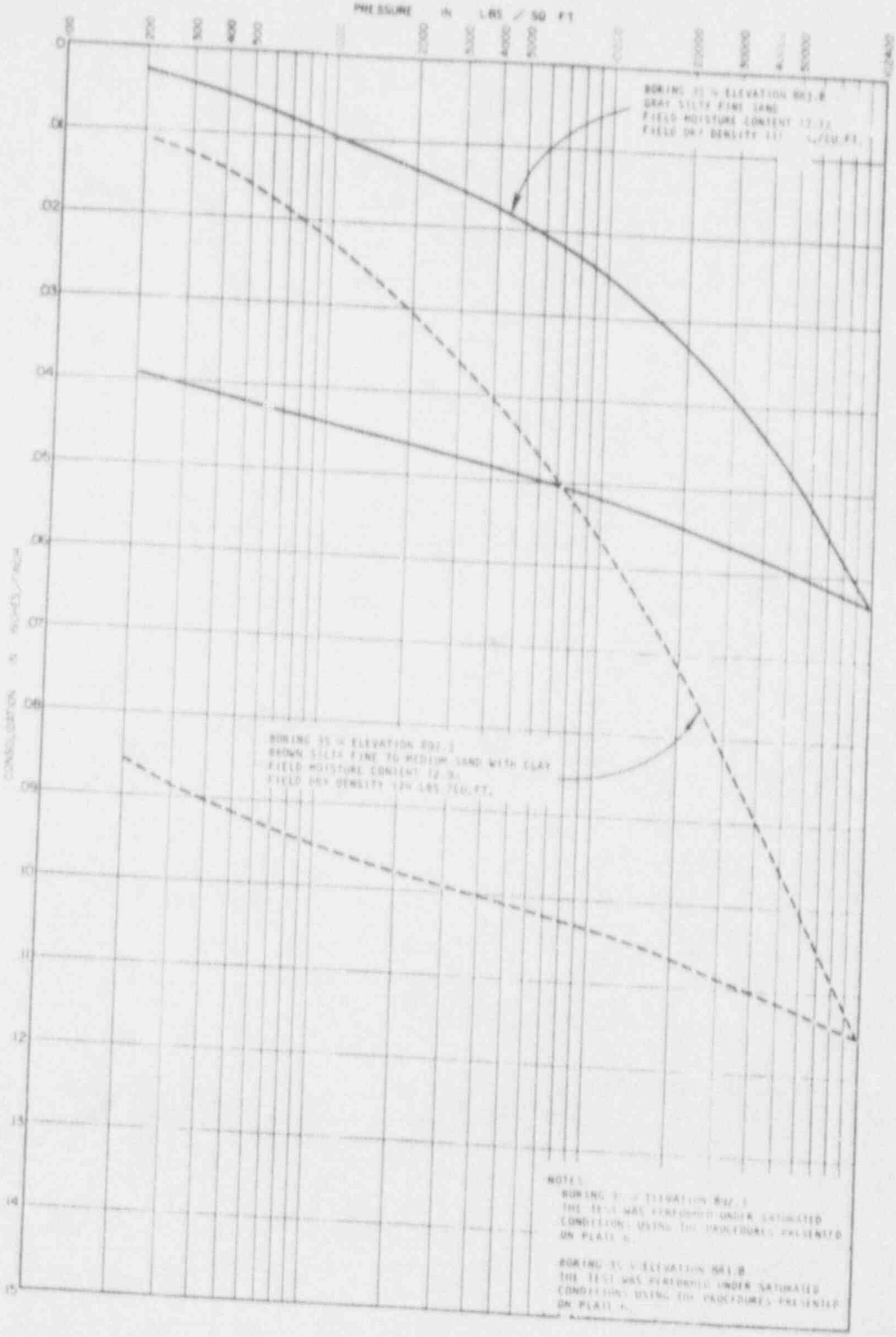


CONSOLIDATION TEST DATA

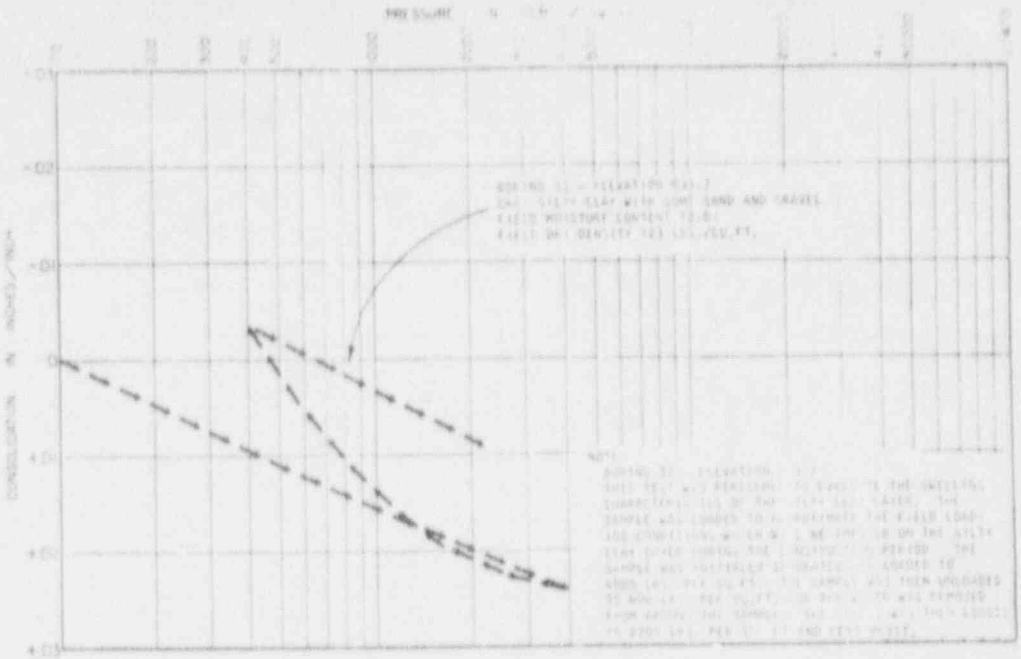
DAMES & MOORE

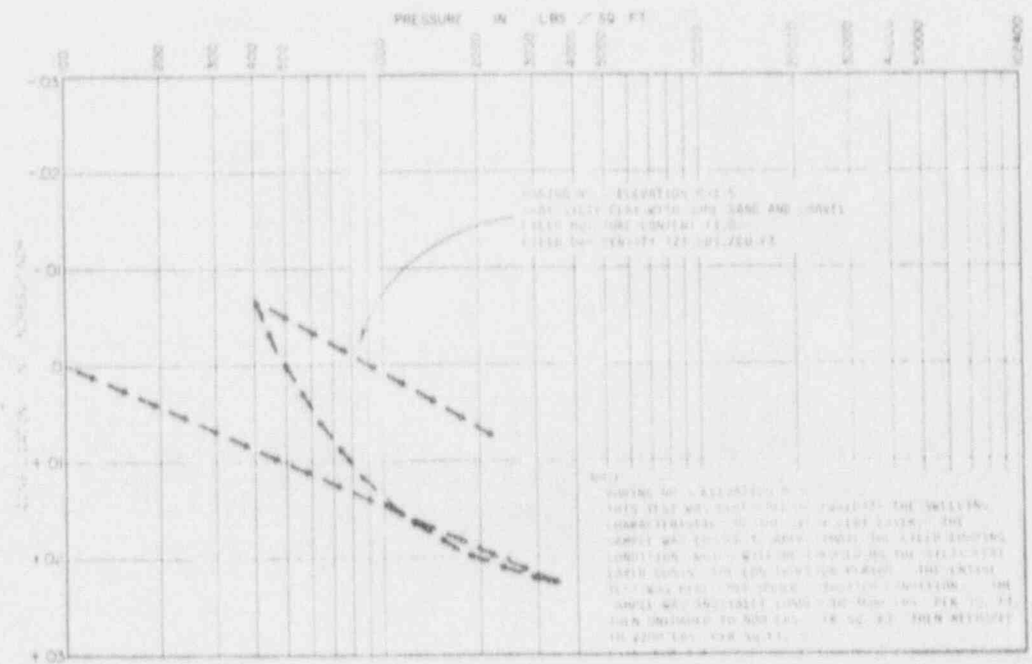
PLATE 3



CONSOLIDATION TEST DATA

DAMES & MOORE





CONSOLIDATION TEST DATA

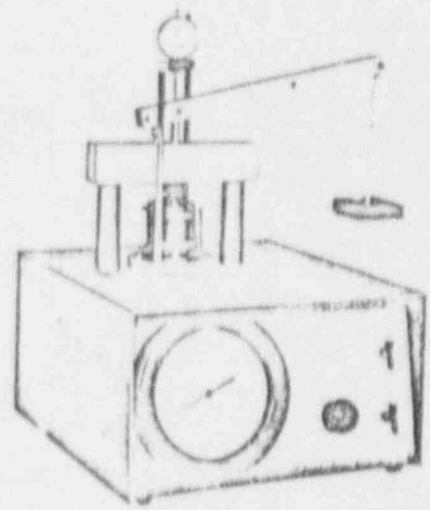
DAMES & MOORE

REVISIONS BY ______ DATE ______

METHOD OF PERFORMING CONSOLIDATION TESTS

CONSOLIDATION TESTS ARE PERFORMED TO EVALUATE THE VOLUME CHANGES OF SOILS SUBJECTED TO INCREASED LOADS. TIME-CONSOLIDATION AND PRESSURE-CONSOLIDATION CURVES MAY BE PLOTTED FROM THE DATA OBTAINED IN THE TESTS. ENGINEERING ANALYSES BASED ON THESE CURVES PERMIT ESTIMATES TO BE MADE OF THE PROBABLE MAGNITUDE AND RATE OF SETTLEMENT OF THE TESTED SOILS UNDER APPLIED LOADS.

EACH SAMPLE IS TESTED WITHIN BRASS RINGS TWO AND ONE-HALF INCHES IN DIAMETER AND ONE INCH IN LENGTH. UNDISTURBED SAMPLES OF IN-PLACE SOILS ARE TESTED IN RINGS TAKEN FROM THE SAMPLING DEVICE IN WHICH THE SAMPLES WERE OBTAINED. LOOSE SAMPLES OF SOILS TO BE USED IN CONSTRUCTING EARTH FILLS ARE COMPACTED IN RINGS TO PREDETERMINED CONDITIONS AND TESTED.



DEAD LOAD-PNEUMATIC CONSOLIDOMETER

IN TESTING, THE SAMPLE IS RIGIDLY CONFINED LATERALLY BY THE BRASS RING. AXIAL LOADS ARE TRANSMITTED TO THE ENDS OF THE SAMPLE BY POROUS DISKS. THE DISKS ALLOW DRAINAGE OF THE LOADED SAMPLE. THE AXIAL COMPRESSION OR EXPANSION OF THE SAMPLE IS MEASURED BY A MICROMETER DIAL INDICATOR AT APPROPRIATE TIME INTERVALS AFTER EACH LOAD INCREMENT IS APPLIED. EACH LOAD IS ORDINARILY TWICE THE PRECEDING LOAD. THE INCREMENTS ARE SELECTED TO OBTAIN CONSOLIDATION DATA REPRESENTING THE FIELD LOADING CONDITIONS FOR WHICH THE TEST IS BEING PERFORMED. EACH LOAD INCREMENT IS ALLOWED TO ACT OVER AN INTERVAL OF TIME DEPENDENT ON THE TYPE AND EXTENT OF THE SOIL IN THE FIELD.

CHECKED BY ______ FILE ______

DAMES & MOORE

REPORT OF FOUNDATION INVESTIGATION

PROPOSED NUCLEAR POWER PLANT - UNIT NUMBER 1
MONTICELLO, MINNESOTA

FOR THE

NORTHERN STATES POWER COMPANY

REPORT OF DOCKET NO. 50-263

SITE ENVIRONMENTAL STUDIES
PROPOSED NUCLEAR POWER PLANT (Suppl Only)
ELLO, MINNESOTA

FC THE Regulaory Docket File Copy

NORTHERN STATES POWER COMPANY

Received w/Ltr Dated 2-6-67

See Rpt

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APPENDICES