LICENSE AMENDMENT REQUEST DATED January 29, 1997

Amendment of Cooling Water System Emergency Intake Design Bases

EXHIBIT B

Appendix A, Technical Specification Pages
Marked Up Pages
(shaded material to be added, strikethrough material to be removed)

B 3.3-4

3.3 ENGINEERED SAFETY FEATURES

Bases continued

The Safeguards Traveling Screens and Emergency **Intake**~~Cooling Water Supply~~ ~~L~~line are designed to provide a supply of screened cooling water **to the safeguards bay** in the event **of**~~that~~ an earthquake**. The earthquake is postulated to**~~1)~~ destroy~~s~~ **Lock and** Dam No. 3 ~~(dropping the water level in the normal canal to the screenhouse) and 2) causes the banks bordering the normal canal to the screenhouse to collapse eliminating the river as a source of cooling water~~. **River level decreases over time, making the normal supply unavailable.** The Safeguards Traveling Screens and Emergency Cooling Water Supply line provide an alternate supply of water to the Safeguards Bay, which contains the two diesel driven and the one vertical motor driven cooling water pumps. Their normal supply is from the Circ Water Bay thru one of two sluice gates. Either one of the two sluice gates or one of the two Safeguards Traveling Screens will adequately supply any of the three cooling water pumps. The Safeguards Traveling Screens are not considered part of the "engineered safety features associated with the operable diesel-driven cooling water pump" for determination of operability of diesel-driven cooling water pumps.

The component cooling water system and the cooling water system provide water for cooling components used in normal operation, such as turbine generator components, and reactor auxiliary components in addition to supplying water for accident functions. These systems are designed to automatically provide two separate redundant paths in each system following an accident. Each redundant path is capable of cooling required components in the unit having the accident and in the operating unit.

There are several manual valves and manually-controlled motor-operated valves in the engineered safety feature systems that could, if one valve is improperly positioned, prevent the required injection of emergency coolant (Reference 7). These valves are used only when the reactor is subcritical and there is adequate time for actuation by the reactor operator. To ensure that the manual valve alignment is appropriate for safety injection during power operation, these valves are tagged and the valve position will be changed only under direct administrative control. For the motor-operated valves, the motor control center supply breaker is physically locked in the open position to ensure that a single failure in the actuation circuit or power supply would not move the valve.

References

1. USAR, Section 3.3.2
2. USAR, Section 14.6.1
3. USAR, Section 6.3.2
4. USAR, Section 6.3
5. USAR, Section 10.4.2
6. USAR, Section 10.4.1
7. USAR, Figure 6.2-1
USAR, Figure 6.2-2
USAR, Figure 6.2-5
USAR, Figure 10.2-11

LICENSE AMENDMENT REQUEST DATED January 29, 1997

Amendment of Cooling Water System Emergency Intake Design Bases

EXHIBIT C

Appendix A, Technical Specification Pages
Revised Pages

B 3.3-4

3.3 ENGINEERED SAFETY FEATURES

Bases continued

The Safeguards Traveling Screens and Emergency Intake Line are designed to provide a supply of screened cooling water to the safeguards bay in the event of an earthquake. The earthquake is postulated to destroy Lock and Dam No. 3. River level decreases over time, making the normal supply unavailable. The Safeguards Traveling Screens and Emergency Cooling Water Supply line provide an alternate supply of water to the Safeguards Bay, which contains the two diesel driven and the one vertical motor driven cooling water pumps. Their normal supply is from the Circ Water Bay thru one of two sluice gates. Either one of the two sluice gates or one of the two Safeguards Traveling Screens will adequately supply any of the three cooling water pumps. The Safeguards Traveling Screens are not considered part of the "engineered safety features associated with the operable diesel-driven cooling water pump" for determination of operability of diesel-driven cooling water pumps.

The component cooling water system and the cooling water system provide water for cooling components used in normal operation, such as turbine generator components, and reactor auxiliary components in addition to supplying water for accident functions. These systems are designed to automatically provide two separate redundant paths in each system following an accident. Each redundant path is capable of cooling required components in the unit having the accident and in the operating unit.

There are several manual valves and manually-controlled motor-operated valves in the engineered safety feature systems that could, if one valve is improperly positioned, prevent the required injection of emergency coolant (Reference 7). These valves are used only when the reactor is subcritical and there is adequate time for actuation by the reactor operator. To ensure that the manual valve alignment is appropriate for safety injection during power operation, these valves are tagged and the valve position will be changed only under direct administrative control. For the motor-operated valves, the motor control center supply breaker is physically locked in the open position to ensure that a single failure in the actuation circuit or power supply would not move the valve.

References

1. USAR, Section 3.3.2
2. USAR, Section 14.6.1
3. USAR, Section 6.3.2
4. USAR, Section 6.3
5. USAR, Section 10.4.2
6. USAR, Section 10.4.1
7. USAR, Figure 6.2-1

USAR, Figure 6.2-2
USAR, Figure 6.2-5
USAR, Figure 10.2-11

LICENSE AMENDMENT REQUEST DATED January 29, 1997

Amendment of Cooling Water System Emergency Intake Design Bases

EXHIBIT D

Updated Safety Analysis Report
Marked Up Pages
(underlined material to be added, strikethrough material to be removed)

USAR 10.4-5
USAR 10.4-6
USAR 10.4-7
USAR 10.4-8
USAR Table 12.2-1 Page 10 of 12

Cooling water is available at the auxiliary feedwater pump that functions as the secondary source of auxiliary feedwater.

A minimum flow of cooling water is furnished to the turbine generators to prevent wiping of bearings and consequent damage during coast-down of the turbines. This source of water may be manually isolated.

The cooling water system also provides water for safeguards-related equipment such as pump oil coolers, pump gland seals, fan-coil units, and the control room air-conditioning chillers.

Because the cooling water pumps are diesel driven, water is available for all services at the time required by the equipment served. If auxiliary power is available, the normal cooling water pumps continue to operate. Only one cooling water pump is required for the safe shutdown of both units (accident in only one unit). Nonessential services are automatically isolated. (Manual isolation of the generator hydrogen cooler control valve bypass cooling 95115
water flow has been justified in Safety Evaluation 389 Add 1 Rev 1 for short durations.) Since the cooling water system is in operation at all times it is in a high state of readiness and available for normal or emergency types of operations.

In the event of a loss of offsite power, the loss of the motor driven pumps result in lowering discharge header pressure. When the low pressure setpoint is reached, the associated diesel driven pump for the pressure switch starts and will provide adequate cooling to the 93-01 94003
assiciated Unit 1 diesel generator and other cooling system loads. One diesel driven pump is sufficient to meet all the cooling system loads of both units.

10.4.1.2.1 Auxiliary Building and Containment Chilled Water System

A common non-safety related chilled water system was added for both units 1 and 2. The system provides chilled water during normal plant operation for the containment atmosphere recirculation coolers and the control rod drive mechanism shroud cooling coils, as well as for the new and existing unit coolers located within the auxiliary building. The chilled water system was integrated with the cooling water system. The combined system provides chilled water during normal plant operation but upon loss of power or safety signal actuation, the system will return to its original design integrity and configuration by isolating the chilled water system from the cooling water equipment.

10.4.1.2.2 Emergency Cooling Water Intake

The Emergency Cooling Water Intake provides water to maintain safe shutdown for both units ~~for reactor shutdown cooling~~ after a Design ~~Operational~~ Basis Earthquake.~~, assuming that the Circulating Water Intake Canal is blocked and Lock and Dam No. 3 downstream of the plant is destroyed.~~ This intake is a 36-in. pipe buried approximately 40 feet below the Circulating Water Intake Canal water level in nonliquefiable soil, connecting the screenwell to a submerged intake crib in a branch channel of the Mississippi River. This Emergency Cooling Water Intake is a Class I structure as is the Approach canal which supplies its intake crib from the main channel of the Mississippi. The intake crib is designed to exclude trash, and means are provided for back flushing. This emergency intake supplies a bay in the screenwell which has Class I traveling screens and which provides suction for the Class I cooling water pumps. ~~The emergency cooling water intake line has been designed to deliver no less than 18,000 gpm with a crib submergence of no more than 4.5 feet caused by the failure of Lock and Dam No. 3. Specific hydraulic analysis has shown that with the expected lowest river level, the 36I intake line should be capable of delivering at least 22,500 gpm, and with the Lock and Dam No. 3 intact, could deliver at least 30,000 gpm. The design criteria for Class I structures and equipment are described in Section 12.~~ 88-002

To maintain both units in safe shutdown, the safeguards cooling water pumps must provide sufficient flow to remove heat from the required components. The supply to the safeguards pumps' suction must be greater than or equal to that demand. In the event of a design basis seismic event, non-seismic qualified components cannot be relied upon to maintain safe shutdown. The effect on the cooling water system is that only the safeguards pumps are available, off-site power is lost, and the instrument air system is not available. Since many control valves fail to the open position upon loss of air or control power, the flow demand in the cooling water increases. If two safeguards cooling water pumps are operating, the cooling water system demand will exceed the supply capacity of the emergency intake line.

At the onset of the seismic event, the emergency intake line and the intake canal both supply the suction of the safeguards pumps. The design basis seismic event assumes that Lock & Dam No. 3 is destroyed by the seismic event. Failure of the Lock & Dam No. 3 causes the upstream and downstream pools to equalize. Over time the upstream pool level is postulated to decrease to 666'-6", the normal level of the downstream pool. This provides 4.5 feet of submergence above the emergency intake line. Original design calculations predict a minimum supply capacity of 18,000 gpm. However, preoperational testing, when extrapolated for minimum submergence, demonstrated that only 15,000 gpm is actually available.

Upon occurrence of the design basis seismic event, the cooling water system flow demand is calculated to be 29,759 gpm (calculation ENG-ME-302). This is with the two diesel driven safeguards cooling water pumps operating, since this creates the highest demand on the suction supply. Initially, the supply to the safeguards cooling water pumps is from both the intake canal and the emergency intake line. The intake canal has been evaluated and determined to remain intact during a design basis seismic event (ENG-CS-100). The volume in the intake canal provides approximately 25 minutes per foot of water depth for a cooling water flow demand of 29,759 gpm.

Assuming no make up from the river to the intake canal, the volume in the intake canal is depleted in approximately 3 1/2 hours. At this time, the emergency intake line will be the sole supply of water to the cooling water pumps. It is necessary for the operators to reduce the cooling water system flow demand to a value within the capacity of the emergency intake line. Procedural guidance directs the operator which cooling water system loads to secure to reduce demand. Instrumentation provides the operator with cooling water header flow and pressure. The procedure ensures components needed to maintain safe shutdown are available.

The basic design intent for the emergency pipe was to provide enough flexibility in the system to withstand earthquakes. This was accomplished by introducing four flexonics expansion joints, two near the screenhouse and the other two in the pipe riser at the intake crib. The articulation provided by the joints is expected to act in a fashion similar to paired flexible joints in steam lines.

In order for the emergency intake pipe to behave elastically, as intended, the portion of the pipe embedded in the screenhouse was wrapped with rodoform to alleviate localized stresses due to the settlement of the soil. Special backfill material was placed around the pipe to prevent liquification of the soil which would result in flotation of the pipe. All natural material has been replaced by nonliquifiable backfill materials up to the liquefaction level in accordance with the recommendations of Dames & Moore.

The design of the 36" emergency intake pipe and the approach canal are based upon recommendations by earthquake consultants J. A. Blume & Associates and Dame & Moore. Professor H. Bolton Seed of the University of California at Berkeley, in his letter dated June 3, 1970 to Mr. Garrison Kost of John A. Blume & Associates in San Francisco, stipulates the following minimum criteria to insure that the emergency service water intake pipe at Prairie Island would not be disrupted by displacements due to soil liquefaction:

a. "The slope of any liquefiable material should not exceed about 1 degree.

b. The pipe line should be supported or protected against settlement or uplift due to liquefaction of the underlying soils.

c. The pipe should be located at least 25 times the height of any bank beyond the toe of the bank in order to protect it from lateral forces due to movement of liquefied soil."

Professor Seed then proceeds to make the following specific recommendations: It will be possible to design:

a. "A section near the plant where the pipe would be placed in non-liquefiable soils.

b. A section to be stabilized against liquefaction by densification and in which the pipe would be brought up to a higher elevation, and

c. A section designed in accordance with the criteria listed above so that the pipe would not be disrupted even if the underlying and adjacent soil should liquefy."

The ~~PS&E~~ design of the 36" emergency intake pipe and the approach canal applies t~~o all of the three criteria outlined above and utilizes the first and third of Dr. Seeds specific~~

~~recommendations. The specific recommendations were applied in the following manner:~~ the following criteria:

Near the screenhouse, where the pipe line is above the liquefiable horizon, ~~we have removed~~ all liquefiable material around the pipe was removed and replaced ~~it~~ by non-liquefiable material.

The east-west run of the emergency intake pipe has been placed below the horizon of the liquefiable soil. Trench backfill materials are non- liquefiable up to the horizon of liquefaction.

At the intake, where the pipe line rises vertically through potentially liquefiable strata, we have provided secure anchorage of the intake crib by piling into the non-liquefiable strata. In order to protect the riser pipe itself, we have designed a considerable degree of flexibility into the riser by installing two Flexonics joints which are capable of swivelling 6° in any direction.

The intake crib is located in a 575 ft. wide intake canal, which has been sized by applying a 25 to 1 slough angle. The bottom of the canal has been kept flat.

In accordance with the explanation and criteria set forth by Dr. Seed, lateral movements of liquefied soil layers are not expected in the intake area, nor do we expect a covering of the intake itself, because the intake crib is located in a 575 ft. wide intake canal which has been sized by applying the 25 to 1 slough angle cited by Dr. Seed. The bottom of the canal has been kept flat.

The bed of the branch channel of the Mississippi River in which the emergency intake crib is located has been backfilled to Elevation 560 in order to minimize any potential gradients which might cause a flow of liquefied materials. The slough angle of 25 to 1 has again been observed at the underwater bank which rises from Elevation 560 to Elevation 564.5.

The non-compacted, non-liquefiable backfill has been designed and specified according to recommendations by John Blume Associates, according to which the sieve analysis is:

70% passing 0.742 in. screen opening
36% - 50% passing #4 screen,
10% passing #10 screen.

The material used for the non-liquefiable backfill closely approximates that recommendation.

TABLE 12.2-1 CLASSIFICATION OF STRUCTURES, SYSTEMS AND COMPONENTS

Item	Class
Classification of Systems and Components (Continued)	
Turbine Plant	
Turbine, Generator, Foundation, Exciter, Oil Purification, Turbine Gland Seal System, Reheaters and Moisture Separators, Generator Cooling Water System, Hydrogen and CO_2 Systems	III
Cooling Water System	
Up to Class I System Isolation Valves	I
All that is not Class I	III
Circulating Water System	
Emergency Cooling Water Intake	I
Approach Canal	I
Circulating Water Pumping Equipment	III
Intake Canal	~~III~~ I*
Circulating Water Pump Discharge Piping	III
Condenser Discharge Piping	III
Intake and Discharge Equipment	III
Cooling Towers and Pumping Equipment	III

LICENSE AMENDMENT REQUEST DATED January 29, 1997

<u>Amendment of Cooling Water System Emergency Intake Design Bases</u>

EXHIBIT E

Updated Safety Analysis Report
Revised Pages

USAR 10.4-5
USAR 10.4-6
USAR 10.4-7
USAR 10.4-8
USAR Table 12.2-1 Page 10 of 12

Cooling water is available at the auxiliary feedwater pump that functions as the secondary source of auxiliary feedwater.

A minimum flow of cooling water is furnished to the turbine generators to prevent wiping of bearings and consequent damage during coast-down of the turbines. This source of water may be manually isolated.

The cooling water system also provides water for safeguards-related equipment such as pump oil coolers, pump gland seals, fan-coil units, and the control room air-conditioning chillers.

Because the cooling water pumps are diesel driven, water is available for all services at the time required by the equipment served. If auxiliary power is available, the normal cooling water pumps continue to operate. Only one cooling water pump is required for the safe shutdown of both units (accident in only one unit). Nonessential services are automatically isolated. (Manual isolation of the generator hydrogen cooler control valve bypass cooling water flow has been justified in Safety Evaluation 389 Add 1 Rev 1 for short durations.) 95115
Since the cooling water system is in operation at all times it is in a high state of readiness and available for normal or emergency types of operations.

In the event of a loss of offsite power, the loss of the motor driven pumps result in lowering discharge header pressure. When the low pressure setpoint is reached, the associated diesel driven pump for the pressure switch starts and will provide adequate cooling to the assiciated Unit 1 diesel generator and other cooling system loads. One diesel driven pump is sufficient to meet all the cooling system loads of both units. 93-01 94003

10.4.1.2.1 <u>Auxiliary Building and Containment Chilled Water System</u>

A common non-safety related chilled water system was added for both units 1 and 2. The system provides chilled water during normal plant operation for the containment atmosphere recirculation coolers and the control rod drive mechanism shroud cooling coils, as well as for the new and existing unit coolers located within the auxiliary building. The chilled water system was integrated with the cooling water system. The combined system provides chilled water during normal plant operation but upon loss of power or safety signal actuation, the system will return to its original design integrity and configuration by isolating the chilled water system from the cooling water equipment.

10.4.1.2.2 <u>Emergency Cooling Water Intake</u>

The Emergency Cooling Water Intake provides water to maintain safe shutdown for both units after a Design Basis Earthquake. This intake is a 36-in. pipe buried approximately 40 feet below the Circulating Water Intake Canal water level in nonliquefiable soil, connecting the screenwell to a submerged intake crib in a branch channel of the Mississippi River. This Emergency Cooling Water Intake is a Class I structure as is the Approach canal which supplies its intake crib from the main channel of the Mississippi. The intake crib is designed to exclude trash, and means are provided for back flushing. This emergency intake supplies a bay in the screenwell which has Class I traveling screens and which provides suction for the Class I cooling water pumps. 88-002

To maintain both units in safe shutdown, the safeguards cooling water pumps must provide sufficient flow to remove heat from the required components. The supply to the safeguards pumps' suction must be greater than or equal to that demand. In the event of a design basis seismic event, non-seismic qualified components cannot be relied upon to maintain safe shutdown. The effect on the cooling water system is that only the safeguards pumps are available, off-site power is lost, and the instrument air system is not available. Since many control valves fail to the open position upon loss of air or control power, the flow demand in the cooling water increases. If two safeguards cooling water pumps are operating, the cooling water system demand will exceed the supply capacity of the emergency intake line.

At the onset of the seismic event, the emergency intake line and the intake canal both supply the suction of the safeguards pumps. The design basis seismic event assumes that Lock & Dam No. 3 is destroyed by the seismic event. Failure of the Lock & Dam No. 3 causes the upstream and downstream pools to equalize. Over time the upstream pool level is postulated to decrease to 666'-6", the normal level of the downstream pool. This provides 4.5 feet of submergence above the emergency intake line. Original design calculations predict a minimum supply capacity of 18,000 gpm. However, preoperational testing, when extrapolated for minimum submergency, demonstrated that only 15,000 gpm is actually available.

Upon occurrence of the design basis seismic event, the cooling water system flow demand is calculated to be 29,759 gpm (calculation ENG-ME-302). This is with the two diesel driven safeguards cooling water pumps operating, since this creates the highest demand on the suction supply. Initially, the supply to the safeguards cooling water pumps is from both the intake canal and the emergency intake line. The intake canal has been evaluated and determined to remain intact during a design basis seismic event (ENG-CS-100). The volume in the intake canal provides approximately 25 minutes per foot of water depth for a cooling water flow demand of 29,759 gpm.

Assuming no make up from the river to the intake canal, the volume in the intake canal is depleted in approximately 3 1/2 hours. At this time, the emergency intake line will be the sole supply of water to the cooling water pumps. It is necessary for the operators to reduce the cooling water system flow demand to a value within the capacity of the emergency intake line. Procedural guidance directs the operator which cooling water system loads to secure to reduce demand. Instrumentation provides the operator with cooling water header flow and pressure. The procedure ensures components needed to maintain safe shutdown are available.

The basic design intent for the emergency pipe was to provide enough flexibility in the system to withstand earthquakes. This was accomplished by introducing four flexonics expansion joints, two near the screenhouse and the other two in the pipe riser at the intake crib. The articulation provided by the joints is expected to act in a fashion similar to paired flexible joints in steam lines.

In order for the emergency intake pipe to behave elastically, as intended, the portion of the pipe embedded in the screenhouse was wrapped with rodoform to alleviate localized stresses due to the settlement of the soil. Special backfill material was placed around the pipe to prevent liquification of the soil which would result in flotation of the pipe. All natural material has been replaced by nonliquifiable backfill materials up to the liquefaction level in accordance with the recommendations of Dames & Moore.

The design of the 36" emergency intake pipe and the approach canal are based upon recommendations by earthquake consultants J. A. Blume & Associates and Dame & Moore. Professor H. Bolton Seed of the University of California at Berkeley, in his letter dated June 3, 1970 to Mr. Garrison Kost of John A. Blume & Associates in San Francisco, stipulates the following minimum criteria to insure that the emergency service water intake pipe at Prairie Island would not be disrupted by displacements due to soil liquefaction:

a. "The slope of any liquefiable material should not exceed about 1 degree.

b. The pipe line should be supported or protected against settlement or uplift due to liquefaction of the underlying soils.

c. The pipe should be located at least 25 times the height of any bank beyond the toe of the bank in order to protect it from lateral forces due to movement of liquefied soil."

Professor Seed then proceeds to make the following specific recommendations: It will be possible to design:

a. "A section near the plant where the pipe would be placed in non-liquefiable soils.

b. A section to be stabilized against liquefaction by densification and in which the pipe would be brought up to a higher elevation, and

c. A section designed in accordance with the criteria listed above so that the pipe would not be disrupted even if the underlying and adjacent soil should liquefy."

The design of the 36" emergency intake pipe and the approach canal applies the following criteria:

Near the screenhouse, where the pipe line is above the liquefiable horizon, all liquefiable material around the pipe was removed and replaced by non-liquefiable material.

The east-west run of the emergency intake pipe has been placed below the horizon of the liquefiable soil. Trench backfill materials are non- liquefiable up to the horizon of liquefaction.

At the intake, where the pipe line rises vertically through potentially liquefiable strata, we have provided secure anchorage of the intake crib by piling into the non-liquefiable strata. In order to protect the riser pipe itself, we have designed a considerable degree of flexibility into the riser by installing two Flexonics joints which are capable of swivelling 6° in any direction.

The intake crib is located in a 575 ft. wide intake canal, which has been sized by applying a 25 to 1 slough angle. The bottom of the canal has been kept flat.

In accordance with the explanation and criteria set forth by Dr. Seed, lateral movements of liquefied soil layers are not expected in the intake area, nor do we expect a covering of the intake itself, because the intake crib is located in a 575 ft. wide intake canal which has been sized by applying the 25 to 1 slough angle cited by Dr. Seed. The bottom of the canal has been kept flat.

The bed of the branch channel of the Mississippi River in which the emergency intake crib is located has been backfilled to Elevation 560 in order to minimize any potential gradients which might cause a flow of liquefied materials. The slough angle of 25 to 1 has again been observed at the underwater bank which rises from Elevation 560 to Elevation 564.5.

The non-compacted, non-liquefiable backfill has been designed and specified according to recommendations by John Blume Associates, according to which the sieve analysis is:

70% passing 0.742 in. screen opening
36% - 50% passing #4 screen,
10% passing #10 screen.

The material used for the non-liquefiable backfill closely approximates that recommendation.

TABLE 12.2-1 CLASSIFICATION OF STRUCTURES, SYSTEMS AND COMPONENTS

Item	Class
Classification of Systems and Components (Continued)	
Turbine Plant	
Turbine, Generator, Foundation, Exciter, Oil Purification, Turbine Gland Seal System, Reheaters and Moisture Separators, Generator Cooling Water System, Hydrogen and CO_2 Systems	III
Cooling Water System	
Up to Class I System Isolation Valves	I
All that is not Class I	III
Circulating Water System	
Emergency Cooling Water Intake	I
Approach Canal	I
Circulating Water Pumping Equipment	III
Intake Canal	I*
Circulating Water Pump Discharge Piping	III
Condenser Discharge Piping	III
Intake and Discharge Equipment	III
Cooling Towers and Pumping Equipment	III

July 10, 1996

Mr. Robert G. Fraser
Northern States Power Company
Prairie Island Nuclear Generating Plant
717 Wakonade Drive, East
Welch, Minnesota 55089-9642

RE: Intake Canal Liquefaction Analysis for the Prairie Island Nuclear Generating Plant (PINGP), Welch, Minnesota - STS Project No. 28723

Dear Mr. Fraser:

In accordance with your authorization and our proposal dated January 19, 1996, STS Consultants, Ltd. (STS) is pleased to provide the following results from the subsurface exploration, laboratory testing and liquefaction analysis which was performed for the above referenced project.

Exploration Program

Our results are based upon three soil borings, laboratory testing of soil samples, and electronic Cone Penetration Tests (CPT) which were performed at 8 locations along the banks of the Intake Canal. The CPT tests were extended to refusal at depths on the order of 43 to 46 feet below grade while the borings were extended to a maximum depth of 67 feet below grade. Laboratory testing consisted of visual classification, water content, dry density determinations, sieve analysis, and minimum and maximum relative density tests.

The use of the CPT test and borings allowed for cross-correlation of information and redundant data to be obtained. The CPT tip resistance values are used to correlate to the SPT blow counts (N values) from the soil sampling operations. Pore pressure measurements within the CPT test provides a redundant measurement of the water table level and verifies the drained characteristics of the project sands. Laboratory sieve analysis and classification was used to establish the fines content of the project sands and verify the CPT generated soil behavior types. SPT blow counts and laboratory test data are summarized on the attached boring logs. Computer generated CPT plots and print-outs are also attached.

STS Consultants Ltd.
Consulting Engineers

1415 Lake Cook Road
Deerfield, Illinois 60015
847.272.6520/Fax 847.498.2721

Liquefaction Analysis

The CPT test log includes a column which indicates the Cyclic Stress Ratio (CSR) to cause liquefaction based upon the tip resistance data obtained in the cone test. The (CSR) is the ratio of cyclic shear stress divided by the effective overburden pressure which results in liquefaction for clean sands (sands with less than 5% fines) subjected to an earthquake magnitude of 7.5 on the Richter scale. This information is generated from Seed and De Alba (1986) which is summarized in Figure 1. The figure is based upon a review of sites around the world which have and have not liquefied during an earthquake. Thus, the CSR column shown on the attached CPT logs represents the cyclic strength of the PINGP site.

The Seismic Stress Ratio (SSR) which would result from the postulated site earthquake was computed utilizing the simplified formula, $SSR = 0.65\ (Amax/g)\ (\sigma_v/\sigma'_v)\ r_d/C_m$

Where:

- $Amax = 0.12$ g
- g = acceleration of gravity.
- σ_v = total overburden pressure,
- σ'_v = effective overburden pressure,
- r_d = depth correction factor,
- C_m = magnitude correction factor (1.5 for PINGP)

Based upon information available in the Final Safety Analysis Report prepared by Dames and Moore for PINGP, the Maximum Credible Earthquake (MCE) for the site will be a magnitude 5 earthquake with a maximum peak surface acceleration of 0.12g. Based upon Seed et. al. (1985) the magnitude correction factor for a Magnitude 5 earthquake is 1.5. A summary of the Seismic Stress Ratio (SSR) for the PINGP site as a function of depth is shown in Table 1.

CYCLIC STRESS RATIO

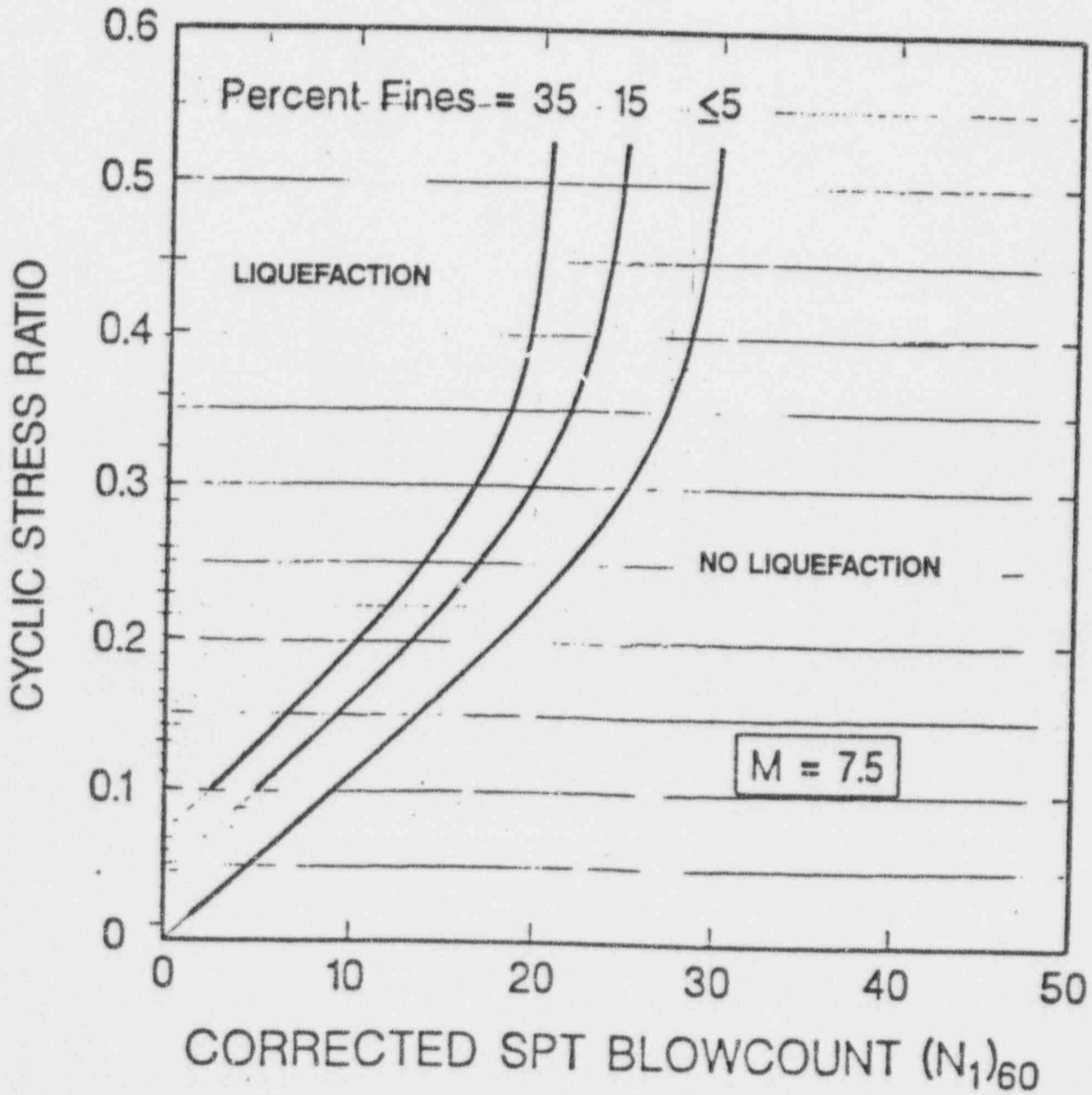


FIG. 1. Relationship between Seismic Shear-Stress Ratio Triggering Liquefaction and $(N_1)_{60}$-Values for Clean and Silty Sand and M = 7.5 Earthquakes [after Seed and De Alba (1986)]

TABLE 1
PINGP SITE LIQUEFACTION POTENTIAL

Depth (Ft)	σ_v (tsf)	σ'_v (tsf)	σ_v/σ'_v	r_d	SSR (M=5.0)	SSR (M=7.5)
20.5	1.23	1.21	1.02	.93	.074	.049
22.5	1.35	1.27	1.06	.92	.077	.051
24.5	1.47	1.33	1.11	.91	.080	.053
26.5	1.59	1.39	1.14	.91	.081	.054
28.5	1.71	1.44	1.19	.90	.083	.055
30.5	1.83	1.50	1.22	.89	.084	.056
32.5	1.95	1.56	1.25	.88	.086	.057
34.5	2.07	1.62	1.28	.87	.087	.058
36.5	2.19	1.67	1.31	.87	.088	.059
38.5	2.31	1.73	1.34	.86	.090	.060
40.5	2.43	1.79	1.36	.85	.090	.060
45.5	2.73	1.94	1.41	.84	.093	.062
50	3.00	2.07	1.45	.82	.093	.062
55	3.30	2.21	1.49	.80	.093	.062
60	3.60	2.36	1.52	.78	.093	.062
65	3.90	2.50	1.56	.76	.093	.062

The values in Table 1 are presented from a depth of 20 to 65 feet below existing grade. The 20 foot depth corresponds to the normal pool elevation of 673.5. The soil above this elevation would not be saturated and would thus not be subjected to liquefaction.

Inspection of the last column in Table 1 indicates that the maximum SSR for the PINGP site is approximately 0.062. This value has been corrected to an earthquake magnitude M = 7.5 so that the SSR will be directly comparable to the CSR values indicated on the CPT print-outs. Inspection of the CPT print-outs indicates that the minimum cyclic strength (CSR) at the CPT test locations below a depth of 20 feet is approximately 0.08 while most values at other depths and locations are considerably greater. The Factor of Safety against soil liquefaction can be defined as the site cyclic strength (CSR) divided by the site seismic stress (SSR). $F.S_{liq}$ = CSR/SSR. This Factor of Safety varies and is computed as a function of depth.

Inspection of the CPT printouts indicates that the minimum Factor of Safety against soil liquefaction is at least 1.5 or greater. A Factor of Safety of 1.5 or greater indicates that the site soils will not lose strength during the Maximum Credible Earthquake. For this reason, static shear strengths may be used in a pseudo-static slope stability analysis to determine canal wall stability.

Slope Stability Analysis

The pseudo-static slope stability analysis has been completed for the typical intake canal cross-section as shown in Figure 2 using the XSTABL computer program. Results of the three runs are attached. The first analysis was performed with the Bishop method of slices which uses a searching technique with a circular failure surface to locate the most critical potential sliding surface. This search of 400 randomly selected slip surfaces indicates that the minimum Factor of Safety under static conditions is 1.7. A Factor of Safety of 1.5 is considered adequate.

Once the critical failure surface is identified, the more rigorous Spencer's procedure is used to calculate the Factor of Safety for the critical slip surface. Spencer's procedure satisfies both moment and force equilibrium of the sliding wedge. This analysis resulted in a Factor of Safety of 1.7 also.

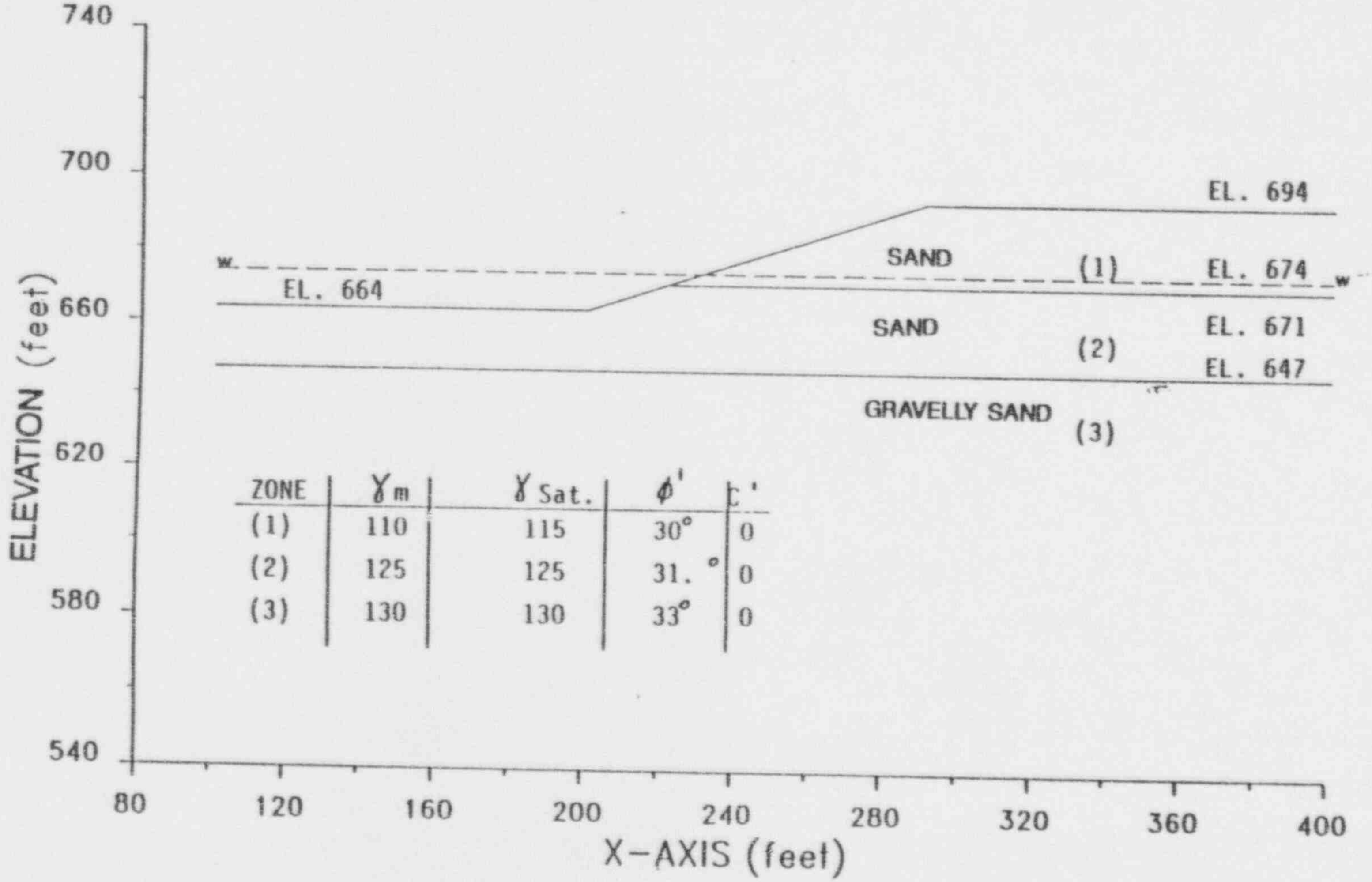
Finally, a third analysis was performed to conservatively model the inertial forces of the MCE on the Intake Canal Walls. Some researchers would consider this step unnecessary since the liquefaction analysis indicated no loss of soil strength during the MCE. However, due to the importance of the structure the analysis was performed using an equivalent static horizontal inertial force equal to 65% of the peak postulated horizontal ground acceleration. The reduction from the peak acceleration is made since the peak acceleration (and the entire earthquake) are in effect only for a short time. Thus, the final analysis was performed using Spencer's procedure with a static horizontal acceleration of 0.12 x 0.65 = 0.078g. This analysis resulted in a Factor of Safety of 1.25. The minimum acceptable Factor of Safety for this conservative analysis would be 1.0.

Conclusions

Based on our analysis and the preceding discussions, we conclude that the Intake Canal Walls consist of clean loose to dense sands which will not liquefy or loose strength during the Maximum Credible Earthquake with the canal at normal pool operating level.

A psuedo-static slope stability analysis indicates that the minimum static Factor of Safety of 1.7 exists for the Intake Canal Wall slopes. The minimum Factor of Safety under earthquake loads was computed to be 1.25. These Factors of Safety are considered adequate for the structure. Hence, no remedial measures are necessary based on the results of our analysis.

PINGP INTAKE CANAL STABILITY ANALYSIS



ZONE	γ_m	$\gamma_{Sat.}$	ϕ'	c'
(1)	110	115	30°	0
(2)	125	125	31.°	0
(3)	130	130	33°	0

FIGURE 2