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MIDLAND PLANT UNITS 1 AND 2
BECHTEL JOB 7220

March 4

WELL OBS-4 SUBSIDENCE REPORT

Prepared by Steven W. Hunt
Reviewed by John E. Anderson
June 11, 1982

INTRODUCTION

On May 19, 1982, the installation of observation well OBS-4 was stopped when soil subsidence west of the casing was noted. To obtain information for analysis of the cause and effects of the subsidence, an investigation was made by S.W. Hunt (a Bechtel geotechnical services engineer working with the Midland project civil/soils group). The information obtained was presented in "Trip Report - Observation Well OBS-4 Investigation," by Steven W. Hunt, dated June 11, 1982.

This report evaluates the information discussed in the Hunt trip report, concludes the most likely cause of the subsidence, and recommends remedial action for the well, surrounding fill, and future well installation.

ANALYSIS OF SUBSIDENCE

Influence of Soil Conditions

As discussed in the trip report, the nearest boring was DG-29 which was located about 7 feet from the well. The boring log indicated loose to dense sand from el 630' to 607' (ground surface to 23 feet) and sandy clay from el 607' to 603' or from 27 to 31 feet below the well OBS-4 ground surface.

Based on the log of well OBS-4, conditions similar to boring DG-29 were encountered. The log indicated sand from el 634' to 610' or from 0 to 24 feet deep and clayey sand between el 610' to 601' or from 24 to 33 feet deep. Both the well log and boring log indicated very loose to loose sand fill above the clayey fill layer (el 607' to about 614'). Both logs indicated sand fill below the clayey fill layer. Boring DG-29 indicated that the sand fill below el 603' was medium dense to dense.

The soil conditions described above provide useful information concerning how well OBS-4 was installed and how the subsidence may have developed. The loose to very loose sand above the clayey layer was in a condition very susceptible to disturbance by "quick" condition bailing. It also was very susceptible to caving if voids developed.

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The clayey sand or sandy clay encountered in depths between 24 to 33 feet was more resistant to "quick" condition bailing disturbance and caving. The clay acted as a cohesive binder, reducing the influence of water and increasing its ability to arch over any voids. In addition, because the well casing was driven from 24 to 33 feet prior to drilling and bailing, voids should not have formed during well installation through the clayey layer.

The sand fill below 33 feet was near the 12-inch drain pipe and was planned as Seismic Category I fill to be compacted to not less than 80% relative density, as determined by ASTM D 2049. The standard penetration test (SPT) blow counts indicated by boring DG-29 were 26 per foot at el 602' and 70 per foot at el 595'. The SPT valves indicated dense fill. Another clue that the fill near the pipe rupture was dense is that penetration of the casing was not obtained after 2 hours of spudding and driving with about 5,500 ft lb of rated energy. If significant loose sand was present around the 12-inch pipe near the the rupture, the 12-inch pipe should have noticeably settled from the direct casing impact and the accompanying vibrations.

Dense sand below 33 feet should have been more resistant to disturbance by "quick" condition bailing than the loose sand above 24 feet. In addition, because the casing at this depth was advanced by driving and because the geologists reported that very little bailing was performed below 33 feet, it is unlikely that a significant amount of material was sucked from below or outside the casing near the 12-inch pipe, thus creating voids.

Influence of Bailing

As previously described in the Hunt trip report, a bailer using suction pressure was used to extract material from inside the 16-inch diameter casing. The procedure at other wells was to drive the casing and then excavate to the casing tip using the bailer. At observation well OBS-4 the casing was advanced to an embedment of 24 feet without the aid of driving. Instead, the casing was advanced under its own weight by operating the bailer near the tip of the casing. The bailer created a quick condition during suction, which allowed the casing to sink as the tip bearing material was removed. In spite of maintenance of a water level inside the casing of at least 5 feet and usually 10 to 15 feet above the groundwater table, bailer suction pressure when operated near the tip of the casing was probably enough to remove loose material from below and outside the casing.

Because the tip of the bailer was operated at or above the casing tip and because the water level in the casing was maintained a minimum of 5 feet above the water table, the bailing procedure described above met the requirements of Specification 7220-C-118(Q).

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As the casing was advanced to 24 feet it is likely that a larger volume of material was removed during bailing than was replaced by the volume of the casing. Thus, it is likely that voids were created between the ground surface and a depth of 24 feet. These voids did not surface during the overnight delay because the sand, especially closer to the surface, contained enough cohesion and strength to minimize caving. Only after driving vibrations were introduced did the rate of caving accelerate and the caving propagate to the surface.

At the 24-foot depth the casing stopped advancing by the "quick" condition bailing method. Several bails were taken at this level while attempting to continue the casing advance. Reduced casing penetration per bail and the presence of clayey material in the bailer spoils led to the decision to cease bailing and commence driving methods of casing advance.

After the casing was driven to 33 feet, the encased soil was drilled (chopped) and removed to 33 feet by bailing. Casing driving was then resumed until an obstruction was encountered at a depth of 34 feet. After checking field drawings for the presence of utilities or pipes, chopping and driving were resumed to try to advance the casing through the obstruction. As reported, very little bailing with very little recovery was performed after the casing was driven to 34 feet.

Just prior to demobilizing the rig, two final bails were taken from the casing. The depth to the soil surface inside the casing was reported to be 29.3 feet prior to bailing. This 4.7 feet of material above the tip of the casing was material which settled out of suspension after drilling (chopping) and material which was not bailed after driving the casing to 34 feet. According to the geologists, several feet of accumulation of material settling out of suspension was common at other well locations. After taking the final two bails, the depth to soil was measured as 30 feet, or 4 feet above the casing tip.

In summary, after the casing was driven to 34 feet, sufficient bailing was not performed to clean the casing to 34 feet, thus adding credence to the concept that a significant void was not formed near the casing tip at 34 feet.

As discussed in the trip report, five to six tubs of loose saturated sand corresponding to a volume of about 2.8 to 3.4 cubic yards was removed during the entire bailing operation. In addition, another 0.1 cubic yard was removed by hand digging the initial 2.3 feet.

The volume displaced by the 16-inch outside diameter casing to 30 and 34-foot depths was 1.6 and 1.8 cubic yards. Assuming the soil prior to drilling to be at a relative density of 80%, and assuming the soil in the tubs to be at a relative density of 0%, an increase in volume of up to 15% was calculated. Increasing 1.8 cubic yards (volume of 34 feet of dense material displaced by casing) by 15% results in a volume of 2.1 cubic yards. Subtracting the volume of 4 feet of loose material in the bottom of the casing, the total estimated loose volume of material displaced by the casing would be 1.9 cubic yards. This is 1.0 to 1.6 cubic yards less than the amount removed. The estimated void size on May 19, 1982, was about 2 cubic yards. On May 25, 1982, after further collapsing, 1.0 cubic yards of loose sand was placed to fill the surface depression. The excess material removed by the bailer agrees well with the size of the void.

still have 1 yd³ to account for

Influence of Driving

The efforts to drive the casing through the obstruction at 34 feet have affected the development of the subsidence in two ways. First, the vibrations propagating from the well casing and the 12-inch drain pipe may have densified any loose sand which may have existed above and near the 12-inch drain line. Secondly, the vibrations from driving could have caused the ceiling of void cavities to collapse, accelerating the propagation of the zone of subsidence towards the ground surface.

Boring logs and soil profiles in the area of well OBS-4 were presented in the Hunt trip report. The nearest boring (DG-29) indicated a zone of very loose sand from approximately el 613' to 607'. Otherwise the boring indicated material with densities sufficiently large that densification due to driving vibrations would be unlikely. Other nearby borings (DG-30, DG-31, DG-13, DG-14, COE-10, and COE-10A) either indicated medium or dense sand fill or clayey fill. The loose sand indicated by boring DG-29 was above a layer of sandy clay and was within the depths where "quick" condition bailing was performed.

A combined influence of bailing and vibrations may have led to the development of voids. Assuming that the vibrations caused by driving could increase the loose sand from an assumed 50% relative density to 75% relative density, a 50-cubic-yard volume (e.g., a 15 x 15-foot area, 6 feet thick) would be required to obtain a 2-cubic-yard decrease in volume. Because it is feasible that 50 cubic yards of very loose sand existed, some of the estimated 2-cubic-yard void may have been due to loose sand densification resulting from the casing impact on the 12-inch drain pipe during driving and chopping.

Influence of Pipe Rupture

Sand flowing into the 12-inch drain pipe after rupture provides a third possible source for the development of a void. Prior to the rupture, the 12-inch line was apparently filled with green-dyed water under a head to el 614'. Assuming a head of water in the casing at el 630' or about 30 feet above the drain pipe, a differential head of 16 feet would have resulted in an influx of water into the 12-inch drain line. Because the valves connecting the 12-inch line to the Unit 2 circulating water lines were open for 6 to 8 hours after the rupture, the influx may have carried some sand into the 12-inch drain line depending on the size of the rupture. A differential head also existed between the groundwater table at el 619' and the water head in the 12-inch drain line. Therefore, both the head of water due to the 16-inch casing and the groundwater table could have resulted in an influx into the 12-inch drain line.

Inspection of the Unit 2 circulating water lines and the end of the 12-inch drain pipe near the Unit 1 condenser water boxes indicated that little if any sand infiltrated into the 12-inch drain line. A small amount of sand (about 1/2 inch in the invert) was found in the Unit 2 circulating water lines. The sand was probably construction residue.

Each foot of 12-inch diameter drain pipe was calculated to have an inside volume of 0.027 cubic yards. Therefore, 37 to 74 feet of 12-inch pipe would have had to be completely filled to account for 1 to 2 cubic yards of void. The Unit 2 valves were about 50 feet from the rupture. If 1 to 2 cubic yards had infiltrated into the 12-inch drain pipe, significant sand should have been detected at the Unit 2 drain line valves.

In summary, the available information concerning the 12-inch drain pipe tends to indicate that the amount of sand, if any, that infiltrated into the pipe through the rupture was not large enough to explain the loss of 1 to 2 cubic yards of material.

CONCLUSION

Most Likely Cause of Subsidence

Based on the available information, the most likely cause of the loss of ground leading to subsidence was the "quick" condition bailing, which occurred during advance of the 16-inch diameter well casing from the ground surface to a depth of 24 feet. Previous experience during borings of over a dozen holes at another Michigan site provided evidence of the tendency of loose saturated sand to flow. The suction caused by raising a split spoon sampler inside a hollow stem auger filled with water 5 to 6 feet above the water table resulted in sand "blowing" 3 to 10 feet up into the auger. No artesian water pressures were present. The rising split spoon caused suction and "quick" conditions to develop. The principle of the bailer operation was also suction as the plunger was raised to fill the bailer.

The presence of the clayey layer below 24 feet, the fact that below 24 feet the casing was driven and then cleaned, and the indication (from boring DG-29 and the lack of penetration during driving) that loose sand was not present at 34 feet all tend to discount the likelihood that the void and zone of subsidence extended to or below the tip of the casing. The disturbed zone was probably confined to the upper 24 feet (above el 610').

The second most likely cause of the loss of ground leading to subsidence was densification of loose sand above el 610' due to driving vibrations. This is the same loose sand suspected of contributing to the loss of ground by the "quick" condition bailing. Both densification by vibrations and "quick" condition bailing may have contributed to the total loss of ground.

Influx of sand into the ruptured 12-inch drain pipe was not considered as a likely source of the loss of ground.

The information used to obtain the above conclusions was based in part on observations containing estimated quantities and was also based on some assumed soil conditions. As such, the conclusions although reasonable, are no more accurate than the information from which they were derived. The possibility that other factors resulted in the subsidence still remains.

Extent of Zone of Subsidence

The estimated extent and shape of the zone of subsidence were shown on Sheet 1 of the attachment to the Hunt trip report. The zone was estimated to be an inverted cone shape (common for subsidence) located west of, and extending 6 to 8 feet from, the well casing. All voids should have collapsed as the subsidence propagated to the surface. The disturbed material should remain stable in its present condition unless influenced by vibrations or dewatering which could cause densification and settlement within the zone of subsidence.

RECOMMENDATIONS

Remedial Action

Remedial action should be considered as a result of the aborted installation of well OBS-4 and the rupture of the 12-inch diameter drain line. The well needs to be relocated as required by the permanent dewatering system design and Specification 7220-C-118(Q). The 12-inch drain should be repaired or the circulating water pipe drainage system revised. Finally, the effects of the zone of subsidence on adjacent piping and structures should be evaluated further.

Relocation of observation well OBS-4 appears to be a problem because of interference restrictions, the locations of other wells, and the extent of the sand area that the well was intended to monitor. If the well cannot be relocated 25 feet from the abandoned location, then installation of the well should be delayed until any remedial action for well OBS-4 and the zone of subsidence has been completed.

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The 12-inch drain line could be repaired or replaced. To repair the rupture, an excavation pit to 34 feet would probably be required. If the line is replaced, the existing line should be grouted and then sealed at the Unit 1 and Unit 2 circulating water line drainage valve pits. Replacement of the 12-inch drain pipe could be made within the turbine building.

Based on the conclusions of this report, evaluations could be made to determine the effects of the disturbed zone on piping and structures and to recommend remedial action. Remedial action alternatives include:

1) Grout and abandon the well casing without recompacting the disturbed zone

2) Grout and abandon well casing after replacement and recompaction of the upper 10 feet of sand within the disturbed zone

3) Grout and abandon well casing was after replacement and recompaction of the sand through the disturbed zone to a 24 foot depth.

If the available information is considered insufficient to make evaluations and recommendations, then a subsurface investigation will be required to determine the extent and strength of material in the zone of subsidence. One nondestructive and very informative method of investigation would be the use of Dutch or static cone penetrometer probes. Three probe pattern alternatives that could be used to define the vertical and horizontal extent of the zone of disturbance are shown on Sheets 2, 3, and 4 of the attachment to this report. Static cone penetrometer probes provide a continuous indication of resistance with depth. Static cone probes have been performed previously at nearby locations in the diesel generator building. A plot of Dutch cone penetrometer probe DCP-1 is shown on Sheet 5 of the attachment. Its location was also shown on Sheet 12 of the Hunt trip report.

Dutch cone resistance pressures would be used as a relative measure of resistance to distinguish disturbed soil in the zone of subsidence from material outside the zone. Interpretations would be based on the results of many probes located both outside and in the suspected zone of disturbance.

Use of standard penetration test (SPT) borings would not be practical on close spacing and would tend to be a more destructive method of testing. However, borings with SPTs allow samples to be taken and examined, whereas Dutch cone probes provide only a qualitative inference of soil type. Some SPT borings and Dutch cone probes could be combined to obtain a more informative subsurface investigation than either would provide alone.

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Future Well Installation With Cable Tool

The procedure for advancing the well casing by bailing to create "quick" conditions was apparently unique to observation well OBS-4. The other wells were advanced by driving the casing, then extracting the inner soil with the bailer. The installation of future wells should require that casing be advanced by driving only and not by bailing to create quick conditions. In addition, the bottom of the bailer should be advanced no closer than 1 foot to the bottom of the casing. By keeping 1 foot of soil in the bottom and by keeping the head of water in the casing at least 5 feet above the water table, the problem of sand blowing or being sucked into the casing should be eliminated. The recommended changes should be made to Specification 7220-C-118(Q).

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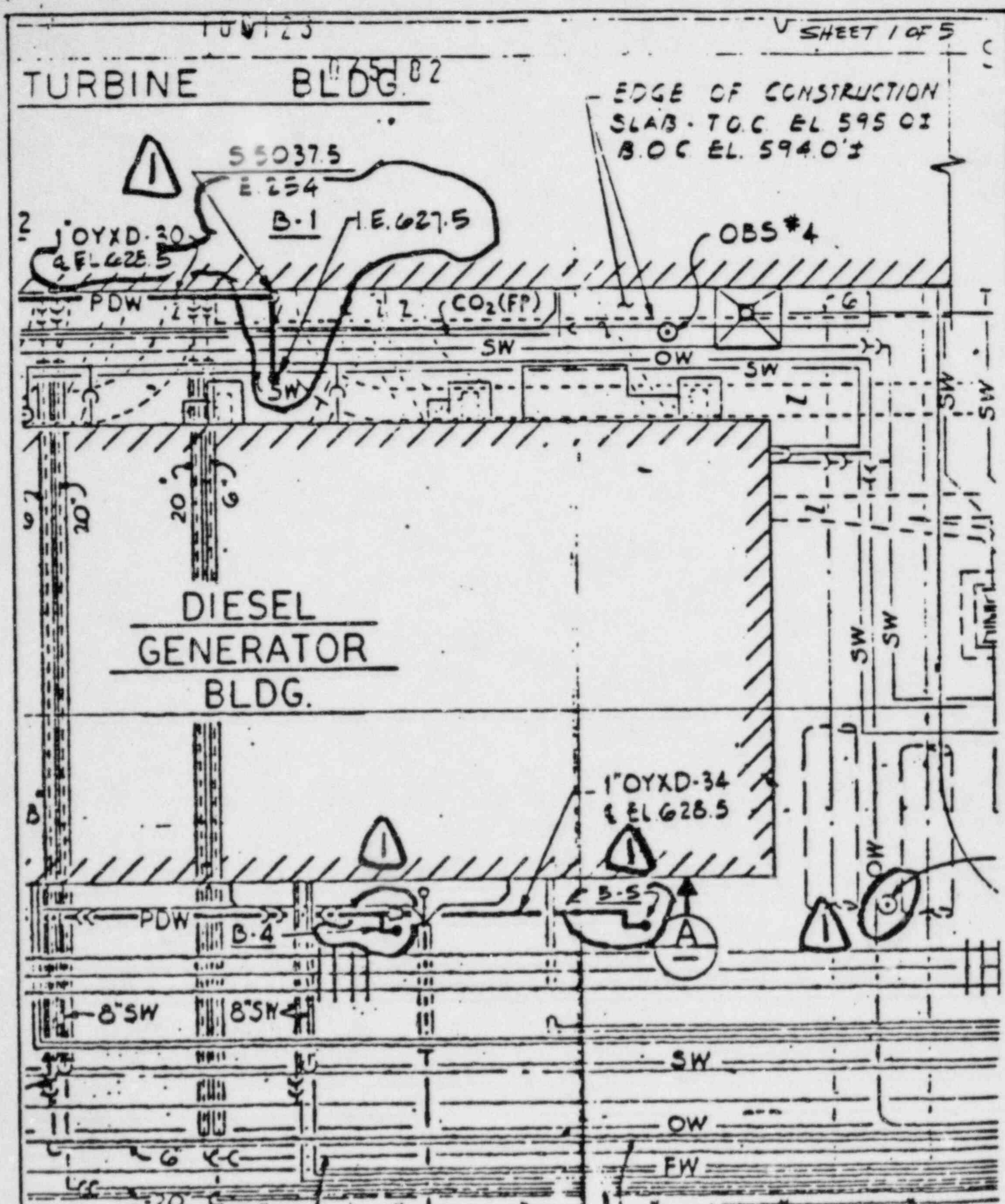
WELL OBS-4 SUBSIDENCE REPORT

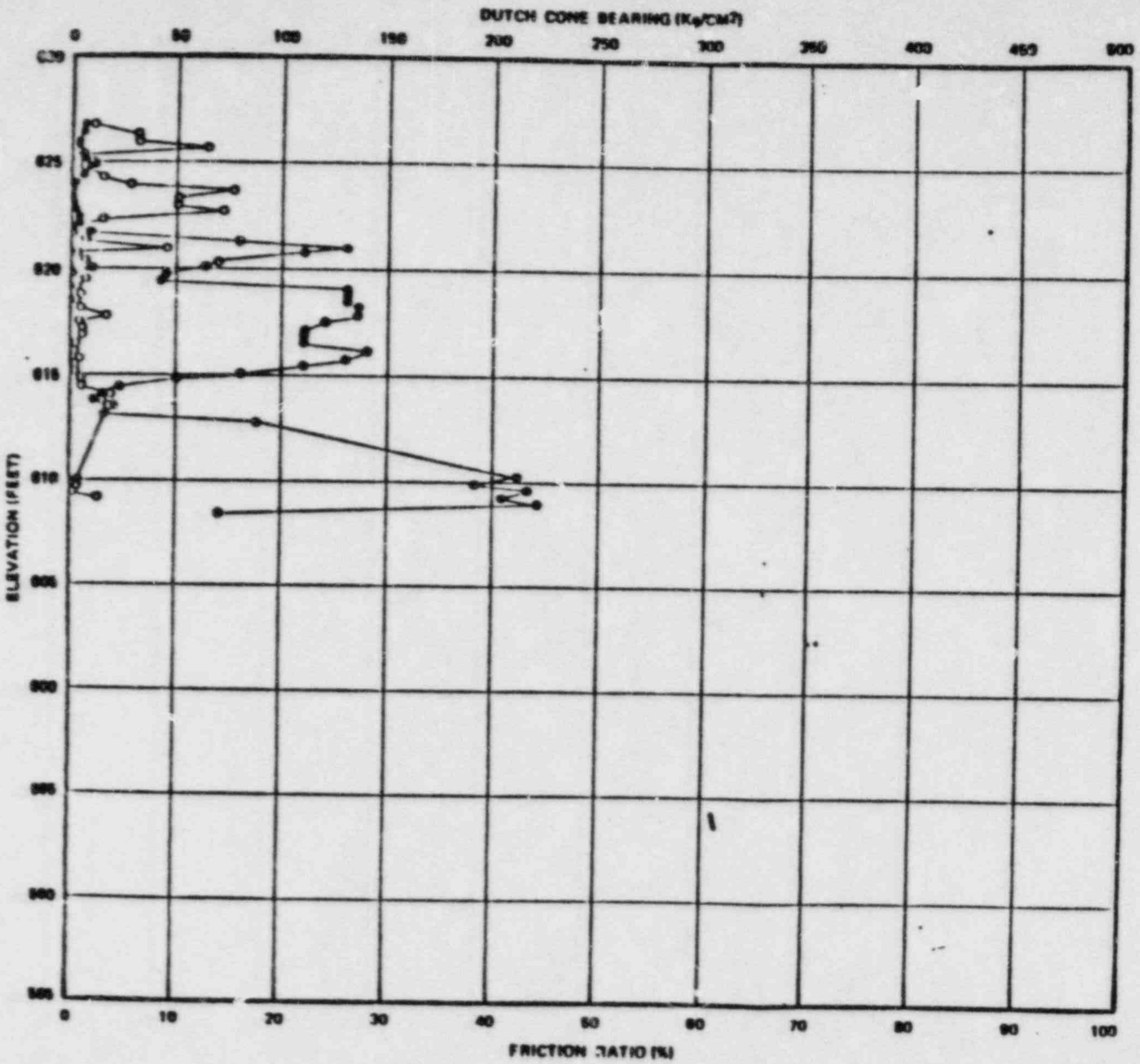
Prepared by Steven W. Hunt
Reviewed by John A. Anderson
June 11, 1982

ATTACHMENTS



PIPING AND STRUCTURES NEAR WELL OBS-4

FROM DRAWING 7220-C-2017 - APPROX SCALE 1"=20'



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EXPLANATION

● DUTCH CONE BEARING

O FRICTION RATIO

GENERAL INFORMATION

COORDINATES: S 5073
E 320

DATE: 8/30.

TOTAL DEPTH: 19.4'

SURFACE ELEVATION: 628.0

SITE: DIESEL GENERATOR BUILDING PRIOR TO SURCHARGE

	ISSUED FOR PPC...
	ISSUED FOR ...

BECHTEL

MIDLAND POWER PLANT

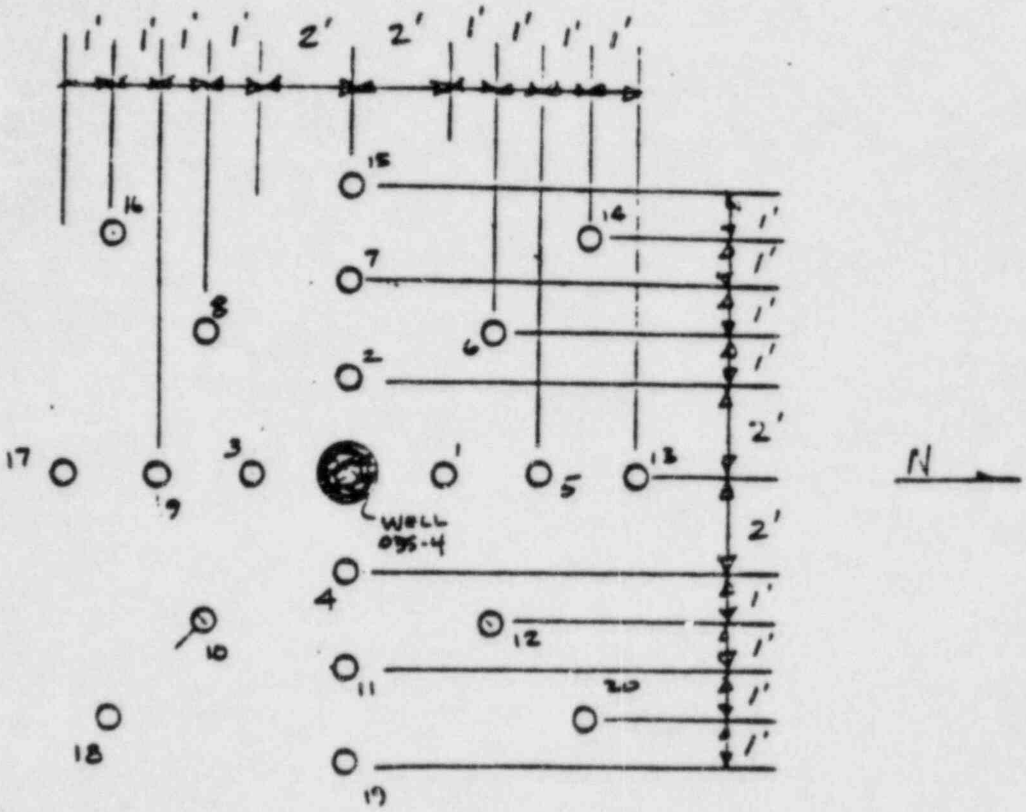
DUTCH CONE BEARING VS ELEVATION

DCP-1

JOB NO.	DRAWING NO.	REV
7220	FIGURE	1

SHEET 5 OF 5

PERFORM TO
40 FT DEPTH
OR REFUSAL



ALT. A

CONE PENETROMETER PROBES TO
DETERMINE EXTENT OF DISTURBED ZONE

SWH 6/82

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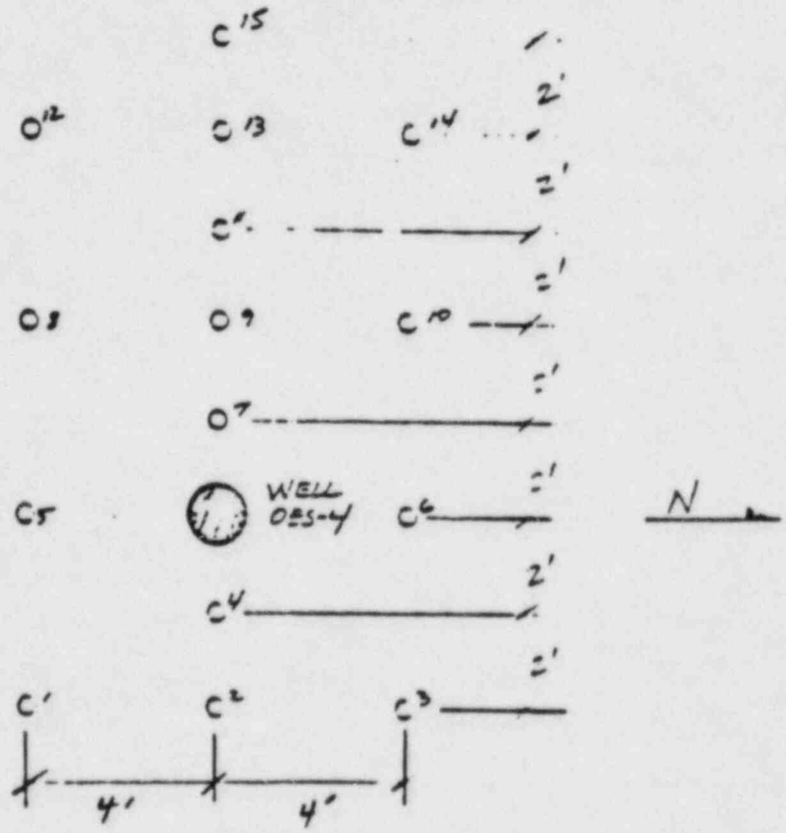
PERFORM TO 40 FT DEPTH OR REFUSAL



ALT B

CONE PENETROMETER PROBES TO DETERMINE EXTENT OF DISTURBED ZONE

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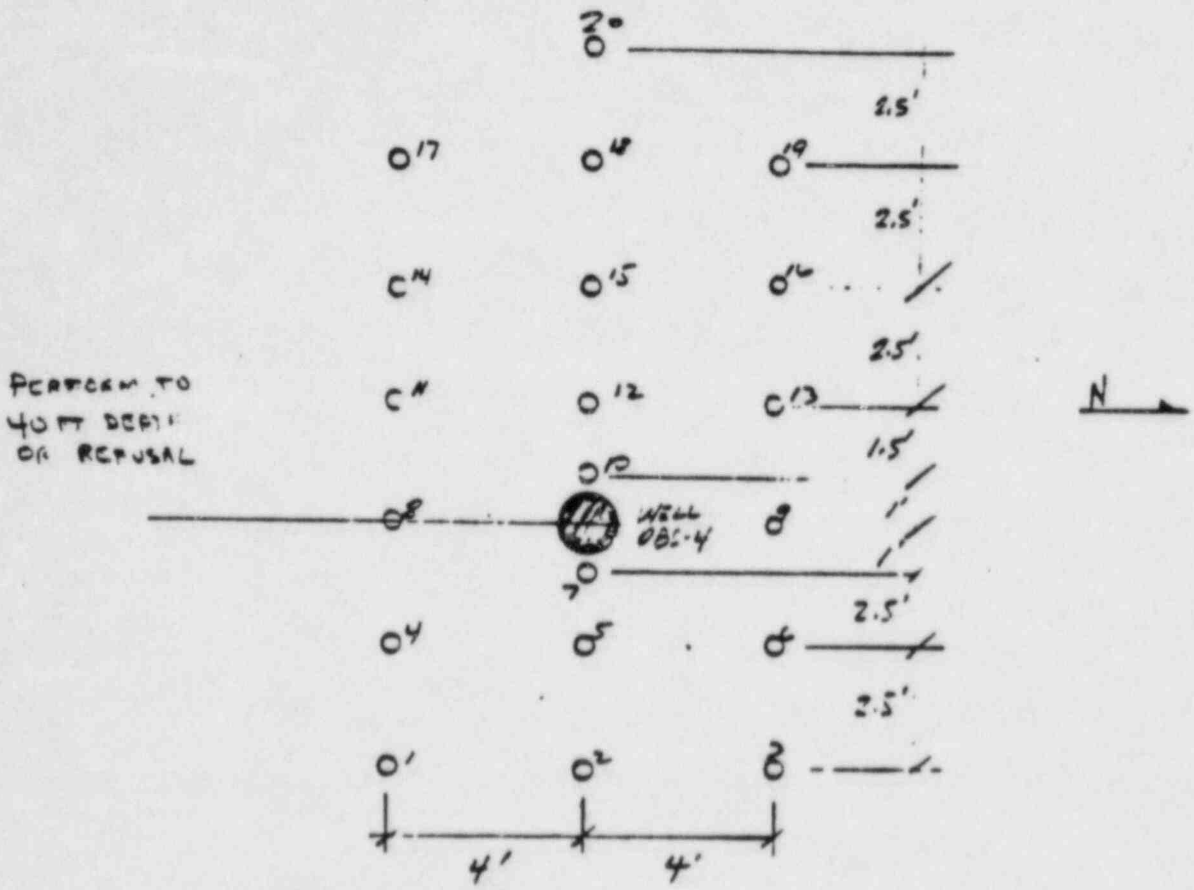
SHEET 4 OF 5



ALT C

CONE PENETROMETER PROBES TO
DETERMINE EXTENT OF DISTURBED ZONE

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GEOTECHNICAL SERVICES ANN ARBOR OFFICE

TRIP REPORT

PROJECT	JOB NUMBER	DATE(S) OF TRIP
Midland	7220-101	May 25, 1982

TRAVELER(S) NAME AND POSITION

Steven W. Hunt - Bechtel Ann Arbor Senior Soils Engineer

TRIP TO/PURPOSE

Observation Well OBS 4 Investigation

PERSONS CONTACTED

	Bechtel		Raymer
Paul Goguen	Ralph Gordon	Gary Cole	Jerry Nubacher
Dobie John	Mark Johnson		Jim Walker
Jay Steele	Allen Fiksdal		

RESULTS (USE ADDITIONAL PAGE IF NECESSARY)

See Attached Report

FOLLOWUP ACTION NEEDED (IDENTIFY ANY SPECIFIC COMMITMENTS)

Analyses, conclusions, and recommendations for action are included in a separate report by S.W. Hunt dated 6-11-82.

PREPARED BY (NAME)	SIGNATURE	LOCATION	DATE
Steven W. Hunt	Steven W Hunt	3A2	6-11-82

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File: 7220-1500

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TRIP REPORT-OBSERVATION WELL OBS 4 INVESTIGATION

Reported by Steven W. Hunt

June 11, 1982

INTRODUCTION

Scope

This trip report discusses the observations and information obtained by the author during a site visit on Tuesday, May 25, 1982. The purpose of the site visit was to obtain as much information as possible concerning the events that preceeded and followed an aborted installation of Observation Well OBS-4 and resulting ground subsidence. Analysis of the information, conclusions, and recommendations for remedial action and future well construction are outside of the scope of this report.

The information presented herein was based on: 1) discussions with Bechtel on-site geologists, 2) discussions with Bechtel Construction Engineers, 3) discussions with the dewatering subcontractor's driller, 4) Field Engineer's Reports, 5) well and boring logs, 6) design drawings, and 7) the writers observations. References to specific sources of information are contained in the discussions.

Background

Observation Well OBS-4 was part of the permanent dewatering system planned to prevent liquefaction of loose soil fill. Sheet 1 of the attachment shows that well OBS-4 was located between the Turbine Building and the northeast corner of the Diesel Generator Building.

The need for permanent dewatering was determined from subsurface investigations between 1978 and 1980 which indicated some zones of loose sandy fill below Category I facilities. Based on discussions with the NRC it was decided to install a permanent dewatering system around most of the power block area. Conceptual well design and general well location was provided to the Midland Project Civil/ Soils Group by Bechtel Geologists. Precise well locations were determined by the Bechtel Civil/Soils Group after review of the design and field drawings. Both permanent dewatering wells and observation wells were planned. The observation wells were intended to serve as part of the permanent ground water monitoring system and also as contingency pumping wells.

The initial function of the permanent dewatering and observation wells was to drawdown the water table to levels required for construction of underpinning piers at the Auxiliary Building and Service Water Pump Structure. Completion of the wells is required prior to licensing of the plant.

The installation of all permanent dewatering well system elements has been monitored continuously by Bechtel Geologist/Hydrogeologists at the site and has also been monitored by Bechtel Q.C. personnel. Procedures for the well installation were according to Technical Specification 7220-C-118 (Q) and Drawings: C-2016, C-2017, C-2018, and C-2019.

During construction of Observation Well OBS-4, located between the Diesel Generator Building and the Turbine Building (See Sheets 1, 2, 12, and 13 of attachment), the well casing hit an obstruction at a depth of 34 ft. which was later determined to be a 12-inch drain pipe for the circulating water pipelines. In order to try to advance the casing past the obstruction, drilling efforts including chopping and casing driving were continued. During driving, a cavity or zone of subsidence estimated to be 2 c.y. in volume appeared just west of the well casing. Shortly after the subsidence appeared, construction was stopped. Investigations were initiated to determine the cause of the subsidence and to determine the extent of effected area and pipes.

CHRONOLOGY OF EVENTS

Hydro-testing of Condensor Water Boxes

About six months ago (December 1981), the Unit #2 condensor water boxes and related piping were filled with water for hydro-testing. The hydro-testing was accomplished by pumping water through upper openings in the condenser water boxes. Green dye was added so that leaks could be distinguished from condensation. In order to confine water to the condenser box area, valves were closed prior to filling. Valve locations and designations are shown on the Piping and Instrument Diagram Drawings (Nos. N-446A and N-446B). In order to isolate the water from the Surface Water Pump Structure and the cooling pond, valves 035, 037, 032, and 091 were closed. Valves 031, 092, 040, and 041 located on the circulating water discharge line drain system were not closed. As shown on the above drawings, on Drawing No. C-51 (Q) and on Sheet 2 of the attachment, a 12-inch drain pipe connects the Unit 2 and Unit 1 circulating water pipe drainage system. During the Unit 2 condenser water box hydro-tests, the Unit 1 valves 033, 067, 084, and 081 were closed isolating the Unit 1 condenser water boxes. The drain line was open through the circulating water piping drain pump (OP-130) to valves 076 and 201 which were closed. The water level during the condenser water box hydro-tests was reported to be at the top of the boxes or about el 634 feet.

About 3 months ago (March 1981), the Unit 2 condenser water boxes were emptied by pumping from the top of the boxes. The green-dyed water was lowered to about el 614 feet as shown on the sketch on Sheet 3 of the attachment which was within the vertical section of the 96 inch diameter circulating water lines. During the pumping, the above-referenced valves were not opened or closed. The water level in the Unit 2 circulating water lines remained the same until after May 20, 1982.

About one month ago (May 6, 1982) filling began at the Unit #1 condenser water boxes and circulating water pipes. Related valves were checked prior to filling but were found to be closed. As in Unit 2, the filling was accomplished by pumping water through openings in the top. No green dye was added during the Unit 1 hydro-testing because condensation water was not a problem. Filling to

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about elevation 630 feet was completed on May 7. However, due to numerous leaks in the condenser water box connections, the water was lowered to about elevation 620 feet by pumping back through the top. The pumping was completed the same day (May 7). Since that time, the Unit 1 condenser box water level status has not changed. Unit 1 valves 033, 067, 084, 081, 077 , 079, 068, 034 have remained closed to date.

It was concluded from the above that the 12-inch diameter drain line was filled with green-dyed water and was connected to a head of water at about el 614 ft when the line was ruptured on May 19, 1982.

Location of Well OBS-4

The coordinates and location for Observation Well OBS-4 are shown on Drawings C-2016 (Q) and C-2017 (Q). The location of well OBS-4 is also shown on Sheets 1, 2, 12, and 13 of the attachment. Surveying of the well location was performed by Bechtel on-site surveying crews. On May 17, 1982, Geologist Mark Johnson requested that Chuck Wilson of the surveying group reconfirm the surveyed location of the well. During the morning of May 18, 1982, reconfirmation of the well location was received. The reconfirmation included a review of a field "Charley Print" drawing showing the as-built locations of piping at the site.

Installation of Well to 34-foot Depth

During the morning of May 18, 1982, a cable tool rig (22-W) was mobilized at Observation Well OBS-4 site. A copy of the field draft of the geologist's well log for OBS-4 is shown on Sheets 4 and 5 of the attachment. About 11:30 AM, a starter hole for the well was hand dug to a depth of 2.3 feet. The digging spoils of about 0.1 cubic yards were spread over the adjacent ground surface. Next a 12.5 foot long section of 16.0 inch O.D. X 0.375 inch wall steel pipe fitted with a 17 inch O.D. driving shoe at the tip was placed in the starter hole. A sketch showing the driving shoe is shown on Sheet 6 of the attachment. After setting the casing the geologist reported that it sank 1 - 2 feet below the bottom of the hand dug hole hold under its own weight. Next, water was pumped inside the casing and bailing was begun. Bailing was performed by lowering a bailing tool to the soil surface in the bottom of the casing, applying suction and extracting the tool. A sketch of the bailing tool and a description of its operation is shown on Sheet 6 of the attachment. Water levels in the casing during bailing were maintained at least 5 ft. and usually to 15 ft. above the ground water table at el 619 ft. The bailing operation is usually performed until the bottom of the bailer reaches the tip of the casing. Location of the bailer with respect to the casing was determined by observation of reference marks on the bailer cable.

After extracting the bailer from the casing, it was upended and dumped into a 3.5 ft. by 3.5 ft. by 1.7 ft. tub for later removal and disposal. The dimensions of the tub provided a maximum volume of 20.4 cubic ft. or 3/4 cubic yard. The geologists reported that 4 to 6 tubs were filled to an average of about 3/4 full before removal and dumping. The Raymer driller indicated that 5 to 6 tubs 3/4th's full of material were removed and dumped. The tubs contained loose saturated drill cuttings and some ponded water. The volume of 5 to 6 tubs of material was calculated to be 2.8 to 3.4 cubic yards.

As a result of the bailing operation the initial 12.5 foot section of casing sank under its own weight and a "quick" condition created at the tip while the bailer is sucking material. After the casing sank to an embedment of about 10 feet, bailing was stopped in order to place and weld an additional 12.7 feet of 16 inch pipe onto the casing. After welding, the bailing operation was resumed until the casing stopped advancing at a depth of about 24 feet. In order to try to advance the casing beyond 24 feet without driving, the driller indicated that several bails were taken at or near this depth. The geologist's log of bailing spoils at 24 ft. indicated that clayey sand fill was encountered explaining the arrest of progress and leading to the decision to begin driving.

Prior to installing the equipment to drive the casing below the 24 foot embedment, another section of pipe (12.3 feet long) was welded to the casing. The total casing length at this time was 37.5 feet.

After welding, the casing the cable tool equipment was placed inside the casing and set up for driving. A sketch showing the cable tool equipment is shown on sheet 7 of the attachment. In order to convert the cable tool from the drilling mode to the driving mode, a clamped driving ram was attached at the approximate location shown on the drill stem on sheet 7 of the attachment. During driving, the driving ram, drill stem, and bit assembly were raised 35 inches and allowed to freefall striking the drive head. An approximate rated energy of this driving system was 5500 ft.-lb. By applying sucessive impacts or blows on the drive head, the casing was driven to a depth of 33 feet. Driving was stopped at this depth because the rate of advance of the casing had diminished and the driller had elected to suspend driving and commence drilling of the encased soil.

In order to drill, the clamped driving ram was removed and the cable tool stem with a drilling (chopping) bit were inserted into the casing. The bit was advanced to a depth of 33 feet loosening and disturbing the material inside the casing by rhythmically lifting and dropping the bit onto the encased soil. Water was added as required during drilling (chopping).

After removing the drilling tool from the casing, the bailing operation was resumed cleaning the hole to a depth of approximately 33 feet. Water was constantly added during bailing to maintain a level at least 5 feet about the ground water depth (15 ft). Then the drilling tool was reset into the casing, the clamped driving ram was attached, and driving was resumed. The casing advanced only one additional foot corresponding to a casing embedment of 34 feet before meeting driving refusal on an obstruction. The obstruction was encountered at about 5:15 p.m. on May 18, 1982. The geologist instructed the drillers to stop work until they were cleared to proceed. The shift ended for the day at about 5:30 p.m. with no additional work on well OBS-4.

Drilling/Driving After Striking Obstruction

The next day (May 19, 1982) at about 7:15 a.m. the geologist informed Chuck Wilson of surveying than an the obstruction at 34 feet was encountered in Well OBS-4. Chuck Wilson referred to his drawings and indicated that there were no known obstructions at that location and elevation. He then indicated that drilling could proceed.

At about 7:30 a.m. the driving operation resumed in an attempt to penetrate what was believed to be a mud mat or similar obstruction. For the next two hours (until 9:30 a.m.) driving and drilling continued without progress. The driller and geologist both estimated that about half the time was spent driving and the other half drilling (chopping). Some bailing was also performed in order to attempt clean the hole but very little material was reportedly removed.

At about 9:30 a.m. the geologist, Mark Johnson, stopped the drilling operation and requested direction from the senior geologist, Allen Fiksdal. Fiksdal informed Bill Paris (geology supervisor in Ann Arbor) of the lack of progress. He also stated that some wood was noted floating inside the casing which may have been part of the obstruction. A decision was made to continue drilling since similar conditions had been observed at other holes where obstructions were encountered.

Events After Subsidence Appeared

At about 10:15 a.m. driving resumed. After about 10 minutes driving was stopped when subsidence was noted immediately west of the casing. The approximate location of the area of subsidence is shown on Sheets 2 and 3 of the attachment. Immediately after development of the subsidence, Chuck Wilson and Jim Betts of Bechtel Construction were informed and at about 11:30 a.m. they examined the hole. At about 11:45 a.m. Dave Miller, a Bechtel on-site geotechnical engineer, and Don Sibbald of Consumers Power Company were informed and brought to the well site. Initially a decision was made to crib over the hole and remove the rig. At about 12:10 p.m. Jim Meisenheimer of Consumers Power Company arrived at the site and joined the discussions. At about 12:30 Paul Goguen of Bechtel Construction also arrived at the site.

Between 12:30 p.m. and 1:00 p.m. cribbing materials arrived and were placed accross the hole and under the cable tool rig jacks. About this time pictures of the void were taken and a rod was pushed into the subsidence zone as a probe. The dimensions of the void were measured and used to determine an estimated void volume of about 2 cubic yards (see Sheet 3 of attachment). The probe penetrated into the ground about 20 feet deep at a shallow angle without encountering enough resistance to stop it.

About 1:12 p.m. Glen Murray of Consumers Power Company informed Sibbald and the rest of the group that the obstruction was a 12-inch drain pipe. At about 1:30 p.m. Murray indicated that R. Landsman of the NRC had been informed.

At about 1:45 p.m. Sibbald asked that two more bails of material be removed from the casing so that less material would cover the 12-inch line in case it was decided to do some probing. Prior to bailing, the depth below ground surface to soil inside the casing was measured as 29.3 ft. After taking the final two bails of material, the water level in the casing was restored to about 4 feet below the ground surface. The final 2 bails removed mostly water and very little soil. After bailing, the depth to soil inside the casing was found to be 30 ft below the ground surface.

At about 1:55 p.m. the driller was told to demobilize the cable tool rig. The 16-inch casing was cut at the ground surface removing about 3 1/2 feet of the length. After the rig was removed, the area was covered with plywood timber and roped off.

Events After Rig Demobilized

After the rig was demobilized, the status of valves between the 12-inch drain pipe and the circulating water lines were checked. The unit 1 condenser water box area valves were found to be closed. In the Unit 2 condenser water box area, valves 031, 041, 040, and 092 were found to be open and were closed isolating the 12-inch diameter drain pipe to perform a pressure test. After the system was isolated, an air supply and a pressure gauge were attached to an instrument line in the Unit 1 valve pit. The pressure gauge indicated a water pressure of approximately 10 psi. The pressure gauge was located at approximately el 599 ft. The pressure calculated from the water at el 614 ft. which was present in the Unit 2 circulating water lines corresponds to about 7 psi. The pressure at el 599 ft. which would have been due to the outside groundwater el 619 ft (which has recorded at piezometer COE-10) corresponds to a pressure of about 9 psi. The pressure at el 599 ft. due to estimated water elevation in the casing at el 630 feet corresponds to about 14 psi. Accuracy of the pressure gauge was considered to be not better than several psi. The fact that the presure reading was higher than the pre-existing static head and in the range of pressure expected by the ground water table and casing head, was an indication that the pipe was ruptured with some inward flow.

At 5:05 p.m. on May 19, 1982, an air pressure was applied to the line which resulted in an increase of pressure at the gauge of 3 1/2 psi. As a result of the air pressure, bubbles were noted rising inside the OBS-4 casing. At 5:07 p.m. the pressure was removed from the system. The air pressure test confirmed that the 12- inch line had been damaged at the OBS-4 location. Field documentation of the valve closing and of the air pressure test was presented on a Field Engineer's Report Form, dated May 19, 1982. Copies are shown on Sheets 8 and 9 of the attachment.

On May 20, 1982, it was discovered that the water inside the casing for OBS-4 had become green and was at el 630 ft. Since the water which was in the 12-inch line when it was ruptured contained green dye it was suspected that the air test pushed some of the green water out of the 12 inch line and into the casing causing the casing water to become green. It is likely that the reason the water level remained at about el 630 ft. in the casing rather than drop to the ground water elevation at about el 619 ft. is due to the silty and clayey material which settled into the bottom of the casing.

In order to help determine whether sand had infiltrated into the 12-inch drain line and into the Unit 2 circulating water lines, pumps were installed into the vertical section of the circulating water lines through the condenser water boxes. Between May 20 and May 23, 1982, the water in the four Unit 2 circulating water pipes was drained to a level of about el 602.5 ft. about 6-9 inches above in the pipe invert. On May 23, field engineers entered all four pipes and found: 1) no gravel or coarse sand, 2) approximately 1/4 to 1/2 inch of slightly

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sandy silt on the invert points of the pipes, and 2) traces of slightly sandy silt in the exposed portions of the 12 inch drains. Field documentation of the Unit 2 circulating water lines observations is included on a Field Engineers Report Form dated May 24, 1982 and is shown on Sheets 10 and 11 of the attachment.

On May 25, 1982, Steve Hunt (the author of this report and a geotechnical engineer working with the Civil/Soils project group) visited the jobsite to obtain as much information as possible concerning Well OBS-4 and the effected drain lines. During the site visit the writer had discussions with the following Bechtel construction personnel: Paul Goguen, Dobie John, Jay Steele, Gary Cole, and Ralph Gordon. The writer also had discussions with Bechtel Geologists Mark Johnson and Allen Fiksdal. Later by telephone, the writer talked to drillers from Raymer (the well drilling subcontractor) Jerry Nubacher and Jim Walker. The information obtained from the above discussions was the basis for this trip report.

In addition to the site discussions the writer observed the OBS-4 Well site. At the time of the observation, the soil had collapsed to the ground surface leaving a depression of about 15 sq. feet in area and 2 feet deep. Subsequently, the depression was filled with 39 -5 gal buckets of loose sand corresponding to about 1 cu. yard of fill. Also while at the well site, a weighted string was lowered into the casing to determine the depth to soil inside of the casing. The writer determined that soil was 29 feet 11 inches below the top of the casing and that the upper 2-3 inches of the material was soft like muck. The soft material was probably silt and clay which settled out of the water after drilling. The casing volume to 30 ft. below ground surface was computed to be 1.6 cubic yards.

ANALYSIS OF SUBSIDENCE

Influence of Bailing

As previously described, a bailer using suction pressure was used to extract material from inside of the 16-inch diameter casing. The normal procedure was to drive the casing and then excavate to the casing tip using the bailer. However, for Observation Well OBS-4 the casing was advanced to an embedment of 24 feet without driving. Instead the casing was advanced by operating the bailer near the tip of the casing, creating a quick condition during suction and allowing the casing to sink as the tip bearing material was removed. In spite of maintenance of a water level inside the casing of at least 5 feet above the groundwater table, bailer suction pressure when operated near the tip of the casing was likely sufficient to remove material from below and outside of the casing. As the casing was advanced to 24 feet it is likely that a larger volume of material was removed during bailing than was replaced by the volume of the casing.

SOIL CONDITIONS

The soil at the site of well OBS-4 consisted of sand and clay fill to at least the bottom of the well at 34 ft. (elevation 600 ft.). A description of the soil from the bailer spoils of the well is shown on Sheets 4 and 5 of the attachment. In addition, other borings and wells have been performed in the area. Sheet 12 of the attachment shows a plan of boring locations in the Diesel Generator Building area. Sheet 13 shows the location of soil profiles DD' and EE' which are shown on Sheets 14 and 15, respectively. Detailed logs of borings DG-13, DG-14, DG-29, DG-30, DG-31, COE 10, and COE 10A are included on Sheets 16-26 of the attachment.

The nearest (6-7 ft.) boring to Well OBS-4 was DG-29. The detailed log of DG-29 is shown on Sheet 19 of the attachment. The log indicates medium dense to dense sand fill from 0 to about 17 ft. and very loose sand fill from about 17 to 23 ft. Between 23 and 27 ft. stiff sandy clay fill was indicated. Below 27 ft., medium dense to dense clean sand fill was indicated.

The very loose sand encountered in boring DG-29 from about 17 to 23 ft. (elevation 613 to 607 ft.) was below the water table (elevation 619 ft.). The sand was in a state making it very susceptible to the "quick" conditions created by the bailer. During bailing, a considerable amount of loose sand was probably removed from outside the casing within the loose sand zone.

Below the loose sand zone (elevation 607 to 610 ft.) both boring DG-29 and the OBS-4 Well Log indicated a layer of sandy clay or clayey sand. DG-29 indicated 4 ft. of sandy clay and OBS-4 Well Log indicated 9 ft. of clayey sand. This clayey layer would have been more resistant to disturbance and removal by "quick" condition bailing and therefore probably stopped the advance of the bailer at 24 ft. Between 24 ft. and 33 ft. the casing was first advanced by driving and then cleaned by bailing. Voids should not have been formed during casing installation between 24 ft. to 33 ft. (elevation 610 to 601 ft.). Below 33 ft. sand was indicated on the well log. However voids below 33 ft. in the sand are not as likely since the casing was advanced by driving rather than by "quick" condition bailing. Therefore no voids may have been created by casing installation from 24 ft. to 34 ft.

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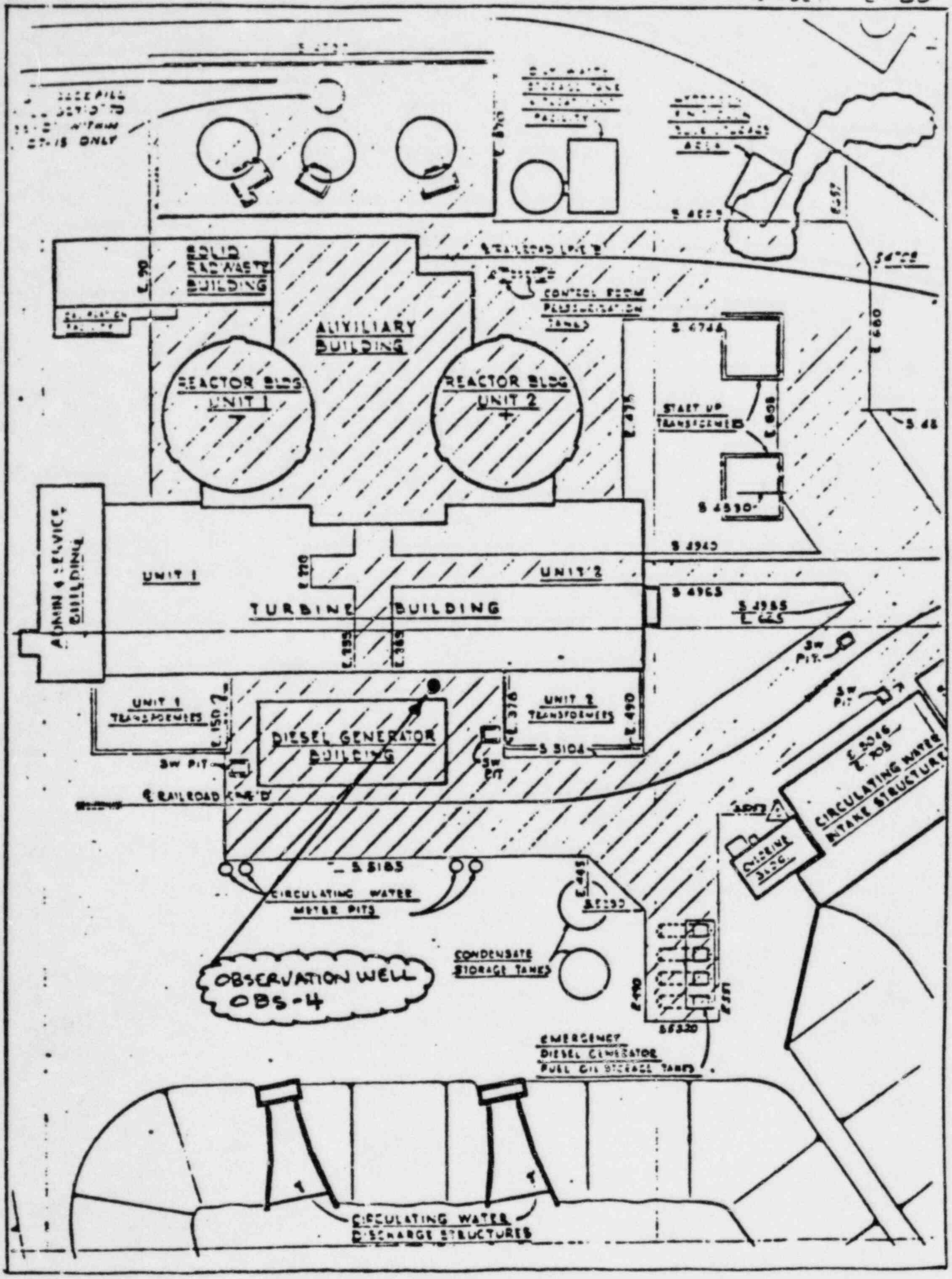
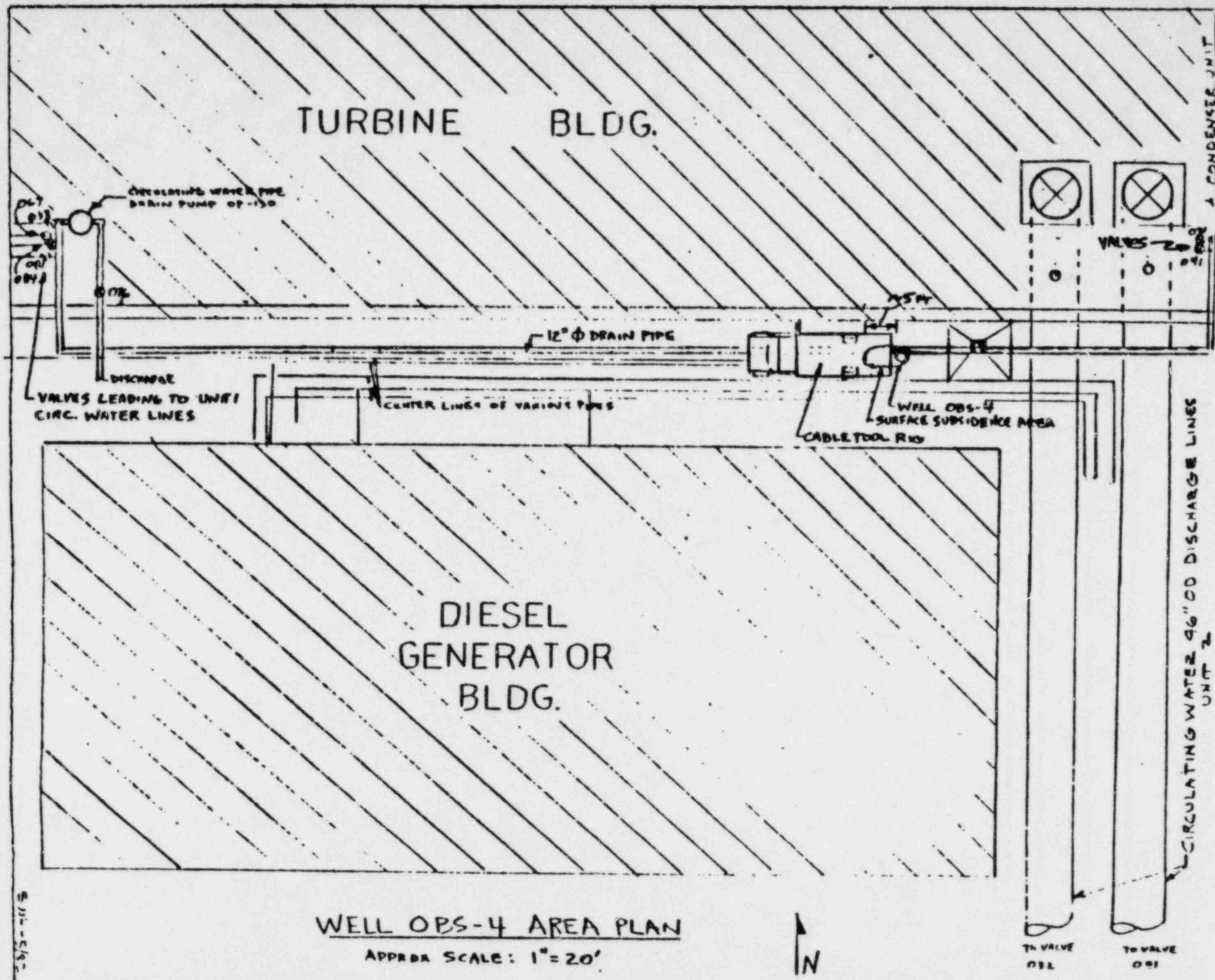
TRIP REPORT - OBSERVATION WELL OBS-4 INVESTIGATION

Reported by Steven W. Hunt

Attachments


SOLID RADWASTE BUILDING
AUXILIARY BUILDING
CONTROL ROOM PRESSURIZATION TANKS
REACTOR BLDG UNIT 1
REACTOR BLDG UNIT 2
START UP TRANSFORMERS
ADMIN & SERVICE BUILDING
UNIT 1
UNIT 2
TURBINE BUILDING
UNIT 1 TRANSFORMERS
UNIT 2 TRANSFORMERS
DIESEL GENERATOR BUILDING
SW PIT
℄ RAILROAD
CIRCULATING WATER INTAKE STRUCTURE
CHLORINE BLDG
CIRCULATING WATER METER PITS
CONDENSATE STORAGE TANKS
OBSERVATION WELL OBS-4
EMERGENCY DIESEL GENERATOR FUEL OIL STORAGE TANKS
CIRCULATING WATER DISCHARGE STRUCTURES



WELL OBS-4 AREA PLAN

APPROX SCALE: 1" = 20'

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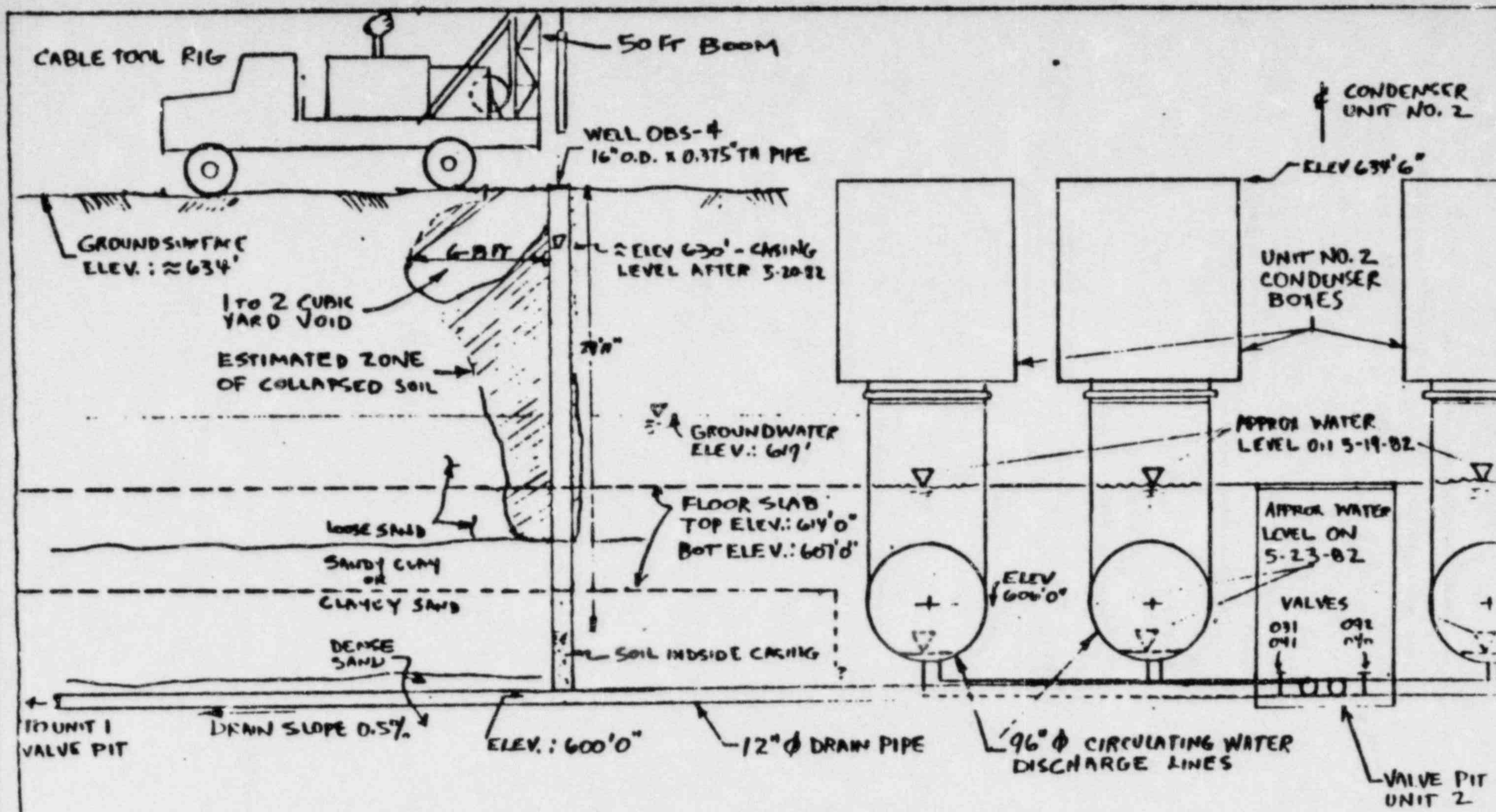
SHT 2 OF 26



WELL OBS. 4 CROSS SECTION

APPROX SCALE 1" = 10'

103123

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VCI 103123 075182 SHEET 4 OF 26

WELL LOG

PROJECT	JOB NO.	SHEET NO.	WELL NO.
MIDLAND UNITS 1 AND 2	7220	1 of 2	CBS-4

SITE	COORDINATES
Diesel Generator/Turbine Building	S-5041.5 E-313

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE	TOTAL DEPTH	SAMPLES
8-18-82		Kelley Dewatering	Bucyrus Erie 22-W	17"	34.0'	10

SCREEN DIA/LENGTH/SLOT	EL TOP OF CASING	GROUND SURFACE EL	DEPTH/EL GROUND WATER	LOGGED BY GEOLOGIST/ENGINEER/TECH.
		634	15'/619	M.D. Johnson

CHECKED BY	DATE	APPROVED BY	DATE

ELEVATION	DEPTH	SAMPLE	GRAPHIC LOG	DESCRIPTION AND CLASSIFICATION	NOTES
634	0				
633.5	.5	S-1		0-.5 Crushed Gravel and Fine to Coarse Grain Sand Gray (Fill)	Excavated starter hole by hand from 0-2.3'
		S-2		.5-24 Sand, Brown, Medium to Coarse-grain, Some fine Grain Gravel (Fill)	17" casing installed in starter hole and dropped quickly 2-3'
	5				O.D. of Drive shoe 1.45'
		S-3			Pipe Joints 1st 12.5; 2nd 25.2; 3rd 31.2 old weld; 37.5
	10	S-4			
	15	S-5			From 2.3' to 24' No drilling necessary as Sand was very lose, casing advanced by own weight with use of bailer.
	20	S-6			Casing stopped advancing @ 24'
610.0	24			24-33 Clayey Sand, Brown, Fine-to Coarse-Grain, Some Fine Grain Gravel (Fill)	Drove casing down to 33'
	25	S-7			Drilled from 24' to 33'
					Advanced casing to 34'
	30	S-8			Obstruction @ 34'
		S-9			End shift 8-18-82 33'
601.0	33	S-10		33-34 Sand, Brown, Fine-to Medium Grain (Fill)	Bailed water from 30' to 34'
600.0	34				
	35				

TYPE OF RIG	SITE	WELL NO.
Grab / Bailer	Diesel Generator/Turbine Building	CBS-4

BECHTEL 106123 075182

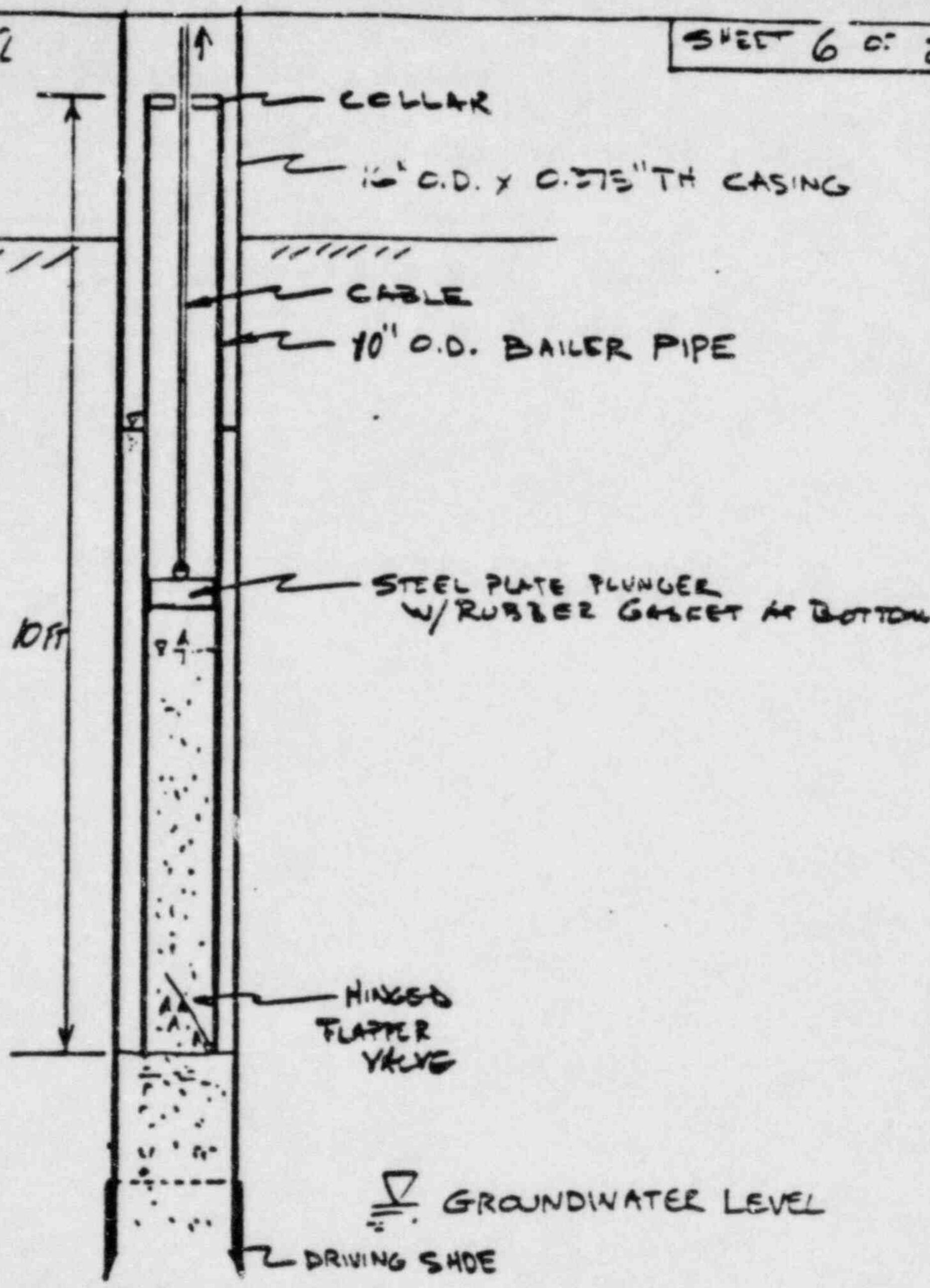
SHEET 5 OF 2[illegible]

WELL LOG

PROJECT	JOB NO.	SHEET NO.	WELL NO.
MIDLAND UNITS 1 AND 2	7220	2 OF 2	OBS-4

ELEVATION	DEPTH	SAMPLE	GRAPHIC LOG	DESCRIPTION AND CLASSIFICATION	NOTES:
				34 - Sand, Brown, Fine to Coarse Grain, Some Clay and Fine Grain Gravel, Trace Wood	Casing would not [illegible] past 34' Several pieces of wood [illegible] in casing
	40				
	45				Well [illegible] 10:25 5-19-82 when cave in of surface next to casing
	50				
	55				
	60				

SAMPLE TYPE	SITE	WELL NO.
Boiler	Diesel Generator / Turbine Buildings	OBS-4



BAILER OPERATION:

* Bailer lowered to soil surface inside casing
* Steel plate plunger slides to bottom
* Steel plate plunger lifted sucking soil and water
* Steel plate plunger contacts collar raising bailer
* Bailer extracted from casing with contents
* Contents dumped into a tub
* Additional water pumped into casing as required to Maintain casing level above ground water level

BAILER TOOL SKETCH

NOT TO SCALE

SWH-5/82

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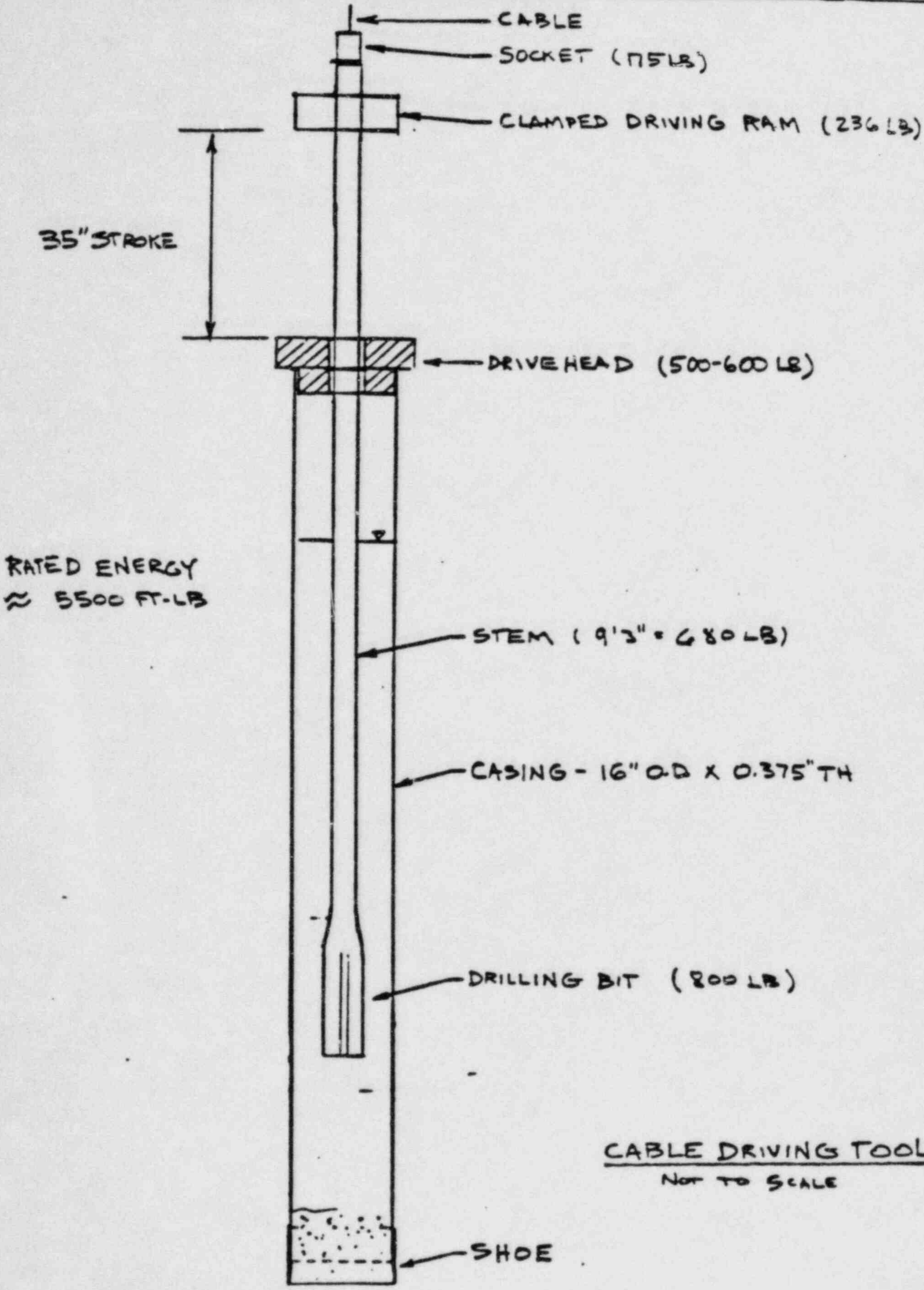


CABLE DRIVING TOOL

NOT TO SCALE

SWA-5/82

75182

SHEET 8 OF 26

FIELD ENGINEER'S REPORT FORM

MIDLAND UNITS 1 & 2

JOB 7220 DATE 5/19/82 PAGE 1 OF 2

ITEM NO.	INSPECTION DESCRIPTION	ACTION REQUIRED/TAKEN
	During installation of outside casing for ~~freeze protection piping~~ PERMANENT DEWATERING OBSERV. WELL #4 (DWG C-2016, 2017), an obstruction was encountered at approx. 35' in depth. Installation of casing proceeded for approx 4 hours. At this time the fill around casing was discovered to be caving in and drilling was stopped.	
	Field Engineering was asked to verify whether or not piping, 12" 2YBJ-8, from "Circulating Water Piping Drain Pump OP-130" had been damaged.	
	Field Engineering proceeded to isolate piping in question by verifying the following valves were closed: 446A-033, 446A-067, 446A-084, 446A-081, 446A-201, 446A-076, 446B-031, 446B-092, 446B-040, 446B-041 (Valves 446B-041, 446B-040, 446B-031, AND 446B-092 ~~was discovered to be partially~~ HAD BEEN opened ~~and was~~ BUT WERE closed prior to pressurizing system.)	
	After system was isolated, an air supply with a pressure gauge was attached to instrument	

REMARKS:

SIGNATURE: D.L. John

ROUTE:
P. GOGUEN
T. VALENZANO
K. PULITO
J. GILMARTIN
N. SWANBERG - A

FILE

FIELD ENGINEER'S REPORT FORM

MIDLAND UNITS 1 & 2

JOB 7220 DATE 5/19/82 PAGE 2 OF 2

ITEM NO.	INSPECTION DESCRIPTION	ACTION REQUIRED/TAKEN
	tubing for OPI-4672. After attaching pressure Gauge, system was discovered to be partially filled with water and approx. 10 ~~lbs~~ PSI was noted on guage. At 5:05 PM, 3½ PSI of air pressure was applied to system at which time bubbles were noted coming up inside the casing pipe. At 5:07 PM, pressure was removed from system after verifying that 12"-2YBJ-8 had been damaged. Valves noted before were left in the closed position.	
	w/ attachments: scoped P&ID's 446A, 446B	

REMARKS:

SIGNATURE: St John

ROUTE

FILE

FIELD ENGINEER'S REPORT FORM

MIDLAND UNITS 1 & 2

075182

JOB 7220

DATE 5/24/82 PAGE 1 OF 2

ITEM NO	INSPECTION DESCRIPTION	ACTION REQUIRED/TAKEN
	During installation of outside casing for dewatering Well on 5/19/82 Pipe 12"-2XR-1-2 was penetrated - Valves isolating the break in the line were secured as reported in Engineer's Report dated 5/19/82 - The Condenser Water Box manways were opened and Water (dyed green) was observed in all Pipes 2 intakes & 2 Discharge (96") at approx the 614'-0 level (Note green dye was used in the Water Box hydro of Condenser 1 & 2 and apparently was not completely drained after completion of test) The 4 pipes were drained 5/20 thru 5/23 until the water level was approx 6" to 9" deep - on 5/23 engineers entered all 4 pipes - The findings are as follows	Samples of Silt were taken with a shovel and bagged - Due to the even distribution and fine texture of the material found it did not appear that the material had originated from the rupture of the 12" pipe - Note: the Water Box was hydroed utilizing pond water and the silt could have originated as natural settlement of Suspended Solids and dust and dirt that was in the pipe at time of test.
	1. No gravel or Sand	
	2. Approx 1/4" - 1 1/2" of Slightly Sandy Silt on invert point of all Pipes	
	3. No build up of sand or gravel could be observed in 12" drains but Small amounts of Slightly Sandy Silt could be observed.	

REMARKS:

ROUTE:
P. GOGUEN
T. VALENZANO
K. PULITO
J. GILMARTIN
N. SWANBERG

SIGNATURE [signature]

FILE

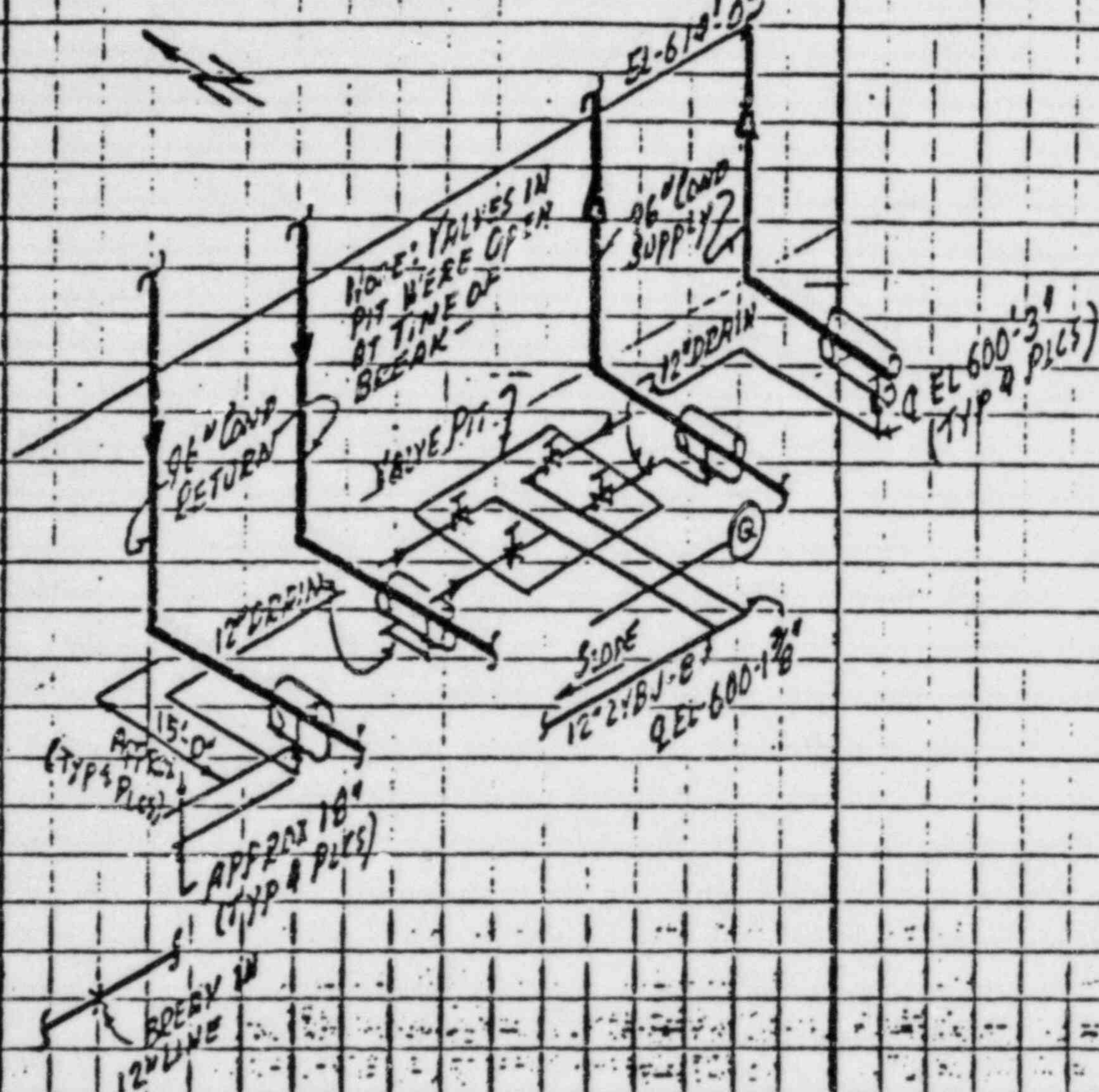
SHEET 11 OF 24

FIELD ENGINEER'S REPORT FORM

075182

MIDLAND UNITS 1 & 2

JOB 7220 DATE 5/24/82 PAGE 2 OF 2

ITEM NO.	INSPECTION DESCRIPTION	ACTION REQUIRED/TAKEN
		

REMARKS:

SIGNATURE

ROUTE
P. COGUEN
T. VALENZANO
K. PULITO
J. GILMARTIN
N. SWANBERG

FILE

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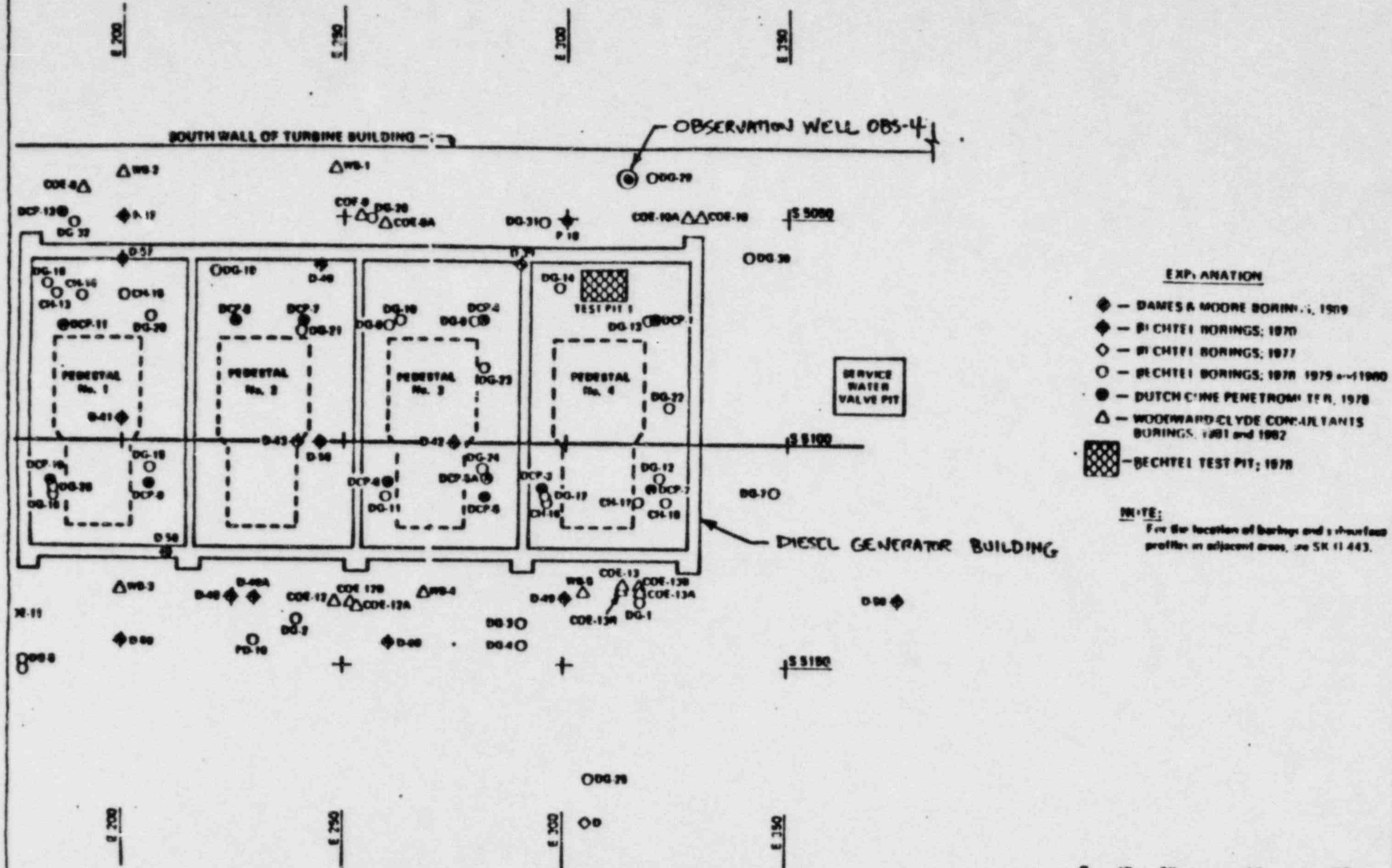
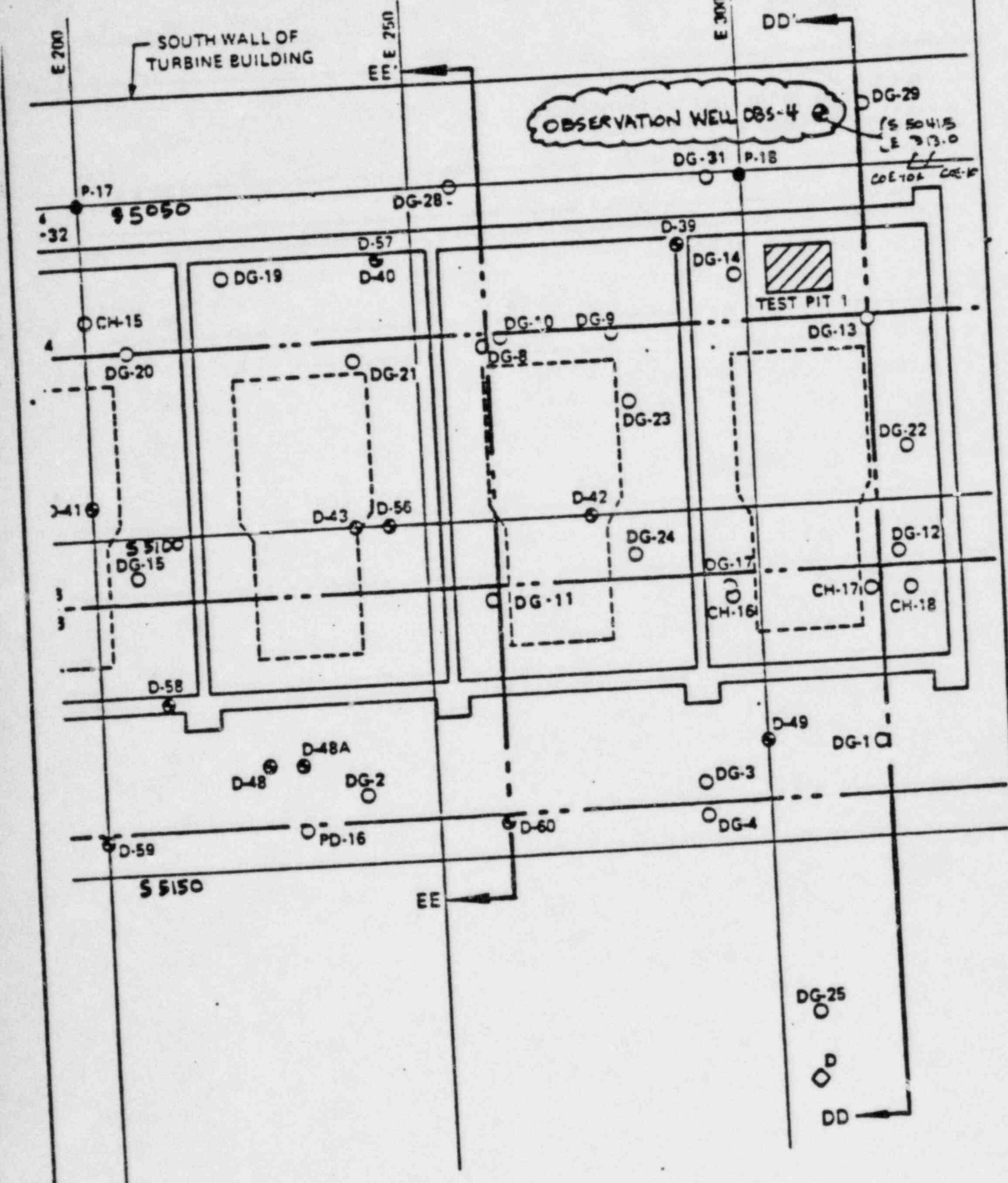


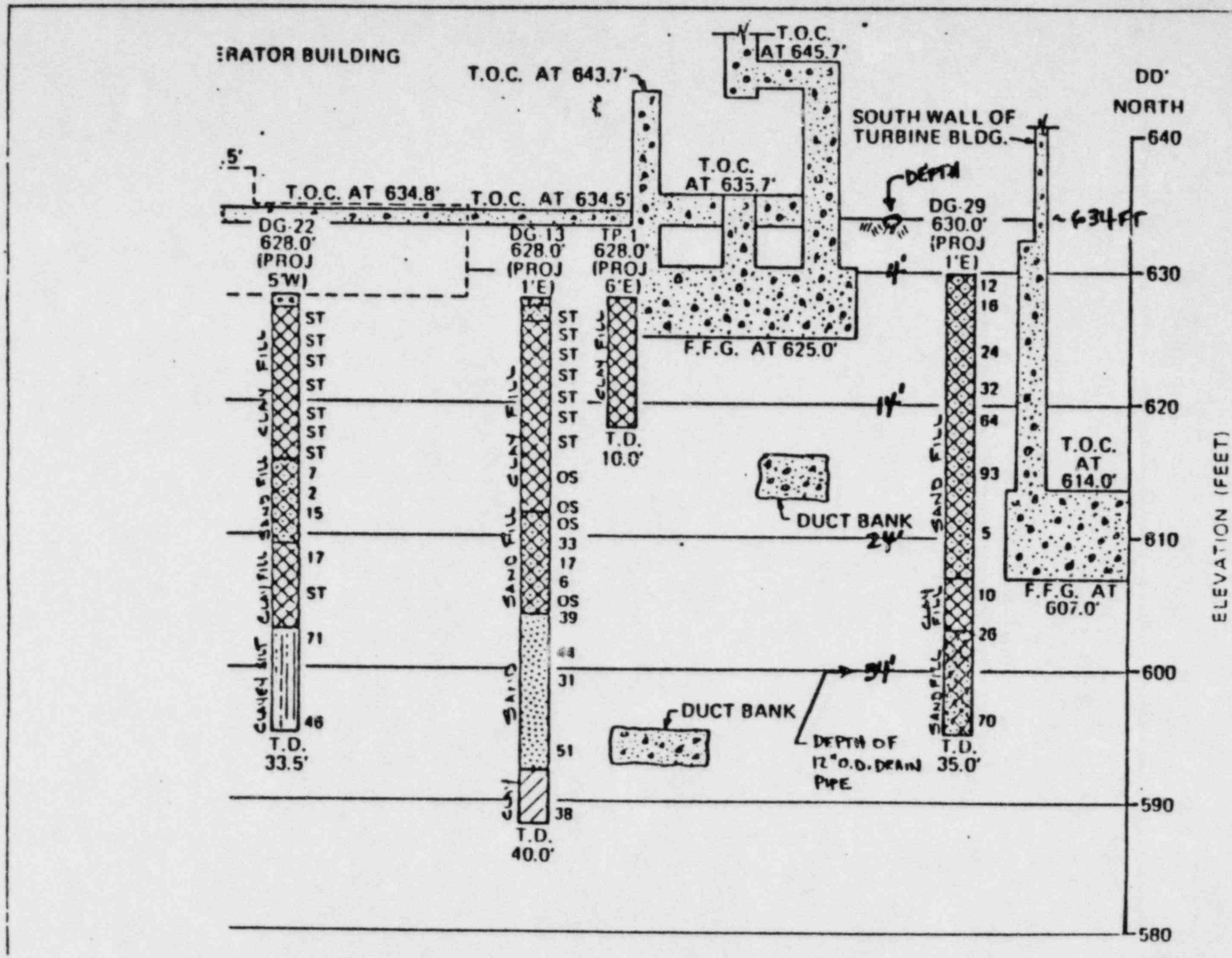
BORING LOCATION PLAN

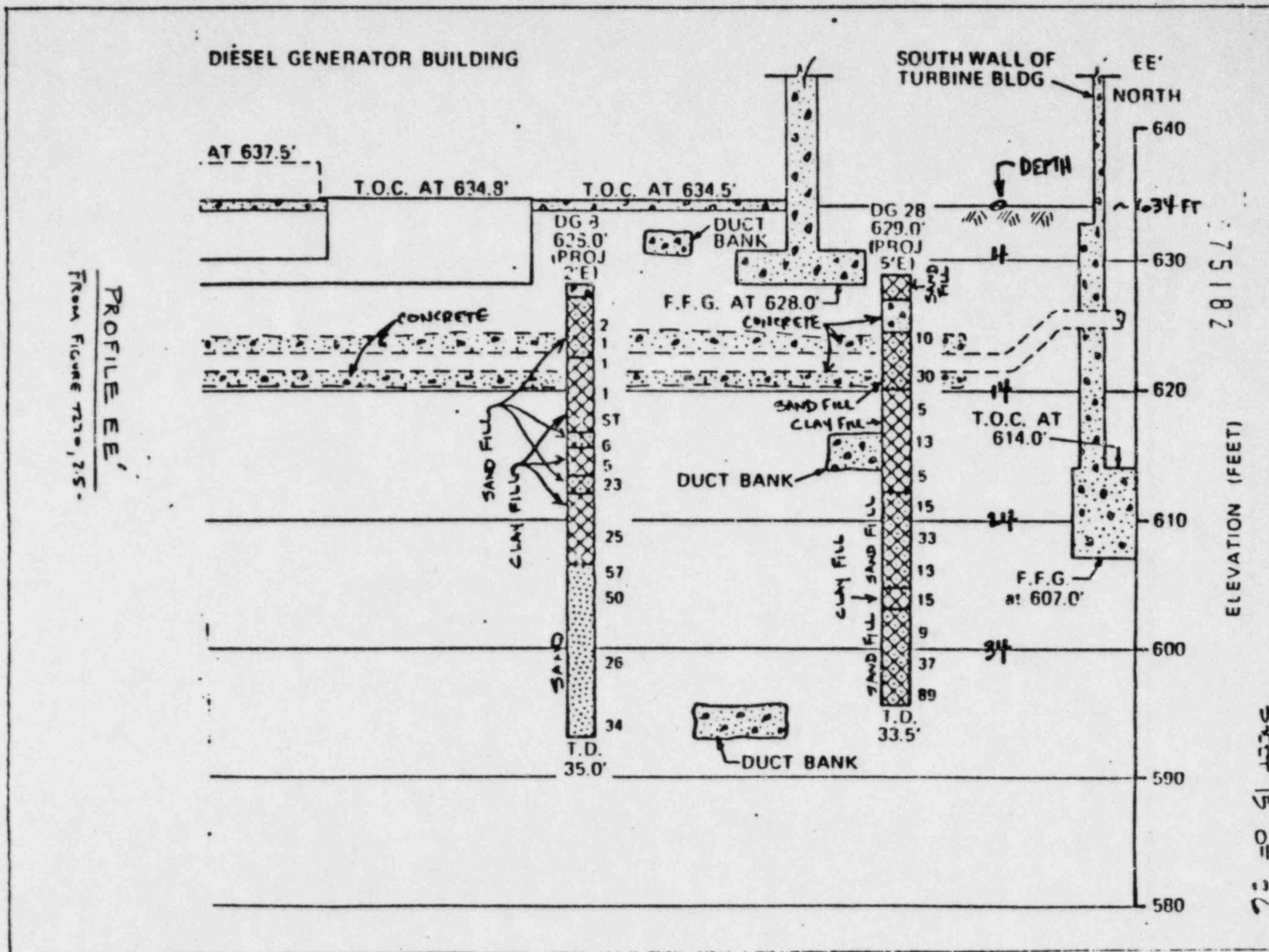
DIESEL GENERATOR BUILDING AREA



PROFILE AND LOCATION PLAN

From Figure 7220, 25-17


RATOR BUILDING
DD'
NORTH
T.O.C. AT 643.7'
T.O.C. AT 645.7'
SOUTH WALL OF TURBINE BLDG.
T.O.C. AT 634.8'
T.O.C. AT 634.5'
T.O.C. AT 635.7'
DEPTH
~634 FT
.5'
DG-22 628.0' (PROJ 5'W)
DG-13 628.0' (PROJ 1'E)
TP-1 628.0' (PROJ 6'E)
DG-29 630.0' (PROJ 1'E)
F.F.G. AT 625.0'
4'
14'
24'
34'
ST
OS
12
16
24
32
64
93
5
10
26
70
7
2
15
17
71
46
33
6
39
44
31
51
38
T.D. 33.5'
T.D. 40.0'
T.D. 10.0'
T.D. 35.0'
T.O.C. AT 614.0'
F.F.G. AT 607.0'
DUCT BANK
DUCT BANK
DEPTH OF 12" O.D. DRAIN PIPE
640
630
620
610
600
590
580
ELEVATION (FEET)


DIESEL GENERATOR BUILDING
AT 637.5'
T.O.C. AT 634.8'
T.O.C. AT 634.5'
DUCT BANK
SOUTH WALL OF TURBINE BLDG
EE'
NORTH
DEPTH
~634 FT
DG 8 625.0' (PROJ 2'E)
DG 28 629.0' (PROJ 5'E)
F.F.G. AT 628.0'
CONCRETE
SAND FILL
CLAY FILL
SAND
DUCT BANK
T.O.C. AT 614.0'
F.F.G. at 607.0'
T.D. 35.0'
T.D. 33.5'
DUCT BANK
640
630
620
610
600
590
580
ELEVATION (FEET)
PROFILE EE'
FROM FIGURE 7.2-, 2.5-
SHEET 15 OF 26
275182

BORING LOG 182

Project	Job No.	Sheet No.	Hole No.
MIDLAND POWER PLANT	7220-101	1 of 2	DG-13

Site	Coordinates	Angle from horiz.	Bearing
Diesel Generator Building	S 5073 E318	90°	

Begun	Completed	Driller	Drill make and model	Hole size	Overburden	Rock	Total depth
9/16/78	9/17/78	Raymond International	CME-45	5"			40.0'

Core recovery	Core boxes	Samples	El. top of casing	Ground el.	Depth/el. ground water	Depth/el. top of rock
		19	629.5	628.0	See Notes	

Sample hammer weight/fall	Casing left in hole: dia./length	Logged by
140 lb. / 30 inches	2"/40.0'	A. S. Marshall

Sample type / dia.	Sample advance (in.)	Recovery (in.)	N	Penetration Blows 0-6"	6-12"	12-18"	Elevation	Depth	Sample	Description and Classification
							628.0	0		
ST 3"	18	16							1	Concrete to 6"; 0-16.5' Man-made fill; Clean Sand, brown, very loose, nonplastic, wet, some clay lenses (SP,CL) (Fill)
ST 3"	18	0							2	
ST 3"	18	14							3	Silty Clay, gray, soft, low plasticity, wet (CL) (Fill)
ST 3"	18	.7						5	4	
ST 3"	18	12							5	
ST 3"	18	12							6	
ST 3"	18	0						10	7	
O 3"	30	24							8	
O 3"	30	19						15	9	
O 3"	12	2	Disturbed				611.5	16.5	10	16.5-24' Clean Sand, brown, dense, nonplastic, wet, trace gravel (SP) (Fill)
SS	18	16	33	9	15	18			11	
SS	18	12	17	6	7	10		20	12	medium dense
SS	18	10	6	5	4	2			13	loose
O 3"	18	0							14	loose
SS	18	18	39	5	15	24	604.0	24	15	24-36' Clean Sand, brown, dense, nonplastic, wet, trace gravel (SP)
								25		
SS	18	18	44	12	17	27			16	
SS	18	18	31	9	14	17			17	
								30		
SS	18	12	51	9	18	33	599.0	35	18	

Notes on water levels, water return, character of drilling, etc.:

1. Drilled with 4" auger to 11', then 5" tricone bit and revert.
2. No significant water loss observed.

Water	Levels
Date	Elevation
9/25/78	622.5
10/11/78	621.5

O-Osterberg Sampler

SS = Split Spoon, ST = Shelby Tube, D = Denison, P = Pitcher, O = Other

Site	Hole No.
Diesel Generator Building	DG-13

106123

075182

BORING LOG

PROJECT: MIDLAND POWER PLANT | JOB NO: 7220-101 | SHEET NO: 2 OF 2 | HOLE NO: DG-13

				Penetration Blows			Elevation	Depth	Description and Classification	Notes
	in.	in.					599.0	35		
							598.0		36-40' Silty Clay, gray, hard, low plasticity, moist (CL)	
SS	18	18	38	10	14	24		39		
							594.0	40	Bottom of hole at 40 feet	

SITE: Diesel Generator Building

HOLE NO: DG-13

2A-210-132

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1 8 0 1 2 3

075182

SHEET 18 OF 26

BORING LOG

Project	Job No.	Sheet No.	Hole No.
MIDLAND POWER PLANT	7220-101	1 of 1	DG-14

Site	Coordinates		Angle from Horiz.	Bearing
Diesel Generator Building	S 5065	E298	90°	

Begun	Completed	Driller	Drill Make and Model	Hole Size	Overburden	Rock	Total Depth
9/19/78	9/20/78	Raymond International	CME-45	5"			30.5'

Core Recovery	Core Boxes	Samples	El. Top of Casing	Ground El.	Depth/El. Ground Water	Depth/El. Top of Rock
		15		628.0	Not Recorded	

Sample Hammer Weight/Fall	Casing Left in Hole: Dia./Length	Logged By
140 lb. / 30 inches		A. S. Marshall

Sample type & dia.	Sample length (in.)	Recovery (in.)	Blows per ft	Penetration Blows 0-6"	6-12"	12-18"	Elevation	Depth	Sample
							628.0	0	
ST 4.5	24	18							1
ST 4.5	24	18							2
ST 4.5	24	18							3
ST 4.5	24	19							4
ST 4.5	24	15							5
SS	18	3	5	3	2	3			6
SS	18	14	18	5	8	10	615.0	13	7
ST 3"	18	15					614.0	14	8
ST 3"	18	0							9
SS	18	10	21	4	9	12			10
SS	18	9	27	7	10	17			11
SS	18	10	22	8	10	12	606.5	21.5	12
SS	12	0	100+	30	78				13
SS	18	18	100	21	40	60			14
SS	18	18	74	18	29	45	597.5	30.5	15

Description and Classification

Concrete to 6"
0-21.5' Man-made fill
Sandy Clay, gray, brown, soft, low plasticity, moist, occasional gravel (CL) (Fill) (sample 1)
stiff at 4' (sample 2)
soft (sample 3)
stiff (sample 4)
stiff (sample 5)
soft (sample 6)

13-14' Slightly silty Sand, brown, medium dense, nonplastic, wet (SP-SM) (Fill) (sample 7)

soft (sample 8)
stiff (sample 10)
stiff (sample 11)
stiff (sample 12)

21.5-30.5' Clean Sand, brown, very dense, nonplastic, wet occasional gravel (SP) (samples 13-15)

Bottom of hole at 30.5 feet

Notes on water levels, water return, character of drilling, etc.

1. Drilled with 4" auger to 11', then 5" tricone bit and revert.
2. No significant water loss observed.
3. Hole grouted full depth.

SS = Split Spoon; ST = Shelby Tube; D = Denison; P = Pitcher; O = Other

Site: Diesel Generator Building — Hole No. DG-14

Revision 18
2/79

106123

075182

SHEET 18 OF 26

BORING LOG

Project	MIDLAND POWER PLANT
Job No.	7220-101
Sheet No.	1 of 1
Hole No.	DG-29
Site	Diesel Generator Building
Coordinates	S 5040 E319
Angle from horiz.	90°
Begun	10/10/78
Completed	10/11/78
Driller	Raymond International
Drill make and model	Acker Ace
Hole size	4"
Total depth	35.0'
Samples	10
El. top of casing	634.0
Ground el.	630.0
Depth/el. ground water	13.5'/620.5'
Sample hammer weight/fall	140 lb. / 30 inches
Casing left in hole: dia./length	2"/30'
Logged by	A. S. Marshall

				Penetration Blows			Elevation	Depth	Sample	Description and Classification	Notes on water levels, water return, character of drilling, etc.
							630.0	0			
SS	18	16	12	5	6	6			1	0-27' Man-made fill 0-23' Clean Sand, brown, medium dense, nonplastic, moist, little gravel (SP) (Fill)	1. Drilled with 4" tricone bit and revert 2. Water loss at 19' 3. No significant water loss observed
SS	18	18	16	7	8	8			2		
SS	18	6	24	4	11	13		5	3		
SS	18	13	32	11	15	17			4	some gravel	
SS	18	16	64	11	30	34		10	5	trace gravel	
SS	18	12	93	27	37	56		15	6		
SS	18	12	5	7	3	2		20	7		
SS	18	12	10	7	6	4	607.0	23	8	23-27' Very sandy Clay, gray, stiff, low plasticity, wet (CL) (Fill) sand, clean in tip of sample 8	
								25			
SS	18	12	26	7	17	13	603.0	27	9	27-35' Clean Sand, brown, medium dense, nonplastic, moist (SP) (Fill)	
								30			
SS	18	18	70	15	24	46	595.0	35	10	Bottom of hole	

Site: Diesel Generator Building — Hole No. DG-29

Revision 18 2/79

BORING LOG

Project	Job No.	Sheet No.	Hole No.
MIDLAND POWER PLANT	7220-101	1 of 1	DG-30

Site	Coordinates	Angle from horiz.	Bearing
Diesel Generator Building	S 5158 W341	90°	

Begun	Completed	Driller	Drill make and model	Hole size	Overburden (ft)	Rock (ft)	Total depth
12/10/78	12//0/78	Raymond International	CME-45	2-15/16			16'

Core recovery (ft/%)	Core boxes	Samples	El. top of casing	Ground el.	Depth/el. ground water	Depth/el. top of rock
		3		635.0	Not Recorded	

Sample hammer weight/fall	Casing left in hole: dia./length	Logged by:
140 lb. / 30 inches		A. S. Marshall

Sample type	Sample advance length	Sample recovery length	Blows/ft	Penetration blows 1st 6"	2nd 6"	3rd 6"	Elevation	Depth	Graphic log	Sample	Description and classification	Notes on water levels, water return, character of drilling, etc.
	in.	in.					635.0	0			0-3' Sandy Clay, gray, stiff, low plasticity, moist (CL) (Fill)	1. Drilled with water and tricone bit.
							632.0	3			3-11' Clean to slightly silty Sand, brown, medium dense, nonplastic, moist (SP,SP-SM) (Fill)	2. No significant water loss observed.
SS	18	18	28	13	15	13		5		1		3. Backfilled with bentonite slurry.
SS	18	14	15	6	7	8	624.0	10 / 11		2	11-16.5' Sandy Clay, gray, hard, low plasticity, moist (CL) (Fill)	
SS	18	14	33	4	13	20		15		3		
							618.5	16.5			Bottom of hole at 16.5 feet	
								20				

SS = Split spoon; ST = Shelby tube; D = Denison; P = Pitcher; O = Other

Site	Hole No.
Diesel Generator Building	DG-30

106123

075182

BORING LOG

PROJECT	JOB NO.	SHEET NO.	HOLE NO.
MIDLAND POWER PLANT	7220-101	1 of 1	DG-31

SITE	COORDINATES	ANGLE FROM HORIZ.	BEARING
Diesel Generator Building	S 5050 E295	90°	

BEGUN	COMPLETED	DRILLER	DRILL MAKE AND MODEL	HOLE SIZE	OVERBURDEN (FT.)	ROCK (FT.)	TOTAL DEPTH
12/11/78	12/11/78	Raymond International	Acker Ace	3 3/4"			19.5'

CORE RECOVERY (FT./%)	CORE BOXES	SAMPLES	EL. TOP OF CASING	GROUND EL.	DEPTH/EL. GROUND WATER	DEPTH/EL. TOP OF ROCK
		4		630.5	Not Recorded	

SAMPLE HAMMER WEIGHT/FALL	CASING LEFT IN HOLE: DIA./LENGTH	LOGGED BY:
140 lb. / 30 inches		A. S. Marshall

Sample Type	Sample Advance Length	Sample Recovery Length	Standard Penetration Resistance	Penetration Blows 1st 6"	2nd 6"	3rd 6"	Elevation	Depth	Sample No.	Description and Classification	Notes on: Water Levels, Water Return, Character of Drilling, etc.
	in.	in.					630.5	0			
SS	18	18	14	6	7	7			1	0-2.5' Clean to slightly silty Sand, brown, medium dense, nonplastic, moist (SP,SP-SM) (Fill)	1. Drilled with water. 2. No significant water loss observed during drilling.
							628.0	2.5		2.5-4' Concrete	
SS	18	12	11	7	5	6	626.5	4	2	4-14' Sandy Clay, brown, gray, stiff, low plasticity, moist (CL) (Fill)	
SS	18	18	37	9	17	20	616.5	14	3	14-18' Clean to slightly silty Sand, brown, dense, nonplastic, moist, some gravel (SP) (Fill)	
SS	18	10	11	23	6	5	612.5	18	4	18-19.5' Sandy Clay, brown, gray, stiff, low plasticity, moist (CL) (Fill)	
							611.0	19.5		Bottom of hole at 19.5 feet	

SS - SPLIT SPOON; ST - SHELBY TUBE; D - DENISON; P - PITCHER; O - OTHER

SITE	HOLE NO.
Diesel Generator Building	DG-31

106123

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CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

UNRESIZED
LOG OF BORING. COE-10 U75182

project: MIDLAND NUCLEAR PLANT	project no. 81C217
location: MIDLAND, MICHIGAN	elevation & datum: +638.9 FT (USGS); COORDINATES: S 5050, E 330
drilling agency: B & G DRILLING	date started: 15 APRIL '81; date finished: 16 APRIL '81
drilling equipment: MOBILE B-56	completion depth: 42.5 FT; rock depth: NOT ENCOUNTERED
size & type of bit: 4" ø AUGER, 4 7/8 in TRICONE ROLLER	no. samples: dist. 3; undist. 13; core NONE
casing: 5 in. ID STEEL	water level: first N/A; compl. N/A; 24 hr. N/A
casing hammer: N/A; weight N/A; drop N/A	driller: LARRY KOBITER; prepared by: LUKE L HEFFERNAN
sampler: OSTERBERG, PITCHER, SPLIT SPOON	supervisor: KEVIN ODEN; reviewed by: 15 Jun 81 James Stenborg
sampler hammer: 2; weight 140 lb; drop 30 in.	

ELEV.	DESCRIPTION	DEPTH SCALE ft	SAMPLES no. loc	type	recov.	penetr. blows/6 in	REMARKS (DRILLING FLUID, FLUID LOSS, DEPTH OF CASING, CASING BLOWS, ETC.)	CASING BLOWS
638.9	BROWN, NONPLASTIC, SAND, FINE-COARSE SUBROUNDED W/ TRACE FINES, OCCASIONAL FINE GRAVEL, DRY-MOIST. (SP)	0–6		AUGER & TRICONE ROLLER	SEE REMARKS		RIG SET UP 0.5 FT WEST AND 0.1 FT. SOUTH OF SURVEY NAIL. DONALD SIBBALD CPCo. APPROVED BORING LOCATION. ADVANCED BORE HOLE TO 4.5 FT W/ 4" ø CFA. SET 5 in. ID CASING TO 3.4 FT. CONTINUE ADVANCING BORE HOLE W/ 4 7/8 in. TRICONE ROLLER BIT AND REVERT DRILLING FLUID TO 60 FT.	N/A
628.9	BROWN, NONPLASTIC, SAND, FINE-COARSE SUBANGULAR - SUBROUNDED, WELL GRADED, MOIST. (SP)	6–8.5	S-1	OS	2.3/2.5 FT	NO PENETRATION	S-1 0.2 FT OF SAMPLE FALLS FROM BOTTOM OF TUBE DURING EXAMINATION. 92% RECOVERY.	
	OCCASIONAL GRAVEL W/ [illegible] SLUDGE, FAINT ORGANIC ODOR	8.5–9.5	S-2	OS	0.9/0.9 FT	NO PT IN SAND	S-2 SAMPLER IS REFUSED AT 9.4 FT DEPTH. HIT HARD MATERIAL AT THIS DEPTH. CPCo. IDENTIFIES MATL AS MUD MAT AND REQUESTS DRILLER TO DRILL THROUGH IT. 89% RECOVERY	
628.9	CONCRETE	9.5–10.8		ROLLER BIT	9.5 in TRICONE	ROLLER BIT	DRILLED OUT WITH ROLLER BIT.	
	NO SAMPLE OBSERVED IN FIELD SEE REMARKS.	10.8–13	S-3	OS	SEE REMARKS		S-3 TUBE BADLY CRIMPED FROM ITS BOTTOM TO 1.4 FT UP. THE REST OF THE TUBE IS OUT OF ROUND. UNABLE TO CLEAN OUT SLOUGH ON TOP OF SAMPLE OR EXAMINE BOTTOM OF SAMPLE. UNABLE TO RECORD ACCURATE RECOVERY FIGURE.	
	HARD, BROWN AND GRAY, LOW-MED PLASTIC, SILTY CLAY W/ [illegible]	13–						

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Fig. A-4

DESIRED OF BORING CCE-10

Elev.	DESCRIPTION	DEPTH SCALE ft	SAMPLES no. loc	type	recov.	penetr. resist bl/6in	REMARKS (DRILLING FLUID, FLUID LOSS, DEPTH OF CASING, CASING BLOWS, ETC.)	CASING BLOWS
	HARD, BROWN AND GRAY, LOW-MED PLASTIC SILTY CLAY W/TRACE-SOME SAND, OCCASIONAL FINE GRAVEL, MOIST. (CL)	15	S-4 (cont.)	PS	1.1/2.5 FT.	PP > 4.5 TSF	S-4 DRILLING INDICATES SOFTER MATL. (INCREASED DRILLING RATE) FROM 15.8 - 15.7 FT. 44% RECOVERY.	↑
	LESS SAND, BECOMES WET.	16	S-5	OS	2.5/2.5 FT SEE REMARKS	NO PP ON SAND	S-5 0.2 FT OF SAMPLE FALLS FROM TUBE UPON EXTRACTION. SAND MOVES TO BOTTOM OF TUBE BEFORE EXAMINATION OF SAMPLE. THE SAMPLE RETAINED ITS PLACE AT THE BOTTOM OF THE TUBE.	
	BROWN, NONPLASTIC, SAND, FINE-MED, SUBROUNDED, POORLY GRADED W/TRACE FINES, OCCASIONAL GRAVEL, WET. (SP) FILL	17, 18						
14.9	NO RECOVERY	19, 20	S-6A	OS	0.0/2.5	—	S-6A NO RECOVERY - UPON EXTRACTION, BROWN FLUID (SAND AND DRILL FLUID) RUNNING OUT OF BOTTOM OF TUBE. TUBE WAS NOT DAMAGED. S-6B SECOND ATTEMPT TO RETAIN SAMPLE FROM 18.5 TO 21.0 FT. (PUSH 0.3 FT BELOW PREVIOUS ATTEMPT) OSTERBERG SAMPLER USED. RECOVERY 0.7/2.5 FT (28%)	
	BROWN, NONPLASTIC SAND, FINE-MED. SUBROUNDED, W/TRACE FINES, WET. (SP)	21	S-6B	SEE REMARKS				
	W/OCCASIONAL GRAVEL	22, 23	S-7	OS	2.3/2.5 FT	NO PP ON SAND	S-7 TUBE BENT ON BOTTOM. OUT OF ROUND. 92% RECOVERY.	
09.9	W/TRACE ORGANICS	24, 25	S-8	OS	SEE REMARKS	NO PP ON SAND	S-8 SAMPLE AT TOP OF TUBE AND BOTTOM OF TUBE. POSSIBLE SEPARATION OF SAMPLE IN TUBE. UNABLE TO ACCURATELY MEASURE RECOVERY. BOTTOM OF TUBE IS BADLY CRIMPED.	N/A
	SAND SIZE BECOMING VERY FINE, W/OCCASIONAL FINE GRAVEL	26, 27	S-9	OS	2.5/2.5 FT	NO PP ON SAND	S-9 100% RECOVERY	
04.9	MIXED COLORS, NON PLASTIC SAND, MED-COARSE, SUBANGULAR-SUBROUNDED, WELL GRADED; W/TRACE FINE GRAVEL, WET. (SW)	28, 29, 30	S-10	OS	2.1/2.5 FT.	NO PP ON SAND	S-10 BOTTOM OF TUBE BENT. 84% RECOVERY.	
		31	S-11	OS	2.2/2.5 FT.	N/P ON SAND	S-11 88% RECOVERY	

106123

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Fig. A-4

SYNTHESIZED LOG OF BORING CCC-10 . 075182

ELEV. ft	DESCRIPTION	DEPTH SCALE ft	SAMPLES no. inc	type	recov.	penetration resistance bl/6 in	REMARKS (DRILLING FLUID, FLUID LOSS, DEPTH OF CASING, CASING BLOWS, ETC.)	CASING BLOWS
			S-11	Cont.			END OF SHIFT 15 APRIL '81 / START OF SHIFT 16 APRIL '81	↑
	GREENISH-BROWN, NON PLASTIC SAND (V FINE-FINE SUBROUNDED POORLY GRADED) W/ TRACE ORGANICS, FAINT ORGANIC ODOR, WET. (SP)	33 – 35	S-12	OS	2.1/2.5 FT.	[illegible] SAND	S-12 BOTTOM OF TUBE BENT 84% RECOVERY	
	GRADES TO GRAY SILTY SAND (SM)	36	S-13	OS	2.4/2.5 FT.	[illegible] CLAY > [illegible]	S-13 BOTTOM OF TUBE BENT 96% RECOVERY	
536.9	HARD, GRAY, MEDIUM PLASTIC SILTY CLAY W/ TRACE ORGANICS, DRY LT GRAY SILT PARTINGS. (CL)	37						N/A
	W/ THIN LAMINATIONS OF LT GRAY DRY SILT (ROCK FLOUR).	38 – 39	S-14	SS	1.2/1.5 FT.	11 / 25 / 39	SWITCHED TO SPLIT SPOON SAMPLING. S-14 80% RECOVERY N= 64	
		40	S-15	SS	1.1/1.5 FT.	15 / 37 / 53	S-15 73% RECOVERY N= 95	
534.9		41 – 42	S-16	SS	1.5/1.5 FT.	16 / 26 / 45	S-16 100% RECOVERY N= 71	↓
	BOTTOM OF BORING 42.5 FT	43 – 49					A MONITORING WELL WAS INSTALLED IN THIS BORE HOLE.	
526.9		47						

8106123 25182

SHEET 25 OF 26
Fig. A-5

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

REVISED LOG OF BORING COE-10A

SHEET 1 OF 2

project: MIDLAND NUCLEAR PLANT	project no. 81C217
location: MIDLAND, MICHIGAN	elevation & datum: 634.0 (USGS); COORDINATES S 5050, E 327
drilling agency: D & G DRILLING	date started: 27 APRIL '81; date finished: 27 APRIL '81
drilling equipment: MOBILE E-61	completion depth: 23.0 FT.; rock depth: NOT ENCOUNTERED
size & type of bit: 6 IN. Ø AUGER, 4 7/8 IN. Ø TRICONE ROLLER	no. samples: dist. 0; undist. 2; core NONE
casing: 5 IN. I.D. STEEL	water level: first N/A; compl. N/A; 24 hr. N/A
casing hammer: N/A; weight N/A; drop N/A	driller: BARRY THOMASSON; prepared by: LUKE L. HEFFERNAN
sampler: OSTERBERG	supervisor: GEORGE R. HESS
sampler hammer: N/A; weight N/A; drop N/A	reviewed by: James Stenson 15 June 1981

ELEV.	DESCRIPTION	DEPTH SCALE ft	SAMPLES no. loc	type	recov.	penetr. resist.	REMARKS (DRILLING FLUID, FLUID LOSS, DEPTH OF CASING, CASING BLOWS, ETC.)	CASING BLOWS
634.0	LT BROWN, FINE-MED GRAINED POORLY GRADED GRAVELLY SAND w/ TRACE SILT, CLAY, MOIST. (SP)	0–1					RIG SET UP WITHIN 0.1 FT OF CPCo SURVEY NAIL LOCATION. DONALD SIBBALD (CPCo) APPROVED DRILLING LOCATION. BORING WAS ADVANCED w/ 6 IN. Ø CFA TO 2.2 FT. DEPTH. ADVANCEMENT OF BORING WAS CONTINUED w/ 4 7/8 IN. TRICONE ROLLER BIT, AND BENTONITE DRILLING FLUID.	N/A
629.0	LT BROWN, SAND, FINE-MED, POORLY GRADED, W/SOME COARSE SAND, MOIST. (SP) FILL	1–9						
	CONCRETE	9–10						
624.0	HARD, MOTTLED LT BROWN AND GRAY, LOW PLASTIC, SILTY CLAY W/ TRACE FINE-MED SAND, FINE-MED GRAVEL, MOIST. (CL)	10–13	S-1	03	1.7/2.5 FT	APPROX 75 PSI	S-1 END OF TUBE SLIGHTLY BENT 68% RECOVERY	
		13	S-2	03	1.6 FT	350 PSI	S-2 64% RECOVERY	

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CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

REVISED OF BORING CCE-10A

DESCRIPTION 075182	DEPTH SCALE ft	SAMPLES no.loc	type	recov.	penetr. resist bl/6in	REMARKS (DRILLING FLUID, FLUID LOSS, DEPTH OF CASING, CASING BLOWS, ETC.)	CASING BLOWS
V. STIFF - HARD, MOTTLED GRAY BROWN LOW-MED PLASTIC SILTY CLAY W/ TRACE - SOME SAND, TRACE FINE GRAVEL, MOIST. (CL)	15	S-2	CMT	↑	↑		N/A
LT. BROWN, SAND (FINE GRAINED, POORLY GRADED), W/ TRACE SILT, MOIST-WET. (SP)	16	S-3	OS	1.0/1.0 FT	NO PP ON SAND	S-3 100% RECOVERY	
BECOMING WET	17–19	S-4	OS	1.25/2.5 FT	NO PP ON SAND	S-4 END OF TUBE BENT INWARD 50% RECOVERY	
	20					BORING CONTINUED W/ 4 7/8" TRICONE ROLLER BIT AND BENTONITE SLURRY TO NEXT SAMPLE ZONE.	
TRACE FINE GRAVEL, MED. SAND.	21–22	S-5	OS	2.1/2.5 FT	NO PP ON SAND	S-5 84% RECOVERY	
BOTTOM OF BORING 23.0	23					SAMPLING ENDED AT 23.0 FT DEPTH BASED ON COHESIVE SOIL (FILL) LOCATION IN BORING CCE-10.	
	24–31					BORING BACKFILLED WITH BENTONITE-CEMENT GROUT UP TO GROUND SURFACE.	

PRINCIPAL STAFF			
RA		ENF	
D/RA		SCS	✓
A/RA		PAO	
DPRP		SLO	
DRMA		RC	
DRMSP			
DE			
ML			
CL		FILE	

orig+3

Consumers Power Company

Midland Project: PO Box 1963, Midland, MI 48640 • (517) 631-8650

March 4, 1983

Mr. W. D. Shafer, Chief
Midland Project Section
US Nuclear Regulatory Commission
Region III
799 Roosevelt Road
Glen Ellyn, IL 60137

MIDLAND PROJECT GWO 7020
NON Q MATERIALS FOR UNDERPINNING
File: 0485.16 UFI: 42*05*22*04 Serial: CSC-6593

This is to confirm a conversation on site between Glenn Murray of CPCo-SMO and Ron Gardner of Region III on 3/3/83. The purpose of the conversation was to obtain concurrance on the purchase of "non-Q" materials for the underpinning instrumentation for the Service Water Pump Structure (C-194). The following will be purchased "non-Q":

1) Structural shapes for instrument covers
2) Plexiglass for covers
3) Fasteners for covers
4) Expanded metal for covers
5) EMT/Rigid raceway materials
6) Instrument covers for extensometers
7) Gasket material for covers
8) Dead and live end anchors for extensometers
9) Support brackets for instruments
10) PVC pipe for telltales
11) Centralizer material for telltales

The above items will be purchased "non-Q". However, CPCo will invoke Quality Assurance Program Requirements upon receipt and installation.

D. B. Miller
Site Manager

DBM/GMM/dmh

MAR 14 1983

8303170385

TELEPHONE CALL **Midland Project** **GWO 7020**

Route

By Bob Wheeler, Glenn Murray **Of** CPCo Const.

To Dr. Ross Landsman **Of** NRC Region III

Date 3/4/ **19** 83 **Time** 2:30

Subject Slope Layback and Turbine Wall Spalling

File 0485.16
UFI: 42*05*22*04
Serial: CSC-6602

We called Dr. Landsman to discuss the final disposition of the slope layback. The latest revision of the drawings C-1420 and C-1421 as built the existing condition the only work remaining to be done is to place temporary cribbing on the east side of the layback adjacent to the Turbine Building on the Unit II side. Dr. Landsman concurred that this work could be performed under the existing approved work authorization.

We also informed Dr. Landsman of the concrete spalling which has occured on the north wall of the Unit II demineralization room in the Turbine Building. We told him it appeared to happen approximately 1 year ago when Mergantime was installing the first waler for the east access shaft. They apparently drilled too deep when drilling the hole for one of the rock bolts causing the spalling.

The spalling came to our attention on late Thursday afternoon after some of the spalling fell off.

MAR 17 1983

Landsman

February 15, 1983

MEMORANDUM FOR: R. F. Warnick, Director, Office of Special Cases

THRU: W. D. Shafer, Chief, Midland Section

FROM: R. B. Landsman, Reactor Inspector, Midland Section

SUBJECT: LICENSEE PERFORMANCE ON PIERS 12E and 12W

RIII on December 9, 1982, authorized CPCo to initiate work activities pertaining to the drift, excavation and installation of Piers 12E and 12W. Subsequent to that authorization the licensee began work on December 13, 1982. Due to the Diesel Generator Building Inspection I have had only enough time to perform five inspections to determine the acceptability of the licensee's work in regards to these piers including removal of fill concrete, shaft excavation and bracing, bell excavation and bracing, and reinforcing details and proposed concreting activities.

I have identified three concerns since underpinning work began which have been subsequently corrected or are in the process of being corrected by the licensee. They are:

✓ a) That the craftworkmen were not receiving the required amount of specialized remedial soils underpinning training. The licensee has agreed to expand the scope of craft training, but does not have the details worked out to date.

b) That the licensee wanted to use a super plasticizer as an additive to the concrete mix in lieu of good concreting practices, i.e., consolidation by vibration. The licensee after what I consider to be excessive discussions finally agreed to vibrate all underpinning concrete in accordance with good engineering practice.

✓ c) That the third party independent assessment team is not reviewing the design documents for technical adequacy. They are only doing implementation review to assure that the design documents are being followed. From discussions with Stone and Webster personnel, it was determined that this important parameter was not included in their contract. The licensee is presently considering including this in the contract documents.

Besides these three concerns no other issues or deviations from regulatory requirements have been identified.

~~8303210312~~

QA personnel

R. B. Landsman
Reactor Inspector

OFFICE	RIII				
SURNAME	Landsman/ls RBL	Shafer WDS			
DATE	02/14/83				

Consumers Power Company

Donald B Miller, Jr
Site Manager
Midland Project

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		RC	
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DEP			
ML			
		FILE	

February 9, 1983

Mr. Wayne Shafer
United States Nuclear Regulatory Commission
Region III
799 Roosevelt Road
Glen Ellyn, IL 60137

MIDLAND PROJECT GWO 7020
SERVICE WATER PUMP STRUCTURE ACTIVITY REVIEW
File: 0485.15.2 UFI: 44*05*22*04 Serial: CSC-6541

On February 2, 1983, Bob Wheeler and Don Sibbald of CPCo met with Ross Landsman and Ron Gardner to discuss Service Water Building open items. Shallow probing for the Service Water Pump Structure, deep probing for the Service Water Pump Structure and dewatering wells for the Service Water Pump Structure were discussed with Dr. Landsman. We were informed by Dr. Landsman that he was still awaiting feedback from Joe Kane of NRR before he could authorize the wells and the deep probing.

Dr. Landsman received a drawing which extended the excavation area associated with the shallow probing for the Service Water Pump Structure. Dr. Landsman said he felt the change from the original excavation was minor and he concurred with the new concept.

D. B. Miller, Jr.
Site Manager

DBM/RMW/lrb

8303140534

FEB 17 1983

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JAN 2 5 1982

Docket Nos.: 50-329/330 OM, OL

APPLICANT: Consumers Power Company

FACILITY: Midland Plant, Units 1 and 2

SUBJECT: SUMMARY OF OCTOBER 2, 1981 MEETING ON SEISMIC MODELS FOR AUXILIARY BUILDING AND SERVICE WATER PUMP STRUCTURES

On October 2, 1981, the NRC staff met in Bethesda, Maryland with Consumers Power Company and Bechtel to discuss seismic models for the Auxiliary Building and Service Water Pump Structure at Midland Plant, Units 1 and 2. Also present were several consultants for the NRC and applicant.

The presentations consisted of a review of information from the applicant's letter to the NRC dated September 30, 1981. Enclosure 1 summarizes the meeting.

Darl Hood

Darl Hood, Project Manager
Licensing Branch #4
Division of Licensing

Enclosure:
As stated

cc: See next page

8202120284

FEB 1 1 1982

MIDLAND

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Geotechnical Engineers, Inc.
ATTN: Dr. Steve J. Poulos
1017 Main Street
Winchester, Massachusetts 01890

To File 0485.16

From GSKeeley, P-14-113B

Date November 4, 1981

CONSUMERS POWER COMPANY

Internal Correspondence

Subject MIDLAND PROJECT - DISCUSSION WITH STAFF AND PRESENTATION OF SEISMIC MODELS FOR AUX BUILDING AND SERVICE WATER PUMP STRUCTURE ON OCTOBER 2, 1981 - FILE 0485.16, B3.7 SERIAL 14968

CC AJBoos, Bechtel
MIMiller, IL&B-Chicago
NWSwanberg, Bechtel
FWilliams, IL&B-Washington
JWCook, P-26-336B (w/o att)
JEBrunner, M-1079
RWHuston, Washington (4)
TJSullivan/DMBudzik, P-24-517A
TRThiruvengadam, P-14-400

Attendees:

Consumers Power Company	NRC	Bechtel
D Budzik	M Bloom*	C McConnel
B Henley	A Hodgen*	B Shunmugavel
G Keeley	D Hood	N Swanberg
T Thiruvengadam	J Kane	
	R Landsmann*	
	W Paton*	
	F Rinaldi	

Consultants

J Grundstrom, Corps of Engineers
J Matra, Naval Surface Weapons Center
H Singh, Corps of Engineers
D Wesley, Structural Mechanics Associates
F Williams, Isham, Lincoln & Beale

* Part time

PRINCIPAL AGREEMENTS:

Consumers Power Company and Bechtel provided a summary presentation of the seismic models for the Midland Auxiliary Building and Service Water Pump Structure (SWPS) which were transmitted to the NRC by J W Cook to H R Denton memo of September 30, 1981. The viewgraphs used for this presentation are attached.

Consumers Power Company concluded by stating that the results of the new analysis are comparable to the original analysis presented in the FSAR, the present model is more detailed than the model in the FSAR, but the basic criteria and techniques are the same. Production work with the seismic models is starting. It is Consumers' position that the present submittal complies with the Board's requirement in the prehearing conference.

The staff had the following questions regarding the presentation:

ic1181-0902a112

Question 1: What percentage of geometric damping was used?

Answer: Geometric damping is cut off at 10% for horizontal and full damping is used for vertical as discussed in the FSAR and BC-TPO-4A.

Question 2: Is there any vibration in torsional modes for the SWPS?

Answer: The torsional mode is not significant. No torsional excitation is included in the model.

Question 3: Is the SWPS underpinning wall on three sides?

Answer: Yes.

Question 4: How is the Site Specific Response Spectra (SSRS) being factored into the analysis?

Answer: The forces due to the SSE specified in the FSAR generated with the use of the new seismic models are multiplied by 1.5 for design of the underpinning. The use of 1.5 times the FSAR earthquake will permit new structures to meet the SSRS. The remaining structures and equipment will be checked with the new seismic models for the FSAR earthquake.

A seismic margin review will be used for the new SSRS and has been discussed in a letter from J W Cook to H R Denton, September 25, 1981.

Question 5: What is the frequency of the Borated Water Storage Tank (BWST)?

Answer: This will be provided with the BWST model to be presented during the first week of November 1981.

Question 6: Which structures will use the top of fill spectra for the SSRS?

Answer: Diesel Generator Building and Borated Water Storage Tanks.

Question 7: What about the Diesel Fuel Oil Tanks?

Answer Their response is small, and the method of analysis will be similar to buried piping.

Question 8: Will the Board rule on the seismic margin review at the soils hearings?

Answer: It is Consumers Power's position that the issue of seismic margin review for the new SSRS should be reviewed during the OL hearings since the work on this item is yet to be started. However, the issue could be raised during the soils hearings.

Question 9: Has the applicant considered extending the hump of the FSAR earthquake to 7.1 CPS for the SWPS vertical mode?

Answer: It is not expected that the vertical mode will produce high loads, and most probably the effect of the hump will be picked up in the analysis considering the variation of the soil modulus.

Question 10: Does the ± 50% apply to the soil shear modulus?

Answer: Yes.

Question 11: Are the soil springs and dampers based on an equivalent area of the building footprint?

Answer: For the soil springs, an equivalent rectangle is used. For dampers, an equivalent circle is used. Details are provided in the submittal.

After a caucus with the staff, D Hood stated that the staff believes they have a favorable reaction. The remedial actions proposed are an improvement over previous proposals. Timing on the review is a problem. The staff's ability to meet the schedule was explored, and the staff has placed Midland on a priority review basis.

Ongoing discussions are needed on calculational results of the auxiliary building and the concrete cracking.

Assuming that the presentations reflect the submittal, the staff agreed that they have enough information to complete a construction permit level review of seismic model for Aux. Bldg.

It is difficult for the staff to conduct a review and also take part in hearings. The NRC recognizes that Midland has an ambitious schedule for hearings and the operating license safety evaluation report and that ~~their~~ NRCs review is now on the critical path for the licensing and construction of the underpinning.

The staff has a large number of reports to review and will provide a schedule for review on October 7, 1981.

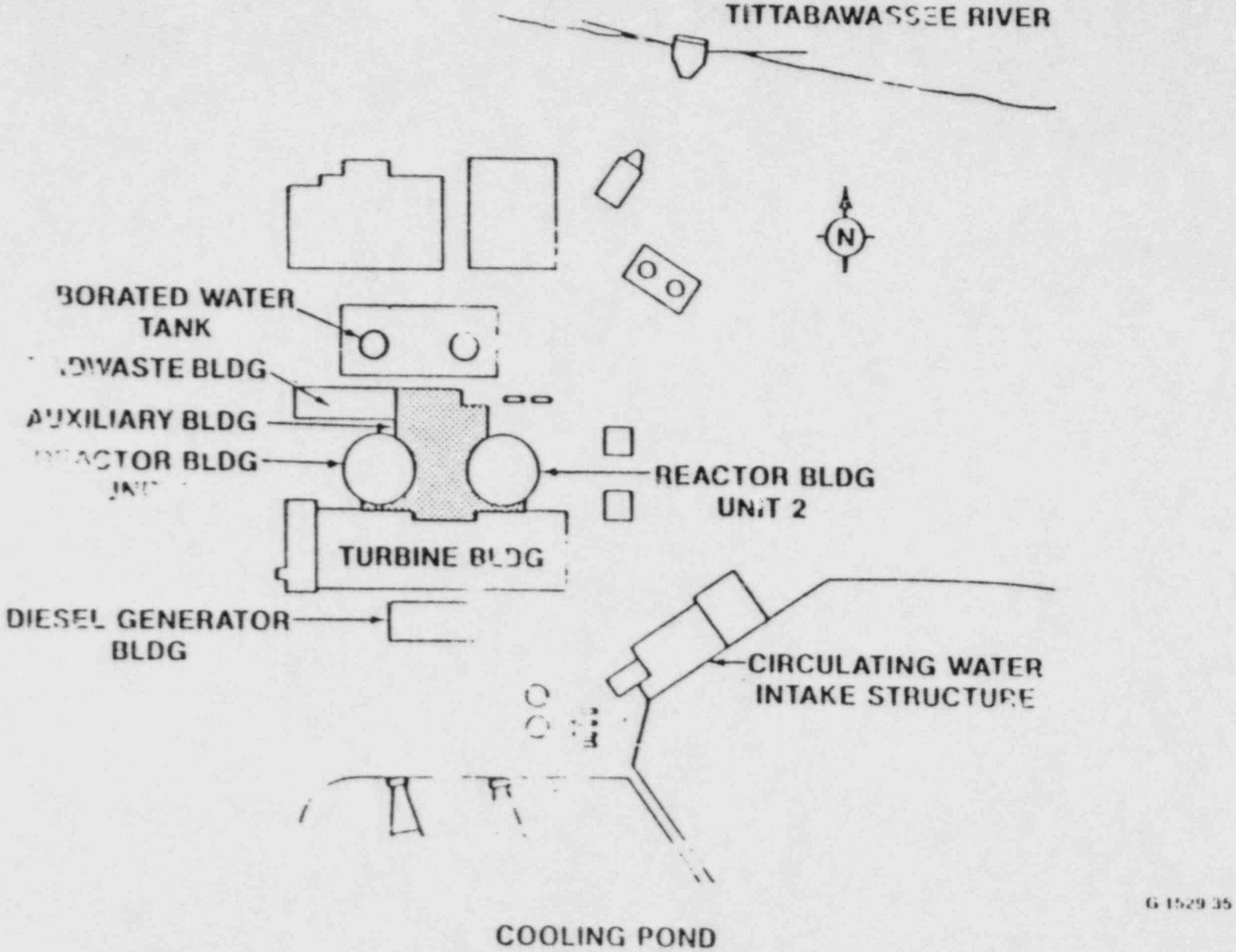
ic1181-0902a112

DYNAMIC MODELS

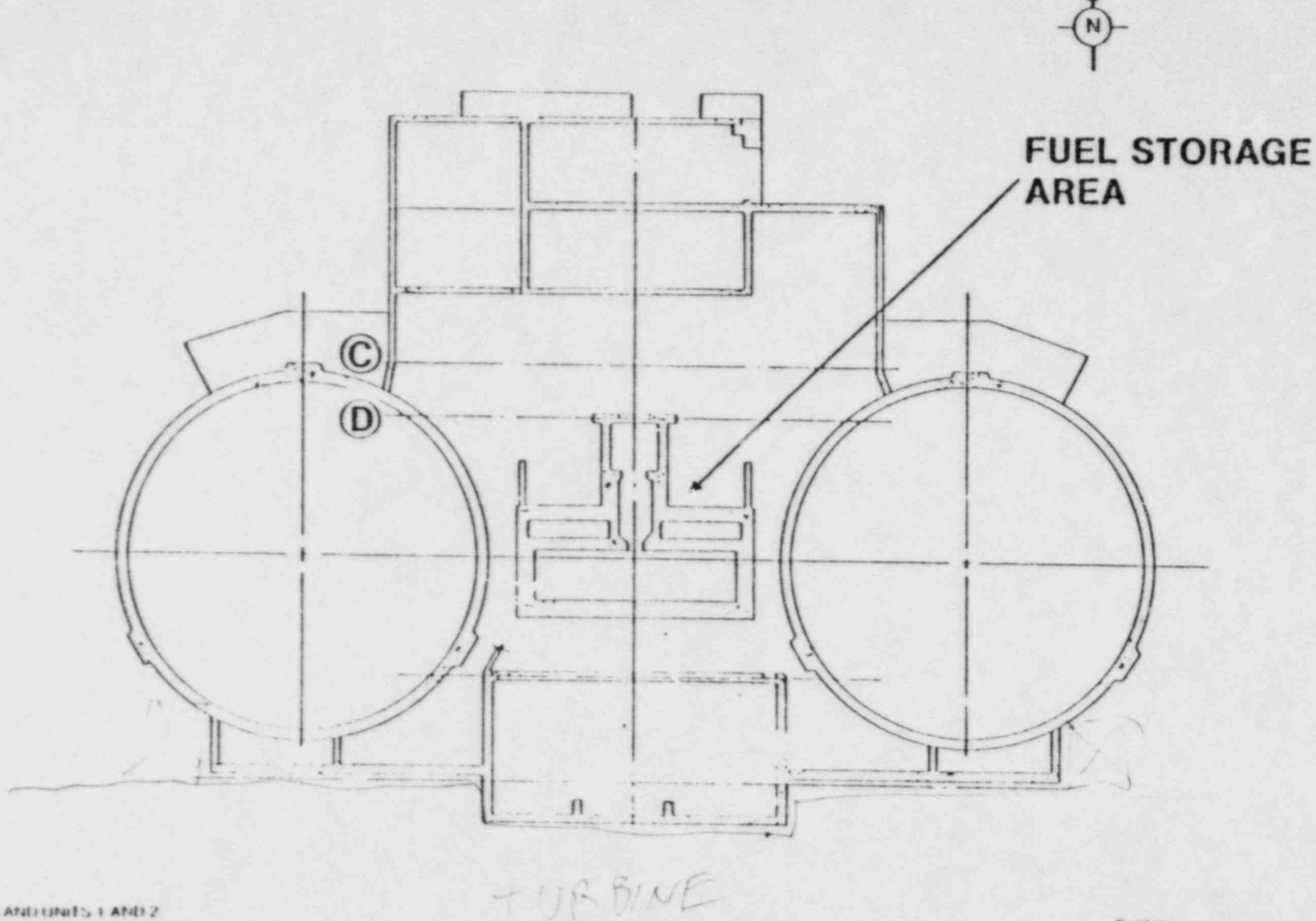
1. INTRODUCTION
   a) NEED FOR ANALYSIS
   b) UNDERPINNING SCHEME
2. METHODOLOGY (3D MODEL AND CRITERIA)
3. MODEL DESCRIPTION
4. SOIL STRUCTURE INTERACTION
5. CONCLUSIONS

SEPTEMBER 29, 1981

MIDLAND SITE PLAN



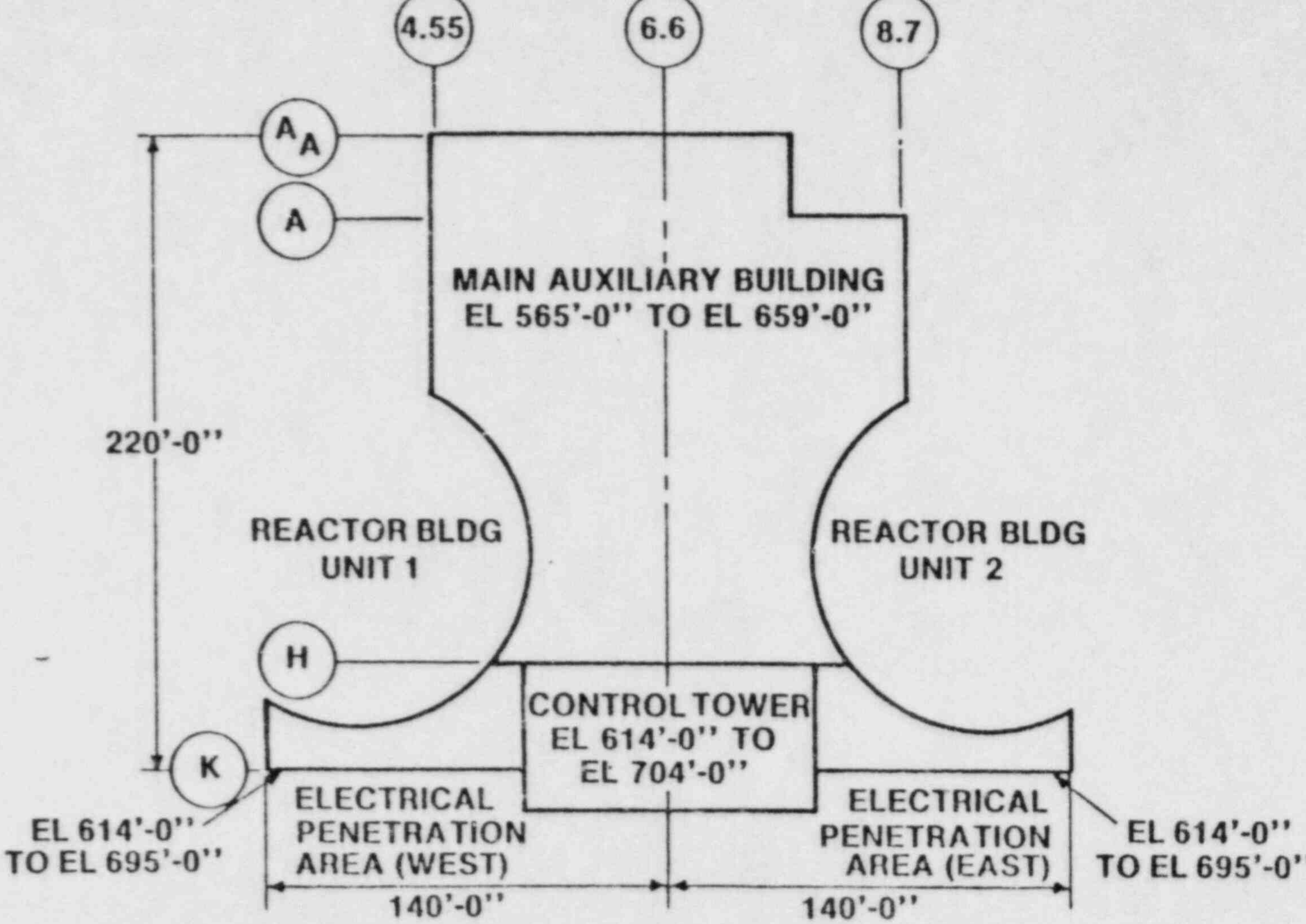
AUXILIARY BUILDING
PLAN AT EL 634'-6"



MIDLAND UNITS 1 AND 2

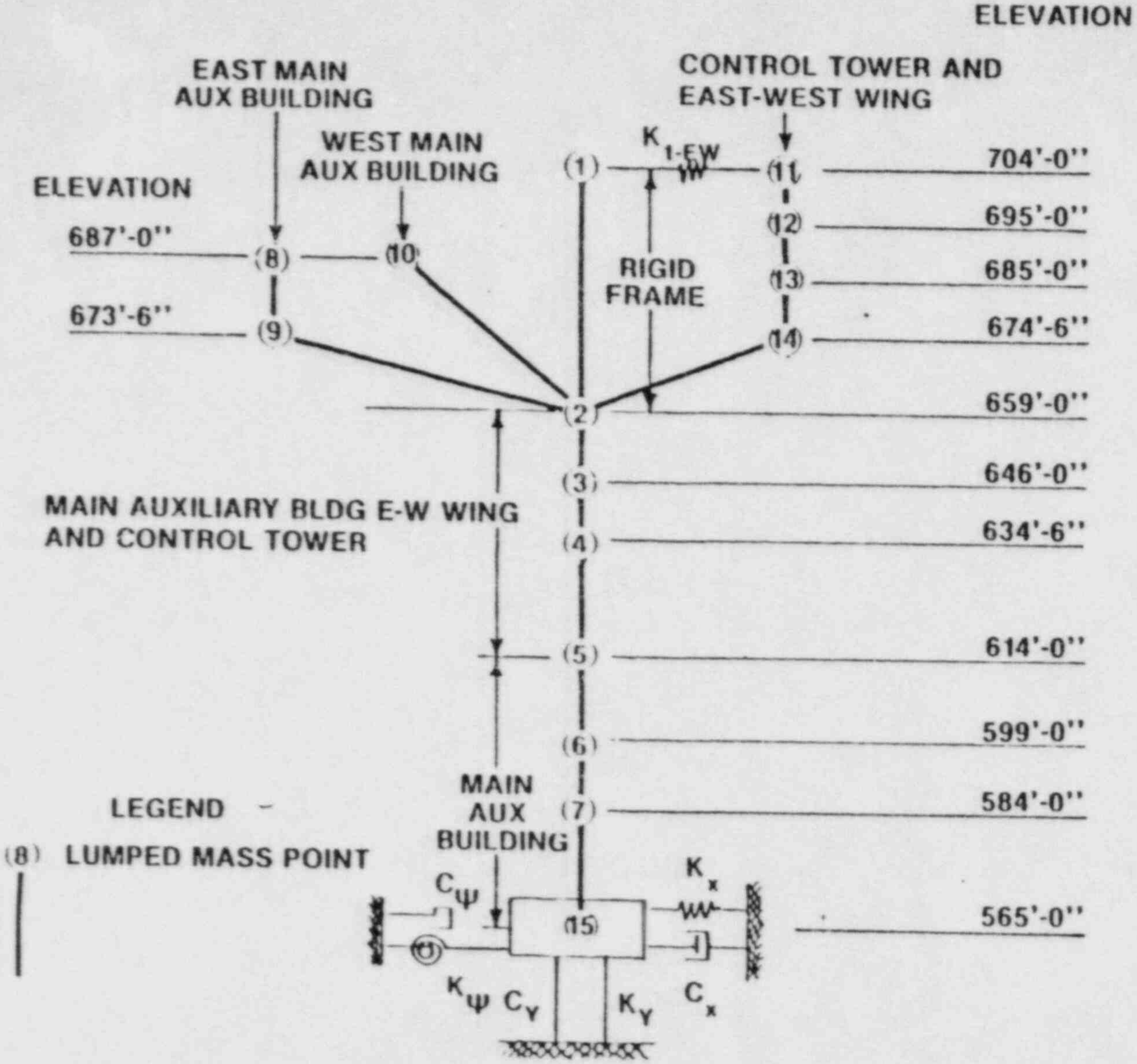
G 1532 18

AUXILIARY BUILDING
SCHEMATIC PLAN



SOIL-STRUCTURE INTERACTION

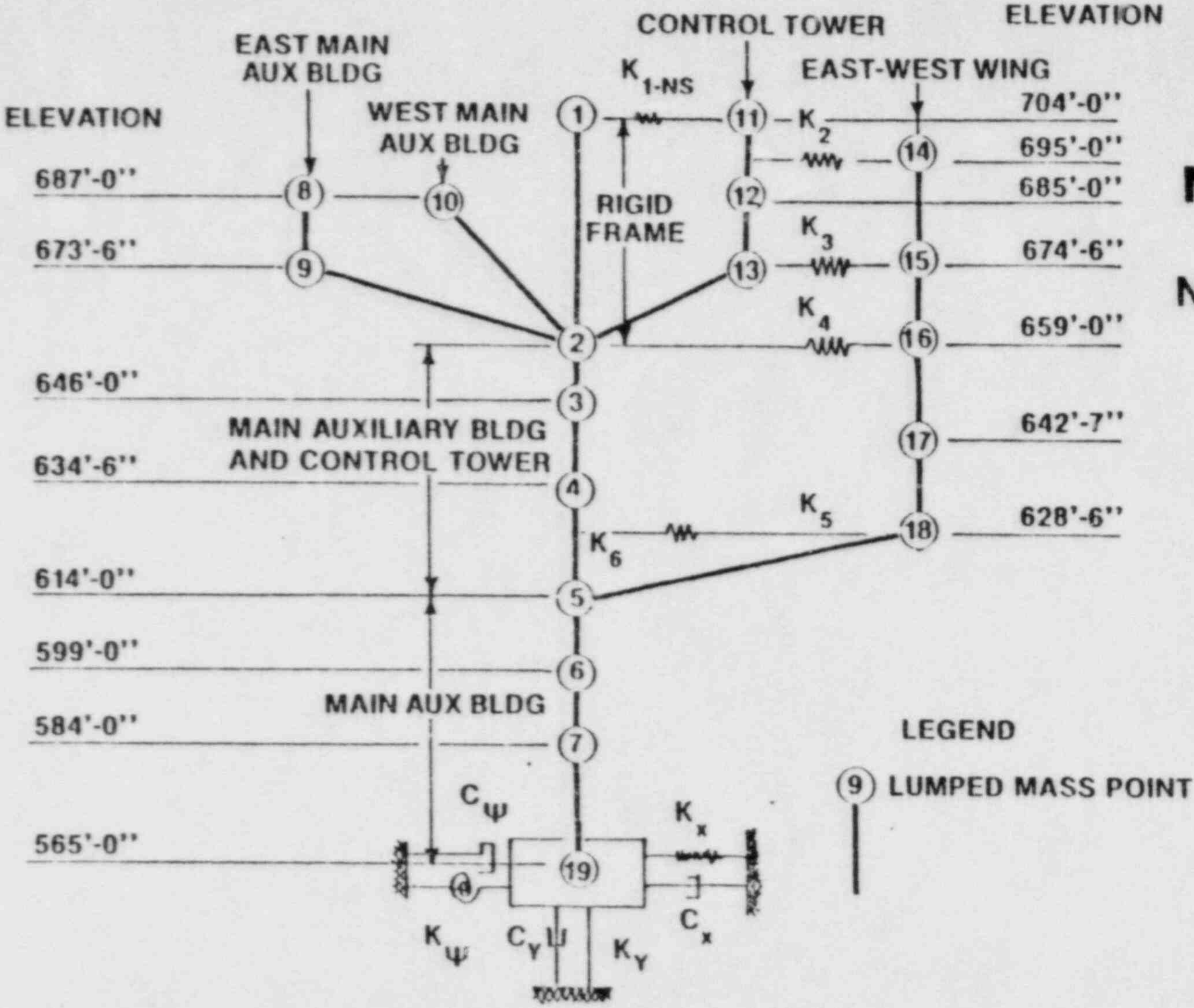
- LUMPED PARAMETER REPRESENTATION
- BASED ON RIGID MAT ON ELASTIC HALF-SPACE
  - Soil Springs
  - Soil Dampers
- COMPOSITE DAMPING
  - Matching Dynamic Amplification Factor
  - Limited to 10% for All Modes Except Those Associated with Rigid Body Motion



AUXILIARY BUILDING MATHEMATICAL MODEL

EAST-WEST EARTHQUAKE AND VERTICAL

FSAR FIGURE 3.7-11



AUXILIARY BUILDING MATHEMATICAL MODEL

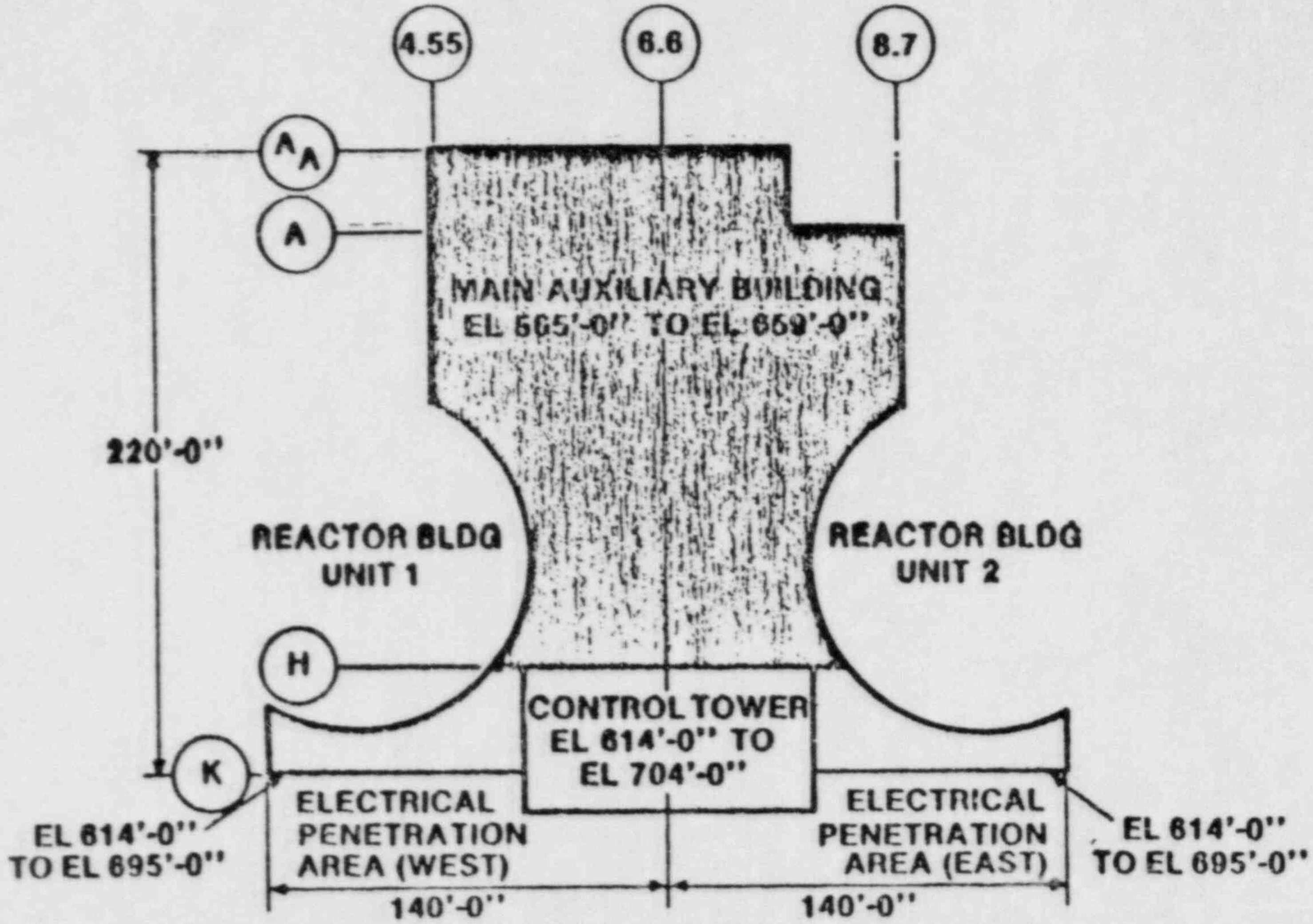
North-South Earthquake

FSAR FIGURE 3.7-10

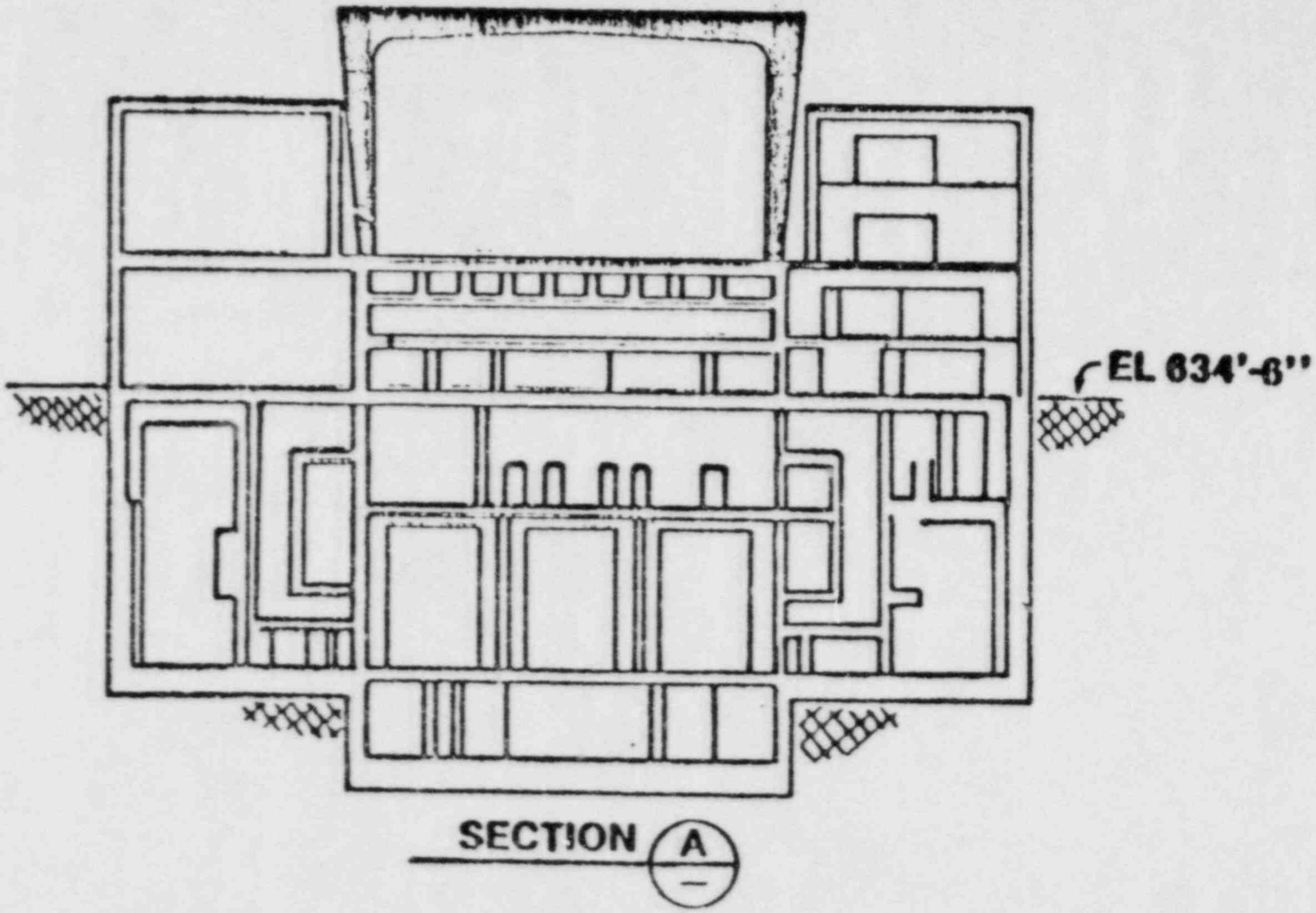
AUXILIARY BUILDING
SEISMIC ANALYSIS

- STRUCTURE GEOMETRY
- SOIL PROPERTIES
- DYNAMIC MODEL
- SOIL/STRUCTURE INTERACTION
- RESULTS

AUXILIARY BUILDING
SCHEMATIC PLAN



AUXILIARY BUILDING
SECTION LOOKING NORTH



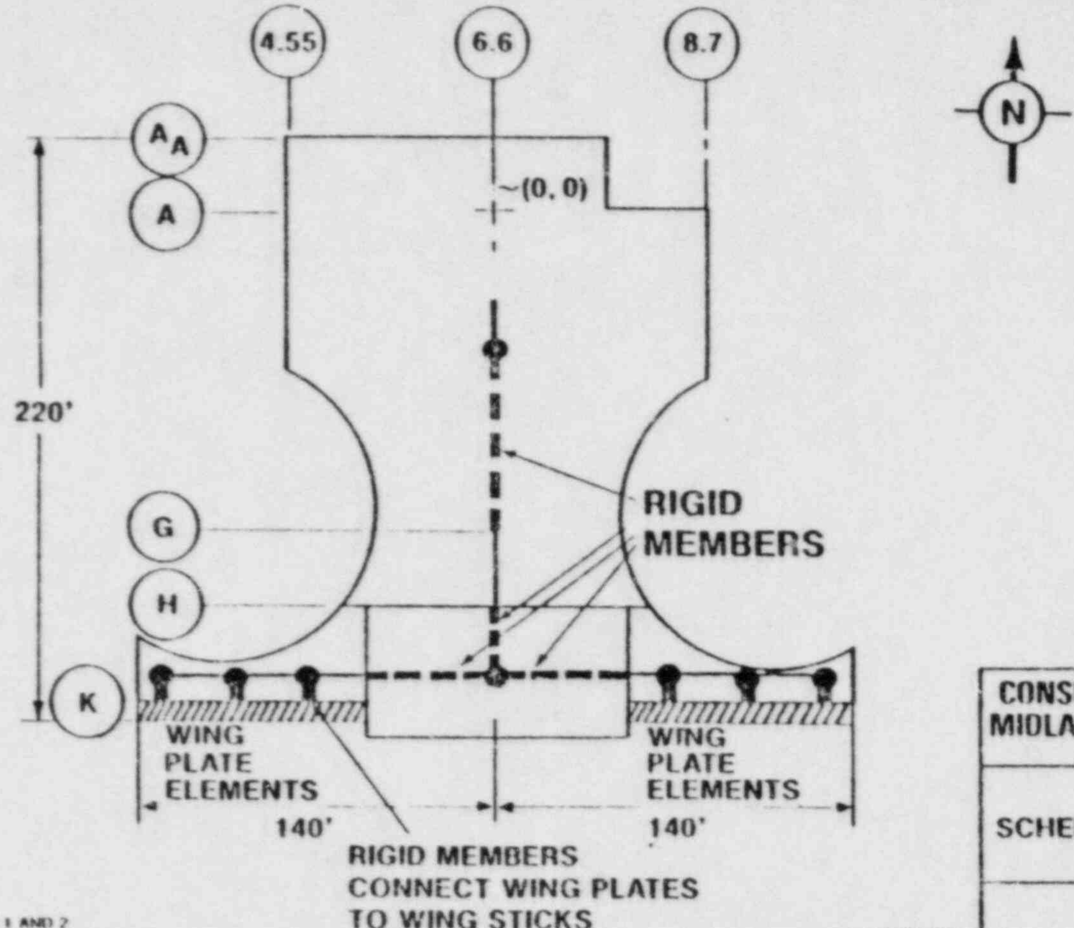
AUXILIARY BUILDING
SEISMIC ANALYSIS
FOUNDATION SOIL PROPERTIES

	Natural	Railroad Bay Area
• Nominal Dynamic Shear Modulus (ksf)	7,746	2,165
• Poisson Ratio	0.42	0.4
• Unit Weight (pcf)	135	120

AUXILIARY BUILDING
SEISMIC ANALYSIS
DYNAMIC MODEL

- THREE-DIMENSIONAL LUMPED MASS STICK MODEL
  - Masses Located at Floor Elevation
  - Beam Elements
  - Plate Elements
  - Rigid Beam Elements

AUXILIARY BUILDING
SCHEMATIC PLAN
(With Conceptual Seismic Model)

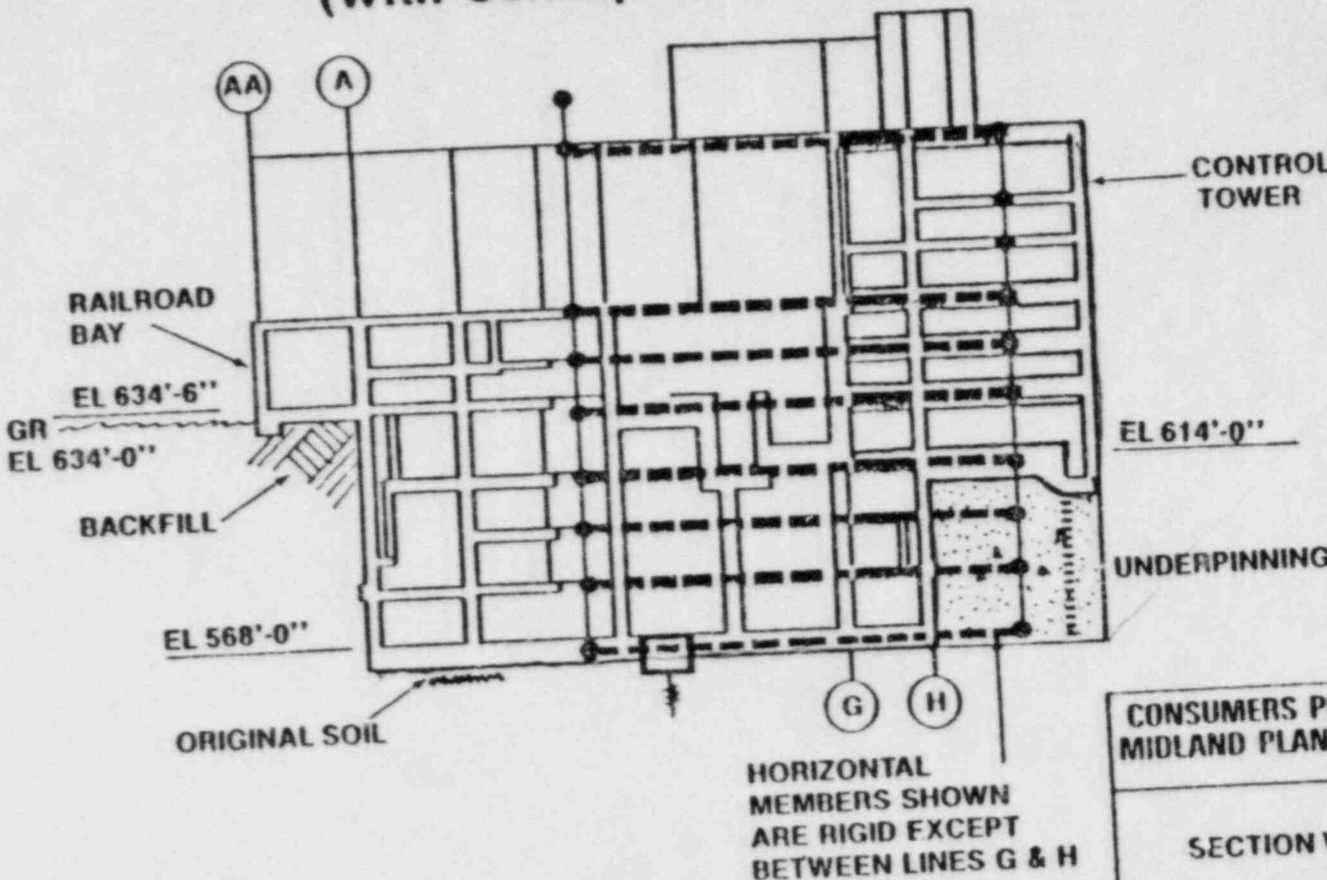


MIDLAND UNITS 1 AND 2
BEC 9/8/81

G 1529 136

CONSUMERS POWER COMPANY MIDLAND PLANT UNITS 1 AND 2
SCHEMATIC PLAN WITH MODEL
FIGURE 2

AUXILIARY BUILDING
TYPICAL SECTION LOOKING EAST
(With Conceptual Seismic Model)

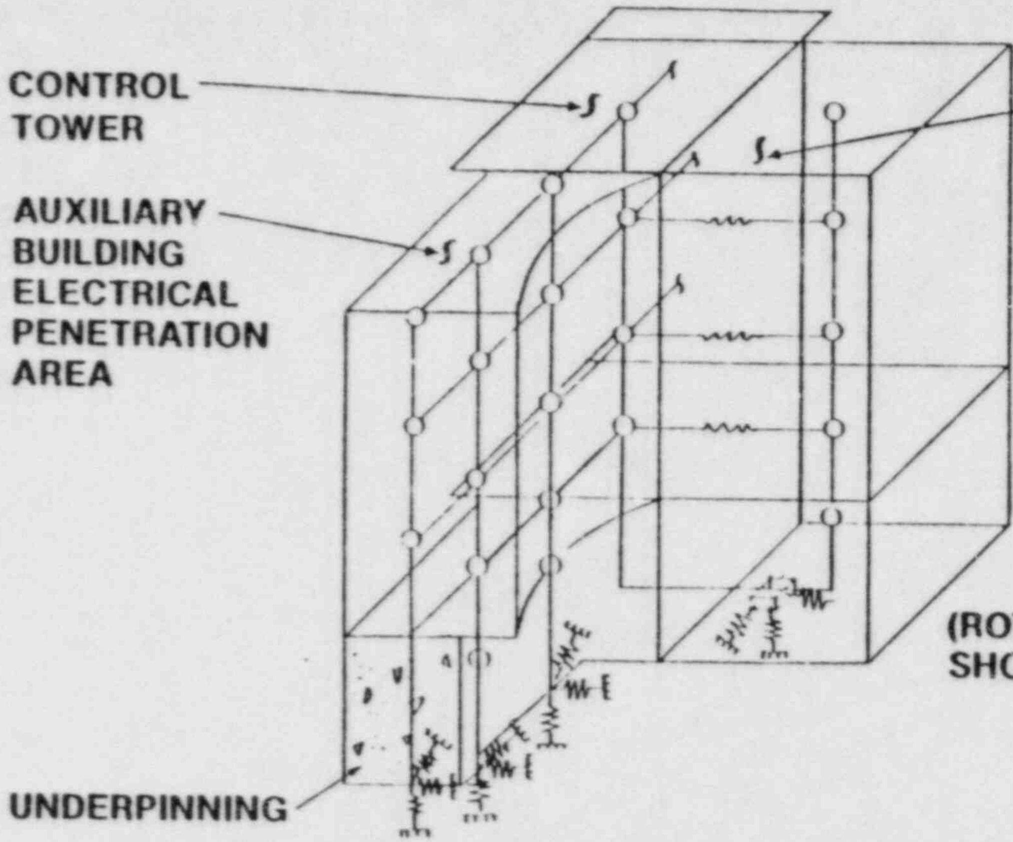


CONSUMERS POWER COMPANY MIDLAND PLANT UNITS 1 AND 2
SECTION WITH MODEL
FIGURE 3

G 1529 134

MIDLAND UNITS 1 AND 2
BI C 9/8/81

AUXILIARY BUILDING
(With Conceptual Seismic Model)



(ROTATIONAL SPRINGS NOT SHOWN FOR CLARITY)

CONSUMERS POWER COMPANY MIDLAND PLANT UNITS 1 AND 2
ROUGH 3-D MODEL
FIGURE 4

MIDLAND UNITS 1 AND 2
REC. 9-8-81

G 1529 133

AUXILIARY BUILDING
SEISMIC ANALYSIS
SOIL/STRUCTURE INTERACTION

- ELASTIC HALF-SPACE IMPEDANCE FUNCTIONS (BC-TOP-4, Rev 3)
  - Equivalent Foundation Soil Properties
  - Equivalent Foundation Area
- SOIL MATERIAL DAMPING (3% of critical)
- EMBEDMENT INFLUENCE (Appendix A)
- DISTRIBUTION OF GLOBAL SPRINGS

AUXILIARY BUILDING
EQUIVALENT SOIL PROPERTIES

- ROCKING

  - $E_{EQUIV} = \frac{I_N E_N + I_F E_F}{I_{TOTAL}}$

  - I_N - Moments of Inertia of Foundation Surface in Contact with In Situ Material

  - I_F - Moment of Inertia of Foundation Surface in Contact with Fill Material

  - E_N - Nominal Dynamic Elastic Modulus of In Situ Material

  - E_F - Nominal Dynamic Elastic Modulus of Fill Material

AUXILIARY BUILDING

EQUIVALENT SOIL PROPERTIES (cont'd)

- TRANSLATION (horizontal)
  - $E_{EQUIV} = \dfrac{A_N E_N + A_F E_F}{A_{TOTAL}}$
  - A_N - Area of Foundation Surface in Contact with In Situ Material
  - A_F - Area of Foundation Surface in Contact with Fill Material
  - E_N - Dynamic Elastic Modulus of In Situ Material
  - E_F - Dynamic Elastic Modulus of Fill Material

AUXILIARY BUILDING
SEISMIC ANALYSIS
EQUIVALENT FOUNDATION AREA

- RECTANGLE

$$I = \frac{bh^3}{12} \qquad A = bh$$

Since A and I are known

$$h = \left(\frac{12\,I}{A}\right)^{1/2}$$

$$b = \frac{A}{h}$$

- EQUIVALENT RECTANGLE IS h × b

AUXILIARY BUILDING
SEISMIC ANALYSIS
EMBEDMENT INFLUENCE
(Appendix A of Report)

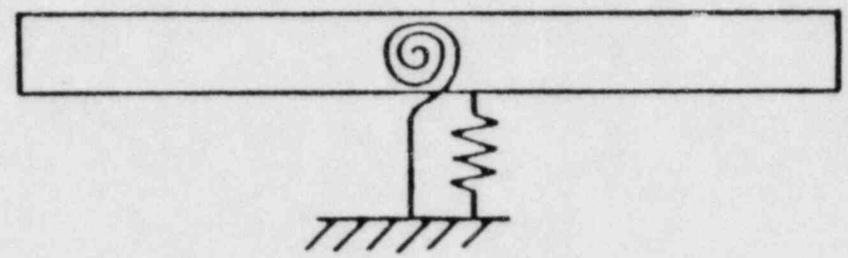
- **BASIC EQUATION**

$$K'_{ii} = K_{ii}\left[1 + (\alpha_{ii} - 1)\frac{G_1}{G_2} f\right]$$

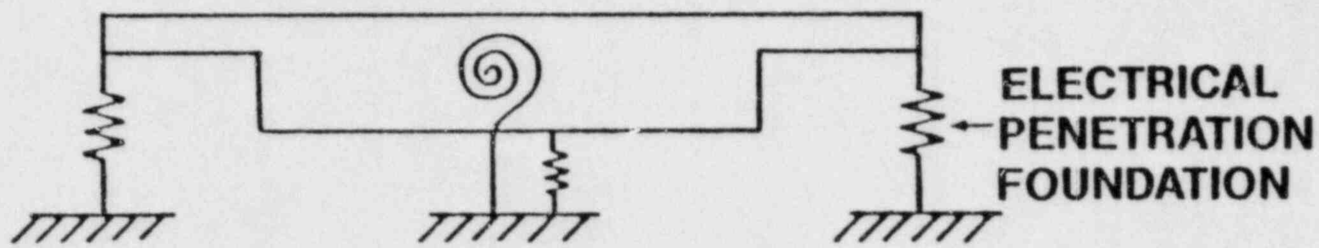
K'_{ii}	=	Elastic Half-Space Spring Adjusted for the Influence of Embedment
K_{ii}	=	Elastic Half-Space Spring
α_{ii}	=	Influence of Full Side Contact
G_1	=	Shear Modulus of Soil Along Building Sides
G_2	=	Shear Modulus of Foundation Soil
f	=	Adjustment for Partial Side Contact

AUXILIARY BUILDING

DISTRIBUTION OF SOIL SPRINGS



ELASTIC HALF-SPACE SPRINGS

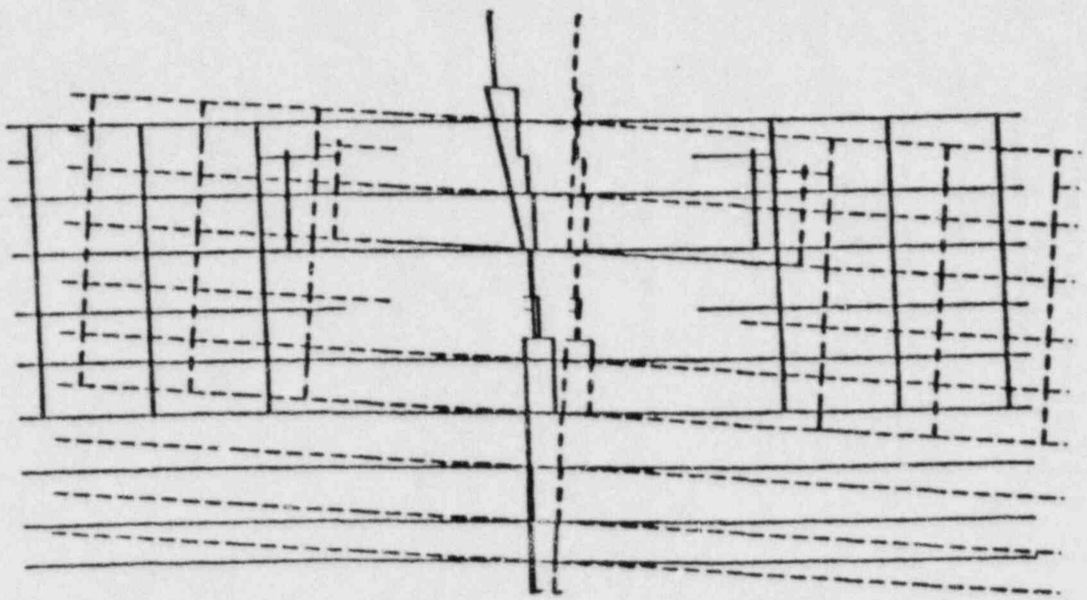


DISTRIBUTED SPRINGS

AUXILIARY BUILDING SEISMIC ANALYSIS RESULTS

- STRUCTURAL BEHAVIOR
  - Primary Frequencies
  - Primary Mode Shapes

AUXILIARY BUILDING
RESULTS

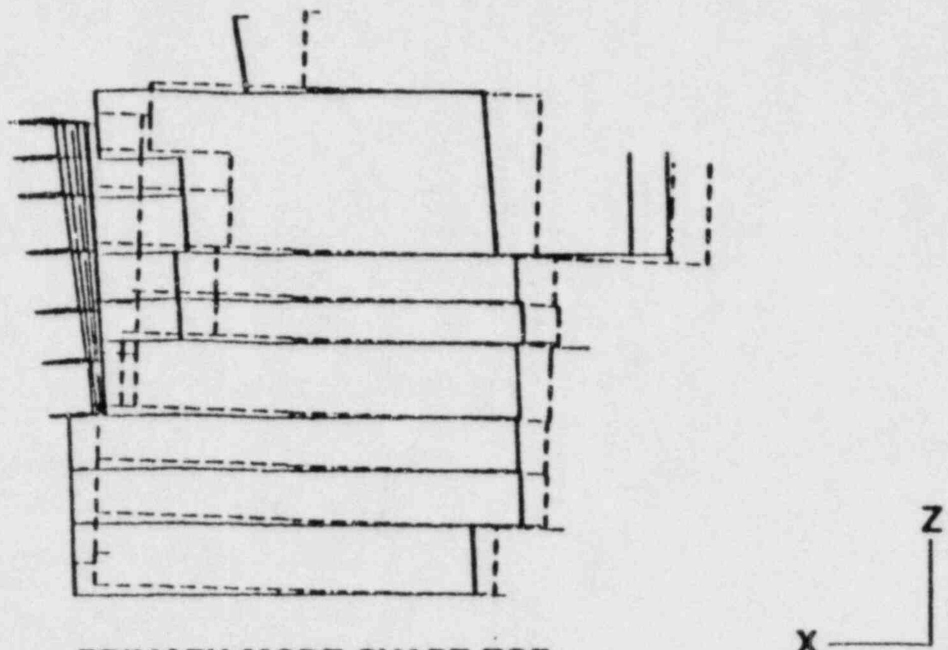


FREQUENCY = 2.8

PARTICIPATION FACTOR = 77

PRIMARY MODE SHAPE FOR EAST-WEST MOTION

AUXILIARY BUILDING
RESULTS



FREQUENCY = 2.9

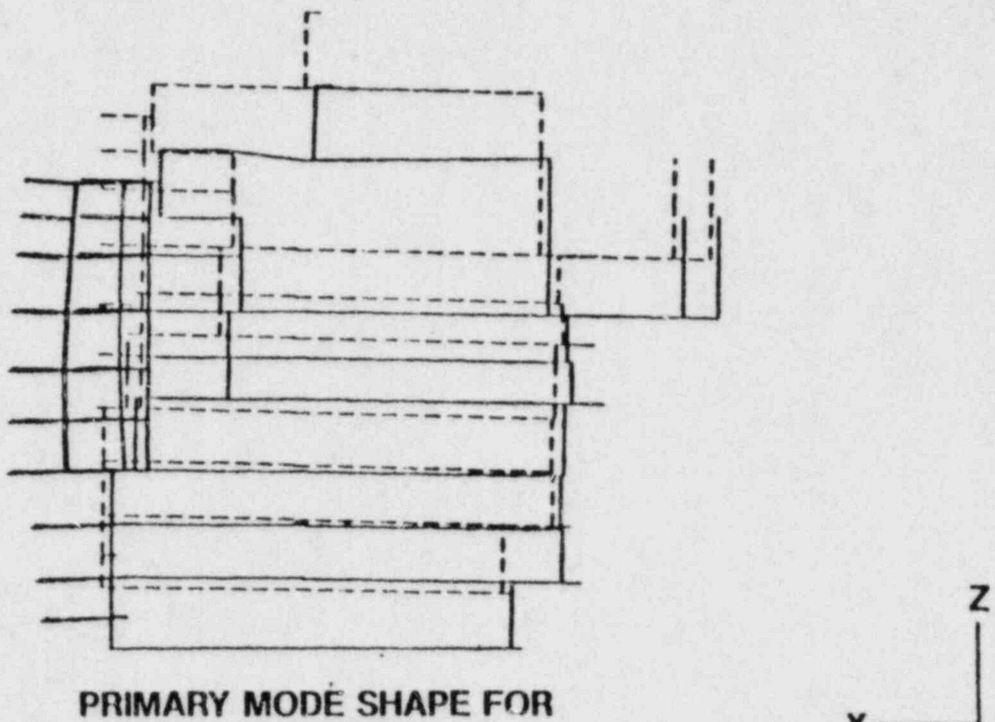
PARTICIPATION FACTOR = 78

PRIMARY MODE SHAPE FOR NORTH-SOUTH MOTION

AUXILIARY BUILDING
RESULTS

FREQUENCY = 4.2

PARTICIPATION FACTOR = 78



PRIMARY MODE SHAPE FOR VERTICAL MOTION

AUXILIARY BUILDING
RESULTS

- BUILDING FORCES
  - Based on Nominal Soil Properties, with Variation of ±50%
  - Mode-byMode Response

    Combined in accordance with NRC Regulatory Guide 1.92

- IN-STRUCTURE SPECTRA
  - Based on Nominal Soil Properties
  - Broadening

    At least ±15% in accordance with Regulatory Guide 1.122

PROPOSED REVISION TO FSAR APPENDIX 3C

COMPUTER PROGRAMS USED IN SEISMIC ANALYSIS OF AUXILIARY BUILDING AND SERVICE WATER PUMP STRUCTURE

RESPONSE SPECTRUM METHOD

TITLE	PURPOSES
BECHTEL STRUCTURAL ANALYSIS PROGRAM (BSAP - CE 800)	SOLVES EIGENVALUE PROBLEM AND CALCULATES STRUCTURAL MODAL DAMPING FOR "FIXED" BASE STRUCTURE RESPONSE SPECTRUM ANALYSIS BY MODAL SUPERPOSITION
BECHTEL STRUCTURAL ANALYSIS PROGRAM (BSAP-DYNAM CE207)	COMPUTES COMPOSITE MODAL DAMPING FOR LUMPED PARAMETER SOIL-STRUCTURE INTERACTION PROBLEM

PROPOSED REVISION TO FSAR APPENDIX 3C

COMPUTER PROGRAMS USED IN SEISMIC ANALYSIS OF AUXILIARY BUILDING AND SERVICE WATER PUMP STRUCTURE

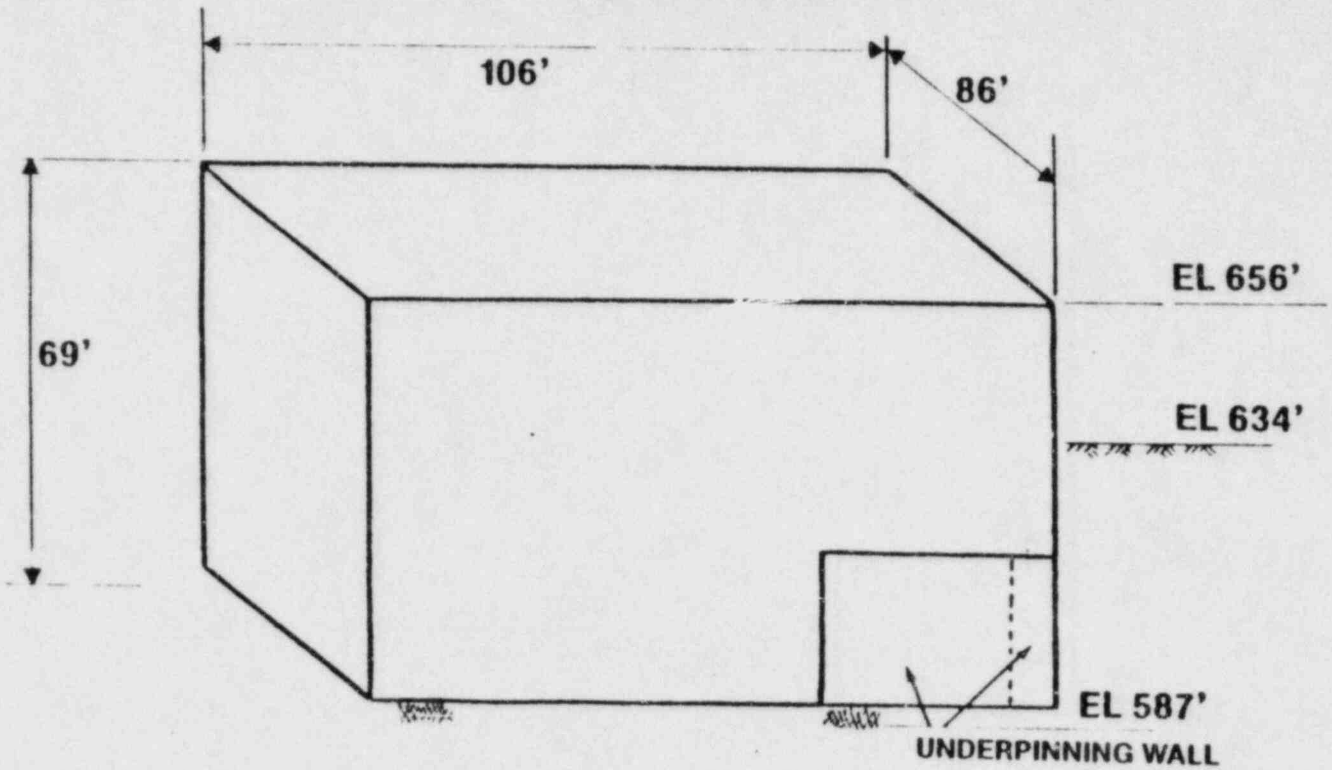
TIME HISTORY ANALYSIS

TITLE	PURPOSES
BECHTEL STRUCTURAL ANALYSIS PROGRAM (BSAP CE800)	SOLVES EIGENVALUE PROBLEM AND CALCULATES STRUCTURAL MODAL DAMPING FOR "FIXED" BASE STRUCTURE TIME HISTORY ANALYSIS BY MODAL SUPERPOSITION
BECHTEL STRUCTURAL ANALYSIS PROGRAM (BSAP-DYNAM CE 207)	COMPUTES COMPOSITE MODAL DAMPING FOR LUMPED PARAMETER SOIL-STRUCTURE INTERACTION PROBLEM
SPECTRA (CE 802)	COMPUTES RESPONSE SPECTRA

SERVICE WATER PUMP STRUCTURE
SEISMIC ANALYSIS

- STRUCTURAL GEOMETRY
- SOIL PROPERTIES
- DYNAMIC MODEL
- SOIL/STRUCTURE INTERACTION
- RESULTS

SERVICE WATER PUMP STRUCTURE



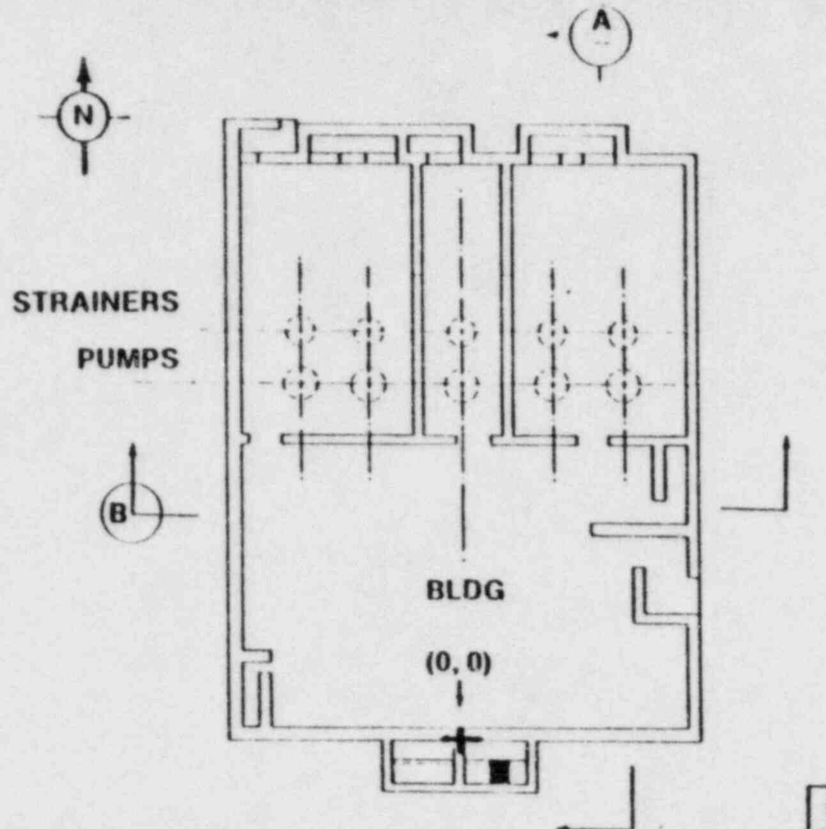
CONSUMERS POWER COMPANY
MIDLAND PLANT UNITS 1 AND 2

SERVICE WATER
PUMP STRUCTURE
SCHEMATIC VIEW

FIGURE 1

G 1858 02
(G 1530-15)

SERVICE WATER PUMP STRUCTURE
PLAN AT EL 634'-6"



CONSUMERS POWER COMPANY MIDLAND PLANT UNITS 1 AND 2
SERVICE WATER PUMP STRUCTURE PLAN
FIGURE 2

G 1858.03
(G 1530.19)

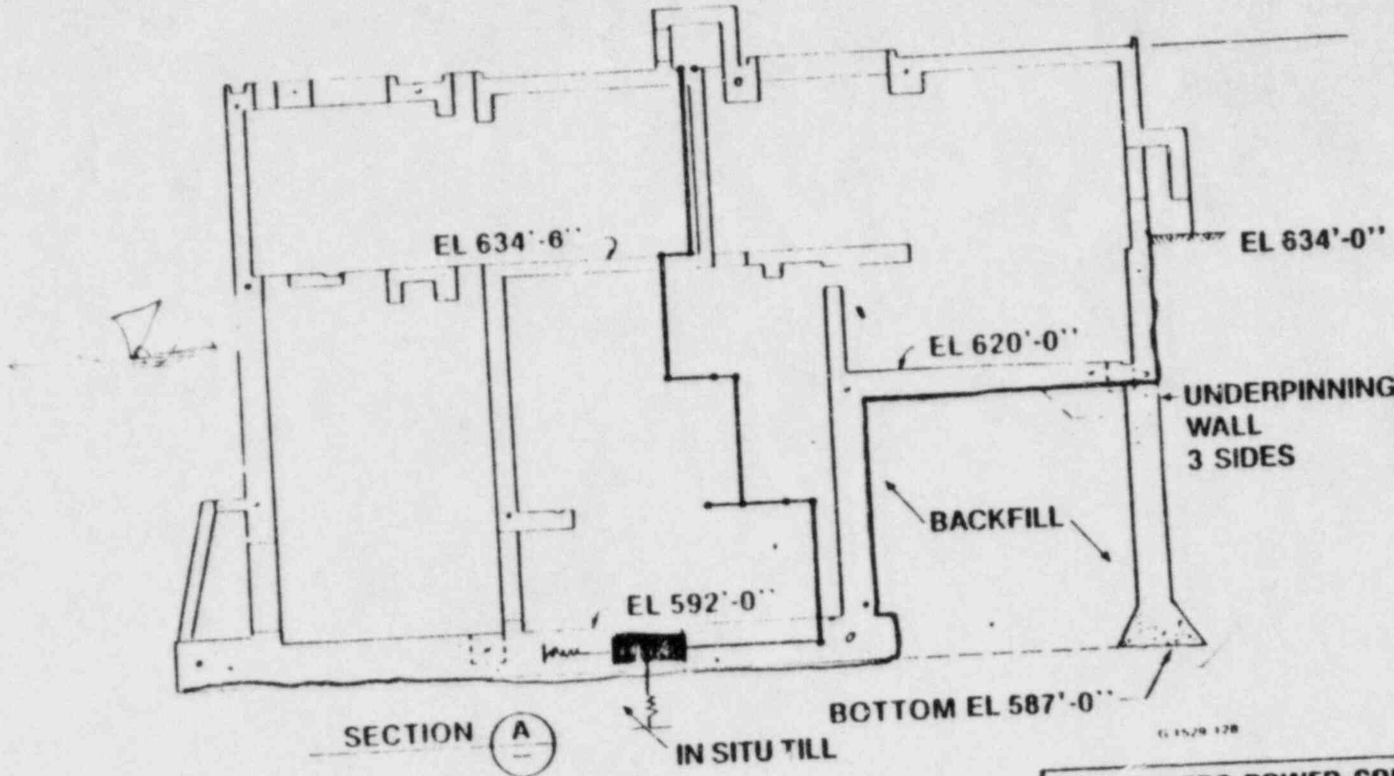
SERVICE WATER PUMP STRUCTURE
SEISMIC ANALYSIS
FOUNDATION SOIL PROPERTIES

	Natural
• Nominal Dynamic Shear Modulus (ksf)	7,746
• Poisson Ratio	0.42
• Unit Weight (pcf)	135

SERVICE WATER PUMP STRUCTURE
SEISMIC ANALYSIS
DYNAMIC MODEL

- **THREE-DIMENSIONAL LUMPED MASS MODEL**
  - **Mass Located at Floor Elevations**
  - **Beam Elements**
  - **Rigid Beam Elements**

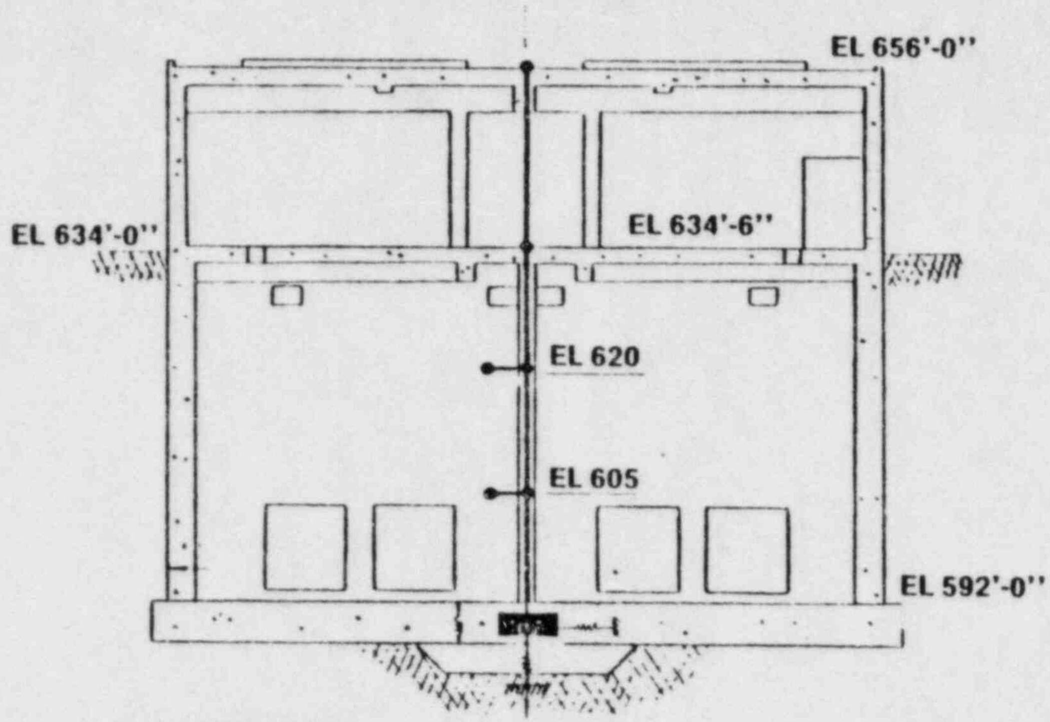
SERVICE WATER PUMP STRUCTURE
SECTION A



CONSUMERS POWER COMPANY MIDLAND PLANT UNITS 1 AND 2
SERVICE WATER PUMP STRUCTURE NORTH-SOUTH SECTION
FIGURE 3

G 1858 04

SERVICE WATER PUMP STRUCTURE
SECTION B



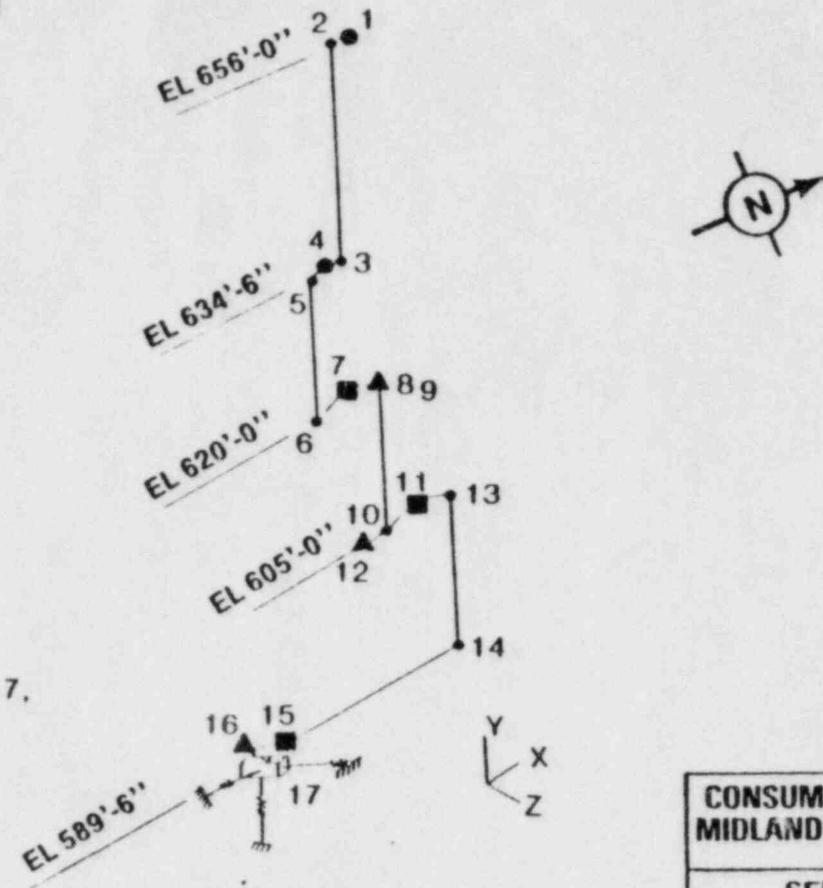
SECTION B

CONSUMERS POWER COMPANY MIDLAND PLANT UNITS 1 AND 2
SERVICE WATER PUMP STURCTURE EAST-WEST VIEW
FIGURE 4

G 1858.05

LEGEND

- • Node locations
- ● Mass for all 3 degrees of freedom
- ■ Mass for two horizontal degrees of freedom
- ▲ Mass for vertical degree of freedom
- Base location. Damper rotational springs not shown for clarity



NOTES:

1. The mass of the water is lumped at mass points 7, 11, and 15 horizontally and at mass point 16 vertically.
2. The mass of the fill entrapped within the underpinning walls is lumped at mass points 7, 11, and 15 for the two horizontal degrees of freedom only.

CONSUMERS POWER COMPANY MIDLAND PLANT UNITS 1 AND 2
SERVICE WATER PUMP STRUCTURE NODE LAYOUT
FIGURE 5

G-1858-01

SERVICE WATER PUMP STRUCTURE
SEISMIC ANALYSIS
SOIL/STRUCTURE INTERACTION

- ELASTIC HALF-SPACE IMPEDANCE FUNCTIONS
  (BC-TOP-4, Rev 3)
  - Equivalent Foundation Area
- SOIL MATERIAL DAMPING (3% of critical)
- EMBEDMENT INFLUENCE (Appendix A)

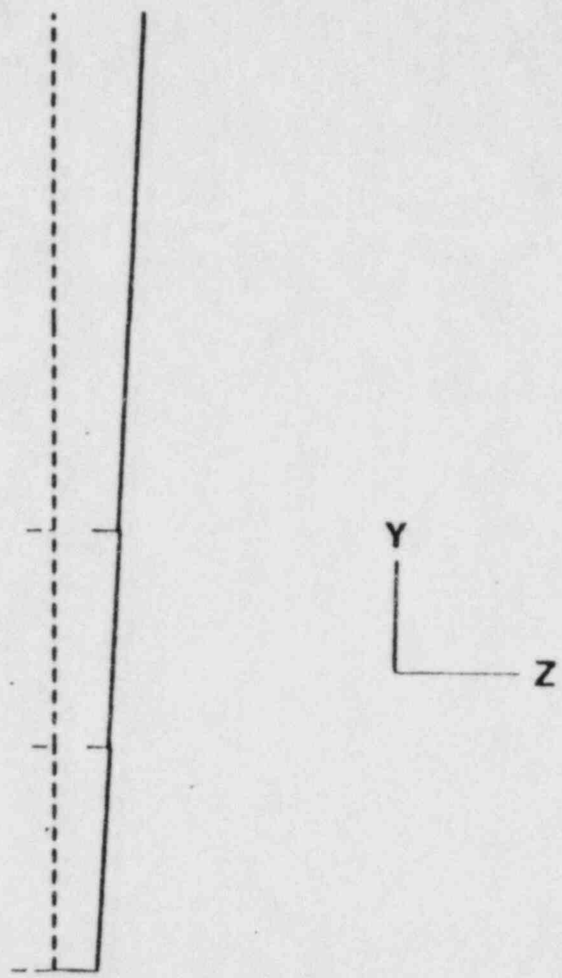
SERVICE WATER PUMP STRUCTURE
RESULTS

- STRUCTURE BEHAVIOR
  - Primary Frequency
  - Primary Modes Shapes

SERVICE WATER PUMP STRUCTURE
RESULTS

FREQUENCY = 4.8

PARTICIPATION
FACTOR = 36

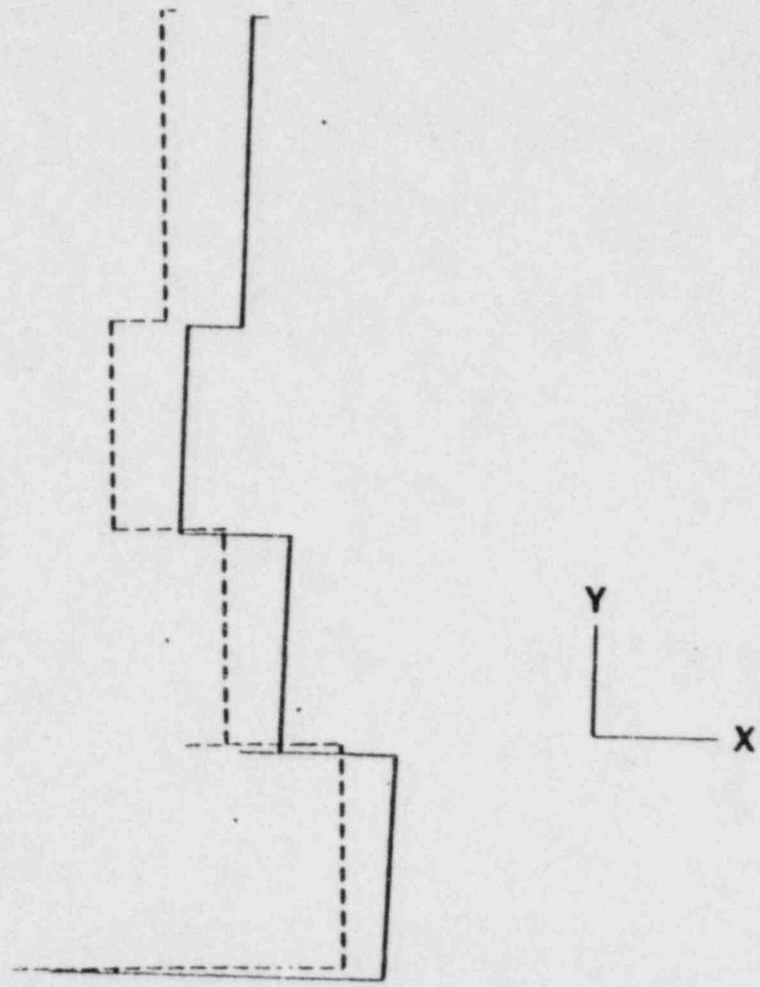


PRIMARY MODE SHAPE FOR
EAST-WEST MOTION

SERVICE WATER PUMP STRUCTURE
RESULTS

FREQUENCY = 4.9

PARTICIPATION FACTOR = 37

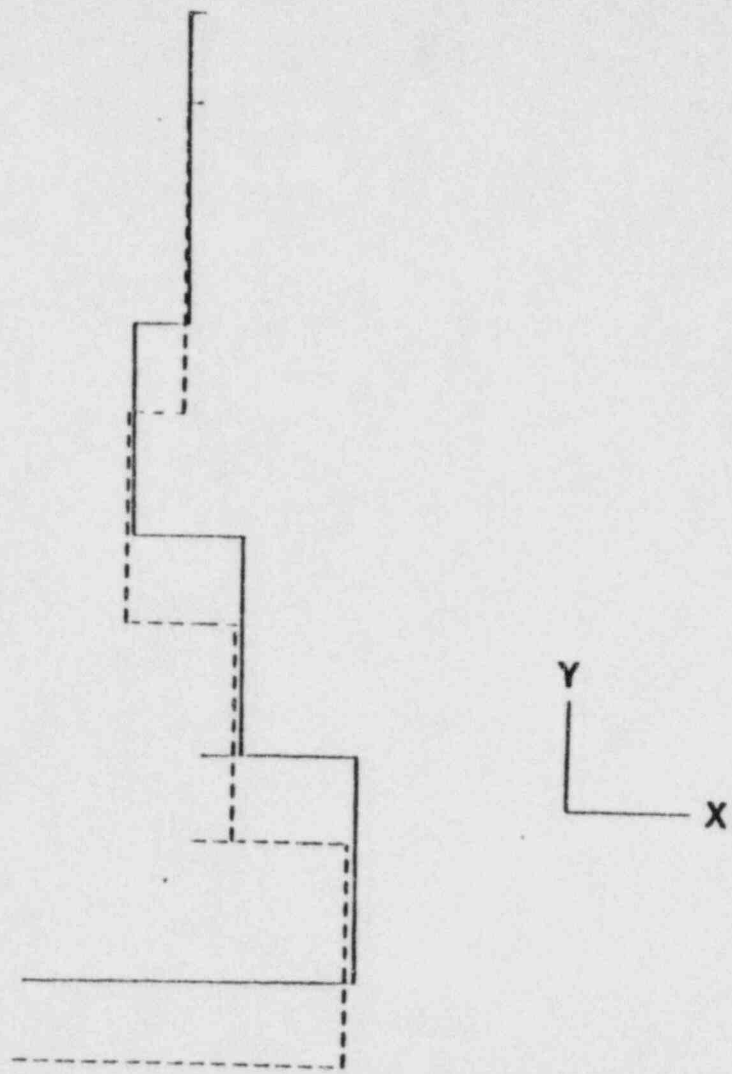


PRIMARY MODE SHAPE FOR NORTH-SOUTH MOTION

SERVICE WATER PUMP STRUCTURE
RESULTS

FREQUENCY = 7.1

PARTICIPATION FACTOR = 35



PRIMARY MODE SHAPE FOR VERTICAL MOTION

SERVICE WATER PUMP STRUCTURE
RESULTS

- BUILDING FORCES
  - Based on Nominal Soil Properties, with Variation of ±50%

- IN-STRUCTURE SPECTRA
  - Based on Nominal Soil Properties
  - Broadening

    At least ±15% in accordance with Regulatory Guide 1.122