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

September 17, 1980

Docket No. 50-133

Mr. P. A. Crane
Vice President and General Counsel
Pacific Gas and Electric Company
77 Beale Street, 31st Floor
San Francisco, California 94106

Dear Mr. Crane:

SUBJECT: Geological Field Trip in the Vicinity of Humboldt Bay Nuclear Power Plant #3

The enclosed trip report is provided for your information. It describes the field trip and site visit to Humboldt Bay Nuclear Power Plant #3 and surrounding region by Dr. Ina B. Alterman, Geologist, on July 14-17, 1980.

Sincerely,

Thomas A. Ippolito, Chief
Operating Reactors Branch #2
Division of Licensing

Enclosure:
Trip Report

cc w/enclosure:
See next page

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cc:

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Field and Trench Observations in the Vicinity of Humboldt Bay Nuclear Power Plant #3

<u>Background</u>: Because of unresolved geologic and seismic issues related to the tectonic instability of the area in which the Humboldt Bay Nuclear Power Plant is located, an Order for Modification of License was issued in May 1976, and the plant shut down until satisfactory compliance with the Order has been determined. In March 1977 PG&E submitted an updated geologic report by their consultants, Earth Science Associates (ESA), in partial fulfillment of the Order requirements, followed by a proposal for a license amendment that would allow restart of the plant. The review of the report by the NRC Geosciences Staff (August 10, 1977) concluded that the evidence provided was insufficient to prove that either of the two faults under consideration were non-capable and recommended that the plant remain in shutdown condition until more conclusive information is provided.

In September 1978, PG&E engaged Woodward/Clyde Consultants (W/C) to undertake a 2-year program of geologic and seismic investigations to resolve the issues. Preliminary results of their study were presented to the NRC staff at a meeting in Bethesda on May 7, 1980, which was attended by representatives of NRC, PG&E and Woodward/Clyde. While they presented no written material, maps, or trench logs, there was general agreement that a geologist from NRC would have to examine the trenches on the plant site before a formal review of their petition to restart is undertaken. Such first-hand information is necessary in assessing the safety of the plant site.

Issues: The geologic and seismic issues in the Order of Modification License (paragraph E.2) that had to be addressed included:

a. The Bay Entrance Fault: the location, age, attitude, amount of displacement and possibility of surface faulting.

b. Little Salmon Fault: same information as above.

c. Origin of displacements in the ravine at Humboldt Hill and the quarry at Fields Landing.

d. Seismic potential of the Freshwater and Table Bluff faults and their relation to the Little Salmon Fault.

e. Seismic monitoring network in the vicinity of the plant.

f. Past and future earthquake monitoring to determine if any local faults are sources of earthquakes around the plant.

The Bay Entrance and Little Salmon faults were the primary focus of the investigation. The concerns relating to these two faults arose from the fact that both appeared to come within one mile of the plant and their capability was not determined. The first reports from ESA concluded that the Little Salmon fault was truncated by an overlying undisturbed sedimentary unit of Plio-Pleistocene age (approximately 1-2 million years) and therefore not capable. The NRC staff, however, found that there was no evidence to prove the age of the capping sediments, nor that the fault was indeed capped. Also, the location and orientation of the fault were not proven to the Staff's satisfaction.

The same reports were not able to show conclusively that the Bay Entrance Fault was not capable, nor were they able to show convincingly the location of the trace with respect to the plant.

One of the major tasks therefore in resolving the issues is dating the sedimentary strata in the area to determine when the fault movements occurred and the age of the oldest undisturbed units.

A second major task is determining the likelihood of a new fault occurring under the plant in the event of an earthquake focused on an active fault in the area of the plant site, should any of the local faults mentioned in the Order prove to be sources of seismic activity.

Participants: The site visit arranged with PG&E also included a field trip to see the regional geology. W/C geologists thought this important so that the NRC geologists could see the site geology of the trench in the context of the regional and local geologic situation.

Frank Bracy, Humboldt Bay Nuclear Power Plant Project Manager, represented PG&E, Lloyd Cluff of W/C, led a team of field geologists on this project, Tom Stevens, Kevin Coppersmith and Burt Swan. I was the only representative from NRC. A geologist from the U.S.G.S., NRC consultant on Humboldt Bay, did not appear as originally anticipated, but visited the site three weeks later.

Itinerary: In keeping with their view that a regional perspective was essential to an appreciation of the significance of the site geology, the first day and part of the second day were spent examining geologic features up to [illegible] miles from the site.

On Monday, July 14, 1980 I met with F. Brady, L. Cluff and the three field geologists at the Eureka Airport in McKinleyville. We spent that afternoon and evening examining structures and surface characteristics in Area 1 of the attached map (Attachment 1). This area is about 20 miles north of the plant site. Structures and associated features seen here include the McKinleyville Fault, the Trinidad Fault, the Big Lagoon Fault (from a distance) and several terrace levels.

The morning of Tuesday, July 15, 1980, was spent in Area 2A, about 15 miles southeast of the plant, examining a former trench site (now backfilled) in the Goose Lake Fault Zone. This was followed by a visit to the still-open "Brazil" trench on Humboldt Hill in Area 2B, about 2 miles south of the plant. We examined structures associated with the Little Salmon Fault. The rest of the afternoon was spent in the three trenches at the plant site.

The last field visit was the morning of Wednesday, July 16, when we examined the quarry in Humboldt Hill in Area 2B, about one mile south of the plant site.

OBSERVATIONS

It should be noted that, because of time limitations and complications resulting from terraces of differing ages and topographic levels, a systematic field review of the stratigraphy was not possible on this brief field trip. Therefore, all strata ages and identifications mentioned in this report were those reported by W C and have not yet been documented.

Faults:

McKinleyville: This fault, about 15 miles north of the plant site, and approximately paralleling the Little Salmon Fault at N40W, is believed to be the zone of the 1954 Eureka earthquake. The only identifiable surface manifestation of this fault was a NW-trending, south-facing escarpment several feet high, close to the airport. A trench that originally crossed the escarpment at right angles is now backfilled.

According to the trench logs and discussions at this locale, the trench shows a thrust fault shear zone with at least two sets of events. The lower unit exposed in the trench, the Crannell Sands, thought to be 300- to 600,000 yrs, has shear fractures both parallel with and conjugate to the fault. Amount of offset on these is not known because of lack of marker beds in this sand unit. These fractures are truncated by an overlying gravel unit interpreted to be about 82,000 yrs. Superimposed on this earlier set of fractures is a thrust fault bringing the older unit over the younger gravels with a vertical displacement of 10 meters.

Bore hole data, according to the W/C geologists, show that vertical displacement is cumulative, increasing with depth to at least 25 meters of offset.

According to their drilling information, the shear zone within which movement occurred is 10 meters wide. They claim it is a narrow zone, highly deformed on the upper plate at the major shear, with fracturing and other manifestations of deformation dying out away from it on the upper thrust plate.

Trinidad Fault: At the north end of the on-land segment of the Trinidad Fault we observed shear fractures on a sea-cliff face. The surface manifestation of this fault, on the Anderson Ranch, was a prominent, straight-line, south-facing escarpment several feet high. Only the aforementioned gravel unit that overlies the Crannell sands is exposed. It is sandy with gravel beds that are offset about 1 1/2 meters of apparent net dip slip. Basement Franciscan Formation rocks are exposed on the upper plate here, the only place this was observed on this trip. The vertical displacement here therefore is interpreted to be 20 m.

An older set of nearly vertical, filled fractures were offset a few cm by younger conjugate shears dipping parallel with and at a high angle to the fault surface. Here over a distance of about 30 feet the parallel shear fractures died out and disappeared more rapidly than the conjugate set. At the furthest exposure from the projected fault, only fractures that were conjugate to the main fault orientation were visible.

Big Lagoon Fault: At Patrick's Point State Park about 35 mi N of the plant site we observed the coastal features from a vantage point. Big Lagoon at the far distance separates a rocky unterraced coast of Franciscan rocks on the north side of the lagoon from a sloping terrace on the south side. The terrace is the youngest in the area, with horizontal terrace deposits 82,000 years old unconformably overlying 700,000 year-old strata dipping northwestward. The straight line of the Big Lagoon and the juxtaposition of the Mesozoic Franciscan Rocks and Pleistocene terrace deposits suggests a NW-trending thrust fault here, essentially parallel with those seen further south, that post-dates the terrace deposits.

Goose Lake Fault Zone: About 15 miles southeast of the plant site near the town of Hydesville (in Area 2A of the enclosed map) a north-facing escarpment and associated linears parallel the Little Salmon Fault. A trench through the escarpment, now backfilled, showed that, despite the suggestion of uplift on the south side, the faults and offsets seen in the trench showed uplift north over south. They did not have an explanation for this contradiction but suggested some tentative geomorphic and mechanical possibilities.

The trench logs again indicate multiple faulting episodes. Here a late Pleistocene alluvium, the Yager Creek, lies unconformably on a 500- to 700,000 year-old unit, the Carlotta, and truncates a variety of deformational structures in two major zones of faulting about 10 m apart. Along the major thrusts seen in the trench, the Carlotta has been thrust over the Yager Creek alluvium. These in turn have been thrust over pond or lake deposits with C_{14} dates of 8-9,000 years.

Here again the geologists emphasized the multiple fault movements occurring repeatedly in the same narrow shear zone.

Trench Visits:

Brazil Trench: The first trench seen on this trip was the "Brazil" trench, located about 2 miles south of the plant on Humboldt Hill, in Area 2B of the attached map. This locality is significant because a quarry and ravine at the north end of this hill, which is just about one mile south of the Humboldt Bay Nuclear Plant, figured significantly into the uncertainties that the NRC Geosciences staff considered in their position of August 1977 not to recommend reopening. Severe deformation of what appeared to be very young material in these two places in Humboldt Hill suggested recent faulting, possibly associated with the Bay Entrance and/or Little Salmon Faults.

both of which were said to be non-capable by PG&E consultants, ESA, in an earlier report.

The west-facing slope of this hill parallels the Little Salmon Fault, the trace of which had been previously projected by W/C to emerge in the bay just SW of the hill.

The trench, the smaller of two parallel trenches, and the only one still open, is cut perpendicular to the hill slope on a broad bench about 30 feet above the Redwood Highway. At the trench bottom, the oldest material is a rather uniform, massive gray clay without noticeable markers beds, identified as the Rio Dell Formation. Overlying the clay on an irregular erosion surface is a gravel unit interpreted by W/C as abrasion platform deposits representing the base of a marine terrace. The age of these younger terrace deposits is unknown. As the Rio Dell is interpreted from magnetic stratigraphy to be greater than 700,000 years old, this trench does not help to resolve the age of faulting. There is however clear evidence of thrusting of Rio Dell over the terrace deposits. Abrasion-platform gravel layers have been offset up to 3 m along thrust faults dipping northeastward about 40° and striking N40-50W, approximately the orientation of the Little Salmon Fault. At least two gravel units have been deformed by drag-folding along two of the longer faults at about the 3 m station of the trench.

The visible displacements do not, however, preclude greater offset at depth, and therefore may be regarded as minimum offset. As the younger material has not been dated, the age of the faulting is unknown.

However, the deformation is regarded as part of the shear zone on the upper plate of the Little Salmon Fault. The fault surface is interpreted as emerging about one-third of the way up the slope of Humboldt Hill below the trench, which would be at an elevation of about 30' above sea level. This is a change in interpretation, as W/C previously mapped the fault trace in the Bay close to the shore.

Humboldt Hill Quarry: The oxidized brown sands and intercalated gravel beds exposed in this quarry are believed to be at least 2000 ft downsection of an important marker bed, the Unit F clay. Paleomagnetic studies show normal polarity which brackets its age between 200,000 yrs (approx. age of Unit F) and 700,000 yrs (Matuyama reversed epoch, the minimum age of the Rio Dell below). A great many offsets and drag of beds brought this quarry to the attention of NRC geologists in their review of the geologic and seismic issues at the time of the issuance of the license modification. W/C contends that aerial photography, geomorphic study and stereonet plots of shears all point to this part of the hill as part of a landslide, close to the toe. The geologists pointed out that all stereo plots of measured conjugate shears in fault zones in the region show two clearly defined concentrations of poles to planes, while a plot of poles to planes in the quarry shows a random distribution. This has convinced them that even if some of the fractures were tectonically developed, landsliding has rotated and otherwise reoriented them and, due to radial extension, caused displacements which are random in orientation.

The present condition of the quarry with its deeply incised Badlands topography was not conducive to any evaluation in a brief visit. Only a few small offsets were observed, most showing normal displacement, a few showing reversed displacement, while none appeared to continue through the strata. In places some fractures offset earlier ones.

<u>Site Trenches</u>: All three site trenches were still open, although some collapse had begun at the eastern end of the main trench, and both the main trench (trench #1 on Attachment 2) and the "nose" trench (trench #3 of attachment 2) had varying amounts of water on the trench bottom.

The main trench trends slightly north of west from close to the containment building towards the "nose" of the terrace on which the plant is built. This trend is approximately normal to the Bay Entrance Fault. At 145 m west of the plant the trench takes a right angle turn shifting the west-trending line of the trench about 35 meters to the south, then continues westward for another 32 meters.

Trench #2 is a steep-floored trench which cuts through the stratigraphic column at the edge of the terrace and trends obliquely to the Bay Entrance fault. The floor descends about 13 m in a horizontal distance of 35 m.

Trench #3 is at a "nose" of the terrace and also descends through the stratigraphic section beginning about one meter below the lowest exposed stratum of the "steep" trench. The lowest level of this trench was inundated by seepage of water so that the disturbed strata below water level were not observable during this site visit.

Main Trench (#1)

The "main" trench had a total E-W length of 228 m (740 ft) beginning 35 m (about 110 ft) west of the containment building. It was entirely within the uppermost terrace deposit, a thick, apparently uniform, gray clay-silt containing wood fragments of varying sizes, pyritized plant stems, and some incorporated grassy material. This unit, interpreted to be in the "Hookton" formation, had a tentative age determination based on C^{14} dates on the wood, which went to the limit of carbon dating of about 35,000 yrs. This therefore establishes the minimum age for the clay. Careful observation showed the apparently uniform gray-silt clay to have thin silt layers which were brought out in places by a technique W/C geologists developed of pouring buckets of water carefully as sheets or films down the trench sides. The result was "instant" differential erosion which brought out the fine alternating laminae of this unit. No shears or offsets of any type were evident through most of the trench.

Steep Trench #2

This trench revealed the stratigraphy beneath the plant, showing in the 18 m vertical descent about 200,000 yrs of deposition. At least three unconformities were recognized, each overlain by downward coarsening sequence from fine clay at the top to coarse sands and gravels resting on the unconformity.

For most of the length of the trench there was no discernable deformation of the strata. Exceptions to thi. .re at the very beginning of the trench, at its highest elevation (designated 32-35 m horizontal distance on the trench log). Small normal faults and graben-like faults with a few centimeters of offsets did not appear to go anywhere. The extensional nature of these is in contradiction to the interpretation of a compressional tectonic setting characterized by thrust faulting. W/C geologists believe these are non-tectonic and simply reflect down-sliding extension on the free-face slope of the terrace.

These faults were not seen in any of the units below. Another exception was the set of shear fractures with reverse displacements of 1-2 cm in the silt unit, seen within the last 10 m at the lower end of the trench. The unconformity above this sheared unit was overlain by undisturbed coarse sand and gravel strata. While I thought I saw faint traces of planes which seemed to continue upward into the coarse and poorly consolidated sand/gravel unit on the unconformity from the lower shear fractures, there was no offset of the unconformity anywhere in the trench.

The significance and age of these shears are uncertain.

Significance: While the shears strike essentially parallel with the regional pattern of faulting, they dip to the SW rather than to the NE and die out toward the plant, according to W/C. They do not appear to relate to any known faults in the area, although they might be conjugate shears on the Bay Entrada upper plate. W/C geologists reject this interpretation because the trench location is at least 1000 ft from the fault. This, they say, is too far away for any deformation on the upper plate, because in their experience with the regional faulting pattern, deformation is confined to narrow shear zones and both primary and conjugate shears related to the faults die out and disappear within a few tens of meters.

Another possibility is that they may be conjugate shears on the lower plate of a fault newly discovered by W/C geologists that will be described later in this report.

W/C has also considered the possibility that these fractures relate to the flexing of brittle strata during the downwarp of the broad syncline that characterizes Buhne Point structure.

Age: The ages of the strata in which the fractures are found, the unconformity, and the overlying gravels have not been precisely determined yet.

The fractured silt is part of a downward coarsening sequence resting on an unconformity directly above the Unit F clay, a distinctive unit that is recognized easily as the "gamma spike unit" of their borehole data studies. In a road cut one mile south of the plant a similar sequence above the Unit F clay has calcareous fossils which have been dated by amino acid racemization at 200,000 yrs. W/C geologists are presently attempting to ascertain the correlation of the trench strata with the roadcut. If they do they will have a bracketed date between 35,000 and 200,000 yrs for the age of these fractures.

Nose Trench #3

Stratigraphically, the "nose" trench begins, at its upper level, about one meter below the lowest stratum of the steep trench but in the same unit. It descends 12 m through a horizontal distance of 26 m beginning in the fractured unit of the steep trench and ending in the Unit F clay. The fractures which are present in the steep trench are not recognized in the same units of the nose trench. This is apparently because the nose trench walls are oriented almost parallel with this set of fractures. The trench contains the Unit F Clay as the lowest exposed unit and its overlying unconformity, both dipping gently to the southeast. The bottom of the trench at its lowest elevation was filled with a few feet of water, so I did not see the exposure. However, the W/C geologists informed me, and the trench logs indicate, that the lowest exposed part of the Unit F Clay has three shears with normal displacements of up to 6 mm. The dip of the beds in this sheared part of Unit F is steeper than the dips further up the trench where no fractures are discernable. As the slip is towards the free face of the terrace escarpment and the steeper dips of the lower beds are in the proper sense of rotation, W/C geologists believe these fractures resulted from extension associated with slump or sliding of the free-face escarpment.

<u>Buhne Point Fault:</u>

After the trench visits, W/C geologists informed me that through subsurface exploration they have discovered another fault close to the plant. The search began in response to reevaluation of a data dropout in a seismic reflection profile. Drilling a series of boreholes across the data dropout line and then parallel to it led to the identification of a low-angle thrust fault apparently similar in geometry (strike, dip, and direction of displacement) to the Little Salmon Fault. They could not give definitive data on orientation, they said, because they had confirmed the presence of the fault only a few days before my visit and had not had time to evaluate the information.

The details presented here are tentative, according to W/C geologists, and subject to modification with further study. The fault strikes approximately N45W, dips 30°W, and the trace passes 700 ft west of the plant. The fault plane is about 700 ft below the plant and comes to within 500 ft of the plant at its closest approach.

Borehole data indicates that the lowest unit downhole, the top of the Rio Dell (1 million yrs), has vertical displacement of 230 ft., an unconformity above the Rio Dell dated at 700,000 yrs shows 160 ft of vertical displacement; a 500,000 yr unit (Unit K) is offset 80 ft; and Unit F (200,000 yrs) shows 20 ft of vertical separation.

The increase in vertical displacement with depth indicates continued fault movement for at least million years. As there has been recurring movement within the past 500,000 years, this fault must be considered a capable fault as defined in Appendix A Part 100 to 10 CFR.

Other details reported by W/C are a fault surface with variable dip but averaging about 30°; and a narrow shear zone about 10 ft. wide.

SUMMARY

Regional Geology: Regionally, the area is characterized by a series of en echelon NW-striking, NE-dipping thrust faults along the coast of Northern California. The faults show repeated movements through time. W/C geologists emphasized that the chief characteristic of these faults is the narrow zone of deformation along which repeated movements appear to be restricted, with deformation confined to the upper plate. These characteristics were noted by W/C in the Little Salmon and newly discovered Buhne Point Faults.

Site and Local Geology: At the site the sediments range in age between 35,000 and 200,000 yrs while locally they are up to 1 million yrs. The trenches show no major deformation in any units, and only minor displacements in sediments 200,000 yrs or older. The displacements do not clearly relate to any of the known faults, and some may be related to slumping on the free faces of the terrace.

The Little Salmon Fault is now recognized by W/C as a capable fault with the fault trace at the lower third of the southwest slope of Humboldt Hill. They are considering the possibility that the Bay Entrance Fault, the trace of which lies between the seaward projection of the Little Salmon Fault and the plant, is a splay of the Little Salmon.

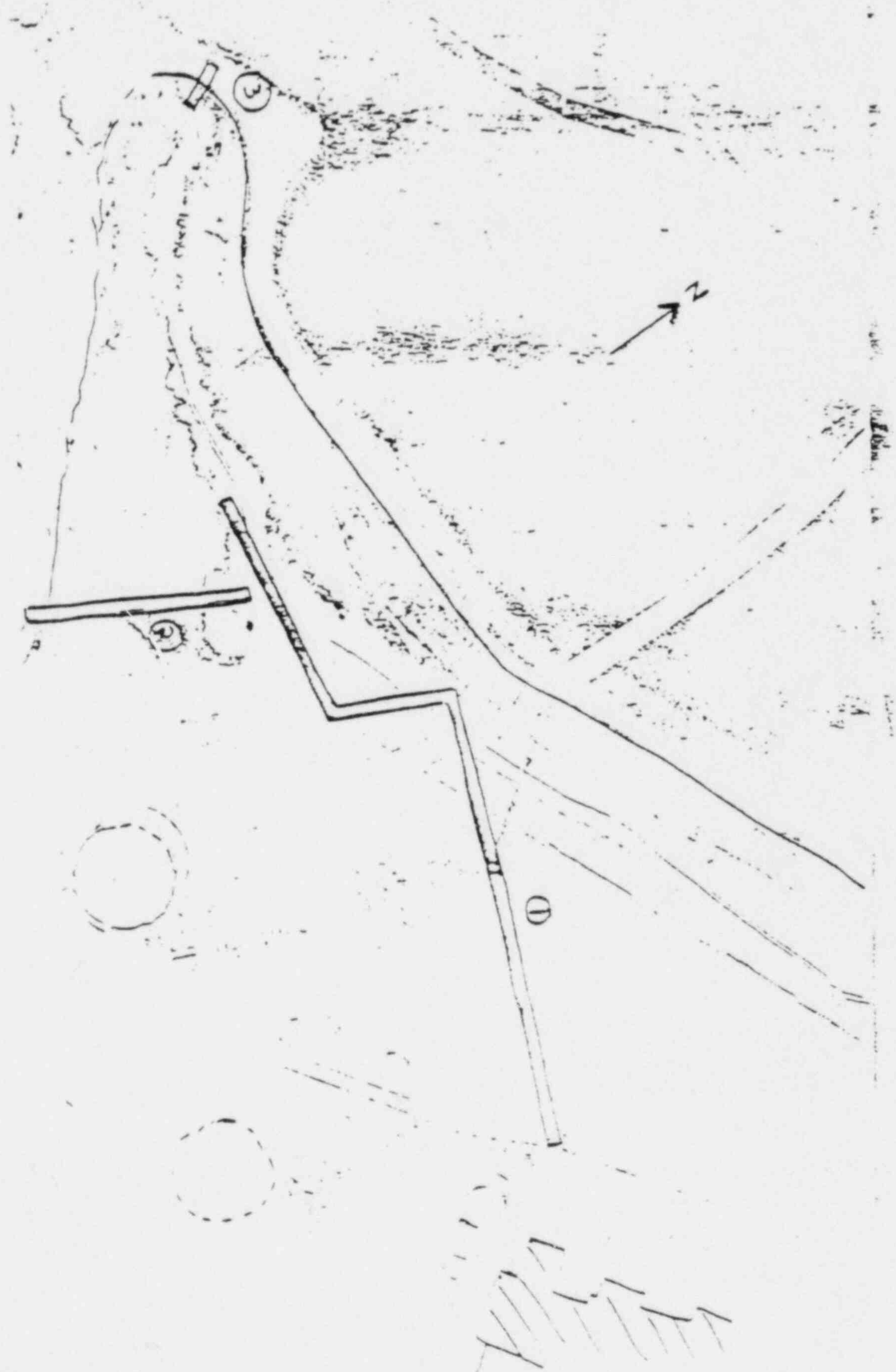
The newly mapped Buhne Point Fault, also capable, emerges at the surface 700 ft west of the plant between the plant and the trace of the Bay Entrance Fault.

W/C geologists pointed out that they do not have any evidence for or against a similar fault plane surfacing directly under the plant, and they could not state with any certainty whether or not such a fault exists.

<u>NRC Geosciences Branch Position</u>: It should be emphasized that all geologic interpretations and opinions expressed in this report are those presented by PG&E's consulting geologists to me during the field trip. I made note of those features I observed directly but made no judgements concerning the validity of their interpretations. Until PG&E and their consultants present a documented written report and a formal review by the Geosciences Branch of NRC has been undertaken, no change in our position is contemplated nor can any judgement be made concerning their findings.

Attachment

Project No. 10788	HUMBOLDT BAY NUCLEAR PLANT	MAP SHOWING AREAS SELECTED FOR DETAILED INVESTIGATIONS
Woodward-Clyde Consultants		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