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R. C. DeYoung, Assistant Director for
Light Water Reactors, Group 1, RL

SAFETY EVALUATION REPORT

PLANT NAME: Washington Public Power Supply System Nuclear Projects 3/5
LICENSING STAGE: CP
DOCKET NUMBER: STN 50-508 and STN 50-509
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NEXT ACTION PLANNED ON PROJECT: N/A
DESCRIPTION OF RESPONSE: N/A
REVIEW STATUS: Complete

Enclosed is our evaluation of the seismology and geology at the WPPSS Satsop Site, Units 1 and 2. This draft input to the SER was prepared by D. R. Budge and J. C. Stepp of the Site Analysis Branch. With respect to these subjects we have concluded, and the SER inputs so state, that the proposed site is suitable for the location of the proposed nuclear power plants.

Original Signed by
H. R. Denton

Harold R. Denton, Assistant Director
for Site Safety
Division of Technical Review
Office of Nuclear Reactor Regulation

Enclosure:
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U. S. NUCLEAR REGULATORY COMMISSION
WASHINGTON PUBLIC POWER SUPPLY SYSTEM
NUCLEAR PROJECTS 3/5
DOCKET NOS. STN 50-508 AND 509

Prepared by: D. R. Budge and J. C. Stepp

2.5 Geology and Seismology

We have completed our review of the geology and seismology data contained in the WPPSS 3/5 Preliminary Safety Analysis Report. During our evaluation, we visited the site on two occasions and reviewed the geology of the region with the Applicant's consultants and staff members from the State of Washington's Department of Natural Resources (Geologic and Earth Resources Division), and the State Highway Department.

Our review was primarily concerned with the regional tectonic structure and its relationship to earthquake occurrence, and with the age of faulting identified in the vicinity of the site. Additional information submitted by the applicant as amendments to the PSAR has demonstrated to our satisfaction that the inferred large deep seated fault blocks, that have been associated with large earthquakes in the southern part of the Puget Sound, are not present in the site area. We have also been satisfied that movement on faults in the vicinity of the site most likely ceased in the late Tertiary and that there are no known structures in the immediate vicinity of the site that could be expected to localize large earthquakes there. Also, we are satisfied that the Applicant's assessment of the possible volcanic risks in the site region are adequate and his data show that a problem of this type does not exist at the location of the proposed plants. We have, therefore, concluded that the applicants proposed SSE of 0.32g is a conservative acceleration for seismic design, when applied at foundation level.

2.5.1 Geology

The proposed Washington Public Power Supply System Nuclear Station Units 1 & 3 Site is located in the Pacific Border Physiographic Province of Washington State about two miles south of the village of Satsop and 16 miles east of the town of Aberdeen. The site area lies in the Chehalis Lowlands which comprises a physiographic zone separating the northern termination of the Oregon Coast Range from the Olympic Mountains.

The site and its environs are largely underlain by Cenozoic strata. Relative to more northern areas of the region, rocks of the site area are not highly deformed. Igneous rocks of Mesozoic and Cenozoic age, however, are more abundant than either sedimentary or metamorphic units throughout the region. The nearest outcrops to the site of Mesozoic and Paleozoic rocks (metamorphic, igneous, and sedimentary types) are found in the highly deformed area some miles to the north and northwest of the proposed plant area. Lithologically, the Cenozoic strata consist predominantly of marine clastic sediments deposited on a basement of Eocene oceanic basalts. At the proposed site, the power block's foundations will rest on massively bedded sandstones of Miocene age assigned by the Applicant's consultants to the "Astoria Formation." Some stratigraphic experts in the area believe these strata should more properly be assigned to a slightly younger lithostratigraphic unit overlying the Astoria Formation, the Montesano Formation.

The tectonic history of the site region is complex with eastward and westward directed low-angle thrusts, grabens, granitic plutons, and stratovolcanoes being best displayed and developed predominantly in the Northern Cascades some miles from the site. Here, the Paleozoic Era is characterized by the metamorphic and eugeosynclinal rocks. In the Mesozoic time span, eugeosynclinal sediments, granitic plutons, low-angle thrusts, and grabens are the general rule. During Cenozoic time, grabens, granitic plutons, and basalt flows predominated Later, during the Cenozoic, several orogenic periods caused folding and faulting of the older formed rocks and general uplift of the region and the stratovolcanoes of the Cascade range began to form. The structural features that were formed during these orogenies, and the region, were subsequently eroded during the Quarternary to produce the present day topography. While it appears that the last major period of deformation in the region ended in the Late Tertiary (Pliocene), evidence from Pleistocene deposits in the coastal areas west of the site, from 1,100 year old fault dates in the Puget Sound area to the north, and from three active stratovolcanoes in the central part of the state to the east of the site, show that tectonism continued on a more minor scale through the Pleistocene into the Holocene.

Numerous reverse faults of a generally northwest or northeast trend marking elongated basement uplifts occur throughout the basaltic rocks of the region. These structural features are cut by east to northeast trending normal faults bounding areas showing different amplitudes of folding. Some of these faults significantly displace Tertiary strata in the region. The above described faults are thought to be the result of northeast compression of the crust, which was recurrent several times throughout the early Tertiary until at least the middle Miocene. The basaltic basement complex shows the highest degree of faulting with the intensity of faulting declining with the decreasing ages of the overlying rock units.

The plant is to be located on the nose of a broad poorly defined anticline which is an extension of one of the areas several uplifts, the Minot peak uplift. Typical of other anticlines in the region, the Minot Peak uplift has the basaltic basement rocks exposed in its core. Several significant faults (some with several thousand feet of displacement) in the site area can be shown by various means (terrace dating, saprolitization rates, erosion rates, etc.) to be associated with deformations no younger in age than Late Tertiary and thus they are not considered to be capable faults within the meaning of Part 100, Appendix A. Also, the site area lacks both the precipitous topography and thick detrital deposits characteristic of active orogenic regions.

A line of stratovolcanoes extends along the Cascade Mountains from northern California to southern British Columbia. Eight of the volcanoes are within 200 miles of the Satsop site, the nearest being Mt. Rainier and Mt. St. Helens each about 80 miles away. All of the volcanoes are believed to have been active within the past 15,000 years and three of them, Mt. St. Helens, Mt. Rainier and Mt. Baker are considered active at the present time.

Mt. Rainier has received the most study and the studies show that it has been intermittently active during the last 10,000 years. This activity has been mainly of the pyroclastic type, but includes at least one flow which extended nine miles from the mountain. Three of the tephra eruptions deposited about one inch of material up to 25 miles east of the mountain. The last major eruption occurred about 2000 years ago but minor eruptive activity occurred 120 years and 150 years ago.

In addition to the eruptions of tephra, numerous mud flows have occurred at Mt. Rainier. The largest of these, the Osceala mud flow, occurred 5700 years ago. It extended about 70 miles down-valley from the volcano. None of the river valleys which could be potential mud flow pathways pass near the Satsop site. We conclude, therefore, that no mudflow hazard exists at the site.

A minor amount of tephra could fall at the plant site in the event of a very large eruption in the Cascade Range. Assuming the largest historic eruption within the Cascade Range to occur at Mt. Rainier results in about one inch of ash at the Satsop site in a 30 day period.

In summary, it can be said that while the geologic conditions of the Satsop site and its environs are very complex, and the area is still tectonically active, based on the applicant's work to date there are no known faults or other structures on the immediate vicinity of the site which could be expected to localize earthquakes in the power block area. Additionally, there are no indications to date of the development of geologically young features in the site area within the meaning of Appendix A which could effect the proposed plants.

2.5.2 Seismology and Seismicity

2.5.2.1 Regional Tectonics

The tectonic deformation of Western North America appears to be intimately related to the interaction of two major lithospheric plates, the North American Plate and the Pacific Plate. The interaction is principally along two major transcurrent faults, the San Andreas fault in California and the Queen Charlotte fault off Western Canada. However, in the area between Cape Mendocino in northern California and the southern extent of the Queen Charlotte fault off the western tip of Vancouver Island the two major plates named above are separated from one another by the small Juan de Fuca Plate.

The interaction between the Juan de Fuca plate and the North American plate is not presently understood. The magnetic anomaly pattern east and west of the Juan de Fuca Ridge indicates that part of the Juan de Fuca Plate has been subducted beneath the North American Plate. Also, the chain of stratovolcanoes which forms the axis of the Cascade Mountains is believed to have been produced by magma from a subducting plate (Atwater, 1970). Several other types of data indicate that an episode of late Cenozoic subduction occurred in this region of western North America. Seismic reflection surveys off the coast show a sediment-filled trench at the base of the continental slope (Hays and Ewing, 1970). Anomalously high gravity values on Vancouver Island are suggestive of a remnant subducting slab beneath the region (Sacey, 1973). Seismic wave velocities indicate that a high velocity slab exists beneath the Puget Sound Basin (McKenzie and Julian, 1971; Crosson, 1972) which is indicative of a subducting lithospheric plate.

Other evidence indicates, however, that subduction along the Juan de Fuca Plate -North American Plate boundary is not currently occurring. In particular, earthquake activity indicative of a Benioff zone (a characteristic of subducting plates) is absent in this region. Also, the orientation of the present regional stress field is inconsistent with active subduction. Analysis of earthquake source mechanisms shows that the maximum principal stress is north-south compressional and the minimum principal stress varies from east-west to nearly vertical (Dehlinger and Couch, 1969; Couch and McFarlane, 1971; Crosson, 1972; Malone, et al, 1975).

The applicant has thoroughly reviewed the above mentioned items and other types of data related to the current interaction of the lithospheric plate boundaries, including studies of plate kinematics (Silver, 1971; Atwater, 1970). While the available data are not clearly definitive, we believe that they tend to support the interpretation that subduction is no longer occurring along the Juan de Fuca-North American Plate boundary.

The applicant has divided the region within 200 miles of the Satsop site into nine "tectonic provinces" (Fig. 2.5.13 of the PSAR). Two of the provinces, the Coast Range and the Puget-Willamette Trough, have been subdivided into subprovinces. These divisions and the province boundaries were determined primarily on the basis of geologic evidence. According to their analysis of the regional tectonics the Satsop Site is within the Willapa Hills subprovince of the Coast Range Tectonic Province.

We agree that the cited geologic evidence generally supports the applicant's interpretation of the tectonic provinces concept for the region, in some instances quite strongly. However, we do not find the tectonic province method above to be a suitable basis for determining the SSE for this site. The entire region has experienced considerable tectonism in the Quaternary. For this reason and also because of the relatively short historic record of earthquake activity, we consider the relatively small-sized tectonic subdivision represented by the Willapa Hills to be an inadequate basis for determining the maximum earthquake intensity at the site. The applicant appears to have also reached this conclusion during his investigations of the site.

The historic earthquakes of the site area show a significant spatial variation in the frequency of earthquake occurrence. The greatest level of activity is within the Puget-Willamette Trough which is a narrow basin between the Cascade Mountains on the east and the Coast Range and Olympic Mountains on the west which lies approximately between parallels 44° North and 49° North. The highest concentration of earthquake activity within this province is within the Puget Sound region which the Applicant has named the Puget Sound Subprovince. In the part of this region which is south of the San Juan Islands and approximately north of Olympia about 70 percent of the historic earthquake activity has occurred. This pattern of historic earthquake activity has been confirmed by the distribution of accurately located small-sized earthquakes during the past five years (Crosson, 1972 and 1974).

The Puget Sound region can be characterized tectonically as an area of major structural blocks bounded by northwest and northeast trending faults. These faults were interpreted from gravity data by Danes, et al, 1965; Rogers, 1970. The intensity of the gravity anomalies in the region is such that faults having as much as 10 km of displacement is indicated (Danes, et al, 1965). Seismic reflection data show that some small faults associated with the inferred faults may offset Pleistocene and younger unconsolidated sediments and repeated vertical control geodetic data indicate that differential movement is continuing to occur across them.

On the basis of the available geological and geophysical data we at the present time consider the major faults interpreted by Danes, et al, 1965 and Rogers, 1975 in the southern part of the Puget Sound to be capable within the meaning of 10 CFR Part 100 Appendix A. Earthquakes do not appear, on the basis of the studies to date, to be simply correlated with the faults which are located on the basis of the gravity gradients. However, the general lack of precision in both the location of the faults and in the location of the earthquake epicenters may account for this observation. Also, earthquakes within the southern Puget Sound appear to occur at depths as great as 100 km whereas elsewhere in the Pacific Northwest they are generally shallower than about 35 km. This region therefore appears to be an area of deep crustal tectonic activity whose positions may be reflected in the upper crust and near surface as fault bounded structural blocks.

The southern boundary of the deep crustal tectonism as indicated by the generally greater earthquake focal depths coincides with a sharp northwest-trending gravity anomaly. This boundary, which the Applicant has named the Olympia lineament, is about 21 miles northeast of the Satsop site at its nearest approach.

2.5.2.2 Maximum Historic Earthquake

A number of moderate to large earthquakes have occurred within 200 miles of the Satsop site during the 146 year historic record. These are listed in the PSAR (Table 2.5.14). A discussion of the principal parameters of each together with estimated acceleration that each produced at the Satsop site is given in PSAR Section 2.5.2.5. The two largest earthquakes within the region occurred on December 15, 1872 and on June 23, 1946. The magnitude of the 1946 earthquake was determined to be 7.3 and, based on comparison of felt areas, the 1872 earthquake must have been equally large. The 1946 earthquakes were centered on the east coast of Vancouver Island about 200 miles from the Satsop site. A recent study conducted for the proposed

Skagit Nuclear Plant indicate that the 1872 earthquake was centered near Lake Chelan about 180 miles northeast of the Satsop site. A strong earthquake occurred in the Olympic Mountains on March 17, 1904. The Applicant conducted a study of felt reports from this event which showed it to have a felt area of 55,000 mi^2 centered about 40 miles northwest of the site. The relatively small felt area indicates that this quake was no larger than magnitude 6-6.5, and its maximum intensity was no greater than MM VIII. The remaining five moderate to large earthquakes were located in the area of deep crustal tectonism and high rate of earthquake activity discussed above in the southern Puget Sound. The closest of these to the site was 27 miles to the northwest and occurred on November 13, 1939; its magnitude was determined to be 5.8 and the maximum intensity was MM VII. Bedrock acceleration at the Satsop site from this earthquake was estimated by the Applicant to be 0.12g. The largest historic earthquake in the southern Puget Sound occurred on April 29, 1949 (M7.1, maximum intensity MM VIII). The applicant has estimated that this earthquake produced a maximum acceleration of 0.11g at the Satsop site. The remaining moderate earthquakes in the region produced maximum bedrock accelerations of 0.06g or less at the site. The nearest known earthquake to the Satsop site occurred on December 13, 1971. It was centered 6 miles northwest of the site and had a magnitude of 3.6. The largest historic earthquake within the Willapa Hills subprovince reached a maximum intensity of MM VI.

2.5.2.3 Safe Shutdown Earthquake

To establish the safe shutdown earthquake (SSE) the Applicant made use of complex seismological considerations that required a determination of the relationship between earthquake source dimension and magnitude and the use of appropriate acceleration attenuation relations. It was further assumed that the major gravity lineaments in the southern Puget Sound are caused by major deep-seated faults and that the faults are capable within the meaning of 10 CFR Part 100, Appendix A. This final assumption has subsequently been confirmed in the case of the Olympia lineament (see the Skagit PSAR) by use of seismic reflection data. With respect to fault length versus earthquake magnitude, we consider the applicant's assumptions to be conservative with respect to the available data and, also, with respect to historical experience in the Puget Sound area. With respect to attenuation, the Applicant made a thorough analysis of both the theoretical results and the available observational data. The analysis included the available data from deeper earthquakes in Japan and Peru in addition to that from the 1949 and 1965 earthquakes in the southern Puget Sound. We consider the Applicant's result to conservatively represent the available data.

The analysis resulted in a maximum acceleration of 0.32g at the Satsop site caused by an estimated maximum earthquake M7.5 centered on the Olympia fault at a distance of 22 miles northeast of the site and this value was proposed for the SSE. We consider 0.32g to be a conservative acceleration for seismic design for the Satsop site. This value is to be used as the high frequency asymptote for the Regulatory Guide 1.60 response spectrum at the free field foundation level.

The operational basis earthquake (OBE) has been established as 0.16g. We consider this value to conservatively represent the accelration which may occur at the site during the operating life of the plant.

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