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50-344

EVALUATION OF DESIGN HAZARDS OF AIRBORNE ASH AND PYROCLASTIC FLOW FOR THE TROJAN POWER PLANT SITE.

Prepared for : Physicians for Social Responsibility (PSR)
SEARCH : 0312

SUMMARY

With renewed activity of Mount St. Helens, possible volcanic hazards to the Trojan Nuclear Power Plant are of interest for public safety. The original Trojan safety analyses for airborne ash and pyroclastic flows are evaluated here. For this evaluation, a regional approach, similar to that employed previously, is used. This evaluation reveals major systematic errors in the original safety analysis. In particular, the volcano was assumed dormant or harmless during the life of the plant. The effect of wind on ash fall was misapplied to the design condition. The effects of blast were ignored. Pyroclastic flows were casually dismissed. The present evaluation presents a preliminary correction of these errors.

The close proximity of Trojan to the most dangerously-active volcano in the conterminous United States is found to impose severe design conditions for both airborne ash and pyroclastic flows--the only volcanic conditions evaluated herein. Preliminary design conditions are found to exceed 16 feet of dry ash or 8 feet of wet ash, resulting from a sudden ash fall. Pyroclastic flows are also found to present a significant design condition because of the 34-mile proximity of Trojan to the volcano and because of the connecting path provided by the Kalama River Valley.

BACKGROUND TO THIS EVALUATION

This report summarizes the results and conclusions of an evaluation of volcanic hazards for the Trojan Nuclear Power Plant site, one mile south of Prescott, Oregon. SEARCH Technical Services selected ash fall and pyroclastic flow for evaluation because of the potential dangers to the plant and because of the relative simplicity of the analysis required for review. Other volcanic hazards are possible.

Norman Buske, a physicist, conducted this evaluation between 16 September and 5 October 1980. He was assisted by Lee Kirkpatrick and Linda Josephson.

The principal investigator has B.A. and M.S. degrees in physics and an M.A. degree in earth and planetary sciences. He has 12 years experience in the prediction and evaluation of environmental disasters and design conditions. He has conducted this work for electric utilities (conventional and nuclear), the U.S. Navy, the petroleum industry, coastal developers, and others, at about 30 sites, worldwide.

TROJAN SITE

Trojan is located on a 635 acre site, on the west bank of the Columbia River estuary, about 42 feet above the high water level. The Kalama River enters the Columbia River on the east bank, opposite the Trojan site. The head of the Kalama River is on Mount St. Helens, 34 miles ENE of Trojan. Figure 1 shows the Trojan site and its location.

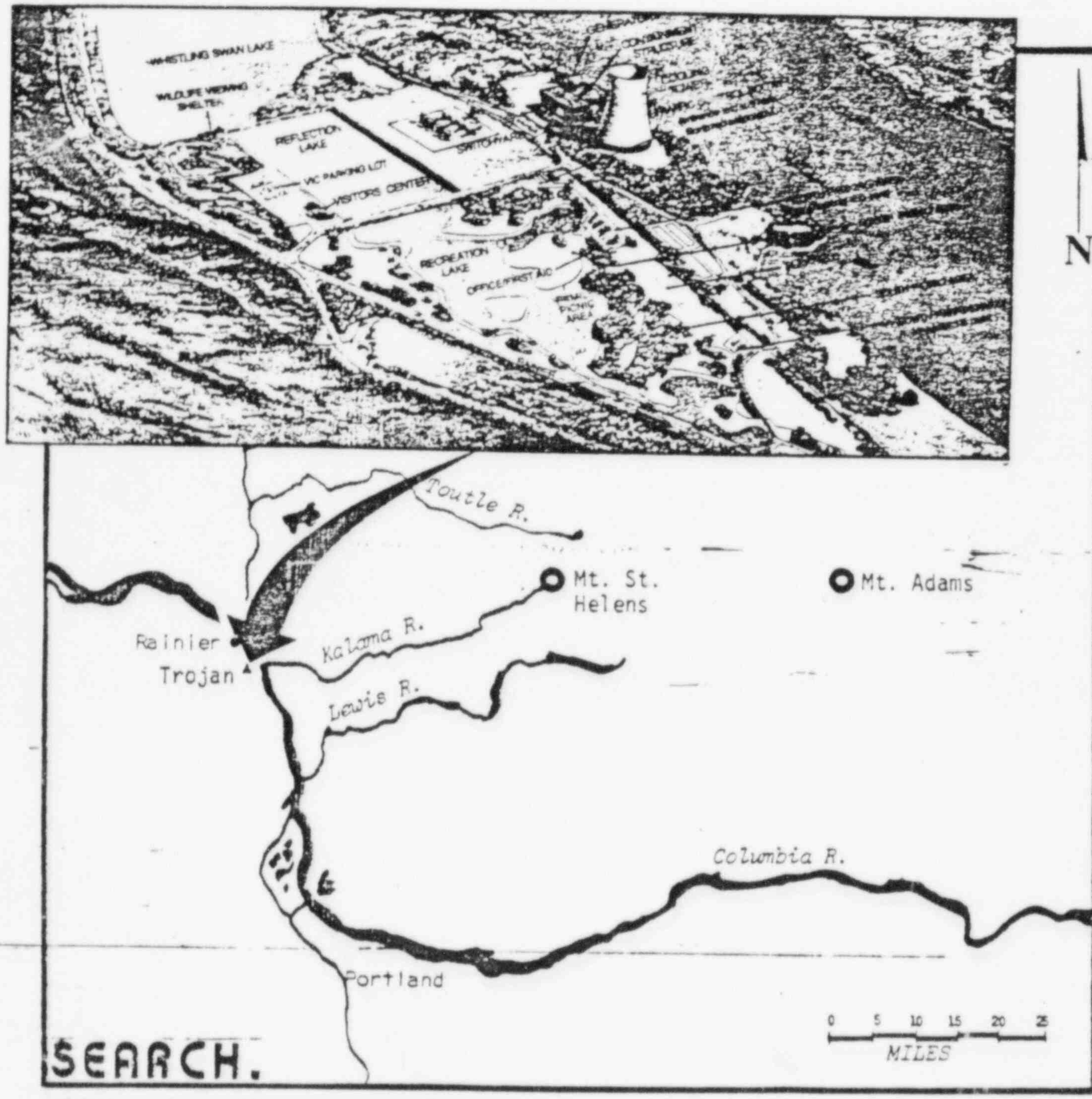
ENVIRONMENTAL DESIGN CRITERIA

Design criteria for nuclear power plants are established by the Nuclear Regulatory Commission (NRC) so that "the facility can be operated without undue risk to the health and safety of the public" [Part 50, 1980, p. 27]. These design criteria are required to reflect

> Appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity and period of time in which the historical data have been accumulated...[emphasis added, p. 28].

The present evaluation of volcanic hazards of Mount St. Helens for the Trojan site is, in effect, an appraisal of the relationship between environmental events and *undue risk to the health and safety of the public*. As a starting point, a definition of *risk* is necessary: For this evaluation, *risk* is the chance that some important facility design condition will be

TROJAN SITE LOCATION



Picture from: "Trojan, Oregon's First Nuclear Generating Station," no date, p. 7

FIGURE 1

exceeded in a specified period of time--usually one year.

Next, the meaning of "*undue* risk to the public" is considered. This is basically a matter of choosing an acceptable value of risk. One possible value is suggested by the Atomic Energy Commission's Reactor Safety Study, as described in the reprint, "Nuclear Reactors: How Dangerous?" [Reader's Digest, R.E. Lapp, April 1975]. This reprint cites a one in 100,000,000 per year chance of serious escape of radioactivity from any single reactor.

That is a very low risk. In fact, it appears to be lower than may be needed to assure public safety. This may be seen by considering the number of nuclear power plants (55 in 1975), the length of time during which no major accidents would be acceptable (say, a 200-year life for the present nuclear industry), a safety factor (say, 10), and the number (say, 10) of more or less unrelated kinds of events which expose a plant to risk of failure. Multiplying these factors, one obtains an acceptable risk of about one in 1,000,000 per year for any single kind of event.

In order to assess such small risks, one must go beyond the plant area and consider the worst conditions recorded in the region--just as the NRC requires. This record includes geologic information.

As a starting point for the evaluation, one turns to Potential Hazards from Future Eruptions of Mount St. Helens Volcano, Washington [G.S. Bull. 1383-C, 1978, p. C1], which states that the volcano is a serious hazard based on its past history of spasmodic explosive behavior including lava flows, pumice falls, pyroclastic flows, and mud flows. A quick look at the historic record shows that:

> Mount St. Helens has been more active and more explosive during the last 4,500 years than any other volcano in the conterminous United States [ibid.].

This activity is outlined in Table 1.

Geological Survey Bulletin 1383-C provides a basis for evaluating volcanic hazards which are "expectable" [title p.]. Thus, the Survey only considers risks greater than about one in 3000 per year [p. C-19]. But a nuclear power plant must be designed to survive *potential* hazards, as well as *expectable* hazards. In order to assure that the public will not be exposed to a release of radioactivity, one must evaluate risks far smaller than those considered by the Survey. This difference is quantifiable as follows:

hazards	attendant risks
expectable ∿	one in 2,000 to 3,000 per year
potential ∿	one in 1,000,000 per year

Attention now turns to the ash fall hazard.

ERUPTIONS AND DORMANT INTERVALS AT MT. ST. HELENS SINCE 500 B.C.

A.D.

1980--Tephra eruptions
1900--Dormant interval of 123 years
1857--Last recorded pyroclastic eruptions
--Eruptions of pyroclastics, domes, lava flows
1800--Pyroclastic eruptions (T), mudflows
--Apparent dormant interval of ca. 150 years
1700--
--Pyroclastic flows (avalanches)
--Dome eruptions, mudflows
1600--
--Apparent dormant interval of ca. 100 years
1500--Airborne pyroclastic eruptions (W), pyroclastic flows
--Pyroclastic flow
1400--Lava flows, pyroclastic flow
--Pyroclastic flows
1300--Dome eruptions (?)
1200--
1100--Apparent dormant interval of 400-500 years
1000--
900--
--Airborne pyroclastic eruption
800--
700--
600--Apparent dormant interval of 400-500 years
500--
400--
--Airborne pyroclastic eruptions, mudflows
300--

A.D.

200--Airborne pyroclastic eruptions
100--Lava flows
0--
--Pyroclastice flows, mudflows
100--

B.C.

--Pyroclastic flows
200--
300--Pyroclastic flows, airborne pyroclastic eruptions
400--Airborne pyroclastic eruptions, mudflows
--Lava flows
500--Apparent dormant interval, 400-500 years

Chronology indicates *known* eruptions.

TABLE 1.

Taken from: Fire and Ice, Stephen L. Harris, 1980, p. 174-175.

ASH FALL

In the following discussion, no distinction is made between "pumice", "ash", and "tephra" falls. They all describe deposition of erupted materials which were carried by the air.

Data from the 18 May 1980 Mount St. Helens eruption indicate that first rains compact freshly fallen ash to about half its original depth ["Areal Distribution, Thickness, and Volume of Downwind Ash from the May 18, 1980 Eruption of Mount St. Helens," U.S.G.S Open File Report 80-1078, A.M. Sarna-Wojcicki, Fig. 3]. Thus, as a conservative approximation, the *present* thickness of old tephra deposits is assumed to be one-half the thickness of the original uncompacted tephra fall.

MOUNT ST. HELENS

Five severe ash falls from Mount St. Helens are outlined in Fig. 2. Because of the strong winds present during the 18 May 1980 eruption, that ash fall was too thin and widely distributed to include in this map [Sarna-Wojcicki, Fig. 3 and p. 7 and Bull. 1383-C, p. C17]. Referring to Fig. 2, layer "Yn" is seen to be the most severe ash fall *recorded*. The compacted ash from that event is 3 feet deep 24 miles north of the volcano [Pumice and Pumicite Occurrences of Washington, State Div. of Mines and Geology Rept. No. 15, W. Carithers, 1945, p. 20] and 18 inches deep on Mt. Rainier 50 miles away [Mount St. Helens, The Volcano of Our Times, D. and D. Roberts, 1980, p. 4].

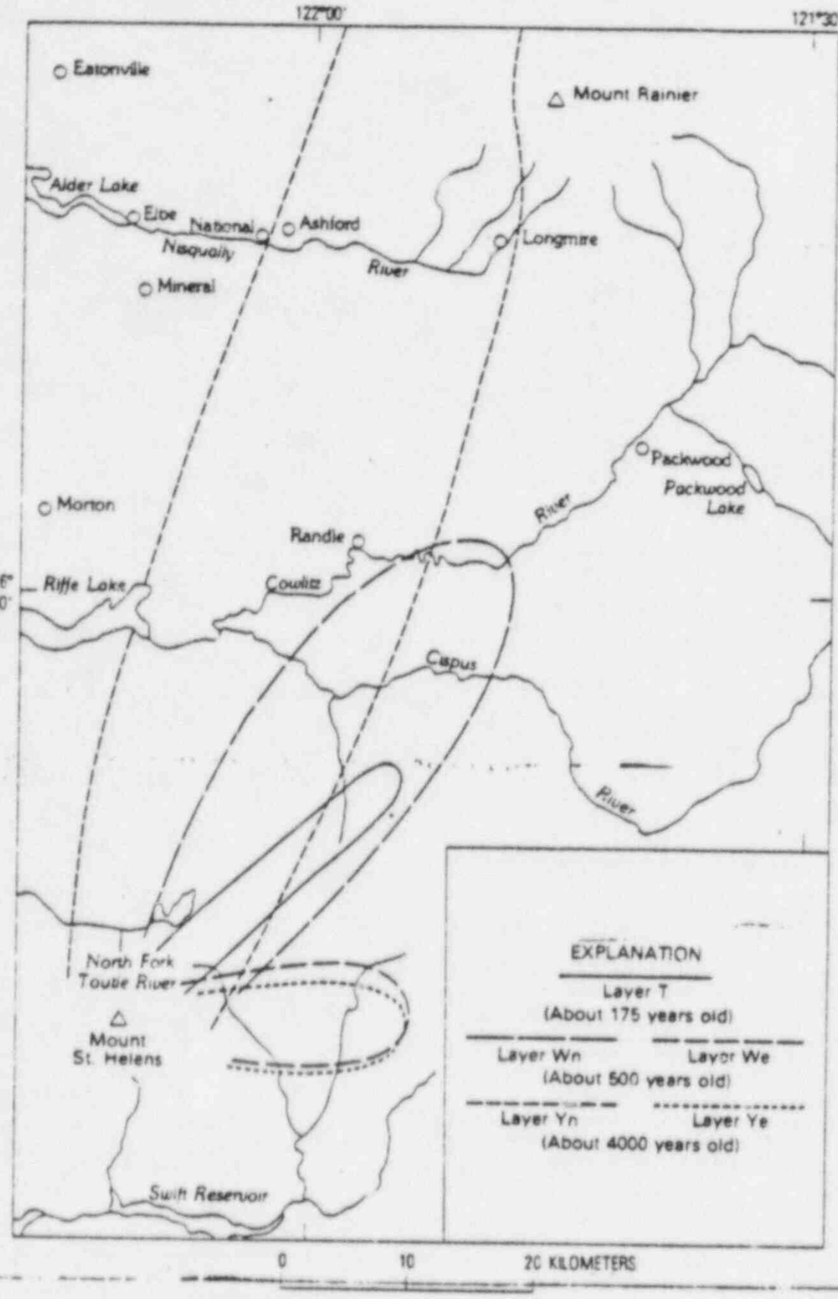
With only a 4500-year geologic record of recent Mount St. Helens activity, it is appropriate to turn to other nearby Cascade volcanoes to evaluate the worst that may reasonably be anticipated. For a full appraisal, one would conduct a detailed study of ash falls from all the Cascade volcanoes. However, in the Trojan Final Safety Analysis Report (FSAR), the Mt. Mazama eruption of some 6600 years ago was selected for use as the worst-case condition [p. 2.5-4] on the basis of the size of the eruption. With the reservation that the biggest blast does not necessarily produce the deepest ash, that selection is followed here.

MT. MAZAMA

Crater Lake lies about 210 miles south of Mount St. Helens. This lake was formed after an eruption of Mt. Mazama--the parent volcano--some 6600 years ago. That eruption is generally considered to be large by recent Cascade volcano standards.

The Mt. Mazama eruption was carefully studied by Howel Williams.

MT. ST. HELENS TEPHRA DEPOSITS



Areas covered by 20 cm or more of tephra during five relatively large tephra eruptions

FIGURE 2

Copied from: Geological Survey Bulletin 1383-C, 1978, p. C6

His Geology of Crater Lake National Park, Oregon [Carnegie Inst. of Wash. Publ. 540, 1942] is still considered authoritative concerning pumice falls and pyroclastic flows from the Mt. Mazama eruption.

Williams' map of ash fall depths and pyroclastic flow distributions appears as Fig. 3. This shows that the main lobe of the Mt. Mazama ash fall was to the NNE, reflecting wind conditions at the time of the eruption. The pumice fell in the typical downwind direction from Crater Lake and left compacted deposits 3 feet thick as far as 67 miles away.

APPLICATION TO THE TROJAN SITE

The Mt. Mazama tephra fall event may be applied to the Trojan site (as in the FSAR, p. 2.5-38) by superpositioning the ash origin onto the location of Mount St. Helens and taking into account the site location to the WSW of the origin. In analyzing the possible impact on Trojan of ash fall from such an eruption of Mount St. Helens, possible future blast directions as well as variations in wind speed and direction must be considered. This the FSAR failed to do.

Close to a volcano, the extent of ash fall depends on the details of the eruption as well as the wind [Bull. 1383-C, p. C-10]. In the 18 May eruption of Mount St. Helens, the blast zone extended at least 50 miles laterally through the atmosphere from the volcano [Sarna-Wojcicki, p. 5 and Figs. 4 and 5b]. There seems to be no justification for assuming that future blasts during the 40-year life of the Trojan plant will all be from the north side. Indeed,

> Future tephra eruptions are possible from vents on any flank of Mount St. Helens, as well as from the summit, and thus any part of the volcano can be affected [Bull. 1383-C, p. C-10].

Similarly, wind speed and direction in the area must be considered to be variable. During the fall, winter and spring seasons, winds are dominantly toward the northeast. However, during the summer season,

> Over extreme southwestern Washington and most of Oregon an anticyclonic cell, with sinking air-flow is found [Atlas of the Pacific Northwest, 6th ed., R. M. Highsmith, Jr., and A.J. Kimerling, eds., 1979, p. 45].

This is shown in Fig. 4. This wind pattern brought a sprinkling of ash to Portland and the Trojan site last summer, following very small eruptions of Mount St. Helens.

The effect of low wind speed is to increase the depth of ash accumulation *close* to the volcano and to decrease the ash depth *far* from the volcano [see Sarna-Wojcicki, p. 5]. If winds do not carry the erupted ash away from the

CONTOURS (FEET) OF MT. MAZAMA TEPHRA FALL AND EXTENT OF PYROCLASTIC FLOWS.

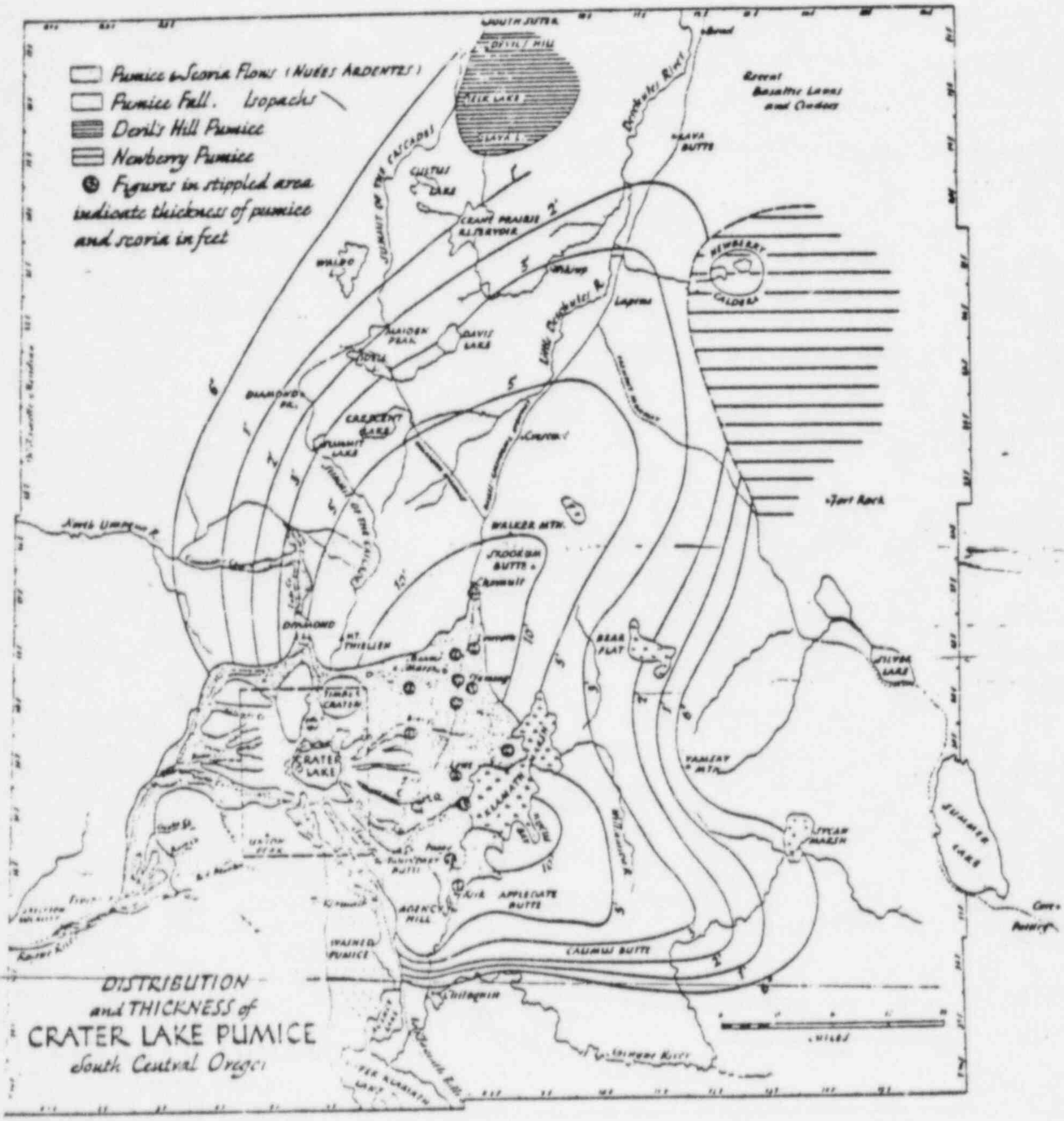


FIGURE 3

Copied from: Geology of Crater Lake National Park, Oregon, Howel Williams, 1942, p. 70.

AVERAGE SUMMER WINDFLOW FOR THE PACIFIC NORTHWEST

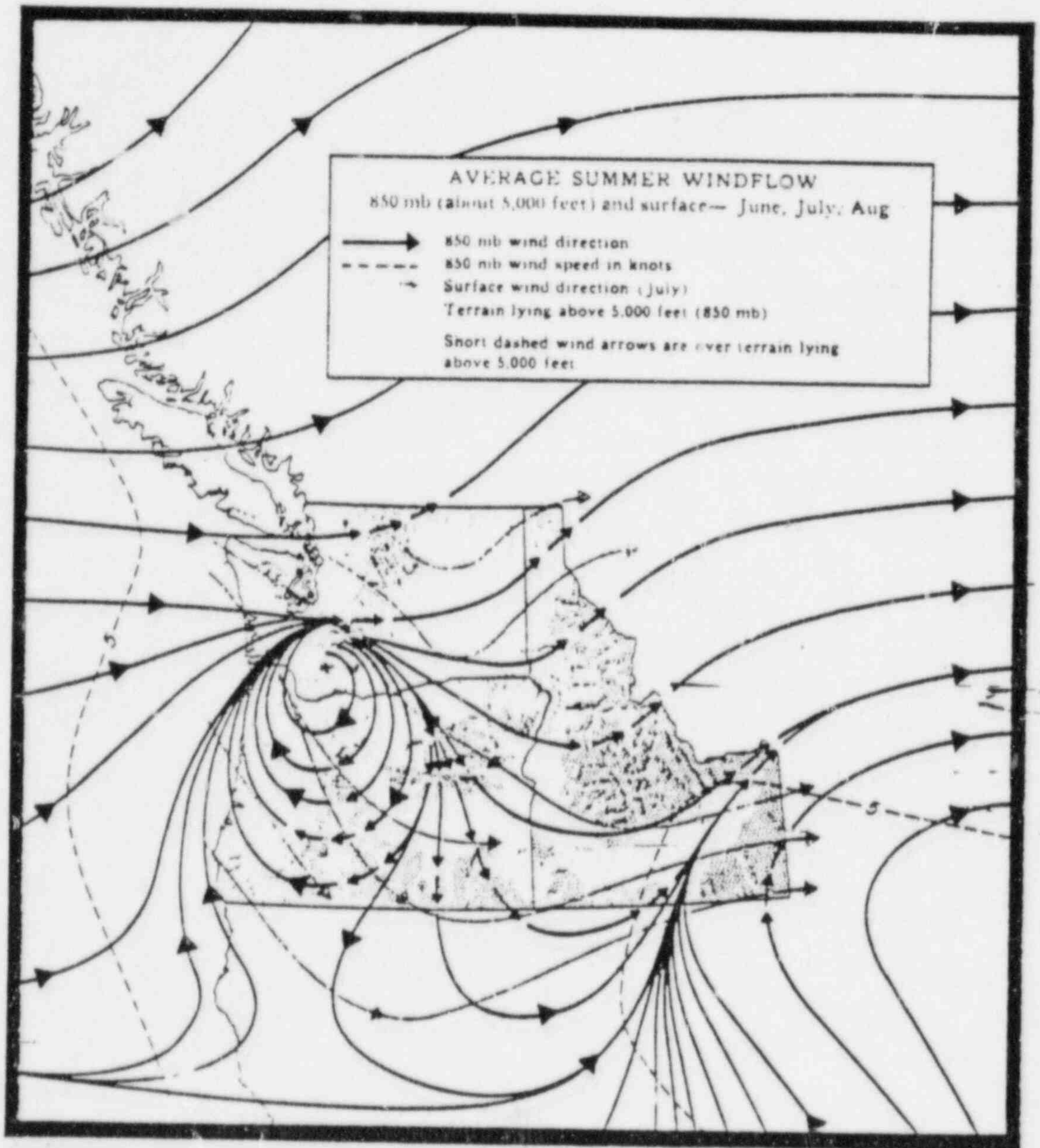


FIGURE 4

Taken from: Atlas of the Pacific Northwest, 6th ed., Highsmith, Jr. and Kimerling, eds., 1979, p. 50.

volcano, more of the ash will fall nearer to the volcano.

Clearly, there is a reasonable chance of ash being carried by wind toward the Trojan site. However, the worst-case ash fall situation appears to be: A west-flank blast occurring with winds directed toward the east. This could produce local air stagnation and heavy ash deposition in the vicinity of Trojan.

On the basis of the possibilities of either easterly winds, calms, or a west-flank blast with winds toward the east, the probability of major deposition at Trojan, assuming that a major Mount St. Helens ash eruption has occurred, is considered to be at least 20 percent.

With this probability in mind, the Mt. Mazama eruption data can be superpositioned over Mount St. Helens, with the major lobe directed roughly toward the Trojan site, Fig. 5. This gives an idea of the potential ash fall at site from a severe eruption of Mount St. Helens. The result: About 8 feet of compacted ash at site. The initial fall of uncompacted ash would probably be at least twice this deep--16 feet.

From the above considerations, the present risk of a Mt. Mazama-class ash eruption from Mount St. Helens is proposed to be about one in 10,000 per year--roughly the length of record. With an estimated 20 percent chance of this deposition being directed toward site, the risk of an uncompacted ash fall of 16 feet at Trojan site is estimated to be one in 50,000 per year.

PYROCLASTIC FLOW

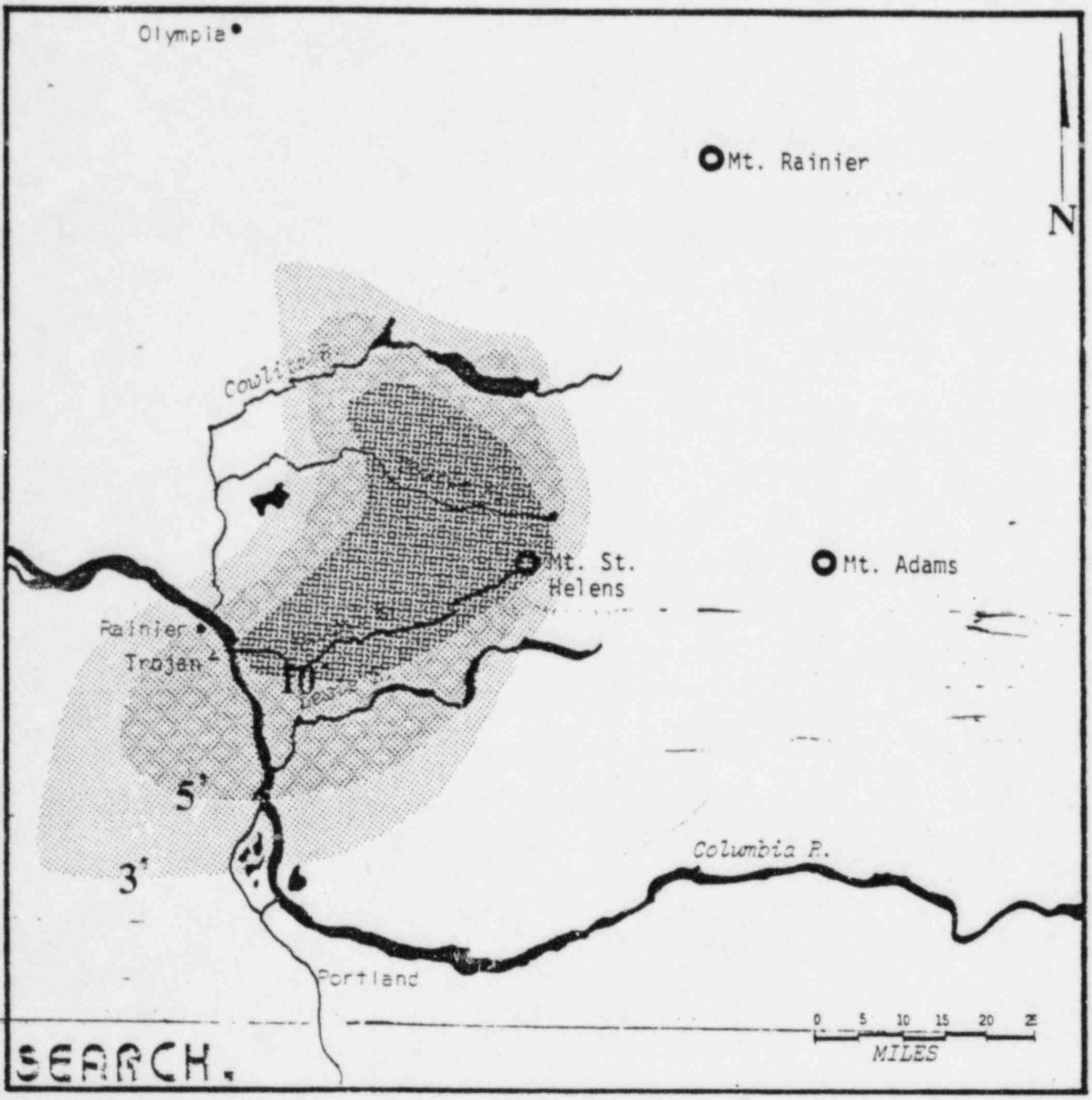
For this evaluation, no distinction is made between the terms "pumice flow", "ash flow", "pyroclastic flow", "nuée ardente", and "glowing avalanche". They all describe an eruption of hot tephra-filled gas, which sweeps down the side of a volcano, often following river valleys.

MOUNT ST. HELENS

Pyroclastic flows are typical of Mount St. Helens eruptions, particularly late in the eruptive cycle ["Eruptive Sequence at Mount St. Helens, Washington," Geol. Abs. with Programs, 3(2), C.A. Hopson, 1971, p. 138]. Even in the primarily airborne ash eruption of 18 May, Mount St. Helens produced pyroclastic flows:

> Traveling at a speed of 100 miles per hour and heated to 800°F., each glowing avalanche melted snow, singed trees, and cremated every smaller life form in its brimstone path [Roberts, p. 6].

POTENTIAL ASH FALL DEPTHS AND DISTRIBUTION FOR MT. ST. HELENS



Crater Lake isopachs rotated 157° counterclockwise and superposed with source at Mt. St. Helens.

FIGURE 5 Shaded areas are for depths greater than 3-feet, 5-feet, and 10- feet. Depth at Trojan site is about 8-feet, compacted ash.

Crater Lake isopachs taken from: <u>Geology of Crater Lake National Park, Oregon</u>, Howel Williams, 1942, p. 70.

More generally,

> During the past 600 years "hurricanes" of incandescent debris repeatedly raced down the volcano's slopes and moved down valleys within a 10-mile radius of the cone [Fire and Ice, S.L. Harris, 1980, p. 172].

The Kalama is one such river valley. From its source on Mount St. Helens, it empties into the Columbia directly across from the Trojan site, 34 straight-line miles from the old summit.

While the 4500-year geologic record for the influence of Mount St. Helens on the Kalama River shows little or no evidence of pyroclastic flows [Bull. 1383-C, Plate 1], one must again turn to the region to estimate the risks required for nuclear power plant design. Following the FSAR use of the Mt. Mazama eruption to develop volcanic design conditions, attention is again directed to that 6600-year old eruption.

MT. MAZAMA

Williams found remains of several pyroclastic flows, one of which traveled 40 miles down the Rogue River Valley, 35 straight-line miles from the source, Fig. 3. At the end of this flow he found charred logs up to 3 feet in diameter [p. 83], evidence of the extreme heat experienced that far from the source.

In considering the possibility of a pyroclastic flow down the Kalama River Valley to the Trojan site, one might imagine that the Columbia River would provide some protection. This may not be the case, as illustrated by the following description of the northern pyroclastic flow from the Mt. Mazama eruption:

> Another seething hurricane of pumice and rock fragments descended to the north, sweeping across Diamond Lake and emptying a load of pumice bombs into the valley of the North Umpqua [Harris, p. 95].

The Diamond Lake crossing was apparently about 3 miles long, and the terminus of this flow was 15 or 20 miles beyond. Clearly, water is no barrier to pyroclastic flows.

If the Mt. Mazama pyroclastic flow distribution is superpositioned onto Mount St. Helens, with the Kalama River Valley (Fig. 1) substituted for the Rogue (Fig. 3), it appears that pyroclastic flows can potentially reach the Trojan site. The risk of this event is estimated to be about one in 10,000 per year on the basis of the length of record and Mount St. Helens' activity.

REVIEW OF TROJAN SAFETY ANALYSIS

The following items have been reviewed as part of the present evaluation:

(1) FSAR Section 2.5, Geology and Seismology.

(2) Richard B. McMullen affidavit of 12 April 1978, Docket 50-344, "Proposed Amendment to Facility Operating License...."

(3) Energy Facility Siting Council (EFSC) letter of 14 July 1980 to PSR.

(4) EFSC response of 11 September 1980 to PSR.

In brief, these references incorrectly consider Mount St. Helens to be dormant or of no quantifiable hazard. The effect of wind on ash fall is evaluated incorrectly, and the direct and indirect effects of blast are totally ignored. Pyroclastic flows are casually and incorrectly dismissed because of the distance and topography involved.

Rather than dwell on the individual errors of the Trojan Safety Analysis, it appears more productive to consider the nature of these errors. The key appears to lie within the following statement:

> The only item with a frequency within the working life of the plant (about 40 yr) are [sic] floods and debris flows with an indicated possible frequency of once in 10 yr to once in 100 yr. There is [sic], as yet, no published data for possible frequencies of volcanic events at Mount St. Helens... [FSAR, 2.5-38].

From this one sees that the Safety Analysis only considered events with risks not much less than one in 40 per year.

The error in this approach is obvious if one considers several, unrelated design events. Suppose that a plant is subject to 10 such events, each having a risk of only one in 200 per year. Thus, each event has a frequency far outside the 40-year life of the plant. The overall risk to the plant is calculated as follows:

$$1 - [(1-1/200\text{yr})^{10}]^{40} = 0.87 \text{ per 40-yr life.}$$

That is, the plant would have an 87 percent chance of failing.

(If this approach was followed in other parts of the safety analysis (not evaluated here), it is obvious that the plant may be subject to extraordinary risk of failure. This possibility should be brought to the attention of the EFSC immediately.)

From this incorrect approach follow the incorrect conclusions of the FSAR concerning the hazards of airborne ash fall and pyroclastic flows.

CONCLUSIONS BASED ON THIS EVALUATION, FOR A NUCLEAR POWER PLANT:

[1] Trojan site should probably have design depths for ash fall in excess of 16 feet for fresh, dry ash or 8 feet of wet ash. This design depth applies directly to design loading of structures and indirectly to plant operations and functions.

[2] Pyroclastic flows should probably be included as a plant design condition. This design condition implies criteria of temperature, wind, erosion and impact, and loading. These criteria apply to structures and to plant operations and functions.

[3] The Trojan Final Safety Analysis shows no comprehension of the analysis or design required to assure safe plant operation. Thus, there is no apparent, present basis to assure safe operation of the facility.

Submitted by,

Norman Buske
Principal Investigator

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SEARCH.