UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division
1201 Pacific Avenue, Suite 600
Tacoma, Washington 98402

March 12, 1984

Mr. Ronald L. Ballard, Chief
Environmental & Hydrologic Engineering Branch
Division of Engineering
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Ballard:

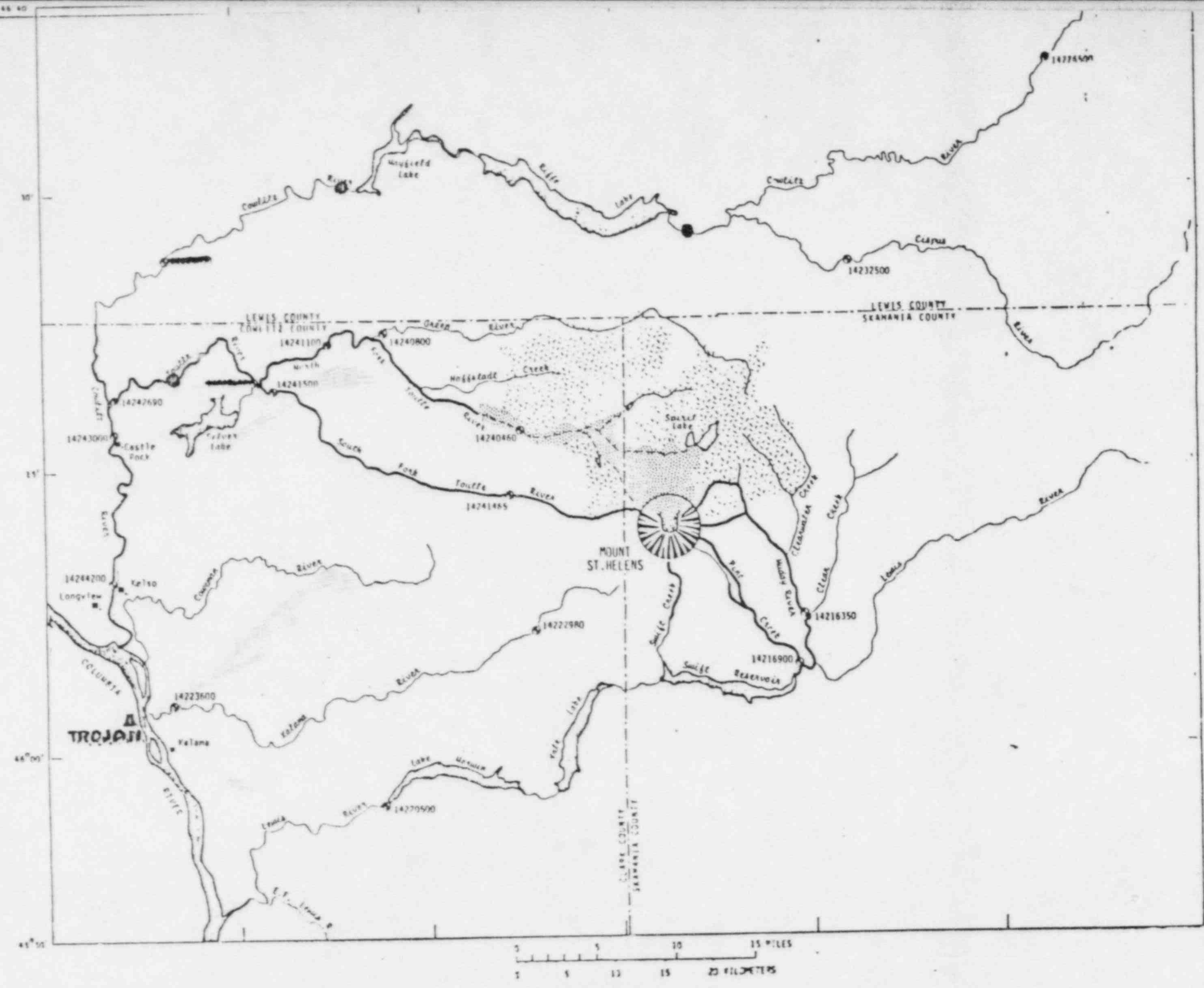
Enclosed as you recently requested are copies of the transparency materials that we presented at our February 23, 1984 meeting in your offices on the subject of the Trojan Nuclear Power Plant.

Sincerely yours,

L. B. Laird
District Chief

Enclosures

A/60


LEWIS COUNTY
COWLITZ COUNTY
LEWIS COUNTY
SKAMANIA COUNTY
CLARK COUNTY
SKAMANIA COUNTY
MOUNT
ST. HELENS
TROJAN
Castle
Rock
Kelso
Longview
Kalama
14242690
14243000
14244200
14241100
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COLUMBIA
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0 5 10 15 MILES
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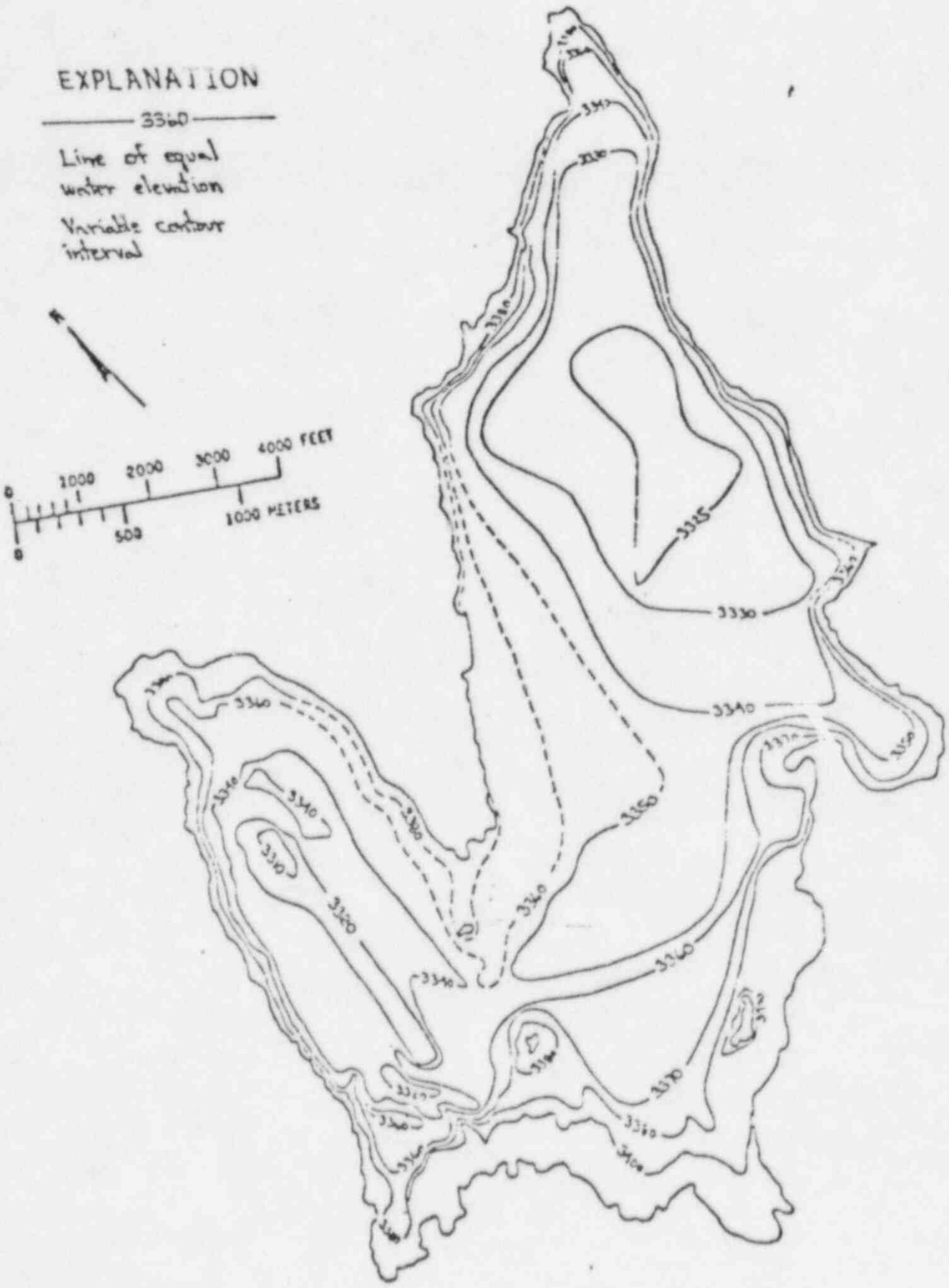

FIGURE .— Spirit Lake bathymetric map (surveyed by U.S. Geological Survey during March–May, 1981)

SPIRIT LAKE BLOCKAGE FAILURE

BREACH CONDITIONS

Parameter	At Failure	At Present (2/84)
Lake stage 1/	3,475 ft	3,461 ft
Lake volume	314,000 ac-ft	272,000 ac-ft
Avalanche deposit volume	3.9×10^9 yd^3 (bulk)	same
Median grain sizes at crest		
Above 3,527 ft	0.06 mm	
3,518 - 3,527 ft	.25 mm	
3,518 - 3,450 ft	.50 mm	
Below 3,450 ft	7.00 mm	
Deposit volume in path	2.6×10^9 yd^3 (bulk)	same
Deposit porosity	32 percent	No change
Deposit saturation	50 percent	>50 percent
Type of failure	piping (4,400 ft to elev. 3,448)	
Breach peak discharge	530,000 ft^3/s	
Sediment volume entrained	2.4×10^9 yd^3 (bulk) 1.63×10^9 yd^3 (solids)	
Breach discharge multiplier	5.0	
Peak discharge multiplied (Camp Baker)	$2.65 \times 10^6 ft^3/s$	
Sediment concentration	65 percent by volume	
Peak discharge (mouth Cowlitz River)	$1.09 \times 10^6 ft^3/s$ (routed)	

1/Maximum stage is 3,532 ft (blockage low point), volume 500,000 ac-ft, minimum lake stage (empty) is 3,310 ft.

SPIRIT LAKE STUDY

Expressions used to determine flood volume multipliers:

- LV = lake volume
- PV = pore volume
- SV = solids volume = AV - PV
- S = saturation
- TV = total volume = LV + SV + PV * S
- PV*S = Water volume in pore space
- C = percent sediment concentration by volume

$$= \frac{SV \times 100}{SV + PV*S + LV} = \frac{SV \times 100}{TV}$$

M = lake volume multiplier to obtain TV

$$= \frac{TV}{LV}$$

AV = avalanche material volume = SV + PV

Example multipliers for several sediment concentrations for lake volume at lake elevation 3,475 ft = 314,000 ac-ft
= 0.507×10^9 yd^3

Volume Table

(All Volumes x 10^9 yd^3)

LV	AV	PV 1/	PV*S 2/	SV	TV	C	M
0.507	.60	.19	.10	.41	1.02	40	2.0
.507	.98	.31	.16	.67	1.34	50	2.6
.507	1.75	.56	.28	1.19	1.98	60	3.9
.507	2.51	.80	.40	1.71	2.62	65	5.1
.507	3.85	1.23	.62	2.62	3.75	70	7.4

1/Porosity = 32%
2/Saturation = 50%

ACTUAL VALUES USED

LV	AV	PV	PV*S	SV	TV	C	M
.51	2.40	.77	.38	1.63	2.52	65	5.0

SPIRIT LAKE BLOCKAGE FAILURE

MUDFLOW ROUTING CONDITIONS

Model: Kinematic wave (Land, USGS, K634)

Distances: Toutle River, 34 miles
Cowlitz River, 16 miles downstream from Toutle River
20 miles upstream from Toutle River

Input: Spirit Lake breach hydrograph, multiplied by 5.0 to include sediment and pore water from avalanche, applied to North Fork Toutle River at Camp Baker, duration 25 hours, peak 14 hours after breach by piping increases to 40,000 ft^3/s.

Channel geometry: Based on cross sections obtained photogrammetrically from photos summer of 1980.

Cross-section spacing: About 1 mile, nodes spaced at 0.2 mile on Toutle River and 0.3 mile on Cowlitz River.

Roughness coefficients: Varied with depth of flow in cross section, Manning's coefficient based on equation developed by Dr. Cheng-lung Chen:

$$n = \frac{0.315 \sqrt{\mu}}{(HR)^{5/6}}$$

with μ (dynamic viscocity) = 50 and depth used instead of hydraulic radius (HR) to avoid discontinuities at transition of channel to floodplain.

Channel deposits: None applied; model does not have moveable bed features.

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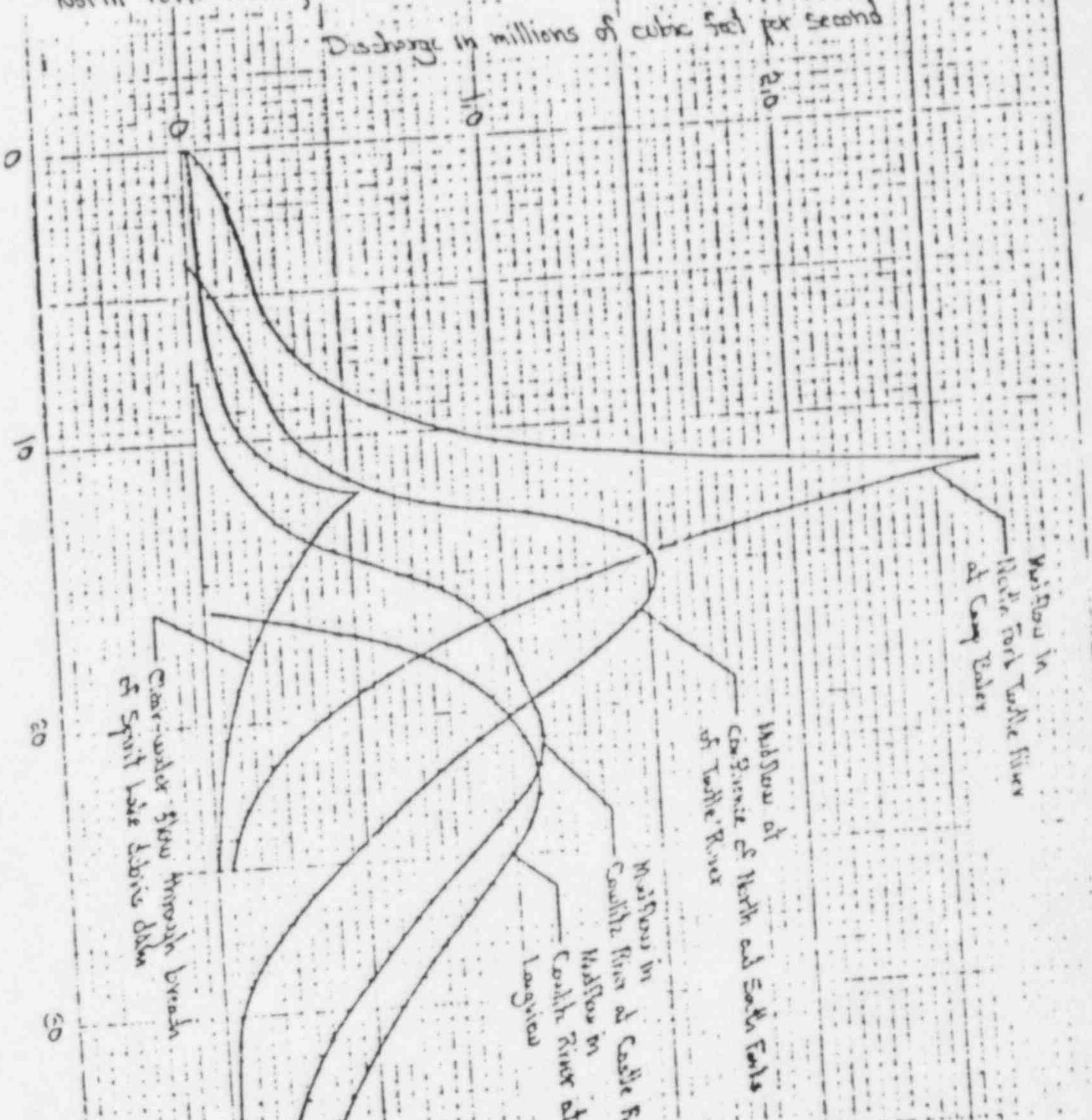
Figure 4.--Discharge hydrographs at selected locations along the North Fork Toutle, Toutle and Cowlitz Rivers



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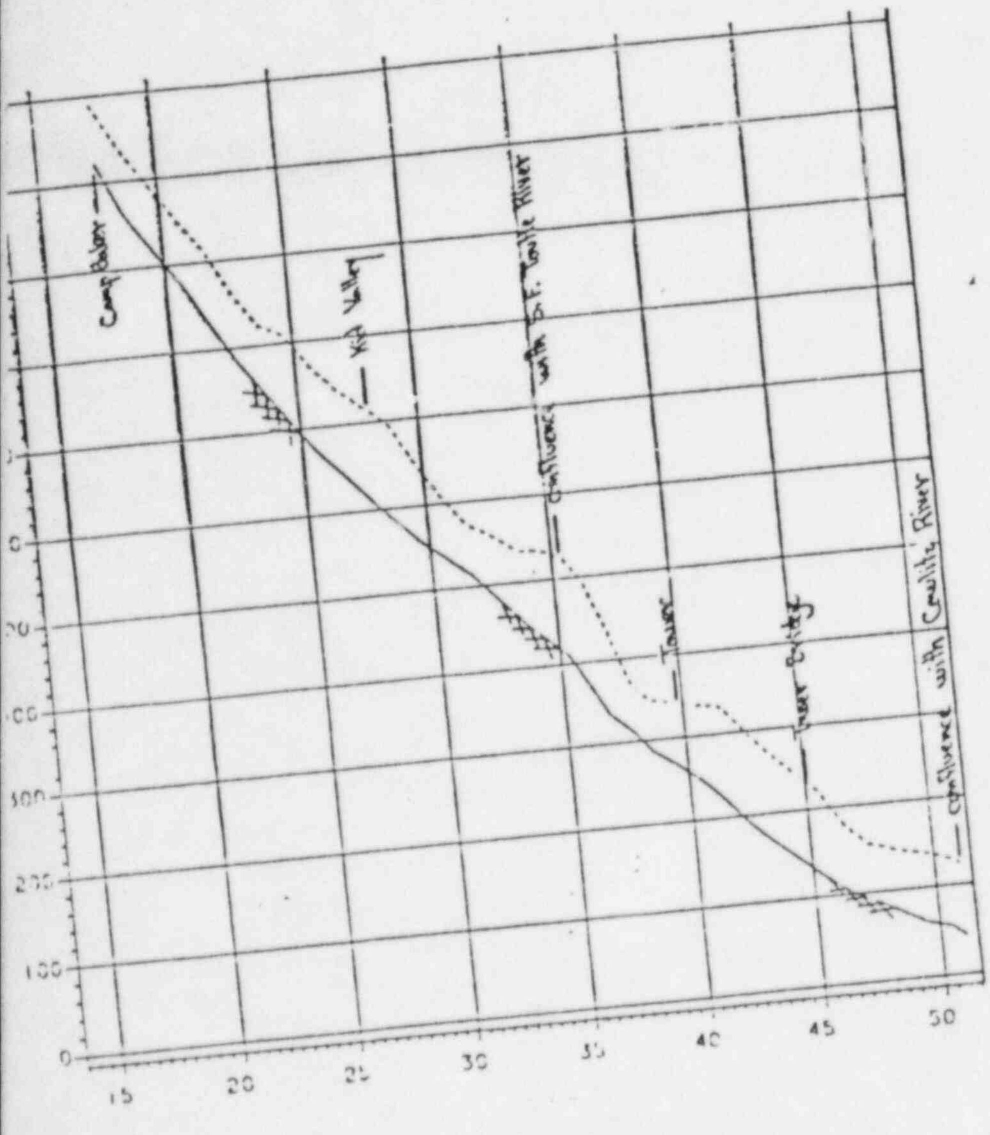
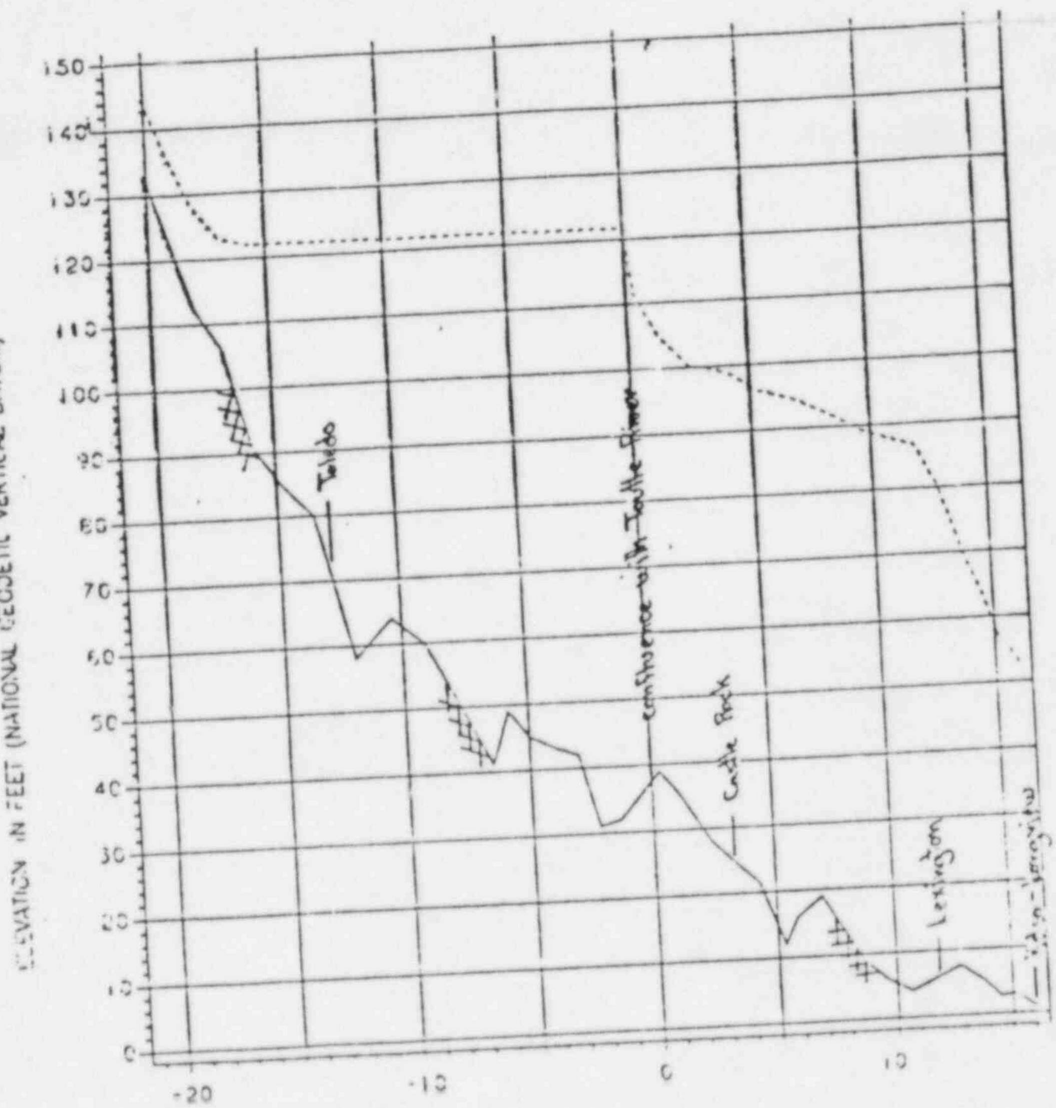


DISTANCE DOWNSTREAM FROM SPIRIT LAKE BREACH, IN RIVER MILES

FIGURE 8.- PROFILE OF PEAK MUDFLOW ELEVATIONS ALONG NORTH FORK TOUTLE AND TOUTLE RIVERS



DISTANCES UPSTREAM AND DOWNSTREAM FROM MOUTH OF TOUTLE RIVER, IN RIVER MILES

FIGURE 9.- PROFILE OF PEAK MUDFLOW ELEVATIONS ALONG COWLITZ R.

TABLE 1.--Simulated water-surface elevations in the Columbia River at Trojan Nuclear Power Plant for the coincidence of high tide, a hypothetical mudflow with a peak discharge of 1.1 million ft^3/s in the Cowlitz River, and selected Columbia River discharges

Columbia River flow condition	Columbia River discharge upstream of Cowlitz River (ft^3/s)	Water-surface elevation (feet)	
		a/	b/
2-year peak	410,000	25	38
10-year peak	610,000	28	44
50-year peak	750,000	30	47
100-year peak	820,000	32	48

a/ Computed with Manning's coefficients for clear water.

b/ Computed with Manning's coefficients for a mudflow downstream of the Cowlitz River and clear water upstream of the Cowlitz River.

TABLE 2.--Simulated water-surface elevations in the Columbia River at Trojan Nuclear Power Plant for selected Columbia River discharges that follow a mudflow that is assumed to have deposited 0.5 billion cubic yards of sediment in the Columbia River channel upstream from the Cowlitz River. The deposit is assumed to have a maximum surface elevation of 30 feet at the Cowlitz River. The surface elevation decreases in the upstream direction at 2.5 feet per mile

Columbia River flow condition	Columbia River discharge upstream of Cowlitz River (ft^3/s)	Water-surface elevation (ft^3/s)
Low flow	250,000	39
2-year peak	410,000	45
10-year peak	610,000	49
50-year peak	750,000	52

VOLUMES

AT CAMP BAKER (TOE OF DEBRIS DAM)

USGS (Debris porosity = 32%, and degree of saturation = 50%).

```
2.4 bcy x 0.68               = 1.63 bcy sediment from debris
2.4 bcy x 0.32 x 0.50 = 0.38 bcy    water from debris
2.4 bcy x 0.32 x 0.50 = 0.38 bcy      air from debris
                                   0.51 bcy    water from Spirit Lake
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AT MOUTH OF COWLITZ RIVER

USGS

Full sediment and water hydrographs were routed from the debris dam.

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                      1.63 bcy sediment
0.38 + 0.51 = 0.89 bcy water
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                      2.52 bcy total
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Peak discharge was obtained by routing a sharply-peaked hydrograph with 65 percent sediment by volume from Camp Baker.

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  708,500 cfs sediment
  381,500 cfs water
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1,090,000 cfs total
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INTO COLUMBIA RIVER

USGS

Gravel and Cobbles (>5 mm) -- on to Columbia River,
40% of debris   40% deposited at confluence

Sands (0.0625 to 5 mm)   -- on to Columbia River,
40% of debris   30% deposited at confluence
                                                10% carried beyond confluence

Silt and Clay (<0.0625 mm) -- on to Columbia River,
20% of debris   20% carried beyond confluence

The total bulked volume of the sediment deposit at the confluence of the Columbia River and the Cowlitz is

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2.4 bcy x (0.40 + 0.30) = 1.68 bcy -- 0.50 bcy upstream (30%)
                                       1.18 bcy downstream (70%)
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COMPARISON OF VOLUMES
INTO COLUMBIA RIVER

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USGS

Gravel and Cobbles (>5 mm) -- on to Columbia River,
40% of debris 40% deposited at confluence

Sands (0.0625 to 5 mm) -- on to Columbia River,
40% of debris 30% deposited at confluence
10% carried beyond confluence

Silt and Clay (<0.0625 mm) -- on to Columbia River,
20% of debris 20% carried beyond confluence

The total bulked volume of the sediment deposit at the confluence of the Columbia River and the Cowlitz is

2.4 bcy x (0.40 + 0.30) = 1.68 bcy -- 0.50 bcy upstream (30%)
1.18 bcy downstream (70%)

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Simons & Li

Gravel and cobbles (>5 mm) -- 40% deposited in Toutle
40% of debris

Sands (0.0625 to 5 mm) -- 20% deposited in Cowlitz
40% of debris 20% deposited at confluence * **

Silt and clay (<0.0625 mm) -- 20% carried beyond confluence
20% of debris

* Table 3.6 has a slight variation in percentage deposited in the Cowlitz, but a 50%/50% split sand/silt-clay was actually used in the computer runs of appendix B.

** The computer runs of appendix B show about 98% (minimun 94%) of the sand load entering the confluence is deposited there.

The bulked volume of the sediment deposit at the confluence of the Columbia River and Cowlitz river is

.45-1.28 bcy x .20 x .98 = .09-.25 bcy -- .02-.05 bcy upstream (20%) ***
.07-.20 bcy downstream (80%)

*** The upstream/downstream split was estimated by scaling profiles in figure 3.5.

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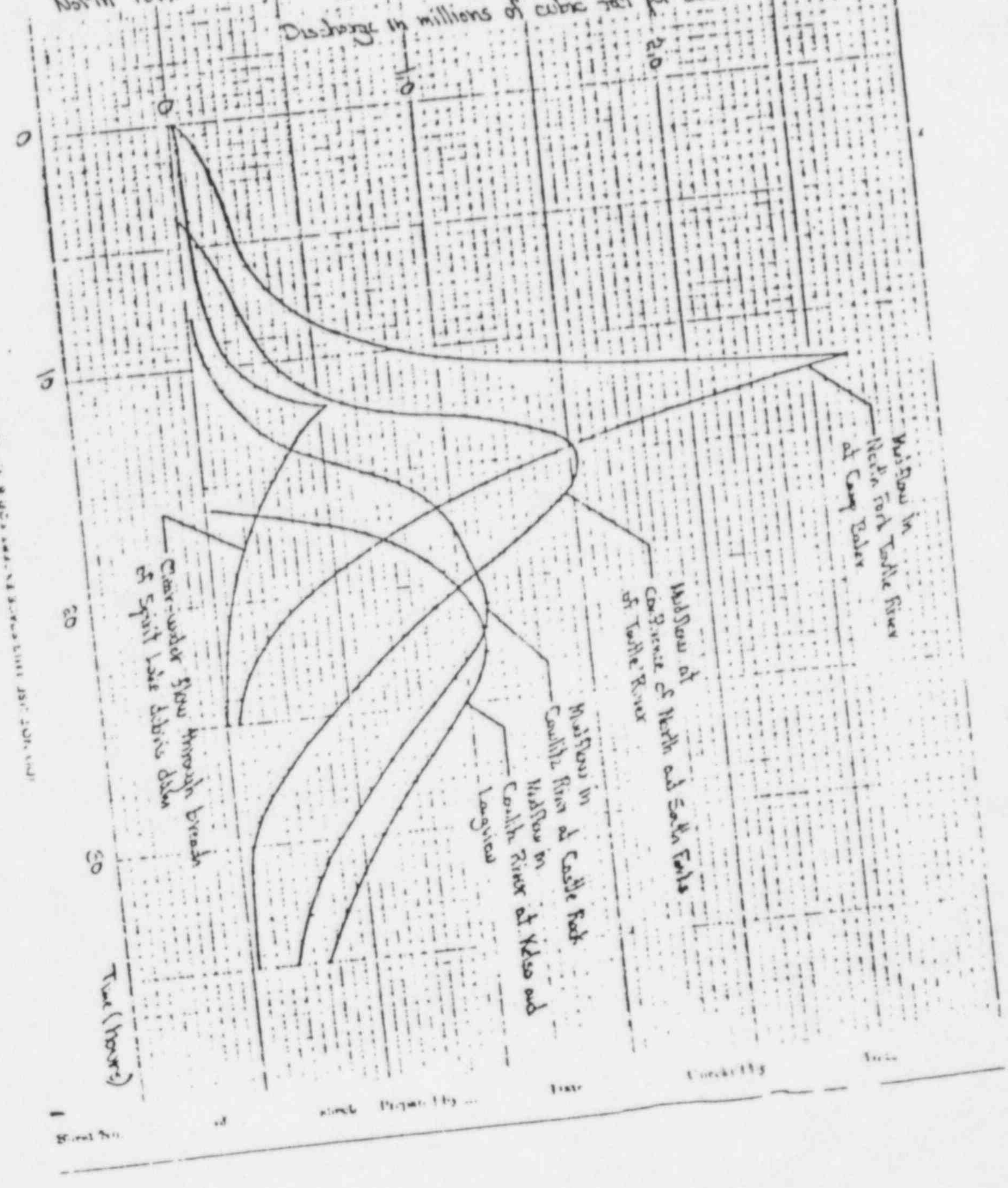

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b/ Computed with Manning's coefficients for a mudflow downstream of the Cowlitz River and clear water upstream of the Cowlitz River.

IMPACT ON TROJAN OF POSSIBLE DISCHARGE OF SPIRIT LAKE

Division of Engineering

By Raymond Gonzales, Environmental and Hydrologic Engineering Branch

The volcanic eruption of Mount St. Helens on May 18, 1980, resulted in a massive and potentially unstable deposit of debris blocking the outlet channel of Spirit Lake and has caused a dramatic increase in the volume of water stored in the lake. If the blockage of the lake were breached, the resulting mudflow flood could possibly affect the safe operation of the Trojan nuclear power plant, located on the Columbia River about 4.5 miles upstream of the mouth of the Cowlitz River. (See the map on the next page.) A mudflow associated with the May 1980 eruption deposited sediment in the Columbia River, mostly in a stretch from about 5 miles downstream of the mouth of the Cowlitz River to 4 miles upstream. The Trojan plant was not directly affected, although large deposits were measured near the intake structure. There now exists a potential for a more severe mudflow.

To reduce the potential for failure of the blockage to Spirit Lake, the Corps of Engineers constructed and is operating a pumping facility at the lake as an interim measure to control the lake level. However, greater-than-normal rainfall, failure or disruption of the pumping system, and/or addition of debris into Spirit Lake from another eruption could cause the lake level to rise excessively.

The NRC has contracted with the Geologic Survey to furnish a conservative estimate of the flows and elevations in the Columbia River at the Trojan plant that would result from a Spirit Lake breakout. One problem is the lack of a good computer model to predict the transport of a mudflow in an upstream direction at river confluences. One scenario considered is the concurrent occurrence of a mudflow in the Cowlitz River and a flood in the Columbia River. For a coincident flow of about 690,000 cubic feet per second (cfs) and on the assumption that the roughness coefficients for the Columbia River downstream of the Cowlitz River simulate the hydraulic properties of mudflows, the water level at the Trojan plant would rise as high as the plant grade elevation of 45 feet above mean sea level (ft msl). (If clear-water roughness coefficients are used, a river flow as high as 850,000 cfs would result in a flood elevation of only 32 ft msl at the Trojan plant.) The other scenario considered was the occurrence of a mudflow depositing sediment in the Columbia River during a low-flow period, followed by a river flood; for a flood flow of about 430,000 cfs or greater, the water level at Trojan would be at or above the plant grade elevation of 45 ft msl.

The Trojan licensee made an independent study of the effect of a mudflow on the plant. The worst case considered was a flow of 800,000 cfs in the Columbia River coincident with a mudflow in the Cowlitz River that would deposit sediment in the Columbia upstream of its confluence with the Cowlitz. A flood elevation of 39 ft msl was estimated at the Trojan plant.

NRR staff has reviewed the analyses of the Geologic Survey and of the licensee. Because of the uncertainty of the applicability of the computer models used and because of the severity of the consequences should flood waters exceed plant grade, the staff concludes that the results of the more conservative Geologic Survey analyses should be used as a basis for establishing limiting conditions for the operation of the Trojan plant.

P/45

The licensee has also considered the possibility of sediment from a mudflow blocking the intake structure and affecting the service water system which provides safety-related cooling water. In the event that the intake to the service water system is lost, the licensee is required by existing Technical Specifications to shut down the plant. In lieu of the service water system, adequate cooling for safe shutdown can be provided for a minimum of 165 hours by the circulating water system and the cooling tower basin without makeup to the system. This cooling capacity can be maintained in the event of concurrent loss of off-site power by use of the cooling tower makeup pumps which can be connected to emergency diesel generators. If the water in the cooling tower is exhausted by evaporative losses before the intake to the service water is restored, additional water can be pumped into the cooling tower by temporary pumping systems or fire pumpers. Water could probably be taken from the Columbia River or from two on-site lakes having a combined volume of approximately 100 million gallons. On the assumptions that only 70% of this volume is available and that there is no inflow to the lakes, makeup water for the cooling tower basin is available for an estimated 97 days.