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A Study of the Effects of a Disaster at Grand Coulee Dam Upon the Hanford Works

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HA Kramer

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Richland, Washington
February 3, 1950

TO: FILE

A STUDY OF THE EFFECTS
OF A DISASTER
AT GRAND COULEE DAM
UPON THE HANFORD WORKS

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INDEX

-000-

	Pages
INTRODUCTION - - - - -	2
MAJOR EFFECTS - - - - -	2-3
DISCUSSION - - - - -	3-5
DETAILS OF EFFECTS FROM A DIRECT HIT - - - - -	5-8
DETAILS OF EFFECTS OF AN INDIRECT HIT - - - - -	8-13
CURVES - - - - -	14

-000-

INTRODUCTION

The following data shows the effect of a disaster at Grand Coulee Dam upon the Hanford Works.

This study was made at the request of the Hanford Works Disaster Committee.

The basis upon which the study was made and the methods involved are explained in the study.

It is calculated that the possible aperture from a single atomic bomb explosion would approximate 137,000 square feet. Actual destruction of German dams was studied by H. L. Bowman of the Atomic Energy Commission. These studies indicate the vulnerability of the dam and the possibility of the above mentioned damage. For convenience and for incremental destruction data, the above aperture was also studied as three trapezoidal openings of total equivalent area.

MAJOR EFFECTS

ASSUMPTIONS:

It is assumed that an atomic bomb or other explosive would be so detonated that the dam would be destroyed, or that the resulting break would be equivalent in proportion to dam bomb destruction in World War II of the German Dams (The Mohne Dam, The Eder Dam, and others), which were destroyed by the British.

The present atomic bomb has more than double the necessary explosive force required. Therefore, the successful destruction of the dam by a properly designed bomb is predicated only by a well engineered placement of the focal point and by the resistance to such an attack.

EFFECTS:

• ASSUMPTION: One direct hit.

DAMAGE:

1. One-half Richland flooded.
2. Midway Substation inundated.
3. Richland isolated.

4. Parts of 100 Areas flooded.

- 100-B { a. 181-B Building
 { b. 182-B Building
 { c. 183-B Building
 { d. Waste Retention Basin

100-D - 181-D Building

100-H - Entire area flooded

100-F - Entire area flooded

5. 300 and 3000 Area - Probably entire areas flooded.

6. Effects would be observed at Richland within 8 to 12 hours.
Peak in 27 hours.
Duration of increased flow: 6 Days

D I S C U S S I O N

The entire subject hinges upon whether the construction of Grand Coulee is vulnerable to an atomic bomb attack.

Preliminary studies indicated that the mass of TNT or other high explosives required was so great as to preclude any major destruction beyond the dismantling of Coulee's Drum Gates.

In April 1949 H. L. Bowman, Atomic Energy Commission's consultant from the Drexel Institute of Technology, went over the preliminary study, including two studies made by the Office of the District Engineer, Portland District, Corps of Engineers, Department of the Army. One of these studies was made at our request and with our collaboration.

Mr. Bowman's opinion at this time was:

1. The atomic bomb as now designed would not survive a drop into water and detonate at a point that would cause enough damage at Coulee to seriously injure Richland.
2. The tonnage of TNT required (7,000 to 13,000 tons) was so great that this explosive use was fantastic.
3. If an atomic bomb could be devised that could be dropped to explode at the right time below water, the fact that the explosive force of an atomic bomb is not a sustained force would preclude the Dam's destruction. The great force of the explosion would travel along the Dam's face and only a small area would be affected and no damage would ensue.

4. Mr. Bowman indicated he would review and would forward to us data indicating whether our study could be useful. With this data he would forward his comments on the information we had collected as to explosive effects.
5. These comments and explosive effect data have just been received. They indicate:
 - a. Grand Coulee Dam is vulnerable.
 - b. He suggests the immediate development of four or more intermediate dams between Hanford and Grand Coulee.

The attached sketches were developed by making several basic assumptions:

1. The effect of a direct hit on Grand Coulee Dam by an atomic bomb would be the equivalent of three openings 267 feet long at the top, 250 feet deep, and 100 feet wide at the bottom. The main dam is 1,650 feet long, the total length is approximately 4,200 feet.
2. Roosevelt Lake would be full (1,290 feet M.S.L.).
3. Maximum flood flow (725,000 c.f.s.).
4. The river between Grand Coulee and the Hanford Works would be receiving an additional 75,000 c.f.s.
5. Intermediate calculations were based on normal river conditions.
6. No engineering data is published covering the trapezoidal openings described, since the discharge will submerge the notches. The method recommended in Table 128, page 164 of Kings Handbook was used. (Peak flows will be slightly below the figures shown in attached sheets and elevations slightly lower.)
7. When and if McNary Dam is in operation, they will begin lowering the pool at Richland within a few moments after the Coulee destruction.
8. The flood routing method used is described on pages 147 to 156, inclusive, Flood Control Manual, Fort Belvoir, XI56. This is known as the Muskingum Method. The routing was checked by the formulae from Pickels Drainage and Flood Control:

$$\frac{I_1 + I_2}{2} t - \frac{O_1 + O_2}{2} = S_2 - S_1 \quad \text{Etc.}$$

The figures from the Muskingum Method were used since the method evaluates both wedge and prismatic storage in the reach.

It is a fault of this method that initial rises on the lower end of the reach are shown prematurely to the actual rise. The timing and size of the peak flow is very accurate.

9. Topography of river channels at each significant Hanford location was carefully checked. Adjacent areas, possibly low enough to be flooded, were examined. River elevations were adjusted to provide for pooling effects or channel widening.
10. Intermediate data was secured by extrapolation.

DETAILS OF EFFECTS FROM A DIRECT HIT

1. Grand Coulee Dam is vulnerable to Atomic Bomb attack.

Dam Data

Length - 4,173 (Concrete)
 Base Width - 500 feet
 Depth to Bed Rock - 550 feet
 Top Width - 30 feet
 Proper Depth for successful bomb - 370 feet
 Proper Distance above Dam - 90 feet to 270 feet

2. A direct hit would cause destruction that would result in a river rise at Richland in 8 to 12 hours.
3. The maximum water elevation at Richland would approximate:

387 feet M.S.L.
 ± 2 feet
 357.1 feet M.S.L. - 1948 Flood Peak

4. The maximum water elevation at 100-B would approximate:

452 feet M.S.L.
 ± 2 feet

Building elevations - 100-B:

181 Building	427 feet M.S.L.
182 Building	442 feet M.S.L.
183 Building Pump Room Floor	440 feet M.S.L.
184 Building Steam Plant	453 feet M.S.L.
185 Building	467 feet M.S.L.
190 Building	467 feet M.S.L.
Waste Retention Basin	
Top of Wall	442'7" M.S.L.
105 Building	469 feet M.S.L.

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5. The maximum water elevation at 100-D would approximate:

440 feet M.S.L.
± 2 feet

Building elevations - 100-D:

181 Building	419 feet M.S.L.
182 Building	451 feet M.S.L.
183 Building	446 feet M.S.L.
184 Building Steam Plant	466 feet M.S.L.
185 Building	467.5 feet M.S.L.
186 Building	468 feet M.S.L.
189 Building	467.5 feet M.S.L.
190 Building	467.5 feet M.S.L.
Waste Retention Basin	
Top of 100-D Wall	451'5" M.S.L.
Top of 100-DR Wall	451'6" M.S.L.
105-D Building	467 feet M.S.L.
105-DR Building	466 feet M.S.L.

6. The maximum water elevation at 100-H would approximate:

433 feet M.S.L.
± 2 feet

Building elevations - 100-H:

181 Building	409 feet M.S.L.
182 Building	422'8" M.S.L.
183 Building Pump Room Floor	395.0 feet M.S.L.
183 Building Head House Floor	418 feet M.S.L.
184 Building Steam Plant	418 feet M.S.L.
190 Building	421 feet M.S.L.
Waste Retention Basin	
Top of Wall	414 feet M.S.L.
105 Building	423 feet M.S.L.

7. The maximum water elevation at 100-F would approximate:

427 feet M.S.L.
± 2 feet

Building elevations - 100-F:

181 Building	405 feet M.S.L.
182 Building	401 feet M.S.L.
183 Building Pump Room Floor	400.5 feet M.S.L.
184 Building Steam Plant	411.5 feet M.S.L.
185 Building	412 feet M.S.L.
189 Building	412 feet M.S.L.
190 Building	412 feet M.S.L.
Waste Retention Basin	
Top of Wall	412.2 feet M.S.L.
105 Building	413 feet M.S.L.

8. The maximum water elevation at the Midway Substation would approximate:

405 feet M.S.L.
+ 2 feet
=

Midway elevations:

Top of rail (Railroad passing below Substation)	(Station 52 + 00)	440.25 feet
Basement of Control Room		455.81 feet
Oil Room Floor (S.P.A.)		455.25 feet
Center Line Water duct entrance (S.P.A.)		441.84 feet
Untanking tower, valve pit floor (S.P.A.)		456.13 feet
Control Room Floor		444.29

9. The maximum river elevation at the 300 Area would approximate:

405 feet M.S.L.
+ 5 feet
=

Because of the pooling and widening that will occur at 405 feet M.S.L., it is not possible to determine elevations closer than 5 feet. This is a flat terrain with many knobs.

Building elevations:

304 Building Steam Plant	380 feet M.S.L.
305 Building	388 feet M.S.L.
Paste Retention Basin	
Top of Wall	380 feet M.S.L.

10. The maximum water elevation at the 3000 Area would approximate:

405 feet M.S.L.
+ 5 feet
=

The river would begin to spread over the flat terrain, and it would be difficult to estimate elevations closer than 5 feet.

11. Richland effects:

Water elevation approximately 367 feet M.S.L.

- Stevens Drive covered from beyond the By-Pass Highway intersection near Saint Road at the irrigation ditch, thence south to the High School.
- That part of the Village would be flooded which is east of a line 300 feet west of, and parallel to Stevens Drive.
- VanGieson Bridge Floor - Elevation 379.9 feet M.S.L.
VanGieson Road - Low Point - 365.3 feet M.S.L.
George Washington Bridge - 361.2 feet M.S.L.
George Washington Road
South of Bridge - 350.5 feet M.S.L.

d. Hospital elevation 361.2 feet M.S.L.
Administration Building 703 361.5 feet M.S.L.
Recreation Hall West Entrance 375.1 feet M.S.L.
Transient Quarters Basement 360.6 feet M.S.L.

DETAILS OF EFFECTS OF INDIRECT HITS

It is believed that one poorly placed bomb might breach an opening equivalent to one notch; two, two notches, etc.

		<u>Predicted Water Elevation Feet M.S.L.</u>		
<u>100-B</u>	<u>Bomb Effect</u>	<u>At Low Flow</u> ($\pm$ 4 ft.)	<u>At Flood Stage</u> ($\pm$ 3 ft.)	<u>At Max. Flood</u> ($\pm$ 2 ft.)
Direct Hit	1 Notch	423	438	443
	2 Notches	429	444	449
	3 Notches	431	446	451
	(Complete Failure	432	447	452
<u>100-D</u>				
Direct Hit	1 Notch	411	426	431
	2 Notches	417	432	437
	3 Notches	419	434	439
	(Complete Failure	420	435	440
<u>100-F</u>				
Direct Hit	1 Notch	398	413	418
	2 Notches	404	419	424
	3 Notches	406	421	426
	(Complete Failure	407	422	427
<u>100-H</u>				
Direct Hit	1 Notch	403	418	423
	2 Notches	409	424	429
	3 Notches	411	426	431
	(Complete Failure	412	427	433
<u>300 Area</u>				
Direct Hit	1 Notch	388	393	396
	2 Notches	392	397	402
	3 Notches	394	399	404
	(Complete Failure	395	400	405

Predicted Water Elevation Feet M.S.L.

<u>Bomb Effect</u>	<u>At Low Flow</u> (<u>± 4 ft.</u>)	<u>At Flood Stage</u> (<u>± 3 ft.</u>)	<u>At Max. Flood</u> (<u>± 2 ft.</u>)
<u>Richland</u>			
1 Notch	373	379	380
2 Notches	377	383	384
(3 Notches	380	385	386
Direct Hit (Complete Failure)	381	386	387

(1948 Flood Elevation - Richland 357.1)

1 Notch = Opening 267 feet wide at top, 250 feet deep, 100 feet wide at bottom.

Note: An indirect atomic bomb explosion is assumed to be behind the dam but not immersed to a proper depth for full effect. Since the drum gates would be forced to an equivalent full opening, the resulting effect is included above.

C A L C U L A T I O N S

Basis: Condition before disaster

#1	Flood Equivalent	1894
#2	Flood Stage	Richland Elevation 348 feet M.S.L.
#3	Low Stage	Richland

T Y P E D I S A S T E R

1. One indirect hit atomic bomb.
2. Two indirect hits atomic bomb.
3. Three indirect hits atomic bomb.
4. Direct hit atomic bomb.

An indirect hit is assumed to effect a trapezoidal opening 267 feet long at the top, 250 feet deep and 100 feet wide at the bottom.

Complete failure is slightly more than three indirect hits.

An indirect hit is a bomb exploding so that the full effect will not be obtained. It is equivalent to one-sixth of the present bomb force.

FLOW THROUGH OPENINGS

King's Formula, page 164:

$$a = 1/3$$

$$b = 100$$

$$\text{Pool } H_2 \quad H_2 \quad 1.5 \quad \frac{H_2}{100} \quad \frac{C_2}{(\text{Table 123})} \quad 0 =$$

TABLE CALCULATIONS

1040	0	0	0	
1060			28800	c.f.s.
1080			85003	c.f.s.
1100			163145	c.f.s.
1120			261158	c.f.s.
1140			380000	c.f.s.
1160			517913	c.f.s.
1180			676056	c.f.s.
1200			856152	c.f.s.
1220			1057770	c.f.s.
1240			1276256	c.f.s.
1250			1399720	c.f.s.
1260			1527084	c.f.s.
1270			1653312	c.f.s.
1280			1792076	c.f.s.
1290			1936970	c.f.s.

--oOo--

The routing time through Roosevelt Lake - 6 hours

Routing formula:

$$K = \frac{T (0.5 (i_2 + i_1) - 0.5 (d_2 + d_1))}{X (i_2 - i_1) + (1.0 - X) (d_2 - d_1)}$$

Natural Discharge

Coulco 725000 c.f.s.
 Richland 800000 c.f.s.

ELEVATION AND FLOW

1,650,000 c.f.s. Each Notch
 1,000,000 c.f.s. Loss of Drum Gates

Hydraulic WaveTotal Flow

	<u>McNary</u>	<u>Richland</u>
Loss of Drum Gates	1,000,000 c.f.s.	1,000,000 c.f.s.
1 Notch	1,720,000 c.f.s.	1,632,000 c.f.s.
2 Notches	2,210,000 c.f.s.	2,250,000 c.f.s.
3 Notches	2,450,000 c.f.s.	2,627,000 c.f.s.
Complete Failure	2,490,000 c.f.s.	2,677,000 c.f.s.

Hydraulic WaveIncrease Only

Loss of Drum Gates	275,000 c.f.s.	275,000 c.f.s.
1 Notch	720,000 c.f.s.	907,000 c.f.s.
2 Notches	1,210,000 c.f.s.	1,525,000 c.f.s.
3 Notches	1,450,000 c.f.s.	1,827,000 c.f.s.
Complete Failure	1,490,000 c.f.s.	1,877,000 c.f.s.

$$\frac{1450}{1827} = \frac{1210}{X_1} = \frac{720}{X_2}$$

.7937

FLOW THROUGH DAM FAILURE

One opening - 1,650,000 c.f.s. at Grand Coulee

Routed from Grand Coulee to the Hanford Works, the flood effect of the opening would be:

Floodwave Effect

1 Opening	907,000 c.f.s.
2 Openings	1,525,000 c.f.s.
3 Openings	1,827,000 c.f.s.
Complete Failure	1,877,000 c.f.s.

At low flow stage river elevation at Richland:

1 Opening	944,000 c.f.s.
2 Openings	1,562,000 c.f.s.
3 Openings	1,864,000 c.f.s.
Complete Failure	1,904,000 c.f.s.

At flood stage of river elevation at Richland:

1 Opening	1,363,000 c.f.s.
2 Openings	2,051,000 c.f.s.
3 Openings	2,320,000 c.f.s.
Complete Failure	2,370,000 c.f.s.

At equivalent 1894 flood at Richland:

1 Opening	1,632,000 c.f.s.
2 Openings	2,250,000 c.f.s.
3 Openings	2,627,000 c.f.s.
Complete Failure	2,677,000 c.f.s.

FLOW THROUGH OPENINGS

Complete Failure

Tail Rise

Ft. M.S.L.

Flow c.f.s.

	975	395,000
	930	610,000
Diff.	15	215,000
	1 F	14,334

Natural Flow

725,000 c.f.s.
610,000 c.f.s.
115,000 c.f.s.

Tail 992'
990'
802'

1290'	Dam Top		
250'	Notch Depth		
1040'	Notch Bottom		
998'	Elev. 725,000 c.f.s.		
Diff. 42'	Q14334 602,023 c.f.s.	1290'	
1040	1,327,023 c.f.s.	1040	
1040	1,650,000 c.f.s. Engrs. Cal.	250 @ 25,000	6,250,000
993'	725,000 c.f.s. Nat. Flow	1040'	1,650,000
42'	925,000 c.f.s. Engrs. Cal.	Total	7,900,000
1'	22,020 c.f.s.		
	5,805,000 c.f.s.		
	1,650,000 c.f.s.		
	4,155,000 c.f.s.		

188.7' + 22,020

1040

1228.7

1290

Diff. 1.3

Complete	7,900,000	40,000	50,000
3 Notches	5,805,000	1/6 240,000	1/6 302,000
2 Notches	3,874,000	1/2 490,000	616,000
1 Notch	1,937,000	1/3 720,000	907,000

PROBABLE FLOW AT RICHLAND, WASH. AFTER AN ATOMIC BOMB EXPLOSION AT GRAND COULEE