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STUDIES OF WHITE OAK CREEK DRAINAGE SYSTEM II. DETERMINATION OF DISCHARGE AT WHITE OAK DAM

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For: N. T. Bray, Supervisor
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This document consists of 24 pages.
Copy 16 of 144.
Series A.

Contract No. W-7405, eng 26

HEALTH PHYSICS DIVISION

WASTE DISPOSAL RESEARCH SECTION

STUDIES OF WHITE OAK CREEK DRAINAGE SYSTEM

II. DETERMINATION OF DISCHARGE AT WHITE OAK DAM

by

L.R. Setter
O.W. Kochtitzky

Date Issued: JUL 11 1950

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STUDIES OF WHITE OAK CREEK DRAINAGE SYSTEM

II. DETERMINATION OF DISCHARGE AT WHITE OAK DAM

by

L.R. Setter[1] and O.W. Kochtitzky[2]

Purpose

In Part I of this series (ORNL-562) a description of White Oak Creek drainage area and calculations of the volume of White Oak Lake were given.

In Part II tables and charts are presented for the determination of the volume of discharge at White Oak Dam. When the discharge is known, measurement of the concentration of radioactivity in the effluent will permit the calculation of the total amount of radioactivity discharged from the lake. If the flow of the Clinch River is known the concentration of radioactivity in the waters of the Clinch River can then be calculated.

These measurements and calculations will permit the estimation of the overall efficiency of the White Oak Creek Drainage System in the reduction or removal of radioactivity (including radioactive decay), the estimation of the conformance of Clinch River water with ingestion tolerance values for drinking water, and the prediction of the effect of flood flows in flushing radioactive material from the lake into the Clinch River.

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(1) Principal Chemist, U.S.P.H.S., formerly Senior Sanitary Engineer, TVA, on loan to ORNL.

(2) Public Health Engineer, TVA, on loan to ORNL.

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Disposal of Radioactive Liquid Wastes

Underground concrete holding tanks are available for storage of radioactive wastes. Considerable chemical precipitation takes place here. Wastes may be jetted from tanks to the evaporator from which the concentrate is returned to tanks for long term storage and the condensate is discharged to the settling basin.

The settling basin is a little more than an acre in area and has a capacity of 1,600,000 gallons. In addition to the evaporator condensate certain process drains which carry moderately contaminated water discharge into it. The influent is measured in a weir box containing five V-notch weirs set at the same elevation. The effluent is skimmed at the opposite end of the basin by a notched wooden trough and is discharged into White Oak Creek through five 8-inch vitrified clay pipes extending through the dike which forms a side of the basin. Because of algal accumulations along the skimming trough and non-uniformity of notch elevation the effluent volume cannot be calculated from this overflow. Since it is impractical to measure independently the discharge from the five pipes, the most desirable solution would be to intercept them for a single measurement.

Intermediate between the tank farm and the settling basin but not routinely used are two ponds. These may be used for diversion and hold up of wastes enroute to the settling basin and for supplementary storage if needed.

These disposal facilities are under the control of the Operations Division subject to limits of radioactivity in the effluent prescribed by the Health Physics Division.

Sampling and testing of the settling basin effluent is done by the Operations Division at 4-hour intervals. The Health Physics Division (Area Monitoring Group) collects samples about 11 A.M. five days a week from the settling basin effluent and White Oak Lake discharge, makes determinations of the potential gamma radiation exposure by immersion; and prepares aliquot samples for beta-gamma radioactivity quantitative measurements.[1]

The flow of White Oak Creek containing the effluent from the settling basin is impounded in the lake formed by White Oak Dam (described in Part I, Drainage Area of the Creek and Capacity of White Oak Lake - ORNL-562). Normal discharge from the lake is through the upper control gate. The lower gate for draining the lake is kept closed and may not be opened without special authorization. Water level in the lake is continuously recorded on a weekly chart by a Bristol Liquid Level Recorder. At the time of daily sampling, notation of the staff gage reading for the gate opening is made on the chart. Any changes made in the gate opening are also noted.

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[1] See CF-48-1-175 memorandum T.H.J. Burnett to E.J. Witkowski "Water Activity Computations".

[redacted]

Calibration of the Bristol Gage

The control gate is opened by a hand wheel which operates a system of gears to lower the gate. An eight inch pointer attached to a collar at the top of the riser stem indicates staff gage readings on a vertical painted wooden gage marked in feet and tenths of feet. The indicated gage reading represents the distance the top of the control gate is below the top of the cofferdam (elevation 750*), that is the height of the 4-foot wide opening.

On July 20, 1948, it was found that the pointer was bent downward so that the indicated opening was 0.35 feet greater than actually existed. Thus, prior to that date all records of gate openings have been 0.35 feet high with the consequence that flows calculated from the gate opening and Bristol gage readings have been higher than the actual discharge. On that date the pointer was straightened and the zero reading became 0.13 feet (top of gate at elevation 750). For a permanent reference measurement the distance between the worm gear hub and the underside of the pointer collar was found to be 72-5/8 inches with the top of the gate at elevation 750.

The data available for calibrating the Bristol gage against water elevation are given in Table I in Appendix I and consist of:

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* Elevations given in feet above Mean Sea Level. See ORNL-562.

[redacted]

[redacted]

1. Data collected by T.H.J. Burnett during September and October, 1947. (Central Files # 47-12-116).

2. Three spot checks during 1948.

3. Records from 4 rains which caused the cofferdam to be overtopped during 1948.

These data corrected to the new zero datum (elevation 750.0, staff gage 0.13) are plotted in Figure 1 which shows a linear relationship between the Bristol gage and lake elevation. Scale divisions on the Bristol gage are equivalent to 0.1025 feet and the top of the cofferdam (elevation 750.0) corresponds to a reading of 76.1 on the Bristol gage. (On January 31, 1950 the Bristol gage reading was found to be 75.0 for lake elevation 750.0. The cause of this change is unknown).

Calculation of Discharge

Normal Flows

During normal flows the discharge is entirely through the upper gate. Discharges given in Table II and plotted on Figure 2 were calculated using the Francis formula for contracted weirs,

$$Q = 3.33 H^{3/2} (L - \frac{2H}{10})$$

In which Q = discharge in cubic feet per second,

L = length of weir in feet,

H = head of water over the weir in feet.

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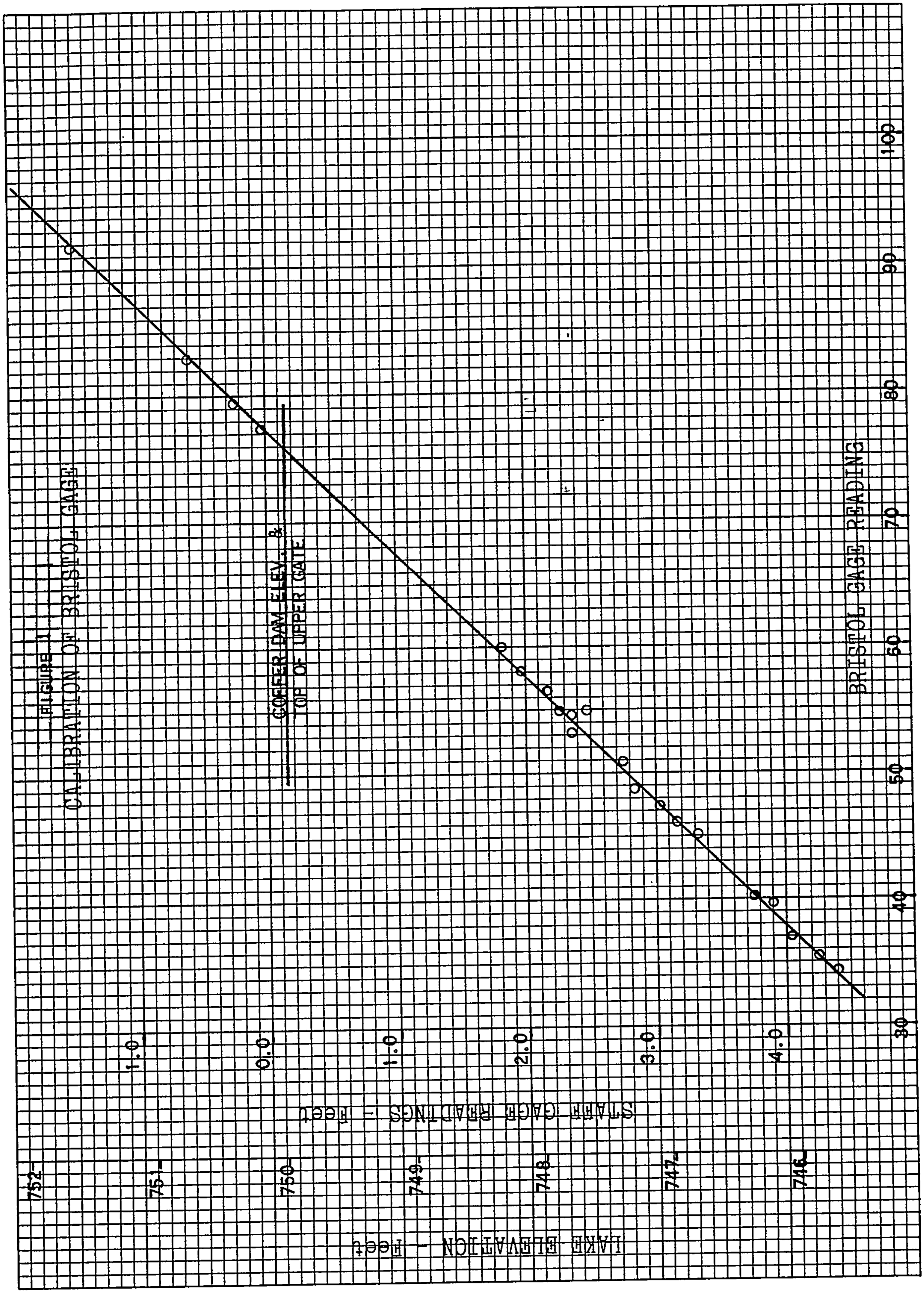

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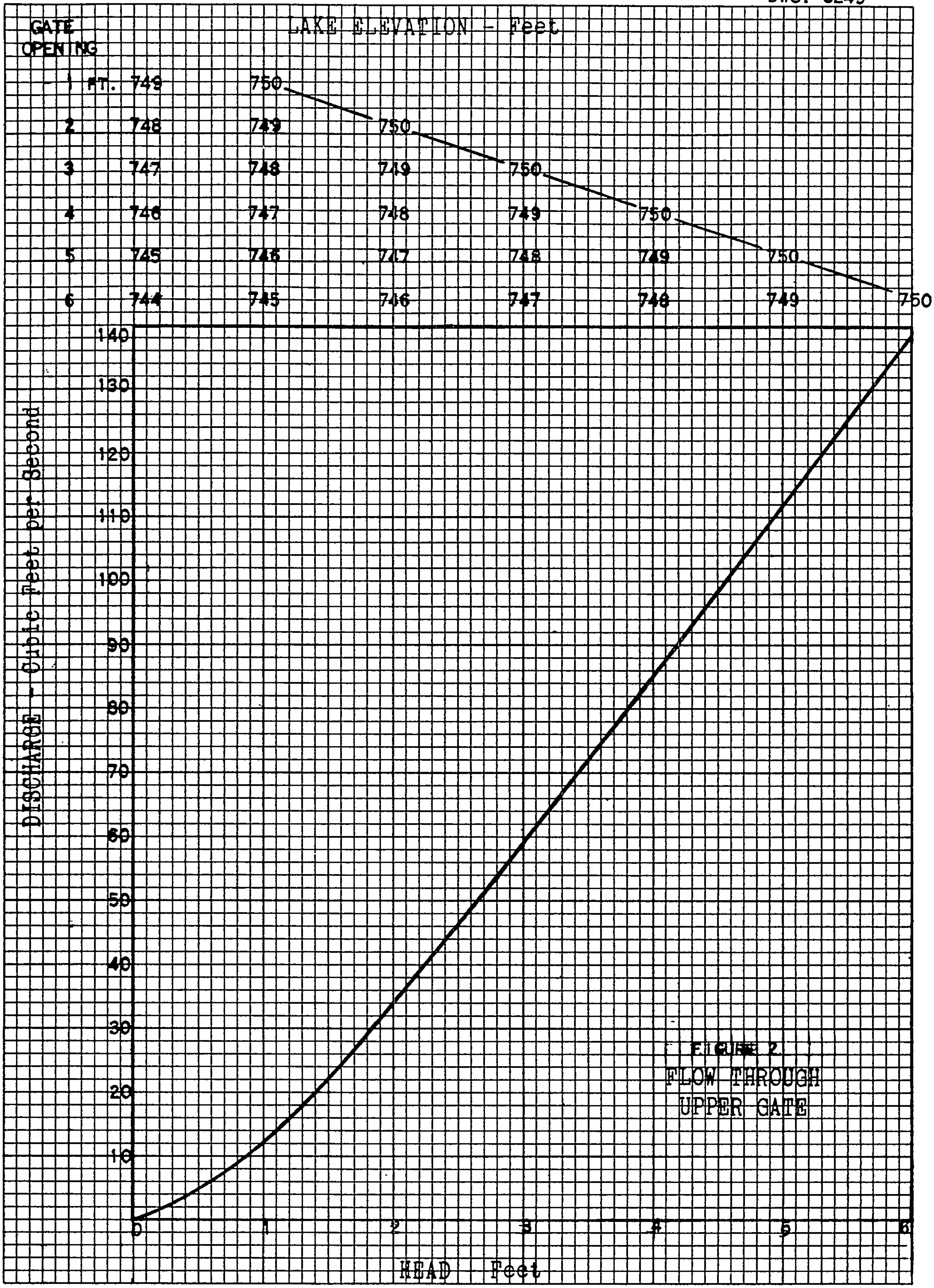

FIGURE 2
FLOW THROUGH
UPPER GATE

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On Figure 2 discharge is plotted against head, expressed in feet, and also against the corresponding lake elevation for various gate openings. Head is the difference between the weir elevation (corrected gate setting) and the lake level. To obtain head in lake elevation from Bristol gage reading Figure 1 should be used.

The lake level as measured by the Bristol gage is supposed to be representative of the head on the weir. Discrepancies may be encountered if:

1. Debris accumulating on the gate screen results in higher levels upstream from the screen than between it and the gate (the pressure bulb is outside the screened area), or

2. The discharge is sufficiently great that the head on the weir exceeds one third the distance from the gate to the pressure bulb (in this case the head measured is not as great as the actual effective head).

Flood Flows

A. Upper Gate

There is a concrete beam across the top of the upper gate so that during flood flows when the cofferdam is overtopped this gate discharges as an orifice rather than as a weir. Under certain conditions

[redacted]

this orifice may be partially submerged due to the limited capacity of the culvert through the earth fill section but the formula used is from "Handbook of Applied Hydraulics" - Davis, and is said not to be appreciably affected by partial submergence. Discharge rating for the gate is given in Table III and Figure 3.

B. <u>Cofferdam</u>

The cofferdam of interlocking Z-section steel piling forms a zig-zag crest and does not provide a straight overflow section when it is overtopped. Considering the depth of web, the length of crest when overflow first begins has been calculated as 57.83 feet. With increasing head the effective length is correspondingly decreased and this decrease is assumed to be a straight line function of head until the head over the cofferdam is equal to the depth of web (1 foot) at which elevation the length of crest is considered to be the axial length of the cofferdam, 43.08 feet for lake levels of 751 and higher. Above elevation 751 the 10.17 feet long concrete beam is overtopped and functions as a weir. The road fill slopes up from the north wing of the cofferdam at a rate of 1.55 feet per foot of elevation above 750. At the south wing of the cofferdam a wall retains the road fill so that it slopes up at a rate of 1.63 feet per foot of elevation above 752.1. The steel beam supporting the platform has bottom elevation at 753.1 and is 13.5 feet long. Thus at elevations above 753.1 a section 9.17 feet long over the concrete slab and a section 4.33 feet long over the cofferdam become restricted

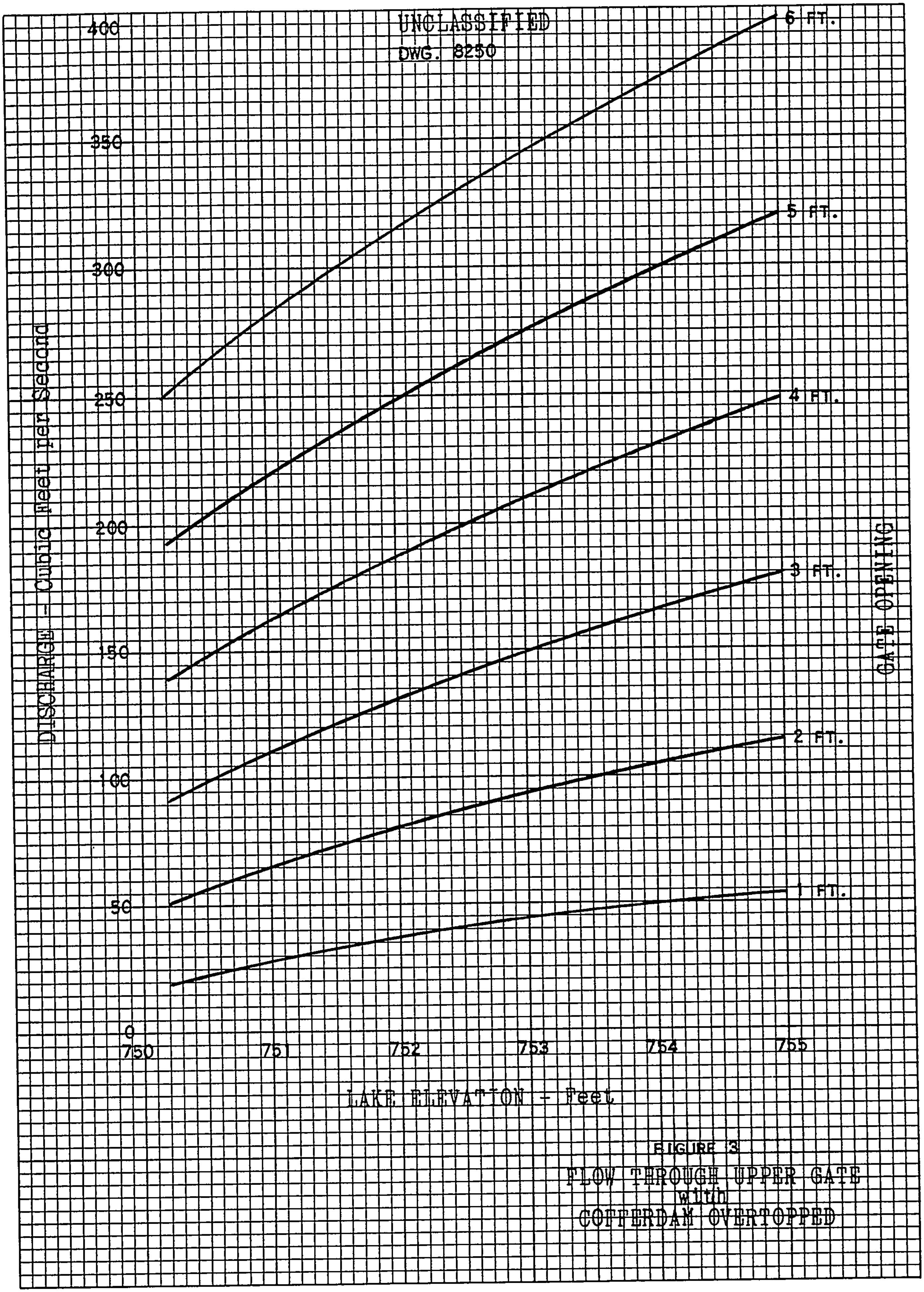

FIGURE 3
FLOW THROUGH UPPER GATE
with
COFFERDAM OVERTOPPED

and discharge as orifices with bottom elevations 751 and 750 respectively. Calculations for flood discharges over the cofferdam must be composites of all these component parts and total discharge must also include the discharge through the upper gate. Discharge tables for the upper gate and cofferdam overflow are given in Table IV and plotted in Figure 4.

During February, 1949, widening of the roadway across the dam resulted in a reduction in the discharge capacity of the cofferdam overflow section. The foregoing discussion and tabulations (with charts) apply to the period subsequent to February, 1949. Prior to February, 1949, discharge over the cofferdam would be higher for a given lake elevation than indicated by these calculations. Tables and figures in Appendix II are for use prior to February, 1949. These should be combined with Table III or Figure 3 for calculating total discharge.

During December, 1949, a work order was prepared and approved, a part of which covers the replacing of the existing pressure bulb type Bristol gage with a float type water level recorder. For this reason all the tables in Appendix I and the charts in the text of this report have been prepared with water level given in elevation (feet above mean sea level) rather than in Bristol gage units.

Summary

Discharge ratings are calculated for White Oak Dam with lake level at various elevations and with various openings of the upper gate. Tables and curves are given.

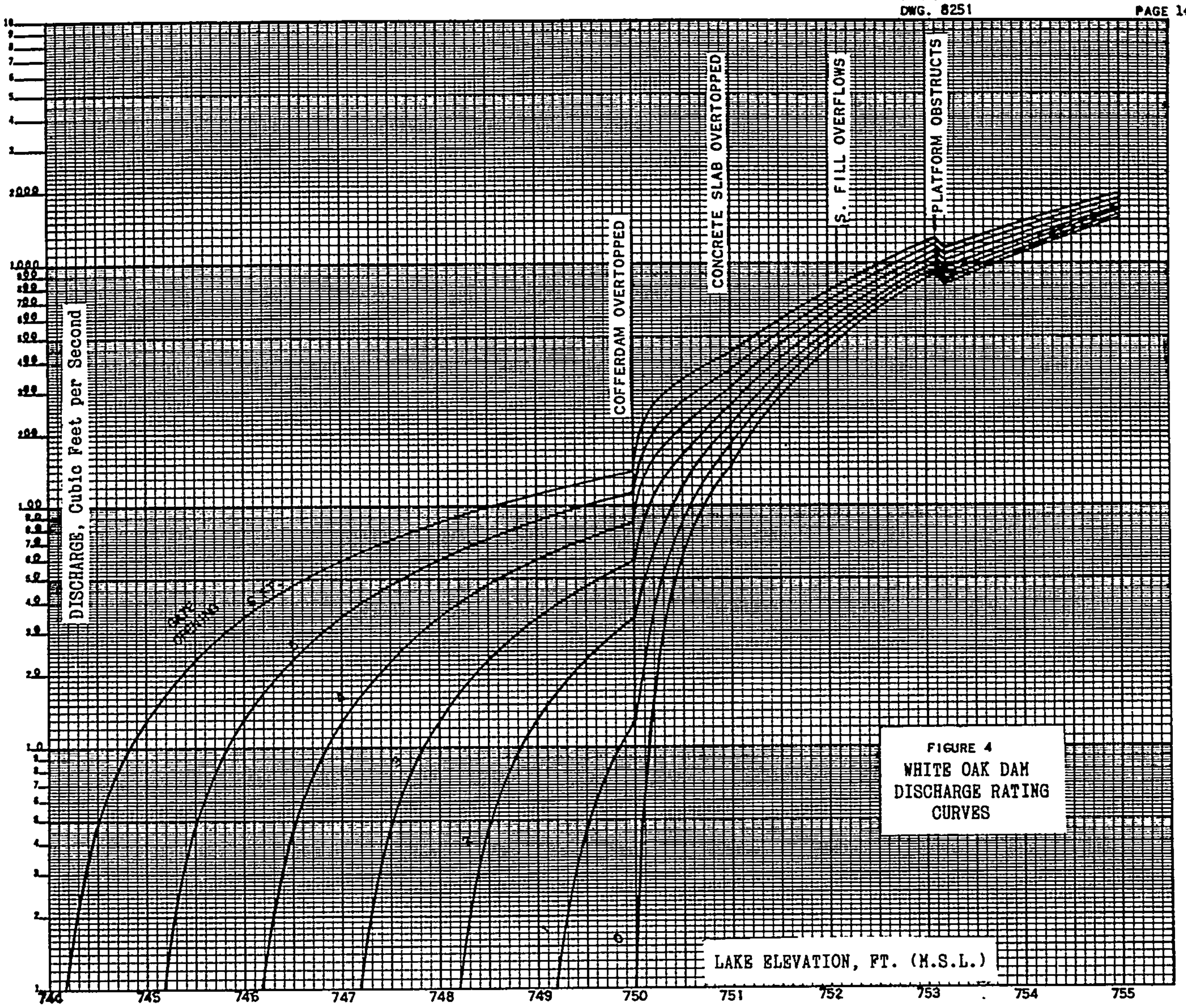

FIGURE 4
WHITE OAK DAM
DISCHARGE RATING
CURVES

Prior to February, 1949, the effective overflow length of the cofferdam was greater than at present. The reduction was due to the widening of the roadway across the earth dam. Tables for calculation of discharge over the cofferdam prior to February, 1949, are given in Appendix II.

Acknowledgements

This study was undertaken by L.R. Setter who prepared the initial draft of the report and the calculations for discharge over the cofferdam as given in Appendix II.

Editing and revising to take into account the changed conditions at the dam was by O.W. Kochtitzky.

The Area Monitoring Group assisted in obtaining measurements of the discharge structure.

Reference was made to earlier measurements by T.H.J. Burnett (CF #47-12-116).

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APPENDIX I

For use with data subsequent

to

February, 1949

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Table I

Observations for Calibration of Bristol Gage

DATE		Bristol Reading	Staff Gage Reading**	Staff Gage Reading* Corrected Elevation 750 = 0.13 feet	Remarks
9-29-47		34.2	4.65	4.43	
9-30-47		35.9	4.5	4.28	Waves
10-1-47		37.2	4.3	4.08	
10-2-47		39.9	4.15	3.93	
10-3-47		40.5	4.0	3.78	
10-6-47		45.1	3.55	3.33	Waves
10-7-47		46.2	3.42	3.20	
10-8-47		47.8	3.26	3.04	
10-9-47		49.0	3.1	2.88	
10-10-47		51.0	2.95	2.73	
10-13-47		53.5	2.6	2.38	
10-14-47		56.5	2.40	2.18	
10-15-47		58.0	2.3	2.08	Waves
10-16-47		58.2	2.2	1.98	
10-18-47		54.8	2.58	2.36	
10-19-47		55.0	2.65	2.43	
7-8-48		55	2.5	2.28	
7-14-48		60	2.05	1.83	
7-15-48		50.8	2.95	2.73	
2-7-48	2 PM	83		-0.595	8.5 inches over piling
2-13-48	8 AM	92		-1.475	19 inches over piling
2-13-48	6 PM	79.7		-0.215	4 inches over piling
3-23-48	9 AM	77.5		-0.025	Estimated 1* inch over piling

* Gage readings adjusted to staff setting after July 20, 1948.

** Gage readings in feet prior to July 20, 1948.

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Table II

Flow through Upper Gate

$$Q = 3.33\ H^{3/2}\ (L - \frac{2H}{10})*$$

Gate Opening Feet / Head, feet	1	2	3	4	5	6	Discharge cfs
	Lake Elevation, Feet						
0.1	749.1	748.1	747.1	746.1	745.1	744.1	.42
0.2	.2	.2	.2	.2	.2	.2	1.18
0.3	.3	.3	.3	.3	.3	.3	2.16
0.4	.4	.4	.4	.4	.4	.4	3.30
0.5	.5	.5	.5	.5	.5	.5	4.59
0.6	.6	.6	.6	.6	.6	.6	6.00
0.7	.7	.7	.7	.7	.7	.7	7.53
0.8	.8	.8	.8	.8	.8	.8	9.15
0.9	.9	.9	.9	.9	.9	.9	10.9
1.0	750.0	749.0	748.0	747.0	746.0	745.0	12.6
1.5		.5	.5	.5	.5	.5	22.6
2.0		750.0	749.0	748.0	747.0	746.0	33.9
2.5			.5	.5	.5	.5	46.1
3.0			750.0	749.0	748.0	747.0	58.8
3.5				.5	.5	.5	72.0
4.0				750.0	749.0	748.0	85.2
4.5					.5	.5	98.6
5.0					750.0	749.0	112.
5.5						.5	124.
6.0						750.0	138.

* Contracted Weir Formula

Q = discharge in cfs.
H = head on weir in feet.
L = length of weir crest in feet

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Table III

Flow through Upper Gate While Cofferdam is Overtopped

$$Q = CA\sqrt{2gh}\ * = .73\ A\sqrt{2gh} = 5.86\ A\sqrt{h}$$

Discharge, cfs

Gate	1 ft.		2 ft.		3 ft.		4 ft.		5 ft.		6 ft.	
Elevation	h	Q	h	Q	h	Q	h	Q	h	Q	h	Q
750.0												
.2	.7	19.6	1.2	51.2	1.7	91.6	2.2	139	2.7	193	3.2	251
.4	.9	22.1	1.4	55.4	1.9	97.0	2.4	145	2.9	199	3.4	259
.6	1.1	24.5	1.6	59.2	2.1	102.	2.6	151	3.1	206	3.6	266
.8	1.3	26.7	1.8	62.8	2.3	106.	2.8	157	3.3	213	3.8	274
751.0	1.5	28.6	2.0	66.2	2.5	111.	3.0	162	3.5	219	4.0	281
.5	2.0	33.0	2.5	74.0	3.0	122.	3.5	175	4.0	233	4.5	298
752.0	2.5	37.0	3.0	81.0	3.5	132.	4.0	187	4.5	248	5.0	314
.5	3.0	40.4	3.5	87.6	4.0	140.	4.5	199	5.0	261	5.5	329
753.0	3.5	43.7	4.0	93.6	4.5	148.	5.0	209	5.5	274	6.0	344
.5	4.0	46.8	4.5	99.1	5.0	157.	5.5	219	6.0	286	6.5	358
754.0	4.5	49.7	5.0	104.	5.5	164.	6.0	230	6.5	298	7.0	371
.5	5.0	52.3	5.5	110.	6.0	172.	6.5	238	7.0	309	7.5	384
755.0	5.5	54.8	6.0	115.	6.5	180.	7.0	248	7.5	320	8.0	396
	$Q = 23.4\sqrt{h}$		$46.8\sqrt{h}$		$70.2\sqrt{h}$		$93.7\sqrt{h}$		$117.1\sqrt{h}$		$140.5\sqrt{h}$	

* Orifice Formula

- Q = discharge, cfs
- C = coefficient of discharge (.73 for this orifice).
- A = area of orifice in sq. ft.
- h = effective head
- g = acceleration due to gravity = 32.2 ft/s/s.

No account taken for exact formula when $h < 2d$.
Not greatly affected by submergence.

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Table IV

Total Flood Flows While Cofferdam is Overtopped

	Discharge cfs						
Gate Opening, Feet	0	1	2	3	4	5	6
Water Level							
750.0	0	13	34	59	85	112	138
.2	16	36	67	108	155	209	267
.4	44	66	99	141	189	243	303
.6	77	102	136	179	228	283	343
.8	110	137	173	216	267	323	384
751.0	145	174	211	256	307	364	426
.5	280	313	354	402	455	513	578
752.0	450	487	531	582	637	698	764
.5	646	686	734	786	845	907	975
753.0	868	912	962	1016	1077	1142	1212
.5	907	954	1006	1064	1126	1193	1265
754.0	1107	1157	1211	1271	1337	1405	1478
.5	1312	1364	1422	1484	1550	1621	1696
755.0	1539	1594	1654	1719	1787	1859	1935

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APPENDIX II

For use with data prior to

February, 1949

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Table V

Flood Discharge over Cofferdam
(Prior to February, 1949)

Francis Formula $Q = 3.33\ LH^{3/2}$ *

Water Elevation Feet	Bristol Gage Reading	Equivalent Length of Weir - Feet	Discharge cfs		
			Over Piling	Over Top of Gate	Total
750.0	76.1	75.0	0	0	0
.1	77.07	73.6	7.9	0	7.9
.2	78.05	72.2	18.4	0	18.4
.3	79.02	70.8	38.8	0	38.8
.4	80.00	69.4	58.4	0	58.4
.5	80.97	68.0	80.0	0	80.0
.6	81.95	66.6	103.0	0	103
.8	83.90	63.8	152	0	152
751.0	85.85	61.0	203	0	203
.5	90.72	61.0	373	9	382
752.0	95.60	61.0	574	26	600
.5	100.47	61.0	783	49	832
753.0	105.35	61.0	1055	75	1130
754.0	115.10	61.0	1618	138	1756

* Suppressed Weir Formula

Q = discharge in cfs
L = length of weir in feet
H = head on weir in feet

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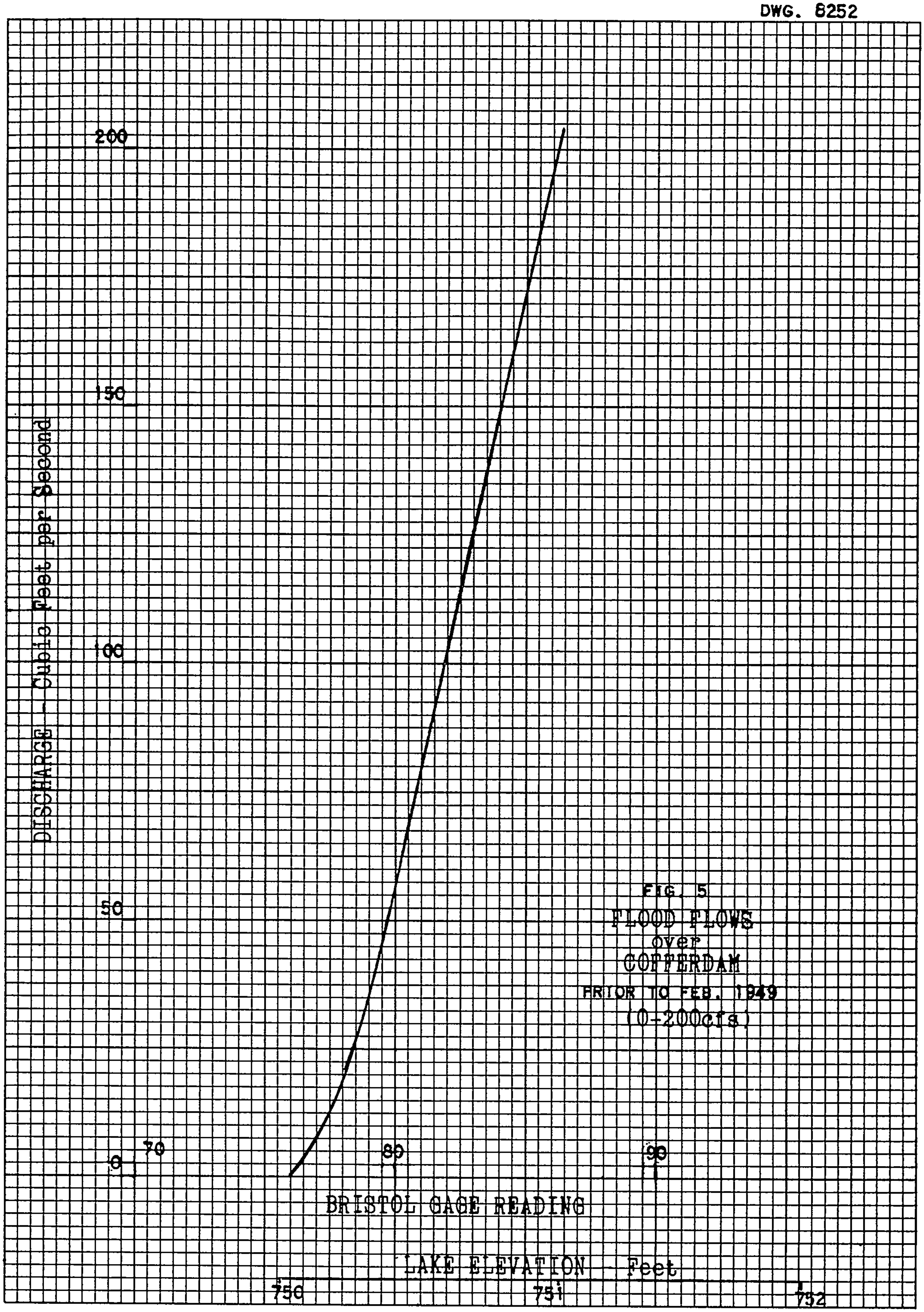

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