C-E Power Systems
Combustion Engineering, Inc.
Route 21-A
Hematite, Missouri 63047

Tel. 314/937-4691
314/296-5640

I+E 70-36

NIS/81/820 release

POWER SYSTEMS

24-162.06-01

March 5, 1981

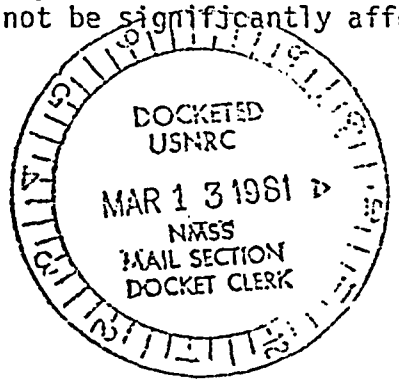
R

Dr. Ed Shum
U.S. Nuclear Regulatory Commission
7915 Eastern Avenue
Silver Spring, Maryland 20910

Dear Dr. Shum:

Enclosed are two copies of our consultant's report concerning the effect of a breach in the Lake Virginia Dam on the 100-year flood elevations in Joachim Creek. This report concludes that a breach of the dam would have a negligible effect on the peak flow of a 100-year flood.

Thus, the 100-year flood levels in the vicinity of the C-E Hematite plant would not be significantly affected.



Very truly yours,

COMBUSTION ENGINEERING, INC.

H. E. Eskridge

H. E. Eskridge
Supervisor, Nuclear Licensing,
Safety and Accountability

/wg
Enclosure

cc: James Hammelman - SAI

H-12

FILE COPY

MAR 30 1981

IV

SPECIAL STUDY FOR JOACHIM CREEK AND LAKE VIRGINIA DAM JEFFERSON COUNTY, MISSOURI

Prepared for:
Combustion Engineering Co.
Hematite, Missouri

February 1981

REITZ & JENS, INC.
Consulting Engineers
1040 N. Lindbergh Blvd.
St. Louis, MO 63132

REITZ & JENS, INC.
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1040 NORTH LINDBERGH
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HENRY M. REITZ, PRESIDENT
STIFEL W. JENS, SENIOR VICE PRESIDENT
JOHN J. BAILEY, JR., VICE PRES., CHIEF ENG.
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SOIL MECHANICS-FOUNDATIONS
HYDROLOGY-HYDRAULICS
RESOURCE RECLAMATION
DRAINAGE-PAVEMENTS
LAND DEVELOPMENT
WATER RESOURCES
SOLID WASTE

February 6, 1981

Mr. Harold Eskridge
Combustion Engineering Co.
P.O. Box 107
Hematite, MO 63047

Re: Joachim Creek & Lake Virginia Study

Dear Mr. Eskridge:

Attached is our report concerning the effect of a breach in the Lake Virginia Dam on the 100-year flood elevations in Joachim Creek. We have, in our files, original copies of the computer output referred to in the report. Each of the "runs" consists of 50 or more pages of closely printed numbers. We can lend you these on request or we can rerun the calculations using the input cards which we also have in our files.

If there is anything in the report that is unclear or if you have any questions, please contact us.

Very truly yours,

JOHN J. BAILEY, JR.

Encl.
JJB/rs

SPECIAL STUDY FOR JOACHIM CREEK AND LAKE VIRGINIA DAM JEFFERSON COUNTY, MISSOURI

Prepared for:
Combustion Engineering Co.
Hematite, Missouri

February 1981

REITZ & JENS, INC.
Consulting Engineers
1040 N. Lindbergh Blvd.
St. Louis, MO 63132

TABLE OF CONTENTS

SPECIAL STUDY FOR JOACHIM CREEK AND LAKE VIRGINIA IN JEFFERSON COUNTY, MISSOURI

1. INTRODUCTION

This report presents the findings of a special study for a portion of Joachim Creek and Lake Virginia Dam in Jefferson County, Mo. near the town of Hematite. The location of the study area is shown on Plate 1. The purpose of the study was to evaluate the effect of failure of the Lake Virginia Dam on flood levels in Joachim Creek in the vicinity of the Combustion Engineering plant near stream mile 14.8±. The intermittent stream from the valley with the Lake Virginia Dam enters Joachim Creek at mile 14.94.

Criteria that the consultants were requested to use for the study included the requirements:

a) that flows established by previous flood hazard studies be accepted;

b) that the Lake Virginia reservoir be assumed to be full to the level of the spillway, at the beginning of the design storm, and

c) that the occurrence of a ½ Probable Maximum Flood (½ PMF) on the Lake Virginia watershed be coincident with occurrence of a 100-year (1% annual chance) flood in Joachim Creek.

Furthermore:

d) that the Lake Virginia dam fail by breaching when it was overtopped.

2. METHOD ADOPTED FOR STUDY

Reference 6 describes procedures for routing dam breach hydrographs through the valley below the dam. Because of the highly variable flow rates during a dam breach, the breach hydrograph is attenuated by valley storage in the reach below the dam. The tributary area of Joachim Creek is about two orders of magnitude greater than the watershed controlled by the Lake Virginia Dam so, for this study, the Lake Virginia dam breach hydrograph for a ½ PMF flood is required to be combined with the hydrograph of a severe flood in Joachim Creek. The consultants first calculated and routed hydrographs of flow in Joachim Creek including outflow past the unbroken Lake Virginia Dam for such a severe flood. Adjustments in various parameters were made to obtain peak flow rates equal to those used in the previous flood study (Reference 1) and the Phase 1 Dam Safety Study for Lake Virginia (Reference 2) until a satisfactory match was obtained. The resulting computer model was then rerun with appropriate instructions which caused it to calculate the effect of a particular breach width and rate of development on the outflow from Lake Virginia (the breach hydrograph). This

breach hydrograph was substituted for the previously used hydrograph of flow from Lake Virginia and the entire routing procedure was repeated. Several breach widths and rates of development were so studied.

3. AVAILABLE DATA

The hydraulic characteristics of the Joachim Creek channel and floodplain were established by other consultants who prepared the Special Flood Study for this reach of Joachim Creek (Reference 1). A copy of their data, prepared on punch cards for input to the HEC-2 computer program (Reference 5), was obtained from the St. Louis District, USCE. This included cross-sections, channel lengths, values of channel and overbank roughness and hydraulic characteristics of bridges.

Hydrologic and hydraulic characteristics of the Lake Virginia watershed were available from the Phase 1 Inspection Report, National Dam Safety Program for the Lake Virginia Dam (Reference 2). These included the drainage area, hydrologic lag time, loss rate indicators, storage volumes in the reservoir at various water elevations, spillway capacities and the profile of the dam crest.

Selected comments from Reference 2, concerning the reservoir area of Lake Virginia, are:

1.2 h. "The reservoir appears to be subject to severe water loss from leakage through either the sides or bottom or both."

2.3 "The lake filled after construction and, at one time, the southwest spillway flowed nearly full. The reservoir seems to drain through a crack or sinkhole in the bottom of the lake."

3.1 a. "A visual inspection of the Lake Virginia dam was made on 10 November 1978."

b. "During field inspections and surveys the reservoir was completely dry except for a small "puddle" no more than 1-1/2 feet deep. Much of the lake bottom appears to have been cultivated during the growing season of 1978."

d. "The reservoir area is effectively empty. Photos show the culture that has developed in the reservoir area."

3.2 "Site observations show a wholly unsatisfactory lake development as far as the amenities and benefits to be anticipated."

Drainage areas at various locations along the reach of Joachim Creek were obtained from Reference 1 and detailed tributary drainage patterns in the vicinity of the reach were measured on the USGS, Festus, Mo., 1:24,000 Quadrangle Map, Edition of 1964.

4. STAGE DISCHARGE AND STORAGE IN JOACHIM CREEK

Computer Program HEC-2 (Reference 5) calculates water surface profiles, storage volumes and other hydraulic parameters from cross-sections, channel roughness values, velocity head losses, bridge geometry and bridge hydraulic data supplied as input to the program. A copy of the data used for the previous study of Joachim Creek was obtained from the St. Louis District office of the Corps of Engineers (Reference 1). The data was in the form of HEC-2 input punch cards including cross-sections, "n" values and bridge data used in calculating the flood profiles. This was rerun to verify the data. Precisely the same high water profiles were obtained as in the previous study by the USCE.

HEC-2 water surface profiles in Joachim Creek were then calculated for rates of flow from 5000 cfs to 70,000 cfs. The stage-discharge relationship at cross-section 7 at mile 14.73, shown on Plate 2, was plotted from the results of this computation. The storage-discharge relationships for the various reaches of Joachim Creek were also calculated by the program as part of the standard output values. These relationships are shown on Plate 3 for three reaches of Joachim Creek, one spanning the sites of the Combustion Engineering plant and the Lake Virginia Dam and the others immediately above and below this reach. Limits of these reaches are shown numerically on Plate 3 and graphically on Plate 1. The middle reach covering the plant and dam extends from Section 3 at mile 13.34 to Section 8 at mile 15.146.

5. HEC-1 COMPUTER PROGRAM

Data required for the HEC-1 computer program include drainage areas, watershed characteristics, index rainfall, and for flood routing, storage-discharge relationships, spillway capacities and characteristics of overflow sections of the dam.

The present consultants established the hydrologic lag time and loss rate indicators for the Joachim Creek main branch and tributaries by methods set out in Reference 5. Twenty-four hour, 100-year rainfall depths were obtained from data assembled by the St. Louis District, USCE. All other data was obtained from previous studies or as described in paragraphs above.

6. HYDROGRAPH ROUTING

a. 100-Year Flood in Joachim Creek:

To establish a reference for comparison with routed dam breach hydrographs, a set of hydrographs for the 100-year flood was routed according to the following sequence:

Calculate Joachim Creek Runoff Hydrograph at mile 15.711
Route Joachim Creek Hydrograph to mile 15.146
Calculate Lake Virginia Runoff Hydrograph
Route Lake Virginia Hydrograph over Dam
Calculate tributary runoff hydrograph between mile 15.146 and mile 13.334
Combine three Hydrographs at mile 15.146
Route Combined Hydrograph to mile 13.334
Calculate Runoff Hydrograph from Bucks Creek
Combine two hydrographs at 13.334
Route Combined Hydrographs to mile 12.631

The initial routing with the consultant's best estimate of the hydrologic lag time and loss parameters resulted in a 32,000 cfs peak flow in the reach between mile 15.146 and mile 13.334. Since this was considerably less than the 39,500 cfs used in Reference 1, the parameters were adjusted to give a peak flow in this reach of 39,069 cfs. Computer input and summaries of output for this final calculation are shown on Sheets A-1 through A-3 in Appendix A. The 100-year index rainfall was increased from 5.4 inches to 6.15 inches (input line 11) and the lag time was decreased from 4.0 hours to 2.5 hours (input line 13) to obtain this 22% increase in peak flow.

b. Breach Hydrographs:

Little if any data or dam and embankment failure, that would be directly applicable to the Lake Virginia Dam, has been published. The consultants believe this particular embankment which is constructed from fairly cohesive soils would be resistant to erosion by overtopping flows and would degrade at a slow rate. Certainly, the embankment would not degrade as rapidly as one constructed from cohesionless material. Even so, the consultants initially tested breaches with development times to bottom of reservoir of 20 minutes. All breaches were timed to start at maximum reservoir elevation, thus releasing the largest possible volume of stored water. Typical breach hydrographs are shown on Sheets A-6 and A-10 in Appendix A. The first is for a 40-foot wide breach and the other is for a 400-foot wide breach which would involve essentially complete disappearance of the dam in

20 minutes. These hydrographs have peak flows of 14,737 and 23,958 cfs respectively. All stored water is released within 30 minutes of the breach starting for the 40-foot wide case 2 breach and within 15 minutes for the 400-foot wide breach.

c. Routing Breach Hydrographs:

When the breach hydrographs were combined with the Joachim Creek hydrographs and routed downstream, rapid drainage of the Lake Virginia reservoir increased flows on the rising side of the Joachim Creek hydrograph as stored water was quickly released. Exhaustion of retention in the reservoir prior to the arrival of the peak flows from the distant upstream portion of the Joachim Creek watershed resulted in decreased contributions from Lake Virginia at the time of the peak flow in Joachim Creek. Case 2 and Case 3 for 40- and 400-foot wide breaches with 20-minute development times, as shown on Plate 4, resulted in an increase of 35 cfs and a decrease of 4 cfs in peak flows in the study reach. Attenuation of the breach hydrographs by effect of valley storage caused considerably smaller increases in discharge on the rising side of the Joachim Creek hydrograph three hours prior to occurrence of the 100-year flood peak in Joachim Creek for the reach in question. Computer input and summaries of output for these cases are shown on Sheets A-4 through A-11 in Appendix A. To obtain any appreciable increase of the peak flow in Joachim Creek it was necessary to assume breach development times of several hours. The greatest increase, to 40,188 cfs in the study reach, resulted from a breach development time of 5 hours which is Case 4 on Plates 4 and 5 and on Sheets A-12 through A-14. Because of the long development time, no breach hydrograph was provided by the computer for Case 4.

7. EFFECT OF DAM BREACH ON FLOOD ELEVATIONS

The indicated time offset of flow from assumed breach of Lake Virginia Dam and the Joachim Creek flood hydrograph result from both occurring from the same rare and intense storm event.

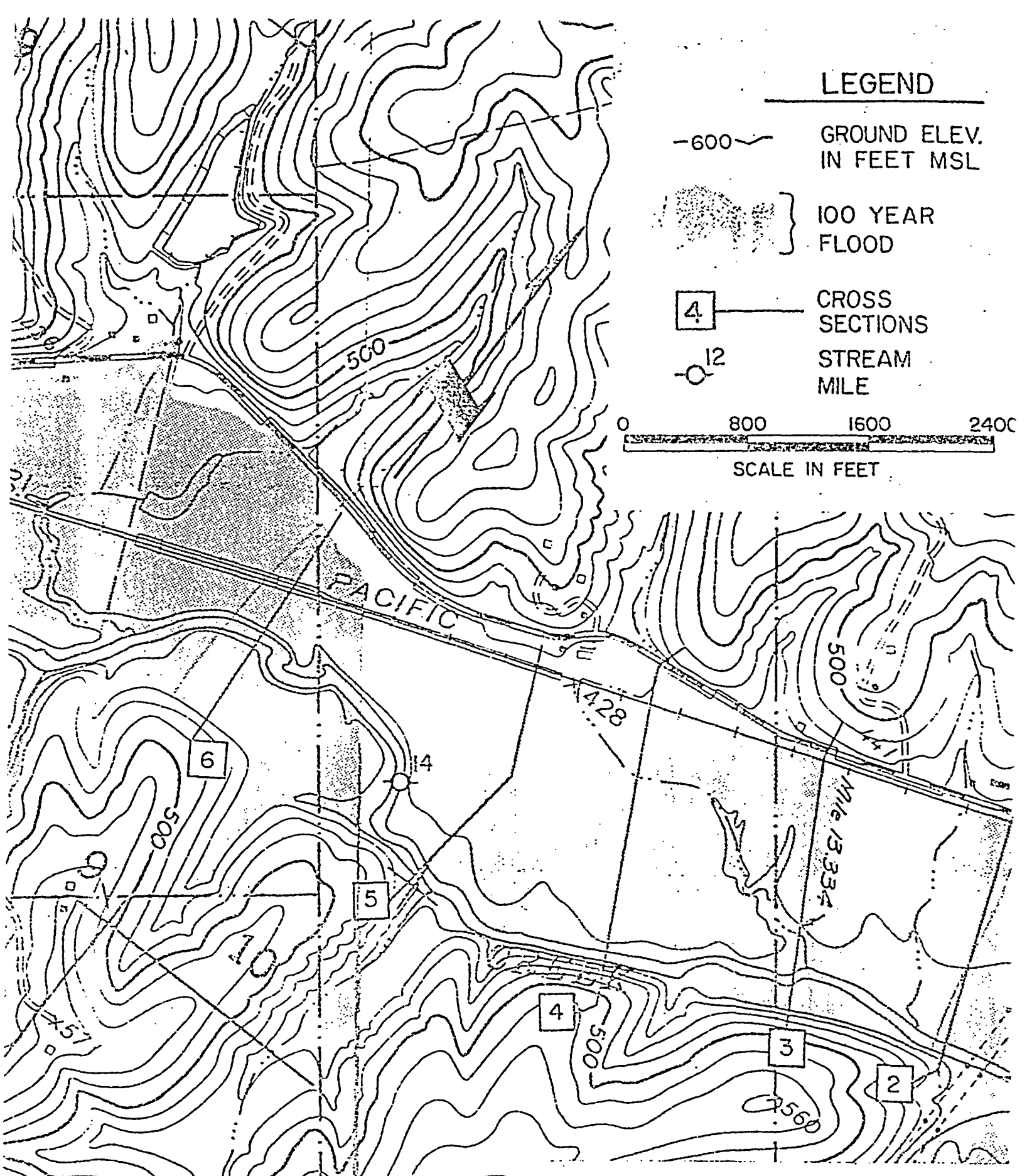
In most of the cases investigated, breaching the Lake Virginia Dam had a negligible effect on the peak flow of the 100-year flood in Joachim Creek. Only by extending the breach development time past the line of peak flow in Joachim Creek, thus allowing stored water to be released at the appropriate time, could a slight increase in peak flows be induced. However, if the breach development time is extended to a greater amount, the rate of release during peak flood flow from the upper reaches of Joachim Creek is again reduced.

The stage-discharge curve on Plate 2 allows a determination of the change in

stage resulting from an increase or decrease in peak flow. For Case 4 an increase of 1119 cfs results in 0.15-foot increase in the level of the 100-year flood. For Cases 2 and 3 the effect on stage was insignificant.

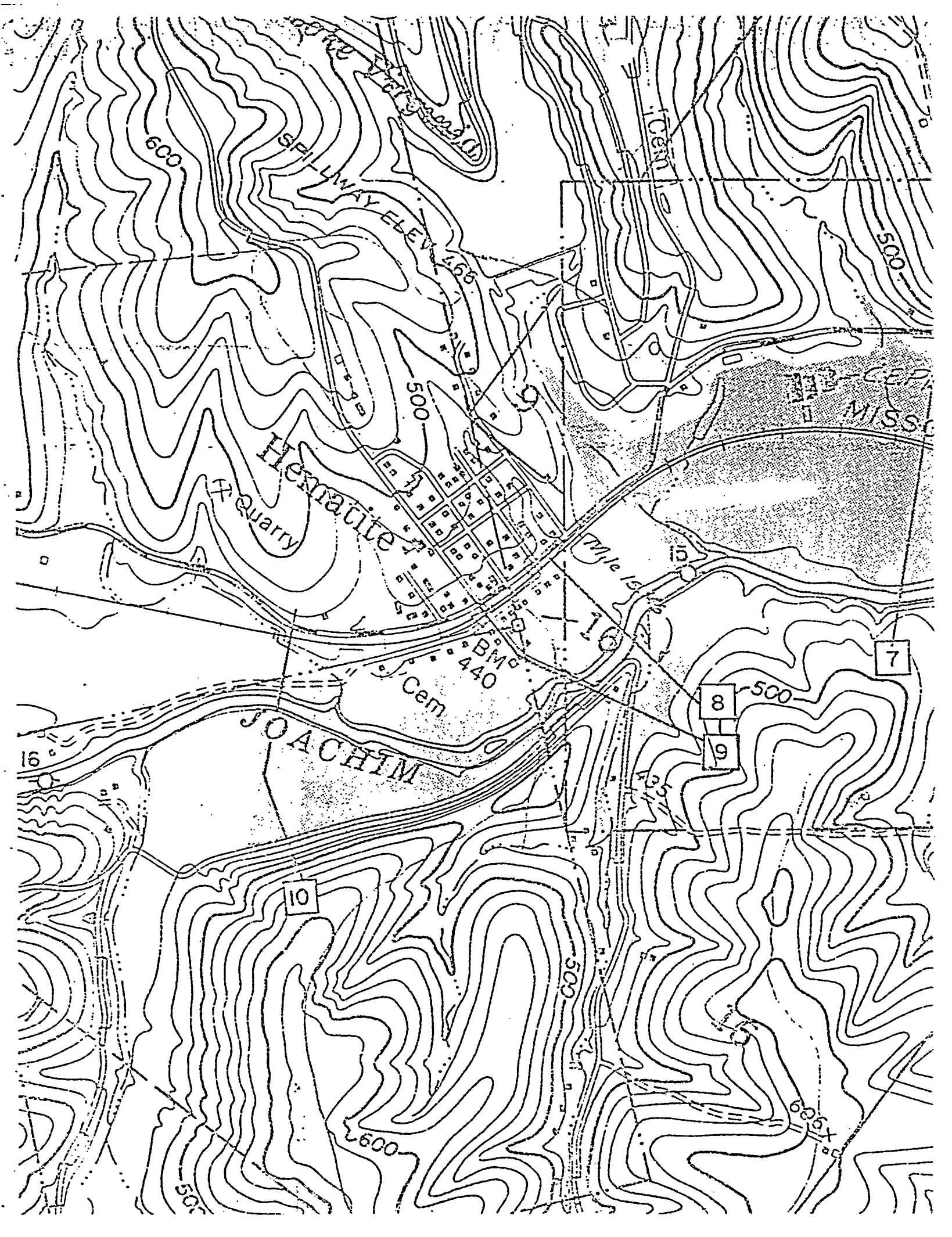
8. EVALUATION OF RESULTS

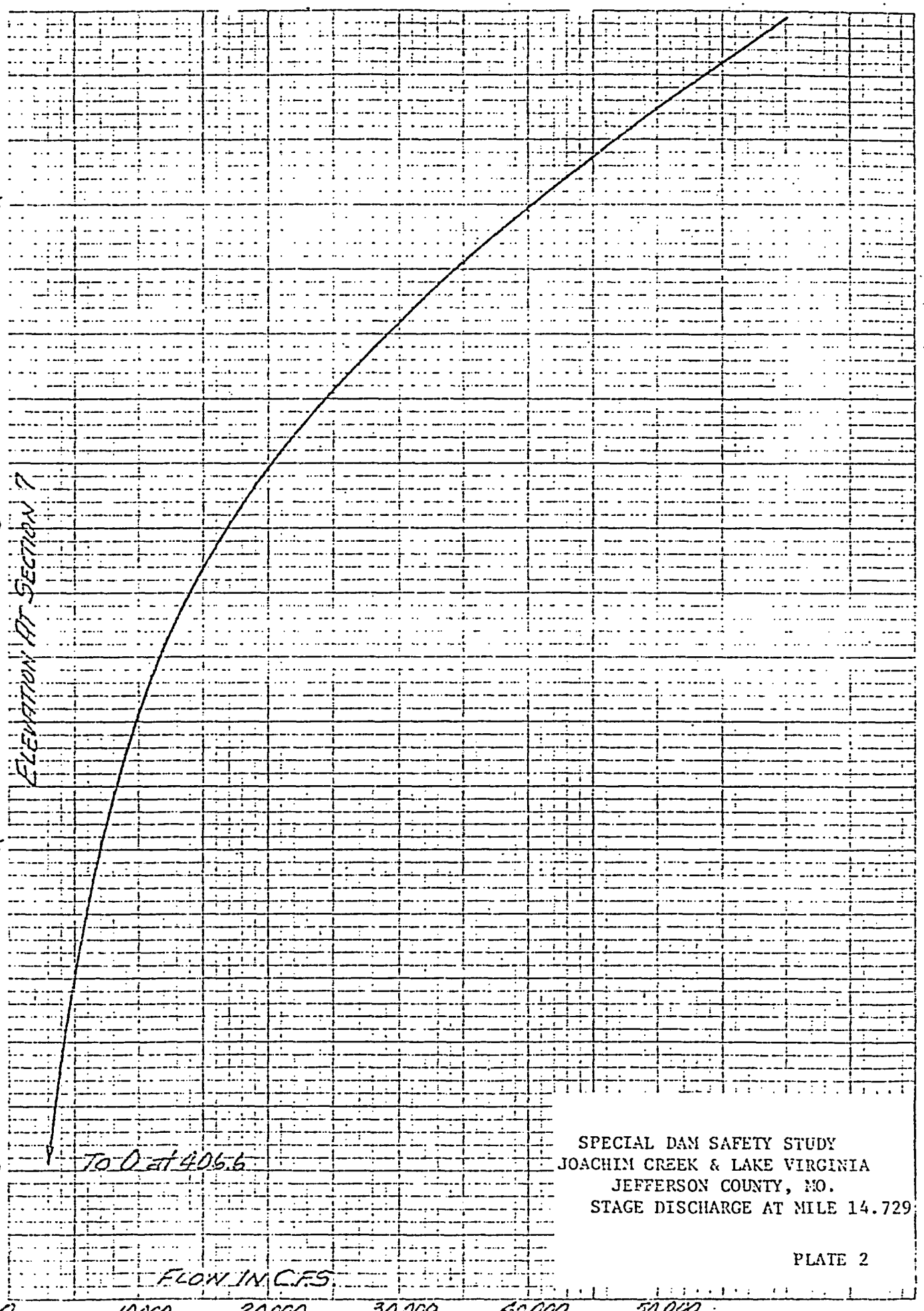
Using the most improbable combination of criteria events that can be conceived, calculations using computer program HEC-1 indicate that breaching of the Lake Virginia Dam by a ½ Probable Maximum Flood could raise the 100-year flood profile in Joachim Creek 0.15-foot. For this to happen it would be necessary for the dam breach to take five hours to develop to its maximum depth. The resulting release of stored water will be at a very low rate of flow. Because of the attenuating effect of the large volume of valley storage in the reach of Joachim Creek below the Lake Virginia Dam, a sudden breach in the dam cannot supply enough flow from the relatively limited volume of water stored behind the dam to produce any significant rise in the Joachim Creek stage on the rising side of the 100-year flood hydrograph.



SPECIAL DAM SAFETY STUDY
JOACHIM CREEK & LAKE VIRGINIA
JEFFERSON COUNTY, MO.
FLOODPLAIN MAP

PLATE 1


Spillway Elev. 468
600
500
Hematite
Quarry
Cem
MISS
Mile 15
15
16
BMC
440
Cem
JOACHIM
7
8
9
10
500
600
600
500



SPECIAL DAM SAFETY STUDY
JOACHIM CREEK & LAKE VIRGINIA
JEFFERSON COUNTY, MO.
STAGE DISCHARGE AT MILE 14.729

PLATE 2

46 0862

5 X 5 TO 1/2 INCH • 7 X 7 INCHES
KEUFFEL & ESSER CO MADE IN U.S.A.

DISCHARGE (Q) - VOLUME (V) FUNCTIONS JOACHIM CREEK (From EXL4F QV 9/5/80)

VOLUMES IN ACRE FT

MILE → 11.875 INCREMENT →		.756	12.631	.704	13.334	1.812	15.146	0.625	15.771
Q cfs									
0	0	0	0		0	0	0	0	0
5000		153	153	104	257	239	496	120	616
10 000		323	323	221	544	628	1172	283	1455
15 000			553	382	935	1030	1965	428	2393
20 000			748	592	1340	1411	2751	536	3287
25 000			1052	882	1934	1774	3708	634	4342
30 000			1260	1089	2349	2128	4477	725	5202
35 000			1391	1243	2634	2250	5554	809	5893
40 000			1521	1398	2919	2765	5684	889	6573
45 000			1653	1553	3206	3080	6286	965	7251
50 000			1784	1711	3495	3396	6891	1038	7929
55 000			1917	1867	3784	3718	7502	1110	8612
60 000			2037	2015	4052	4033	8085	1180	9265
65 000		2170	2170	2170	4340	4267	5707	1250	9957
70 000	0	2254	2254	2353	4607	4496	9303	1319	10622

Same as col. to Right

STUDY

FUNCTIONS JOACHIM

7/29/80

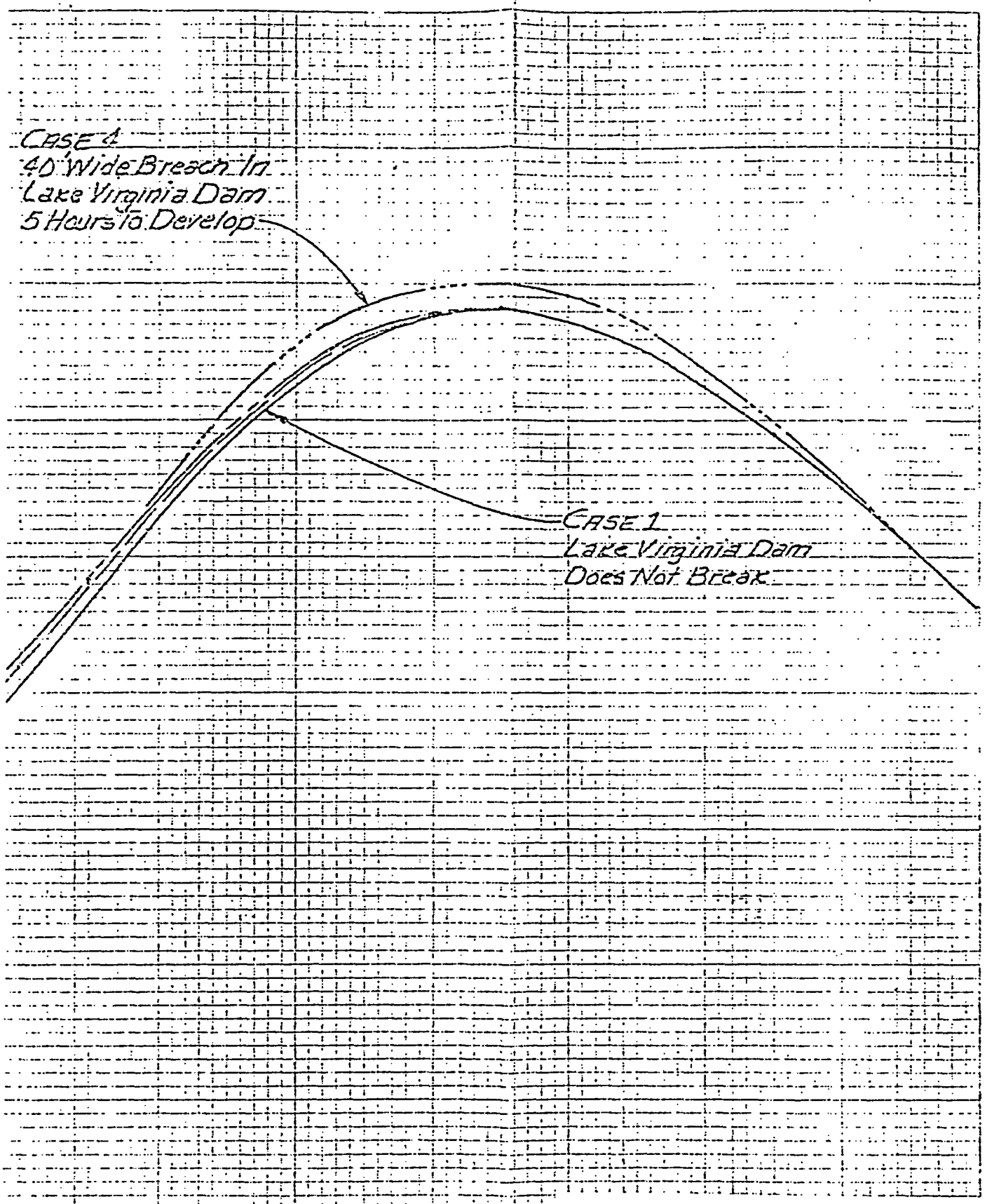
SPECIAL DAM SAFETY STUDY
JOACHIM CREEK & LAKE VIRGINIA
JEFFERSON COUNTY, MO.
STORAGE DISCHARGE FUNCTIONS
Mile 11.875 to Mile 15.771

Plate 3

CASE COMPUTER RUN I.D. (Computer Run)	DAM BREAK Width	Time to Develop	PEAK Lake Virginia cfs	Time	FLOWS Reach 15.146 to 13.334 cfs	Time
1. ØXLOH5B	NO BREAK		3552	@ 16.00	39069	@ 19.15
2. ØXLOPA7	40 ft.	20 min.	14737	@ 16.25	39104	@ 19.15
3. ØXLOPBR	400 ft.	20 min.	23958	@ 16.07	39065	@ 19.15
4. ØXLOØ87	40 ft.	5 hrs.	3642	@ 16.00	40188	@ 19.10

SPECIAL DAM SAFETY STUDY
JOACHIM CREEK & LAKE VIRGINIA
JEFFERSON COUNTY, MO.
COMPUTER RESULTS

Plate 4



SPECIAL DAM SAFETY STUDY
JOACHIM CREEK & LAKE VIRGINIA
JEFFERSON COUNTY, MO.
DISCHARGES IN REACH 13.334 to 15.146

PLATE 5

STORM

18 19 20 21

REFERENCES

1. Special Study for Joachim Creek, prepared for U.S. Army Corps of Engineers St. Louis District by Clark Dietz Engineers, March 1980.
2. Phase I Inspection Report National Dam Safety Program - Lake Virginia Dam, (Mo. Inventory #30425), U.S. Army Engineers, District St. Louis, November 1978.
3. HEC-1 Flood Hydrograph Package, U.S. Army Corps of Engineers Hydrologic Engineering Center, User's Manual, January 1973, 723-010.
4. HEC-1 Flood Hydrograph Package, U.S. Army Corps of Engineers, Hydrologic Engineering Center, User's Manual for Dam Safety Investigations, September 1978.
5. HEC-2 Water Surface Profiles, U.S. Army Corps of Engineers, Hydrologic Engineering Center, User's Manual, February 1972, 723-02A.
6. Simplified Dam Breach Routing Procedure, Technical Release No. 66, U.S. Department of Agriculture, Soil Conservation Service, Engineering Division Design Unit, March 1979.
7. HR33, Seasonal Variations of Probable Maximum Precipitation, East of the 105th Meridian for Areas 10 to 1000 Square Miles and Durations from 6 to 48 Hours, U.S. Department of Commerce, NOAA, National Weather Service, 1956.
8. Engineering Handbook, Section 4; Hydrology, Supplement A, U.S. Department of Agriculture, Soil Conservation Service.

APPENDIX A

COMPUTER INPUT

AND SELECTED OUTPUT

```
*******************************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  26 FEB 79
*******************************************
A        FLOOD ROUTING IN JOACHIM CREEK
A        LAKE VIRGINIA DAM DOES NOT BREAK
A        100 YEAR FLOOD ON JOACHIM 1/2 PMF ON LAKE VIRGINIA
B    200       0       5       0       0       0       0       0      -4       0
1      5
J      1       1       1
J1   1.0
K      0  15.711                       1       3       1
1  ***** HYDROGRAPH OF FLOW ABOVE MILE 15.711
H      1       2  94.400                       1                       1
P           6.15      79      97     107
T                                                     -1     -73            0.02
W2         2.500
X          -0.20     2.0
K      1  15.146                       1       3       1
1  ***** ROUTE JOACHIM CREEK FLOW MILE 15.711 TO 15.146
Y                                1       1
Y1     1                                              -1
Y2   0.0    120.    283.    428.    536.    634.    725.    809.    889.    965.
Y2 1030.   1110.   1180.   1250.   1319.
Y3     0    5000   10000   15000   20000   25000   30000   35000   40000   45000
Y3 50000   55000   60000   65000   70000
K      0  LAKE V                       1       3       1
1   **** LAKE VIRGINIA INFLOW HYDROGRAPH
M      1       2   0.742                       1                       1
P          14.82     101     120     130
T                                                     -1     -80            0.09
W2          0.30
X          -0.20     2.0
K      1  OVRDAM                       1       2       1
1  ***** RESERVOIR ROUTING - SPILLWAY RATING CURVE     - SLOPING DAM *****
Y                                1       1
Y1     1                                          -465.5      -1
Y4 465.5   466.0   466.5   467.0   467.5   468.0   468.5   469.0   469.5   470.0
Y4 470.5   471.0   471.5
Y5   0.0     4.0    13.0    28.5    50.0    78.5   112.0   152.0   244.0   279.0
Y5 435.0   654.0   920.0
$A   0.0   25.71    41.8    78.9
$E   444     466     480     500
$$ 465.5
$D 469.1
$L    25     200     325     475     575     650     700     710     720
$V 469.1   469.8   470.0   470.6   470.7   471.0   472.2   475.0   478.0
K      0  15-13                        1       3       1
1  ***** LOCAL RUNOFF TRIBUTARY BETWEEN MILE 15.146 AND 13.334
M      1       2   3.658                       1                       1
P            5.4     101     120     130
T                                                     -1     -73            0.05
W2          0.55
X          -0.20     2.0
```

ØXLOH5B

SPECIAL DAM SAFETY STUDY
JOACHIM CREEK & LAKE VIRGINIA
Case 1 Computer Input

```
K      3  15.146                                  1         3         1
I    ***** COMBINE HYDROGRAPHS MILE 15.146
K      1  13.334                                  1         3         1
I   ***** ROUTE JOACHIM CREEK FLOW MILE 15.146 TO 13.334
Y                                       1         1
Y1     1                                                             -1
Y2   0.0      239.      628.     1030.     1411.     1774.     2128.     2450.     2765.     3080.
Y2 3396.     3718.     4033.     4367.     4696.
Y3     0      5000     10000     15000     20000     25000     30000     35000     40000     45000
Y3 50000     55000     60000     65000     70000
K      0  BUCKS                                   1         3         1
I    ***** LOCAL RUNOFF TRIBUTARY BETWEEN MILE 13.334 AND 12.631
M      1         2    8.400                                 1                             1
P               5.4       101       120       130
T                                                                    -1       -73                  0.03
W2              1.30
X              -0.40      1.5
K      2  13.334                                  1         3         1
I    ***** COMBINE HYDROGRAPHS MILE 13.334
K      1  12.631                                  1         3         1
I   ***** ROUTE JOACHIM CREEK FLOW MILE 13.334 TO 12.631
Y                                       1         1
Y1     1                                                             -1
Y2   0.0      104.      221.      382.      592.      882.     1089.     1243.     1398.     1553.
Y2 1711.     1867.     2015.     2170.     2353.
Y3     0      5000     10000     15000     20000     25000     30000     35000     40000     45000
Y3 50000     55000     60000     65000     70000
K     99
```

ØXL0H5B

SPECIAL DAM SAFETY STUDY
JOACHIM CREEK & LAKE VIRGINIA

Case 1 Computer Input (Cont.)

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	AREA	PLAN	RATIOS APPLIED TO FLOWS RATIO 1 1.00
HYDROGRAPH AT	15.711	94.40 (244.49)	1	40829. (1156.16)(
ROUTED TO	15.146	94.40 (244.49)	1	40581. (1149.11)(
HYDROGRAPH AT	LAKE V	.74 (1.92)	1	3932. (111.33)(
ROUTED TO	OVRDAM	.74 (1.92)	1	3552. (100.57)(
HYDROGRAPH AT	15-13	3.66 (9.47)	1	3999. (113.24)(
3 COMBINED	15.146	98.80 (255.89)	1	42191. (1194.73)(
ROUTED TO	13.334	98.80 (255.89)	1	39069. (1106.31)(
HYDROGRAPH AT	BUCKS	8.40 (21.76)	1	5787. (163.88)(
2 COMBINED	13.334	107.20 (277.65)	1	41504. (1175.25)(
ROUTED TO	12.631	107.20 (277.65)	1	40823. (1155.96)(

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	465.50	465.50	469.10
STORAGE	176.	176.	273.
OUTFLOW	0.	0.	170.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	471.24	2.14	338.	3552.	7.83	16.00	0.00

```
**********************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  26 FEB 79
**********************************
                A        FLOOD ROUTING IN JOACHIM CREEK
                A        100 YEAR FLOOD ON JOACHIM 1/2 PMF ON LAKE VIRGINIA
                A        LAKE VIRGINIA DAM BREAKS WHEN OVERFLOW IS AT MAXIMUM DEPTH
                B     288       0       5       0       0       0       0       0      -4       0
                I       5
                J       1       1       1
                J1    1.0
                K       0  15.711                       1       3       1
                1   ***** HYDROGRAPH OF FLOW ABOVE MILE 15.711
                M       1       2  94.400               1                       1
                P            6.15      79      97     107
                T                                               -1     -73            0.02
                W2          2.500
                X           -0.10     3.0
                K       1  15.146                       1       3       1
                1   ***** ROUTE JOACHIM CREEK FLOW MILE 15.711 TO 15.146
                Y                               1       1
                Y1      1                                       -1
                Y2    0.0    120.    283.    428.    536.    634.    725.    809.    889.    965.
                Y2  1038.   1110.   1180.   1250.   1319.
                Y3      0    5000   10000   15000   20000   25000   30000   35000   40000   45000
                Y3  50000   55000   60000   65000   70000
                K       0  LAKE V                       1       3       1
                1    **** LAKE VIRGINIA INFLOW HYDROGRAPH
                M       1       2   0.742               1                       1
                P           14.82     101     120     130
                T                                               -1     -60            0.09
                W2           0.30
                X           -0.20     2.0
                K       1  OVRDAM                       1       2       1
                1    ***** DAM BREACH  40 FEET WIDE 20 MINUTES TO DEVELOP
                Y                               1       1
                Y1      1                                   -465.5      -1
                Y4  465.5   466.0   466.5   467.0   467.5   468.0   468.5   469.0   469.5   470.0
                Y4  470.5   471.0   471.5
                Y5    0.0     4.0    13.0    28.5    50.0    78.5   112.0   152.0   244.0   279.0
                Y5  435.0   654.0   920.0
                $A    0.0   25.71    41.8    78.9
                $E    444     466     480     500
                $S  465.5
                $D  469.1
                $L     25     200     325     475     575     650     700     710     720
                $V  469.1   469.8   470.0   470.6   470.7   471.0   472.2   475.0   478.0
                $B    40.     0.5   444.5 0.33333   465.5  471.22
                K       0  15-13                        1       3       1
                1    ***** LOCAL RUNOFF TRIBUTARY BETWEEN MILE 15.146 AND 13.334
                M      .1       2   3.658               1                       1
                P             5.4     101     120     130
                T                                               -1     -73            0.05
                W2           0.55
```

ØXLOPA7

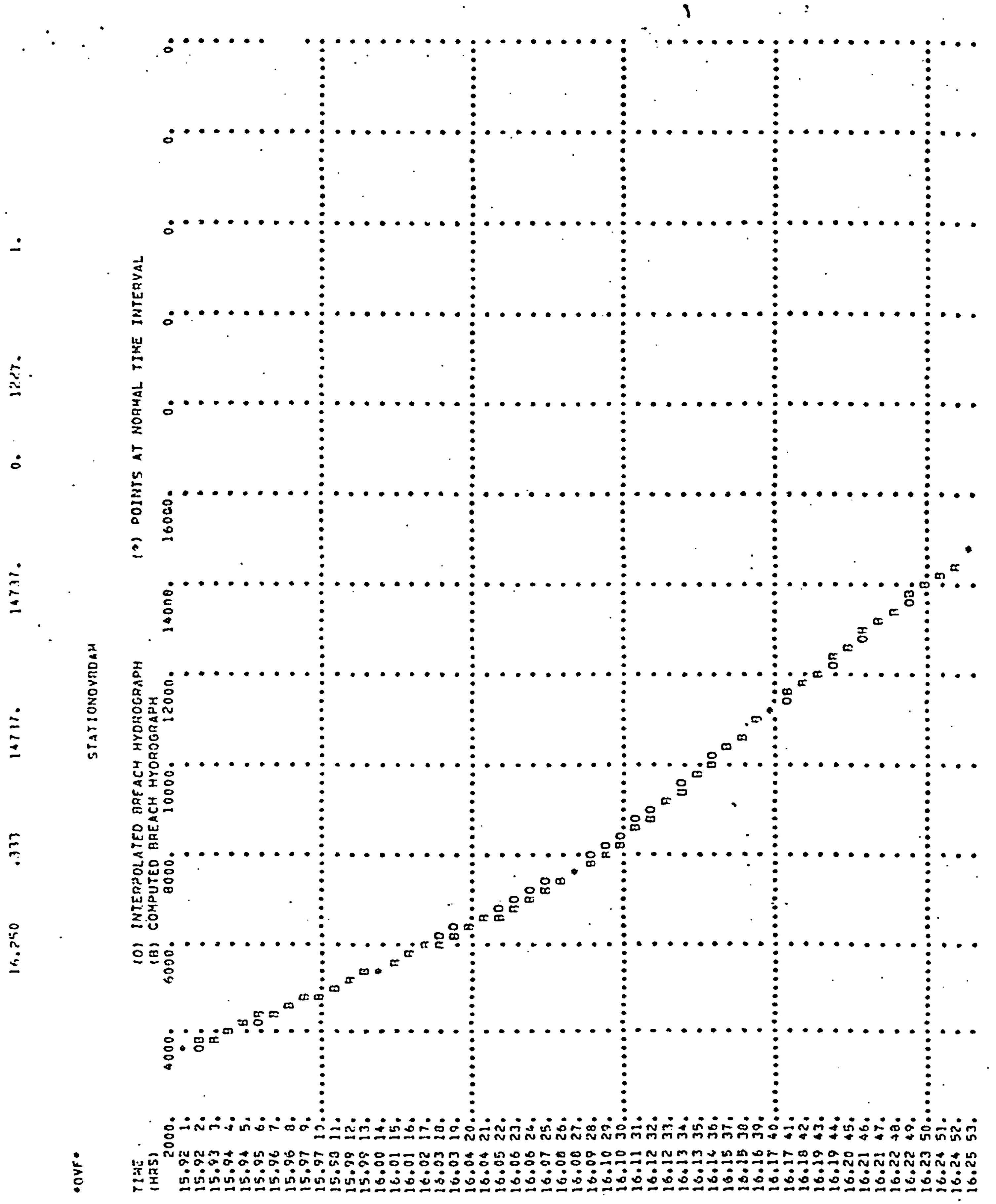
SPECIAL DAM SAFETY STUDY
JOACHIM CREEK & LAKE VIRGINIA
Case 2 Computer Input

Sheet A-4

```
X          -0.20     2.0
K       3  15.146                        1       3       1
1    ***** COMBINE HYDROGRAPHS MILE 15.146
K       1  13.334                        1       3       1
1  ***** ROUTE JOACHIM CREEK FLOW MILE 15.146 TO 13.334
Y                                1       1
Y1      1                                               -1
Y2    0.0    239.    628.   1030.   1411.   1774.   2128.   2450.   2765.   3000.
Y2  3396.   3718.   4033.   4367.   4696.
Y3      0    5000   10000   15000   20000   25000   30000   35000   40000   45000
Y3  50000   55000   60000   65000   70000
K       0  BUCKS                         1       3       1
1    ***** LOCAL RUNOFF TRIBUTARY BETWEEN MILE 13.334 AND 12.631
M       1       2   8.400                        1                       1
P             5.4     101     120     130
T                                                       -1     -73             0.03
W2           1.30
X           -0.40     1.5
K       2  13.334                        1       3       1
1    ***** COMBINE HYDROGRAPHS MILE 13.334
K       1  12.631                        1       3       1
1  ***** ROUTE JOACHIM CREEK FLOW MILE 13.334 TO 12.631
Y                                1       1
Y1      1                                               -1
Y2    0.0    104.    221.    382.    592.    882.   1089.   1243.   1398.   1553.
Y2  1711.   1867.   2015.   2170.   2353.
Y3      0    5000   10000   15000   20000   25000   30000   35000   40000   45000
Y3  50000   55000   60000   65000   70000
K      99
```

ØXLOPA7

SPECIAL DAM SAFETY STUDY
JOACHIM CREEK & LAKE VIRGINIA
Case 2 Computer Input (Cont.



SPECIAL DAM SAFETY STUDY
JOACHIM CREEK & LAKE VIRGINIA
Case 2 Computer Output
Dam Breach Hydrograph

ØXLOPA7

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	AREA	PLAN	RATIOS APPLIED TO FLOWS RATIO 1 1.00
HYDROGRAPH AT	15.711	94.40 (244.49)	1	40829. (1156.16)(
ROUTED TO	15.146	94.40 (244.49)	1	40581. (1149.11)(
HYDROGRAPH AT	LAKE V	.74 (1.92)	1	3932. (111.33)(
ROUTED TO	OVRDAM	.74 (1.92)	1	14737. (417.30)(
HYDROGRAPH AT	15-13	3.66 (9.47)	1	3999. (113.24)(
3 COMBINED	15.146	98.80 (255.89)	1	42090. (1191.85)(
ROUTED TO	13.334	98.80 (255.89)	1	39104. (1107.31)(
HYDROGRAPH AT	BUCKS	8.40 (21.76)	1	5787. (163.88)(
2 COMBINED	13.334	107.20 (277.65)	1	41604. (1178.08)(
ROUTED TO	12.631	107.20 (277.65)	1	40943. (1159.37)(

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	465.50	465.50	469.10
STORAGE	176.	176.	273.
OUTFLOW	0.	0.	170.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	471.25	2.15	338.	14737.	2.61	16.25	15.92

SPECIAL DAM S
JOACHIN CREEK
Case 3 Compute

ØXLOPBR

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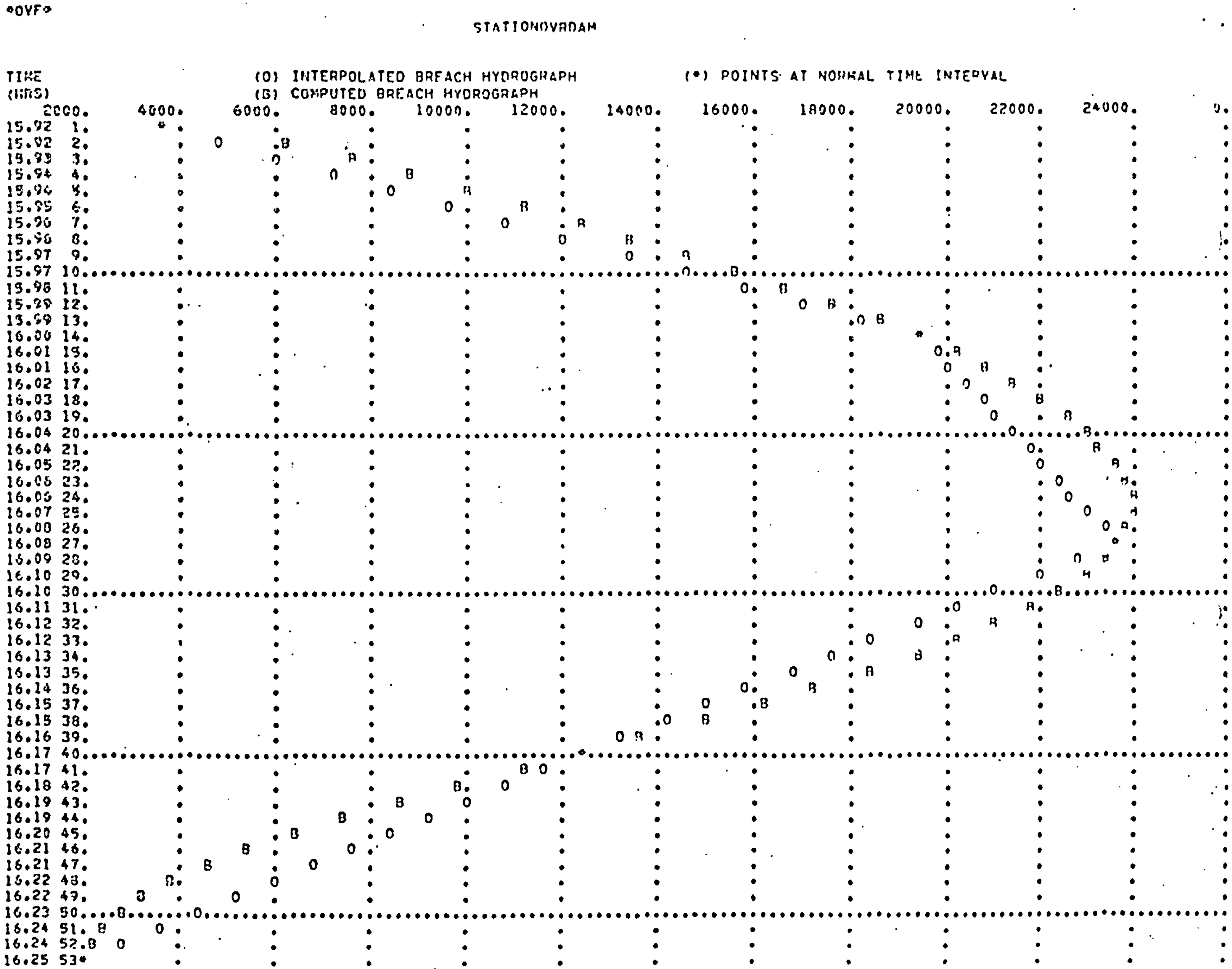
**********
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION     JULY 1978
  LAST MODIFICATION  26 FEB 79
**********
    1             A       FLOOD ROUTING IN JOACHIM CREEK
    2             A       100 YEAR FLOOD ON JOACHIM 1/2 PMF ON LAKE VIRGINIA
    3             A       LAKE VIRGINIA DAM BREAKS WHEN OVERFLOW IS AT MAXIMUM DEPTH
    4             B   288       0       5       0       0       0       0       0      -4       0
    5             I     5
    6             J     1       1       1
    7             J1  1.0
    8             K     0  15.711                       1       3       1
    9             1  ***** HYDROGRAPH OF FLOW ABOVE MILE 15.711
   10             M     1       2  94.400                       1                       1
   11             P          6.15      79      97     107
   12             T                                                       -1     -73             0.02
   13             W2         2.500
   14             X         -0.20     2.0
   15             K     1  15.146                       1       3       1
   16             1  ***** ROUTE JOACHIM CREEK FLOW MILE 15.711 TO 15.146
   17             Y                               1       1
   18             Y1    1                                         -1
   19             Y2  0.0     120.    283.    428.    536.    634.    725.    809.    889.    9
   20             Y2 1038.    1110.   1180.   1250.   1319.
   21             Y3    0     5000   10000   15000   20000   25000   30000   35000   40000   45000
   22             Y3 50000    55000   60000   65000   70000
   23             K     0  LAKE V                       1       3       1
   24             1   **** LAKE VIRGINIA INFLOW HYDROGRAPH
   25             M     1       2   0.742                       1                       1
   26             P          14.82     101     120     130
   27             T                                                       -1     -80             0.09
   28             W2         0.30
   29             X         -0.20     2.0
   30             K     1  OVRDAM                       1       2       1
   31             I   ***** DAM BREACH 400 FEET WIDE 20 MINUTES TO DEVELOP
   32             Y                               1       1
   33             Y1    1                                         -465.5     -1
   34             Y4 465.5    466.0   466.5   467.0   467.5   468.0   468.5   469.0   469.5   470.0
   35             Y4 470.5    471.0   471.5
   36             Y5    0.0     4.0    13.0    28.5    50.0    70.5   112.0   152.0   244.0   279.0
   37             Y5 435.0    654.0   920.0
   38             $A    0.0   25.71    41.8    78.9
   39             $E    444     466     480     500
   40             $$ 465.5
   41             $D 469.1
   42             $L     25     200     325     475     575     650     700     710     720
```

```
X          -0.20      2.0
K       3  15.146                         1         3         1
1     ***** COMBINE HYDROGRAPHS MILE 15.146
K       1  13.334                         1         3         1
1    ***** ROUTE JOACHIM CREEK FLOW MILE 15.146 TO 13.334
Y                                1        1
Y1      1                                                    -1
Y2    0.0     239.      628.     1030.     1411.     1776.     2128.     2450.     2765.     3060.
Y2 3396.     3718.     4033.     4367.     4696.
Y3      0     5000     10000     15000     20000     25000     30000     35000     40000     45000
Y3 50000     55000     60000     65000     70000
K       0  BUCKS                          1         3         1
1     ***** LOCAL RUNOFF TRIBUTARY BETWEEN MILE 13.334 AND 12.631
M       1         2    8.400                        1                             1
P                5.4       101       120       130
T                                                            -1        -73                 0.03
U2              1.30
X              -0.40       1.5
K       2  13.334                         1         3         1
1     ***** COMBINE HYDROGRAPHS MILE 13.334
K       1  12.631                         1         3         1
1    ***** ROUTE JOACHIM CREEK FLOW MILE 13.334 TO 12.631
Y                                1        1
Y1      1                                                    -1
Y2    0.0     104.      221.      382.      592.      882.     1089.     1243.     1398.     1553.
Y2 1711.     1867.     2015.     2170.     2353.
Y3      0     5000     10000     15000     20000     25000     30000     35000     40000     45000
Y3 50000     55000     60000     65000     70000
K      99
```

ØXLOPBR

SPECIAL DAM SAFETY STUDY
JOACHIM CREEK & LAKE VIRGINIA
Case 3 Computer Input (Cont.)



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SPECIAL DAM SAFETY STUDY
JOACHIM CREEK & LAKE VIRGINIA
Case 3 Computer Output
Dam Breach Hydrograph

Sheet A-10

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	AREA	PLAN	RATIOS APPLIED TO FLOWS RATIO 1 1.00
HYDROGRAPH AT	15.711	94.40 (244.49)	1	40829. (1156.16)
ROUTED TO	15.146	94.40 (244.49)	1	40581. (1149.11)
HYDROGRAPH AT	LAKE Y	.74 (1.92)	1	3932. (111.33)
ROUTED TO	OVRDAM	.74 (1.92)	1	23664. (670.09)
HYDROGRAPH AT	15-13	3.66 (9.47)	1	3999. (113.24)
3 COMBINED	15.146	98.80 (255.89)	1	42162. (1193.89)
ROUTED TO	13.334	98.80 (255.89)	1	39065. (1106.20)
HYDROGRAPH AT	BUCKS	8.40 (21.76)	1	5787. (163.88)
2 COMBINED	13.334	107.20 (277.65)	1	41551. (1176.58)
ROUTED TO	12.631	107.20 (277.65)	1	40885. (1157.73)

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	465.50	465.50	469.10
STORAGE	176.	176.	273.
OUTFLOW	0.	0.	170.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	471.24	2.14	338.	23958.	2.67	16.07	15.92

ØXLOPBR

SPECIAL DAM SAFETY STUDY
JOACHIN CREEK & LAKE VIRGINIA
Case 3 Computer Output Summar

```
********************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  26 FEB 79
********************************
A       FLOOD ROUTING IN JOACHIM CREEK
A       100 YEAR FLOOD ON JOACHIM 1/2 PHF ON LAKE VIRGINIA
A       LAKE VIRGINIA DAM BREAKS WHEN OVERFLOW IS AT MAXIMUM DEPTH
B      288       0       5       0       0       0       0       0      -4       0
1        5
J        1       1       1
J1     1.0
K        0  15.711                       1       3       1
1   ***** HYDROGRAPH OF FLOW ABOVE MILE 15.711
M        1       2  94.400                       1                       1
P             6.15      79      97     107
T                                                       -1     -73            0.02
W2           2.500
X            -0.10     3.0
K        1  15.146                       1       3       1
1   ***** ROUTE JOACHIM CREEK FLOW MILE 15.711 TO 15.146
Y                                1       1
Y1       1                                              -1
Y2     0.0    120.    283.    428.    536.    634.    725.    809.    889.    965.
Y2   1038.   1110.   1180.   1250.   1319.
Y3       0    5000   10000   15000   20000   25000   30000   35000   40000   45000
Y3   50000   55000   60000   65000   70000
K        0  LAKE V                       1       3       1
1    **** LAKE VIRGINIA INFLOW HYDROGRAPH
M        1       2   0.742                       1                       1
P            14.82     101     120     130
T                                                       -1     -80            0.09
W2            0.30
X            -0.20     2.0
K        1  OVRDAM                       1       2       1
1    ***** DAM BREACH  40 FEET WIDE FIVE HOURS TO DEVELOP
Y                                1       1
Y1       1                                          -465.5      -1
Y4   465.5   466.0   466.5   467.0   467.5   468.0   468.5   469.0   469.5   470.0
Y4   470.5   471.0   471.5
Y5     0.0     4.0    13.0    28.5    50.0    78.5   112.0   152.0   244.0   279.0
Y5   435.0   654.0   920.0
$A     0.0   25.71    41.8    78.9
$E     444     466     480     500
$$   465.5
$D   469.1
$L      25     200     325     475     575     650     700     710     720
$V   469.1   469.8   470.0   470.6   470.7   471.0   472.2   475.0   478.0
$B     40.     0.5   444.5     5.0   465.5  471.22
K        0  15-13                        1       3       1
1    ***** LOCAL RUNOFF TRIBUTARY BETWEEN MILE 15.146 AND 13.334
M        1       2   3.658                       1                       1
P              5.4     101     120     130
T                                                       -1     -73            0.05
W2            0.55
```

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SPECIAL DAM SAFETY STUDY
JOACHIM CREEK & LAKE VIRGINIA
Case 4 Computer Input

```
X          -0.20     2.0
K      3  15.146                          1       3       1
1    ***** COMBINE HYDROGRAPHS MILE 15.146
K      1  13.334                          1       3       1
1   ***** ROUTE JOACHIM CREEK FLOW MILE 15.146 TO 13.334
Y                                  1      1
Y1     1                                                 -1
Y2   0.0      239.     620.    1030.    1411.    1774.    2128.    2450.    2765.    3080.
Y2 3396.     3718.    4033.    4367.    4696.
Y3     0      5000    10000    15000    20000    25000    30000    35000    40000    45000
Y3 50000     55000    60000    65000    70000
K      0  BUCKS                           1       3       1
1    ***** LOCAL RUNOFF TRIBUTARY BETWEEN MILE 13.334 AND 12.631
M      1       2   8.400                          1                        1
P              5.4      101      120      130
T                                                        -1     -73                0.03
W2            1.30
X          -0.40     1.5
K      2  13.334                          1       3       1
1    ***** COMBINE HYDROGRAPHS MILE 13.334
K      1  12.631                          1       3       1
1   ***** ROUTE JOACHIM CREEK FLOW MILE 13.334 TO 12.631
Y                                  1      1
Y1     1                                                 -1
Y2   0.0      104.     221.     382.     592.     882.    1069.    1243.    1398.    1553.
Y2 1711.     1867.    2015.    2170.    2353.
Y3     0      5000    10000    15000    20000    25000    30000    35000    40000    45000
Y3 50000     55000    60000    65000    70000
K     99
```

'SPECIAL DAM SAFETY STUDY
JOACHIM CREEK & LAKE VIRGINIA
Case 4 Computer Input (Cont.)

ØXLØ87

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	AREA	PLAN	RATIO APPLIED TO FLOWS RATIO 1 1.00
HYDROGRAPH AT	15.711	94.40 (244.49)	1	40829. (1156.16)(
ROUTED TO	15.146	94.40 (244.49)	1	40581. (1149.11)(
HYDROGRAPH AT	LAKE V	.74 (1.92)	1	3932. (111.33)(
ROUTED TO	OVRDAM	.74 (1.92)	1	3642. (103.13)(
HYDROGRAPH AT	15-13	3.66 (9.47)	1	3999. (113.24)(
3 COMBINED	15.146	98.80 (255.89)	1	43576. (1233.93)(
ROUTED TO	13.334	98.80 (255.89)	1	40186. (1137.99)(
HYDROGRAPH AT	BUCKS	8.40 (21.76)	1	5787. (163.88)(
2 COMBINED	13.334	107.20 (277.65)	1	42703. (1209.22)(
ROUTED TO	12.631	107.20 (277.65)	1	41943. (1187.69)(

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	465.50	465.50	469.10
STORAGE	176.	176.	273.
OUTFLOW	0.	0.	170.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	471.24	2.14	338.	3642.	3.67	16.00	15.92