TRC

Five-Year Periodic Inflow Design Flood Control System Plan

Fly Ash Reservoir II
Brilliant, Ohio

October 2021

Prepared For:

Cardinal Operating Company
306 County Road 7E
Brilliant, Ohio 43913

Prepared By:

TRC
1382 West Ninth Street, Suite 400
Cleveland, Ohio 44113

Nakia Addison
Project Manager

Shawn McGee, P.E.
Office Practice Leader

Jonathan Hotstream
Senior Scientist

TABLE OF CONTENTS

APPENDICES

1.0 Introduction

The Cardinal Power Plant (Plant) is located in Wells Township, Jefferson County, near the town of Brilliant in eastern Ohio. The Plant is owned by Buckeye Power and AEP Generation Resources (GENCO). Cardinal Operating Company operates the Plant. The Plant utilizes the Fly Ash Reservoir II (FAR II) surface impoundment for storing coal combustion residuals (CCR). The FAR II is subject to the requirements of the United States Environmental Protection Agency's (USEPA) final CCR rule Title 40 Code of Federal Regulations (40 CFR) Part 257 Subpart D - "Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments." The Initial Inflow Design Flood Control System Plan was completed and placed into the Plant's operating record on October 9, 2016. A periodic Inflow Design Flood Control System Plan is required every 5 years pursuant to 40 CFR 257.82(c)(4).

The FAR II is impounded behind a dam that is approximately 250-feet high with a 30-foot-wide crest. The most recent dam modification was in 2013 where it was raised to its current height using back-to-back mechanically stabilized earth walls. The dam has had no major modifications since 2016, and conditions evaluated in the Initial Inflow Design Flood Control System Plan are representative of current conditions.

Federal Regulations

An owner or operator of an existing or new CCR surface impoundment or any lateral expansion must design, construct, operate, and maintain an inflow design flood control system for the CCR surface impoundment to:

(1) adequately manage flow into the CCR surface impoundment during and following the peak discharge of the inflow design flood;

(2) adequately manage flow from the CCR unit to collect and control the peak discharge resulting from the inflow design flood. The inflow design flood is based on the hazard potential classification of the unit as required by 40 CFR 257.73. The inflow design floods for specific hazard potential classifications are as follows:

   i. The probable maximum flood for high hazard potential CCR surface impoundments,

   ii. The 1,000-year flood for significant hazard potential CCR surface impoundments,

   iii. The 100-year flood for low hazard potential CCR surface impoundments, or

   iv. The 25-year flood for incised CCR surface impoundments; and

(3) discharge from the CCR unit must be handled in accordance with the surface water requirements of 40 CFR 257.3-3.

2.0 Objective

This report was prepared by TRC Engineers, Inc. (TRC) to fulfill requirements for the periodic Inflow Design Flood Control System Plan documenting how the inflow design flood control system has been designed and constructed to meet the requirements of 40 CFR 257.82. This is the first 5-year periodic assessment as required per 40 CFR 257.82(c)(3).

To develop the periodic assessment TRC performed the following scope:

- Reviewed historical documents including:
  - Inflow Design Flood Control Plan, September 2016, prepared by AEP Geotechnical Engineering Services (refer to Attachment A)
  - Components of the FAR II Dam Permit Modification Application (S&ME, 2012)
    - Appendix C: Hydrologic and Hydraulic Analysis
  - 2016-2021 Annual FAR II Dam Inspection Reports
- Performed a site visit on September 1, 2021 to observe current conditions, and
- Developed a 5-year periodic Inflow Design Flood Control System Plan.

3.0 Design Storm

The FAR II is classified as a high hazard potential Dam (TRC, 2021); therefore, the FAR II must adequately manage peak discharges from the probable maximum flood (PMF). The FAR II dam was designed for a PMF event of 26.5 inches of precipitation for a 6-hour period based on Hydrometeorological Report 51 by the National Weather Service.

4.0 Inflow Design Flood Control System

4.1 Inflow Management

The FAR II dam acts as the primary inflow control by impounding the drainage area and regulating outflow through the service spillway. At the maximum design pool elevation, 974 feet National Geodetic Vertical Datum 1929 (NGVD 29), the impoundment has a surface area of approximately 161 acres. There is sufficient storage above the operating pool elevations to manage discharge though the service spillway during storm events up to the 24-hour, 50-year storm event without activating the emergency spillway.

4.2 Outflow Management

The FAR II has two designed outlets: the service spillway and the emergency spillway. The service spillway allows management of the operating pool elevation and allows discharge from the FAR II. The inlet to the service spillway is a rectangular weir with stoplogs that can be added or removed to control water elevations in FAR II. The rectangular weir connects to a sloping concrete shaft on the upstream dam face which discharges into a 54-inch diameter pre-stressed concrete cylinder pipe. The concrete pipe transitions to a steel pipe where it daylights on the downstream face of the dam. Discharge from the service spillway occurs at an energy dissipator into Blockhouse Run.

The emergency spillway is an open channel spillway provided to manage flood events. The spillway has been designed to pass the PMF without overtopping the dam. Refer to Appendix A for additional detail on the outlet features.

4.3 Hydraulic Evaluation

FAR II was designed and constructed with a service spillway and an emergency spillway to control outflow.

Under the current conditions, the top of dam elevation is 983.0 feet (NGVD 29), and the maximum operating pool elevation is 974 feet NGVD 29. During the PMF, the estimated peak impounded water elevation is 981.9 feet NGVD 29. The existing configuration provides 1.1 ft of freeboard during the PMF. See Appendix A for more details. A summary of the hydraulic analysis of FAR II during the PMF is presented below:

Parameter	Current Conditions
Contributing Drainage Area	1,352 acres
Composite Runoff Curve Number, East Watershed	71
Composite Runoff Curve Number, West Watershed	75
Design Peak Inflow, Probable Maximum Flood	15,988 cubic feet per second (cfs)
Peak Discharge from Probable Maximum Flood	5,502 cfs
Top of Dam Elevation	983 feet NGVD 29
Pool Elevation, assuming probable maximum flood	981.9 feet NGVD 29

4.4 Discharge

Discharge from FAR II is regulated in accordance with an NPDES permit issued by the Ohio Environmental Protection Agency. The permit grants the Plant permission to discharge from the facility to Blockhouse Run in accordance with effluent limitations, monitoring requirements, and other conditions. The NPDES permit is issued in accordance with the provisions of the Federal Clean Water Act. Therefore, by complying with the NPDES permit, the discharge from FAR II is also being handled in accordance with the applicable surface water requirements.

5.0 Site Visit

TRC performed a site visit on September 1, 2021 to observe the current conditions of the FAR II. Based on the observations made during the site visit, the conditions modeled in Initial Inflow Design Flood Control Plan (AEP, 2016) accurately reflect the current conditions of the FAR II. The outlet features for the FAR II appeared to in good working order and functioning as designed.

6.0 Conclusions

The FAR II meets the requirements of 40 CFR 257.82 of adequately controlling the inflows and outflows of peak discharge for the following reasons:

- FAR II can adequately receive and store inflows for the PMF.
- The service spillway and emergency spillway were designed and constructed to collect and control peak outflow associated with the PMF in a controlled manner.
- The discharge from FAR II is permitted under a NPDES permit which was issued in accordance with the provisions of the Federal Clean Water Act.

This plan has been completed in compliance with the requirements set forth in 40 CFR 257.82. This document will be placed in the Plant's CCR operating record, and posted to the publicly accessible CCR website, and government notifications will be provided.

A periodic inflow design flood control system plan must be prepared every 5 years from the completion date of this Plan. The next Plan update is required by October 2026.

The Plan must be amended whenever the periodic review period is reached, or if changes in site conditions occur that will substantially affect the current written Plan.

7.0 Limitations

The observations, assessment, and recommendations presented in this Report are based on our limited scope of work and on information disclosed by our visual observations, the conditions of the site at the time of the September 1, 2021 inspection, the design information available at the time of this investigation, and only apply to the Cardinal FAR II Dam. This work has been performed in accordance with our authorized scope of work and is based on the level of effort and investigative techniques using that degree of care and skill ordinarily exercised under similar conditions by reputable members of the profession practicing in the same or similar locality at the time of service. No other warranties, expressed or implied, are made or intended by this Report. These services were intended to provide an indication of the current, observable conditions of the dam at the time of the visual observations on the date indicated in this Report. Such a limited visual review does not account for other non-visible, hidden, subsurface or material condition analyses, and the professional services rendered are not guaranteed to be a representation by TRC of inaccessible and unobservable site conditions or actual conditions subsequent to the date of TRC's site visit. Therefore, the evaluations, conclusions, recommendations and opinions provided in this Report are subject to change as a result of future natural or manmade processes and as a result of an additional comprehensive, intrusive investigation and engineering analyses beyond TRC's visual observations. TRC is not responsible for any conclusions or opinions drawn by others from the data included herein, nor are the recommendations specifically presented in this Report intended for use or reliance as construction specifications.

8.0 Certification

I, the undersigned Ohio Professional Engineer, hereby certify that I am familiar with the technical requirements of 40 CFR 257 Subpart D. I also certify that it is my professional opinion that, to the best of my knowledge, information, and belief, that the information in this demonstration is in accordance with current good and accepted engineering practice(s) and standard(s) and meets the requirements of 40 CFR 257.82(c).

For the purpose of this document, "certify" and "certification" shall be interpreted and construed to be a "statement of professional opinion." The certification is understood and intended to be an expression of my professional opinion as a Licensed Professional Engineer, based upon knowledge, information, and belief. The statement(s) of professional opinion are not and shall not be interpreted or construed to be a guarantee or a warranty of the analysis herein.

Shawn D. McGee, P.E.	PE.68761
Name	Engineer License Number

	10/8/2021
Signature of Professional Engineer	Date

9.0 References

American Electric Power Service Corporation (AEP). 2016. Inflow Design Flood Control Plan – CFR 257.82: Fly Ash Reservoir II – Cardinal Plant, Brilliant, Ohio. Geotechnical Engineering Services. October 2016.

S&ME. 2012. Permit Modification Application for the Fly Ash Reservoir II Dam at the Cardinal Power Plant. Brilliant, Ohio.

Schreiner, L.C., and J.T. Riedel. 1978. Probable Maximum Precipitation Estimates, United States East of the 105th Meridian (HMR No. 51), National Weather Service, National Oceanic and Atmospheric Administration, United States Department of Commerce, Washington, DC.

TRC. 2021. CCR Surface Impoundment – Hazard Potential Classification: Fly Ash Reservoir II. July 2021.

Appendix A: Initial Inflow Flood Control Plan

INFLOW DESIGN FLOOD CONTROL PLAN

CFR 257.82

Fly Ash Reservoir II

Cardinal Plant
Brilliant, Ohio

September, 2016

Prepared for: Cardinal Operating Company - Cardinal Plant

Brilliant, Ohio

Prepared by: Geotechnical Engineering Services

American Electric Power Service Corporation

1 Riverside Plaza

Columbus, OH 43215

GERS-16-061

INFLOW DESIGN FLOOD CONTROL PLAN
CFR 257.82
FLY ASH POND FAR II
CARDINAL PLANT

GERS-16-061

PREPARED BY	Mohammad A. Ajlouni, Ph.D.,P.E.	**DATE**	8/26/2016
REVIEWED BY	M. Leilah Saadi, E.I.T.	**DATE**	9/9/16
APPROVED BY	Gary F. Zych, P.E. Manager – AEP Geotechnical Engineering	**DATE**	9/12/2016

STATE OF OHIO
MOHAMMAD A AJLOUNI 67074
REGISTERED PROFESSIONAL ENGINEER

I certify to the best of my knowledge, information, and belief that the information contained in inflow design flood control plan meets the requirements of 40 CFR § 257.82

Table of CONTENTS

1.0 OBJECTIVE

This report was prepared by AEP- Geotechnical Engineering Services (GES) section to fulfill requirements of CFR 257.82 for the hydrologic and hydraulic evaluation of CCR surface impoundments.

2.0 DESCRIPTION OF THE CCR UNIT

The Cardinal Power Plant in Wells Township, Jefferson County, near the town of Brilliant in eastern Ohio. It is owned by Buckeye Power and AEP Generation Resources (GENCO) and is operated by Cardinal Operating Company. The facility operates two surface impoundments for storing CCR; the Bottom Ash Complex and Cardinal Fly Ash Reservoir II (FAR II) Dam. This report deals with the hydrologic and hydraulic evaluation for the Fly Ash Pond FAR II.

The FAR II Dam is a valley filled dam with a unique structure whose current configuration is the result of the original earth fill dam and two separate raisings. The original earth fill dam (Stage 1) consisted of a 180 feet high arched earth embankment incorporating a zoned cross section. At 925 feet NGVD, the dam featured a 70-foot wide by 1,055-feet long crest. The maximum operating pool that could be achieved with the original configuration was El. 913. In 1997, the original dam was raised, referred to as Stage 2. Following this raising, the dam was 237 feet high with a 30-foot wide crest. In 2013, the dam was raised 13 feet using back-to-back MSE walls, bringing the dam into its current, Stage 3 configuration. The principal features of the typical section are the MSE wall themselves and a vinyl sheet pile wall extending from the existing clay core to the top of the PMF flood level for seepage cutoff purposes. The FAR II Dam received sluiced fly ash and waste water from the plant via the bottom ash pond.

3.0 INFLOW DESIGN FLOOD 257.82(a)(3)

The facility is classified as a High Hazard Potential Dam. The Inflow Design Flood is the Probable Maximum Flood (PMF).

4.0 FLOOD CONTROL PLAN 257.82(c)

All storm water runoff from the watershed drains into the reservoir created by the Fly Ash Pond Dam. The design spillway system has enough capacity to pass the probable maximum flood without overtopping the dam. The design is based on the normal pool being at maximum normal operating pool and utilizing only the emergency spillway to handle the PMF without overtopping the crest of the dam. The water discharged through the emergency spillway is directed away from the dam such that it causes no threat to the stability of the structure.

The analysis in Attachment A includes excerpts of the 2013 design report and the associated report Appendix C that provides the description of the spillway system, flood storage capacity, inflow peak discharge and volume, peak discharge from the facility and maximum pool elevation.

The calculations show that the facility has the capacity to manage the inflow design flood.

ATTACHMENT A

Attachment A-1

Excerpts from 2013 Design Report

Hydrology and Hydraulics

4. HYDROLOGIC AND HYDRAULIC ANALYSIS

4.1 Introduction

The existing hydrologic conditions at the proposed dam site are described herein. Blockhouse Run, the major drainage feature in the project area, drains directly into the Ohio River. Approximately one mile upstream of the Ohio River, Blockhouse Run splits into two branches, designated as the East Branch and the West Branch.

The East Branch drains the eastern watershed as delineated in the Watershed Map on Plate 2 of Appendix C. The active fly ash dam II inundates the East Branch. The West Branch has been dammed to form the old Fly Ash Reservoir I (FAR I).

The location of the dam is shown on the drawings. Extension of the dam will inundate approximately 161 acres, or 24 percent of the area in the eastern watershed. Since the location of the dam is situated downstream of the discharge points of the old dam, runoff from the western watershed drains into the existing reservoir. Therefore, the spillway system of the proposed dam raising has been designed to meet ODNR Class I design criteria based on the runoff from both watersheds. The following sections present the hydrologic considerations and analyses performed during the design phase of this project.

4.2 Basin Characteristics

Figure 3.1 shows the limits of the watershed boundary for the existing Fly Ash Reservoir II(FAR II). The total drainage area above the dam has been divided into two watersheds, East and West, for analysis of the storm runoff entering the reservoir, as shown on Plate 2 of Appendix C.

A review of available topographic maps and aerial photos was made to determine essential basin characteristics for each watershed. Such characteristics include the drainage boundaries, areas, slopes, soil types, ground cover, land use and the time of concentration. The time of concentration is defined as the elapsed time for runoff to travel from the hydraulically most distant part of the watershed to some reference point downstream.

The old fly ash dam is located in the western watershed. Present land use within the drainage area is limited to reclaimed strip mine areas, some woodlands, and the inactive FAR I. Reclamation of the reservoir area is actively in progress in the form of a residual waste landfill above the level of the ponded fly ash. A built-out landfill condition was also analyzed for the western watershed, using the 2005 FAR I PTI. The PTI listed a Curve Number (CN) of 74, therefore the composite CN of the current FAR I condition of 75 was used. See Plates 4 through 6 of Appendix C.

Woodlands and scattered reclaimed strip mines constitute the existing land use in the East watershed. Construction of the proposed fly ash dam raising will inundate approximately 161 acres at Elevation 974.0 feet NGVD, the maximum operating pool elevation.

Soil types in the areas have been identified by the Soil Conservation Service (SCS) of the U.S. Department of Agriculture and classified into hydrologic soil groups. Within the study area, all soils fall under the hydrologic soil group B. Table 4.2.1, below, lists the basin characteristics for the Western and Eastern watersheds.

Table 4.2.1 Basin Characteristics

BASIN CHARACTERISTICS	WATERSHED			
	WEST		EAST	
	Woods	**Landfill**	**Woods**	**Reservoir**
Drainage area (acres)	519	158	514	161
Average land slope %	30	n/a	25	n/a
Hydrologic soil group	C	C	C	n/a
SCS curve number (CN)	70	91	70	100
Composite CN	75		n/a	
Time of concentration (hours)	0.87		0.57	0.1
TOTAL AREA (acres)	677		675	

4.3 Characteristics of Proposed Reservoir

A previously referenced, Drawing No. 2 shows the location of the existing dam. Based on this layout, the reservoir will have the following surface areas and storage capacities - as shown below in Table 4.3.1.

Table 4.3.1 Surface Areas and Storage Capacities

ELEVATION	(Ft. NGVD)	AREA (AC)	STORAGE (AC-FT)
Maximum Pool	974.0	161	11,868
Emerg. Spillway	975.5	165	12,200
Top of Dam	983.0	184	13,500

The area-capacity-elevation curve developed for this dam is shown on Plate 3 of Appendix C.

4.4 Design and Assumptions

Rainfall - runoff data was not available for the site because the streams flow intermittently. Therefore, runoff hydrographs were generated using the U.S. Army Corps of Engineers HEC-1 computer program. The SCS dimensionless unit hydrograph method was employed in the calculation of the hydrographs. For each watershed, separate runoff hydrographs were computed and then later combined to form a single inflow hydrograph for the proposed reservoir.

Runoff from the West watershed was analyzed based on current landfill construction activity. The landfill area was assumed to be in a disturbed (unvegetated) condition. A composite curve number was used to represent the unvegetated landfill and surrounding wooded areas. This is shown on Plate 4 of Appendix C.

In the East watershed, the reservoir surface is modeled as a subbasin to convert direct rainfall into a runoff hydrograph. The ash sluice water of 13.3 mgd (20.6 cfs) is represented as a base flow in the East watershed.

Once computed, the runoff hydrographs from the three subbasin watersheds are combined and routed through the reservoir.

4.4.1 Service Spillway

According to OAC 1501:21-13-04, design of the principal (service) spillway for class I dams must be such that the average frequency use of the emergency spillway is predicted to be less than once in fifty years. The estimated precipitation for a 50-year storm was obtained from the NOAA Atlas 14. For a 6-hour storm, the precipitation is 3.43 inches, whereas the 24-hour storm amount is 4.51 inches, as shown on Plate 9 of Appendix C.

Both 6-hour and 24-hour storm durations with average soil moisture conditions were checked. The 24-hour storm resulted in a higher maximum water surface, therefore this storm duration was used for developing the 50-year storm inflow hydrograph.

4.4.2 Emergency Spillway

OAC 1501:21-13-02 specifies that for class I dams, the spillway system shall safely pass the design flood equal to the probable maximum flood (PMF) without any overtopping of the dam. The PMF is the result of the probable maximum precipitation (PMP), defined as the greatest depth of precipitation for a given duration that is meteorologically possible for a given basin at a particular time of year. Generalized estimates of the PMP have been published by the

Hydrometerological branch of the National Weather Service, as shown on Plates 11 and 12 of Appendix C. For the study area, a 6-hour PMP of 26.5 inches was used as the design rainfall event. The antecedent moisture conditions of the soil cover were assumed to be average.

The layout of the control section and outlet channel for the emergency spillway is shown on the Emergency Spillway Plan.

The emergency spillway control section will be a section of mass concrete at Elevation 975.5. It will have a bottom length of 108 feet and side slopes consisting of access ramps at 2 to 15% grades. Downstream of the access ramps and control section, vertical concrete retaining walls wrap into the spillway and guide flow down the channel. The width of the control section along the flow direction will be 15 feet. The downstream channel of the spillway will be stepped. Steps will be formed of the mass concrete beginning at the downstream end of the control section and tying-in to the existing RCC steps. The calculations show that flow downstream of the control section becomes supercritical. The spillway channel transitions from an approximate 3.5H:2V slope along the proposed concrete steps to a 5H:2V slope along the existing RCC steps..

4.5 Analysis

All reservoir flood routings were conducted using the HEC-1 computer program. The program routes floods through the reservoir by the modified Puls method. In general, reservoir storage data and either spillway dimensions or discharge-rating curves are supplied by the user.

4.5.1 Service Spillway

Analysis of the service spillway system consisted of routing the 50-year storm to establish the invert of the emergency spillway. A design for the service spillway was determined and a stage-discharge curve was computed. A maximum operating level of elevation 974 was predetermined based on the projected life of the dam raising. Reservoir routings of the 50-year storm were performed using the maximum operating level of the reservoir.

Inflow was calculated as weir flow over the 4-foot stop log. Above Elevation 976, flow will enter through the top of the vertical service spillway structure. This flow was analyzed as both weir and orifice flow. Rating calculations for the service spillway are included on Plates 13 through 19 of Appendix C.

4.5.2 Emergency Spillway

Hydrologic reservoir routings were conducted to analyze the emergency spillway and its ability to pass the probable maximum flood without overtopping the dam. A flat rectangular control section was designed with a width of 15 feet and length of 108 feet. Discharge over the spillway was rated based on calculations of critical depth using the Corps of Engineers HEC-RAS computer program. Cross sections were taken at changes in geometry, slope or surface roughness. Manning's n roughness coefficients were input based on the expected channel surface conditions. Based on literature (see Plates 40 through 42 of Appendix C), a relatively high Manning's roughness coefficient of n=0.07 was used to model the stepped spillway surface. As shown on the drawings, proposed reinforced concrete training walls extend from the crest of the dam to a point approximately 3 feet beyond the proposed stepped channel transitions into the existing steps. Downstream from the training walls section, the spillway width becomes 110 feet, consistent with the current configuration.

The calculated relationship between stage and discharge was then used in the routing process to determine the maximum discharge and pool elevation. This information was used as the emergency spillway rating and input into HEC-1.

Discharges from the emergency spillway are routed away from the dam through an existing outlet channel.

4.6 Results

4.6.1 Service Spillway-Hydraulic Capacity

The proposed new principal spillway is a vertical concrete shaft structure with a 4-foot wide opening on one side. The spillway shaft will tie into the existing inclined spillway structure. The existing structure drains into a 54-inch diameter Prestressed Concrete Cylinder Pipe (P.C.C.P.), which then ties into a 42-inch steel pipe extending down the dam. The existing energy dissipator at the outlet of the steel pipe will be utilized. During most of the operating conditions, discharge through the service spillway will be controlled by weir flow over the stop logs in the opening of the shaft. The maximum operating level is set at elevation 974.0 feet. This corresponds to a maximum stop log elevation of 972.5 based on the base inflow of 20.6 cfs.

The peak inflow during the 50-year, 24-hour storm is 486 cfs, which results from 4.51 inches of rainfall according to NOAA Atlas 14. The reservoir level will rise to elevation 975.2 feet based on an initial pool level of elevation 974. The peak outflow from the dam will be 58 cfs. The HEC-1 output for the reservoir routings are contained on Plates 44 through 75 of Appendix C.

4.6.2 Service Spillway-Structural Capacity

The 54-inch P.C.C.P. portion of the service spillway was also analyzed for additional internal and external pressures due to the 13-foot dam raising. The pipe is installed under the dam embankment and was trenched into bedrock. Pipe crushing calculations were performed to analyze the additional loading on the pipe from the raised dam. Previous calculations (see 2000 As-Built Drawing No. 13-30043-5) indicate that the pipe was designed to handle 80 feet of overburden material at 125 pcf. The proposed top of dam will be 74.6 feet above the pipe, therefore the existing concrete pipe will be suitable to handle the additional load. Additional information on as-built drawing 13-30043-5 also indicates that the pipe is capable of handling internal pressure up to 35 psi. It is possible that at high headwater elevations, the spillway pipe could become pressurized. Under the maximum pool elevation of 983.0, the maximum static head on the downstream portion of the pipe would be 80.5 feet, or 34.9 psi. As the water will be flowing through the pipe, the actual pressure on the pipe will be less than this value; therefore the pressure should not exceed the pipe rating of 36 psi. See Plates 20 and 21 of Appendix C.

4.6.3 Emergency Spillway

The development of the PMF hydrograph indicates a peak inflow to the reservoir equal to 16,329 cfs. This value represents the combined hydrographs from the West and East watersheds. Values of the runoff from each watershed and the combined runoff are shown in Appendix C.

Based on the flood routing, the calculated peak discharge from the dam is 5,409 cfs at a maximum pool elevation of 981.9 feet NGVD. The PMF routing was also checked with the service spillway blocked, which resulted in a maximum pool elevation of 982.8 and 0.2 feet of freeboard.

Both 6-hour and 24-hour storm durations were checked. The 6-hour storm resulted in a higher maximum water surface, therefore this storm duration was used for developing the PMF inflow hydrograph.

Depth of flow in the spillway was determined based on the HEC-RAS analysis. In the proposed spillway section, the training walls were kept a minimum of 1 foot above the critical water surface depth of 4.5 feet, as shown on Plates 23 and 32 of Appendix C. The training wall height downstream of the steps transition was kept to a minimum of 1 foot above the resultant water surface depth during the PMF event (2 to 2.5 feet). The existing wall height of 4 feet meets this requirement. The HEC-RAS output is presented as Plates 25 through 36 of Appendix C. The structural analysis of the raised emergency spillway is presented elsewhere in this report.

4.7 Summary and Conclusions

The hydrologic/hydraulic studies for the proposed dam raising included estimating the PMF and 50-year flood hydrographs and designing the emergency and service spillways. The U.S. Army Corps of Engineers computer programs HEC-1 and HEC-RAS were used in the analyses. The Hydrograph presented on Plate 43 of Appendix C displays the resultant inflow and outflow hydrographs from HEC-1 based on the PMF event. Table 4.7.1, gives a complete summary of the study.

The proposed spillway system has enough capacity to pass the probable maximum flood without overtopping the dam. The water discharged through the emergency spillway is directed away from the dam such that it causes no threat to the stability of the structure.

Table 4.7.1 Hydrologic/Hydraulic Summary for Proposed Raising Of Dam

HYDROLOGIC AND HYDRAULIC SUMMARY		
Drainage Area	AREA (AC)	2.2 Sq. Mi.
Design Floods (Inflow)		
	PMF Peak	16,329 cfs
	50-Yr Peak	547 cfs
Peak Discharge		
	PMF	5,409 cfs
	50-Yr	58 cfs
Maximum Pool Elevations, NVGD		
	PMF	981.9 ft
	50-Yr	975.2 ft
Emergency Spillway - Overflow Control Section - Concrete		
	Crest Elevation, NGVD	975.5 ft
	Bottom Width	105.0 ft
	Side Slopes	Vertical
Service Spillway - Size		
	Top of Vertical Concrete Structure	976.0 ft
	Stop Log Width	4.0 ft
	Conduit Size	54" & 42"
	Maximum Operating Pool Level, NGVD	974.0 ft

Attachment A-2

2013 Report Appendix C

Hydrologic and Hydraulics Analysis

APPENDIX C

HYDROLOGIC AND HYDRAULIC ANALYSIS

STATE OF OHIO
ALLEN J.
SMITH JR
E-71835
REGISTERED
PROFESSIONAL ENGINEER

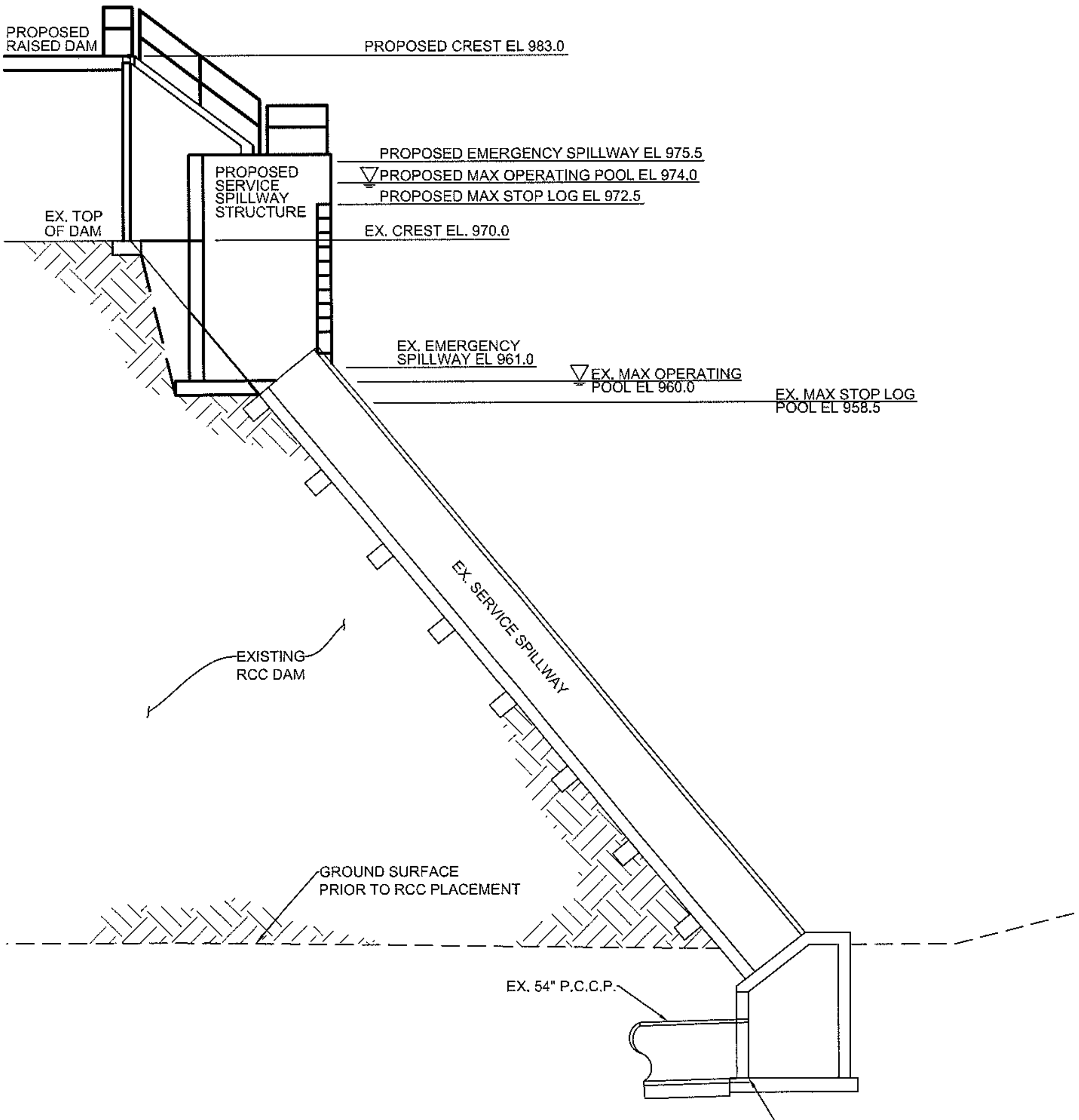
9-28-12

Appendix C calculations checked and reviewed by: ____________________

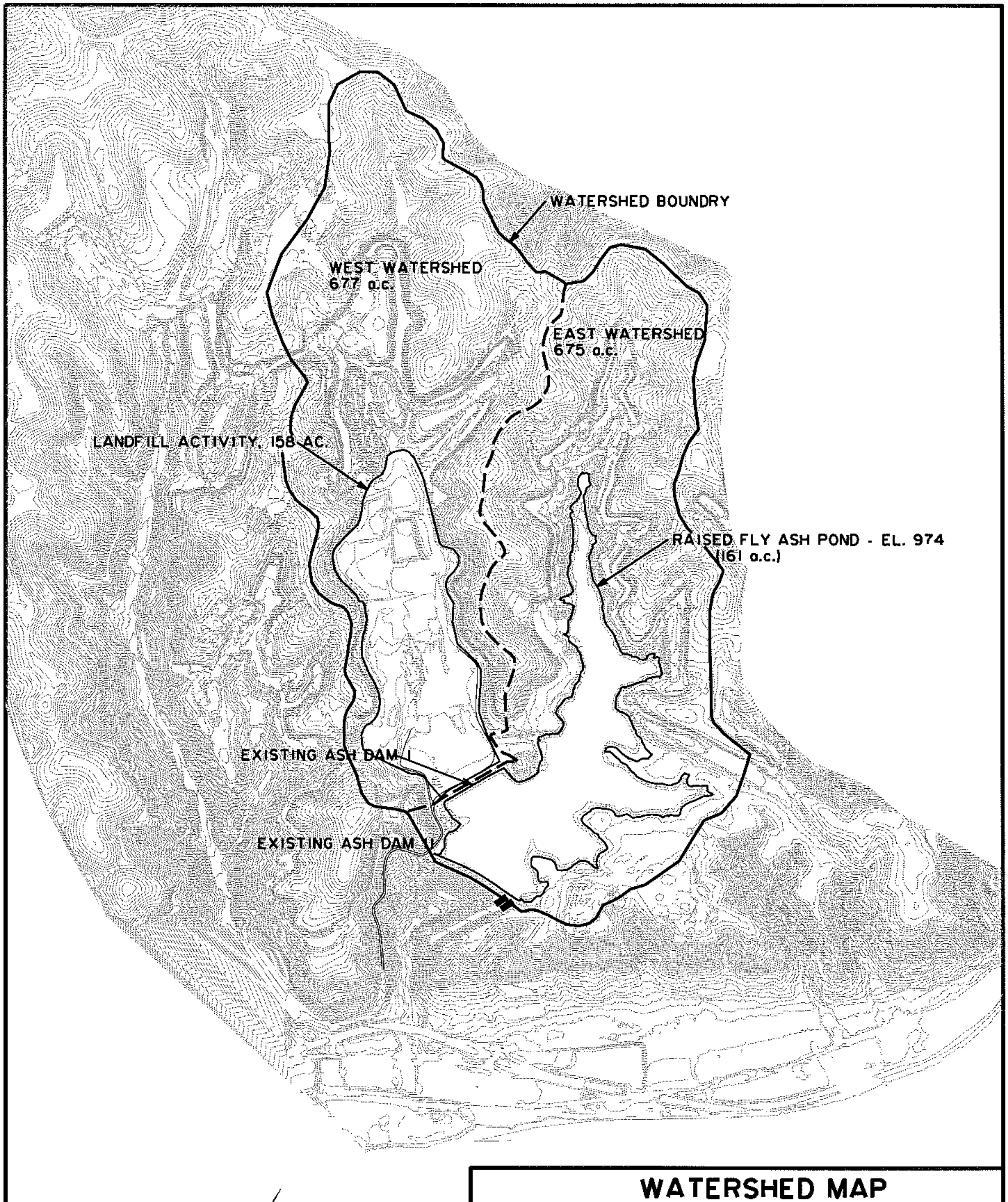
Stephen J. Loskota, P.E.
S&ME, Inc.

Appendix C calculations prepared by: ____________________

A.J. Smith, P.E.
S&ME, Inc.



SERVICE SPILLWAY SCHEMATIC
NTS



WATERSHED MAP

CARDINAL PLANT
FLY ASH RETENTION POND II
BRILLIANT, OHIO

S&ME
WWW.SMEINC.COM

Project: 011-11497-042	Drawn By: BAM
Drawing Date: 3/16/12	Approved By: AJS
Revision Date:	Scale: AS SHOWN

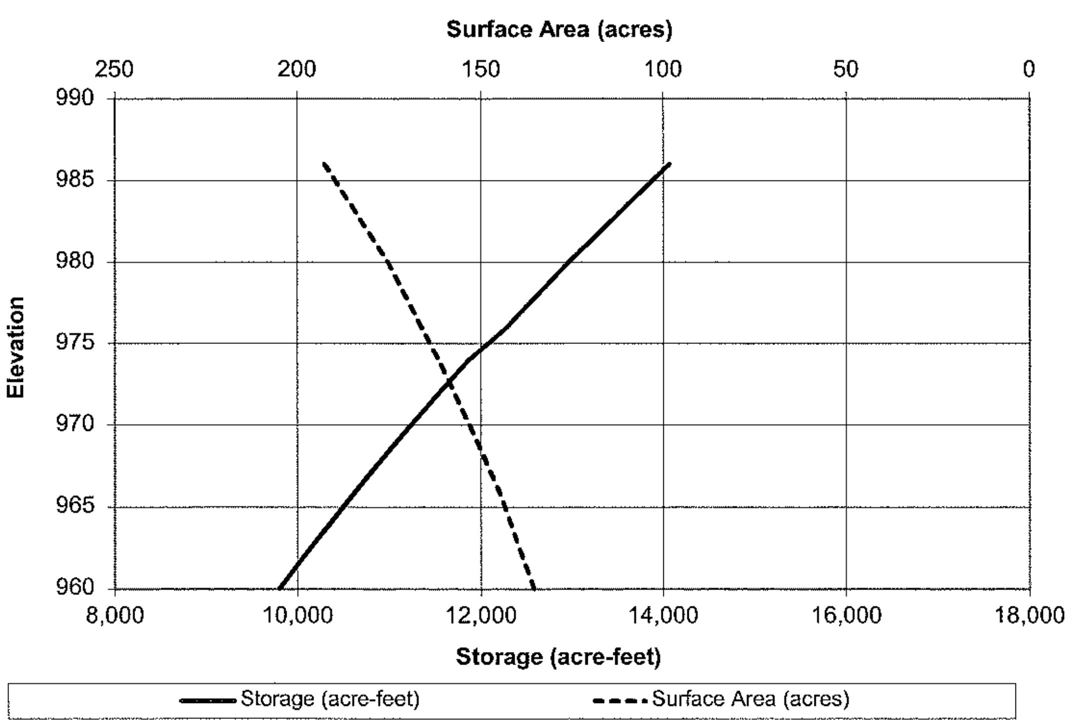
PLATE 2

Storage Volume Calc
Cardinal Plant - Fly Ash Reservoir No. 2 Raising

Stage-storage for a dam raising design with a proposed crest at El. 983
Area calcuations above El. 970 (present crest) based on ground surface elevation contours
Ground surface elevations taken from 2-foot contour interval base map from aerial photo dated 3-5-2009

	Elev	area (ft^2) (ft^2)	area (ac)	ave area (ft^2)	height (ft)	vol (ft^3) (ft^3)	Vol (ac-ft)	Cum Vol (ac-ft)	*Total Vol (ac-ft)*
ex. pool	960	5,903,719	135.5					0	*9,800*
				5,973,619	2	11,947,238	274		
	962	6,043,519	138.7					274	*10,074*
				6,114,867	2	12,229,735	281		
	964	6,186,216	142.0					555	*10,355*
				6,259,072	2	12,518,144	287		
	966	6,331,928	145.4					842	*10,642*
				6,500,135	4	26,000,539	597		
ex. crest	970	6,668,342	153.1					1,439	*11,239*
				6,850,086	4	27,400,345	629		
prop. pool	974	7,031,831	161.4					2,068	*11,868*
				7,109,159	2	14,218,319	326		
prop. E.S.	975.5	*7,186,488*	165.0					2,395	*12,195*
		(interpolated)		7,212,264	0.5	3,606,132	83		
	976	7,238,040	166.2					2,478	*12,278*
				7,434,667	4	29,738,670	683		
	980	7,631,295	175.2					3,160	*12,960*
				7,820,348	3	23,461,043	539		
prop. crest	983	*8,009,400*	183.9					3,699	*13,499*
		(interpolated)		8,198,450	3	24,595,349	565		
	986	8,387,500	192.6					4,263	*14,063*

Cardinal FAD 2 - Stage-Storage Curves



CARDINAL FAD 2

CALCULATE COMPOSITE CN - WEST WATERSHED

Based off of Worksheet 2 in Appendix D of 210-VI-TR-55, Second Ed., June 1986

Soil Name/ Hydrologic Group	Cover Description	CN	Area (ac)	Product of CN x Area
C	Newly graded areas	91	158.0	14,378
	(no vegetation)			
C	Woods, good	70	519.0	36,330

Totals	677.0	50,708

Composite CN	74.9

Use CN = **75**

Check FAR 1 Landfill Post-Development conditions:

From 2005 FAR 1 PTI by GeoSyntec, Post-Development conditions for the final cover system is a CN of **74.** (see attached)

Therefore, use current landfill construction condition of CN = **75.**

- **Hydrologic Soil Groups:**
  Interim Conditions – Interim site conditions will include exposed temporary waste slopes. FGD waste material is assumed to exhibit similar characteristics to soils of Hydrologic Soils Group C.

  Post-Development - Soil used to construct the final cover system will consist of low permeability material, which will exhibit characteristics of Hydrologic Soils Group C.

- **Curve Number (CN):**
  Interim Conditions – For interim slopes, a CN of 91 is selected, the value recommended by SCS for hydrologic soil group C for "newly graded areas".

  Post-Development - For the final cover system, a curve number (CN) of 74 is used, the value recommended by SCS for hydrologic soil group C for "open spaces in good condition (grass cover > 75%)". A summary of runoff CN values provided by SCS [SCS, 1986] are provided in Table 2.

- **Time of Concentration T_c:** The T_c value represents the total time for stormwater runoff to travel from the hydraulically most distant point of a watershed or drainage area to a point of interest. Factors affecting T_c include surface roughness, channel shape and flow patterns, and slope. For this analysis the calculation of T_c evaluates the impact of three different types of stormwater runoff flow:

  - **sheet flow** – flow over plane surfaces, which is limited to a maximum length of 150 ft.;
  - **shallow concentrated flow** – after about 150 ft., sheet flow will begin to concentrate, but not necessarily defined in a specific channel; and
  - **channel flow** – flow that is confined to a defined channel section.

  The T_c value for a drainage area is the sum of the individual various travel time (T_t) values of the above flow types. The equations for calculating the T_t are presented below

  - **Sheet Flow:** $$T_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,s^{0.4}}$$

  - **Shallow Concentrated Flow:** $$T_t = \frac{L}{3{,}600\,V}$$

TABLE 2
Summary of Typical Runoff Curve Numbers

Table 2-2a Runoff curve numbers for urban areas[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]	(from FAR 1 PTI)	63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

[1]Average runoff condition, and $I_a = 0.2S$.
[2]The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
[3]CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
[4]Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
[5]Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4, based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table 2-2a Runoff curve numbers for urban areas [1]

Cover description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	Average percent impervious area [2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) [3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) [4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
→ Newly graded areas (pervious areas only, no vegetation) [5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

1 Average runoff condition, and $I_a = 0.2S$.

2 The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.

3 CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.

4 Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.

5 Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table 2-2c Runoff curve numbers for other agricultural lands [1]

Cover description		Curve numbers for hydrologic soil group			
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing. [2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element. [3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 [4]	48	65	73
Woods—grass combination (orchard or tree farm). [5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods. [6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 [4]	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

1 Average runoff condition, and $I_a = 0.2S$.
2 *Poor:* <50%) ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed.
3 *Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.
4 Actual curve number is less than 30; use CN = 30 for runoff computations.
5 CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.
6 *Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

NOAA Atlas 14, Volume 2, Version 3
Location name: Mingo Junction, Ohio, US*
Coordinates: 40.2666, -80.6517
Elevation: 1001ft*
* source: Google Maps

POINT PRECIPITATION FREQUENCY ESTIMATES

G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval(years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.320 (0.283-0.363)	0.383 (0.339-0.435)	0.463 (0.409-0.526)	0.524 (0.462-0.594)	0.603 (0.530-0.683)	0.663 (0.581-0.750)	0.720 (0.628-0.814)	0.780 (0.678-0.880)	0.859 (0.742-0.969)	0.916 (0.789-1.03)
10-min	0.497 (0.440-0.565)	0.598 (0.529-0.680)	0.720 (0.636-0.817)	0.809 (0.713-0.916)	0.922 (0.811-1.04)	1.01 (0.881-1.14)	1.09 (0.946-1.23)	1.16 (1.01-1.31)	1.26 (1.09-1.42)	1.33 (1.15-1.50)
15-min	0.610 (0.540-0.692)	0.731 (0.647-0.831)	0.883 (0.781-1.00)	0.995 (0.877-1.13)	1.14 (1.00-1.29)	1.24 (1.09-1.41)	1.35 (1.18-1.52)	1.45 (1.26-1.64)	1.58 (1.36-1.78)	1.67 (1.44-1.88)
30-min	0.807 (0.714-0.916)	0.979 (0.866-1.11)	1.21 (1.07-1.37)	1.38 (1.22-1.57)	1.61 (1.41-1.82)	1.78 (1.56-2.01)	1.95 (1.70-2.20)	2.11 (1.84-2.39)	2.34 (2.02-2.63)	2.50 (2.15-2.82)
60-min	0.985 (0.872-1.12)	1.20 (1.06-1.37)	1.52 (1.34-1.72)	1.76 (1.55-1.99)	2.09 (1.83-2.36)	2.34 (2.05-2.65)	2.60 (2.27-2.94)	2.87 (2.49-3.24)	3.23 (2.79-3.64)	3.51 (3.02-3.96)
2-hr	1.13 (0.992-1.31)	1.37 (1.20-1.58)	1.74 (1.52-2.00)	2.02 (1.76-2.32)	2.41 (2.10-2.76)	2.72 (2.37-3.12)	3.05 (2.63-3.48)	3.39 (2.91-3.86)	3.85 (3.28-4.38)	4.22 (3.58-4.80)
3-hr	1.21 (1.07-1.40)	1.46 (1.29-1.69)	1.84 (1.62-2.14)	2.14 (1.88-2.48)	2.56 (2.24-2.96)	2.90 (2.53-3.34)	3.26 (2.83-3.75)	3.63 (3.13-4.18)	4.15 (3.55-4.77)	4.56 (3.87-5.25)
6-hr	1.44 (1.28-1.65)	1.73 (1.54-1.98)	2.17 (1.93-2.47)	2.52 (2.24-2.87)	3.02 (2.67-3.43)	3.43 (3.01-3.88)	3.86 (3.37-4.37)	4.32 (3.75-4.87)	4.96 (4.26-5.59)	5.49 (4.67-6.17)
12-hr	1.70 (1.53-1.90)	2.04 (1.83-2.28)	2.52 (2.26-2.82)	2.91 (2.61-3.25)	3.49 (3.11-3.88)	3.97 (3.52-4.39)	4.47 (3.94-4.93)	5.01 (4.39-5.51)	5.79 (5.01-6.35)	6.42 (5.51-7.01)
24-hr	2.02 (1.87-2.18)	2.41 (2.24-2.61)	2.94 (2.74-3.18)	3.39 (3.14-3.65)	4.00 (3.70-4.31)	4.51 (4.15-4.85)	5.04 (4.62-5.40)	5.59 (5.10-5.98)	6.37 (5.77-6.81)	6.99 (6.30-7.46)
2-day	2.37 (2.21-2.55)	2.82 (2.63-3.03)	3.42 (3.19-3.67)	3.90 (3.63-4.19)	4.57 (4.24-4.90)	5.11 (4.73-5.47)	5.67 (5.22-6.06)	6.24 (5.73-6.67)	7.04 (6.42-7.51)	7.66 (6.95-8.18)
3-day	2.53 (2.38-2.71)	3.01 (2.83-3.22)	3.63 (3.40-3.88)	4.12 (3.86-4.41)	4.81 (4.49-5.13)	5.36 (4.98-5.71)	5.92 (5.49-6.31)	6.50 (6.00-6.92)	7.29 (6.69-7.76)	7.92 (7.22-8.42)
4-day	2.70 (2.55-2.87)	3.21 (3.02-3.41)	3.84 (3.62-4.08)	4.35 (4.09-4.62)	5.05 (4.74-5.36)	5.61 (5.24-5.95)	6.18 (5.76-6.55)	6.76 (6.27-7.16)	7.55 (6.97-8.01)	8.17 (7.50-8.67)
7-day	3.25 (3.08-3.44)	3.84 (3.63-4.06)	4.55 (4.31-4.82)	5.12 (4.83-5.41)	5.88 (5.54-6.22)	6.48 (6.09-6.85)	7.09 (6.65-7.49)	7.71 (7.20-8.14)	8.52 (7.92-9.00)	9.14 (8.45-9.67)
10-day	3.74 (3.55-3.94)	4.41 (4.19-4.66)	5.18 (4.92-5.47)	5.78 (5.49-6.10)	6.59 (6.24-6.95)	7.22 (6.83-7.61)	7.85 (7.40-8.27)	8.47 (7.96-8.94)	9.29 (8.69-9.80)	9.91 (9.23-10.5)
20-day	5.24 (5.00-5.51)	6.16 (5.87-6.48)	7.13 (6.79-7.50)	7.89 (7.51-8.29)	8.89 (8.45-9.33)	9.64 (9.15-10.1)	10.4 (9.83-10.9)	11.1 (10.5-11.7)	12.0 (11.3-12.7)	12.7 (11.9-13.4)
30-day	6.58 (6.26-6.93)	7.70 (7.33-8.12)	8.83 (8.41-9.30)	9.72 (9.25-10.2)	10.9 (10.3-11.4)	11.7 (11.1-12.4)	12.6 (11.9-13.2)	13.4 (12.7-14.1)	14.4 (13.6-15.2)	15.2 (14.3-16.0)
45-day	8.42 (8.04-8.81)	9.82 (9.38-10.3)	11.1 (10.6-11.7)	12.1 (11.6-12.7)	13.4 (12.8-14.0)	14.4 (13.7-15.0)	15.3 (14.5-16.0)	16.1 (15.3-16.9)	17.2 (16.2-18.0)	17.9 (16.9-18.8)
60-day	10.1 (9.73-10.6)	11.8 (11.3-12.3)	13.3 (12.7-13.8)	14.4 (13.8-15.0)	15.8 (15.1-16.4)	16.8 (16.0-17.5)	17.7 (16.9-18.5)	18.6 (17.7-19.4)	19.6 (18.7-20.5)	20.3 (19.3-21.3)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

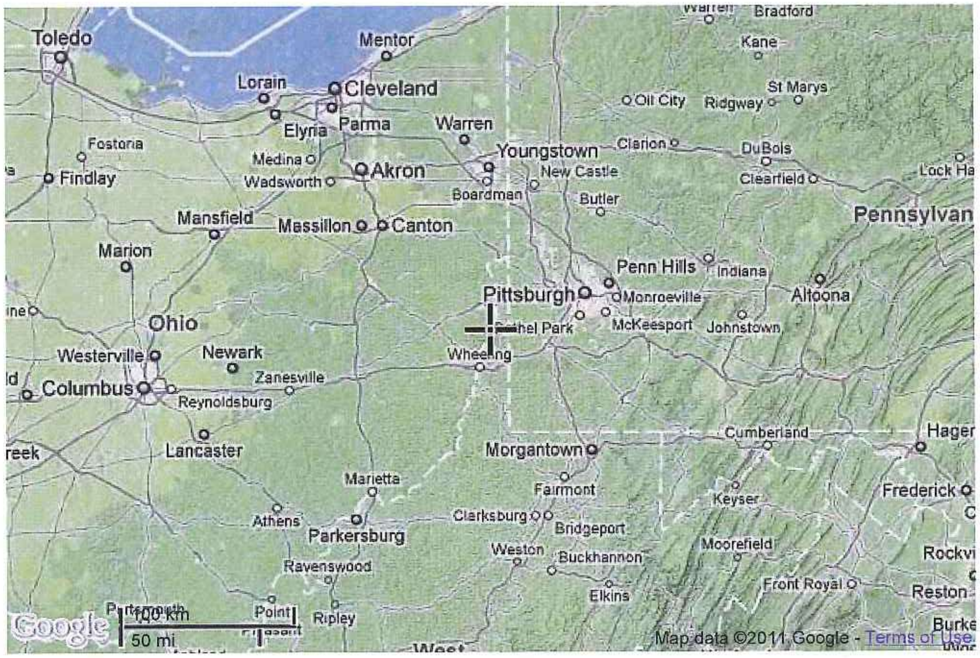
Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

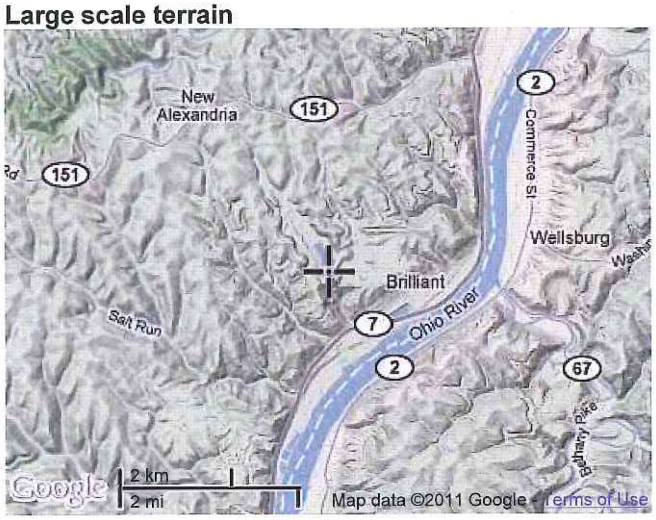
Back to Top

PF graphical

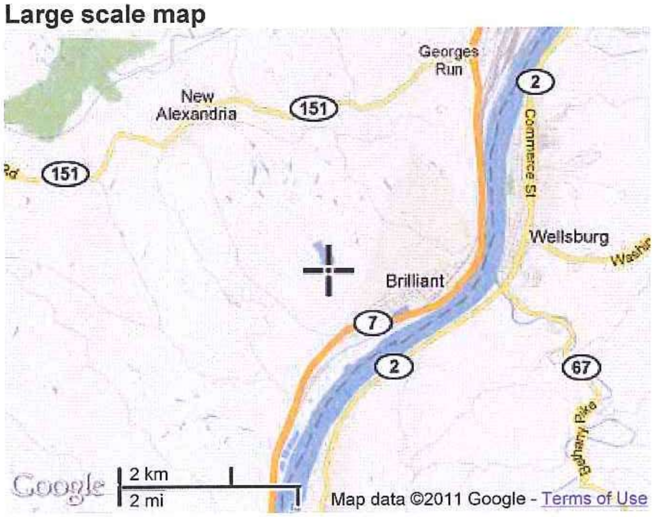
PLATE 9



Large scale terrain



Large scale map



Large scale aerial

PLATE 10

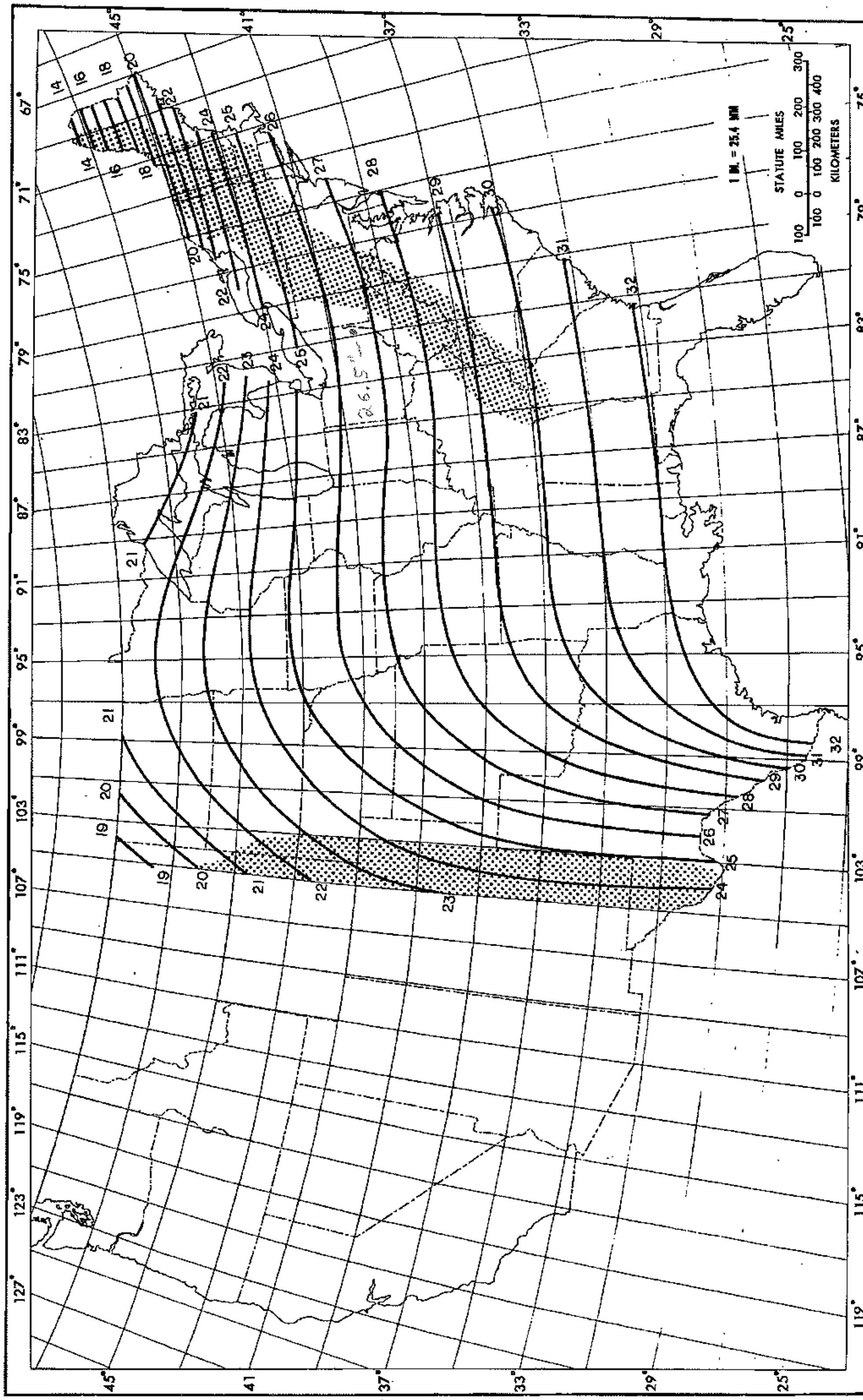


Figure 18.--All-season PMP (in.) for 6 hr 10 mi² (26 km²).

From HMR 51

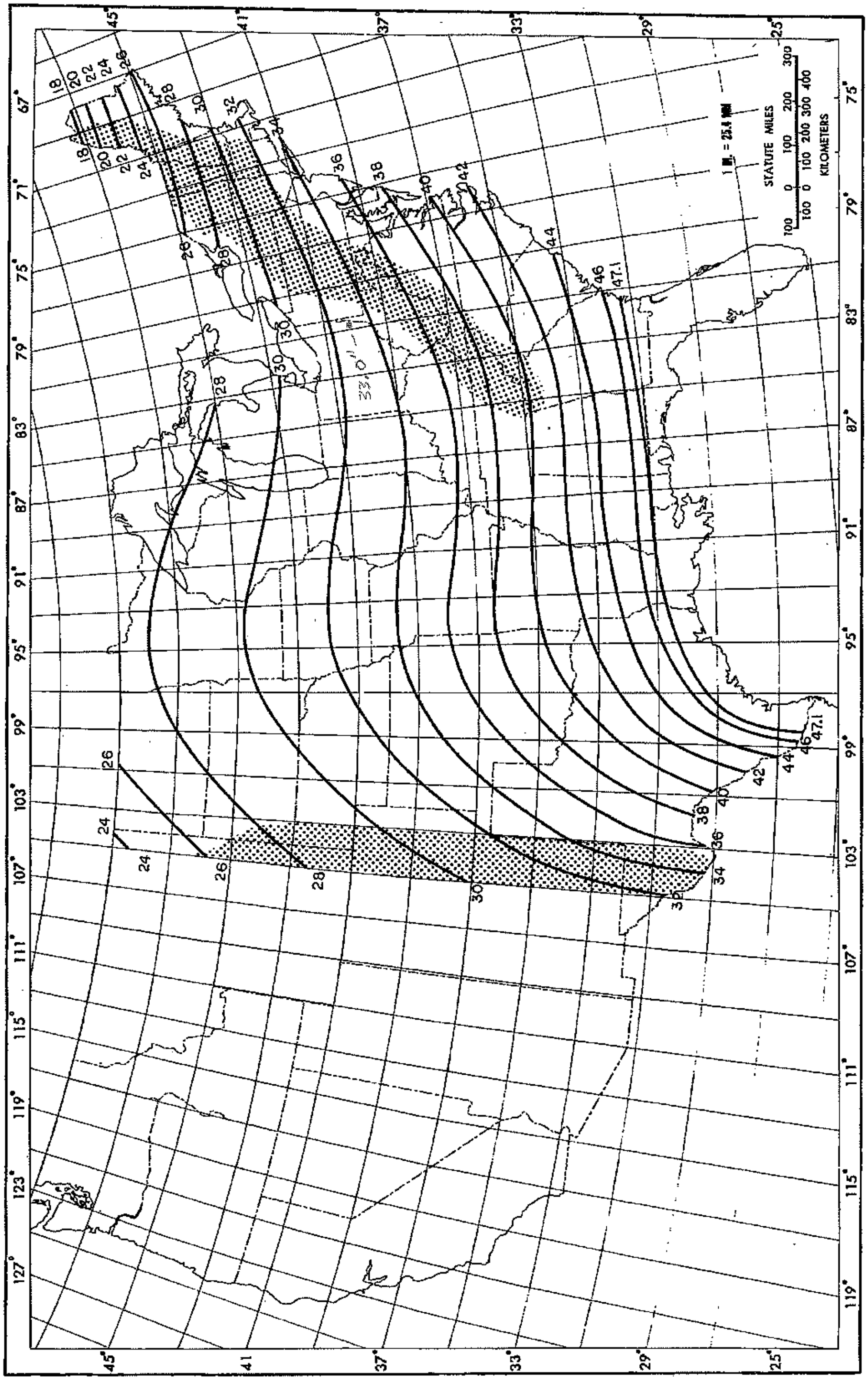


Figure 20.--All-season PMP (in.) for 24 hr 10 mi^2 (26 km^2).

From HMR 51

Cardinal FAD 2 Dam Raising Spillway Capacity - Proposed Top of Dam El. 983, ES width = 105'

	Lake Elevation	Box Struc. Weir Flow	Box Struc. Orifice Flow	Stop Log Weir Flow	**Structure Outflow**	Pipe Inlet Flow	Pressure Pipe Flow	**Control Outflow**	***Control Outflow***	E. Spillway Flow	**Total Outflow**	Control Type
	feet	cfs	cfs	cfs	**cfs**	cfs	cfs	**cfs**	***MGD***	cfs		
Top of Stop Log	972.50	-	-	0.0	**0.0**	-	-	**0.0**	***0.0***	-	**0.0**	-
	973.00	-	-	4.7	**4.7**	615.4	357.8	**4.7**	***3.0***	-	**4.7**	Stop Log Weir Flow
	973.50	-	-	13.3	**13.3**	618.0	358.2	**13.3**	***8.6***	-	**13.3**	Stop Log Weir Flow
Max Operating Pool	974.00	-	-	24.5	**24.5**	620.5	358.6	**24.5**	***15.8***	-	**24.5**	Stop Log Weir Flow
	974.50	-	-	37.7	**37.7**	623.0	358.9	**37.7**	***24.3***	-	**37.7**	Stop Log Weir Flow
	975.00	-	-	52.7	**52.7**	625.6	359.3	**52.7**	***34.0***	-	**52.7**	Stop Log Weir Flow
Emergency Spillway	975.50	-	-	69.2	**69.2**	628.1	359.7	**69.2**	***44.7***	0.0	**69.2**	Stop Log Weir Flow
	976.27	12.3	63.7	87.2	**99.5**	631.9	360.3	**99.5**	***64.3***	200.0	**299.5**	Stop Log Weir Flow
	976.89	73.6	115.7	87.2	**160.8**	635.0	360.8	**160.8**	***103.9***	500.0	**660.8**	Stop Log Weir Flow
	977.70	194.3	159.9	87.2	**247.1**	638.9	361.4	**247.1**	***159.7***	1000.0	**1247.1**	Stop Log Weir Flow
	978.37	319.8	188.8	87.2	**276.0**	642.2	361.9	**276.0**	***178.4***	1500.0	**1776.0**	Stop Log Weir Flow
	978.98	450.9	211.7	87.2	**298.9**	645.2	362.3	**298.9**	***193.2***	2000.0	**2298.9**	Stop Log Weir Flow
	980.06	717.0	247.1	87.2	**334.3**	650.4	363.2	**334.3**	***216.1***	3000.0	**3334.3**	Stop Log Weir Flow
	981.02	985.8	274.8	87.2	**362.0**	655.0	363.9	**362.0**	***233.9***	4000.0	**4362.0**	Stop Log Weir Flow
	981.90	1256.1	297.9	87.2	**385.1**	659.2	364.5	**364.5**	***235.6***	5000.0	**5364.5**	Pressure Pipe Flow
	982.32	1392.5	308.3	87.2	**395.5**	661.2	364.9	**364.9**	***235.8***	5500.0	**5864.9**	Pressure Pipe Flow
	982.73	1530.2	318.1	87.2	**405.4**	663.2	365.2	**365.2**	***236.0***	6000.0	**6365.2**	Pressure Pipe Flow
Top of Dam = 983.0	983.00	1623.2	324.5	87.2	**411.7**	664.4	365.4	**365.4**	***236.1***			

Cardinal FAD 2 Stop Logs Weir Rating
Weir Flow

$$Q = C_{SCW} L H^{\frac{3}{2}}$$

$$C_{SCW} = 3.27 + 0.4\left(\frac{H}{H_c}\right)$$

for $H/H_c < 0.3$, C_{SCW} becomes 3.33

***L*=** **4.00**
***g*=** **32.2**
***Crest Elevation*=** **972.5**

Elevation	H	Q
972.50	0.00	0.0
973.00	0.50	4.7
973.50	1.00	13.3
974.00	1.50	24.5
974.50	2.00	37.7
975.00	2.50	52.7
975.50	3.00	69.2
976.00	3.50	87.2

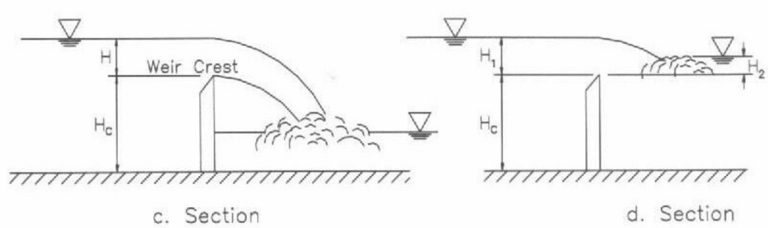


Figure 8-13. Sharp crested weirs.

Reference:
FHWA-SA-96-078
Urban Drainage Design Manual
Hydraulic Engineering Circular 22
November, 1996

Cardinal FAD 2 Existing Spillway Pipe Rating
Pipe Inlet Control

$$Q = CA\sqrt{2gh_1}$$

for C=0.62 orifice equation becomes:

$$Q = 3.91D^2\sqrt{h_1}$$

d= 54.000 INCHES 54" PCCP
Invert Elevation = 910.33

Headwater Elevation (ft.)	Orifice	
	Discharge (cfs)	Velocity (ft/s)
972.50	612.9	0.0
973.00	615.4	38.7
973.50	618.0	38.9
974.00	620.5	39.0
974.50	623.0	39.2
975.00	625.6	39.4
975.50	628.1	39.5
976.27	631.9	39.8
976.89	635.0	39.9
977.70	638.9	40.2
978.37	642.2	40.4
978.98	645.2	40.6
980.06	650.4	40.9
981.02	655.0	41.2
981.90	659.2	41.5
982.32	661.2	41.6
982.73	663.2	41.7
983.00	664.4	41.8

Reference:
FHWA-SA-96-078
Urban Drainage Design Manual
Hydraulic Engineering Circular 22
November, 1996

Cardinal FAD 2 Existing Spillway Pipe Rating
Pressure Pipe Flow Computed with the Energy Equation
(from inlet to outlet)

Manning's n= 0.015
Inlet Invert: 910
Outlet Invert (z_2): 736
Entrance Coefficent K_e= 0.9
Outlet Coefficent K_o= 1.0
MH Coefficent K_{MH}= 0.5
Bends Coefficent K_b= 0.8
Pipe Diameter in inches= 42
Pipe Diameter in feet (D)= *3.50*
Pipe Eq. Length in feet (L)= 852
Darcy-Weisbach *f*= *0.027*

Assuming Free Outlet (TW=El. 739.5):

Headwater Elevation (z_1) (ft)	Outlet Velocity (ft/s)	Outlet Flow Rate (ft^3/s)
972.50	37.1	357.4
973.00	37.2	357.8
973.50	37.2	358.2
974.00	37.3	358.6
974.50	37.3	358.9
975.00	37.3	359.3
975.50	37.4	359.7
976.27	37.4	360.3
976.89	37.5	360.8
977.70	37.6	361.4
978.37	37.6	361.9
978.98	37.7	362.3
980.06	37.7	363.2
981.02	37.8	363.9
981.90	37.9	364.5
982.32	37.9	364.9
982.73	38.0	365.2
983.00	38.0	365.4

The Darcy-Weisbach friction factor is related to Manning's n through the following equation:

$$f = \frac{185 \quad n^2}{D^{\frac{1}{3}}}$$

The Energy Equation is:

$$\frac{p_1}{\gamma} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{v_2^2}{2g} + z_2 + \sum h_L$$

Where:

$$\sum h_L = \frac{v^2}{2g}\left(f\frac{L}{D} + K_e + K_o + K_b\right)$$

Because p_1, v_1 and p_2 all are equal to 0 the energy equation becomes:

$$z_1 - z_2 = \frac{v^2}{2g} + \frac{v^2}{2g}\left(f\frac{L}{D} + K_e + K_o + K_b\right)$$

Solving for v gives:

$$v = \sqrt{\frac{2g(z_1 - z_2)}{\left(1 + \left(f\frac{L}{D} + K_e + K_o + K_b\right)\right)}}$$

Determine flow rate Q by:

$$Q = VA$$

Cardinal FAD 2 Vertical Box Structure Overflow Rating
Weir Flow

$$Q = C_{SCW} L H^{\frac{3}{2}}$$

$$C_{SCW} = 3.27 + 0.4\left(\frac{H}{H_c}\right)$$

for $H/H_c < 0.3$, C_{SCW} becomes 3.33

Size= **5'-8" x 7'-6 " inside dimensions**

L=	**26.3**
g=	**32.2**
Crest Elevation=	**976.0**

Elevation	H	Q
976.00	0.00	0.0
976.27	0.27	12.3
976.89	0.89	73.6
977.70	1.70	194.3
978.37	2.37	319.8
978.98	2.98	450.9
980.06	4.06	717.0
981.02	5.02	985.8
981.90	5.90	1256.1
982.32	6.32	1392.5
982.73	6.73	1530.2
983.00	7.00	1623.2

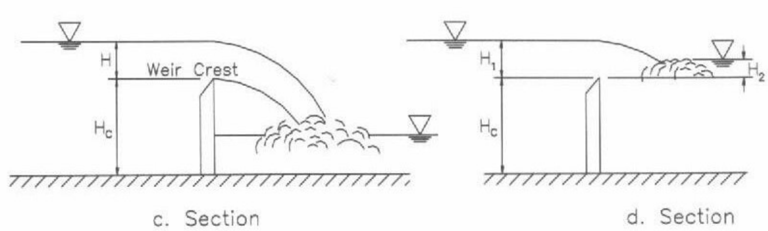


Figure 8-13. Sharp crested weirs.

Reference:
FHWA-SA-96-078
Urban Drainage Design Manual
Hydraulic Engineering Circular 22
November, 1996

Cardinal FAD 2 Vertical Box Structure Overflow Rating
Orifice Flow

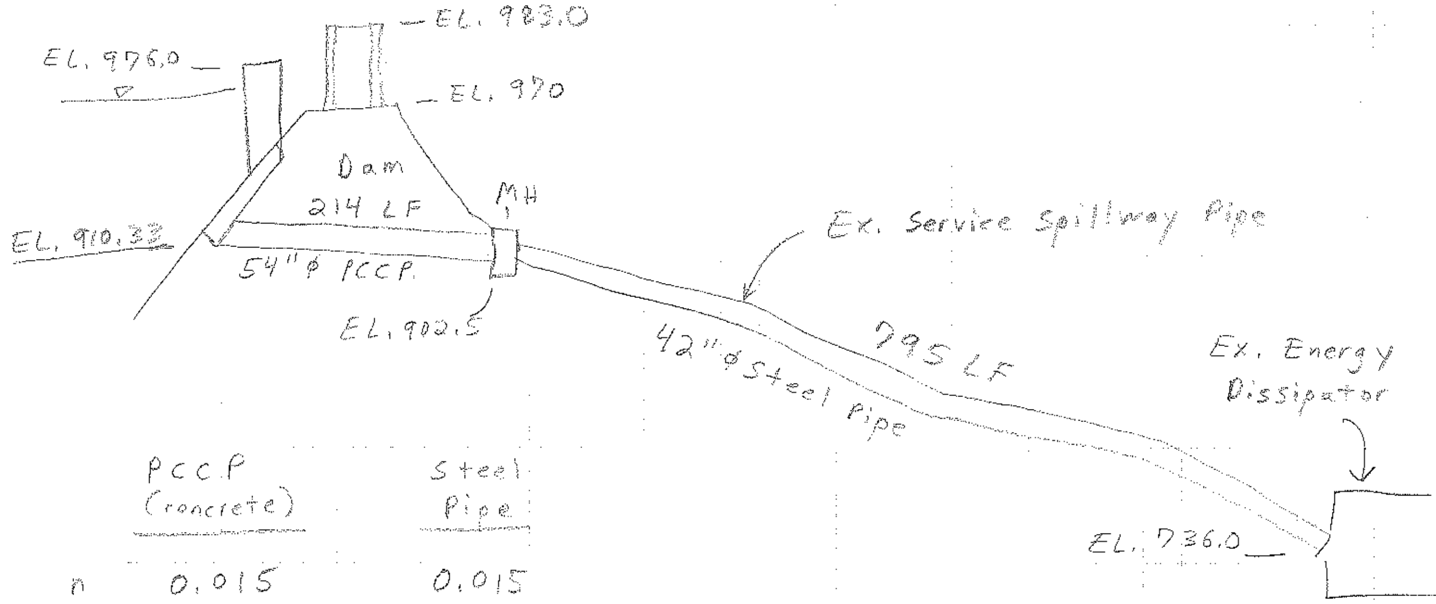
$$Q = CA\sqrt{2gh_1}$$

Size= **5'-8" x 7'-6 " inside dimensions**
A= **42.5** **S.F.**
Grating % Open Area **60** **%**
Orifice Centroid Elevation = **976.0**

Headwater Elevation (ft.)	**Orifice**	
	Discharge (cfs)	**Velocity (ft/s)**
976.00	*0.0*	
976.27	*63.7*	1.5
976.89	*115.7*	2.7
977.70	*159.9*	3.8
978.37	*188.8*	4.4
978.98	*211.7*	5.0
980.06	*247.1*	5.8
981.02	*274.8*	6.5
981.90	*297.9*	7.0
982.32	*308.3*	7.3
982.73	*318.1*	7.5
983.00	*324.5*	7.6

Reference:
FHWA-SA-96-078
Urban Drainage Design Manual
Hydraulic Engineering Circular 22
November, 1996

Cardinal Dam - Extended Service Spillway



	PCCP (concrete)	Steel Pipe
n	0.015	0.015
D	54"	42"
f	0.025	0.027
L	214'	795'
L_e	57'	

$$f = \frac{185 n^2}{D^{1/3}}$$

Equivalent Length of 54" pipe to 42":

$$L_e = L\left(\frac{f}{f_e}\right)\left(\frac{D_e}{D}\right)^5 \quad , \quad \frac{f}{f_e} = 0.93$$

$$= (214\ ft)(0.93)\left(\frac{3.5}{4.5}\right)^5 = 57'$$

Outlet Control - Full Pipe Flow

$$\text{Headwater} = \text{Tailwater} + \frac{V^2}{2g}\left(1 + K_e + K_{MH} + K_{bends} + K_f + K_o\right)$$

$K_e = 0.9$

$K_o = 1.0$

$$K_f = f\left(\frac{L}{D}\right) = 0.027\left(\frac{795+57}{3.5}\right) = 6.6$$

$$HW = TW + \frac{V^2}{2g}\left(1 + 0.9 + 0.5 + 4(0.2) + 6.6 + 1.0\right)$$

$$HW - TW = \frac{V^2}{2g}\ (10.8)$$

Let TW = Crown of pipe ≈ 739.5

$$\therefore \left(\frac{(HW-739.5)\ 2g}{10.8}\right)^{1/2} = V \ ; \quad V = 2.44\,(HW-739.5)^{1/2}$$

$A = 9.621\ ft^2$

$Q = VA$

- See spreadsheet for HW vs. Q, stop log weir flow ~~[illegible]~~ until ~ EL. 982

S&ME

Cincinnati (513) 771-8471
Cleveland (216) 901-1000
Columbus (614) 793-2226

Project/Proposal No. 011-11497-042 Calculated By AJS Date 9-24-12

Project/Proposal Name Cardinal Checked By SJC Date 9/27/12

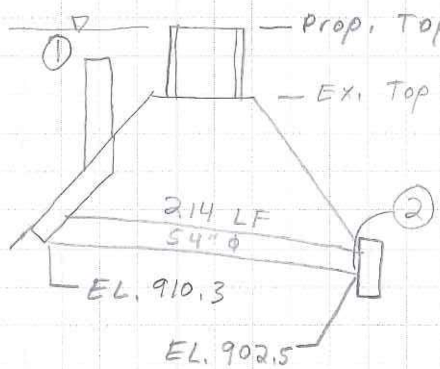
Subject Spillway Pipe Internal Pressure Sheet ______ of ______

Reference 2000 As-Buit Dwg. No. 13-30043-5 General Note 2

Check pressure in 54" P.C.C.P. Pipe is rated for 35 psi.

Weir inlet should control except for higher headwaters.

Check pressure with headwater at Top of Dam (EL. 983.0)



$z_1 = 983.0$
$z_2 = 902.5$
$80.5'$ ✓

Energy Equation:

$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + \sum h_L \quad ; \quad p_1, V_1 = 0$$

$$\frac{p_2}{\gamma} = (z_1 - z_2) - \frac{V_2^2}{2g} - \sum h_L$$

$$\frac{p_2}{62.4 \text{ lb/ft}^3} = (983.0 - 902.5) - \frac{V_2^2}{64.4} - \sum h_L$$

$$p_2 \, [\text{lb/ft}^2] = 80.5(62.4) - \frac{V_2^2}{1.03} - \sum h_L (62.4)$$

$$p_2 \, [\text{lb/in}^2] = 34.9 - \frac{V_2^2}{148} - \frac{\sum h_L}{0.4}$$

$80.5' = 34.9$ psi ✓

$\therefore p_2 < 34.9$ psi with flow

$34.9 \text{ psi} < 35 \text{ psi}$ ✓

S&ME

Cincinnati (513) 771-8471
Cleveland (216) 901-1000
Columbus (614) 793-2226

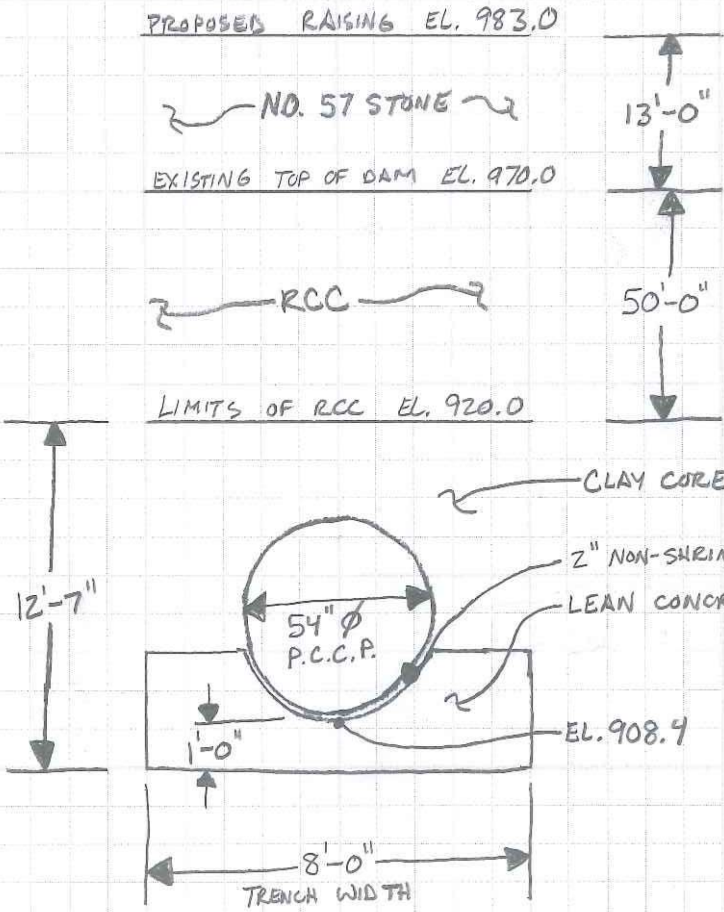
Project/Proposal No. 1176-12-004A Calculated By MRM Date 9/26/12
Project/Proposal Name CARDINAL FAD II RAISING Checked By SJL Date 9/27/12
Subject PIPE STRENGTH CALCULATIONS Sheet ____ of ____

TASK: DETERMINE SUITABILITY OF EXISTING 54"Ø P.C.C.P SPILLWAY PIPE UNDER ADDITIONAL PROPOSED LOADING CONDITIONS.

RESULTS:

COVER OVER SPILLWAY PIPE INCLUDING ADDITIONAL COVER = 74.6 FT. BASED ON DRAWING 13-30043-5, THE 54"Ø SPILLWAY PIPE WAS DESIGNED TO HANDLE 80 FT SO OUR ADDITIONAL COVER STILL FALLS WITHIN THE PIPE STRENGTH CAPACITY.

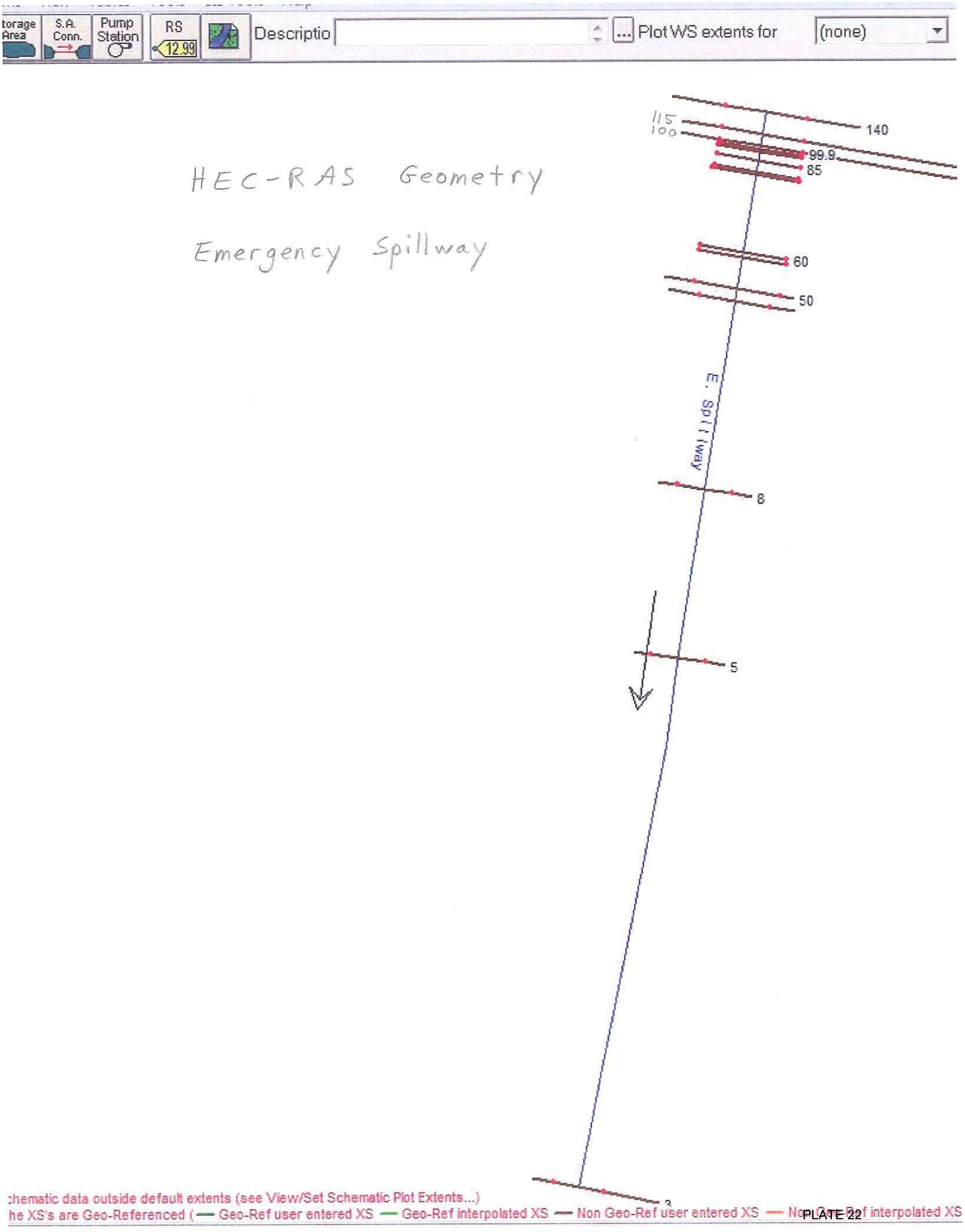
SKETCH OF EXISTING VS PROPOSED (NOT TO SCALE)

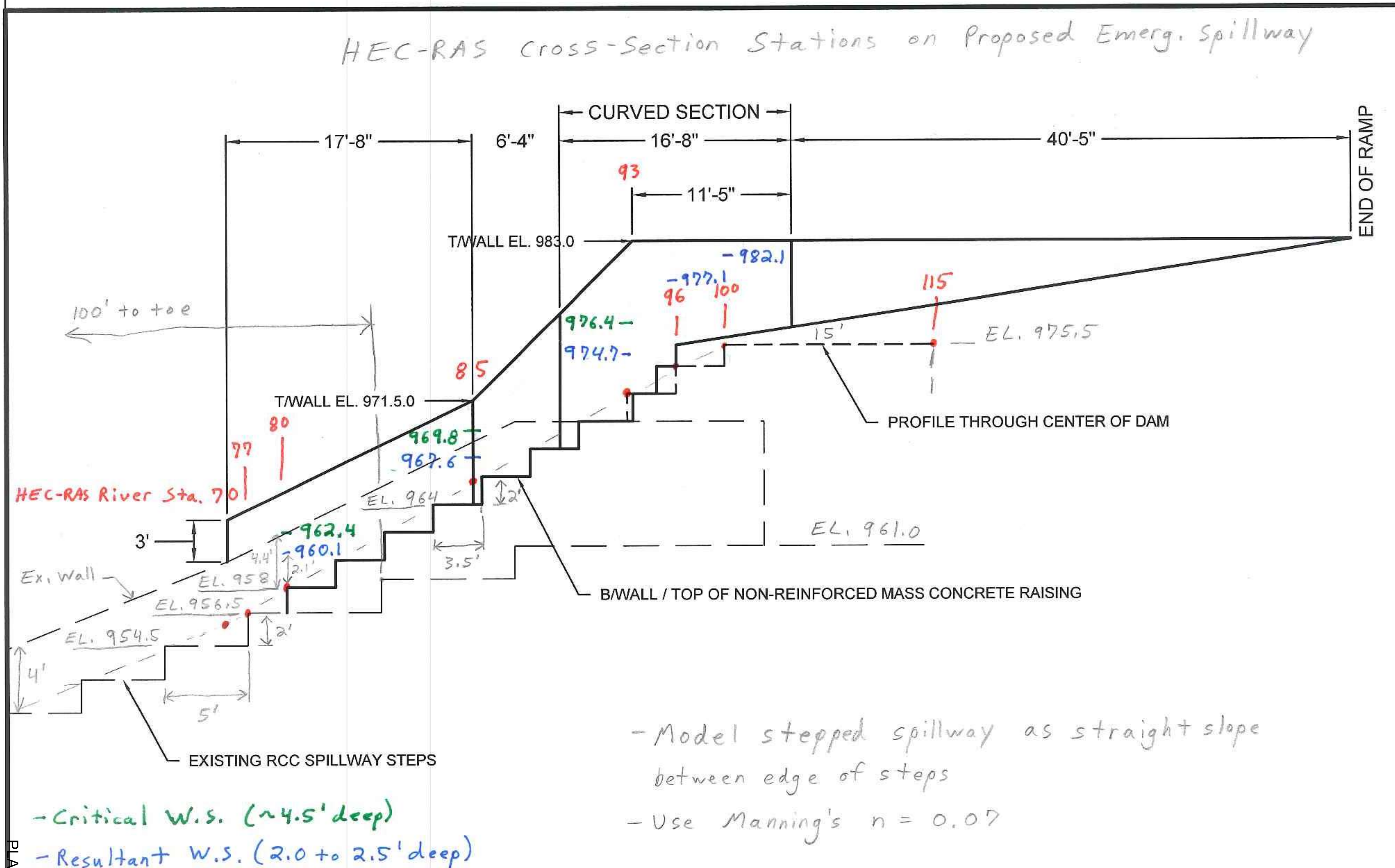


EL. 983.0 (PROP. TOD)
− EL. 908.4 (INV. PIPE)
74.6 FT COVER

HEC-RAS Geometry

Emergency Spillway

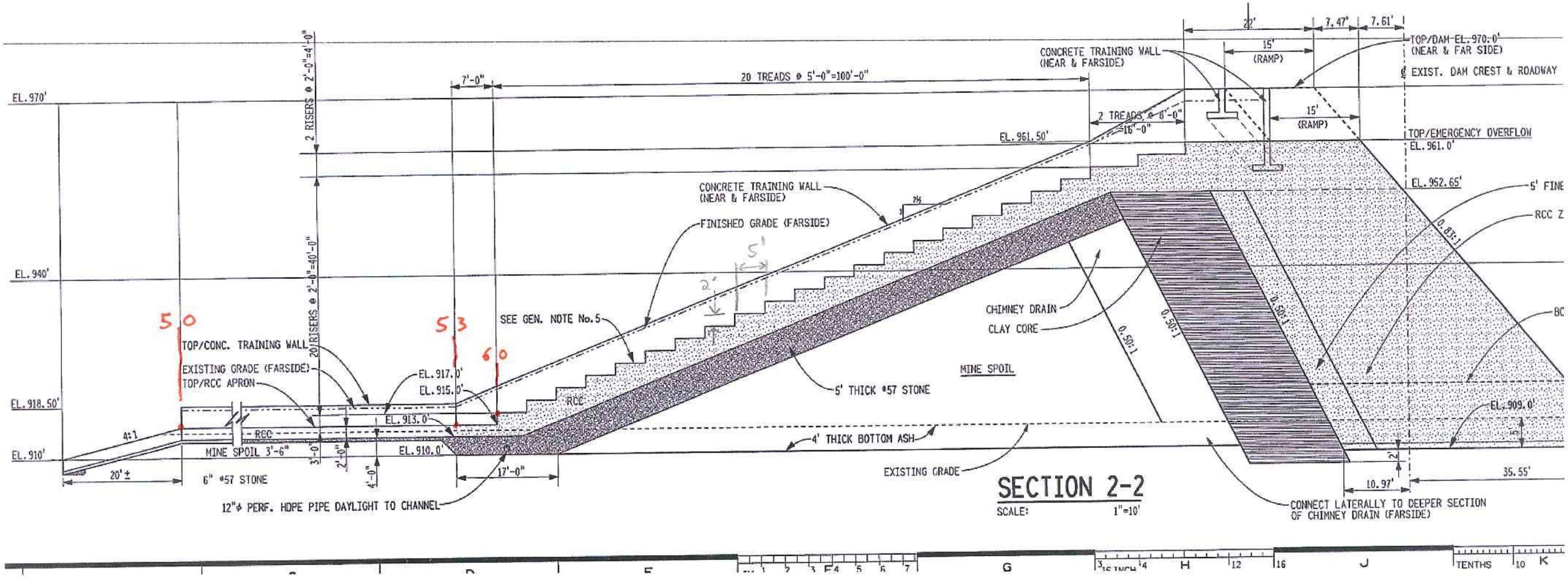




RIGHT TRAINING WALL PROFILE

From 2000 As-Built
Dwg. No. 13-30041-6

HEC-RAS Cross-Section Stations on Existing Emerg. Spillway



HEC-RAS Plan: Plan 22 River: E. Spillway Reach: 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	140	PF 1	200.00	940.00	976.27	940.28	976.27	0.000000	0.03	8703.65	240.00	0.00
1	140	PF 2	500.00	940.00	976.89	940.51	976.89	0.000000	0.07	8853.88	240.00	0.00
1	140	PF 3	1000.00	940.00	977.70	940.81	977.70	0.000000	0.13	9047.40	240.00	0.00
1	140	PF 4	1500.00	940.00	978.37	941.07	978.37	0.000000	0.19	9209.44	240.00	0.01
1	140	PF 5	2000.00	940.00	978.98	941.29	978.98	0.000000	0.25	9354.95	240.00	0.01
1	140	PF 6	3000.00	940.00	980.06	941.69	980.06	0.000001	0.37	9613.49	240.00	0.01
1	140	PF 7	4000.00	940.00	981.02	942.04	981.02	0.000001	0.48	9844.20	240.00	0.01
1	140	PF 8	5000.00	940.00	981.90	942.37	981.90	0.000002	0.59	10056.02	240.00	0.02
1	140	PF 9	5500.00	940.00	982.32	942.54	982.32	0.000002	0.64	10156.63	240.00	0.02
1	140	PF 10	6000.00	940.00	982.73	942.69	982.73	0.000002	0.69	10254.30	240.00	0.02
1	115.1	PF 1	200.00	975.50	976.16		976.26	0.008703	2.61	81.00	142.14	0.57
1	115.1	PF 2	500.00	975.50	976.74		976.88	0.005540	3.18	173.06	175.04	0.50
1	115.1	PF 3	1000.00	975.50	977.52		977.68	0.003505	3.51	327.48	219.50	0.44
1	115.1	PF 4	1500.00	975.50	978.19		978.36	0.002549	3.63	488.12	255.18	0.39
1	115.1	PF 5	2000.00	975.50	978.80		978.96	0.001970	3.65	649.07	274.43	0.35
1	115.1	PF 6	3000.00	975.50	979.87		980.04	0.001413	3.73	962.46	308.48	0.31
1	115.1	PF 7	4000.00	975.50	980.83		981.00	0.001091	3.75	1267.33	323.63	0.29
1	115.1	PF 8	5000.00	975.50	981.71		981.89	0.000908	3.78	1557.18	335.36	0.27
1	115.1	PF 9	5500.00	975.50	982.13		982.31	0.000843	3.81	1698.33	340.92	0.26
1	115.1	PF 10	6000.00	975.50	982.54		982.71	0.000790	3.83	1837.51	346.32	0.25
1	115	PF 1	200.00	975.50	976.16		976.26	0.001226	2.62	80.95	142.13	0.57
1	115	PF 2	500.00	975.50	976.74		976.88	0.000780	3.19	173.02	175.02	0.50
1	115	PF 3	1000.00	975.50	977.52		977.68	0.000493	3.51	327.44	219.49	0.44
1	115	PF 4	1500.00	975.50	978.19		978.36	0.000359	3.63	488.11	255.18	0.39
1	115	PF 5	2000.00	975.50	978.80		978.96	0.000277	3.65	649.04	274.43	0.35
1	115	PF 6	3000.00	975.50	979.87		980.04	0.000199	3.73	962.44	308.48	0.31
1	115	PF 7	4000.00	975.50	980.83		981.00	0.000153	3.75	1267.31	323.63	0.29
1	115	PF 8	5000.00	975.50	981.71		981.89	0.000128	3.78	1557.18	335.36	0.27
1	115	PF 9	5500.00	975.50	982.13		982.31	0.000119	3.81	1698.33	340.92	0.26
1	115	PF 10	6000.00	975.50	982.54		982.71	0.000111	3.83	1837.51	346.32	0.25
1	100	PF 1	200.00	975.50	976.12		976.24	0.001460	2.76	76.48	140.33	0.62
1	100	PF 2	500.00	975.50	976.72		976.86	0.000820	3.24	170.09	174.07	0.52
1	100	PF 3	1000.00	975.50	977.51		977.67	0.000502	3.53	325.32	218.89	0.44
1	100	PF 4	1500.00	975.50	978.18		978.35	0.000362	3.64	486.46	254.98	0.39
1	100	PF 5	2000.00	975.50	978.79		978.96	0.000279	3.66	647.63	274.26	0.36
1	100	PF 6	3000.00	975.50	979.87		980.04	0.000199	3.74	961.40	308.37	0.32

HEC-RAS Plan: Plan 22 River: E. Spillway Reach: 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	100	PF 7	4000.00	975.50	980.83		981.00	0.000154	3.75	1266.50	323.59	0.29
1	100	PF 8	5000.00	975.50	981.71		981.88	0.000128	3.79	1556.51	335.33	0.27
1	100	PF 9	5500.00	975.50	982.13		982.30	0.000119	3.81	1697.67	340.90	0.26
1	100	PF 10	6000.00	975.50	982.53		982.71	0.000111	3.84	1836.83	346.30	0.25
1	99.9	PF 1	200.00	975.50	975.98	975.98	976.22	0.091785	3.95	50.60	105.01	1.00
1	99.9	PF 2	500.00	975.50	976.39	976.39	976.83	0.075231	5.37	93.08	105.02	1.01
1	99.9	PF 3	1000.00	975.50	976.91	976.91	977.62	0.064567	6.77	147.71	105.04	1.01
1	99.9	PF 4	1500.00	975.50	977.34	977.34	978.28	0.058886	7.75	193.68	105.05	1.01
1	99.9	PF 5	2000.00	975.50	977.73	977.73	978.86	0.055267	8.53	234.60	105.06	1.01
1	99.9	PF 6	3000.00	975.50	978.43	978.43	979.91	0.050473	9.76	307.49	105.08	1.01
1	99.9	PF 7	4000.00	975.50	979.05	979.05	980.84	0.047379	10.74	372.45	105.09	1.01
1	99.9	PF 8	5000.00	975.50	979.62	979.62	981.69	0.044943	11.56	432.64	105.11	1.00
1	99.9	PF 9	5500.00	975.50	979.89	979.89	982.10	0.044050	11.94	460.88	105.12	1.00
1	99.9	PF 10	6000.00	975.50	980.15	980.15	982.49	0.043279	12.30	488.18	105.12	1.01
1	96	PF 1	200.00	974.00	974.32	974.48	974.88	0.376398	6.04	33.13	105.01	1.89
1	96	PF 2	500.00	974.00	974.53	974.89	975.78	0.417760	8.99	55.65	105.01	2.18
1	96	PF 3	1000.00	974.00	974.86	975.41	976.78	0.338287	11.13	89.86	105.02	2.12
1	96	PF 4	1500.00	974.00	975.16	975.84	977.53	0.280174	12.37	121.29	105.03	2.03
1	96	PF 5	2000.00	974.00	975.43	976.23	978.18	0.242904	13.30	150.45	105.03	1.96
1	96	PF 6	3000.00	974.00	975.95	976.93	979.29	0.196469	14.67	204.51	105.04	1.85
1	96	PF 7	4000.00	974.00	976.43	977.55	980.26	0.167924	15.70	254.77	105.05	1.78
1	96	PF 8	5000.00	974.00	976.88	978.12	981.13	0.148546	16.55	302.19	105.06	1.72
1	96	PF 9	5500.00	974.00	977.09	978.39	981.55	0.141529	16.95	324.66	105.07	1.70
1	96	PF 10	6000.00	974.00	977.30	978.65	981.95	0.134987	17.30	346.96	105.07	1.68
1	93	PF 1	200.00	972.00	972.28	972.48	973.00	0.556401	6.79	29.47	105.01	2.26
1	93	PF 2	500.00	972.00	972.48	972.89	973.98	0.561951	9.82	50.91	105.01	2.49
1	93	PF 3	1000.00	972.00	972.76	973.41	975.21	0.508273	12.57	79.53	105.01	2.55
1	93	PF 4	1500.00	972.00	973.00	973.84	976.16	0.450602	14.26	105.17	105.02	2.51
1	93	PF 5	2000.00	972.00	973.23	974.23	976.95	0.402379	15.47	129.30	105.02	2.46
1	93	PF 6	3000.00	972.00	973.66	974.93	978.24	0.331961	17.17	174.72	105.03	2.35
1	93	PF 7	4000.00	972.00	974.07	975.55	979.32	0.283724	18.38	217.66	105.04	2.25
1	93	PF 8	5000.00	972.00	974.46	976.12	980.27	0.249809	19.34	258.54	105.04	2.17
1	93	PF 9	5500.00	972.00	974.65	976.39	980.72	0.237044	19.78	278.10	105.05	2.14
1	93	PF 10	6000.00	972.00	974.83	976.65	981.15	0.225141	20.17	297.57	105.05	2.11
1	85	PF 1	200.00	965.40	965.68	965.88	966.41	0.574097	6.85	29.19	105.01	2.29

HEC-RAS Plan: Plan 22 River: E. Spillway Reach: 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	85	PF 2	500.00	965.40	965.88	966.29	967.40	0.574378	9.89	50.58	105.02	2.51
1	85	PF 3	1000.00	965.40	966.13	966.81	968.77	0.573735	13.04	76.70	105.02	2.69
1	85	PF 4	1500.00	965.40	966.33	967.24	969.96	0.567474	15.29	98.14	105.03	2.79
1	85	PF 5	2000.00	965.40	966.52	967.63	971.03	0.556871	17.05	117.30	105.04	2.84
1	85	PF 6	3000.00	965.40	966.85	968.33	972.88	0.525993	19.72	152.20	105.05	2.89
1	85	PF 7	4000.00	965.40	967.16	968.95	974.45	0.491903	21.68	184.55	105.06	2.88
1	85	PF 8	5000.00	965.40	967.45	969.52	975.80	0.457272	23.19	215.67	105.07	2.85
1	85	PF 9	5500.00	965.40	967.60	969.79	976.42	0.441252	23.83	230.82	105.07	2.83
1	85	PF 10	6000.00	965.40	967.74	970.05	976.99	0.425444	24.41	245.88	105.08	2.81
1	80	PF 1	200.00	958.00	958.29	958.48	958.96	0.503104	6.59	30.37	105.01	2.16
1	80	PF 2	500.00	958.00	958.50	958.89	959.91	0.507624	9.53	52.49	105.02	2.37
1	80	PF 3	1000.00	958.00	958.76	959.41	961.21	0.507442	12.57	79.57	105.02	2.54
1	80	PF 4	1500.00	958.00	958.97	959.84	962.36	0.508227	14.79	101.45	105.03	2.65
1	80	PF 5	2000.00	958.00	959.15	960.23	963.42	0.508657	16.60	120.53	105.04	2.73
1	80	PF 6	3000.00	958.00	959.46	960.93	965.38	0.509361	19.53	153.67	105.05	2.84
1	80	PF 7	4000.00	958.00	959.74	961.55	967.15	0.504588	21.85	183.14	105.06	2.92
1	80	PF 8	5000.00	958.00	960.01	962.12	968.76	0.494769	23.74	210.63	105.06	2.95
1	80	PF 9	5500.00	958.00	960.13	962.39	969.50	0.488171	24.57	223.93	105.07	2.97
1	80	PF 10	6000.00	958.00	960.26	962.65	970.22	0.481204	25.33	236.95	105.07	2.97
1	77	PF 1	200.00	956.50	956.75	956.98	957.66	0.830089	7.65	26.14	105.01	2.70
1	77	PF 2	500.00	956.50	956.95	957.39	958.68	0.715384	10.56	47.36	105.01	2.77
1	77	PF 3	1000.00	956.50	957.20	957.91	960.04	0.646310	13.51	74.00	105.02	2.84
1	77	PF 4	1500.00	956.50	957.41	958.34	961.20	0.609956	15.62	96.04	105.03	2.88
1	77	PF 5	2000.00	956.50	957.60	958.73	962.29	0.594015	17.39	115.05	105.03	2.93
1	77	PF 6	3000.00	956.50	957.91	959.43	964.26	0.571945	20.22	148.42	105.04	3.00
1	77	PF 7	4000.00	956.50	958.19	960.05	966.05	0.555768	22.49	177.91	105.05	3.04
1	77	PF 8	5000.00	956.50	958.45	960.62	967.68	0.539953	24.38	205.17	105.06	3.07
1	77	PF 9	5500.00	956.50	958.58	960.89	968.44	0.531104	25.20	218.33	105.06	3.08
1	77	PF 10	6000.00	956.50	958.70	961.15	969.16	0.522282	25.96	231.19	105.06	3.08
1	70	PF 1	200.00	956.10	956.41	956.58	957.00	0.399350	6.14	32.55	105.01	1.94
1	70	PF 2	500.00	956.10	956.60	956.99	958.00	0.497833	9.47	52.80	105.01	2.35
1	70	PF 3	1000.00	956.10	956.85	957.51	959.36	0.527568	12.72	78.65	105.02	2.59
1	70	PF 4	1500.00	956.10	957.05	957.94	960.54	0.531031	14.98	100.12	105.03	2.70
1	70	PF 5	2000.00	956.10	957.23	958.33	961.64	0.535132	16.85	118.71	105.03	2.79
1	70	PF 6	3000.00	956.10	957.54	959.03	963.63	0.533230	19.80	151.57	105.04	2.90
1	70	PF 7	4000.00	956.10	957.82	959.65	965.43	0.527691	22.14	180.70	105.05	2.97

HEC-RAS Plan: Plan 22 River: E. Spillway Reach: 1 (Continued)

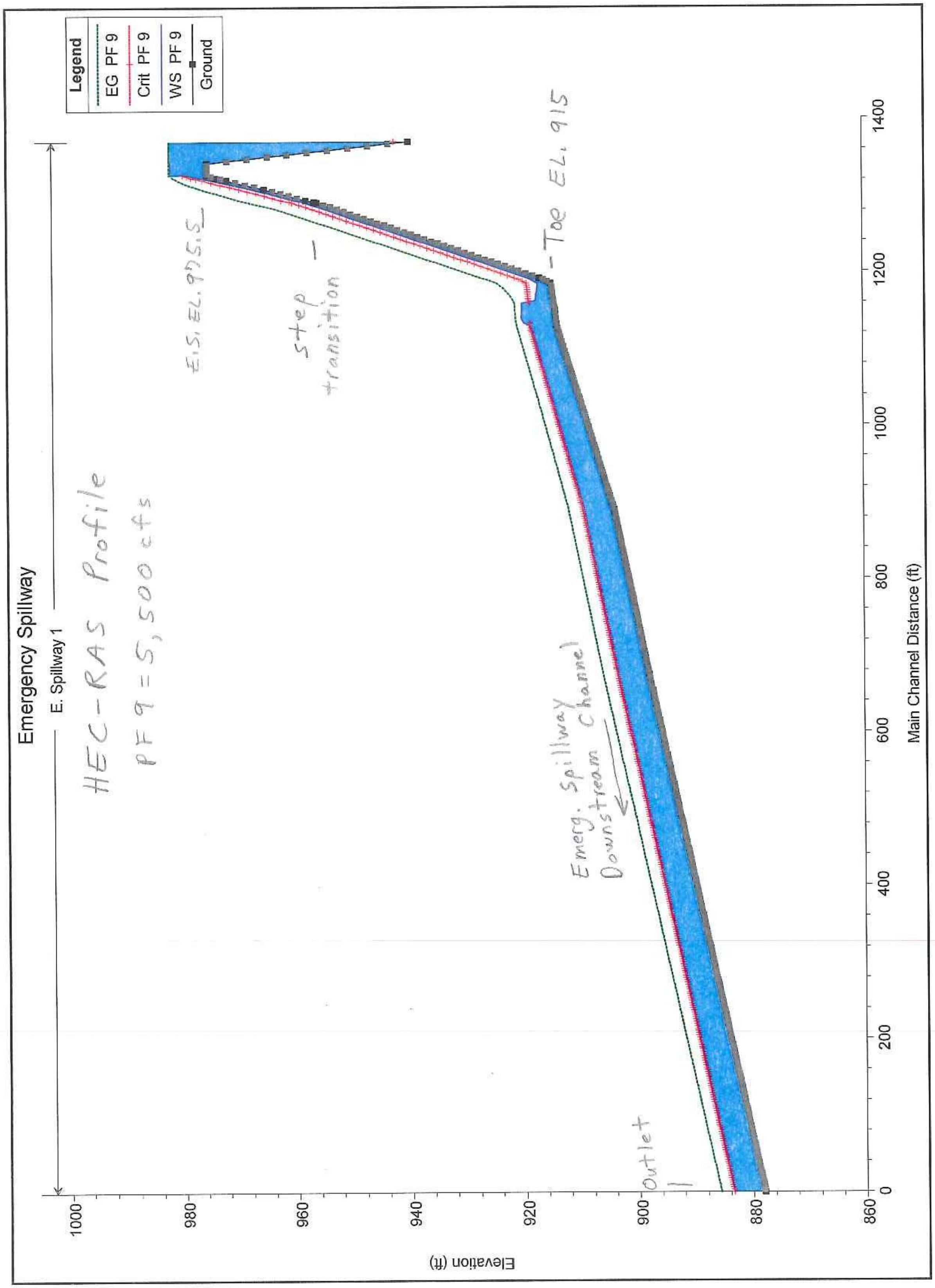
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	70	PF 8	5000.00	956.10	958.08	960.22	967.08	0.518801	24.08	207.65	105.06	3.02
1	70	PF 9	5500.00	956.10	958.20	960.49	967.84	0.511571	24.92	220.80	105.06	3.03
1	70	PF 10	6000.00	956.10	958.32	960.75	968.58	0.505503	25.71	233.47	105.06	3.04
1	69.9	PF 1	200.00	956.10	956.39	956.57	956.99	0.438962	6.20	32.24	110.01	2.02
1	69.9	PF 2	500.00	956.10	956.58	956.96	957.99	0.541413	9.53	52.45	110.02	2.43
1	69.9	PF 3	1000.00	956.10	956.81	957.47	959.35	0.571684	12.79	78.22	110.04	2.67
1	69.9	PF 4	1500.00	956.10	957.01	957.89	960.53	0.574944	15.06	99.60	110.05	2.79
1	69.9	PF 5	2000.00	956.10	957.17	958.27	961.63	0.578905	16.93	118.13	110.05	2.88
1	69.9	PF 6	3000.00	956.10	957.47	958.94	963.61	0.576374	19.89	150.87	110.07	2.99
1	69.9	PF 7	4000.00	956.10	957.73	959.54	965.42	0.570016	22.24	179.90	110.08	3.07
1	69.9	PF 8	5000.00	956.10	957.98	960.09	967.07	0.560262	24.19	206.75	110.09	3.11
1	69.9	PF 9	5500.00	956.10	958.10	960.37	967.82	0.552450	25.03	219.84	110.10	3.12
1	69.9	PF 10	6000.00	956.10	958.21	960.62	968.56	0.545879	25.82	232.47	110.11	3.13
1	60	PF 1	200.00	917.00	917.30	917.47	917.86	0.386204	5.97	33.50	110.02	1.91
1	60	PF 2	500.00	917.00	917.53	917.86	918.69	0.392246	8.65	57.78	110.03	2.10
1	60	PF 3	1000.00	917.00	917.79	918.37	919.83	0.395936	11.45	87.34	110.05	2.27
1	60	PF 4	1500.00	917.00	918.01	918.79	920.83	0.396575	13.47	111.35	110.06	2.36
1	60	PF 5	2000.00	917.00	918.20	919.16	921.75	0.396544	15.12	132.33	110.07	2.43
1	60	PF 6	3000.00	917.00	918.53	919.84	923.44	0.395788	17.77	168.89	110.09	2.53
1	60	PF 7	4000.00	917.00	918.82	920.44	925.00	0.396406	19.94	200.62	110.10	2.60
1	60	PF 8	5000.00	917.00	919.09	920.99	926.46	0.395771	21.80	229.49	110.12	2.66
1	60	PF 9	5500.00	917.00	919.21	921.27	927.16	0.395239	22.63	243.10	110.13	2.68
1	60	PF 10	6000.00	917.00	919.33	921.52	927.86	0.395732	23.44	256.04	110.13	2.71
1	53	PF 1	200.00	915.00	915.34	915.47	915.79	0.280219	5.42	36.88	110.02	1.65
1	53	PF 2	500.00	915.00	915.58	915.86	916.54	0.286142	7.87	63.51	110.03	1.83
1	53	PF 3	1000.00	915.00	915.88	916.37	917.55	0.285147	10.38	96.38	110.04	1.95
1	53	PF 4	1500.00	915.00	916.11	916.79	918.45	0.289592	12.26	122.36	110.06	2.05
1	53	PF 5	2000.00	915.00	916.31	917.17	919.29	0.295808	13.84	144.49	110.07	2.13
1	53	PF 6	3000.00	915.00	916.66	917.84	920.86	0.306301	16.45	182.38	110.08	2.25
1	53	PF 7	4000.00	915.00	916.95	918.44	922.34	0.315517	18.62	214.84	110.10	2.35
1	53	PF 8	5000.00	915.00	917.22	918.99	923.73	0.321483	20.48	244.25	110.11	2.42
1	53	PF 9	5500.00	915.00	917.34	919.27	924.41	0.324559	21.33	257.90	110.12	2.46
1	53	PF 10	6000.00	915.00	917.46	919.52	925.08	0.327665	22.15	270.95	110.12	2.49
1	52.9	PF 1	200.00	915.00	915.35	915.47	915.77	0.101776	5.22	38.34	110.02	1.56
1	52.9	PF 2	500.00	915.00	915.58	915.86	916.53	0.114142	7.79	64.19	110.03	1.80

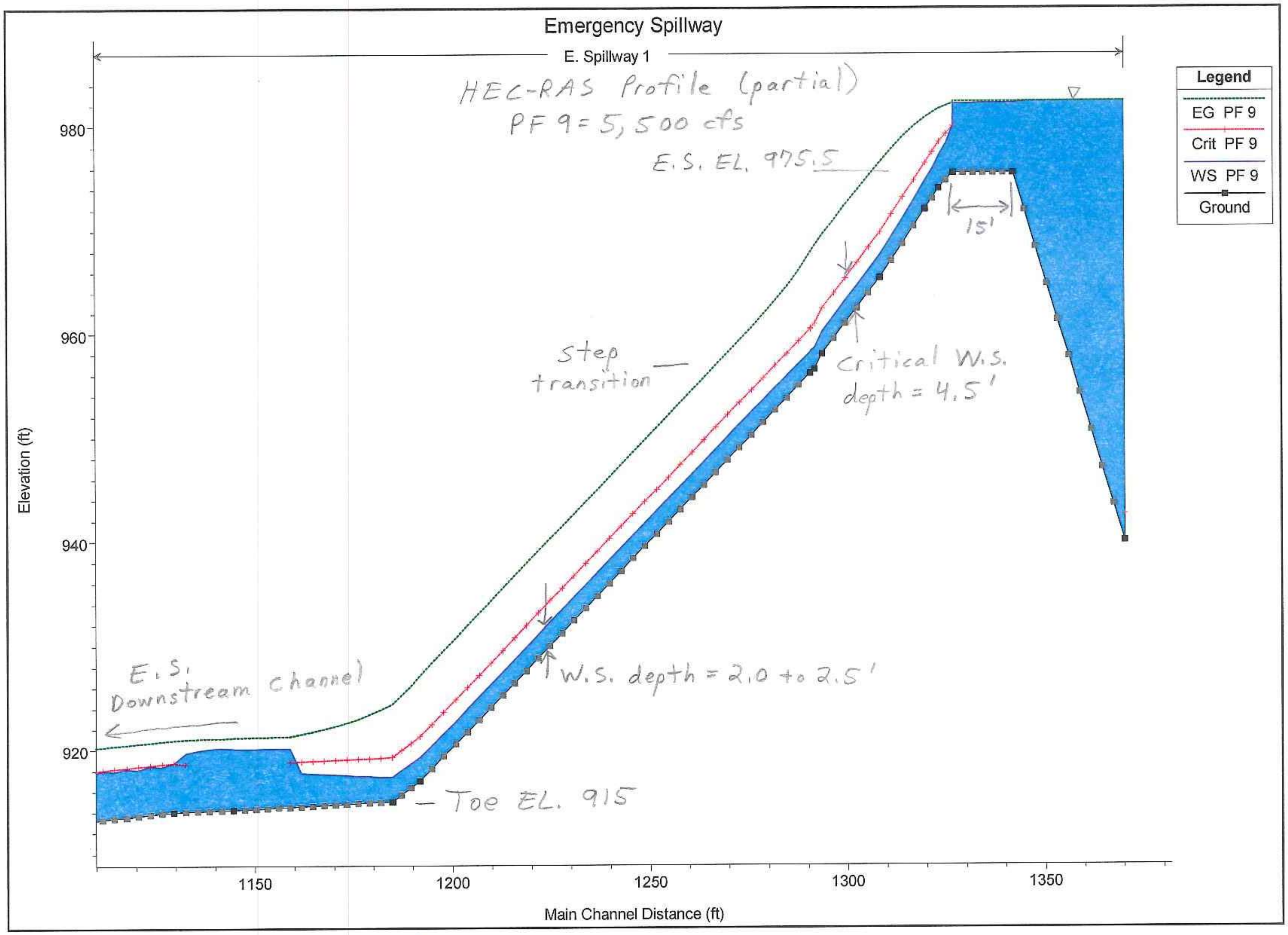
HEC-RAS Plan: Plan 22 River: E. Spillway Reach: 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	52.9	PF 3	1000.00	915.00	915.88	916.37	917.53	0.115522	10.32	96.95	110.04	1.94
1	52.9	PF 4	1500.00	915.00	916.12	916.79	918.43	0.117970	12.21	122.89	110.06	2.04
1	52.9	PF 5	2000.00	915.00	916.32	917.17	919.27	0.120881	13.80	144.98	110.07	2.12
1	52.9	PF 6	3000.00	915.00	916.66	917.84	920.84	0.125556	16.41	182.83	110.08	2.24
1	52.9	PF 7	4000.00	915.00	916.96	918.44	922.32	0.129536	18.59	215.27	110.10	2.34
1	52.9	PF 8	5000.00	915.00	917.22	918.99	923.71	0.132129	20.44	244.66	110.11	2.42
1	52.9	PF 9	5500.00	915.00	917.35	919.27	924.39	0.133445	21.30	258.30	110.12	2.45
1	52.9	PF 10	6000.00	915.00	917.47	919.53	925.06	0.134768	22.12	271.35	110.12	2.48
1	50	PF 1	200.00	914.20	914.91		915.01	0.009510	2.56	78.07	110.03	0.54
1	50	PF 2	500.00	914.20	915.46		915.66	0.008811	3.61	138.44	110.05	0.57
1	50	PF 3	1000.00	914.20	916.17		916.50	0.007907	4.61	216.78	110.08	0.58
1	50	PF 4	1500.00	914.20	916.77		917.20	0.007375	5.31	282.36	110.11	0.58
1	50	PF 5	2000.00	914.20	917.28		917.82	0.007096	5.89	339.49	110.13	0.59
1	50	PF 6	3000.00	914.20	918.19		918.92	0.006743	6.83	439.76	110.17	0.60
1	50	PF 7	4000.00	914.20	918.99		919.89	0.006531	7.59	527.71	110.20	0.61
1	50	PF 8	5000.00	914.20	919.72		920.77	0.006356	8.22	609.31	113.67	0.62
1	50	PF 9	5500.00	914.20	920.06		921.18	0.006299	8.52	647.93	115.29	0.62
1	50	PF 10	6000.00	914.20	920.39		921.58	0.006233	8.79	685.98	116.86	0.62
1	49.9	PF 1	200.00	914.20	914.91		915.01	0.009218	2.52	78.78	112.38	0.53
1	49.9	PF 2	500.00	914.20	915.46		915.66	0.008274	3.50	141.01	114.22	0.55
1	49.9	PF 3	1000.00	914.20	916.17		916.50	0.007140	4.39	223.38	116.61	0.55
1	49.9	PF 4	1500.00	914.20	916.77		917.20	0.006450	4.98	293.73	118.62	0.55
1	49.9	PF 5	2000.00	914.20	917.29		917.82	0.006035	5.44	356.12	120.37	0.55
1	49.9	PF 6	3000.00	914.20	918.21		918.91	0.005460	6.16	468.14	123.45	0.54
1	49.9	PF 7	4000.00	914.20	919.02		919.87	0.005051	6.70	569.64	126.18	0.54
1	49.9	PF 8	5000.00	914.20	919.77		920.75	0.004734	7.14	664.25	128.67	0.53
1	49.9	PF 9	5500.00	914.20	920.11		921.16	0.004621	7.34	708.55	129.82	0.53
1	49.9	PF 10	6000.00	914.20	920.44		921.56	0.004516	7.52	751.83	130.93	0.53
1	30	PF 1	200.00	914.00	914.53	914.53	914.80	0.036552	4.15	48.50	92.33	1.00
1	30	PF 2	500.00	914.00	914.98	914.98	915.46	0.029619	5.60	90.14	94.28	1.00
1	30	PF 3	1000.00	914.00	915.55	915.55	916.30	0.025256	7.02	144.55	96.77	0.99
1	30	PF 4	1500.00	914.00	916.02	916.02	917.00	0.023257	8.04	190.31	98.82	1.00
1	30	PF 5	2000.00	914.00	916.44	916.44	917.62	0.021709	8.81	232.32	100.66	0.99
1	30	PF 6	3000.00	914.00	917.18	917.18	918.70	0.019651	10.02	308.60	103.92	0.99
1	30	PF 7	4000.00	914.00	917.83	917.83	919.64	0.018488	10.99	376.97	106.76	0.99
1	30	PF 8	5000.00	914.00	918.43	918.43	920.50	0.017510	11.79	441.74	109.39	0.99

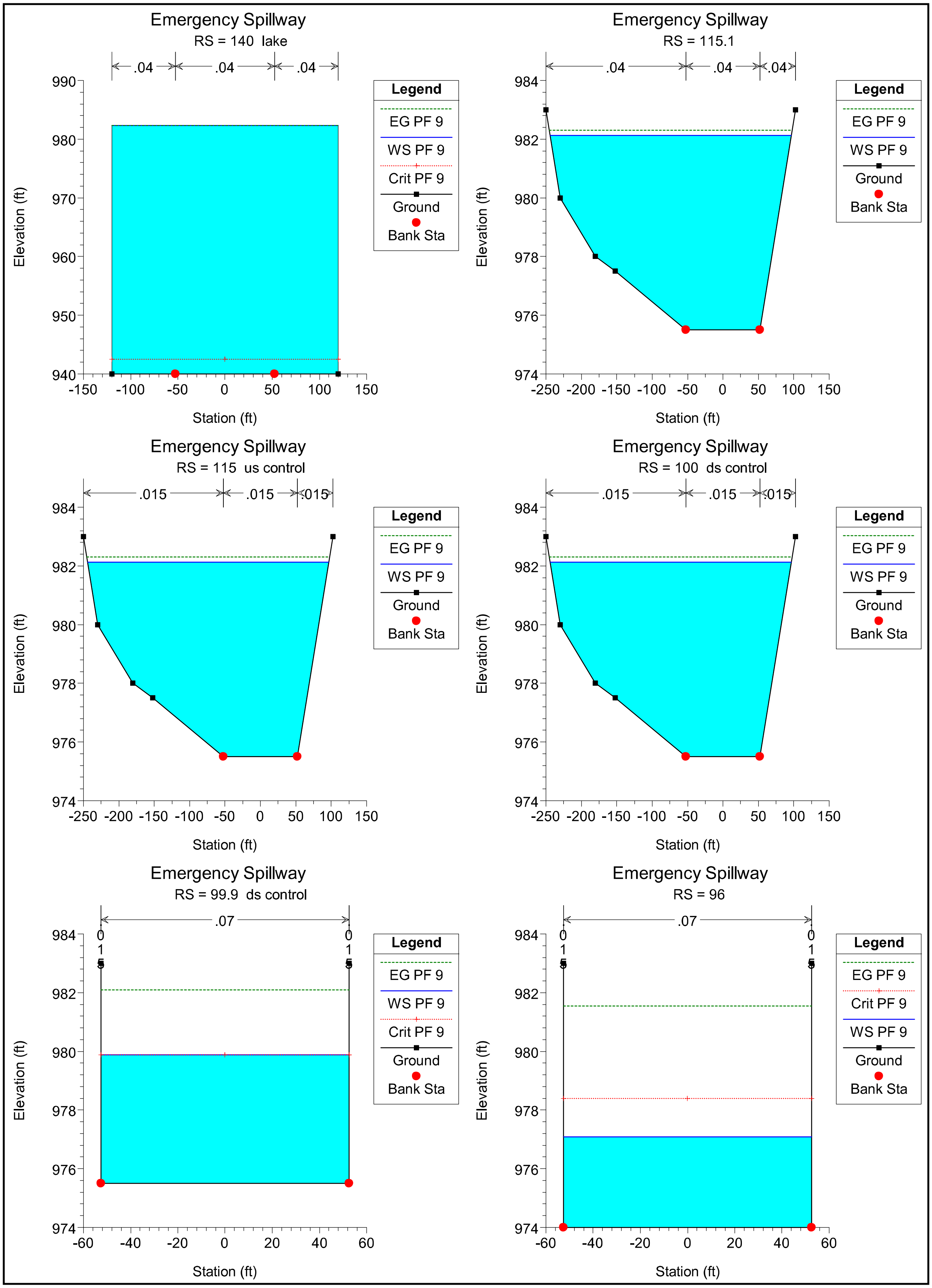
HEC-RAS Plan: Plan 22 River: E. Spillway Reach: 1 (Continued)

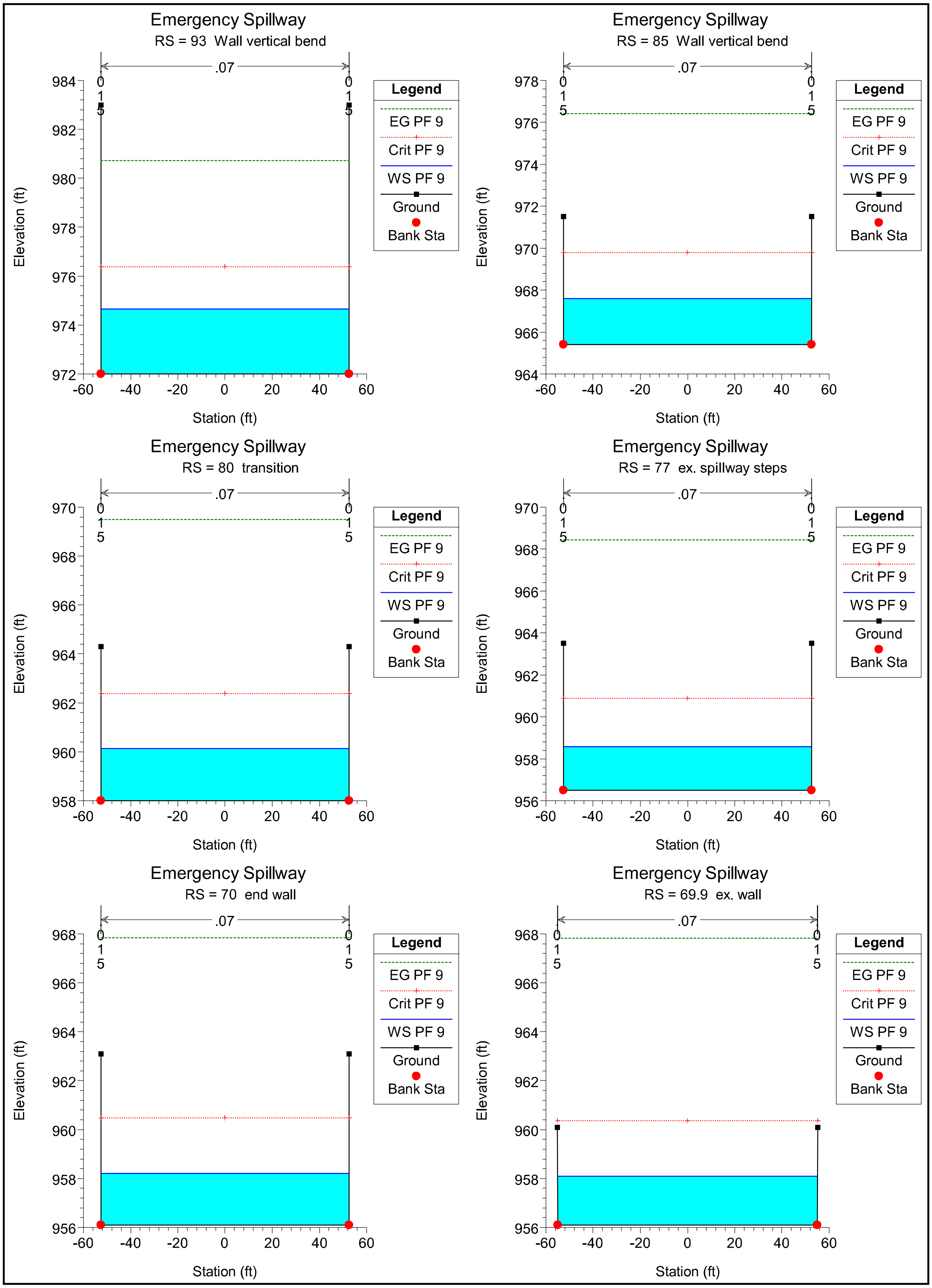
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	30	PF 9	5500.00	914.00	918.73	918.73	920.91	0.016968	12.11	474.09	110.67	0.98
1	30	PF 10	6000.00	914.00	919.00	919.00	921.30	0.016592	12.44	504.77	111.88	0.98
1	8	PF 1	200.00	904.00	904.67	904.63	904.94	0.027464	4.20	48.00	72.75	0.90
1	8	PF 2	500.00	904.00	905.04	905.15	905.74	0.040065	6.77	74.76	74.23	1.17
1	8	PF 3	1000.00	904.00	905.57	905.82	906.77	0.039315	8.85	115.07	76.42	1.24
1	8	PF 4	1500.00	904.00	906.00	906.37	907.63	0.039161	10.37	148.05	78.16	1.29
1	8	PF 5	2000.00	904.00	906.39	906.86	908.38	0.037780	11.48	179.08	79.77	1.31
1	8	PF 6	3000.00	904.00	907.04	907.72	909.74	0.037500	13.41	231.48	82.40	1.36
1	8	PF 7	4000.00	904.00	908.40	908.49	910.56	0.018523	12.07	347.73	87.98	1.01
1	8	PF 8	5000.00	904.00	909.09	909.19	911.54	0.017473	12.91	409.07	90.78	1.01
1	8	PF 9	5500.00	904.00	909.39	909.50	912.00	0.017277	13.34	436.71	92.01	1.01
1	8	PF 10	6000.00	904.00	909.71	909.82	912.44	0.016859	13.69	465.80	93.30	1.01
1	5	PF 1	200.00	898.00	898.66	898.63	898.94	0.029687	4.30	46.83	72.47	0.93
1	5	PF 2	500.00	898.00	899.06	899.15	899.73	0.037008	6.61	76.49	73.98	1.13
1	5	PF 3	1000.00	898.00	899.67	899.82	900.73	0.032456	8.36	121.81	76.25	1.14
1	5	PF 4	1500.00	898.00	900.34	900.38	901.52	0.022966	8.83	174.27	78.78	1.02
1	5	PF 5	2000.00	898.00	900.84	900.87	902.24	0.021127	9.63	214.07	80.66	1.01
1	5	PF 6	3000.00	898.00	901.26	901.73	903.61	0.029568	12.50	248.50	82.24	1.22
1	5	PF 7	4000.00	898.00	902.35	902.50	904.60	0.019600	12.31	339.75	86.30	1.04
1	5	PF 8	5000.00	898.00	903.03	903.21	905.59	0.018457	13.17	399.59	88.86	1.03
1	5	PF 9	5500.00	898.00	903.33	903.52	906.06	0.018223	13.61	426.65	90.00	1.04
1	5	PF 10	6000.00	898.00	903.65	903.84	906.51	0.017721	13.95	455.43	91.19	1.03
1	3	PF 1	200.00	878.00	878.68	878.66	878.98	0.030014	4.41	46.07	70.91	0.94
1	3	PF 2	500.00	878.00	879.12	879.19	879.77	0.034177	6.58	78.12	74.75	1.10
1	3	PF 3	1000.00	878.00	879.73	879.87	880.76	0.030618	8.32	125.22	80.06	1.12
1	3	PF 4	1500.00	878.00	880.34	880.42	881.53	0.023880	8.99	175.92	85.40	1.04
1	3	PF 5	2000.00	878.00	880.77	880.91	882.21	0.023299	9.95	213.82	89.19	1.05
1	3	PF 6	3000.00	878.00	881.56	881.75	883.38	0.021500	11.29	286.81	96.06	1.05
1	3	PF 7	4000.00	878.00	882.38	882.48	884.37	0.018037	11.88	368.74	103.24	1.00
1	3	PF 8	5000.00	878.00	883.14	883.15	885.25	0.015782	12.35	448.84	109.79	0.96
1	3	PF 9	5500.00	878.00	883.17	883.44	885.68	0.018586	13.47	453.01	110.12	1.04
1	3	PF 10	6000.00	878.00	883.60	883.73	886.05	0.016496	13.38	500.82	113.85	1.00

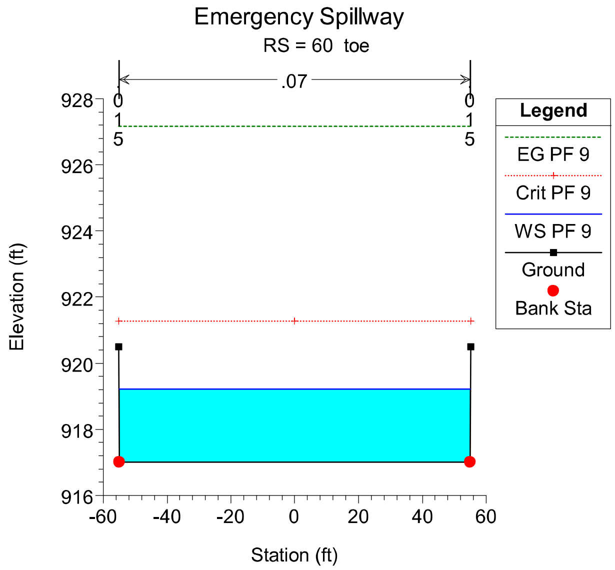

Emergency Spillway
E. Spillway 1
HEC-RAS Profile
PF9 = 5,500 cfs
Legend
EG PF 9
Crit PF 9
WS PF 9
Ground
E.S. EL. 975.5
step transition
Toe EL. 915
Emerg. Spillway Downstream Channel
Outlet
Elevation (ft)
Main Channel Distance (ft)
1000
980
960
940
920
900
880
860
0
200
400
600
800
1000
1200
1400

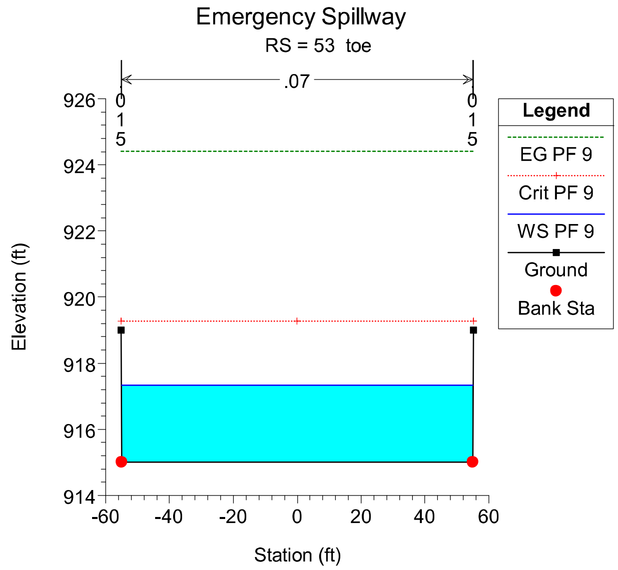


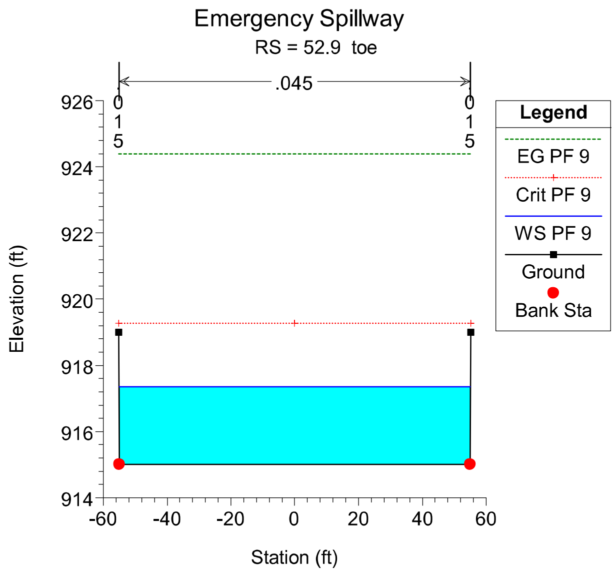
Emergency Spillway
E. Spillway 1
HEC-RAS Profile (partial)
PF 9 = 5,500 cfs
E.S. EL. 975.5
Legend
EG PF 9
Crit PF 9
WS PF 9
Ground
15'
Step transition
Critical W.S. depth = 4.5'
E.S. Downstream channel
W.S. depth = 2.0 to 2.5'
Toe EL. 915
Elevation (ft)
980
960
940
920
1150
1200
1250
1300
1350
Main Channel Distance (ft)

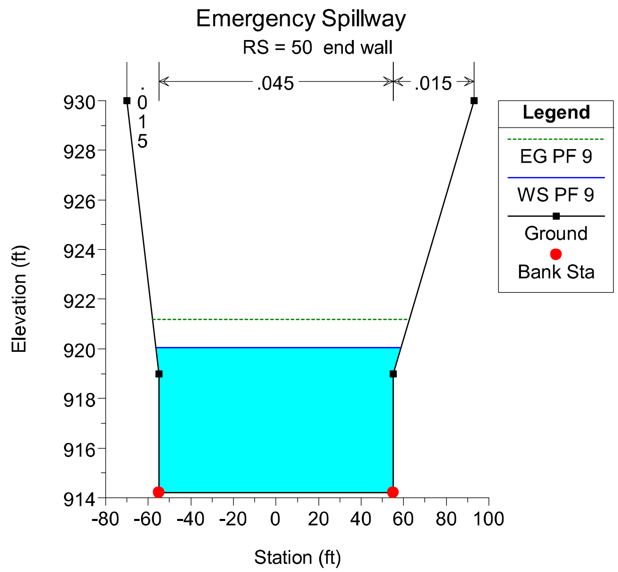

Emergency Spillway
RS = 140 lake
.04
.04
.04
Elevation (ft)
Station (ft)
990
980
970
960
950
940
-150
-100
-50
0
50
100
150
Legend
EG PF 9
WS PF 9
Crit PF 9
Ground
Bank Sta
Emergency Spillway
RS = 115.1
.04
.04
.04
Elevation (ft)
Station (ft)
984
982
980
978
976
974
-250
-200
-150
-100
-50
0
50
100
150
Legend
EG PF 9
WS PF 9
Ground
Bank Sta
Emergency Spillway
RS = 115 us control
.015
.015
.015
Elevation (ft)
Station (ft)
Legend
EG PF 9
WS PF 9
Ground
Bank Sta
Emergency Spillway
RS = 100 ds control
.015
.015
.015
Elevation (ft)
Station (ft)
Legend
EG PF 9
WS PF 9
Ground
Bank Sta
Emergency Spillway
RS = 99.9 ds control
.07
Elevation (ft)
Station (ft)
-60
-40
-20
0
20
40
60
Legend
EG PF 9
WS PF 9
Crit PF 9
Ground
Bank Sta
Emergency Spillway
RS = 96
.07
Elevation (ft)
Station (ft)
Legend
EG PF 9
Crit PF 9
WS PF 9
Ground
Bank Sta

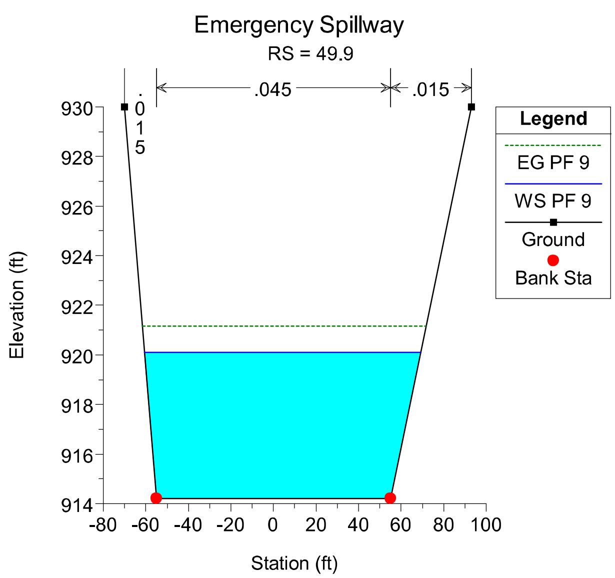

Emergency Spillway
RS = 93 Wall vertical bend
Emergency Spillway
RS = 85 Wall vertical bend
Emergency Spillway
RS = 80 transition
Emergency Spillway
RS = 77 ex. spillway steps
Emergency Spillway
RS = 70 end wall
Emergency Spillway
RS = 69.9 ex. wall
.07
Legend
EG PF 9
Crit PF 9
WS PF 9
Ground
Bank Sta
Elevation (ft)
Station (ft)

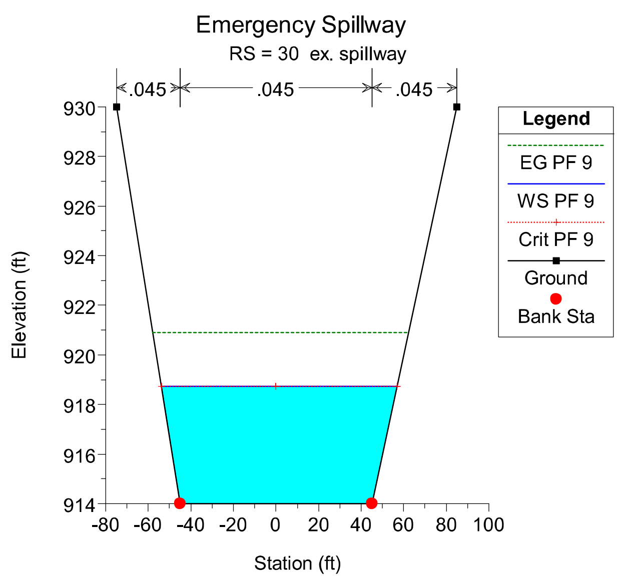

Emergency Spillway
RS = 60 toe
.07
Legend
EG PF 9
Crit PF 9
WS PF 9
Ground
Bank Sta
Elevation (ft)
Station (ft)

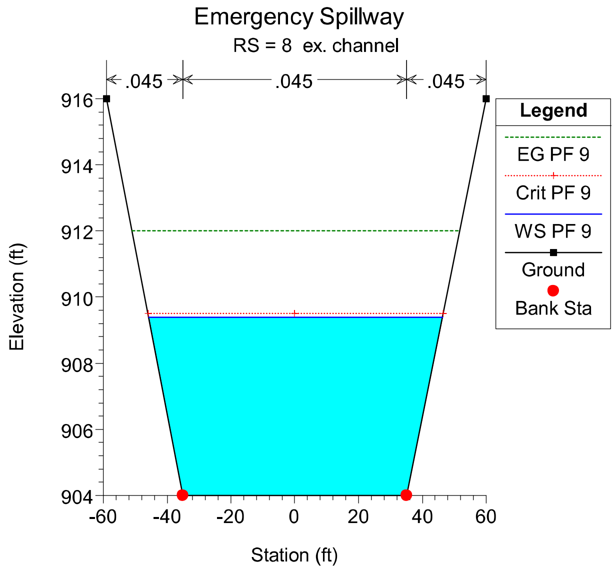

Emergency Spillway
RS = 53 toe
.07
Legend
EG PF 9
Crit PF 9
WS PF 9
Ground
Bank Sta
Elevation (ft)
Station (ft)

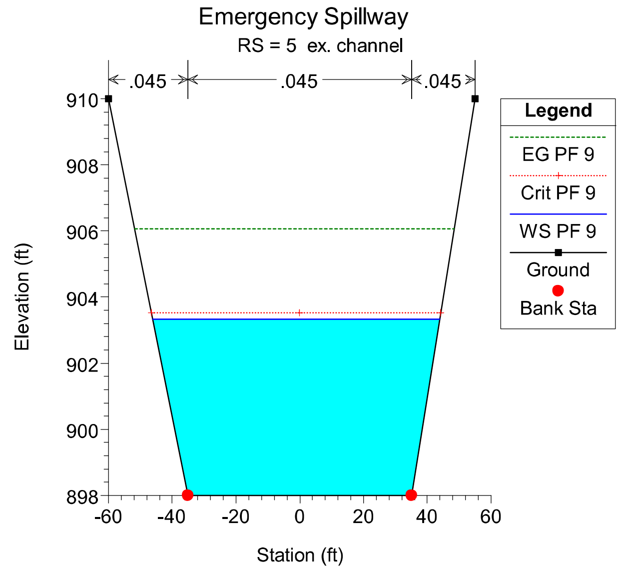

Emergency Spillway
RS = 52.9 toe
.045
Legend
EG PF 9
Crit PF 9
WS PF 9
Ground
Bank Sta
Elevation (ft)
Station (ft)


Emergency Spillway
RS = 50 end wall
.045
.015
Legend
EG PF 9
WS PF 9
Ground
Bank Sta
Elevation (ft)
Station (ft)


Emergency Spillway
RS = 49.9
.045
.015
Legend
EG PF 9
WS PF 9
Ground
Bank Sta
Elevation (ft)
Station (ft)


Emergency Spillway
RS = 30 ex. spillway
.045
.045
.045
Legend
EG PF 9
WS PF 9
Crit PF 9
Ground
Bank Sta
Elevation (ft)
Station (ft)


Emergency Spillway
RS = 8 ex. channel
.045
.045
.045
Legend
EG PF 9
Crit PF 9
WS PF 9
Ground
Bank Sta
Elevation (ft)
916
914
912
910
908
906
904
-60
-40
-20
0
20
40
60
Station (ft)


Emergency Spillway
RS = 5 ex. channel
.045
.045
.045
Legend
EG PF 9
Crit PF 9
WS PF 9
Ground
Bank Sta
Elevation (ft)
910
908
906
904
902
900
898
-60
-40
-20
0
20
40
60
Station (ft)

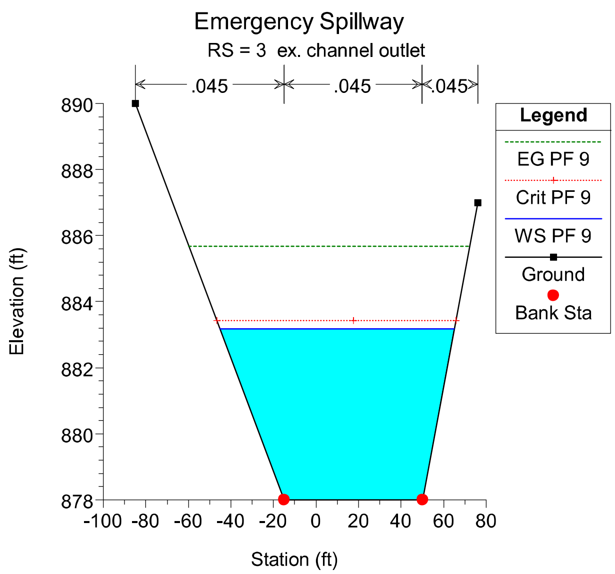

Emergency Spillway
RS = 3 ex. channel outlet
.045
.045
.045
Legend
EG PF 9
Crit PF 9
WS PF 9
Ground
Bank Sta
Elevation (ft)
890
888
886
884
882
880
878
-100
-80
-60
-40
-20
0
20
40
60
80
Station (ft)

Table 3-1 (Continued) Manning's 'n' Values

Type of Channel and Description	Minimum	Normal	Maximum
C. *Excavated or Dredged Channels*			
1. **Earth, straight and uniform**			
a. Clean, recently completed	0.016	0.018	0.020
b. Clean, after weathering	0.018	0.022	0.025
c. Gravel, uniform section, clean	0.022	0.025	0.030
d. With short grass, few weeds	0.022	0.027	0.033
2. **Earth, winding and sluggish**			
a. No vegetation	0.023	0.025	0.030
b. Grass, some weeds	0.025	0.030	0.033
c. Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
d. Earth bottom and rubble side	0.028	0.030	0.035
e. Stony bottom and weedy banks	0.025	0.035	0.040
f. Cobble bottom and clean sides	0.030	0.040	0.050
3. **Dragline-excavated or dredged**			
a. No vegetation	0.025	0.028	0.033
b. Light brush on banks	0.035	0.050	0.060
4. **Rock cuts**			
a. Smooth and uniform	0.025	0.035	0.040
b. Jagged and irregular	0.035	0.040	0.050
5. **Channels not maintained, weeds and brush**			
a. Clean bottom, brush on sides	0.040	0.050	0.080
b. Same as above, highest stage of flow	0.045	0.070	0.110
c. Dense weeds, high as flow depth	0.050	0.080	0.120
d. Dense brush, high stage	0.080	0.100	0.140

Other sources that include pictures of selected streams as a guide to n value determination are available (Fasken, 1963; Barnes, 1967; and Hicks and Mason, 1991). In general, these references provide color photos with tables of calibrated n values for a range of flows.

Although there are many factors that affect the selection of the n value for the channel, some of the most important factors are the type and size of materials that compose the bed and banks of a channel, and the shape of the channel. Cowan (1956) developed a procedure for estimating the effects of these factors to determine the value of Manning's n of a channel. In Cowan's procedure, the value of n is computed by the following equation:

Table 3-1 (Continued) Manning's 'n' Values

Type of Channel and Description	Minimum	Normal	Maximum
B. *Lined or Built-Up Channels*			
1. **Concrete**			
a. Trowel finish	0.011	0.013	0.015
b. Float Finish	0.013	0.015	0.016
c. Finished, with gravel bottom	0.015	0.017	0.020
d. Unfinished	0.014	0.017	0.020
e. Gunite, good section	0.016	0.019	0.023
f. Gunite, wavy section	0.018	0.022	0.025
g. On good excavated rock	0.017	0.020	
h. On irregular excavated rock	0.022	0.027	
2. **Concrete bottom float finished with sides of:**			
a. Dressed stone in mortar	0.015	0.017	0.020
b. Random stone in mortar	0.017	0.020	0.024
c. Cement rubble masonry, plastered	0.016	0.020	0.024
d. Cement rubble masonry	0.020	0.025	0.030
e. Dry rubble on riprap	0.020	0.030	0.035
3. **Gravel bottom with sides of:**			
a. Formed concrete	0.017	0.020	0.025
b. Random stone in mortar	0.020	0.023	0.026
c. Dry rubble or riprap	0.023	0.033	0.036
4. **Brick**			
a. Glazed	0.011	0.013	0.015
b. In cement mortar	0.012	0.015	0.018
5. **Metal**			
a. Smooth steel surfaces	0.011	0.012	0.014
b. Corrugated metal	0.021	0.025	0.030
6. **Asphalt**			
a. Smooth	0.013	0.013	
b. Rough	0.016	0.016	
7. **Vegetal lining**	0.030		0.500

Determine Manning's "n" for stepped spillway model in HEC-RAS

References: Boes, R.M., and Hager, W.H. (2003). "Hydraulic Design of Stepped Spillways." J. Hydraul. Eng. 129(9).

Ghare, A.D., Porey P.D., and Ingle, R.N. (2005). "Discussion of "Hydraulic Design of stepped Spillways" by Boes + Hager". J. Hydraul. Eng. 131. p. 524.

Fig. 1 of Discussion plots Manning's n vs. $\frac{Y_c}{H}$ for different H^*

$Y_c = \frac{h_c}{h_u}$ normalized critical depth

h_c = critical depth

h_u = uniform flow depth

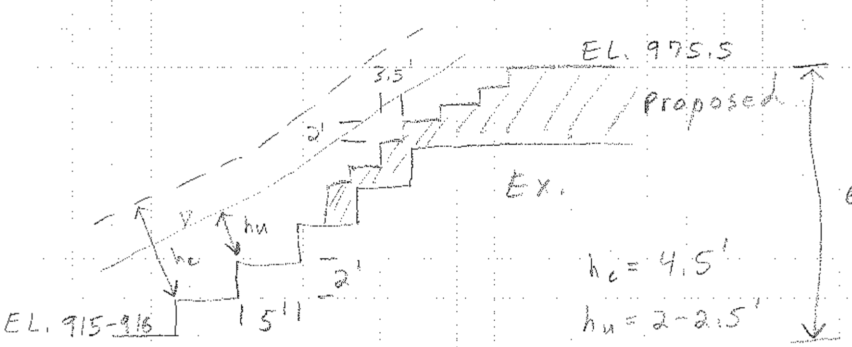
H = spillway height = 60'

$H^* = \frac{\text{spillway height}}{\text{step height}} = \frac{60'}{2'} = 30$

from HEC-RAS, $\frac{h_c}{h_u} = \frac{4.5'}{2'} = 2.25 = Y_c$ (for n = 0.07)

$\frac{Y_c}{H} = \frac{2.25}{60} = 0.0375$

From Fig. 1, n = 0.07 for $\frac{Y_c}{H} = 0.0375$, $H^* = 30$



flow and main stream skimming flows: An experimental study." *Can. J. Civ. Eng.* 31(1), 33-44.
Henderson, F. M. (1966). *Open channel flow*, MacMillan, New York.
Laali, A. R., and Michel, J. M. (1984). "Air entrainment in ventilated cavities: Case of the fully developed 'half cavity'." *J. Fluids Eng., Trans ASME*, Sept., 106, 327–335.
Matos, J. (2000). "Hydraulic design of stepped spillways over RCC dams." *Intl Workshop on Hydraulics of Stepped Spillways*, Zürich, Switzerland, H. E. Minor and W. H. Hager, eds., Balkema, Rotterdam, The Netherlands, 187–194.
Michel, J. M. (1984). "Some features of water flows with ventilated cavities." *J. Fluids Eng., Trans ASME*, Sept., 106, 319–326.
Ohtsu, I, Yasuda, Y., and Takahashi, M. (2000). "Characteristics of skimming flow over stepped spillways." *J. Hydraul. Eng.*, 126(11), 869–871.
Shvajnshtejn, A. M. (1999). "Stepped spillways and energy dissipation." *Gidrotekh. Stroit.*, 5, 15–21 (in Russian).
Silberman, E., and Song, C. S. (1961). "Instability of ventilated cavities." *J. Ship Res.*, 5(1), 13–33.
Toombes, L., and Chanson, H. (2000). "Air-water flow and gas transfer at aeration cascades: A comparative study of smooth and stepped chutes." *Int. Workshop on Hydraulics of Stepped Spillways*, Zürich, Switzerland, Balkema, Rotterdam, The Netherlands, 77–84.
Verron, J., and Michel, J. M. (1984). "Base-vented hydrofoils of finite span under a free surface: An experimental investigation." *J. Ship Res.*, 28(2), 90–106.
Yasuda, Y., and Chanson, H. (2003). "Micro- and macroscopic study of two-phase flow on a stepped chute." *Proc., 30th IAHR Biennial Congress*, Thessaloniki, Greece, J. Ganoulis and P. Prinos, eds., vol. D, 695–702.
Yasuda, Y., and Ohtsu, I. (1999). "Flow resistance of skimming flow in stepped channels." *Proc., 28th IAHR Congress*, Graz, Austria, session B14, (CD-ROM).

Discussion of "Hydraulic Design of Stepped Spillways" by Robert M. Boes and Willi H. Hager

September 2003, Vol. 129, No. 9, pp. 671–679.
DOI: 10.1061/(ASCE)0733-9429(2003)129:9(671)

A. D. Ghare[1]; P. D. Porey[2]; and R. N. Ingle[3]
[1]Sr. Lecturer, Civil Engineering Dept., D. C. V. Raman Institute of Technology, Nagpur, India.
[2]Professor, Civil Engineering Dept., Visvesvaraya National Institute of Technology, Nagpur, India.
[3]Emeritus Fellow, Civil Engineering Dept., Visvesvaraya National Institute of Technology, Nagpur, India.

The authors are to be complimented for presenting extensive experimental data on characteristics of aerated skimming flow over stepped spillways along with hydraulic design aspects of stepped spillways. The authors have focused their attention on various aspects, including onset of skimming flow, aeration characteristics, residual energy, and training wall design.

Considering the applicability of the design guidelines, the discussers would like to know the height of stepped spillway in the experimental setup for all 3 cases. Further, the authors may clarify regarding the limiting height of prototype stepped spillways up to which the design guidelines presented in this paper could be applied.

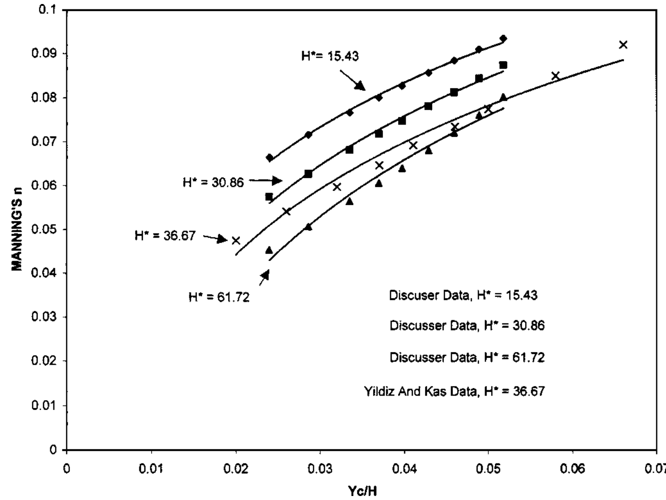


Fig. 1. Variation of Manning's n for different H^* values

The discussers would also like to know the number of steps provided in each case and the location of first step along the spillway profile. Can the authors suggest any readily usable explicit guidelines from hydraulic considerations for deciding on the step height, apart from the given RCC lift thickness? Some other investigators, including Rice and Kadavy (1996), Yildiz and Kas (1998), Chamani and Rajaratnam (1999) have indicated that the step height s affects the energy dissipation over stepped spillway.

Eq. (24) includes K, the roughness height perpendicular to the pseudobottom, which can be considered to be a representative term for step height s. In the last paragraph on energy dissipation, it is mentioned that Fig. 12 gives an idea of main parameters involved in the expression of relative residual energy. However, Fig. 12 does not indicate effect of any step height parameter on relative residual energy head ratio $[H_{res}/H_{max}]$. Fig. (1) shows a plot compiled by discussers based on experimental data obtained by Ghare (2003) and Yildiz and Kas (1998), which show the effect of step height on Manning's equivalent n for a stepped spillway. In this plot H^* is considered a ratio of spillway height to step height. Can authors provide any other dimensionless plot that covers all the main parameters including step height s affecting the performance of the stepped spillway under skimming flow regime?

Proposed Eq. (24) is based on the results obtained from Eqs. (20) and (21). Hence the use of Eq. (24) appears to be a tedious process. As indicated by the authors in Fig. (12), the variation in relative residual energy head ratio for $\Phi=40°$ and 50° is not appreciable; hence a simpler relationship for relative residual energy can be presented eliminating Φ as a variable. The resulting relationship would be applicable for Φ greater than 40°. Without a properly designed energy dissipation system on the downstream side, the hydraulic design of a stepped spillway system would be incomplete. The discussers would like to know the opinion of the authors regarding the applicability of the conventional conjugate depth relationship for stilling basin design in case of a stepped spillway where highly aerated flow near the toe of the spillway is encountered.

References

Chamani, M. R., and Rajaratnam, N. (1999). "Characteristics of skimming flows over stepped spillways." *J. Hydr. Engrg.* 125(4), 361–367.

PLATE 40

$=(h_{w,e1}+h_{w,e2})/2=0.87$ m in the continuity equation yields a terminal velocity of $v_{w,e}=q_d/h_{w,e}=20/0.87\approx 23$ m/s.

If the chute was long enough for the attainment of uniform flow, i.e., $H_{\text{dam}}=H_{\text{dam},u}\approx 70$ m, the normalized residual head would read $H_{\text{res}}/H_{\max}=0.36$ according to Eq. (24*b*), with $f_b=0.067$ from Eq. (21), $D_{h,w,u}\approx 4h_{w,u}=4\cdot 0.80=3.20$ m and $0.1<K/D_{h,w,u}=0.23<1.0$. In this case, 64% of the flow energy of $H_{\max}\approx 75.2$ m would be dissipated on the spillway, and the terminal velocity would amount to $v_{w,e}\approx 20/0.80=25$ m/s.

Training Wall Design

With $\eta=1.2$ for concrete dams, the required sidewall height from Eq. (25) is $h_d=2.09$ m, with $h_{90,u}=1.74$ m from Eq. (5). A sidewall height of 2.1 m is proposed. If the downstream dam face were prone to erosion, and if it were essential to avoid overtopping of the training walls, distinction should be made about whether the crest profile above the point of tangency is smooth or stepped. In the latter case, the required wall height should be at least $h_d=1.5h_{90,u}=2.61$ m, whereas for a smooth crest profile, the wall height should be $h_d=h_{spray}=4s=4\times 1.2=4.8$ m over about $L=25s=25\times 1.2=30$ m from the crest to allow for the spray resulting from nappe impact on the first steps below the smooth crest (Boes and Minor 2002).

Conclusions

The following findings of the present experimental study apply:

1. The onset of skimming flow is expressed by the ratio of critical depth to step height and follows a linear function as expressed in Eq. (1).
2. The uniform equivalent clear water depth $h_{w,u}$ on stepped spillways depends on the chute angle and unit discharge only, as given in Eq. (4).
3. The characteristic uniform mixture depth $h_{90,u}$ according to Eq. (5) is a function of step height, unit discharge and chute angle.
4. The drawdown length to the approximate location of uniform flow attainment as given in Eq. (13) depends on chute angle and unit discharge only.
5. The bottom roughness friction factor is approximated for a wide range of spillway angles and relative roughness by Eq. (20) or (21).
6. The significant effect of aeration on the reduction of friction factors is illustrated by the ratio f_w/f_m as function of the mean air concentration, Eq. (22), where f_w and f_m are friction factors with and without consideration of flow aeration, respectively.
7. A general expression of residual energy head along stepped chutes is given in Eq. (24), with distinction between developing and uniform flow regions.
8. Stepped spillway training walls should be designed according to Eq. (25), taking into account the erosion potential of the downstream dam face.

These conclusions in conjunction with the results of Boes and Hager (2003) allow for the hydraulic design of stepped spillways for a wide range of boundary conditions including typical applications both for embankment and gravity dams.

Acknowledgment

The present project was financed by the Swiss National Science Foundation, Grant No. 21-45424.95. The assistance of Professor Y. Yasuda, Nihon University, Tokyo, in providing experimental data is also gratefully acknowledged.

Notation

The following symbols are used in this paper:

$\bar{b}$ = spillway or river width;
$\bar{C}$ = depth-averaged air concentration;
C_i = depth-averaged air concentration at inception point;
$\bar{C}_u$ = uniform depth-averaged air concentration;
$C(y)$ = local air concentration;
$D_{h,w}$ = $4R_{h,w}$ hydraulic diameter;
$D_{h,\text{eff}}$ = $wD_{h,w}$ effective hydraulic diameter;
F = $u/(gh)^{1/2}$ local Froude number;
F_0 = $q_w/(gh_0^3)^{1/2}$ approach Froude number at jetbox;
F_* = $q_w/(g\sin\phi s^3)^{1/2}$ roughness Froude number;
f = Darcy–Weisbach friction factor of unaerated flow;
f_b = friction factor of bottom roughness;
f_m = Darcy–Weisbach friction factor in two-phase flow without consideration of aeration;
f_s = skin friction factor of sidewall roughness;
f_w = Darcy–Weisbach friction factor in two-phase flow with consideration of aeration;
g = gravitational acceleration;
H_{dam} = vertical spillway or dam height;
$H_{\text{dam},u}$ = vertical distance from spillway crest to close uniform equivalent clear water flow;
$H_{\max}$ = maximum reservoir energy head;
H_{res} = residual energy head;
h = local flow depth;
h_c = critical depth;
h_d = training wall design height;
h_m = mixture depth;
$h_{m,i}$ = mixture depth at inception point;
h_{spray} = spray height resulting from nappe impact on steps;
h_u = uniform flow depth;
h_w = $(1-\bar{C})h_{90}$ equivalent clear water depth;
$h_{w,e}$ = clear water depth at chute end;
$h_{w,i}$ = clear water depth at inception point;
$h_{w,u}$ = uniform equivalent clear water depth;
h_{90} = $h(C=0.90)$ characteristic mixture depth with local air concentration of $C=0.90$;
h_0 = approach flow depth at jetbox;
$h_{90,u}$ = uniform characteristic mixture depth;
K = $s\cdot\cos\phi$ roughness height perpendicular to pseudobottom;
L_i = black water length from spillway crest to inception point;
L_s = $s/\sin\phi=K/(\sin\phi\cos\phi)=2K/\sin(2\phi)$ distance between step edges, roughness spacing;
Q_d = design discharge;
Q_w = water discharge;
q_d = design discharge per unit width;
q_w = water discharge per unit width;
R = $uD_{h,w}/\nu$ Reynolds number;
$R_{h,w}$ = hydraulic radius;
S_f = friction slope;
s = step height;
u = flow velocity in x direction;
$v_{m,i}$ = mixture velocity at inception point;
$v_{w,e}$ = clear water velocity at chute end;

PLATE 41

J. Hydraul. Eng. 2003.129:671-679.

$v_{w,i}$ = clear water velocity at inception point;
w = shape correction coefficient;
x = streamwise coordinate originating at spillway crest;
x_s = $h_c^3/(h_{w,u}^2 \sin\phi)$ scaling length;
x_u = drawdown length from spillway crest to close uniform equivalent clear water flow;
Y = h/h_u normalized local flow depth;
Y_c = h_c/h_u normalized critical depth;
y = transverse coordinate originating at pseudobottom;
z_i = vertical black water length from spillway crest to inception point;
α = energy correction coefficient;
η = safety factor;
ν = kinematic viscosity of water
Π_1 = $0.5-0.42\sin(2\phi)$ function taking into account roughness spacing;
Π_2 = $(K/D_{h,w})^{0.2}$ function taking into account relative chute roughness;
σ = factor originating from Gauckler–Manning–Strickler formula;
ϕ = chute angle from horizontal; and
χ = x/x_s normalized streamwise coordinate.

References

Boes, R. M. (2000). "Zweiphasenströmung und Energieumsetzung auf Grosskaskaden." PhD thesis, VAW, ETH Zurich, Switzerland (in German).

Boes, R. M., and Hager, W. H. (1998). "Fiber-optical experimentation in two-phase cascade flow." *Proc., Int. RCC Dams Seminar*, K. Hansen, ed., Denver.

Boes, R. M., and Hager, W. H. (2003). "Two-phase flow characteristics of stepped spillways." *J. Hydraul. Eng.,* 129(9), 661–570.

Boes, R. M., and Minor, H.-E. (2000). "Guidelines for the hydraulic design of stepped spillways." *Proc., Int. Workshop on Hydraulics of Stepped Spillways*, VAW, ETH Zurich, H.-E. Minor and W. H. Hager, eds., Balkema, Rotterdam, The Netherlands, 163–170.

Boes, R., and Minor, H.-E. (2002). "Hydraulic design of stepped spillways for RCC dams." *Hydropower Dams,* 9(3), 87–91.

Chamani, M. R., and Rajaratnam, N. (1999a). "Onset of skimming flow on stepped spillways." *J. Hydraul. Eng.,* 125(9), 969–971.

Chamani, M. R., and Rajaratnam, N. (1999b). "Characteristics of skimming flow over stepped spillways." *J. Hydraul. Eng.,* 125(4), 361–368.

Chanson, H. (1994). *Hydraulic design of stepped cascades, channels, weirs and spillways*, Pergamon, Oxford, U.K.

Chanson, H. (1996). "Prediction of the transition nappe/skimming flow on a stepped channel." *J. Hydraul. Res.,* 34(3), 421–429.

Chanson, H. (2000). "Experience, operation and accidents with stepped cascades." *Presented at the Int. Workshop on Hydraulics of Stepped Spillways*, VAW, ETH, Zurich.

Chanson, H., Yasuda, Y., and Ohtsu, I. (2000). "Flow resistance in skimming flow: A critical review." *Proc., Int. Workshop on Hydraulics of Stepped Spillways*, VAW, ETH Zurich, H.-E. Minor and W. H. Hager, eds., Balkema, Rotterdam, The Netherlands, 95–102.

Chow, V. T. (1959). *Open channel hydraulics*, McGraw-Hill, New York.

Frizell, K. H., Smith, D. H., and Ruff, J. F. (1994). "Stepped overlays proven for use in protecting overtopped embankment dams." *Proc., ASDSO Annual Conf.*, Boston.

Hager, W. H. (1991). "Uniform aerated chute flow." *J. Hydraul. Eng.,* 117(4), 528–533.

Hager, W. H., and Blaser, F. (1998). "Drawdown curve and incipient aeration for chute flow." *Can. J. Civ. Eng.,* 25(3), 467–473.

Hager, W. H., and Boes, R. M. (2000). "Backwater and drawdown curves in stepped spillway flow." *Proc., Int. Workshop on Hydraulics of Stepped Spillways*, VAW, ETH Zurich, H.-E. Minor and W. H. Hager, eds., Balkema, Rotterdam, The Netherlands, 129–136.

Homann, C., Schramm, J., Demny, G., and Köngeter, J. (2000). "Wellenerscheinungen in der Hochwasserentlastungskaskade der Sorpetalsperre." *Proc., 2. Ju Wi-Treffen*, VAW, ETH Zurich, Switzerland, 30–32 (in German).

James, C. S. (2001). "Discussion of 'Onset of skimming flow on stepped spillways' by M. R. Chamani and N. Rajaratnam." *J. Hydraul. Eng.,* 127(6), 519.

Marchi, E. (1961). "Il moto uniforme delle correnti liquide nei condotti chiusi e aperti." *Energ. Elet.,* 38(4), 289–301, (5), 393–413 (in Italian).

Matos, J. (2000a). "Discussion of 'Hydraulics of skimming flow on modeled stepped spillways' by G. G. S. Pegram, A. K. Officer, and S. R. Mottram." *J. Hydraul. Eng.,* 126(12), 948–950.

Matos, J. (2000b). "Discussion of 'Characteristics of skimming flow over stepped spillways' by M. R. Chamani and N. Rajaratnam." *J. Hydraul. Eng.,* 126(11), 865–869.

Matos, J. (2001). "Discussion of 'Onset of skimming flow on stepped spillways' by M. R. Chamani and N. Rajaratnam." *J. Hydraul. Eng.,* 127(6), 519–521.

Matos, J., and Quintela, A. (1995). "Guidelines for the hydraulic design of stepped spillways for concrete dams." *ICOLD Energy Dissipation Bull.*.

Matos, J., Sanchez, M., Quintela, A., and Dolz, J. (1999). "Characteristic depth and pressure profiles in skimming flow over stepped spillways." *Proc., 28th IAHR Congress*, (CD-ROM) H. Bergmann, R. Krainer, and H. Breinhälter, eds., Graz, Austria B14.

Ohtsu, I., and Yasuda, Y. (1997). "Characteristics of flow conditions on stepped channels." *Proc., 27th IAHR Congress*, F. M. Holly and A. Alsaffar, eds., San Francisco, 583–588.

Ohtsu, I., Yasuda, Y., and Takahashi, M. (2000). "Discussion of 'Hydraulics of skimming flow on modeled stepped spillways' by G. G. S. Pegram, A. K. Officer, and S. R. Mottram." *J. Hydraul. Eng.,* 126(12), 950–951.

Ohtsu, I., Yasuda, Y., and Takahashi, M. (2001). "Discussion of 'Onset of skimming flow on stepped spillways' by M. R. Chamani and N. Rajaratnam." *J. Hydraul. Eng.,* 127(6), 522–524.

Rajaratnam, N. (1990). "Skimming flow in stepped spillways." *J. Hydraul. Eng.,* 116(4), 587–591.

Schläpfer, D. (2000). "Treppenschussrinnen." MSc thesis, VAW, ETH Zurich, Switzerland (in German).

Schröder, R. C. M. (1990). "Hydraulische Methoden zur Erfassung von Rauheiten." *DVWK Bull. 92*, Paul Parey, Germany (in German).

Stephenson, D. (1991). "Energy dissipation down stepped spillways." *Int. Water Power Dam Constr.,* 43(9), 27–30.

Tatewar, S. P., Ingle, R. N., and Porey, P. D. (2001). "Discussion of 'Onset of skimming flow on stepped spillways,' by M. R. Chamani and N. Rajaratnam." *J. Hydraul. Eng.,* 127(6), 524.

Tozzi, M. J. (1992). "Caracterização/comportamento de escoamentos em vertedouros com paramento em degraus." PhD thesis. Univ. of São Paulo, Sao Paulo, Brazil (in Portuguese).

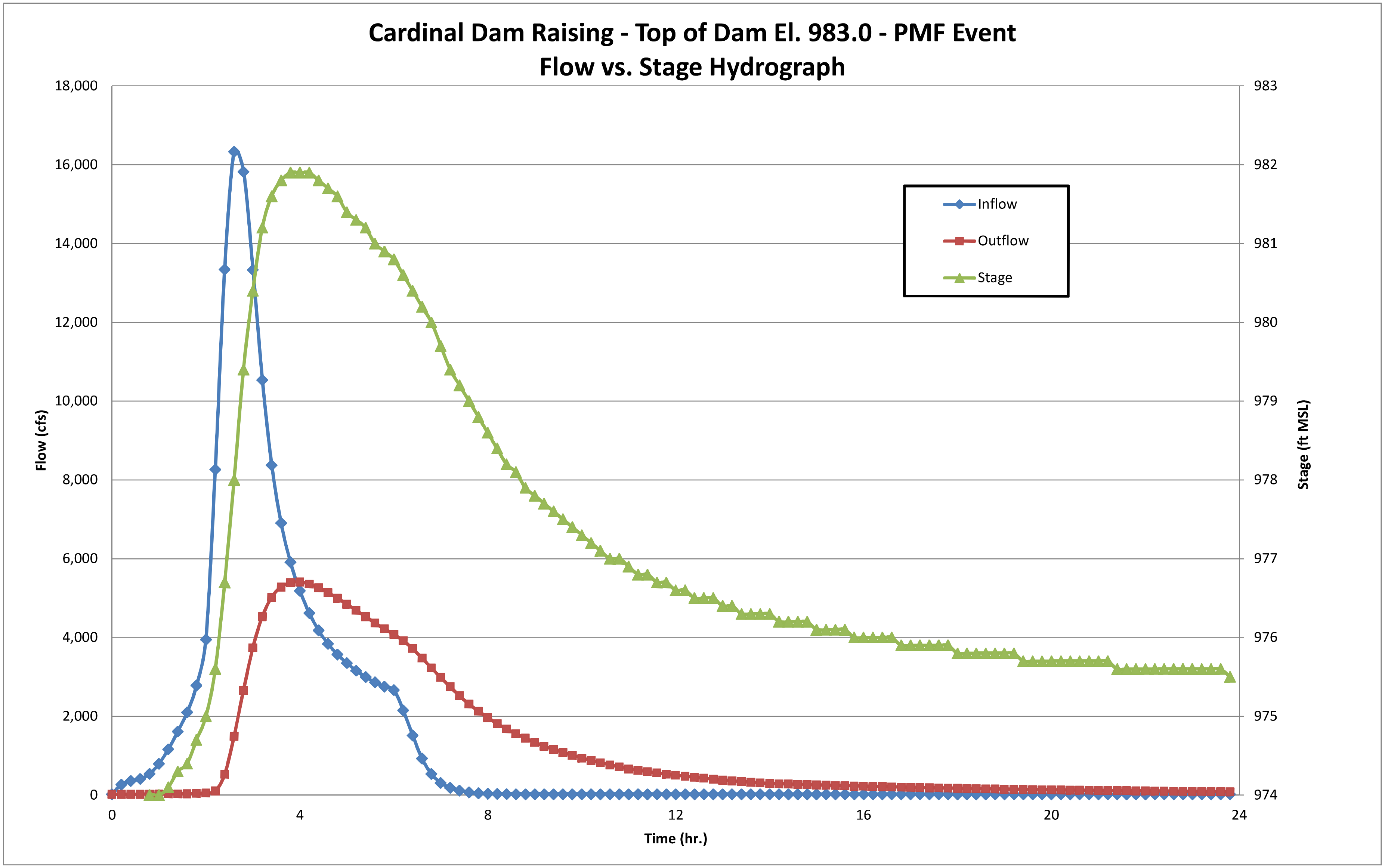
Wahrheit-Lensing, A. (1996). "Selbstbelüftung und Energieumwandlung beim Abfluss über treppenförmige Entlastungsanlagen." PhD thesis, Univ. of Karlsruhe, Karlsruhe, Germany (in German).

Yasuda, Y., and Ohtsu, I. (1999). "Flow resistance of skimming flows in stepped channels." *Proc., 28th IAHR Congress*, H. Bergmann, R. Krainer, and H. Breinhälter, eds. (CD-ROM), Graz, Austria, B14.

Yildiz, D., and Kas, I. (1998). "Hydraulic performance of stepped chute spillways." *Hydropower Dams,* 5(4), 64–70.

PLATE 42

J. Hydraul. Eng. 2003.129:671-679.



Cardinal Dam Raising - Top of Dam El. 983.0 - PMF Event
Flow vs. Stage Hydrograph
Flow (cfs)
Stage (ft MSL)
Time (hr.)
Inflow
Outflow
Stage
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
983
982
981
980
979
978
977
976
975
974
0
4
8
12
16
20
24

```
1***************************************
***************************************
 *                                      *                                        *
*
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *                                        *   U.S. ARMY CORPS OF ENGINEERS
*
 *             JUN   1998               *                                        *   HYDROLOGIC ENGINEERING CENTER
*
 *          VERSION 4.1                 *                                        *         609 SECOND STREET
*
 *                                      *                                        *      DAVIS, CALIFORNIA 95616
*
 *  RUN DATE   22SEP12  TIME  16:34:01  *                                        *          (916) 756-1104
*
 *                                      *                                        *
*
 ***************************************
***************************************
```

PMF

```
X     X  XXXXXXX   XXXXX          X
X     X  X        X     X        XX
X     X  X        X               X
XXXXXXX  XXXX     X       XXXXX   X
X     X  X        X               X
X     X  X        X     X         X
X     X  XXXXXXX   XXXXX         XXX
```

```
THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM
```

```
1                                        HEC-1 INPUT                                          PAGE  1

         LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

 *** FREE ***
           1           ID   CARDINAL FLY ASH DAM #2
           2           ID   THIRD RAISING - CREST OF 983 FT
           3           ID   DESIGN FLOOD     PMP, 6-HR
           4           ID   FILE: FAD2-PMP-105FT
           5           IT      12       0       0     120
           6           IO       1
           7           PG      10    26.5
           8           PC       0   .0130    .027    .042    .059    .078    .099    .122    .147     .18
           9           PC     .23     .38     .53    .625     .67    .705    .736    .764     .79    .814
          10           PC    .836    .856    .875   .8931   .9103   .9267   .9423   .9573   .9719   .9861
          11           PC     1.0

          12           KK     WEST RUNOFF FROM FAD#1 WATERSHED
          13           KM   RECLAIMED POND AND LANDFILL
          14           BA    1.06
          15           LS       0      75
          16           PR      10
          17           PW       1
          18           PT      10
          19           UD    0.52

          20           KK     EAST RUNOFF FROM EAST WATERSHED
          21           KM   WOODS ONLY
          22           BA    0.75
          23           LS       0      70
          24           PR      10
          25           PW       1
          26           PT      10
          27           UD    0.34

          28           KK     LAKE INSTANTANEOUS RUNOFF FROM LAKE SURFACE
          29           KM   LAKE ONLY
          30           BA    0.30
          31           BF      20
          32           LS       0     100
          33           PR      10
          34           PW       1
          35           PT      10
          36           UD     0.1

          37           KK       IN COMBINE INFLOWS FROM WEST AND EAST WATERSHEDS AND LAKE SURFACE
          38           HC       3

          39           KK      DAM ROUTE FLOOD HYDROGRAPHS THRU FAD#2
          40           KM   STARTING POOL IS MAXIMUM OPERATING LEVEL
          41           KM   MAXIMUM TOP OF STOP LOG IS 972.5
          42           KM   STOP LOG WIDTH IS 4 FT
```

```
          43          RS      1   FLOW   20.6
          44          SA  135.5  138.7  142.0  145.4  153.1  161.4  166.2  175.2  192.6
          45          SE    960    962    964    966    970    974    976    980    986
          46          SQ      0    4.7   13.3   24.5   37.7   52.7   69.2  299.5  660.8 1247.1
          47          SQ 1776.0 2298.9 3334.3 4362.0 5364.5 5864.9 6365.2
          48          SE  972.5    973  973.5    974  974.5    975  975.5 976.27 976.89  977.7
          49          SE 978.37 978.98 980.06 981.02  981.9 982.32 982.73
1                                                 HEC-1 INPUT                                    PAGE  2

        LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

          50          SS  975.5
          51          ST    983
          52          ZZ
1*****************************************
****************************************
 *                                       *                                                   *
*
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                                   *   U.S. ARMY CORPS OF ENGINEERS
*
 *             JUN   1998                * .                                                 *   HYDROLOGIC ENGINEERING CENTER
*
 *          VERSION 4.1                  *                                                   *         609 SECOND STREET
*
 *                                       *                                                   *      DAVIS, CALIFORNIA 95616
*
 *  RUN DATE   22SEP12  TIME  16:34:01   *                                                   *           (916) 756-1104
*
 *                                       *                                                   *
*
 *****************************************
****************************************




                          CARDINAL FLY ASH DAM #2
                          THIRD RAISING - CREST OF 983 FT
                          DESIGN FLOOD     PMP, 6-HR
                          FILE: FAD2-PMP-105FT

    6 IO          OUTPUT CONTROL VARIABLES
                        IPRNT          1  PRINT CONTROL
                        IPLOT          0  PLOT CONTROL
                        QSCAL         0.  HYDROGRAPH PLOT SCALE

     IT           HYDROGRAPH TIME DATA
                         NMIN         12  MINUTES IN COMPUTATION INTERVAL
                        IDATE      1   0  STARTING DATE
                        ITIME       0000  STARTING TIME
                           NQ        120  NUMBER OF HYDROGRAPH ORDINATES
                       NDDATE      1   0  ENDING DATE
                       NDTIME       2348  ENDING TIME
                        ICENT         19  CENTURY MARK

                    COMPUTATION INTERVAL      .20 HOURS
                         TOTAL TIME BASE    23.80 HOURS

         ENGLISH UNITS
              DRAINAGE AREA          SQUARE MILES
              PRECIPITATION DEPTH    INCHES
              LENGTH, ELEVATION      FEET
              FLOW                   CUBIC FEET PER SECOND
              STORAGE VOLUME         ACRE-FEET
              SURFACE AREA           ACRES
              TEMPERATURE            DEGREES FAHRENHEIT


 *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
***

             **************
             *            *
   12 KK     *     WEST   *      RUNOFF FROM FAD#1 WATERSHED
             *            *
             **************
                          RECLAIMED POND AND LANDFILL

                SUBBASIN RUNOFF DATA

   14 BA          SUBBASIN CHARACTERISTICS
                        TAREA        1.06  SUBBASIN AREA

                  PRECIPITATION DATA

   18 PT           TOTAL STORM STATIONS        10
    0 PW                        WEIGHTS      1.00

   16 PR             RECORDING STATIONS        10
   17 PW                        WEIGHTS      1.00

   15 LS          SCS LOSS RATE
```

```
            STRTL          .67  INITIAL ABSTRACTION
            CRVNBR       75.00  CURVE NUMBER
            RTIMP          .00  PERCENT IMPERVIOUS AREA

 19 UD          SCS DIMENSIONLESS UNITGRAPH
                  TLAG           .52  LAG
```

***

PRECIPITATION STATION DATA

STATION	TOTAL	AVG. ANNUAL	WEIGHT
10	26.50	.00	1.00

TEMPORAL DISTRIBUTIONS

STATION 10, WEIGHT = 1.00

.01	.01	.01	.02	.02	.02	.02	.02	.03	.05
.15	.15	.10	.05	.03	.03	.03	.03	.02	.02
.02	.02	.02	.02	.02	.02	.01	.01	.01	.01
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	

WARNING *** TIME INTERVAL IS GREATER THAN .29*LAG

UNIT HYDROGRAPH
15 END-OF-PERIOD ORDINATES

180.	607.	826.	718.	453.	259.	157.	92.	54.	32.
19.	11.	7.	4.	1.					

****
***

HYDROGRAPH AT STATION WEST

****
***

DA MON	HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q	*	DA MON	HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q
1	0000	1	.00	.00	.00	0.	*	1	1200	61	.00	.00	.00	0.
1	0012	2	.34	.34	.00	0.	*	1	1212	62	.00	.00	.00	0.
1	0024	3	.37	.37	.00	0.	*	1	1224	63	.00	.00	.00	0.
1	0036	4	.40	.35	.05	10.	*	1	1236	64	.00	.00	.00	0.
1	0048	5	.45	.31	.14	57.	*	1	1248	65	.00	.00	.00	0.
1	0100	6	.50	.28	.22	167.	*	1	1300	66	.00	.00	.00	0.
1	0112	7	.56	.25	.31	343.	*	1	1312	67	.00	.00	.00	0.
1	0124	8	.61	.22	.39	566.	*	1	1324	68	.00	.00	.00	0.
1	0136	9	.66	.19	.47	815.	*	1	1336	69	.00	.00	.00	0.
1	0148	10	.87	.20	.68	1100.	*	1	1348	70	.00	.00	.00	0.
1	0200	11	1.32	.23	1.10	1504.	*	1	1400	71	.00	.00	.00	0.
1	0212	12	3.97	.40	3.58	2516.	*	1	1412	72	.00	.00	.00	0.
1	0224	13	3.97	.21	3.77	4635.	*	1	1424	73	.00	.00	.00	0.
1	0236	14	2.52	.09	2.43	7003.	*	1	1436	74	.00	.00	.00	0.
1	0248	15	1.19	.03	1.16	8174.	*	1	1448	75	.00	.00	.00	0.
1	0300	16	.93	.02	.90	7671.	*	1	1500	76	.00	.00	.00	0.
1	0312	17	.82	.02	.80	6310.	*	1	1512	77	.00	.00	.00	0.
1	0324	18	.74	.02	.73	5000.	*	1	1524	78	.00	.00	.00	0.
1	0336	19	.69	.01	.67	4045.	*	1	1536	79	.00	.00	.00	0.
1	0348	20	.64	.01	.62	3386.	*	1	1548	80	.00	.00	.00	0.
1	0400	21	.58	.01	.57	2915.	*	1	1600	81	.00	.00	.00	0.
1	0412	22	.53	.01	.52	2566.	*	1	1612	82	.00	.00	.00	0.
1	0424	23	.50	.01	.49	2292.	*	1	1624	83	.00	.00	.00	0.
1	0436	24	.48	.01	.47	2077.	*	1	1636	84	.00	.00	.00	0.
1	0448	25	.46	.01	.45	1908.	*	1	1648	85	.00	.00	.00	0.
1	0500	26	.43	.01	.43	1771.	*	1	1700	86	.00	.00	.00	0.
1	0512	27	.41	.01	.41	1657.	*	1	1712	87	.00	.00	.00	0.
1	0524	28	.40	.01	.39	1562.	*	1	1724	88	.00	.00	.00	0.
1	0536	29	.39	.01	.38	1484.	*	1	1736	89	.00	.00	.00	0.
1	0548	30	.38	.01	.37	1419.	*	1	1748	90	.00	.00	.00	0.
1	0600	31	.37	.00	.36	1366.	*	1	1800	91	.00	.00	.00	0.
1	0612	32	.00	.00	.00	1258.	*	1	1812	92	.00	.00	.00	0.
1	0624	33	.00	.00	.00	1007.	*	1	1824	93	.00	.00	.00	0.
1	0636	34	.00	.00	.00	686.	*	1	1836	94	.00	.00	.00	0.
1	0648	35	.00	.00	.00	413.	*	1	1848	95	.00	.00	.00	0.
1	0700	36	.00	.00	.00	241.	*	1	1900	96	.00	.00	.00	0.
1	0712	37	.00	.00	.00	143.	*	1	1912	97	.00	.00	.00	0.
1	0724	38	.00	.00	.00	83.	*	1	1924	98	.00	.00	.00	0.
1	0736	39	.00	.00	.00	49.	*	1	1936	99	.00	.00	.00	0.
1	0748	40	.00	.00	.00	28.	*	1	1948	100	.00	.00	.00	0.
1	0800	41	.00	.00	.00	16.	*	1	2000	101	.00	.00	.00	0.
1	0812	42	.00	.00	.00	9.	*	1	2012	102	.00	.00	.00	0.
1	0824	43	.00	.00	.00	5.	*	1	2024	103	.00	.00	.00	0.
1	0836	44	.00	.00	.00	2.	*	1	2036	104	.00	.00	.00	0.
1	0848	45	.00	.00	.00	0.	*	1	2048	105	.00	.00	.00	0.
1	0900	46	.00	.00	.00	0.	*	1	2100	106	.00	.00	.00	0.

1	0912	47	.00	.00	.00	0.	*	1	2112	107	.00	.00	.00	0.
1	0924	48	.00	.00	.00	0.	*	1	2124	108	.00	.00	.00	0.
1	0936	49	.00	.00	.00	0.	*	1	2136	109	.00	.00	.00	0.
1	0948	50	.00	.00	.00	0.	*	1	2148	110	.00	.00	.00	0.
1	1000	51	.00	.00	.00	0.	*	1	2200	111	.00	.00	.00	0.
1	1012	52	.00	.00	.00	0.	*	1	2212	112	.00	.00	.00	0.
1	1024	53	.00	.00	.00	0.	*	1	2224	113	.00	.00	.00	0.
1	1036	54	.00	.00	.00	0.	*	1	2236	114	.00	.00	.00	0.
1	1048	55	.00	.00	.00	0.	*	1	2248	115	.00	.00	.00	0.
1	1100	56	.00	.00	.00	0.	*	1	2300	116	.00	.00	.00	0.
1	1112	57	.00	.00	.00	0.	*	1	2312	117	.00	.00	.00	0.
1	1124	58	.00	.00	.00	0.	*	1	2324	118	.00	.00	.00	0.
1	1136	59	.00	.00	.00	0.	*	1	2336	119	.00	.00	.00	0.
1	1148	60	.00	.00	.00	0.	*	1	2348	120	.00	.00	.00	0.
							*							

```
******************************************************************************************************************************
***

    TOTAL RAINFALL =    26.50, TOTAL LOSS =    3.62, TOTAL EXCESS =   22.88

  PEAK FLOW      TIME                          MAXIMUM AVERAGE FLOW
                                    6-HR        24-HR       72-HR      23.80-HR
+   (CFS)        (HR)
                           (CFS)
+    8174.       2.80                2588.        658.        658.        658.
                         (INCHES)   22.704      22.881      22.881      22.881
                          (AC-FT)    1284.       1294.       1294.       1294.

                           CUMULATIVE AREA =    1.06 SQ MI


 *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
***

             **************
             *            *
  20 KK      *     EAST   *      RUNOFF FROM EAST WATERSHED
             *            *
             **************
                           WOODS ONLY

                SUBBASIN RUNOFF DATA

  22 BA           SUBBASIN CHARACTERISTICS
                        TAREA           .75  SUBBASIN AREA

                  PRECIPITATION DATA

  26 PT            TOTAL STORM STATIONS        10
   0 PW                         WEIGHTS      1.00

  24 PR              RECORDING STATIONS        10
  25 PW                         WEIGHTS      1.00

  23 LS           SCS LOSS RATE
                        STRTL          .86  INITIAL ABSTRACTION
                       CRVNBR        70.00  CURVE NUMBER
                        RTIMP          .00  PERCENT IMPERVIOUS AREA

  27 UD           SCS DIMENSIONLESS UNITGRAPH
                         TLAG          .34  LAG
                                                                      ***

                PRECIPITATION STATION DATA

                         STATION    TOTAL    AVG. ANNUAL    WEIGHT
                              10    26.50          .00        1.00

                  TEMPORAL DISTRIBUTIONS

                  STATION        10,  WEIGHT =   1.00
                        .01       .01       .01       .02       .02       .02       .02       .02       .03       .05
                        .15       .15       .10       .05       .03       .03       .03       .03       .02       .02
                        .02       .02       .02       .02       .02       .02       .01       .01       .01       .01
                        .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                        .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                        .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                        .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                        .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                        .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                        .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                        .00       .00       .00       .00       .00       .00       .00       .00       .00       .00
                        .00       .00       .00       .00       .00       .00       .00       .00       .00

 WARNING *** TIME INTERVAL IS GREATER THAN .29*LAG

                                                             UNIT HYDROGRAPH
                                                       10 END-OF-PERIOD ORDINATES
               329.      820.      669.      314.      153.       73.       34.       16.        8.        4.
```

****
***

HYDROGRAPH AT STATION EAST

****
***

DA MON	HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q	*	DA MON	HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q
1	0000	1	.00	.00	.00	0.	*	1	1200	61	.00	.00	.00	0.
1	0012	2	.34	.34	.00	0.	*	1	1212	62	.00	.00	.00	0.
1	0024	3	.37	.37	.00	0.	*	1	1224	63	.00	.00	.00	0.
1	0036	4	.40	.38	.01	5.	*	1	1236	64	.00	.00	.00	0.
1	0048	5	.45	.36	.09	40.	*	1	1248	65	.00	.00	.00	0.
1	0100	6	.50	.34	.17	134.	*	1	1300	66	.00	.00	.00	0.
1	0112	7	.56	.31	.25	280.	*	1	1312	67	.00	.00	.00	0.
1	0124	8	.61	.28	.33	454.	*	1	1324	68	.00	.00	.00	0.
1	0136	9	.66	.25	.41	641.	*	1	1336	69	.00	.00	.00	0.
1	0148	10	.87	.27	.61	871.	*	1	1348	70	.00	.00	.00	0.
1	0200	11	1.32	.31	1.01	1265.	*	1	1400	71	.00	.00	.00	0.
1	0212	12	3.97	.57	3.41	2563.	*	1	1412	72	.00	.00	.00	0.
1	0224	13	3.97	.31	3.67	4966.	*	1	1424	73	.00	.00	.00	0.
1	0236	14	2.52	.13	2.39	6527.	*	1	1436	74	.00	.00	.00	0.
1	0248	15	1.19	.05	1.14	6074.	*	1	1448	75	.00	.00	.00	0.
1	0300	16	.93	.04	.89	4601.	*	1	1500	76	.00	.00	.00	0.
1	0312	17	.82	.03	.79	3361.	*	1	1512	77	.00	.00	.00	0.
1	0324	18	.74	.03	.72	2611.	*	1	1524	78	.00	.00	.00	0.
1	0336	19	.69	.02	.67	2157.	*	1	1536	79	.00	.00	.00	0.
1	0348	20	.64	.02	.62	1871.	*	1	1548	80	.00	.00	.00	0.
1	0400	21	.58	.02	.57	1670.	*	1	1600	81	.00	.00	.00	0.
1	0412	22	.53	.01	.52	1506.	*	1	1612	82	.00	.00	.00	0.
1	0424	23	.50	.01	.49	1371.	*	1	1624	83	.00	.00	.00	0.
1	0436	24	.48	.01	.47	1270.	*	1	1636	84	.00	.00	.00	0.
1	0448	25	.46	.01	.44	1195.	*	1	1648	85	.00	.00	.00	0.
1	0500	26	.43	.01	.42	1132.	*	1	1700	86	.00	.00	.00	0.
1	0512	27	.41	.01	.40	1075.	*	1	1712	87	.00	.00	.00	0.
1	0524	28	.40	.01	.39	1024.	*	1	1724	88	.00	.00	.00	0.
1	0536	29	.39	.01	.38	981.	*	1	1736	89	.00	.00	.00	0.
1	0548	30	.38	.01	.37	946.	*	1	1748	90	.00	.00	.00	0.
1	0600	31	.37	.01	.36	917.	*	1	1800	91	.00	.00	.00	0.
1	0612	32	.00	.00	.00	777.	*	1	1812	92	.00	.00	.00	0.
1	0624	33	.00	.00	.00	469.	*	1	1824	93	.00	.00	.00	0.
1	0636	34	.00	.00	.00	222.	*	1	1836	94	.00	.00	.00	0.
1	0648	35	.00	.00	.00	106.	*	1	1848	95	.00	.00	.00	0.
1	0700	36	.00	.00	.00	50.	*	1	1900	96	.00	.00	.00	0.
1	0712	37	.00	.00	.00	23.	*	1	1912	97	.00	.00	.00	0.
1	0724	38	.00	.00	.00	10.	*	1	1924	98	.00	.00	.00	0.
1	0736	39	.00	.00	.00	4.	*	1	1936	99	.00	.00	.00	0.
1	0748	40	.00	.00	.00	1.	*	1	1948	100	.00	.00	.00	0.
1	0800	41	.00	.00	.00	0.	*	1	2000	101	.00	.00	.00	0.
1	0812	42	.00	.00	.00	0.	*	1	2012	102	.00	.00	.00	0.
1	0824	43	.00	.00	.00	0.	*	1	2024	103	.00	.00	.00	0.
1	0836	44	.00	.00	.00	0.	*	1	2036	104	.00	.00	.00	0.
1	0848	45	.00	.00	.00	0.	*	1	2048	105	.00	.00	.00	0.
1	0900	46	.00	.00	.00	0.	*	1	2100	106	.00	.00	.00	0.
1	0912	47	.00	.00	.00	0.	*	1	2112	107	.00	.00	.00	0.
1	0924	48	.00	.00	.00	0.	*	1	2124	108	.00	.00	.00	0.
1	0936	49	.00	.00	.00	0.	*	1	2136	109	.00	.00	.00	0.
1	0948	50	.00	.00	.00	0.	*	1	2148	110	.00	.00	.00	0.
1	1000	51	.00	.00	.00	0.	*	1	2200	111	.00	.00	.00	0.
1	1012	52	.00	.00	.00	0.	*	1	2212	112	.00	.00	.00	0.
1	1024	53	.00	.00	.00	0.	*	1	2224	113	.00	.00	.00	0.
1	1036	54	.00	.00	.00	0.	*	1	2236	114	.00	.00	.00	0.
1	1048	55	.00	.00	.00	0.	*	1	2248	115	.00	.00	.00	0.
1	1100	56	.00	.00	.00	0.	*	1	2300	116	.00	.00	.00	0.
1	1112	57	.00	.00	.00	0.	*	1	2312	117	.00	.00	.00	0.
1	1124	58	.00	.00	.00	0.	*	1	2324	118	.00	.00	.00	0.
1	1136	59	.00	.00	.00	0.	*	1	2336	119	.00	.00	.00	0.
1	1148	60	.00	.00	.00	0.	*	1	2348	120	.00	.00	.00	0.

****
***

TOTAL RAINFALL = 26.50, TOTAL LOSS = 4.53, TOTAL EXCESS = 21.97

PEAK FLOW	TIME		MAXIMUM AVERAGE FLOW			
			6-HR	24-HR	72-HR	23.80-HR
+ (CFS)	(HR)					
		(CFS)				
+ 6527.	2.60		1767.	447.	447.	447.
		(INCHES)	21.902	21.971	21.971	21.971
		(AC-FT)	876.	879.	879.	879.

CUMULATIVE AREA = .75 SQ MI

*** ***
***

```
 **************
 *            *
28 KK * LAKE *      INSTANTANEOUS RUNOFF FROM LAKE SURFACE
 *            *
 **************
```

LAKE ONLY

SUBBASIN RUNOFF DATA

30 BA SUBBASIN CHARACTERISTICS
TAREA .30 SUBBASIN AREA

31 BF BASE FLOW CHARACTERISTICS
STRTQ 20.00 INITIAL FLOW
QRCSN .00 BEGIN BASE FLOW RECESSION
RTIOR 1.00000 RECESSION CONSTANT

PRECIPITATION DATA

35 PT TOTAL STORM STATIONS 10
0 PW WEIGHTS 1.00

33 PR RECORDING STATIONS 10
34 PW WEIGHTS 1.00

32 LS SCS LOSS RATE
STRTL .00 INITIAL ABSTRACTION
CRVNBR 100.00 CURVE NUMBER
RTIMP .00 PERCENT IMPERVIOUS AREA

36 UD SCS DIMENSIONLESS UNITGRAPH
TLAG .10 LAG

***

PRECIPITATION STATION DATA

STATION	TOTAL	AVG. ANNUAL	WEIGHT
10	26.50	.00	1.00

TEMPORAL DISTRIBUTIONS

STATION 10, WEIGHT = 1.00

.01	.01	.01	.02	.02	.02	.02	.02	.03	.05
.15	.15	.10	.05	.03	.03	.03	.03	.02	.02
.02	.02	.02	.02	.02	.02	.01	.01	.01	.01
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	

WARNING *** TIME INTERVAL IS GREATER THAN .29*LAG

UNIT HYDROGRAPH
5 END-OF-PERIOD ORDINATES

719.	201.	40.	8.	0.

****
***

HYDROGRAPH AT STATION LAKE

****
***

DA	MON	HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q	*	DA	MON	HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q
1		0000	1	.00	.00	.00	20.	*	1		1200	61	.00	.00	.00	20.
1		0012	2	.34	.00	.34	268.	*	1		1212	62	.00	.00	.00	20.
1		0024	3	.37	.00	.37	356.	*	1		1224	63	.00	.00	.00	20.
1		0036	4	.40	.00	.40	394.	*	1		1236	64	.00	.00	.00	20.
1		0048	5	.45	.00	.45	441.	*	1		1248	65	.00	.00	.00	20.
1		0100	6	.50	.00	.50	491.	*	1		1300	66	.00	.00	.00	20.
1		0112	7	.56	.00	.56	543.	*	1		1312	67	.00	.00	.00	20.
1		0124	8	.61	.00	.61	594.	*	1		1324	68	.00	.00	.00	20.
1		0136	9	.66	.00	.66	645.	*	1		1336	69	.00	.00	.00	20.
1		0148	10	.87	.00	.87	811.	*	1		1348	70	.00	.00	.00	20.
1		0200	11	1.32	.00	1.32	1180.	*	1		1400	71	.00	.00	.00	20.
1		0212	12	3.97	.00	3.97	3185.	*	1		1412	72	.00	.00	.00	20.
1		0224	13	3.97	.00	3.97	3738.	*	1		1424	73	.00	.00	.00	20.
1		0236	14	2.52	.00	2.52	2799.	*	1		1436	74	.00	.00	.00	20.
1		0248	15	1.19	.00	1.19	1573.	*	1		1448	75	.00	.00	.00	20.
1		0300	16	.93	.00	.93	1058.	*	1		1500	76	.00	.00	.00	20.
1		0312	17	.82	.00	.82	865.	*	1		1512	77	.00	.00	.00	20.
1		0324	18	.74	.00	.74	765.	*	1		1524	78	.00	.00	.00	20.
1		0336	19	.69	.00	.69	705.	*	1		1536	79	.00	.00	.00	20.
1		0348	20	.64	.00	.64	652.	*	1		1548	80	.00	.00	.00	20.

1	0400	21	.58	.00	.58	600.	*	1	1600	81	.00	.00	.00	20.
1	0412	22	.53	.00	.53	549.	*	1	1612	82	.00	.00	.00	20.
1	0424	23	.50	.00	.50	517.	*	1	1624	83	.00	.00	.00	20.
1	0436	24	.48	.00	.48	492.	*	1	1636	84	.00	.00	.00	20.
1	0448	25	.46	.00	.46	468.	*	1	1648	85	.00	.00	.00	20.
1	0500	26	.43	.00	.43	447.	*	1	1700	86	.00	.00	.00	20.
1	0512	27	.41	.00	.41	427.	*	1	1712	87	.00	.00	.00	20.
1	0524	28	.40	.00	.40	410.	*	1	1724	88	.00	.00	.00	20.
1	0536	29	.39	.00	.39	398.	*	1	1736	89	.00	.00	.00	20.
1	0548	30	.38	.00	.38	388.	*	1	1748	90	.00	.00	.00	20.
1	0600	31	.37	.00	.37	379.	*	1	1800	91	.00	.00	.00	20.
1	0612	32	.00	.00	.00	112.	*	1	1812	92	.00	.00	.00	20.
1	0624	33	.00	.00	.00	38.	*	1	1824	93	.00	.00	.00	20.
1	0636	34	.00	.00	.00	23.	*	1	1836	94	.00	.00	.00	20.
1	0648	35	.00	.00	.00	20.	*	1	1848	95	.00	.00	.00	20.
1	0700	36	.00	.00	.00	20.	*	1	1900	96	.00	.00	.00	20.
1	0712	37	.00	.00	.00	20.	*	1	1912	97	.00	.00	.00	20.
1	0724	38	.00	.00	.00	20.	*	1	1924	98	.00	.00	.00	20.
1	0736	39	.00	.00	.00	20.	*	1	1936	99	.00	.00	.00	20.
1	0748	40	.00	.00	.00	20.	*	1	1948	100	.00	.00	.00	20.
1	0800	41	.00	.00	.00	20.	*	1	2000	101	.00	.00	.00	20.
1	0812	42	.00	.00	.00	20.	*	1	2012	102	.00	.00	.00	20.
1	0824	43	.00	.00	.00	20.	*	1	2024	103	.00	.00	.00	20.
1	0836	44	.00	.00	.00	20.	*	1	2036	104	.00	.00	.00	20.
1	0848	45	.00	.00	.00	20.	*	1	2048	105	.00	.00	.00	20.
1	0900	46	.00	.00	.00	20.	*	1	2100	106	.00	.00	.00	20.
1	0912	47	.00	.00	.00	20.	*	1	2112	107	.00	.00	.00	20.
1	0924	48	.00	.00	.00	20.	*	1	2124	108	.00	.00	.00	20.
1	0936	49	.00	.00	.00	20.	*	1	2136	109	.00	.00	.00	20.
1	0948	50	.00	.00	.00	20.	*	1	2148	110	.00	.00	.00	20.
1	1000	51	.00	.00	.00	20.	*	1	2200	111	.00	.00	.00	20.
1	1012	52	.00	.00	.00	20.	*	1	2212	112	.00	.00	.00	20.
1	1024	53	.00	.00	.00	20.	*	1	2224	113	.00	.00	.00	20.
1	1036	54	.00	.00	.00	20.	*	1	2236	114	.00	.00	.00	20.
1	1048	55	.00	.00	.00	20.	*	1	2248	115	.00	.00	.00	20.
1	1100	56	.00	.00	.00	20.	*	1	2300	116	.00	.00	.00	20.
1	1112	57	.00	.00	.00	20.	*	1	2312	117	.00	.00	.00	20.
1	1124	58	.00	.00	.00	20.	*	1	2324	118	.00	.00	.00	20.
1	1136	59	.00	.00	.00	20.	*	1	2336	119	.00	.00	.00	20.
1	1148	60	.00	.00	.00	20.	*	1	2348	120	.00	.00	.00	20.

****
***

TOTAL RAINFALL = 26.50, TOTAL LOSS = .00, TOTAL EXCESS = 26.50

PEAK FLOW	TIME		MAXIMUM AVERAGE FLOW			
			6-HR	24-HR	72-HR	23.80-HR
+ (CFS)	(HR)					
		(CFS)				
+ 3738.	2.40		869.	236.	236.	236.
		(INCHES)	26.923	28.959	28.959	28.959
		(AC-FT)	431.	463.	463.	463.

CUMULATIVE AREA = .30 SQ MI

*** ***
***

```
           **************
           *            *
  37 KK    *     IN     *    COMBINE INFLOWS FROM WEST AND EAST WATERSHEDS AND LAKE SURFACE
           *            *
           **************
```

38 HC HYDROGRAPH COMBINATION
ICOMP 3 NUMBER OF HYDROGRAPHS TO COMBINE

***

****
***

HYDROGRAPH AT STATION IN
SUM OF 3 HYDROGRAPHS

****
***

DA	MON HRMN	ORD	FLOW	*	DA	MON HRMN	ORD	FLOW	*	DA	MON HRMN	ORD	FLOW	*	DA	MON HRMN	ORD	FLOW
1	0000	1	20.	*	1	0600	31	2663.	*	1	1200	61	20.	*	1	1800	91	20.
1	0012	2	268.	*	1	0612	32	2148.	*	1	1212	62	20.	*	1	1812	92	20.
1	0024	3	356.	*	1	0624	33	1513.	*	1	1224	63	20.	*	1	1824	93	20.

1	0036	4	409.	*	1	0636	34	931.	*	1	1236	64	20.	*	1	1836	94	20.
1	0048	5	538.	*	1	0648	35	539.	*	1	1248	65	20.	*	1	1848	95	20.
1	0100	6	793.	*	1	0700	36	311.	*	1	1300	66	20.	*	1	1900	96	20.
1	0112	7	1165.	*	1	0712	37	186.	*	1	1312	67	20.	*	1	1912	97	20.
1	0124	8	1613.	*	1	0724	38	114.	*	1	1324	68	20.	*	1	1924	98	20.
1	0136	9	2102.	*	1	0736	39	73.	*	1	1336	69	20.	*	1	1936	99	20.
1	0148	10	2781.	*	1	0748	40	49.	*	1	1348	70	20.	*	1	1948	100	20.
1	0200	11	3949.	*	1	0800	41	36.	*	1	1400	71	20.	*	1	2000	101	20.
1	0212	12	8264.	*	1	0812	42	29.	*	1	1412	72	20.	*	1	2012	102	20.
1	0224	13	13339.	*	1	0824	43	25.	*	1	1424	73	20.	*	1	2024	103	20.
1	0236	14	16329.	*	1	0836	44	22.	*	1	1436	74	20.	*	1	2036	104	20.
1	0248	15	15821.	*	1	0848	45	20.	*	1	1448	75	20.	*	1	2048	105	20.
1	0300	16	13330.	*	1	0900	46	20.	*	1	1500	76	20.	*	1	2100	106	20.
1	0312	17	10536.	*	1	0912	47	20.	*	1	1512	77	20.	*	1	2112	107	20.
1	0324	18	8376.	*	1	0924	48	20.	*	1	1524	78	20.	*	1	2124	108	20.
1	0336	19	6907.	*	1	0936	49	20.	*	1	1536	79	20.	*	1	2136	109	20.
1	0348	20	5909.	*	1	0948	50	20.	*	1	1548	80	20.	*	1	2148	110	20.
1	0400	21	5186.	*	1	1000	51	20.	*	1	1600	81	20.	*	1	2200	111	20.
1	0412	22	4621.	*	1	1012	52	20.	*	1	1612	82	20.	*	1	2212	112	20.
1	0424	23	4179.	*	1	1024	53	20.	*	1	1624	83	20.	*	1	2224	113	20.
1	0436	24	3839.	*	1	1036	54	20.	*	1	1636	84	20.	*	1	2236	114	20.
1	0448	25	3571.	*	1	1048	55	20.	*	1	1648	85	20.	*	1	2248	115	20.
1	0500	26	3350.	*	1	1100	56	20.	*	1	1700	86	20.	*	1	2300	116	20.
1	0512	27	3158.	*	1	1112	57	20.	*	1	1712	87	20.	*	1	2312	117	20.
1	0524	28	2996.	*	1	1124	58	20.	*	1	1724	88	20.	*	1	2324	118	20.
1	0536	29	2863.	*	1	1136	59	20.	*	1	1736	89	20.	*	1	2336	119	20.
1	0548	30	2753.	*	1	1148	60	20.	*	1	1748	90	20.	*	1	2348	120	20.
				*					*					*				

```
*****************************************************************************************************************
***

  PEAK FLOW      TIME                          MAXIMUM AVERAGE FLOW
                                     6-HR        24-HR        72-HR       23.80-HR
+   (CFS)        (HR)
                              (CFS)
+   16329.       2.60                 5184.       1340.        1340.        1340.
                           (INCHES)  22.843      23.422       23.422       23.422
                           (AC-FT)    2571.       2636.        2636.        2636.

                            CUMULATIVE AREA =    2.11 SQ MI


 *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
***

            **************
            *            *
  39 KK     *      DAM   *      ROUTE FLOOD HYDROGRAPHS THRU FAD#2
            *            *
            **************
                            STARTING POOL IS MAXIMUM OPERATING LEVEL
                            MAXIMUM TOP OF STOP LOG IS 972.5
                            STOP LOG WIDTH IS 4 FT

               HYDROGRAPH ROUTING DATA

  43 RS          STORAGE ROUTING
                      NSTPS          1  NUMBER OF SUBREACHES
                       ITYP       FLOW  TYPE OF INITIAL CONDITION
                     RSVRIC      20.60  INITIAL CONDITION
                          X        .00  WORKING R AND D COEFFICIENT

  44 SA                AREA      135.5     138.7     142.0     145.4     153.1     161.4     166.2     175.2     192.6
```

```
45 SE        ELEVATION     960.00   962.00   964.00   966.00   970.00   974.00   976.00   980.00   986.00

46 SQ        DISCHARGE         0.       5.      13.      25.      38.      53.      69.     300.     661.
1247.
                            1776.    2299.    3334.    4362.    5365.    5865.    6365.

48 SE        ELEVATION     972.50   973.00   973.50   974.00   974.50   975.00   975.50   976.27   976.89
977.70
                           978.37   978.98   980.06   981.02   981.90   982.32   982.73

50 SS        SPILLWAY
                    CREL    975.50  SPILLWAY CREST ELEVATION
                   SPWID       .00  SPILLWAY WIDTH
                    COQW       .00  WEIR COEFFICIENT
                    EXPW      1.50  EXPONENT OF HEAD

51 ST        TOP OF DAM
                   TOPEL    983.00  ELEVATION AT TOP OF DAM
                  DAMWID       .00  DAM WIDTH
                    COQD       .00  WEIR COEFFICIENT
                    EXPD       .00  EXPONENT OF HEAD
```

***

COMPUTED STORAGE-ELEVATION DATA

STORAGE	.00	274.19	554.89	842.28	1439.21	2068.14	2395.73	3078.45	4181.44
ELEVATION	960.00	962.00	964.00	966.00	970.00	974.00	976.00	980.00	986.00

COMPUTED STORAGE-OUTFLOW-ELEVATION DATA

(INCLUDING FLOW OVER DAM)

STORAGE	.00	274.19	554.89	842.28	1439.21	1828.40	1907.79	1987.70	2068.14	2149.14
OUTFLOW	.00	.00	.00	.00	.00	.00	4.70	13.30	24.50	37.70
ELEVATION	960.00	962.00	964.00	966.00	970.00	972.50	973.00	973.50	974.00	974.50
STORAGE	2230.74	2312.93	2395.73	2440.69	2544.53	2681.49	2795.89	2900.93	3078.45	3088.97
OUTFLOW	52.70	69.20	218.74	299.50	660.80	1247.10	1776.00	2298.90	3276.78	3334.30
ELEVATION	975.00	975.50	976.00	976.27	976.89	977.70	978.37	978.98	980.00	980.06
STORAGE	3258.64	3416.47	3492.58	3567.37	4181.44					
OUTFLOW	4362.00	5364.50	5864.90	6365.20	10355.69					
ELEVATION	981.02	981.90	982.32	982.73	986.00					

****
***

HYDROGRAPH AT STATION DAM

****
***

DA MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	*	DA MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	*	DA MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE
1	0000	1	21.	2040.1	973.8	*	1	0800	41	1966.	2833.9	978.6	*	1	1600	81	225.	2399.1	976.0
1	0012	2	21.	2042.1	973.8	*	1	0812	42	1812.	2803.2	978.4	*	1	1612	82	219.	2395.7	976.0
1	0024	3	22.	2046.9	973.9	*	1	0824	43	1679.	2774.8	978.2	*	1	1624	83	213.	2392.5	976.0
1	0036	4	22.	2052.8	973.9	*	1	0836	44	1557.	2748.4	978.1	*	1	1636	84	207.	2389.4	976.0
1	0048	5	23.	2060.2	974.0	*	1	0848	45	1444.	2724.0	977.9	*	1	1648	85	202.	2386.3	975.9
1	0100	6	25.	2070.8	974.0	*	1	0900	46	1339.	2701.3	977.8	*	1	1700	86	196.	2383.4	975.9
1	0112	7	28.	2086.5	974.1	*	1	0912	47	1242.	2680.3	977.7	*	1	1712	87	191.	2380.5	975.9
1	0124	8	31.	2108.9	974.3	*	1	0924	48	1159.	2660.8	977.6	*	1	1724	88	186.	2377.7	975.9
1	0136	9	36.	2139.0	974.4	*	1	0936	49	1081.	2642.6	977.5	*	1	1736	89	181.	2375.0	975.9
1	0148	10	43.	2178.6	974.7	*	1	0948	50	1009.	2625.7	977.4	*	1	1748	90	177.	2372.4	975.9
1	0200	11	53.	2233.4	975.0	*	1	1000	51	941.	2609.9	977.3	*	1	1800	91	172.	2369.8	975.8
1	0212	12	106.	2333.3	975.6	*	1	1012	52	878.	2595.2	977.2	*	1	1812	92	168.	2367.3	975.8
1	0224	13	529.	2506.6	976.7	*	1	1024	53	820.	2581.5	977.1	*	1	1824	93	163.	2364.9	975.8
1	0236	14	1495.	2735.0	978.0	*	1	1036	54	765.	2568.7	977.0	*	1	1836	94	159.	2362.6	975.8
1	0248	15	2661.	2966.4	979.4	*	1	1048	55	714.	2556.8	977.0	*	1	1848	95	155.	2360.3	975.8
1	0300	16	3739.	3155.5	980.4	*	1	1100	56	666.	2545.8	976.9	*	1	1900	96	151.	2358.1	975.8
1	0312	17	4529.	3284.7	981.2	*	1	1112	57	629.	2535.4	976.8	*	1	1912	97	147.	2356.0	975.8
1	0324	18	5021.	3362.1	981.6	*	1	1124	58	595.	2525.6	976.8	*	1	1924	98	143.	2353.9	975.7

1	0336	19	5280.	3403.1	981.8	*	1	1136	59	563.	2516.4	976.7	*	1	1936	99	140.	2351.9	975.7
1	0348	20	5393.	3420.8	981.9	*	1	1148	60	533.	2507.6	976.7	*	1	1948	100	136.	2350.0	975.7
1	0400	21	5409.	3423.2	981.9	*	1	1200	61	504.	2499.4	976.6	*	1	2000	101	133.	2348.1	975.7
1	0412	22	5357.	3415.3	981.9	*	1	1212	62	477.	2491.6	976.6	*	1	2012	102	129.	2346.2	975.7
1	0424	23	5263.	3400.4	981.8	*	1	1224	63	451.	2484.3	976.5	*	1	2024	103	126.	2344.5	975.7
1	0436	24	5139.	3380.8	981.7	*	1	1236	64	427.	2477.3	976.5	*	1	2036	104	123.	2342.7	975.7
1	0448	25	4997.	3358.4	981.6	*	1	1248	65	405.	2470.8	976.5	*	1	2048	105	120.	2341.1	975.7
1	0500	26	4845.	3334.4	981.4	*	1	1300	66	383.	2464.6	976.4	*	1	2100	106	117.	2339.4	975.7
1	0512	27	4687.	3309.5	981.3	*	1	1312	67	363.	2458.8	976.4	*	1	2112	107	114.	2337.9	975.7
1	0524	28	4527.	3284.4	981.2	*	1	1324	68	343.	2453.3	976.3	*	1	2124	108	112.	2336.3	975.6
1	0536	29	4367.	3259.4	981.0	*	1	1336	69	325.	2448.1	976.3	*	1	2136	109	109.	2334.8	975.6
1	0548	30	4220.	3235.1	980.9	*	1	1348	70	308.	2443.2	976.3	*	1	2148	110	106.	2333.4	975.6
1	0600	31	4078.	3211.4	980.8	*	1	1400	71	296.	2438.5	976.3	*	1	2200	111	104.	2332.0	975.6
1	0612	32	3920.	3185.3	980.6	*	1	1412	72	288.	2434.0	976.2	*	1	2212	112	101.	2330.6	975.6
1	0624	33	3720.	3152.4	980.4	*	1	1424	73	280.	2429.7	976.2	*	1	2224	113	99.	2329.3	975.6
1	0636	34	3481.	3113.1	980.2	*	1	1436	74	272.	2425.4	976.2	*	1	2236	114	97.	2328.0	975.6
1	0648	35	3229.	3069.8	980.0	*	1	1448	75	265.	2421.3	976.2	*	1	2248	115	94.	2326.8	975.6
1	0700	36	2986.	3025.4	979.7	*	1	1500	76	258.	2417.3	976.1	*	1	2300	116	92.	2325.6	975.6
1	0712	37	2748.	2982.1	979.4	*	1	1512	77	251.	2413.5	976.1	*	1	2312	117	90.	2324.4	975.6
1	0724	38	2521.	2941.1	979.2	*	1	1524	78	244.	2409.7	976.1	*	1	2324	118	88.	2323.3	975.6
1	0736	39	2309.	2902.7	979.0	*	1	1536	79	237.	2406.1	976.1	*	1	2336	119	86.	2322.2	975.6
1	0748	40	2131.	2867.0	978.8	*	1	1548	80	231.	2402.5	976.0	*	1	2348	120	84.	2321.1	975.5
						*							*						

****

PEAK OUTFLOW IS 5409. AT TIME 4.00 HOURS

PEAK FLOW	TIME		MAXIMUM AVERAGE FLOW			
			6-HR	24-HR	72-HR	23.80-HR
+ (CFS)	(HR)					
		(CFS)				
+ 5409.	4.00		3785.	1198.	1198.	1198.
		(INCHES)	16.677	20.947	20.947	20.947
		(AC-FT)	1877.	2357.	2357.	2357.

PEAK STORAGE	TIME	MAXIMUM AVERAGE STORAGE			
		6-HR	24-HR	72-HR	23.80-HR
+ (AC-FT)	(HR)				
3423.	4.00	3153.	2585.	2585.	2585.

PEAK STAGE	TIME	MAXIMUM AVERAGE STAGE			
		6-HR	24-HR	72-HR	23.80-HR
+ (FEET)	(HR)				
981.94	4.00	980.41	977.10	977.10	977.10

CUMULATIVE AREA = 2.11 SQ MI

1

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

	OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD			BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
+					6-HOUR	24-HOUR	72-HOUR			
+	HYDROGRAPH AT	WEST	8174.	2.80	2588.	658.	658.	1.06		
+	HYDROGRAPH AT	EAST	6527.	2.60	1767.	447.	447.	.75		
+	HYDROGRAPH AT	LAKE	3738.	2.40	869.	236.	236.	.30		
+	3 COMBINED AT	IN	16329.	2.60	5184.	1340.	1340.	2.11		
+	ROUTED TO	DAM	5409.	4.00	3785.	1198.	1198.	2.11		

981.94 4.00

1

SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION DAM
(PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED DURING BREACH FORMATION)

PLAN 1 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	973.83	975.50	983.00
STORAGE	2040.	2313.	3617.
OUTFLOW	21.	69.	6695.

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	981.94	.00	3423.	5409.	.00	4.00	.00

*** NORMAL END OF HEC-1 ***

981.94 < 983.0 ✓

```
1***************************************
***************************************
 *                                     *
*
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *
*
 *             JUN   1998               *
*
 *           VERSION 4.1                *
*
 *                                      *
*
 *  RUN DATE   22SEP12  TIME  16:46:48  *
*
 *                                      *
*
 ***************************************
***************************************
```

PMF, assume service spillway is blocked.

```
*
*  U.S. ARMY CORPS OF ENGINEERS
*  HYDROLOGIC ENGINEERING CENTER
*      609 SECOND STREET
*    DAVIS, CALIFORNIA 95616
*       (916) 756-1104
*
```

```
X     X  XXXXXXX   XXXXX         X
X     X  X        X     X       XX
X     X  X        X              X
XXXXXXX  XXXX     X        XXXXX X
X     X  X        X              X
X     X  X        X     X        X
X     X  XXXXXXX   XXXXX        XXX
```

THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM


```
         LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

 *** FREE ***
           1           ID   CARDINAL FLY ASH DAM #2
           2           ID   THIRD RAISING - CREST OF 983 FT
           3           ID   DESIGN FLOOD     PMP, 6-HR
           4           ID   FILE: FAD2-PMP-105FT-noPS
           5           IT      12       0       0     120
           6           IO       1
           7           PG      10    26.5
           8           PC       0   .0130    .027    .042    .059    .078    .099    .122    .147     .18
           9           PC     .23     .38     .53    .625     .67    .705    .736    .764     .79    .814
          10           PC    .836    .856    .875   .8931   .9103   .9267   .9423   .9573   .9719   .9861
          11           PC     1.0

          12           KK    WEST RUNOFF FROM FAD#1 WATERSHED
          13           KM   RECLAIMED POND AND LANDFILL
          14           BA    1.06
          15           LS       0      75
          16           PR      10
          17           PW       1
          18           PT      10
          19           UD    0.52

          20           KK    EAST RUNOFF FROM EAST WATERSHED
          21           KM   WOODS ONLY
          22           BA    0.75
          23           LS       0      70
          24           PR      10
          25           PW       1
          26           PT      10
          27           UD    0.34

          28           KK    LAKE INSTANTANEOUS RUNOFF FROM LAKE SURFACE
          29           KM   LAKE ONLY
          30           BA    0.30
          31           BF      20
          32           LS       0     100
          33           PR      10
          34           PW       1
          35           PT      10
          36           UD     0.1

          37           KK      IN COMBINE INFLOWS FROM WEST AND EAST WATERSHEDS AND LAKE SURFACE
          38           HC       3

          39           KK     DAM ROUTE FLOOD HYDROGRAPHS THRU FAD#2
          40           KM   STARTING POOL IS MAXIMUM OPERATING LEVEL
          41           KM   ASSUME PRINCIPAL SPILLWAY IS BLOCKED
          42           RS       1    FLOW    20.6
```

```
         43          SA   135.5   138.7   142.0   145.4   153.1   161.4   166.2   175.2   192.6
         44          SE     960     962     964     966     970     974     976     980     986
         45          SQ       0       0       0       0       0       0       0     200     500    1000
         46          SQ    1500    2000    3000    4000    5000    5500    6000
         47          SE   972.5     973   973.5     974   974.5     975   975.5  976.27  976.89   977.7
         48          SE  978.37  978.98  980.06  981.02   981.9  982.32  982.73
         49          SS   975.5
1                                                   HEC-1 INPUT                                            PAGE  2

       LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

         50          ST     983
         51          ZZ
1*****************************************
***************************************
 *                                       *                                                  *
*
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                                  *   U.S. ARMY CORPS OF ENGINEERS
*
 *             JUN   1998                *                                                  *   HYDROLOGIC ENGINEERING CENTER
*
 *          VERSION 4.1                  *                                                  *         609 SECOND STREET
*
 *                                       *                                                  *      DAVIS, CALIFORNIA 95616
*
 *  RUN DATE   22SEP12  TIME  16:46:48   *                                                  *          (916) 756-1104
*
 *                                       *                                                  *
*
 *****************************************
***************************************




                         CARDINAL FLY ASH DAM #2
                         THIRD RAISING - CREST OF 983 FT
                         DESIGN FLOOD     PMP, 6-HR
                         FILE: FAD2-PMP-105FT-noPS

    6 IO          OUTPUT CONTROL VARIABLES
                        IPRNT           1  PRINT CONTROL
                        IPLOT           0  PLOT CONTROL
                        QSCAL          0.  HYDROGRAPH PLOT SCALE

      IT          HYDROGRAPH TIME DATA
                         NMIN          12  MINUTES IN COMPUTATION INTERVAL
                        IDATE       1   0  STARTING DATE
                        ITIME        0000  STARTING TIME
                           NQ         120  NUMBER OF HYDROGRAPH ORDINATES
                       NDDATE       1   0  ENDING DATE
                       NDTIME        2348  ENDING TIME
                        ICENT          19  CENTURY MARK

                    COMPUTATION INTERVAL     .20 HOURS
                         TOTAL TIME BASE   23.80 HOURS

         ENGLISH UNITS
              DRAINAGE AREA          SQUARE MILES
              PRECIPITATION DEPTH    INCHES
              LENGTH, ELEVATION      FEET
              FLOW                   CUBIC FEET PER SECOND
              STORAGE VOLUME         ACRE-FEET
              SURFACE AREA           ACRES
              TEMPERATURE            DEGREES FAHRENHEIT


 *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
***

             **************
             *            *
   12 KK     *     WEST   *      RUNOFF FROM FAD#1 WATERSHED
             *            *
             **************
                         RECLAIMED POND AND LANDFILL

                SUBBASIN RUNOFF DATA

   14 BA          SUBBASIN CHARACTERISTICS
                        TAREA        1.06  SUBBASIN AREA

                  PRECIPITATION DATA

   18 PT           TOTAL STORM STATIONS        10
    0 PW                        WEIGHTS      1.00

   16 PR             RECORDING STATIONS        10
   17 PW                        WEIGHTS      1.00

   15 LS          SCS LOSS RATE
                        STRTL         .67  INITIAL ABSTRACTION
```

CRVNBR 75.00 CURVE NUMBER
RTIMP .00 PERCENT IMPERVIOUS AREA

19 UD SCS DIMENSIONLESS UNITGRAPH
TLAG .52 LAG

***

PRECIPITATION STATION DATA

STATION	TOTAL	AVG. ANNUAL	WEIGHT
10	26.50	.00	1.00

TEMPORAL DISTRIBUTIONS

STATION 10, WEIGHT = 1.00

.01	.01	.01	.02	.02	.02	.02	.02	.03	.05
.15	.15	.10	.05	.03	.03	.03	.03	.02	.02
.02	.02	.02	.02	.02	.02	.01	.01	.01	.01
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	

WARNING *** TIME INTERVAL IS GREATER THAN .29*LAG

UNIT HYDROGRAPH
15 END-OF-PERIOD ORDINATES

180.	607.	826.	718.	453.	259.	157.	92.	54.	32.
19.	11.	7.	4.	1.					

****

HYDROGRAPH AT STATION WEST

****

DA	MON HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q	*	DA	MON HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q
1	0000	1	.00	.00	.00	0.	*	1	1200	61	.00	.00	.00	0.
1	0012	2	.34	.34	.00	0.	*	1	1212	62	.00	.00	.00	0.
1	0024	3	.37	.37	.00	0.	*	1	1224	63	.00	.00	.00	0.
1	0036	4	.40	.35	.05	10.	*	1	1236	64	.00	.00	.00	0.
1	0048	5	.45	.31	.14	57.	*	1	1248	65	.00	.00	.00	0.
1	0100	6	.50	.28	.22	167.	*	1	1300	66	.00	.00	.00	0.
1	0112	7	.56	.25	.31	343.	*	1	1312	67	.00	.00	.00	0.
1	0124	8	.61	.22	.39	566.	*	1	1324	68	.00	.00	.00	0.
1	0136	9	.66	.19	.47	815.	*	1	1336	69	.00	.00	.00	0.
1	0148	10	.87	.20	.68	1100.	*	1	1348	70	.00	.00	.00	0.
1	0200	11	1.32	.23	1.10	1504.	*	1	1400	71	.00	.00	.00	0.
1	0212	12	3.97	.40	3.58	2516.	*	1	1412	72	.00	.00	.00	0.
1	0224	13	3.97	.21	3.77	4635.	*	1	1424	73	.00	.00	.00	0.
1	0236	14	2.52	.09	2.43	7003.	*	1	1436	74	.00	.00	.00	0.
1	0248	15	1.19	.03	1.16	8174.	*	1	1448	75	.00	.00	.00	0.
1	0300	16	.93	.02	.90	7671.	*	1	1500	76	.00	.00	.00	0.
1	0312	17	.82	.02	.80	6310.	*	1	1512	77	.00	.00	.00	0.
1	0324	18	.74	.02	.73	5000.	*	1	1524	78	.00	.00	.00	0.
1	0336	19	.69	.01	.67	4045.	*	1	1536	79	.00	.00	.00	0.
1	0348	20	.64	.01	.62	3386.	*	1	1548	80	.00	.00	.00	0.
1	0400	21	.58	.01	.57	2915.	*	1	1600	81	.00	.00	.00	0.
1	0412	22	.53	.01	.52	2566.	*	1	1612	82	.00	.00	.00	0.
1	0424	23	.50	.01	.49	2292.	*	1	1624	83	.00	.00	.00	0.
1	0436	24	.48	.01	.47	2077.	*	1	1636	84	.00	.00	.00	0.
1	0448	25	.46	.01	.45	1908.	*	1	1648	85	.00	.00	.00	0.
1	0500	26	.43	.01	.43	1771.	*	1	1700	86	.00	.00	.00	0.
1	0512	27	.41	.01	.41	1657.	*	1	1712	87	.00	.00	.00	0.
1	0524	28	.40	.01	.39	1562.	*	1	1724	88	.00	.00	.00	0.
1	0536	29	.39	.01	.38	1484.	*	1	1736	89	.00	.00	.00	0.
1	0548	30	.38	.01	.37	1419.	*	1	1748	90	.00	.00	.00	0.
1	0600	31	.37	.00	.36	1366.	*	1	1800	91	.00	.00	.00	0.
1	0612	32	.00	.00	.00	1258.	*	1	1812	92	.00	.00	.00	0.
1	0624	33	.00	.00	.00	1007.	*	1	1824	93	.00	.00	.00	0.
1	0636	34	.00	.00	.00	686.	*	1	1836	94	.00	.00	.00	0.
1	0648	35	.00	.00	.00	413.	*	1	1848	95	.00	.00	.00	0.
1	0700	36	.00	.00	.00	241.	*	1	1900	96	.00	.00	.00	0.
1	0712	37	.00	.00	.00	143.	*	1	1912	97	.00	.00	.00	0.
1	0724	38	.00	.00	.00	83.	*	1	1924	98	.00	.00	.00	0.
1	0736	39	.00	.00	.00	49.	*	1	1936	99	.00	.00	.00	0.
1	0748	40	.00	.00	.00	28.	*	1	1948	100	.00	.00	.00	0.
1	0800	41	.00	.00	.00	16.	*	1	2000	101	.00	.00	.00	0.
1	0812	42	.00	.00	.00	9.	*	1	2012	102	.00	.00	.00	0.
1	0824	43	.00	.00	.00	5.	*	1	2024	103	.00	.00	.00	0.
1	0836	44	.00	.00	.00	2.	*	1	2036	104	.00	.00	.00	0.
1	0848	45	.00	.00	.00	0.	*	1	2048	105	.00	.00	.00	0.
1	0900	46	.00	.00	.00	0.	*	1	2100	106	.00	.00	.00	0.
1	0912	47	.00	.00	.00	0.	*	1	2112	107	.00	.00	.00	0.

1	0924	48	.00	.00	.00	0.	*	1	2124	108	.00	.00	.00	0.
1	0936	49	.00	.00	.00	0.	*	1	2136	109	.00	.00	.00	0.
1	0948	50	.00	.00	.00	0.	*	1	2148	110	.00	.00	.00	0.
1	1000	51	.00	.00	.00	0.	*	1	2200	111	.00	.00	.00	0.
1	1012	52	.00	.00	.00	0.	*	1	2212	112	.00	.00	.00	0.
1	1024	53	.00	.00	.00	0.	*	1	2224	113	.00	.00	.00	0.
1	1036	54	.00	.00	.00	0.	*	1	2236	114	.00	.00	.00	0.
1	1048	55	.00	.00	.00	0.	*	1	2248	115	.00	.00	.00	0.
1	1100	56	.00	.00	.00	0.	*	1	2300	116	.00	.00	.00	0.
1	1112	57	.00	.00	.00	0.	*	1	2312	117	.00	.00	.00	0.
1	1124	58	.00	.00	.00	0.	*	1	2324	118	.00	.00	.00	0.
1	1136	59	.00	.00	.00	0.	*	1	2336	119	.00	.00	.00	0.
1	1148	60	.00	.00	.00	0.	*	1	2348	120	.00	.00	.00	0.
							*							

```
*****************************************************************************************************************************
***

    TOTAL RAINFALL =   26.50, TOTAL LOSS =     3.62, TOTAL EXCESS =   22.88

  PEAK FLOW      TIME                          MAXIMUM AVERAGE FLOW
                                       6-HR        24-HR       72-HR      23.80-HR
+   (CFS)        (HR)
                               (CFS)
+    8174.       2.80                  2588.        658.        658.        658.
                             (INCHES)  22.704      22.881      22.881      22.881
                              (AC-FT)   1284.       1294.       1294.       1294.

                               CUMULATIVE AREA =     1.06 SQ MI


*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
***

            **************
            *            *
  20 KK     *     EAST   *      RUNOFF FROM EAST WATERSHED
            *            *
            **************
                          WOODS ONLY

              SUBBASIN RUNOFF DATA

  22 BA         SUBBASIN CHARACTERISTICS
                      TAREA          .75  SUBBASIN AREA

                PRECIPITATION DATA

  26 PT           TOTAL STORM STATIONS          10
   0 PW                        WEIGHTS        1.00

  24 PR             RECORDING STATIONS          10
  25 PW                        WEIGHTS        1.00

  23 LS         SCS LOSS RATE
                      STRTL          .86  INITIAL ABSTRACTION
                     CRVNBR        70.00  CURVE NUMBER
                      RTIMP          .00  PERCENT IMPERVIOUS AREA

  27 UD         SCS DIMENSIONLESS UNITGRAPH
                       TLAG          .34  LAG

                                                                   ***

              PRECIPITATION STATION DATA

                     STATION    TOTAL    AVG. ANNUAL     WEIGHT
                          10    26.50            .00       1.00

                TEMPORAL DISTRIBUTIONS

                STATION       10, WEIGHT =   1.00
```

.01	.01	.01	.02	.02	.02	.02	.02	.03	.05
.15	.15	.10	.05	.03	.03	.03	.03	.02	.02
.02	.02	.02	.02	.02	.02	.01	.01	.01	.01
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	

```
 WARNING *** TIME INTERVAL IS GREATER THAN .29*LAG

                                                              UNIT HYDROGRAPH
                                                         10 END-OF-PERIOD ORDINATES
        329.       820.       669.       314.       153.        73.        34.        16.         8.         4.
```

****
***

HYDROGRAPH AT STATION EAST

****
***

DA MON	HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q	*	DA MON	HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q
1	0000	1	.00	.00	.00	0.	*	1	1200	61	.00	.00	.00	0.
1	0012	2	.34	.34	.00	0.	*	1	1212	62	.00	.00	.00	0.
1	0024	3	.37	.37	.00	0.	*	1	1224	63	.00	.00	.00	0.
1	0036	4	.40	.38	.01	5.	*	1	1236	64	.00	.00	.00	0.
1	0048	5	.45	.36	.09	40.	*	1	1248	65	.00	.00	.00	0.
1	0100	6	.50	.34	.17	134.	*	1	1300	66	.00	.00	.00	0.
1	0112	7	.56	.31	.25	280.	*	1	1312	67	.00	.00	.00	0.
1	0124	8	.61	.28	.33	454.	*	1	1324	68	.00	.00	.00	0.
1	0136	9	.66	.25	.41	641.	*	1	1336	69	.00	.00	.00	0.
1	0148	10	.87	.27	.61	871.	*	1	1348	70	.00	.00	.00	0.
1	0200	11	1.32	.31	1.01	1265.	*	1	1400	71	.00	.00	.00	0.
1	0212	12	3.97	.57	3.41	2563.	*	1	1412	72	.00	.00	.00	0.
1	0224	13	3.97	.31	3.67	4966.	*	1	1424	73	.00	.00	.00	0.
1	0236	14	2.52	.13	2.39	6527.	*	1	1436	74	.00	.00	.00	0.
1	0248	15	1.19	.05	1.14	6074.	*	1	1448	75	.00	.00	.00	0.
1	0300	16	.93	.04	.89	4601.	*	1	1500	76	.00	.00	.00	0.
1	0312	17	.82	.03	.79	3361.	*	1	1512	77	.00	.00	.00	0.
1	0324	18	.74	.03	.72	2611.	*	1	1524	78	.00	.00	.00	0.
1	0336	19	.69	.02	.67	2157.	*	1	1536	79	.00	.00	.00	0.
1	0348	20	.64	.02	.62	1871.	*	1	1548	80	.00	.00	.00	0.
1	0400	21	.58	.02	.57	1670.	*	1	1600	81	.00	.00	.00	0.
1	0412	22	.53	.01	.52	1506.	*	1	1612	82	.00	.00	.00	0.
1	0424	23	.50	.01	.49	1371.	*	1	1624	83	.00	.00	.00	0.
1	0436	24	.48	.01	.47	1270.	*	1	1636	84	.00	.00	.00	0.
1	0448	25	.46	.01	.44	1195.	*	1	1648	85	.00	.00	.00	0.
1	0500	26	.43	.01	.42	1132.	*	1	1700	86	.00	.00	.00	0.
1	0512	27	.41	.01	.40	1075.	*	1	1712	87	.00	.00	.00	0.
1	0524	28	.40	.01	.39	1024.	*	1	1724	88	.00	.00	.00	0.
1	0536	29	.39	.01	.38	981.	*	1	1736	89	.00	.00	.00	0.
1	0548	30	.38	.01	.37	946.	*	1	1748	90	.00	.00	.00	0.
1	0600	31	.37	.01	.36	917.	*	1	1800	91	.00	.00	.00	0.
1	0612	32	.00	.00	.00	777.	*	1	1812	92	.00	.00	.00	0.
1	0624	33	.00	.00	.00	469.	*	1	1824	93	.00	.00	.00	0.
1	0636	34	.00	.00	.00	222.	*	1	1836	94	.00	.00	.00	0.
1	0648	35	.00	.00	.00	106.	*	1	1848	95	.00	.00	.00	0.
1	0700	36	.00	.00	.00	50.	*	1	1900	96	.00	.00	.00	0.
1	0712	37	.00	.00	.00	23.	*	1	1912	97	.00	.00	.00	0.
1	0724	38	.00	.00	.00	10.	*	1	1924	98	.00	.00	.00	0.
1	0736	39	.00	.00	.00	4.	*	1	1936	99	.00	.00	.00	0.
1	0748	40	.00	.00	.00	1.	*	1	1948	100	.00	.00	.00	0.
1	0800	41	.00	.00	.00	0.	*	1	2000	101	.00	.00	.00	0.
1	0812	42	.00	.00	.00	0.	*	1	2012	102	.00	.00	.00	0.
1	0824	43	.00	.00	.00	0.	*	1	2024	103	.00	.00	.00	0.
1	0836	44	.00	.00	.00	0.	*	1	2036	104	.00	.00	.00	0.
1	0848	45	.00	.00	.00	0.	*	1	2048	105	.00	.00	.00	0.
1	0900	46	.00	.00	.00	0.	*	1	2100	106	.00	.00	.00	0.
1	0912	47	.00	.00	.00	0.	*	1	2112	107	.00	.00	.00	0.
1	0924	48	.00	.00	.00	0.	*	1	2124	108	.00	.00	.00	0.
1	0936	49	.00	.00	.00	0.	*	1	2136	109	.00	.00	.00	0.
1	0948	50	.00	.00	.00	0.	*	1	2148	110	.00	.00	.00	0.
1	1000	51	.00	.00	.00	0.	*	1	2200	111	.00	.00	.00	0.
1	1012	52	.00	.00	.00	0.	*	1	2212	112	.00	.00	.00	0.
1	1024	53	.00	.00	.00	0.	*	1	2224	113	.00	.00	.00	0.
1	1036	54	.00	.00	.00	0.	*	1	2236	114	.00	.00	.00	0.
1	1048	55	.00	.00	.00	0.	*	1	2248	115	.00	.00	.00	0.
1	1100	56	.00	.00	.00	0.	*	1	2300	116	.00	.00	.00	0.
1	1112	57	.00	.00	.00	0.	*	1	2312	117	.00	.00	.00	0.
1	1124	58	.00	.00	.00	0.	*	1	2324	118	.00	.00	.00	0.
1	1136	59	.00	.00	.00	0.	*	1	2336	119	.00	.00	.00	0.
1	1148	60	.00	.00	.00	0.	*	1	2348	120	.00	.00	.00	0.

****
***

TOTAL RAINFALL = 26.50, TOTAL LOSS = 4.53, TOTAL EXCESS = 21.97

	PEAK FLOW	TIME		MAXIMUM AVERAGE FLOW			
				6-HR	24-HR	72-HR	23.80-HR
+	(CFS)	(HR)					
			(CFS)				
+	6527.	2.60		1767.	447.	447.	447.
			(INCHES)	21.902	21.971	21.971	21.971
			(AC-FT)	876.	879.	879.	879.

CUMULATIVE AREA = .75 SQ MI

*** ***
***

```
              **************
              *            *
  28 KK       *    LAKE    *     INSTANTANEOUS RUNOFF FROM LAKE SURFACE
              *            *
              **************
                     LAKE ONLY

                SUBBASIN RUNOFF DATA

  30 BA           SUBBASIN CHARACTERISTICS
                        TAREA        .30  SUBBASIN AREA

  31 BF           BASE FLOW CHARACTERISTICS
                        STRTQ      20.00  INITIAL FLOW
                        QRCSN        .00  BEGIN BASE FLOW RECESSION
                        RTIOR    1.00000  RECESSION CONSTANT

                  PRECIPITATION DATA

  35 PT            TOTAL STORM STATIONS       10
   0 PW                         WEIGHTS     1.00

  33 PR               RECORDING STATIONS      10
  34 PW                         WEIGHTS     1.00

  32 LS           SCS LOSS RATE
                        STRTL        .00  INITIAL ABSTRACTION
                       CRVNBR     100.00  CURVE NUMBER
                        RTIMP        .00  PERCENT IMPERVIOUS AREA

  36 UD           SCS DIMENSIONLESS UNITGRAPH
                         TLAG        .10  LAG

                                                                ***

                PRECIPITATION STATION DATA

                         STATION    TOTAL    AVG. ANNUAL    WEIGHT
                              10    26.50            .00      1.00

                  TEMPORAL DISTRIBUTIONS

                  STATION       10,  WEIGHT =   1.00
                        .01      .01      .01      .02      .02      .02      .02      .02      .03      .05
                        .15      .15      .10      .05      .03      .03      .03      .03      .02      .02
                        .02      .02      .02      .02      .02      .02      .01      .01      .01      .01
                        .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                        .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                        .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                        .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                        .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                        .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                        .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                        .00      .00      .00      .00      .00      .00      .00      .00      .00      .00
                        .00      .00      .00      .00      .00      .00      .00      .00      .00

WARNING *** TIME INTERVAL IS GREATER THAN .29*LAG

                                                          UNIT HYDROGRAPH
                                                      5 END-OF-PERIOD ORDINATES
                719.      201.      40.       8.        0.

*****************************************************************************************************************************
***

                                                 HYDROGRAPH AT STATION      LAKE

*****************************************************************************************************************************
***
```

DA	MON	HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q	*	DA	MON	HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q
1		0000	1	.00	.00	.00	20.	*	1		1200	61	.00	.00	.00	20.
1		0012	2	.34	.00	.34	268.	*	1		1212	62	.00	.00	.00	20.
1		0024	3	.37	.00	.37	356.	*	1		1224	63	.00	.00	.00	20.
1		0036	4	.40	.00	.40	394.	*	1		1236	64	.00	.00	.00	20.
1		0048	5	.45	.00	.45	441.	*	1		1248	65	.00	.00	.00	20.
1		0100	6	.50	.00	.50	491.	*	1		1300	66	.00	.00	.00	20.
1		0112	7	.56	.00	.56	543.	*	1		1312	67	.00	.00	.00	20.
1		0124	8	.61	.00	.61	594.	*	1		1324	68	.00	.00	.00	20.
1		0136	9	.66	.00	.66	645.	*	1		1336	69	.00	.00	.00	20.
1		0148	10	.87	.00	.87	811.	*	1		1348	70	.00	.00	.00	20.
1		0200	11	1.32	.00	1.32	1180.	*	1		1400	71	.00	.00	.00	20.
1		0212	12	3.97	.00	3.97	3185.	*	1		1412	72	.00	.00	.00	20.
1		0224	13	3.97	.00	3.97	3738.	*	1		1424	73	.00	.00	.00	20.
1		0236	14	2.52	.00	2.52	2799.	*	1		1436	74	.00	.00	.00	20.
1		0248	15	1.19	.00	1.19	1573.	*	1		1448	75	.00	.00	.00	20.
1		0300	16	.93	.00	.93	1058.	*	1		1500	76	.00	.00	.00	20.
1		0312	17	.82	.00	.82	865.	*	1		1512	77	.00	.00	.00	20.
1		0324	18	.74	.00	.74	765.	*	1		1524	78	.00	.00	.00	20.
1		0336	19	.69	.00	.69	705.	*	1		1536	79	.00	.00	.00	20.
1		0348	20	.64	.00	.64	652.	*	1		1548	80	.00	.00	.00	20.

1	0400	21	.58	.00	.58	600.	*	1	1600	81	.00	.00	.00	20.
1	0412	22	.53	.00	.53	549.	*	1	1612	82	.00	.00	.00	20.
1	0424	23	.50	.00	.50	517.	*	1	1624	83	.00	.00	.00	20.
1	0436	24	.48	.00	.48	492.	*	1	1636	84	.00	.00	.00	20.
1	0448	25	.46	.00	.46	468.	*	1	1648	85	.00	.00	.00	20.
1	0500	26	.43	.00	.43	447.	*	1	1700	86	.00	.00	.00	20.
1	0512	27	.41	.00	.41	427.	*	1	1712	87	.00	.00	.00	20.
1	0524	28	.40	.00	.40	410.	*	1	1724	88	.00	.00	.00	20.
1	0536	29	.39	.00	.39	398.	*	1	1736	89	.00	.00	.00	20.
1	0548	30	.38	.00	.38	388.	*	1	1748	90	.00	.00	.00	20.
1	0600	31	.37	.00	.37	379.	*	1	1800	91	.00	.00	.00	20.
1	0612	32	.00	.00	.00	112.	*	1	1812	92	.00	.00	.00	20.
1	0624	33	.00	.00	.00	38.	*	1	1824	93	.00	.00	.00	20.
1	0636	34	.00	.00	.00	23.	*	1	1836	94	.00	.00	.00	20.
1	0648	35	.00	.00	.00	20.	*	1	1848	95	.00	.00	.00	20.
1	0700	36	.00	.00	.00	20.	*	1	1900	96	.00	.00	.00	20.
1	0712	37	.00	.00	.00	20.	*	1	1912	97	.00	.00	.00	20.
1	0724	38	.00	.00	.00	20.	*	1	1924	98	.00	.00	.00	20.
1	0736	39	.00	.00	.00	20.	*	1	1936	99	.00	.00	.00	20.
1	0748	40	.00	.00	.00	20.	*	1	1948	100	.00	.00	.00	20.
1	0800	41	.00	.00	.00	20.	*	1	2000	101	.00	.00	.00	20.
1	0812	42	.00	.00	.00	20.	*	1	2012	102	.00	.00	.00	20.
1	0824	43	.00	.00	.00	20.	*	1	2024	103	.00	.00	.00	20.
1	0836	44	.00	.00	.00	20.	*	1	2036	104	.00	.00	.00	20.
1	0848	45	.00	.00	.00	20.	*	1	2048	105	.00	.00	.00	20.
1	0900	46	.00	.00	.00	20.	*	1	2100	106	.00	.00	.00	20.
1	0912	47	.00	.00	.00	20.	*	1	2112	107	.00	.00	.00	20.
1	0924	48	.00	.00	.00	20.	*	1	2124	108	.00	.00	.00	20.
1	0936	49	.00	.00	.00	20.	*	1	2136	109	.00	.00	.00	20.
1	0948	50	.00	.00	.00	20.	*	1	2148	110	.00	.00	.00	20.
1	1000	51	.00	.00	.00	20.	*	1	2200	111	.00	.00	.00	20.
1	1012	52	.00	.00	.00	20.	*	1	2212	112	.00	.00	.00	20.
1	1024	53	.00	.00	.00	20.	*	1	2224	113	.00	.00	.00	20.
1	1036	54	.00	.00	.00	20.	*	1	2236	114	.00	.00	.00	20.
1	1048	55	.00	.00	.00	20.	*	1	2248	115	.00	.00	.00	20.
1	1100	56	.00	.00	.00	20.	*	1	2300	116	.00	.00	.00	20.
1	1112	57	.00	.00	.00	20.	*	1	2312	117	.00	.00	.00	20.
1	1124	58	.00	.00	.00	20.	*	1	2324	118	.00	.00	.00	20.
1	1136	59	.00	.00	.00	20.	*	1	2336	119	.00	.00	.00	20.
1	1148	60	.00	.00	.00	20.	*	1	2348	120	.00	.00	.00	20.

****
***

TOTAL RAINFALL = 26.50, TOTAL LOSS = .00, TOTAL EXCESS = 26.50

PEAK FLOW	TIME		MAXIMUM AVERAGE FLOW			
			6-HR	24-HR	72-HR	23.80-HR
+ (CFS)	(HR)					
		(CFS)				
+ 3738.	2.40		869.	236.	236.	236.
		(INCHES)	26.923	28.959	28.959	28.959
		(AC-FT)	431.	463.	463.	463.

CUMULATIVE AREA = .30 SQ MI

*** ***
***

****
*   *
37 KK * IN * COMBINE INFLOWS FROM WEST AND EAST WATERSHEDS AND LAKE SURFACE
*   *
****

38 HC HYDROGRAPH COMBINATION
ICOMP 3 NUMBER OF HYDROGRAPHS TO COMBINE

***

****
***

HYDROGRAPH AT STATION IN
SUM OF 3 HYDROGRAPHS

****
***

DA	MON	HRMN	ORD	FLOW	*	DA	MON	HRMN	ORD	FLOW	*	DA	MON	HRMN	ORD	FLOW	*	DA	MON	HRMN	ORD	FLOW
1		0000	1	20.	*	1		0600	31	2663.	*	1		1200	61	20.	*	1		1800	91	20.
1		0012	2	268.	*	1		0612	32	2148.	*	1		1212	62	20.	*	1		1812	92	20.
1		0024	3	356.	*	1		0624	33	1513.	*	1		1224	63	20.	*	1		1824	93	20.

1	0036	4	409.	*	1	0636	34	931.	*	1	1236	64	20.	*	1	1836	94	20.
1	0048	5	538.	*	1	0648	35	539.	*	1	1248	65	20.	*	1	1848	95	20.
1	0100	6	793.	*	1	0700	36	311.	*	1	1300	66	20.	*	1	1900	96	20.
1	0112	7	1165.	*	1	0712	37	186.	*	1	1312	67	20.	*	1	1912	97	20.
1	0124	8	1613.	*	1	0724	38	114.	*	1	1324	68	20.	*	1	1924	98	20.
1	0136	9	2102.	*	1	0736	39	73.	*	1	1336	69	20.	*	1	1936	99	20.
1	0148	10	2781.	*	1	0748	40	49.	*	1	1348	70	20.	*	1	1948	100	20.
1	0200	11	3949.	*	1	0800	41	36.	*	1	1400	71	20.	*	1	2000	101	20.
1	0212	12	8264.	*	1	0812	42	29.	*	1	1412	72	20.	*	1	2012	102	20.
1	0224	13	13339.	*	1	0824	43	25.	*	1	1424	73	20.	*	1	2024	103	20.
1	0236	14	16329.	*	1	0836	44	22.	*	1	1436	74	20.	*	1	2036	104	20.
1	0248	15	15821.	*	1	0848	45	20.	*	1	1448	75	20.	*	1	2048	105	20.
1	0300	16	13330.	*	1	0900	46	20.	*	1	1500	76	20.	*	1	2100	106	20.
1	0312	17	10536.	*	1	0912	47	20.	*	1	1512	77	20.	*	1	2112	107	20.
1	0324	18	8376.	*	1	0924	48	20.	*	1	1524	78	20.	*	1	2124	108	20.
1	0336	19	6907.	*	1	0936	49	20.	*	1	1536	79	20.	*	1	2136	109	20.
1	0348	20	5909.	*	1	0948	50	20.	*	1	1548	80	20.	*	1	2148	110	20.
1	0400	21	5186.	*	1	1000	51	20.	*	1	1600	81	20.	*	1	2200	111	20.
1	0412	22	4621.	*	1	1012	52	20.	*	1	1612	82	20.	*	1	2212	112	20.
1	0424	23	4179.	*	1	1024	53	20.	*	1	1624	83	20.	*	1	2224	113	20.
1	0436	24	3839.	*	1	1036	54	20.	*	1	1636	84	20.	*	1	2236	114	20.
1	0448	25	3571.	*	1	1048	55	20.	*	1	1648	85	20.	*	1	2248	115	20.
1	0500	26	3350.	*	1	1100	56	20.	*	1	1700	86	20.	*	1	2300	116	20.
1	0512	27	3158.	*	1	1112	57	20.	*	1	1712	87	20.	*	1	2312	117	20.
1	0524	28	2996.	*	1	1124	58	20.	*	1	1724	88	20.	*	1	2324	118	20.
1	0536	29	2863.	*	1	1136	59	20.	*	1	1736	89	20.	*	1	2336	119	20.
1	0548	30	2753.	*	1	1148	60	20.	*	1	1748	90	20.	*	1	2348	120	20.
				*					*					*				

```
*****************************************************************************************************************************
***

  PEAK FLOW      TIME                          MAXIMUM AVERAGE FLOW
                                     6-HR         24-HR        72-HR       23.80-HR
+   (CFS)        (HR)
                              (CFS)
+   16329.       2.60                5184.        1340.        1340.        1340.
                           (INCHES) 22.843       23.422       23.422       23.422
                            (AC-FT)  2571.        2636.        2636.        2636.

                            CUMULATIVE AREA =     2.11 SQ MI



 *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
***

             **************
             *            *
   39 KK     *      DAM   *      ROUTE FLOOD HYDROGRAPHS THRU FAD#2
             *            *
             **************
                              STARTING POOL IS MAXIMUM OPERATING LEVEL
                              ASSUME PRINCIPAL SPILLWAY IS BLOCKED

                HYDROGRAPH ROUTING DATA

   42 RS          STORAGE ROUTING
                       NSTPS           1  NUMBER OF SUBREACHES
                        ITYP        FLOW  TYPE OF INITIAL CONDITION
                      RSVRIC       20.60  INITIAL CONDITION
                           X         .00  WORKING R AND D COEFFICIENT

   43 SA                AREA     135.5     138.7     142.0     145.4     153.1     161.4     166.2     175.2     192.6

   44 SE           ELEVATION    960.00    962.00    964.00    966.00    970.00    974.00    976.00    980.00    986.00
```

```
  45 SQ        DISCHARGE         0.        0.        0.        0.        0.        0.        0.      200.      500.
1000.
                              1500.     2000.     3000.     4000.     5000.     5500.     6000.

  47 SE        ELEVATION     972.50    973.00    973.50    974.00    974.50    975.00    975.50    976.27    976.89
977.70
                             978.37    978.98    980.06    981.02    981.90    982.32    982.73

  49 SS        SPILLWAY
                      CREL     975.50  SPILLWAY CREST ELEVATION
                     SPWID        .00  SPILLWAY WIDTH
                      COQW        .00  WEIR COEFFICIENT
                      EXPW       1.50  EXPONENT OF HEAD

  50 ST        TOP OF DAM
                     TOPEL     983.00  ELEVATION AT TOP OF DAM
                    DAMWID        .00  DAM WIDTH
                      COQD        .00  WEIR COEFFICIENT
                      EXPD        .00  EXPONENT OF HEAD
```

***

COMPUTED STORAGE-ELEVATION DATA

STORAGE	.00	274.19	554.89	842.28	1439.21	2068.14	2395.73	3078.45	4181.44
ELEVATION	960.00	962.00	964.00	966.00	970.00	974.00	976.00	980.00	986.00

COMPUTED STORAGE-OUTFLOW-ELEVATION DATA

(INCLUDING FLOW OVER DAM)

STORAGE	.00	274.19	554.89	842.28	1439.21	1828.40	1907.79	1987.70	2068.14	2149.14
OUTFLOW	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ELEVATION	960.00	962.00	964.00	966.00	970.00	972.50	973.00	973.50	974.00	974.50
STORAGE	2230.74	2312.93	2395.73	2440.69	2544.53	2681.49	2795.89	2900.93	3078.45	3088.97
OUTFLOW	.00	.00	129.87	200.00	500.00	1000.00	1500.00	2000.00	2944.45	3000.00
ELEVATION	975.00	975.50	976.00	976.27	976.89	977.70	978.37	978.98	980.00	980.06
STORAGE	3258.64	3416.47	3492.58	3567.37	4181.44					
OUTFLOW	4000.00	5000.00	5500.00	6000.00	9988.09					
ELEVATION	981.02	981.90	982.32	982.73	986.00					

****

HYDROGRAPH AT STATION DAM

****

DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	*	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	*	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE
1		0000	1	21.	2326.0	975.6	*	1		0800	41	2015.	2903.7	979.0	*	1		1600	81	217.	2446.4	976.3
1		0012	2	24.	2328.0	975.6	*	1		0812	42	1863.	2872.2	978.8	*	1		1612	82	207.	2443.2	976.3
1		0024	3	31.	2332.7	975.6	*	1		0824	43	1725.	2843.0	978.6	*	1		1624	83	199.	2440.2	976.3
1		0036	4	40.	2338.4	975.7	*	1		0836	44	1596.	2815.9	978.5	*	1		1636	84	195.	2437.3	976.2
1		0048	5	51.	2345.5	975.7	*	1		0848	45	1478.	2790.8	978.3	*	1		1648	85	190.	2434.4	976.2
1		0100	6	67.	2355.5	975.8	*	1		0900	46	1377.	2767.6	978.2	*	1		1700	86	186.	2431.7	976.2
1		0112	7	90.	2370.3	975.8	*	1		0912	47	1282.	2745.9	978.1	*	1		1712	87	182.	2428.9	976.2
1		0124	8	123.	2391.4	976.0	*	1		0924	48	1194.	2725.8	978.0	*	1		1724	88	178.	2426.3	976.2
1		0136	9	167.	2419.7	976.1	*	1		0936	49	1112.	2707.1	977.9	*	1		1736	89	174.	2423.7	976.2
1		0148	10	246.	2456.5	976.4	*	1		0948	50	1036.	2689.7	977.7	*	1		1748	90	170.	2421.2	976.2
1		0200	11	391.	2506.8	976.7	*	1		1000	51	971.	2673.4	977.7	*	1		1800	91	166.	2418.8	976.1
1		0212	12	699.	2598.7	977.2	*	1		1012	52	915.	2658.2	977.6	*	1		1812	92	162.	2416.4	976.1
1		0224	13	1345.	2760.4	978.2	*	1		1024	53	863.	2643.8	977.5	*	1		1824	93	159.	2414.1	976.1
1		0236	14	2394.	2974.7	979.4	*	1		1036	54	814.	2630.3	977.4	*	1		1836	94	155.	2411.8	976.1
1		0248	15	3602.	3190.8	980.6	*	1		1048	55	767.	2617.5	977.3	*	1		1848	95	152.	2409.6	976.1
1		0300	16	4671.	3364.3	981.6	*	1		1100	56	723.	2605.5	977.3	*	1		1900	96	148.	2407.5	976.1
1		0312	17	5407.	3478.4	982.2	*	1		1112	57	682.	2594.2	977.2	*	1		1912	97	145.	2405.4	976.1
1		0324	18	5829.	3541.8	982.6	*	1		1124	58	643.	2583.6	977.1	*	1		1924	98	142.	2403.4	976.0
1		0336	19	6018.	3570.1	982.7	*	1		1136	59	607.	2573.6	977.1	*	1		1936	99	139.	2401.4	976.0

1	0348	20	6059.	3576.2	982.8	*	1	1148	60	572.	2564.2	977.0	*	1	1948	100	136.	2399.4	976.0
1	0400	21	6005.	3568.2	982.7	*	1	1200	61	540.	2555.4	977.0	*	1	2000	101	133.	2397.5	976.0
1	0412	22	5891.	3551.0	982.6	*	1	1212	62	509.	2547.0	976.9	*	1	2012	102	130.	2395.7	976.0
1	0424	23	5736.	3527.8	982.5	*	1	1224	63	484.	2539.1	976.9	*	1	2024	103	127.	2393.9	976.0
1	0436	24	5555.	3500.8	982.4	*	1	1236	64	463.	2531.6	976.8	*	1	2036	104	124.	2392.2	976.0
1	0448	25	5365.	3472.0	982.2	*	1	1248	65	442.	2524.5	976.8	*	1	2048	105	122.	2390.5	976.0
1	0500	26	5170.	3442.3	982.0	*	1	1300	66	423.	2517.7	976.7	*	1	2100	106	119.	2388.8	976.0
1	0512	27	4975.	3412.5	981.9	*	1	1312	67	404.	2511.2	976.7	*	1	2112	107	117.	2387.2	975.9
1	0524	28	4788.	3382.9	981.7	*	1	1324	68	386.	2505.0	976.7	*	1	2124	108	114.	2385.6	975.9
1	0536	29	4605.	3353.9	981.6	*	1	1336	69	369.	2499.1	976.6	*	1	2136	109	112.	2384.1	975.9
1	0548	30	4427.	3325.8	981.4	*	1	1348	70	353.	2493.4	976.6	*	1	2148	110	109.	2382.6	975.9
1	0600	31	4257.	3298.9	981.2	*	1	1400	71	337.	2488.1	976.6	*	1	2200	111	107.	2381.1	975.9
1	0612	32	4072.	3270.0	981.1	*	1	1412	72	322.	2482.9	976.5	*	1	2212	112	105.	2379.7	975.9
1	0624	33	3860.	3234.7	980.9	*	1	1424	73	308.	2478.1	976.5	*	1	2224	113	103.	2378.3	975.9
1	0636	34	3616.	3193.1	980.7	*	1	1436	74	295.	2473.4	976.5	*	1	2236	114	101.	2377.0	975.9
1	0648	35	3348.	3147.7	980.4	*	1	1448	75	282.	2469.0	976.4	*	1	2248	115	99.	2375.7	975.9
1	0700	36	3075.	3101.7	980.1	*	1	1500	76	270.	2464.7	976.4	*	1	2300	116	97.	2374.4	975.9
1	0712	37	2831.	3057.0	979.9	*	1	1512	77	258.	2460.7	976.4	*	1	2312	117	95.	2373.2	975.9
1	0724	38	2606.	3014.5	979.6	*	1	1524	78	247.	2456.9	976.4	*	1	2324	118	93.	2371.9	975.9
1	0736	39	2394.	2974.7	979.4	*	1	1536	79	236.	2453.2	976.3	*	1	2336	119	91.	2370.8	975.8
1	0748	40	2197.	2937.8	979.2	*	1	1548	80	226.	2449.7	976.3	*	1	2348	120	89.	2369.6	975.8
						*							*						

****
***

PEAK OUTFLOW IS 6059. AT TIME 3.80 HOURS

PEAK FLOW	TIME		MAXIMUM AVERAGE FLOW			
			6-HR	24-HR	72-HR	23.80-HR
+ (CFS)	(HR)					
		(CFS)				
+ 6059.	3.80		4139.	1319.	1319.	1319.
		(INCHES)	18.238	23.055	23.055	23.055
		(AC-FT)	2052.	2594.	2594.	2594.

PEAK STORAGE	TIME	MAXIMUM AVERAGE STORAGE			
		6-HR	24-HR	72-HR	23.80-HR
+ (AC-FT)	(HR)				
3576.	3.80	3268.	2678.	2678.	2678.

PEAK STAGE	TIME	MAXIMUM AVERAGE STAGE			
		6-HR	24-HR	72-HR	23.80-HR
+ (FEET)	(HR)				
982.78	3.80	981.06	977.64	977.64	977.64

CUMULATIVE AREA = 2.11 SQ MI

1

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

	OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD			BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
+					6-HOUR	24-HOUR	72-HOUR			
+	HYDROGRAPH AT	WEST	8174.	2.80	2588.	658.	658.	1.06		
+	HYDROGRAPH AT	EAST	6527.	2.60	1767.	447.	447.	.75		
+	HYDROGRAPH AT	LAKE	3738.	2.40	869.	236.	236.	.30		
+	3 COMBINED AT	IN	16329.	2.60	5184.	1340.	1340.	2.11		
+	ROUTED TO	DAM	6059.	3.80	4139.	1319.	1319.	2.11		
+									982.78	3.80

1 SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION DAM

(PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED DURING BREACH FORMATION)

PLAN 1 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	975.58	975.50	983.00
STORAGE	2326.	2313.	3617.
OUTFLOW	21.	0.	6329.

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	982.78	.00	3576.	6059.	.00	3.80	.00

*** NORMAL END OF HEC-1 ***

982.78 < 983.0 ✓

50-yr storm

```
1**************************************                        *
****************************************
*                                      *                        *
*
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *                        *  U.S. ARMY CORPS OF ENGINEERS
*
*             JUN   1998               *                        *  HYDROLOGIC ENGINEERING CENTER
*
*           VERSION 4.1                *                        *        609 SECOND STREET
*
*                                      *                        *      DAVIS, CALIFORNIA 95616
*
*  RUN DATE   22SEP12  TIME  23:34:16  *                        *         (916) 756-1104
*
*                                      *                        *
*
****************************************
**************************************


X     X  XXXXXXX   XXXXX           X
X     X  X        X     X         XX
X     X  X        X                X
XXXXXXX  XXXX     X         XXXXX  X
X     X  X        X                X
X     X  X        X     X          X
X     X  XXXXXXX   XXXXX          XXX


THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

1                                         HEC-1 INPUT                                          PAGE  1

        LINE         ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

*** FREE ***
           1         ID   CARDINAL FLY ASH DAM #2
           2         ID   THIRD RAISING - CREST OF 983 FT
           3         ID   DESIGN FLOOD      50 YR, 24-HR
           4         ID   FILE: FAD2-50YR
           5         IT     48       0       0     100
           6         IO      1
           7         PG     10    4.51
           8         PC      0   .0130    .027    .042    .059    .078    .099    .122    .147     .18
           9         PC    .23     .38     .53    .625     .67    .705    .736    .764     .79    .814
          10         PC   .836    .856    .875   .8931   .9103   .9267   .9423   .9573   .9719   .9861
          11         PC    1.0

          12         KK    WEST RUNOFF FROM FAD#1 WATERSHED
          13         KM   RECLAIMED POND AND LANDFILL
          14         BA   1.06
          15         LS      0      75
          16         PR     10
          17         PW      1
          18         PT     10
          19         UD   0.52

          20         KK    EAST RUNOFF FROM EAST WATERSHED
          21         KM   WOODS ONLY
          22         BA   0.75
          23         LS      0      70
          24         PR     10
          25         PW      1
          26         PT     10
          27         UD   0.34

          28         KK    LAKE INSTANTANEOUS RUNOFF FROM LAKE SURFACE
          29         KM   LAKE ONLY
          30         BA   0.30
          31         BF     20
          32         LS      0     100
          33         PR     10
          34         PW      1
          35         PT     10
          36         UD    0.1

          37         KK      IN COMBINE INFLOWS FROM WEST AND EAST WATERSHEDS AND LAKE SURFACE
          38         HC      3

          39         KK     DAM ROUTE FLOOD HYDROGRAPHS THRU FAD#2
          40         KM   STARTING POOL IS MAXIMUM OPERATING LEVEL
          41         KM   MAXIMUM TOP OF STOP LOG IS 972.5
          42         KM   STOP LOG WIDTH IS 4 FT
```

```
           43           RS      1   FLOW    20.6
           44           SA  135.5  138.7  142.0  145.4  153.1  161.4  166.2  175.2  192.6
           45           SE    960    962    964    966    970    974    976    980    986
           46           SQ      0    4.7   13.3   24.5   37.7   52.7   69.2
           47           SE  972.5    973  973.5    974  974.5    975  975.5
           48           SS  975.5
           49           ST    983
1                                                HEC-1 INPUT                                                PAGE  2

         LINE           ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

           50           ZZ
1****************************************
****************************************
 *                                      *                                                  *
*
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)  *                                                  *   U.S. ARMY CORPS OF ENGINEERS
*
 *              JUN  1998               *                                                  *   HYDROLOGIC ENGINEERING CENTER
*
 *          VERSION 4.1                 *                                                  *         609 SECOND STREET
*
 *                                      *                                                  *      DAVIS, CALIFORNIA 95616
*
 *  RUN DATE   22SEP12  TIME  23:34:16  *                                                  *          (916) 756-1104
*
 *                                      *                                                  *
*
 ****************************************
****************************************




                              CARDINAL FLY ASH DAM #2
                              THIRD RAISING - CREST OF 983 FT
                              DESIGN FLOOD     50 YR, 24-HR
                              FILE: FAD2-50YR

    6 IO         OUTPUT CONTROL VARIABLES
                       IPRNT           1  PRINT CONTROL
                       IPLOT           0  PLOT CONTROL
                       QSCAL          0.  HYDROGRAPH PLOT SCALE

      IT         HYDROGRAPH TIME DATA
                        NMIN          48  MINUTES IN COMPUTATION INTERVAL
                       IDATE       1   0  STARTING DATE
                       ITIME        0000  STARTING TIME
                          NQ         100  NUMBER OF HYDROGRAPH ORDINATES
                      NDDATE       4   0  ENDING DATE
                      NDTIME        0712  ENDING TIME
                       ICENT          19  CENTURY MARK

                   COMPUTATION INTERVAL     .80 HOURS
                        TOTAL TIME BASE   79.20 HOURS

          ENGLISH UNITS
               DRAINAGE AREA          SQUARE MILES
               PRECIPITATION DEPTH    INCHES
               LENGTH, ELEVATION      FEET
               FLOW                   CUBIC FEET PER SECOND
               STORAGE VOLUME         ACRE-FEET
               SURFACE AREA           ACRES
               TEMPERATURE            DEGREES FAHRENHEIT


 *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
***

             **************
             *            *
   12 KK     *    WEST    *      RUNOFF FROM FAD#1 WATERSHED
             *            *
             **************
                              RECLAIMED POND AND LANDFILL

                SUBBASIN RUNOFF DATA

   14 BA          SUBBASIN CHARACTERISTICS
                        TAREA        1.06  SUBBASIN AREA

                  PRECIPITATION DATA

   19 PT           TOTAL STORM STATIONS         10
    0 PW                        WEIGHTS       1.00

   16 PR             RECORDING STATIONS         10
   17 PW                        WEIGHTS       1.00

   15 LS          SCS LOSS RATE
                        STRTL         .67  INITIAL ABSTRACTION
                       CRVNBR       75.00  CURVE NUMBER
```

RTIMP .00 PERCENT IMPERVIOUS AREA

19 UD SCS DIMENSIONLESS UNITGRAPH
TLAG .52 LAG

***

PRECIPITATION STATION DATA

STATION	TOTAL	AVG. ANNUAL	WEIGHT
10	4.51	.00	1.00

TEMPORAL DISTRIBUTIONS

STATION 10, WEIGHT = 1.00

.01	.01	.01	.02	.02	.02	.02	.02	.03	.05
.15	.15	.10	.05	.03	.03	.03	.03	.02	.02
.02	.02	.02	.02	.02	.02	.01	.01	.01	.01
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	

WARNING *** TIME INTERVAL IS GREATER THAN .29*LAG

UNIT HYDROGRAPH
5 END-OF-PERIOD ORDINATES

539. 240. 59. 14. 4.

****

HYDROGRAPH AT STATION WEST

****

DA MON	HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q	*	DA MON	HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q
1	0000	1	.00	.00	.00	0.	*	2	1600	51	.00	.00	.00	0.
1	0048	2	.06	.06	.00	0.	*	2	1648	52	.00	.00	.00	0.
1	0136	3	.06	.06	.00	0.	*	2	1736	53	.00	.00	.00	0.
1	0224	4	.07	.07	.00	0.	*	2	1824	54	.00	.00	.00	0.
1	0312	5	.08	.08	.00	0.	*	2	1912	55	.00	.00	.00	0.
1	0400	6	.09	.09	.00	0.	*	2	2000	56	.00	.00	.00	0.
1	0448	7	.09	.09	.00	0.	*	2	2048	57	.00	.00	.00	0.
1	0536	8	.10	.10	.00	0.	*	2	2136	58	.00	.00	.00	0.
1	0624	9	.11	.11	.00	0.	*	2	2224	59	.00	.00	.00	0.
1	0712	10	.15	.14	.01	3.	*	2	2312	60	.00	.00	.00	0.
1	0800	11	.23	.19	.03	18.	*	3	0000	61	.00	.00	.00	0.
1	0848	12	.68	.46	.21	123.	*	3	0048	62	.00	.00	.00	0.
1	0936	13	.68	.34	.34	235.	*	3	0136	63	.00	.00	.00	0.
1	1024	14	.43	.17	.26	232.	*	3	0224	64	.00	.00	.00	0.
1	1112	15	.20	.07	.13	155.	*	3	0312	65	.00	.00	.00	0.
1	1200	16	.16	.05	.11	109.	*	3	0400	66	.00	.00	.00	0.
1	1248	17	.14	.04	.10	89.	*	3	0448	67	.00	.00	.00	0.
1	1336	18	.13	.04	.09	79.	*	3	0536	68	.00	.00	.00	0.
1	1424	19	.12	.03	.08	73.	*	3	0624	69	.00	.00	.00	0.
1	1512	20	.11	.03	.08	69.	*	3	0712	70	.00	.00	.00	0.
1	1600	21	.10	.03	.07	64.	*	3	0800	71	.00	.00	.00	0.
1	1648	22	.09	.02	.07	59.	*	3	0848	72	.00	.00	.00	0.
1	1736	23	.09	.02	.06	56.	*	3	0936	73	.00	.00	.00	0.
1	1824	24	.08	.02	.06	53.	*	3	1024	74	.00	.00	.00	0.
1	1912	25	.08	.02	.06	51.	*	3	1112	75	.00	.00	.00	0.
1	2000	26	.07	.02	.06	49.	*	3	1200	76	.00	.00	.00	0.
1	2048	27	.07	.02	.05	47.	*	3	1248	77	.00	.00	.00	0.
1	2136	28	.07	.02	.05	45.	*	3	1336	78	.00	.00	.00	0.
1	2224	29	.07	.01	.05	44.	*	3	1424	79	.00	.00	.00	0.
1	2312	30	.06	.01	.05	43.	*	3	1512	80	.00	.00	.00	0.
2	0000	31	.06	.01	.05	42.	*	3	1600	81	.00	.00	.00	0.
2	0048	32	.00	.00	.00	16.	*	3	1648	82	.00	.00	.00	0.
2	0136	33	.00	.00	.00	4.	*	3	1736	83	.00	.00	.00	0.
2	0224	34	.00	.00	.00	1.	*	3	1824	84	.00	.00	.00	0.
2	0312	35	.00	.00	.00	0.	*	3	1912	85	.00	.00	.00	0.
2	0400	36	.00	.00	.00	0.	*	3	2000	86	.00	.00	.00	0.
2	0448	37	.00	.00	.00	0.	*	3	2048	87	.00	.00	.00	0.
2	0536	38	.00	.00	.00	0.	*	3	2136	88	.00	.00	.00	0.
2	0624	39	.00	.00	.00	0.	*	3	2224	89	.00	.00	.00	0.
2	0712	40	.00	.00	.00	0.	*	3	2312	90	.00	.00	.00	0.
2	0800	41	.00	.00	.00	0.	*	4	0000	91	.00	.00	.00	0.
2	0848	42	.00	.00	.00	0.	*	4	0048	92	.00	.00	.00	0.
2	0936	43	.00	.00	.00	0.	*	4	0136	93	.00	.00	.00	0.
2	1024	44	.00	.00	.00	0.	*	4	0224	94	.00	.00	.00	0.
2	1112	45	.00	.00	.00	0.	*	4	0312	95	.00	.00	.00	0.
2	1200	46	.00	.00	.00	0.	*	4	0400	96	.00	.00	.00	0.
2	1248	47	.00	.00	.00	0.	*	4	0448	97	.00	.00	.00	0.
2	1336	48	.00	.00	.00	0.	*	4	0536	98	.00	.00	.00	0.
2	1424	49	.00	.00	.00	0.	*	4	0624	99	.00	.00	.00	0.
2	1512	50	.00	.00	.00	0.	*	4	0712	100	.00	.00	.00	0.

****
***

TOTAL RAINFALL = 4.51, TOTAL LOSS = 2.45, TOTAL EXCESS = 2.06

PEAK FLOW	TIME		MAXIMUM AVERAGE FLOW			
			6-HR	24-HR	72-HR	79.20-HR
+ (CFS)	(HR)					
		(CFS)				
+ 235.	9.60		142.	59.	20.	18.
		(INCHES)	1.166	2.058	2.058	2.058
		(AC-FT)	66.	116.	116.	116.

CUMULATIVE AREA = 1.06 SQ MI

*** ***
***

```
          **************
          *            *
20 KK     *    EAST    *    RUNOFF FROM EAST WATERSHED
          *            *
          **************
                 WOODS ONLY
```

SUBBASIN RUNOFF DATA

22 BA SUBBASIN CHARACTERISTICS
TAREA .75 SUBBASIN AREA

PRECIPITATION DATA

26 PT TOTAL STORM STATIONS 10
0 PW WEIGHTS 1.00

24 PR RECORDING STATIONS 10
25 PW WEIGHTS 1.00

23 LS SCS LOSS RATE
STRTL .86 INITIAL ABSTRACTION
CRVNBR 70.00 CURVE NUMBER
RTIMP .00 PERCENT IMPERVIOUS AREA

27 UD SCS DIMENSIONLESS UNITGRAPH
TLAG .34 LAG

***

PRECIPITATION STATION DATA

STATION	TOTAL	AVG. ANNUAL	WEIGHT
10	4.51	.00	1.00

TEMPORAL DISTRIBUTIONS

STATION 10, WEIGHT = 1.00

.01	.01	.01	.02	.02	.02	.02	.02	.03	.05
.15	.15	.10	.05	.03	.03	.03	.03	.02	.02
.02	.02	.02	.02	.02	.02	.01	.01	.01	.01
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	

WARNING *** TIME INTERVAL IS GREATER THAN .29*LAG

UNIT HYDROGRAPH
5 END-OF-PERIOD ORDINATES

449. 126. 25. 5. 0.

****
***

HYDROGRAPH AT STATION EAST

****
***

DA MON	HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q	*	DA MON	HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q
1	0000	1	.00	.00	.00	0.	*	2	1600	51	.00	.00	.00	0.
1	0048	2	.06	.06	.00	0.	*	2	1648	52	.00	.00	.00	0.
1	0136	3	.06	.06	.00	0.	*	2	1736	53	.00	.00	.00	0.
1	0224	4	.07	.07	.00	0.	*	2	1824	54	.00	.00	.00	0.
1	0312	5	.08	.08	.00	0.	*	2	1912	55	.00	.00	.00	0.

1	0400	6	.09	.09	.00	0.	*	2	2000	56	.00	.00	.00	0.
1	0448	7	.09	.09	.00	0.	*	2	2048	57	.00	.00	.00	0.
1	0536	8	.10	.10	.00	0.	*	2	2136	58	.00	.00	.00	0.
1	0624	9	.11	.11	.00	0.	*	2	2224	59	.00	.00	.00	0.
1	0712	10	.15	.15	.00	0.	*	2	2312	60	.00	.00	.00	0.
1	0800	11	.23	.22	.01	3.	*	3	0000	61	.00	.00	.00	0.
1	0848	12	.68	.54	.14	62.	*	3	0048	62	.00	.00	.00	0.
1	0936	13	.68	.42	.26	135.	*	3	0136	63	.00	.00	.00	0.
1	1024	14	.43	.22	.21	132.	*	3	0224	64	.00	.00	.00	0.
1	1112	15	.20	.09	.11	83.	*	3	0312	65	.00	.00	.00	0.
1	1200	16	.16	.07	.09	61.	*	3	0400	66	.00	.00	.00	0.
1	1248	17	.14	.06	.08	52.	*	3	0448	67	.00	.00	.00	0.
1	1336	18	.13	.05	.08	47.	*	3	0536	68	.00	.00	.00	0.
1	1424	19	.12	.04	.07	45.	*	3	0624	69	.00	.00	.00	0.
1	1512	20	.11	.04	.07	42.	*	3	0712	70	.00	.00	.00	0.
1	1600	21	.10	.04	.06	39.	*	3	0800	71	.00	.00	.00	0.
1	1648	22	.09	.03	.06	36.	*	3	0848	72	.00	.00	.00	0.
1	1736	23	.09	.03	.06	35.	*	3	0936	73	.00	.00	.00	0.
1	1824	24	.08	.03	.05	33.	*	3	1024	74	.00	.00	.00	0.
1	1912	25	.08	.03	.05	32.	*	3	1112	75	.00	.00	.00	0.
1	2000	26	.07	.02	.05	31.	*	3	1200	76	.00	.00	.00	0.
1	2048	27	.07	.02	.05	30.	*	3	1248	77	.00	.00	.00	0.
1	2136	28	.07	.02	.05	29.	*	3	1336	78	.00	.00	.00	0.
1	2224	29	.07	.02	.05	28.	*	3	1424	79	.00	.00	.00	0.
1	2312	30	.06	.02	.04	27.	*	3	1512	80	.00	.00	.00	0.
2	0000	31	.06	.02	.04	27.	*	3	1600	81	.00	.00	.00	0.
2	0048	32	.00	.00	.00	7.	*	3	1648	82	.00	.00	.00	0.
2	0136	33	.00	.00	.00	1.	*	3	1736	83	.00	.00	.00	0.
2	0224	34	.00	.00	.00	0.	*	3	1824	84	.00	.00	.00	0.
2	0312	35	.00	.00	.00	0.	*	3	1912	85	.00	.00	.00	0.
2	0400	36	.00	.00	.00	0.	*	3	2000	86	.00	.00	.00	0.
2	0448	37	.00	.00	.00	0.	*	3	2048	87	.00	.00	.00	0.
2	0536	38	.00	.00	.00	0.	*	3	2136	88	.00	.00	.00	0.
2	0624	39	.00	.00	.00	0.	*	3	2224	89	.00	.00	.00	0.
2	0712	40	.00	.00	.00	0.	*	3	2312	90	.00	.00	.00	0.
2	0800	41	.00	.00	.00	0.	*	4	0000	91	.00	.00	.00	0.
2	0848	42	.00	.00	.00	0.	*	4	0048	92	.00	.00	.00	0.
2	0936	43	.00	.00	.00	0.	*	4	0136	93	.00	.00	.00	0.
2	1024	44	.00	.00	.00	0.	*	4	0224	94	.00	.00	.00	0.
2	1112	45	.00	.00	.00	0.	*	4	0312	95	.00	.00	.00	0.
2	1200	46	.00	.00	.00	0.	*	4	0400	96	.00	.00	.00	0.
2	1248	47	.00	.00	.00	0.	*	4	0448	97	.00	.00	.00	0.
2	1336	48	.00	.00	.00	0.	*	4	0536	98	.00	.00	.00	0.
2	1424	49	.00	.00	.00	0.	*	4	0624	99	.00	.00	.00	0.
2	1512	50	.00	.00	.00	0.	*	4	0712	100	.00	.00	.00	0.
							*							

```
*************************************************************************************************************************
***

    TOTAL RAINFALL =    4.51, TOTAL LOSS =    2.83, TOTAL EXCESS =    1.68

  PEAK FLOW     TIME                         MAXIMUM AVERAGE FLOW
                                 6-HR        24-HR       72-HR      79.20-HR
+   (CFS)       (HR)
                        (CFS)
+     135.      9.60              80.         34.         11.          10.
                      (INCHES)   .931       1.681       1.681        1.681
                       (AC-FT)    37.         67.         67.          67.

                    CUMULATIVE AREA =      .75 SQ MI
```

```
 *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
***

            **************
            *            *
  28 KK     *    LAKE    *      INSTANTANEOUS RUNOFF FROM LAKE SURFACE
            *            *
            **************
                         LAKE ONLY

               SUBBASIN RUNOFF DATA

  30 BA          SUBBASIN CHARACTERISTICS
                       TAREA          .30  SUBBASIN AREA

  31 BF          BASE FLOW CHARACTERISTICS
                       STRTQ        20.00  INITIAL FLOW
                       QRCSN          .00  BEGIN BASE FLOW RECESSION
                       RTIOR      1.00000  RECESSION CONSTANT

                 PRECIPITATION DATA

  35 PT           TOTAL STORM STATIONS          10
   0 PW                        WEIGHTS        1.00

  33 PR             RECORDING STATIONS          10
  34 PW                        WEIGHTS        1.00

  32 LS          SCS LOSS RATE
```

```
                    STRTL         .00  INITIAL ABSTRACTION
                   CRVNBR      100.00  CURVE NUMBER
                    RTIMP         .00  PERCENT IMPERVIOUS AREA

  36 UD         SCS DIMENSIONLESS UNITGRAPH
                     TLAG         .10  LAG
```

***

PRECIPITATION STATION DATA

STATION	TOTAL	AVG. ANNUAL	WEIGHT
10	4.51	.00	1.00

TEMPORAL DISTRIBUTIONS

STATION 10, WEIGHT = 1.00

.01	.01	.01	.02	.02	.02	.02	.02	.03	.05
.15	.15	.10	.05	.03	.03	.03	.03	.02	.02
.02	.02	.02	.02	.02	.02	.01	.01	.01	.01
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	

WARNING *** TIME INTERVAL IS GREATER THAN .29*LAG

UNIT HYDROGRAPH
5 END-OF-PERIOD ORDINATES

180.	50.	10.	2.	0.

****
***

HYDROGRAPH AT STATION LAKE

****
***

DA	MON	HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q	*	DA	MON	HRMN	ORD	RAIN	LOSS	EXCESS	COMP Q
1		0000	1	.00	.00	.00	20.	*	2		1600	51	.00	.00	.00	20.
1		0048	2	.06	.00	.06	31.	*	2		1648	52	.00	.00	.00	20.
1		0136	3	.06	.00	.06	34.	*	2		1736	53	.00	.00	.00	20.
1		0224	4	.07	.00	.07	36.	*	2		1824	54	.00	.00	.00	20.
1		0312	5	.08	.00	.08	38.	*	2		1912	55	.00	.00	.00	20.
1		0400	6	.09	.00	.09	40.	*	2		2000	56	.00	.00	.00	20.
1		0448	7	.09	.00	.09	42.	*	2		2048	57	.00	.00	.00	20.
1		0536	8	.10	.00	.10	44.	*	2		2136	58	.00	.00	.00	20.
1		0624	9	.11	.00	.11	47.	*	2		2224	59	.00	.00	.00	20.
1		0712	10	.15	.00	.15	54.	*	2		2312	60	.00	.00	.00	20.
1		0800	11	.23	.00	.23	69.	*	3		0000	61	.00	.00	.00	20.
1		0848	12	.68	.00	.68	155.	*	3		0048	62	.00	.00	.00	20.
1		0936	13	.68	.00	.68	178.	*	3		0136	63	.00	.00	.00	20.
1		1024	14	.43	.00	.43	138.	*	3		0224	64	.00	.00	.00	20.
1		1112	15	.20	.00	.20	86.	*	3		0312	65	.00	.00	.00	20.
1		1200	16	.16	.00	.16	64.	*	3		0400	66	.00	.00	.00	20.
1		1248	17	.14	.00	.14	56.	*	3		0448	67	.00	.00	.00	20.
1		1336	18	.13	.00	.13	52.	*	3		0536	68	.00	.00	.00	20.
1		1424	19	.12	.00	.12	49.	*	3		0624	69	.00	.00	.00	20.
1		1512	20	.11	.00	.11	47.	*	3		0712	70	.00	.00	.00	20.
1		1600	21	.10	.00	.10	45.	*	3		0800	71	.00	.00	.00	20.
1		1648	22	.09	.00	.09	43.	*	3		0848	72	.00	.00	.00	20.
1		1736	23	.09	.00	.09	41.	*	3		0936	73	.00	.00	.00	20.
1		1824	24	.08	.00	.08	40.	*	3		1024	74	.00	.00	.00	20.
1		1912	25	.08	.00	.08	39.	*	3		1112	75	.00	.00	.00	20.
1		2000	26	.07	.00	.07	38.	*	3		1200	76	.00	.00	.00	20.
1		2048	27	.07	.00	.07	37.	*	3		1248	77	.00	.00	.00	20.
1		2136	28	.07	.00	.07	37.	*	3		1336	78	.00	.00	.00	20.
1		2224	29	.07	.00	.07	36.	*	3		1424	79	.00	.00	.00	20.
1		2312	30	.06	.00	.06	36.	*	3		1512	80	.00	.00	.00	20.
2		0000	31	.06	.00	.06	35.	*	3		1600	81	.00	.00	.00	20.
2		0048	32	.00	.00	.00	24.	*	3		1648	82	.00	.00	.00	20.
2		0136	33	.00	.00	.00	21.	*	3		1736	83	.00	.00	.00	20.
2		0224	34	.00	.00	.00	20.	*	3		1824	84	.00	.00	.00	20.
2		0312	35	.00	.00	.00	20.	*	3		1912	85	.00	.00	.00	20.
2		0400	36	.00	.00	.00	20.	*	3		2000	86	.00	.00	.00	20.
2		0448	37	.00	.00	.00	20.	*	3		2048	87	.00	.00	.00	20.
2		0536	38	.00	.00	.00	20.	*	3		2136	88	.00	.00	.00	20.
2		0624	39	.00	.00	.00	20.	*	3		2224	89	.00	.00	.00	20.
2		0712	40	.00	.00	.00	20.	*	3		2312	90	.00	.00	.00	20.
2		0800	41	.00	.00	.00	20.	*	4		0000	91	.00	.00	.00	20.
2		0848	42	.00	.00	.00	20.	*	4		0048	92	.00	.00	.00	20.
2		0936	43	.00	.00	.00	20.	*	4		0136	93	.00	.00	.00	20.
2		1024	44	.00	.00	.00	20.	*	4		0224	94	.00	.00	.00	20.
2		1112	45	.00	.00	.00	20.	*	4		0312	95	.00	.00	.00	20.
2		1200	46	.00	.00	.00	20.	*	4		0400	96	.00	.00	.00	20.
2		1248	47	.00	.00	.00	20.	*	4		0448	97	.00	.00	.00	20.
2		1336	48	.00	.00	.00	20.	*	4		0536	98	.00	.00	.00	20.
2		1424	49	.00	.00	.00	20.	*	4		0624	99	.00	.00	.00	20.

2 1512 50 .00 .00 .00 20. * 4 0712 100 .00 .00 .00 20.

****

TOTAL RAINFALL = 4.51, TOTAL LOSS = .00, TOTAL EXCESS = 4.51

PEAK FLOW	TIME		MAXIMUM AVERAGE FLOW			
			6-HR	24-HR	72-HR	79.20-HR
+ (CFS)	(HR)					
		(CFS)				
+ 178.	9.60		107.	56.	32.	31.
		(INCHES)	3.081	6.956	11.948	12.692
		(AC-FT)	49.	111.	191.	203.

CUMULATIVE AREA = .30 SQ MI

*** ***

```
              **************
              *            *
   37 KK      *       IN   *     COMBINE INFLOWS FROM WEST AND EAST WATERSHEDS AND LAKE SURFACE
              *            *
              **************

   38 HC          HYDROGRAPH COMBINATION
                      ICOMP           3  NUMBER OF HYDROGRAPHS TO COMBINE
```

***

****

HYDROGRAPH AT STATION IN
SUM OF 3 HYDROGRAPHS

****

DA	MON	HRMN	ORD	FLOW	*	DA	MON	HRMN	ORD	FLOW	*	DA	MON	HRMN	ORD	FLOW	*	DA	MON	HRMN	ORD	FLOW
1		0000	1	20.	*	1		2000	26	118.	*	2		1600	51	20.	*	3		1200	76	20.
1		0048	2	31.	*	1		2048	27	114.	*	2		1648	52	20.	*	3		1248	77	20.
1		0136	3	34.	*	1		2136	28	111.	*	2		1736	53	20.	*	3		1336	78	20.
1		0224	4	36.	*	1		2224	29	108.	*	2		1824	54	20.	*	3		1424	79	20.
1		0312	5	38.	*	1		2312	30	106.	*	2		1912	55	20.	*	3		1512	80	20.
1		0400	6	40.	*	2		0000	31	105.	*	2		2000	56	20.	*	3		1600	81	20.
1		0448	7	42.	*	2		0048	32	46.	*	2		2048	57	20.	*	3		1648	82	20.
1		0536	8	44.	*	2		0136	33	26.	*	2		2136	58	20.	*	3		1736	83	20.
1		0624	9	47.	*	2		0224	34	21.	*	2		2224	59	20.	*	3		1824	84	20.
1		0712	10	57.	*	2		0312	35	20.	*	2		2312	60	20.	*	3		1912	85	20.
1		0800	11	91.	*	2		0400	36	20.	*	3		0000	61	20.	*	3		2000	86	20.
1		0848	12	339.	*	2		0448	37	20.	*	3		0048	62	20.	*	3		2048	87	20.
1		0936	13	547.	*	2		0536	38	20.	*	3		0136	63	20.	*	3		2136	88	20.
1		1024	14	502.	*	2		0624	39	20.	*	3		0224	64	20.	*	3		2224	89	20.
1		1112	15	324.	*	2		0712	40	20.	*	3		0312	65	20.	*	3		2312	90	20.
1		1200	16	234.	*	2		0800	41	20.	*	3		0400	66	20.	*	4		0000	91	20.
1		1248	17	197.	*	2		0848	42	20.	*	3		0448	67	20.	*	4		0048	92	20.
1		1336	18	178.	*	2		0936	43	20.	*	3		0536	68	20.	*	4		0136	93	20.
1		1424	19	167.	*	2		1024	44	20.	*	3		0624	69	20.	*	4		0224	94	20.
1		1512	20	158.	*	2		1112	45	20.	*	3		0712	70	20.	*	4		0312	95	20.
1		1600	21	148.	*	2		1200	46	20.	*	3		0800	71	20.	*	4		0400	96	20.
1		1648	22	138.	*	2		1248	47	20.	*	3		0848	72	20.	*	4		0448	97	20.

```
    1    1736   23       132.   *    2     1336   48         20.   *    3      0936   73        20.   *    4      0536   98
20.
    1    1824   24       127.   *    2     1424   49         20.   *    3      1024   74        20.   *    4      0624   99
20.
    1    1912   25       122.   *    2     1512   50         20.   *    3      1112   75        20.   *    4      0712  100
20.
                                *                                 *                                 *

*********************************************************************************************************************
***

  PEAK FLOW     TIME                          MAXIMUM AVERAGE FLOW
                                      6-HR        24-HR       72-HR      79.20-HR
+   (CFS)       (HR)
                              (CFS)
+      547.      9.60                 325.        148.         63.          59.
                            (INCHES)  1.339       2.612       3.330        3.436
                             (AC-FT)  151.        294.        375.         387.

                             CUMULATIVE AREA =    2.11 SQ MI


 *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
***

            **************
            *            *
  39 KK     *     DAM    *     ROUTE FLOOD HYDROGRAPHS THRU FAD#2
            *            *
            **************
                              STARTING POOL IS MAXIMUM OPERATING LEVEL
                              MAXIMUM TOP OF STOP LOG IS 972.5
                              STOP LOG WIDTH IS 4 FT

               HYDROGRAPH ROUTING DATA

  43 RS          STORAGE ROUTING
                      NSTPS          1  NUMBER OF SUBREACHES
                       ITYP       FLOW  TYPE OF INITIAL CONDITION
                     RSVRIC      20.60  INITIAL CONDITION
                          X        .00  WORKING R AND D COEFFICIENT

  44 SA                AREA       135.5      138.7      142.0      145.4      153.1      161.4      166.2      175.2      192.6

  45 SE          ELEVATION       960.00     962.00     964.00     966.00     970.00     974.00     976.00     980.00     986.00

  46 SQ          DISCHARGE           0.         5.        13.        25.        38.        53.        69.

  47 SE          ELEVATION       972.50     973.00     973.50     974.00     974.50     975.00     975.50

  48 SS          SPILLWAY
                       CREL      975.50  SPILLWAY CREST ELEVATION
                      SPWID         .00  SPILLWAY WIDTH
                       COQW         .00  WEIR COEFFICIENT
                       EXPW        1.50  EXPONENT OF HEAD

  49 ST          TOP OF DAM
                      TOPEL      983.00  ELEVATION AT TOP OF DAM
                     DAMWID         .00  DAM WIDTH
                       COQD         .00  WEIR COEFFICIENT
                       EXPD         .00  EXPONENT OF HEAD

                                                                   ***

                                               COMPUTED STORAGE-ELEVATION DATA

           STORAGE        .00     274.19     554.89     842.28    1439.21    2068.14    2395.73    3078.45    4181.44
         ELEVATION     960.00     962.00     964.00     966.00     970.00     974.00     976.00     980.00     986.00

                                            COMPUTED STORAGE-OUTFLOW-ELEVATION DATA

                                                   (INCLUDING FLOW OVER DAM)

           STORAGE        .00     274.19     554.89     842.28    1439.21    1828.40    1907.79    1987.70    2068.14    2149.14
           OUTFLOW        .00        .00        .00        .00        .00        .00       4.70      13.30      24.50      37.70
         ELEVATION     960.00     962.00     964.00     966.00     970.00     972.50     973.00     973.50     974.00     974.50

           STORAGE    2230.74    2312.93    2395.73    3078.45    4181.44
           OUTFLOW      52.70      69.20      85.70     217.70     415.70
         ELEVATION     975.00     975.50     976.00     980.00     986.00

*********************************************************************************************************************
***

                                                HYDROGRAPH AT STATION       DAM

*********************************************************************************************************************
***
                                        *                                 *
```

DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE	DA	MON	HRMN	ORD	OUTFLOW	STORAGE	STAGE
1		0000	1	21.	2040.1	973.8	2		0312	35	57.	2249.9	975.1	3		0624	69	44.	2183.3	974.7
1		0048	2	21.	2040.4	973.8	2		0400	36	56.	2247.6	975.1	3		0712	70	44.	2181.8	974.7
1		0136	3	21.	2041.1	973.8	2		0448	37	56.	2245.2	975.1	3		0800	71	43.	2180.2	974.7
1		0224	4	21.	2042.1	973.8	2		0536	38	55.	2242.9	975.1	3		0848	72	43.	2178.7	974.7
1		0312	5	21.	2043.1	973.8	2		0624	39	55.	2240.6	975.1	3		0936	73	43.	2177.2	974.7
1		0400	6	21.	2044.3	973.9	2		0712	40	54.	2238.3	975.0	3		1024	74	43.	2175.7	974.7
1		0448	7	21.	2045.6	973.9	2		0800	41	54.	2236.1	975.0	3		1112	75	42.	2174.2	974.7
1		0536	8	22.	2047.1	973.9	2		0848	42	53.	2233.8	975.0	3		1200	76	42.	2172.7	974.6
1		0624	9	22.	2048.6	973.9	2		0936	43	53.	2231.7	975.0	3		1248	77	42.	2171.3	974.6
1		0712	10	22.	2050.6	973.9	2		1024	44	52.	2229.5	975.0	3		1336	78	42.	2169.9	974.6
1		0800	11	23.	2054.0	973.9	2		1112	45	52.	2227.4	975.0	3		1424	79	41.	2168.5	974.6
1		0848	12	24.	2066.6	974.0	2		1200	46	52.	2225.3	975.0	3		1512	80	41.	2167.1	974.6
1		0936	13	29.	2094.1	974.2	2		1248	47	51.	2223.2	975.0	3		1600	81	41.	2165.7	974.6
1		1024	14	34.	2126.6	974.4	2		1336	48	51.	2221.2	974.9	3		1648	82	41.	2164.3	974.6
1		1112	15	38.	2151.5	974.5	2		1424	49	51.	2219.1	974.9	3		1736	83	40.	2163.0	974.6
1		1200	16	41.	2167.3	974.6	2		1512	50	50.	2217.1	974.9	3		1824	84	40.	2161.7	974.6
1		1248	17	43.	2178.7	974.7	2		1600	51	50.	2215.2	974.9	3		1912	85	40.	2160.4	974.6
1		1336	18	45.	2188.2	974.7	2		1648	52	49.	2213.2	974.9	3		2000	86	40.	2159.1	974.6
1		1424	19	46.	2196.5	974.8	2		1736	53	49.	2211.3	974.9	3		2048	87	39.	2157.8	974.6
1		1512	20	48.	2204.1	974.8	2		1824	54	49.	2209.4	974.9	3		2136	88	39.	2156.5	974.5
1		1600	21	49.	2211.0	974.9	2		1912	55	48.	2207.5	974.9	3		2224	89	39.	2155.3	974.5
1		1648	22	50.	2217.2	974.9	2		2000	56	48.	2205.6	974.8	3		2312	90	39.	2154.0	974.5
1		1736	23	51.	2222.7	975.0	2		2048	57	48.	2203.8	974.8	4		0000	91	38.	2152.8	974.5
1		1824	24	52.	2227.8	975.0	2		2136	58	47.	2202.0	974.8	4		0048	92	38.	2151.6	974.5
1		1912	25	53.	2232.5	975.0	2		2224	59	47.	2200.2	974.8	4		0136	93	38.	2150.4	974.5
1		2000	26	54.	2236.9	975.0	2		2312	60	47.	2198.4	974.8	4		0224	94	38.	2149.3	974.5
1		2048	27	55.	2241.0	975.1	3		0000	61	46.	2196.6	974.8	4		0312	95	38.	2148.1	974.5
1		2136	28	56.	2244.8	975.1	3		0048	62	46.	2194.9	974.8	4		0400	96	37.	2146.9	974.5
1		2224	29	56.	2248.3	975.1	3		0136	63	46.	2193.2	974.8	4		0448	97	37.	2145.8	974.5
1		2312	30	57.	2251.6	975.1	3		0224	64	46.	2191.5	974.8	4		0536	98	37.	2144.7	974.5
2		0000	31	58.	2254.8	975.1	3		0312	65	45.	2189.8	974.7	4		0624	99	37.	2143.6	974.5
2		0048	32	58.	2256.0	975.2	3		0400	66	45.	2188.2	974.7	4		0712	100	37.	2142.5	974.5
2		0136	33	57.	2254.5	975.1	3		0448	67	45.	2186.5	974.7							
2		0224	34	57.	2252.3	975.1	3		0536	68	44.	2184.9	974.7							

****
***

PEAK OUTFLOW IS 58. AT TIME 24.80 HOURS

PEAK FLOW	TIME		MAXIMUM AVERAGE FLOW			
			6-HR	24-HR	72-HR	79.20-HR
+ (CFS)	(HR)					
		(CFS)				
+ 58.	24.80		57.	54.	46.	43.
		(INCHES)	.235	.949	2.412	2.524
		(AC-FT)	26.	107.	271.	284.

PEAK STORAGE	TIME	MAXIMUM AVERAGE STORAGE			
		6-HR	24-HR	72-HR	79.20-HR
+ (AC-FT)	(HR)				
2256.	24.80	2252.	2236.	2191.	2178.

PEAK STAGE	TIME	MAXIMUM AVERAGE STAGE			
		6-HR	24-HR	72-HR	79.20-HR
+ (FEET)	(HR)				
975.15	24.80	975.13	975.03	974.76	974.68

CUMULATIVE AREA = 2.11 SQ MI

1

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

	OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
+	HYDROGRAPH AT	WEST	235.	9.60	142.	59.	20.	1.06		
+	HYDROGRAPH AT	EAST	135.	9.60	80.	34.	11.	.75		
+	HYDROGRAPH AT	LAKE	178.	9.60	107.	56.	32.	.30		
+	3 COMBINED AT	IN	547.	9.60	325.	148.	63.	2.11		
+	ROUTED TO	DAM	58.	24.80	57.	54.	46.	2.11		
+									975.15	24.80

1 SUMMARY OF DAM OVERTOPPING/BREACH ANALYSIS FOR STATION DAM
(PEAKS SHOWN ARE FOR INTERNAL TIME STEP USED DURING BREACH FORMATION)

PLAN 1 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	973.83	975.50	983.00
STORAGE	2040.	2313.	3617.
OUTFLOW	21.	69.	317.

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	975.15	.00	2256.	58.	.00	24.80	.00

*** NORMAL END OF HEC-1 ***

975.15 < 975.5 ✓