Culvert Design System

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Implementation Division (HDV-21)

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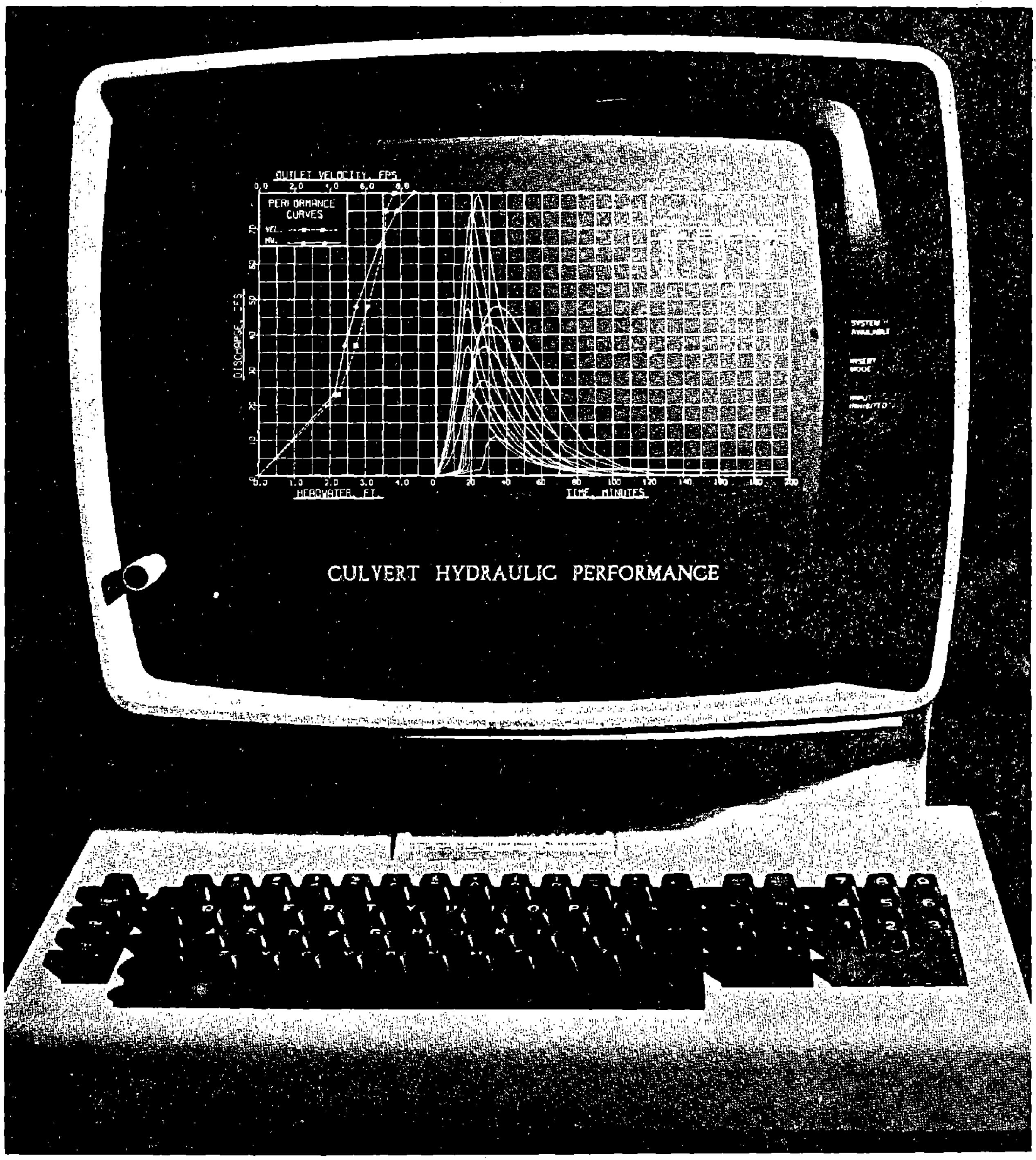

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Memorandum

DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

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In reply refer to: HDV-21

SUBJECT: Transmittal of Report
No. FHWA-TS-80-245
"Wyoming Culvert Design System"

FROM: Chief, Implementation Division
Office of Development
Washington, D.C

TO: Regional Federal Highway Administrators
Regions 1-10; and Direct Federal
Division Engineers

This publication provides the program documentation, user instructions, and sample problems for the "Wyoming Culvert Design System."

As an engineering tool, this system allows either the hydraulic design of a culvert or hydraulic review of an existing or proposed culvert size. The design or review process for drainage culverts is accomplished by routing a hydrograph through the culvert, thereby taking advantage of temporary upstream pond storage which attenuates the flood peak and allows for smaller size structures.

The system can be used in any geographical region provided the flood hydrographs are available or by incorporating hydrographs obtained from the United States Geological Survey's small watershed studies.

The FHWA Bridge Division agrees that the Wyoming Culvert Design approach of using a flood routing and storage method, although limited to conventional inlet culvert design, will complement FHWA's conventional and improved inlet culvert design methods.

The computer program can be obtained for a nominal fee from the Wyoming Highway Department's Hydraulic Branch.

Distribution of this design manual is being made in accordance with the procedures developed by the Implementation Division in cooperation with the field offices. A limited number of extra copies will be available from the Implementation Division (HDV-21).

Please refer any questions concerning this publication to Mr. Robert C. Wood at (202) 426-9205.

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Robert J. Betsold

Attachments

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16. Abstract

As an engineering tool, this system can either hydraulically design a culvert or hydraulically review an existing or proposed culvert size. The design or review process for drainage culverts is accomplished by routing a hydrograph through the culvert, thereby taking advantage of temporary upstream pond storage. Analysis employing the irrigation design alternative uses only the peak discharge. Various hydrograph relationships, culvert shapes, material, and inlet types can be investigated. The system provides certain environmental and flood hazard data in addition to the culvert hydraulics. The system can be used in any geographical region provided discharges, hydrographs, and flood volumes can be identified. Although not part of the system, these practices better enable the engineer to identify any "safety factors" and related cost benefits associated with the culvert design.

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WYOMING STATE HIGHWAY DEPARTMENT

HYDRAULICS SECTION

CDS

(Culvert Design System)

Program Documentation

User Instructions

and

Sample Problems

January, 1980

The contents of this report and the related computer system were developed for use by the Wyoming Highway Department Hydraulics Section. The contents of either the report or the computer system do not necessarily reflect the official views or policy of the U. S. Department of Transportation. This material should not be used for any specific application without independent examination and verification of its accuracy and suitability for such application by professionally qualified personnel. The Wyoming Highway Department assumes no liability or responsibility for and makes no representations or warranties as to applicability or suitability of this report and related computer system and anyone making use thereof or relying thereon assumes all risk and liability arising from such use or reliance.

This report does not constitute a standard, specification, or regulation.

PREFACE

As an engineering tool, this system can either hydraulically design a culvert or hydraulically review an existing or proposed culvert size. The design or review process for drainage culverts is accomplished by routing a hydrograph through the culvert, thereby taking advantage of temporary upstream pond storage. Analysis employing the irrigation design alternative uses only the peak discharge. Various hydrograph relationships, culvert shapes, material, and inlet types can be investigated. The system provides certain environmental and flood hazard data in addition to the culvert hydraulics. The system can be used in any geographical region provided discharges, hydrographs, and flood volumes can be identified. Although not part of the system, these practices better enable the engineer to identify any "safety factors" and related cost benefits associated with the culvert design.

The system consists of 39 computer programs for computations and plotting and an executive program which controls the flow of the user designated execution of the program segment.

All programs are written in FORTRAN IV with the exception of one assembler routine ("GEN4") used in plotting. The plotting programs require either a Xynetics, Calcomp, or similar type of software plotting package. The system requires approximately 278 K bytes of core storage. The original system was developed on an IBM 370/155 with OS/MVS operating system and an off-line Xynetics 1100 flatbed plotter. If the system is used with a Calcomp plotter, modifications must be made to the plotting routines. A list of these changes made by Kansas is shown on page 176.

The authors of this system in a desire to further the use of the computer to reduce laborious hand computations and improve the quality of hydraulics design through more precise analysis and the ability to rapidly evaluate different alternatives, are willing to answer questions related to this system. Any comments, criticism, suggestions for improvement, etc., would also be welcome.

Contact either:

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or

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF SYMBOLS

Documentation	Program	Units	Definition
A'	CI(1)	Dimensionless	Coefficient from Tables 3 to 7.
A_P	ARAIND PONDAR	Acres	Total surface area of pond. ARAIND is variable used for printing purposes, whereas PONDAR is used for internal control during routing analysis.
A_{TW}	***	ft^2	A rectangular area synthesized at the culvert outlet corresponding to culvert width, B, and tailwater depth, T_w.
A_b	A**	ft^2	Culvert outlet area corresponding to Y_b.
A_c	A**	ft^2	Critical area of waterway corresponding to critical depth is defined as d_c.
A_f	AE	ft^2	Cross sectional area of a culvert barrel flowing full.
A_p	A**	ft^2	Cross sectional area of a culvert barrel flowing partially full.
a	TA	ft^2	A channel's waterway cross sectional area or $a = \sum_{i=1}^{1-9} a_i$
a'_j	AREAS	ft^2	Cross sectional end area corresponding to a given incremental stage elevation for $1 \leq j \leq 9$, where j is the number of cross section.
a_i	A**	ft^2	The total natural channel waterway area, a, is equal to the sum of its incremental waterway areas, a_i.
B	B	ft	A culvert barrel width being evaluated at a given point in time for a specific discharge.
B'	CI(2)	Dimensionless	Coefficient from Tables 3 to 7.

LIST OF SYMBOLS (continued)

Documentation	Program	Units	Definition
B_s	*		Conversion factor changing cubic feet to acre-feet or 43,560 ft^3/A-F.
C'	CI(3)	Dimensionless	Coefficient from Tables 3 to 7.
D	D	ft	The culvert barrel height being evaluated at a given point in time for a specific discharge.
D'	DI(4)	Dimensionless	Coefficient from Tables 3 to 7.
D_{hw}	DHW	ft	This is the input design headwater which is the maximum upstream pond depth to be tolerated *for a specific frequency of flood event.*
D_{in}	RUNOFF	Minutes	An optional input value to indicate the maximum acceptable outflow hydrograph time base. This is a general measure of acceptable inundation time for a specific frequency of flood event (same as for D_{hw}).
D_{po}	PONDSZ	Acres	An optional input value to indicate the maximum acceptable inundated pond area, A_p. This is for a specific frequency of flood event (same as for D_{hw}).
d	DN	ft	Flow depth that would occur within a culvert barrel assuming uniform flow and exclusive of inlet/tailwater/culvert length.
d_a		ft	Average flow depth in a natural channel cross section for a specific discharge. This would be the average of all incremental flow depths within a subsection of Figure 1.
d_c	DC	ft	Critical culvert flow depth for a specific discharge. This depth can not exceed the barrel's vertical height.
d_i	D**	ft	This is the flow depth within a natural channel cross section increment within a subsection (1-9) for a given water surface (reference Figure 1).

LIST OF SYMBOLS (continued)

Documentation	Program	Units	Definition
d_p	***	ft	Hydraulic depth corresponding to the culvert's partial water area, A_p or $d_p = A_p \div T_p$.
E'	CI(5)	Dimensionless	Coefficient from Tables 3 to 7.
e	*		Base of the natural logarithm or 2.718281828.
F	***		A regression value derived from Equation 48c for use in Equation 48b.
F'	CI(6)	Dimensionless	Coefficient from Tables 3 to 7.
F_r	FR**	Dimensionless	The Froude number is a dimensionless measure of gravity's effect on the state of flow and is expressed as the ratio of inertial forces to gravity forces or $F_r = v \div \sqrt{gh_d}$
$\overline{F}_r$	FR**	Dimensionless	The average Froude number for a natural channel cross section based on the incremental Froude numbers (reference Figure 1).
F_{rb}	FR**	Dimensionless	Froude number occurring at the culvert outlet.
f_r	FR**	Dimensionless	Similar to F_r, this symbol is for the Froude number in each increment within a subsection of a channel cross section.
G_{vd}	GVD	ft	The maximum allowable *inside* vertical culvert dimension that will fit under the road commensurate with available cover, culvert thickness, and the streambed elevation. This is a program control value only and not necessarily the vertical culvert dimension that will be established by the design. This value prevents the program from selecting a culvert that has insufficient cover for installation.
g	*	ft/sec^2	Gravity on earth or 32.2 ft/sec^2.

LIST OF SYMBOLS (continued)

Documentation	Program	Units	Definition
H	H	ft	Head required just to overcome culvert barrel friction, entrance losses, and to develop the outlet velocity head when a culvert is in barrel or outlet control. *The reader is cautioned* that in the computer logic, H is used to define two separate data elements through the initialization process (see H_o).
H_d	***	ft	The channel's cross section hydraulic depth is a function of the water surface top width, T, and cross sectional area, a, of a waterway or $H_d = a \div T$.
H_e	HO	ft	*Approximate* distance from outlet flow line to the energy line at the outlet. This is defined as $(d_c + D) \div 2$ or T_w, whichever is greater.
H_f	***	ft	Friction loss head due to the culvert boundary.
H_i	HI	ft	This is the inlet headwater which is caused only by the culvert inlet geometry and is measured from the culvert's inlet flow line to the pond surface.
H_ℓ	***	ft	Entrance loss head due to the upstream pond contracting in order to enter a culvert barrel.
H_o	H	ft	This is the outlet headwater due only to barrel, outlet, and inlet effects. *It is noteworthy* that in terms of the computer logic symbols, it first identifies the foregoing friction/entrance/velocity head as H. Later in the program logic, H is re-initialized to be H + HO - L(SO), or the outlet headwater which additionally considers energy and elevation heads. Equations 11, 12, and 13 in the text better explain this confusing aspect of the program logic. H_o is measured from the culvert's inlet flow line to the pond surface.

LIST OF SYMBOLS (continued)

Documentation	Program	Units	Definition
H_v	***	ft	Velocity head due to some velocity, v; i. e., $H_v = v^2/2g$
H_w	HWC**	ft	H_w is termed headwater (as opposed to the allowable or design headwater H_{wc}) and is the upstream pond depth that occurs at a point in time during the flood routing due to a specific discharge, Q_d.
H_{wc}	HWC**	ft	H_{wc} is the computer term for the greater value of H_i (inlet headwater for Q_d) or H_o (outlet headwater for Q_d).
H_{wf}	QFHI	ft	This is the headwater corresponding to that unique full barrel discharge, Q_f, necessary for the culvert barrel to just reach full flow conditions (see Q_f).
I	***	acre-feet	Average hydrograph inflow to pond during incremental time period, Δt.
I_1	HQ	acre-feet	Instantaneous inflow at the beginning of the incremental time period, Δt.
I_2		acre-feet	Instantaneous inflow at the end of the time period, Δt.
$I\Delta t$	TOTIN	acre-feet	Total volume flowing into the upstream pond over a predetermined incremental time interval, Δt, on the hydrograph TOTIN = $Q_i\Delta t$.
j	***	Dimensionless	Counter to identify the number of the cross section (10 maximum).
K_e	CE	Dimensionless	Entrance loss coefficient for a specific type culvert entrance. Reference Tables 8, 9, and 10.
L	CL	ft	Culvert length.
LS_o	***	ft	Elevation difference between inlet and outlet.
L_{v_j}	***	ft	Horizontal distance between cross sections (Δ stationing in feet) for $1 \le j \le 9$ where j is the number of the cross section.

LIST OF SYMBOLS (continued)

Documentation	Program	Units	Definition
1			This is culvert length, L, divided by the culvert's vertical dimension, D, or L/D = 1.
ln			Natural logarithm or $\log_e$.
M_{TW}	TWM	lbs	Specific force at outlet due to tailwater, T_w.
M_b	PM	lbs	Specific force at culvert outlet.
N	NPIPES	each	Number of barrels in a given culvert installation.
N_{hr}	***	N/A	A parameter used in identifying Type V, VI, and VII flow on Figure 10a (reference Equation 48d).
n	ZN	Dimensionless	Manning's friction value for a waterway or culvert.
O	QOUT	acre-feet	Average outflow from pond during time period, Δt.
O_1	***	acre-feet	Instantaneous outflow at the beginning of the incremental time period, Δt.
O_2	***	cfs	Instantaneous outflow at the end of the incremental time period, Δt.
$O\Delta t$	TOTUT	acre-feet	Total volume flowing out of the upstream pond over a predetermined incremental time interval, Δt, on the hydrograph.
P	***	ft	Wetted perimeter of a natural channel cross section boundary for a waterway area corresponding to a given depth. This is the part of a waterway in actual contact with the water.
P_f	***	ft	Similar to P, except this is the wetted perimeter for a full culvert barrel.
P_p	***	ft	Similar to P, except this is the wetted perimeter for a partial full culvert barrel.

LIST OF SYMBOLS (continued)

Documentation	Program	Units	Definition
Q_d	QOUT	cfs	Average discharge being routed through a culvert occurring over a predetermined time interval, Δt; i.e., this is the actual discharge entering and leaving the culvert outlet at a given point in time. In routing a flood through a culvert, an outflow hydrograph is generated. QOUT for various time intervals, Δt, are these outflow hydrograph discharges. Q_d = QOUT.
Q_f	QF	cfs	The minimum discharge required to cause a culvert barrel to flow full considering only the barrel slope and roughness in accordance with Manning's equation.
Q_i	HQ	cfs	Average rate of "inflow" flood discharge from the watershed occurring over a predetermined incremental time interval, Δt, on the hydrograph; i.e., this is the natural discharge entering the upstream pond and except at a unique point in time differs from Q_d, which has been influenced by upstream pond storage.
Q_p	DRQ	cfs	This is the peak discharge occurring on a watershed and its relationship to a hydrograph is illustrated in Figure 5.
q		cfs	Total discharge occurring within cross section of area or $q = \sum_{1}^{1-9} = \Sigma q_i$
q_{1-9}		cfs	That portion of the total channel discharge occurring within a subdivided portion of a cross section (Figure 1).
q_i		cfs	This is the incremental discharge occurring within an increment of each subsection of the natural channel's cross section (Figure 1). The total cross section discharge q, is the sum of these incremental discharges, or $q = \Sigma q_i$

LIST OF SYMBOLS (continued)

Documentation	Program	Units	Definition
R	R**	ft	Hydraulic radius of a waterway or waterway area divided by wetted perimeter.
R_c	R**	ft	This is the hydraulic radius corresponding to critical depth, d_c, in the culvert barrel critical waterway or critical area divided by critical wetted perimeter.
R_f	RE	ft	Hydraulic radius of a culvert barrel flowing full or $(A_f) \div (P_f)$. The wetted perimeter, P_f, in this unique case would be the inside circumference of the culvert (an exception was made with box culverts, the inside top width was omitted to preclude a discontinuity in the logic). Also, see text to see how this definition was handled due to use of regression equations.
R_n	RN	ft	R_n is the hydraulic radius used to compute outlet control headwater. $R_c \le R_n \le R_f$ and $R_n \cong R_f$ at full flow.
R_p	RN	ft	Hydraulic radius of partial waterway area; partial waterway area divided by partial wetted perimeter.
r	***	ft	This is the geometric radius applied to streamline the inlet edge of a culvert in order to improve its hydraulic performance (see Figure 10, inset sketch). Program does not use r as such, but obtained values of r/D from Tables 8, 9, and 10.
S	S	ft/ft	Downstream natural channel slope. For natural channels, the hydraulic gradient of the channel is often assumed to equal the average streambed slope in uniform channels. In Wyoming, 1000 feet of streambed profile closely approximates the hydraulic gradient in reasonably uniform channels.

LIST OF SYMBOLS (continued)

Documentation	Program	Units	Definition
S_1	VSTORD**	acre-feet	Storage volume in the pond at the beginning of the incremental time period, Δt.
S_2	VSTORD**	acre-feet	Storage volume in the pond at the end of the incremental time period.
S_c	SC	ft/ft	Critical slope of the culvert as computed from Manning's equation using R_c, V_c, and an appropriate n value for the culvert type.
S_o	SO	ft/ft	Culvert slope.
S_o1	EQNA or EQNB	ft/ft	This is a computed slope used to compare against the actual culvert slope, S_o, to determine if Type V or Types VI and VII flow are occurring according to Figure 8. S_o1 is the dependent regression variable of Figure 10a or 10b (references Equations 47a and 48a).
S_u	UPSTSL	ft/ft	Upstream channel slope used to compute the storage table when cross sections are input.
T	TT**	ft	Top width for a waterway's water surface.
T_c	TT	ft	Critical top width of waterway corresponding to critical depth, d_c.
T_h		Minutes	Total time base of inflow hydrograph; the total duration of the runoff from the watershed into the culvert site is defined as T_h (see Figure 5).
T_p	TT**	ft	The top water surface width in a culvert barrel flowing part full.

LIST OF SYMBOLS (continued)

Documentation	Program	Units	Definition
T_w	TW	ft	Maximum depth of flow occurring in the natural channel just beyond the culvert outlet due to the discharge released by the culvert but exclusive of any other culvert effects such as may be caused by the outlet jet. The tailwater must reflect any changes imposed by existing (pre-construction) conditions downstream of the culvert (existing culverts, channel modifications, etc.). This is also the flood depth for a given discharge that occurs prior to any proposed construction. In tractive shear computations, τ, this is the depth at the point of interest.
Time Unit	TIMEUN	Minutes	Reference time unit definition in Equation 8.
t'_j		ft	Water surface top width for cross section at ends of prism for 1 j 9 where j is the number of the cross section.
$\bar{V}$	V**	ft/sec	The weighted average of all incremental velocities in a natural channel cross section (Figure 1).
V	VFUL, VV**, VF	ft/sec	This symbol represents the various outlet velocities that could exist at a culvert outlet in order to simplify Equation 16 notation.
V_{TW}	VS	ft/sec	Maximum velocity that occurs in the natural channel downstream of the culvert outlet, exclusive of culvert effects.
V_b	V**	ft/sec	Velocity occurring just as the discharge, Q_d, leaves the culvert barrel. This velocity corresponds to the culvert brink depth Y_b and corresponding area, A_b.
V_c	VV**	ft/sec	The velocity corresponding to critical depth, d_c, in the culvert barrel. Critical velocity can not be less than the full velocity in the culvert barrel.
V_f	VFUL	ft/sec	Velocity where the barrel is flowing full for a given discharge.

LIST OF SYMBOLS (continued)

Documentation	Program	Units	Definition
V_o	VF	ft/sec	V_o is a unique velocity used to compute outlet control headwater and is similar to V_p but is constrained such that $V_c \geq V_o \geq V_f$.
V_p	VV**	ft/sec	This is the part full velocity occuring inside a culvert exclusive of inlet and outlet conditions.
V_s	VSTORD	acre-feet	Volume of flood stored upstream from a culvert at a given point in time $(\Sigma\Delta t)$.
V_ℓ	TOTIN	acre-feet	This is the total volume of runoff for a given flood event and is based on the time discharge relationship (hydrograph) arriving at the site (Figure 5).
v	V**	ft/sec	Weighted average velocity occurring within cross section of area a.
v_i	V**	ft/sec	The velocity occurring within each increment within a subsection (1-9) of the cross section (Figure 1) is the incremental velocity.
X		N/A	$Q_d/D^{5/2}$ for circular pipe and $Q_d/D^{3/2}B$ for box and arch pipe.
X_1, $X_2 \rightarrow X_n$	X(n)	ft	This is X_i (where i = 1, 2,...n) or transverse cross section coordinate points measured horizontally from furtherest survey point on the left.
Y	TERM		This is the independent regression variable of Equations 47a and 48a and is defined by Equations 47b and 48b.
Y_b	***	ft	This is the brink depth occurring at a culvert outlet. Table 3 identifies the best estimate of brink depth for a given flow type.

LIST OF SYMBOLS (continued)

Documentation	Program	Units	Definition
Y_1, $Y_2 \rightarrow Y$	Y(n)	ft	This is Y_i (where i = 1, 2,...n) or vertical cross section coordinate points measured above lowest point in entire cross section. Y corresponds to X_i distance (where i = 1, 2,...n).
α	QI**	Dimensionless	This is the non-uniform velocity coefficient as defined in hydraulic textbooks (5). $\alpha = \frac{\int vi^3 ai}{v^3 a}$
β	P		This is the non-uniform momentum correction coefficient as defined in hydraulics textbooks (5). $\beta = \frac{\int vi^2 ai}{va}$
β_1	BETA1		Non-uniform pressure distribution factor (16).
β_2	***		Non-uniform velocity distribution factor (16).
τ	SHM	lbs/ft^2	Maximum actual tractive shear occurring on the bed or a measure of force exerted by moving water against the streambed; $\tau = \omega T_w S_o$.
τ_1	SH	lbs/ft^2	The force exerted on the streambed within each increment of a subsection on Figure 1 is the incremental of tractive shear; $\tau = \omega d_i S_o$.
ω	*	lbs/ft^3	Unit weight of water which is assumed to be 62.4 lbs/ft^3 regardless of sediment concentrations and water temperature.
ΔS		acre-feet	Change in pond storage during time period, Δt.
Δt	DELTAT	minutes	Optional input time interval selected to subdivide hydrograph time, T_h, into finite elements, Δt, for purposes of flood routing as desired by User. If not input, Δt becomes an internal variable based on Time Unit multiplied by Unit of Time (reference Table, Figure 6).

LIST OF SYMBOLS (continued)

Documentation	Program	Units	Definition
π	*	Dimensionless	180° (not radians).
ℓ	CLB	Dimensionless	As used in Equation 48, this is the culvert length, L, divided by the culvert height, D. times 0.01; i.e., $\ell = 0.01(L/D)$.

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*Used as a constant in the program, no variable name assigned.
**Variable used more than once in program.
***Value calculated as needed or stored in a table of values, no variable name assigned.

Chapter 1

ENGINEERING DOCUMENTATION

INTRODUCTION

In the past, highway engineers have used different assumptions in designing highway culverts. These include identification of the design flood, the hydraulics of culverts, and the storage effect of temporary ponding. Until now, these assumptions were sufficient to satisfy highway drainage design requirements.

The escalating cost of highway drainage construction, the advent of environmental concern, recent Federal flood hazard regulations, the possibility of malpractice litigation combined with growing legal awareness by the public all imposes a need for more exacting drainage design and documentation. This need was first recognized when most states undertook research directed at better identification of flood magnitudes and their related risks. About the same time, extensive research on culvert hydraulics quantified many aspects of culvert hydraulics; research is also continually updating and improving culvert hydraulics. Evaluating the effect of temporary storage has historically been confined to dams, major rivers, and reservoirs; i.e., the methodology to evaluate temporary ponding upstream from a culvert has existed for many years, but was dependent on research to identify flood characteristics--particularly on the smaller watersheds. In Wyoming, the flood research necessary to identify the necessary hydrograph shapes and volumes was completed in 1974 (1).

Use of the flood routing technique is too time consuming to be applied manually to most culverts. For this reason, a computer system was developed to accomplish this task. The system has been constructed in a modular fashion to facilitate changes and enhancements. Several practical enhancements have already been identified. The logic to estimate silting problems (both upstream and in the barrel) has been investigated by Wacker (2), but requires further study and programming. It is hoped the Federal Highway Administration's (FHWA) logic for an improved inlet program can be modified and incorporated into this system (an attempt has been made to provide for this linkage). The value of an approximate culvert cost estimating routine, plus special formats that re-order the output to conform to acceptable flood hazard documentation in accordance with Wyoming's practices is under study. A linkage with the culvert outlet protection program (3,6,7) is also contemplated.

Hydraulic engineers have long recognized the value of temporary storage as a "safety factor" in their culvert designs. However, without employing a tedious flood routing procedure, they did not know the magnitude of this safety factor which could vary from zero to a very large and costly value. The practice of flood routing through a culvert must not be considered as one that eliminates the engineer's "last safety factor." Rather, flood routing practices allow the engineer to better identify the magnitude of this "safety factor" so more intelligent decisions can be made in selecting a cost effective culvert size. With flood routing practices in culvert design, a "safety factor" can be included in several ways such as by limiting the headwater, increasing the design discharge by one or more standard deviations (if known), and arbitrarily increasing the culvert size (perhaps by a certain dollar amount based on a percentage of the required culvert size). These alternatives are not intended to be all inclusive. The point is that the cost benefits of a safety factor can be best determined only when the engineer has reasonable knowledge of the significant variables involved in the design.

SYSTEM OVERVIEW

The system provides four distinct types of analysis that can be classified into two broad options: *design* and *review*. The *design option* selects a culvert size and number of barrels compatible with the engineering data, environmental constraints, and site geometry. With this option, the User can request the program to consider any or all of the following culvert types: round concrete, round metal, arch concrete, arch metal, oval concrete (horizontal placement only), and concrete box. There is an upper limit of six barrels for commercial culverts or five for concrete box culverts. This limit could easily be changed with a minor program modification.

The *review option* provides hydraulic performance data for a specific culvert identified by the User. In this option, the User identifies the culvert type (in accordance with those listed above), size, inlet type, slope, and number of barrels.

Within the *design option*, the User must select one of *two methods of design: irrigation design* or *drainage design*. The *irrigation design* method ignores any upstream pond storage and selects a culvert capable of passing the peak discharge. Irrigation ditches in western states operate for long periods at full or near full capacity, thereby precluding any available pond storage. The *drainage design* method uses any temporary upstream pond storage by routing a hydrograph through the site.

The *review option* uses the same equations as the *design option*. Again, Users must indicate whether they want a specific culvert reviewed using the *irrigation design* method or the *drainage design* method, where a hydrograph is routed through the system.

Provision has been made in the *design option* for the User to obtain data for manually plotting a culvert performance curve (Figure 5). This is accomplished by the User identifying the *design* discharge and five other *performance* discharges deemed suitable to define a performance curve. With these discharges, the system will first size a culvert using the *design* *option* and then review this design culvert size using the five *performance* discharges. This satisfies FHWA requirements (4) for a culvert performance curve and assists in making a flood hazard assessment *provided* the basic flood (100-year event) is one of the five performance discharges. It is not necessary to input the five performance discharges in order to secure a culvert design, however.

The *review option* can also be used to obtain a culvert performance curve for a predetermined culvert size and geometry. With this option, the program reviews the specified culvert size, type, and geometry using the discharges provided (six maximum).

The system has a choice of two hydrograph alternatives in both the *design option* or *review option*. The first alternative allows the User to input a hydrograph of his choice for a given discharge. Each of the six discharges that can be input to the system will also require input of their own unique hydrograph. The second alternative is where the User does not elect to input a hydrograph. With the second alternative, the system generates a hydrograph internally based on Wyoming's flood studies (1). These studies are for semiarid regions having watersheds ranging from 0 to about 15 square miles. In Wyoming's snowmelt regions, urbanized watersheds and any watershed greater than 15 square miles, it is necessary to input a hydrograph for the design to be valid. An alternative in Wyoming's snowmelt region would be to specify the *irrigation design* option as snowmelt hydrographs tend to have relatively long duration hydrographs.

These systems also have a plotting capability. The DESCRIPTION OF OUTPUT describes the plotter output which is shown in Figure 23. Basically, the output consists of a culvert performance curve, channel performance curves, and inflow/outflow hydrograph relationships (where it is applicable). The various plots are also integrated with the flood-frequency projections for the site.

SYSTEM OPERATION

The system develops tabular data for either manual or automated plotting of the stage-storage relationship and for plotting a stage-storage relationship to define the tailwater (T_w) (Figure 4). The stage-discharge relationship is sometimes referred to as a rating curve and it identifies flood stages prior to any new construction. The User can override these internally computed stage-storage and stage-discharge tables by inputting his own tabular relationships. This might be necessary in order to define complex upstream storage geometry or to reflect complex tailwater situations (backwater from existing culverts, bridges, etc.). When deemed advisable, a flow distribution can also be provided by this system (discussed later). Having quantified the hydraulic site conditions, the system selects an initial trial size and type[1] culvert when in the *design*

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[1] The minimum size is used as the initial trial size only for the first culvert type specified for analysis. Subsequest culvert types for which an analysis is requested at a given site have their initial <u>trial</u> size selected on the basis of the required cross sectional area for the previous culvert found to be satisfactory. This logic was required to minimize computerization.

option (both drainage and irrigation methods of design). This initial trial size is an 18" round or equivalent size commercial (factory manufactured) culvert. Notably, the minimum box culvert size is a 4 foot square opening in accordance with Wyoming practices. The User may select an incremental hydrograph time interval (flood routing period), Δt, in accordance with the USER INSTRUCTIONS, or use the internally generated Δt based on the hydrograph shape, thereby allowing the program to compute an incremental volume for routing. With this incremental volume selection, the system computes an average discharge, Q_d, over the selected time interval. Those not familiar with engineering terminology should remember that volume is just that, volume; whereas discharge is a volume per unit of time; i.e., *cubic feet* as opposed to *cubic feet per second*. With this average discharge, the system interpolates a tailwater, T_w, (Figure 4) using the tabular stage-discharge relationship and then computes a trial culvert headwater, H_{wc}, (upstream pond depth, Figure 4) necessary to force this average discharge through the culvert. This computation considers both inlet and outlet control parameters and selects the governing control (8). Having determined a trial headwater, the system can identify the amount of storage volume generated upstream using the stage-storage relationship. From the foregoing hydrograph time interval, Δt, an incremental flood volume arriving at the site during the selected time interval or routing period can be identified. The product of the average discharge, Q_d, used to identify the tailwater, T_w, and the selected time interval, Δt, provide an estimate of the flood volume passing through the culvert during the incremental time interval. The amount of incremental flood volume input to the site must equal the amount of flood volume temporarily stored plus the amount of flood volume passed through the culvert and on downstream. This is a verbal description of the basic flood routing equation used in this system (5). Mathematically, the basic flood routing equation is:

$$I - O = \frac{S}{t} \text{ -- } \quad 1a$$

or

$$2\,\frac{S_1}{\Delta t} - O_1 + I_1 + I_2 = 2\,\frac{S_2}{\Delta t} + O_2 \text{ -------------------------- } \quad 1b$$

The basic flood routing equation as used in this system considers the accumulation of storage in a culvert's pond as depending upon the difference between the rates of inflow and outflow. For an interval of time, Δt, the basic flood routing equation can express this relationship by Equation 1c which evolves from Equation 1a as:

$$\Delta S = Q_i \Delta t - Q_i \Delta t \text{ -- } \quad 1c$$

These equations can be shown to be

$$\frac{I_1 + I_2}{2} = \Delta S + \frac{O_1}{2} + \frac{O_2}{2} \text{ ---------------------------------- } \quad 1d$$

On the initial trial for a given culvert size and type,[2] the system assumes $Q_d = (Q_i + Q_{i-1})/2$ and then selects a tailwater, T_w, commensurate

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[2] Ibid.

with this assumed outflow discharge. This discharge is routed through the upstream pond and culvert. The balance indicated in Equation 1d obviously can not occur if there is any storage. This failure to balance Equation 1d tells the system to (1) decrease the previously assumed outflow discharge, Q_d, and (2) select a new lower tailwater, T_w, commensurate with this new trial outflow discharge, Q_d. The balancing procedure is repeated. This time the flood volume passed through the culvert will be reduced since the outflow discharge, Q_d, was reduced. As such, Equation 1d may balance; if not, the foregoing logic is iterated until a volume balance is reached within the greater of the following limits:

$$\pm .6(\text{Time Unit})Q_i \text{ or } \pm(60 \text{ cfs})(\text{Time Unit})$$

The second value was needed because Q_i can be zero while the system is still discharging the stored runoff. If the program does not balance within 30 iterations, the program will force a balance by picking a headwater that corresponds to the amount of stored volume required. This is acceptable because Q_d and thus the volume out will have become almost constant and the volume in is also fixed so volume stored can be directly calculated. This should only happen if there is an extremely large amount of storage available or if a discontinuity exists in the logic. A message is printed out whenever this forced balance is required.

After an incremental volume balance is reached, the time is advanced another increment, Δt, on the hydrograph. Each subsequent incremental volume balance must necessarily consider the amount of pond storage, S_2, occupied by the previous incremental volume balance. Each time the incremental time interval, Δt, is advanced along the hydrograph base, it identifies another increment of flood volume, $Q_i\Delta t$, a new average inflow discharge, Q_i, and the foregoing balancing procedure is repeated. Again, the system keeps track of the total storage volume being created or depleted in the upstream pond through each incremental time interval, Δt, in accordance with the logic set forth in Equation 1d.

This processing of the hydrograph through successive time increments, Δt, continues until the outflow hydrograph drops below 0.5 cfs. The system monitors the increase in upstream pond depth to insure it does not exceed a design maximum termed *design headwater*, D_{hw}. The design headwater is portrayed in Figure 4 and is an input value. If the design headwater is exceeded, the system increments the culvert opening, returns to the beginning of the hydrograph and repeats the flood routing process until a culvert size is obtained that precluded the upstream pond from exceeding the design headwater. In addition, the system also monitors the pond's *surface area*, D_{po}, and *inundation time*, D_{in}, and similarly increments the culvert size should these input constraints be exceeded.

The system will increase the number of culvert barrels if it can not satisfy the *design headwater* (D_{hw}), *surface area* (D_{po}), and *inundation time* (D_{in}) limitations with a culvert having the greatest allowable vertical culvert dimension, G_{vd}, specified for the site. The G_{vd} is an input value to prevent the system from selecting a culvert that is not compatible with embankment cover requirements (see Figure 4). The system increments the number of barrels, N, when it reaches the upper limit for the greatest vertical dimension established by the available structure geometries. These maximum vertical barrel dimensions for each culvert type are contained internally in the system (10 feet for boxes, 21 feet for round metal, 8 feet for round concrete, 158 inches for metal arches, 54 inches for concrete arches, and 116 inches for concrete ovals). When the number of barrels is incremented, the program adds one more pipe and searches for a size with a larger combined equivalent area than the last pipe(s) it checked before incrementing. Once this size is found, the program selects the next smallest size and returns to the beginning of the hydrograph and repeats the flood routing process. If D_{hw}, D_{po} or D_{in} is exceeded the program will increment the pipe size. If D_{hw}, D_{po} or D_{in} is not exceeded, the pipe size will be decremented until a size that exceeds one of the constraints is found and then the program will return to the next larger size that was already found to be satisfactory.

Once a culvert size commensurate with the design headwater (D_{hw}), pond surface area (D_{po}), and inundation time (D_{in}), and cover limitations have been determined, the system proceeds to identify the flow type in accordance with Figure 8 which then allows the system to identify the outlet conditions (velocity, flow type, Froude number, brink depth; see Figures 4 and 8).

Having completed the design, the system then reviews the culvert size selected in the design process. This is done using the other input discharges (five maximum). This review process provides the performance curve. Obviously, in the review process, there is no need to keep the upstream pond depth below the design headwater nor to limit pond surface area and inundation time so these constraints are bypassed. Also, where the User selects the review option by inputting a specific culvert and requesting a review, these constraints are also bypassed.

When the irrigation method is selected, the system omits the flood routing process and only seeks to satisfy the design headwater limitation, D_{hw}, for the peak discharge, Q_p. With the review option, the design headwater limitation is again bypassed as the system is working with an input culvert size.

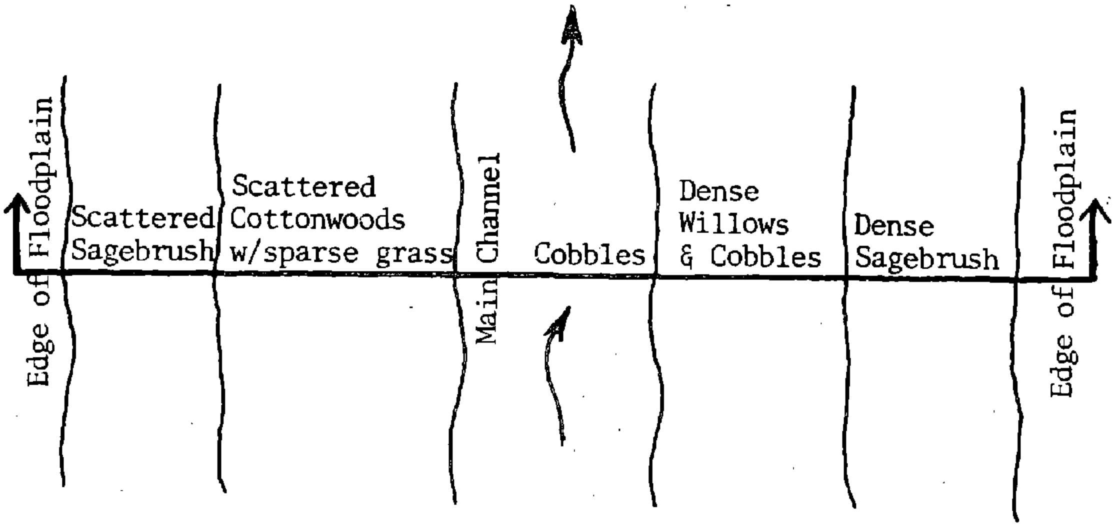
The system logic can be subdivided into six general engineering categories. These are: (1) stage-discharge, (2) stage-storage, (3) hydrograph, (4) headwater, (5) flow types and outlet conditions, and (6) flow distribution. These categories are discussed in an engineering sense to facilitate understanding of the system by the engineer.

Stage-Discharge

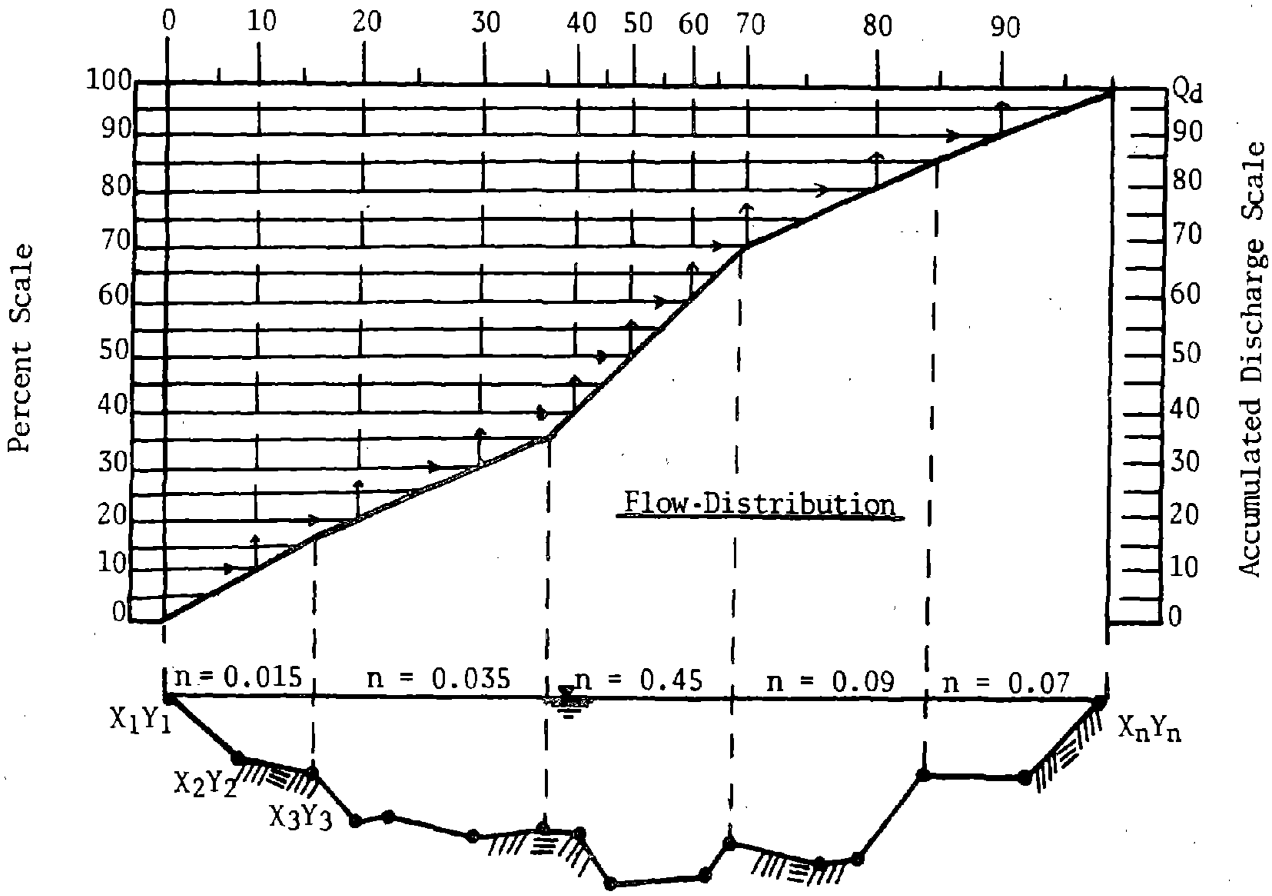
A unique site feature affecting a culvert's performance is the stage-discharge relationship (often termed "rating curve"). This relation is portrayed graphically by plotting flow depth vs. discharge. From this relationship, the program can obtain the various tailwater, T_w, values necessary in evaluating flow characteristics immediately downstream of the culvert outlet (often termed "getaway" conditions by laymen; see Figure 4). Hence, the cross section and profile slope used to compute the stage-discharge relationship must be typical of *downstream* conditions. This relationship predicts the natural flow depth of a flood for any particular discharge within the capacity limits of the channel cross section submitted to the program. A sample cross section is shown in Figure 1, whereas Figure 2 reflects the profile slope. Figure 4 also illustrates this concept. In passing, it should be mentioned that natural flow depth and stage are often used synonymously. Flow depth is measured above the streambed and stage is the corresponding elevation.

In addition to providing the discharge at various stages (for flow depths), the flow distribution logic also identifies other hydraulic characteristics unique to that particular cross section. These include discharge, q_i; velocity, v; Froude number, F_r; and tractive shear, τ, at various points across the cross section. The flow distribution is discussed in detail later.

Provision has been made in this system so the User can subdivide a cross section into a maximum of nine subsections with one subsection being the minimum requirement. Figure 1 reflects a cross section having five subsections. This provision provides considerable flexibility for the User in identifying different flow depths (geometry) and variable channel friction values due to soil and vegetation that may occur on a given cross section (Manning's n).



Plan View



Valley Section

Figure 1

Cross Section

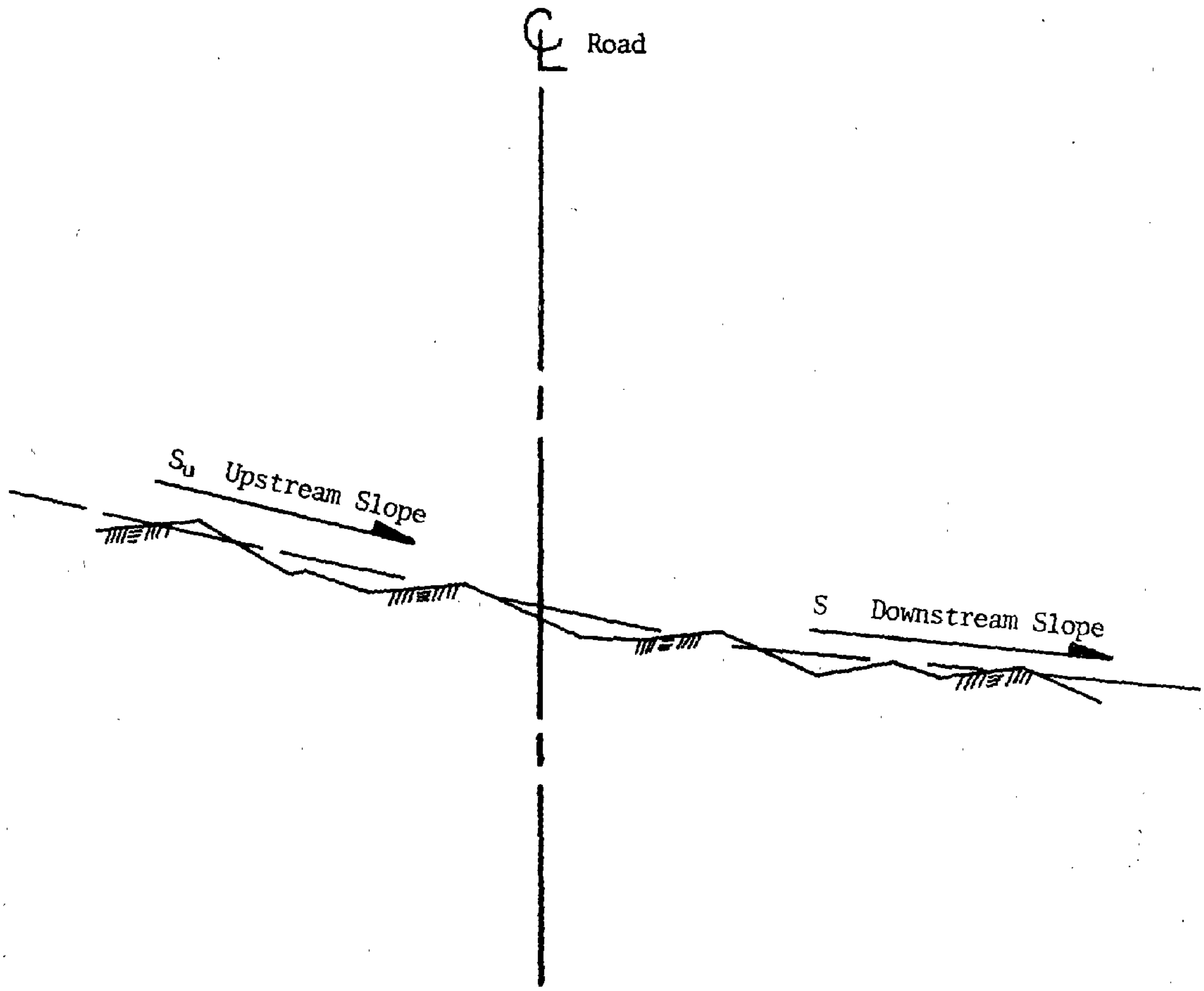


Figure 2

Profile Slope of Streambed

The various depth-discharge relationships necessary in defining the stage-discharge or rating curve are computed using Manning's equation and the equation of continuity. More complete discussion of these equations are found in various texts (5,14).

$$v = \frac{1.486}{n} R^{2/3} S_o^{1/2} \text{ (Manning's equation) --------------- } 2$$

$$q = va \text{ (Continuity equation) ----------------------------- } 3$$

The stage-discharge and flow distribution logic uses the channel cross section in one of two ways to compute hydraulic properties and the stage-discharge relationships.

1. With a homogeneous channel cross section (only one subsection), the program provides hydraulic characteristics for the entire cross section; i.e., the output reflects only average values for the entire cross section. A homogeneous cross section is defined as having uniform friction, n, and geometry across the entire cross section. Hence, the entire cross section is considered as one subsection; i.e., the cross section is not subdivided.

2. When the cross section is subdivided to reflect irregular shapes or different vegetal and friction patterns, the output will reflect the hydraulic properties from each individual subsection. As stated before, the program can accommodate up to nine subsections per cross section. In the analysis, the system logic subdivided each subsection further into relatively equal increments as reflected on Figure 1. This is discussed later in more detail under Flow Distribution.

The computational procedure is similar for both of the above applications; i.e., the latter application differs only in that it requires logic to sum discharges from each subsection for a given elevation level (stage). Both applications use Equations 2 and 3 for the discharge and velocity relationships. The application of Equations 2 and 3 is accomplished by starting at the lowest point within a subsection and using simple geometry to compute the initial incremental cross sectional area and wetted perimeter, compute an incremental discharge, and then increment the depth to the next higher elevation level (coordinate point $X_1 \rightarrow X_n$, $Y_1 \rightarrow Y_n$). The various incremental hydraulic properties are computed every 0.3 feet between elevation levels and at each elevation level as identified by the cross section coordinate points. Note the program makes use of Equations 2 and 3 elsewhere in the program (their variables may be algebraically interchanged making them somewhat obscure).

The Froude number is computed using:

$$F_r = \frac{v}{\sqrt{gH_d}} \text{ --- } 4$$

The Froude number evaluates the gravitational and momentum effects on the flow. Again, this is discussed in detail in hydraulic texts by Chow (5).

The program evaluates the streambed stability by estimating the tractive shear, τ, occurring on the bed. This is a gross estimate found in most texts and is computed using Equation 5:

$$\tau = \omega S_o (T_w) \text{ -- } 5$$

Comparing the tractive shear, τ, with allowable values for various streambed materials as found in modern open channel texts provides the User with an estimate of the channel stability.

The foregoing hydraulic properties for each increment within a subsection of a cross section are optionally available. The program can, on request, provide this information within the range of the six input discharges used to develop the culvert performance curve. This is accomplished through the program option, Flow Distribution (discussed later).

The User should be alerted that the stage-discharge relationship and related hydraulic properties are, at best, only approximate. The entire computational process presumes a uniform channel (uniform shape, friction, and hydraulic gradient). When this assumption is grossly in error, the User may wish to obtain additional cross sections reflecting the various channel irregularities identified above and compute a stage-discharge curve and related hydraulic properties using a water surface profile type analysis (not part of this program, see Reference 5). For this reason, provision has been made for the User to input a table of stage-discharge values, thereby overriding the internally computed stage-discharge relationship. Reservoirs or other unique downstream conditions affecting the culvert outlet may also necessitate inputting a table of stage-discharge values.

Stage-Storage

Routing flood hydrographs through a culvert requires quantification of upstream storage. The program accomplishes this by generating an internal stage-storage table. In this case, "stage" is the upstream pond depth above the culvert inlet flow line and not the natural flow depth discussed under Stage-Discharge. Storage is the volumetric storage occurring upstream from the culvert for a given stage or pond depth (culvert headwater, H_w, see Figure 4). This program provides two alternative means of computing the stage-storage relationship. One method uses a cross section and channel slope such as shown on Figures 1 and 2 that are input to the program. Provision has been made for the User to include ten or more cross sections in order to define the upstream stage-storage characteristics. The other method uses an externally computed stage-storage table which can be input to override the internally computed stage-storage table computed by the cross section alternative.

When the User does not specifically identify a cross section *at the culvert entrance* for the upstream stage-storage relationship, the program will internally assume the first upstream cross section that is provided also defines the cross section at the culvert inlet. The stage-storage relationship is then computed using the assumed cross section at the culvert inlet, the first upstream cross section at its indicated upstream location, and then any other upstream cross sections (Figure 3). A downstream cross section may be input to serve as the cross section reflecting upstream storage provided the elevations are adjusted accordingly. *The User is cautioned that* in this simplistic solution, the downstream section must be typical of upstream storage capacities.

"Humps" or islands in a cross section introduce a unique problem in the internal stage-volume definition. If only one cross section is used to define upstream pond storage and it reflects an island or "hump," the program necessarily must assume this island or "hump" has no length! With large, permanent islands, this assumption could introduce a significant error in the stage-storage relationship. Where "humps" are small or reflect temporary or mobile bars, this assumption may be acceptable. The problem of permanent islands can be alleviated in one of two ways. The first way is to provide several upstream cross sections sufficient to define the island length; say one cross section across both ends and another across the center of the island. The second way is to compute and input a stage-storage table as discussed earlier.

The internal logic procedure for computing the stage-storage relationship is based on the average end area method commonly associated with earthwork computations. This method makes use of the foregoing cross section(s) and is illustrated in Figure 3. In equation form:

$$V_s = \sum_{j=1}^{9} \left(\frac{a'_j + a'_{j+1}}{2} \right) L_v \div B_s \text{ ----------------------------- } \qquad 6$$

Equation 6 is internally incremented through the elevation levels (stages) identified on the cross section, thereby resulting in a table of stage-storage relationships. Whether any given upstream cross section is used to define the storage prism depends on whether the ponded water will be sufficiently deep so as to reach upstream to that cross section. This is done by having the program search and determines that portion, if any, of a cross section which is within the pond. Upstream from the last cross section and still *within the incremental storage prism* for any incremental depth, the program assumes a triangular-shaped prism by projecting the upstream stream slope (input) to where it intercepts the incremental pond level. This projection identifies the length, L_v, and computes this volume by setting the last upstream cross section end area to zero. That portion of the upstream pond storage lying above the roadway fill slope is excluded from the pond storage (reference Figure 4).

The *surface area* for any incremental level of ponding (inundated area), A_p, is computed in a similar manner using the cross section top widths, t', for a given depth (stage) of pond and the distance, L_v, between cross sections (Figure 3). In equation form:

$$A_p = \sum_{j=1}^{9} \left(\frac{t'_j + t'_{j+1}}{2} \right) L_v \div B_s \text{ ---------------------------- } \qquad 7$$

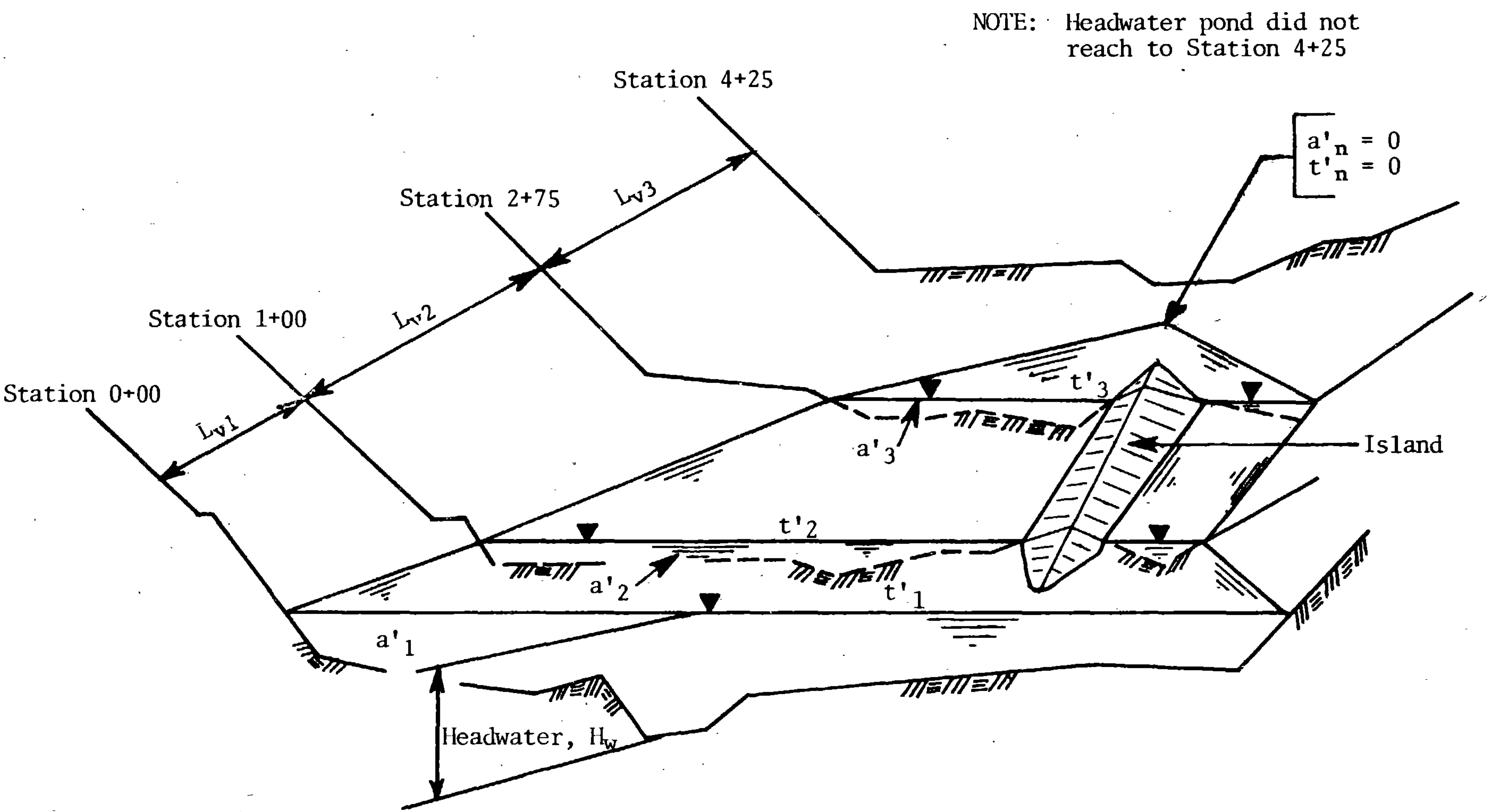


Figure 3

Upstream Storage Prism
(only one elevation level shown)

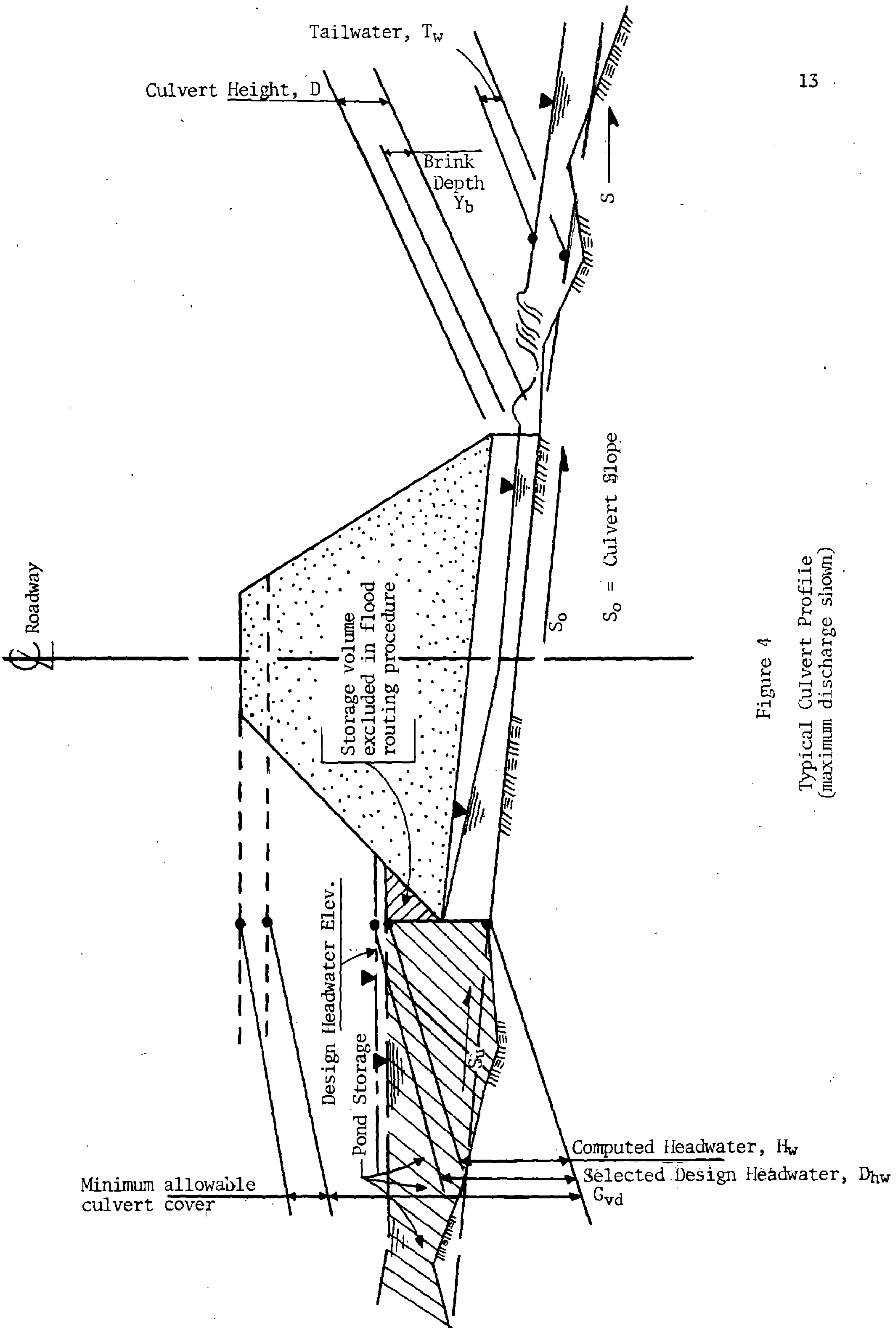


Figure 4

Typical Culvert Profile
(maximum discharge shown)

The pond's surface area for the remaining triangular portion on the upstream end of any incremental prism assumes one of the top widths to be zero.

If it is believed the upstream stage-storage relationship can not be reasonably identified with cross sections, then the User should manually compute a separate stage-storage relationship. This might be necessary where there are complex reservoirs, channel confluences, etc. The procedure is to manually develop a table of incremental values for storage vs. stage (depth) for inputting to the program. Contour mapping facilitates identification of complex upstream storage areas. Planimetering the area at various elevation levels provides areas in the *horizontal plane* as opposed to the *vertical plane* (see Figure 3) that can be used to manually compute a stage-storage relationship using logic similar to Equation 6. The stage vs. area inundated is tabulized manually and input to the system to define this relationship.

The User can do several things to improve the accuracy of the stage-storage relationships:

1. When using the downstream cross section to define the upstream storage pond is justified, be sure to raise all cross section elevations so they are relative to the streambed elevation *at the culvert entrance.*
2. The storage existing above the upstream fill slope will be ignored (see Figure 4). At present, this program does not account for this storage; consider this a safety factor in the design. This storage could be significant with high fills and/ or wide cross sections, thereby justifying inputting a manually computed stage-storage and area inundated tables.
3. When the downstream cross section (or the upstream cross section, if one is available) does not adequately reflect the cross section at the culvert entrance, then consider using the road's centerline cross section as the initial cross section used in computing the stage-storage relationship. Again, be sure to adjust the elevations to agree with the culvert's inlet elevation and also adjust the lateral distances to normalize a skewed or curved centerline section.
4. Always use the average channel slope occurring upstream from the culvert to compute the stage-storage relationship (see Figure 4). This slope can often vary from the average slope through a site.
5. The User should be aware of inaccuracies arising from "humps" or islands in the cross section. Small, mobile and temporary islands should not introduce significant errors, whereas large islands could result in a gross under-design. Input at least three cross sections when a permanent island or "hump" will significantly affect the storage; consider developing and inputting a stage-storage and area inundated table as an alternative. It may be possible to synthesize the necessary cross sections where none are available by assuming an island length (distance between cross sections) using the survey plan view or aerial photographs.
6. Use the stage-storage table input alternative on very complex sites. This added design cost should be weighed against the site's importance, however.

7. Use average distance rather than survey station distances between upstream cross sections for storage areas having a sinuous shape.

Hydrograph

In order to route floods through the culvert, roadway, and site geometry, it is necessary to define a hydrograph (time vs. discharge relationship for flood). The example of Figure 6 displays a typical, single peak hydrograph common to small, semiarid watersheds. Research conducted by the United States Geological Survey in Wyoming (1) has defined such hydrograph relationships for watersheds ranging from zero to 15 square miles shown in dimensionless form on Figure 5. The dimensionless data from Figure 5 is contained within the system as reflected in Table 1; i.e., this particular dimensionless relationship is stored and used internally within the program to compute hydrographs. This particular hydrograph relationship can be suppressed as noted later.

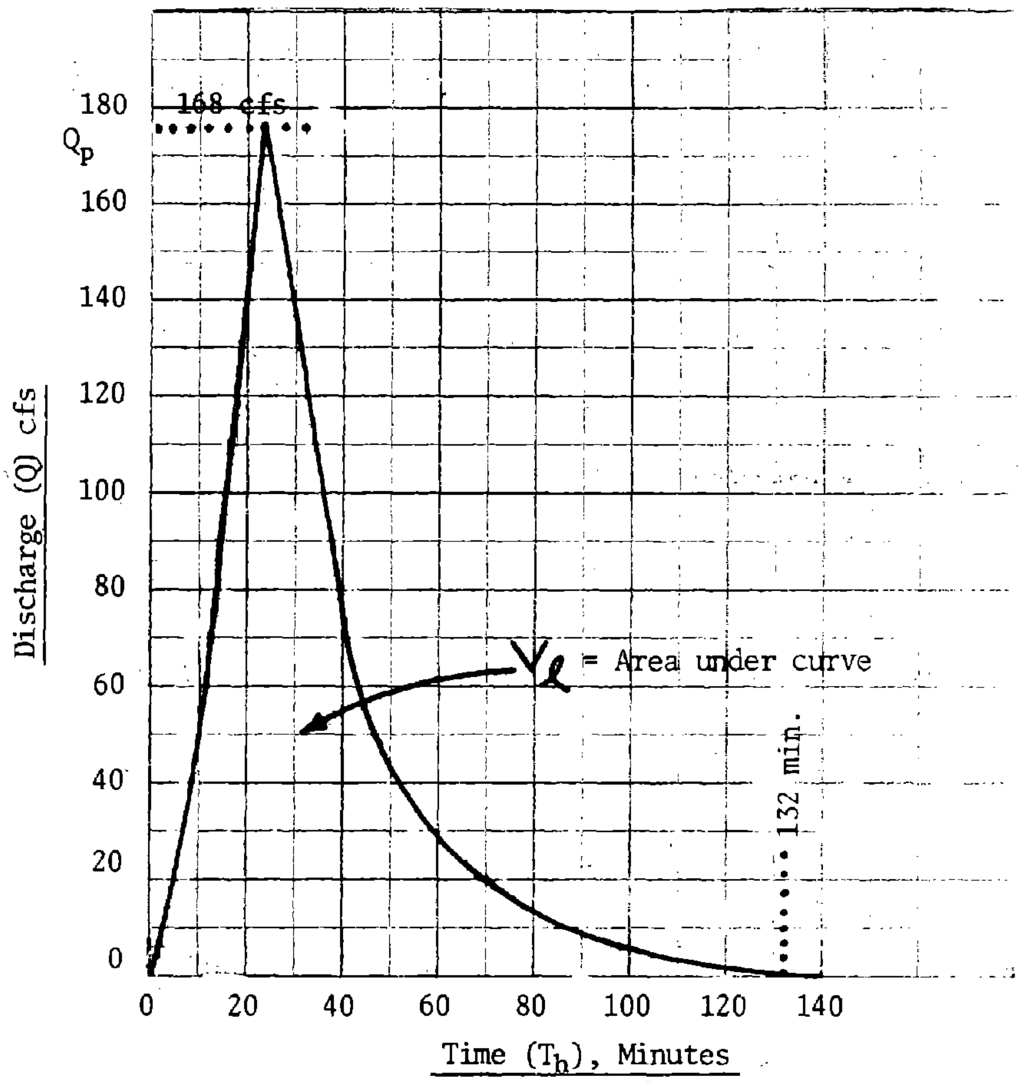
The total volume contained under the hydrograph curve for a given frequency is identified by the same U.S. Geological Survey report in terms of drainage area (1). The standard error of estimate for the volume relationship can be significantly improved by also including such watershed parameters as maximum basin relief, basin slope, and channel slope in the expression used to compute the hydrograph volume. Therefore, because of these many alternative values of flood volume consistent with different projections of risk accuracies, the User must identify and input the desired volume in units of acre-feet. The simplistic form of these volume equations appear in the DESCRIPTION OF INPUT, but the User is cautioned that these are simplistic equations and that reference should be studied before they are used.

From the U.S. Geological Study (1), it was possible to identify a simple hydrograph shape that provided a reasonable simulation of the time/discharge relationship for watersheds in semiarid regions of Wyoming under 15 or more square miles in contributing area. This shape is a function of volume, V_ℓ, and peak discharge, Q_p. The relationship between these variables is shown in the following equations:

$$\text{Minutes per Time Unit} = 726\,\frac{(V_\ell \div 970)}{(Q_p \div 60)} \quad \text{------------------} \quad 8$$

$$\text{Cubic Feet/Second per Flow Unit} = \frac{Q_p}{60} \quad \text{--------------------} \quad 9$$

The example of Table 2 and Figure 6 illustrate the use of these equations. In the example of Table 2, the peak discharge, Q_p, is 168 cfs and the corresponding volume, V_ℓ, is 7.03 acre-feet. The time and flow units of Table 1 correspond to these defined by the research and for convenience are also displayed in Figure 5.



Example (reference Table 2)

Q_p = Q peak = 168 cfs
V_ℓ = Volume = 7.03 acre-feet

$$\text{Flow Unit} = \frac{Q_p}{60} = 2.8$$

$$\text{Time Unit} = (726)\left(\frac{\frac{V_\ell}{970}}{\frac{Q_p}{60}}\right) = 1.88$$

Figure 5

Computed Hydrograph
(In accordance with Reference 1)

Table 1

Dimensionless Hydrograph
Flow/Time Units

Unit of Time	$\frac{\text{Min.}}{\text{T.U.}}$[1]	Min.	Unit of Flow	$\frac{Q}{\text{T.U.}}$[2]	Q
0			0		
3			5.6		
5			13		
7			25		
10			49		
11			57		
12			60		
13			59		
14			55		
18			38		
23			23		
30			12		
40			5.2		
50			2.0		
60			0.5		
70			0		

[1] $\frac{\text{Minutes}}{\text{T.U.}} = 726\left(\frac{V/970}{Q/60}\right)$

[2] $\frac{Q}{\text{F.U.}} = \frac{Q}{60}$

T.U.= Time Unit

F.U.= Flow Unit

Table 2

Sample of Computed Hydrograph
(Reference Figure 6)

Units of Time	Minutes/Time Unit	Minutes	Units of Flow	cfs/Flow Unit	cfs
0	1.88	0	0	2.80	0
3		6	5.6		16
5		9	13		36
7		13	25		70
10		19	49		137
11		21	57		160
12		23	60		168
13		24	59		165
14		26	55		154
18		34	38		106
23		43	23		64
30		56	12		34
40		75	5.2		15
50		94	2.0		5.6
60		113	0.5		1.4
70	1.88	132	0	2.80	0

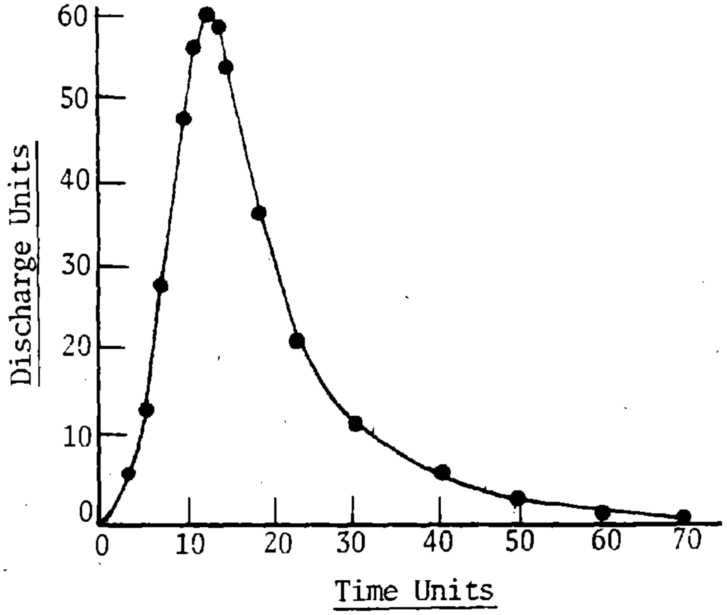


Figure 6

Dimensionless Hydrograph

The foregoing described how the program computes the hydrograph internally. When drainage areas are larger than about 15 square miles in semiarid regions, they frequently exhibit complex characteristics; multiple peaks, broad time bases, delayed peaks, and possibly other characteristics that preclude such simple generalization as afforded by research by Craig and Rankle (1). As such, drainages of this size are considered outside the research limits. For this reason, provision has been made whereby the User can suppress the internal hydrograph computation. This alternative is done by inputting a hydrograph of the User's choice. Input data consists of a series of incremental discharges, Q_i, and their corresponding incremental time values, Δt. Obviously, three would be the minimum number of discharge and time values needed to describe a hydrograph (the commonly used "triangular" hydrograph). The maximum number of discharge and time values is 200 (67 cards). *This particular alternative makes this culvert design system technically usable in any geographic region in the world, provided a reasonable hydrograph can be synthesized.*

Headwater

This logic determines the upstream pond depth, H_w (Figure 4), identifies flow types, and computes the culvert barrel's outlet properties (velocity, depth, Froude number). The *governing* headwater within Zone 1 of Figure 7 is identified by first comparing the headwater that would result if the culvert were in inlet control, H_i, to the headwater that would result if the culvert were in outlet control, H_o (8,9). The greater of the two headwaters governs within Zone 1. Either inlet or outlet control can occur within Zone 1 depending on the culvert geometry, discharge, and other site characteristics.

As the discharge, Q_d, is increased, the headwater increases to where the inlet becomes submerged (about a headwater over vertical culvert dimension of $H_w/D \simeq 1.2$). When $1.2 \leq H_w/D < 1.5$, the culvert headwater, H_w , tends to fluctuate, vortexes form to introduce air into the culvert, and the discharge capacity varies (shaded region of Figure 5). This phenomenon occurs as the culvert approaches and reaches its full flow capacity, Q_f. Zone 2 of Figure 7 reflects this graphically.

This fluctuation created a discontinuity in the program logic. This program avoids this fluctuating process by considering only the "worse case." This is done by computing the full barrel headwater, H_{wf}, associated with the full barrel discharge, Q_f. This establishes point b on Figure 7. Line bc is the minimum headwater used in Zone 2 of Figure 7. Zone 3 is recognized by the computer as that region where the computed headwater, H_w, exceeds the full flow headwater, H_{wf}. These three zones are not to be considered specific blocks or segments of logic within the system but rather as a means whereby this portion of the documentation can simply describe the technical solution used in linking part full barrel flow to full barrel flow without incurring a discontinuity in the program's logic.

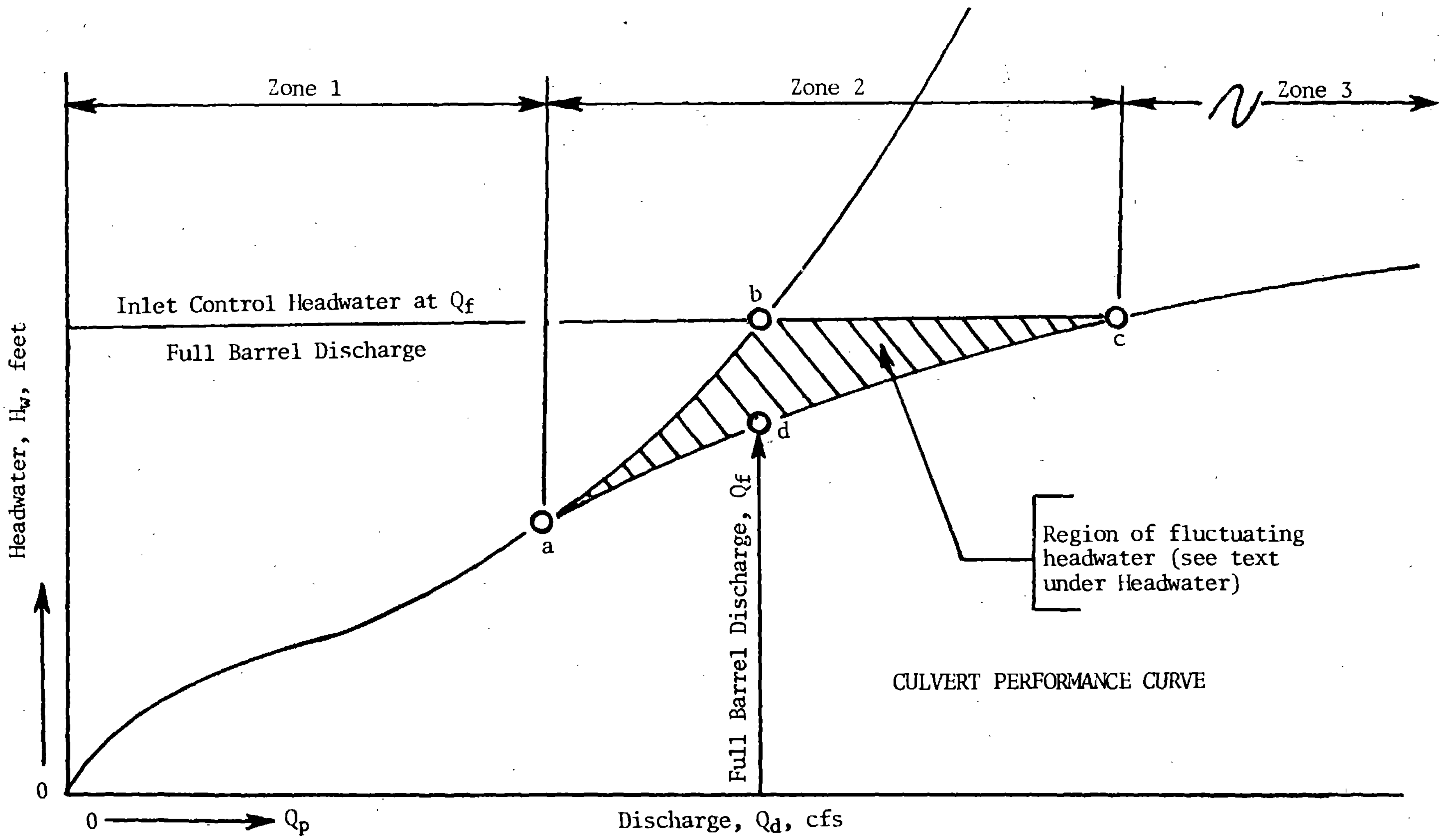


Figure 7

Schematic Culvert Performance Curve

In Zone 1, the inlet control headwater, H_i, for various culvert and inlet types is defined by Equation 10. These headwater equations were obtained through regression of data generated by laboratory studies conducted by the National Bureau of Standards between 1955 and 1967. Reference Tables 3, 4, 5, 6, and 7 for coefficients used in Equation 10.

$$H_i = (A' + B'X + C'X^2 + D'X^3 + E'X^4 + F'X^5)D \text{ ------------- } 10$$

The headwater for outlet control is computed using a form of Bernoulli's equation. Specifically:

$$H_o = H + H_e - (LS_o) \text{ -- } 11$$

The reader is cautioned that in the culvert logic, the system has by initialization procedures, defined the term H as two different but related items. Initially, it defines H in Equation 11 in accordance with this documentation. Further on in the program logic, it redefines H_o in Equation 11 as H.

The energy line for *part full flow* at the outlet, H_e , has been approximated by using the larger of tailwater, T_w, (8) or the hypothetical value[3]

$$\frac{d_c + d}{2} \text{ -- } 12$$

This situation is considered to be *tailwater control* which is one type of *outlet control*.

When the culvert reaches *full flow*, the outlet energy line is defined by using the larger of tailwater, T_w, or the outlet energy which is expressed only as the vertical culvert height, D, as the velocity head is contained in Equation 13. This situation is considered to be *barrel control*, another form of outlet control.

In the transition between the outlet control and barrel control values a discontinuity exists. The following value

$$D - D(\frac{Q_f - Q_d}{.01Q_f})$$

is used to bridge the discontinuity.

The product of culvert length and slope, LS_o, defines the elevation difference in Bernoulli's equation. As such, it reduces the resultant outlet headwater, H_o, by providing elevation head in accordance with Equation 11.

---

[3] Normally, this expression is considered to be $(d_c + D) \div 2$. The normal culvert depth (d) was used in lieu of vertical culvert height (D) in order to avoid program errors and gross inaccuracies when very small hydrograph discharges are being routed through the culvert.

Any time the flow, Q_d, is equal to or greater than the full barrel flow, a full barrel condition is used. This latter criteria may be slightly in error as there are certain unique situations where a full barrel develops beyond the inlet, whereas in the vicinity of the entrance due to flow contraction, full flow does not occur (reference Figure 7). The error is assumed to be insignificant as it would occur primarily with very short culvert barrels.

Table 3

Circular Concrete and Elliptical Concrete Inlet Control Coefficients (10)

Inlet Type	Code*	A'	B'	C'	D'	E'	F'
Socket-end Projecting	1	0.108786	0.662381	-0.233801	0.0579585	-0.0055789	0.000205052
Square Edge Projecting	2	0.167287	0.558766	-0.159813	0.0420069	-0.0036925	0.000125169
Socket-end Headwall	3	0.114099	0.653562	-0.233615	0.0597723	-0.0061634	0.000242832
Square Edge Headwall	4	0.087483	0.706578	-0.253295	0.0667001	-0.0066165	0.000250619
End Section	5	0.120659	0.630768	-0.218423	0.0591815	-0.0059917	0.000229287
Bevel (A) R/D = 0.067	6	0.063343	0.766512	-0.316097	0.0876701	-0.0098369	0.000416760
Bevel (B) R/D = 0.033	7	0.081730	0.698353	-0.253683	0.0651250	-0.0071975	0.000312451

*Note: This is first digit of computer code in Table 9.

Table 4

Concrete Arch Inlet Control Coefficients (10)

Inlet Type	Code*	A'	B'	C'	D'	E'	F'
Socket-end Projecting	1	0.089053	0.712545	-0.270921	0.079250	-0.0079805	0.000293213
Socket-end Headwall	3	0.111281	0.610579	-0.194937	0.051289	-0.0048054	0.000168547
Mitered	8	0.083301	0.795145	-0.434075	0.163774	-0.0249139	0.00141066

*Note: This is first digit of computer code in Table 9.

Table 5

Circular Metal Inlet Control Coefficients (11)

Inlet Type	Code*	A'	B'	C'	D'	E'	F'
Projecting	2	0.187321	0.567719	-0.156544	0.0447052	-0.0034360	0.000089661
Headwall	4	0.167433	0.538595	-0.149374	0.0391543	-0.0034397	0.000115882
End Section	5	0.120659	0.630768	-0.218423	0.0591815	-0.0059917	0.000229287
Bevel (A) R/D = 0.067	6	0.063343	0.766512	-0.316097	0.0876701	-0.0098369	0.000416760
Bevel (B) R/D = 0.033	7	0.081730	0.698353	-0.253683	0.0651250	-0.0071975	0.000312451
Mitered (or Step Bevel)	8	0.107137	0.757789	-0.361462	0.1233932	-0.0160642	0.000767390

*Note: This is first digit of computer code in Table 8.

Table 6

Metal Arch Inlet Control Coefficients

Inlet Type	Code*	A'	B'	C'	D'	E'	F'
Projecting	2	0.089053	0.712545	-0.270921	0.0792502	-0.0079805	0.00029321
Headwall	4	0.111281	0.610579	-0.194937	0.0512893	-0.0048054	0.000168547
Mitered (or Step Bevel)	8	0.083301	0.795145	-0.434075	0.1637740	-0.0249139	0.00141066

*Note: This is first digit of computer code in Table 8.

Table 7

Concrete Box Inlet Control Coefficients (12, 13)

Inlet Type	Code*	A'	B'	C'	D'	E'	F'
Wingwalls α = 30° to 75° Square top edge	1	0.072493	0.507087	-0.117474	0.022170	-0.0014896	0.000038013
Wingwalls α = 90° and 15° Square top edge	2	0.122117	0.505435	-0.108560	0.020781	-0.0013676	0.000034564
Wingwalls parallel (α = 0°) Square top edge	3	0.144138	0.461363	-0.092151	0.020003	-0.0013645	0.000035843
Wingwalls α = 18° to 33.7° 1½:1 top bevel	4	0.0695633	0.4412465	-0.0743498	0.01273183	-0.0007588	0.00001774
Headwalls α = 90° inlet Skewed to 45° Square top edge	5	0.122117	0.505435	-0.10856	0.0207809	-0.00136757	0.00003456
Headwalls α = 90° inlet Skewed to 45° 1:1 top bevel	6	0.1566086	0.3989353	-0.0640392	0.01120135	-0.0006449	0.000014566
Headwalls α = 90° inlet Skewed 90° 1½:1 Top bevel	7	0.0967588	0.4551575	-0.0812895	0.0125577	-0.00067794	0.0000148

*Note: This is first digit of computer code in Table 10.

The head or energy, H, required to pass a given quantity of water through a culvert operating in barrel control and ignoring outlet conditions (tailwater, T_w) consists of three major parts. These three parts usually express energy in feet of water and include a velocity head, H_v; an entrance loss, H_ℓ; and a barrel friction loss, H_f. This energy is obtained through ponding water at the entrance and can be expressed as:

$$H = H_v + H_\ell + H_f \quad \text{-----------} \quad 13$$

When the barrel is full, the velocity head, H_v, is defined by Equation 14 with V_f being the full flow velocity.

$$H_v = V_f^2/2g \quad \text{-----------} \quad 14$$

If the barrel is not flowing full, the velocity head, H , is computed using partial flow area to generate a unique velocity, V. With part full flow, it was necessary to develop a constraint in the computer logic in order to preclude the high velocities often generated by steep culverts operating in inlet control from erroneously forcing the culvert into outlet control due to the high velocity head being generated. This was done by limiting the *maximum part full* velocity, V, to that velocity corresponding to critical depth or V_c (the *minimum* part full velocity is of course that velocity corresponding to full flow, V_f); i.e., $V_c \geq V \geq V_f$. The logic for this constraint is simple. Minimum energy corresponds to that energy associated with critical flow conditions, and when the velocity exceeds critical velocity, the culvert is sufficiently steep as to have its velocity and velocity head generated solely by the culvert slope (gravity) and not by an upstream pond depth (elevation). Naturally, this presumes tailwater control is not affecting the ability of the culvert slope to generate this velocity.

If the tailwater momentum is greater than the pipe momentum, the velocity head, H_v, is computed using the velocity associated with the tailwater depth or D, whichever is less. The same limits on velocity are used as in the preceding paragraph with one additional restraint. If tailwater momentum governs and the tailwater depth is less than d_n, the velocity associated with d_n is used to compute H_v.

The entrance loss is expressed in terms of the velocity head and an entrance loss coefficient, K_e, that is unique for various types of commonly used culvert entrances. These coefficients can be found in Tables 8, 9, and 10. For a *full barrel*, the velocity head is the same as defined in Equation 4. Using this velocity head, the following expression is used to compute that portion of the head, H, in Equation 13 that is attributed to entrance losses.

$$H_\ell = K_e \frac{V^2}{2g} \quad \text{-----------} \quad 15$$

As explained previously with *part full* barrels, the critical velocity, V_c, is the maximum velocity used to compute the velocity head portion of Equation 15 with the full flow velocity being the minimum velocity that can ever be used for this velocity head.

The barrel friction loss, H_f, shall be defined for Equation 16 as:

$$H_f = \left|\frac{29.1\ n^2 L}{R_n^{1.33}}\right| \left|\frac{V_f}{V_o}\right|^{2/3} \frac{(V)^2}{2g} \quad \text{-----------} \quad 16$$

Table 8

Metal Pipe Inlet Codes (10, 11)

Inlet Type	Circular				Pipe-Arch		Entrance Coefficient K_e
	Riveted	Riveted 25% Paved	Structural Plate	Structural Plate 25% Paved	Unpaved	25% Paved	
Projecting	21	22	23	24	23	24	0.9
Headwall	41	42	43	44	43	44	0.5
End Section	51	52	53	54	--	--	0.5
Bevel (A) R/D = 0.067	61	62	63	64	--	--	0.2
Bevel (B) R/D = 0.033	71	72	73	74	--	--	0.2
Mitered (or Step Bevel)	81	82	83	84	83	84	0.7
Manning's n	0.024	0.021	0.032	0.026	0.032	0.026	

Table 9

Concrete Pipe Inlet Codes (10, 11)

Inlet Type	Circular	Arch	Ellipse	Entrance Coefficient, K_e
Socket-end Projecting	11	11	11	0.2
Square Edge Projecting	21	--	21	0.5
Socket-end Headwall	31	31	31	0.2
Square Edge Headwall	41	--	41	0.5
End Section	51	--	51	0.5
Bevel (A) R/D = 0.067	61	--	61	0.2
Bevel (B) R/D = 0.033	71	--	71	0.2
Mitered	--	81	--	0.5

Table 10

Box Culvert Inlet Codes (12, 13)

Inlet Type	Concrete	Entrance Coefficient, K_e
Wingwalls ∝ = 30° to 75° Square top edge (R/D = 0)	11	0.4
Wingwalls ∝ = 90° and 15° Square top edge (R/D = 0)	21	0.5
Wingwalls ∝ parallel (∝ = 0°) Square top edge (R/D = 0)	31	0.7
Wingwalls ∝ = 30° to 75° 1½:1 top bevel (R/D = 0.083)	41	0.2
Headwalls ∝ = 90° Inlet skew 90° to 45° Square top edge (R/D = 0)	51	0.5
Headwalls ∝ = 90° Inlet skew 90° to 45° 1:1 top bevel (R/D = 0.042)	61	0.2
Headwalls ∝ = 90° Inlet skew 90° 1½:1 top bevel (R/D = 0.083	71	0.2

Equation 16 is obtained from the familiar Darcy-Weisbach equation (14), which has been manipulated by others to make use of the friction value, n, in Manning's euqation (15). Note that for this system, Equation 16 has been modified by the term $(V_f \div V_o)^{2/3}$ and by using V_o in lieu of the full flow velocity normally associated with the Darcy-Weisbach equation. This was an arbitrary modification used by the Wyoming Highway Department in attempting to more closely approximate the true friction losses for part full flow. Also noteworthy is that this equation is continuous between part full and full flow conditions; i.e., at full flow, the true Darcy-Weisbach equation exists in accordance with accepted theory as $V_o = V_f$. Similar to V_o, the value used for the hydraulic radius in Equation 16, R_n, is that corresponding to the barrel flow conditions but constrained between critical and full flow conditions or $R_c \leq R_n \leq R_f$.

Admittedly, the friction loss in part full flow is not computed with any great exactness by this system. Ideally, a water surface profile through the barrel is required to best identify the losses. To circumvent a sophisticated water surface profile procedure, the foregoing approximation offered by modifying Equation 16 was used.

Program problems were encountered when the head, H_o, was being computed for small design discharges, Q_d, that had small flow depths in the barrel. To resolve this problem, the lower limit on outlet control headwater, H_o, was limited to the normal culvert flow depth, d, as a minimum. There was no upper limit constraint.

Flow Types and Outlet Conditions

The program has a routine to identify the flow types presented in Figure 8. Once the flow types have been identified, the program then estimates the hydraulic properties existing at the outlet. These properties include outlet flow depth (brink depth, Y_b; velocity, V_b; specific force, M_b; and Froude number F_{rb}. These are the essential properties necessary to input into a separate culvert outlet protection program (6,7).

These flow types not only serve to identify the outlet flow characteristics, but also aid the engineer in sketching or visualizing the water surface profile through the culvert. Identification of the water surface profile serves several useful purposes among which is a visual check on the analysis (does the profile look valid in light of the site conditions, tailwater, etc.), suitability of various outlet protection devices, whether the structure is in inlet or outlet control and hence the suitability of inlet improvements. The engineer will undoubtedly identify other uses for these flow profiles. *It should be noted that while these flow profiles are similar to those used by the U.S. Geological Survey, they should not be construed as implying that the U.S. Geological Survey culvert equations are used in this system, with the single exception of differentiating between Types V, VI, and VII flow as shown on Figure 10 and related discussion regarding Figure 10.*

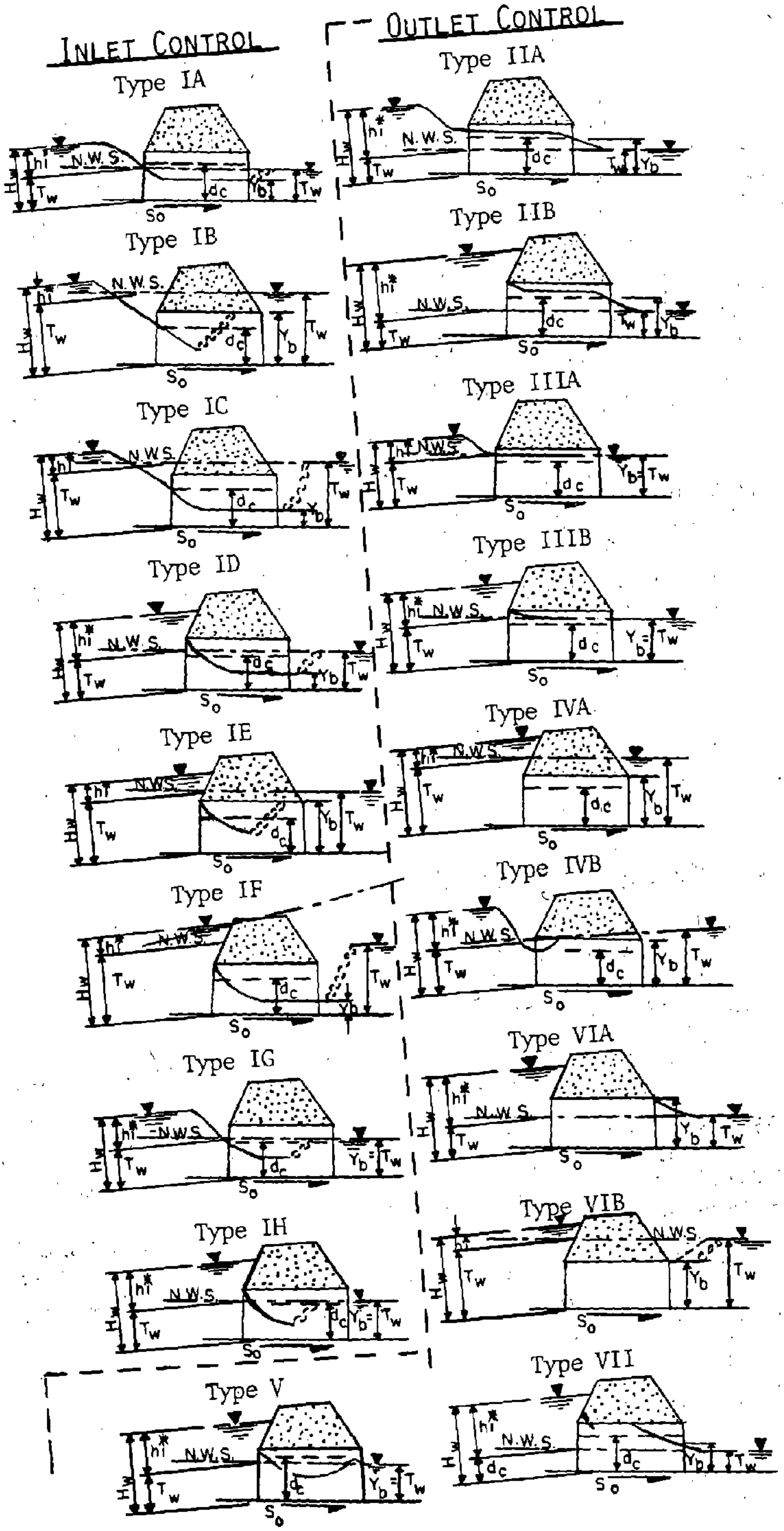


Figure 8

Culvert Flow Types
(also reference Table 3)

The routine for identifying the various flow types uses the criteria shown on Figure 8 and Table 11. Once the flow type is identified, the necessary culvert outlet properties are computed using the following expressions. Froude number and specific force equations are familiar expressions commonly found in hydraulic textbooks (5,14) as is the continuity equation used to compute outlet velocity, V_b.

Froude Number:

$$F_{rb} = \frac{V_b}{\sqrt{gY_b}} \tag{18}$$

Culvert Outlet Specific Force:

$$M_b = \beta_1 \omega A_b \frac{Y_b}{2} + \beta_2 \frac{\omega}{g} Q_d V_b \tag{19}$$

Tailwater Specific Force:

$$M_{TW} = \omega A_{TW} \frac{TW}{2} + \frac{\omega}{g} (Q_d) V \tag{20}$$

Culvert Outlet Velocity:

$$V_b = \frac{(Q_d)}{A_b} \tag{21}$$

The specific force equations (19 and 20) *do not* use the centroid of the outlet area, A_b, as recommended in the literature by Chow (5). This complexity has been eliminated through research by Simons (16) which has shown that the specific force at culvert outlets of different geometric shape varies in accordance with correction factors, β_1 and β_2. These coefficients have been identified for circular and rectangular culverts only. It was, therefore, assumed that the β_1 and β_2 values for rectangular shapes are sufficient for arch and oval culverts. The β_1 and β_2 coefficients are defined by Equations 22 and 23 and by first assuming β_1 is as defined in Equation 23; i.e., the control term $6\beta_1$, uses β_1 as defined by Equation 23.

Round Culverts

$$\text{If} \quad 6\beta_1 < \frac{Q_d}{B^{5/2}}, \text{ use } \beta_1 = 0.82666 + 0.75654(T_w \div Y_b) - 0.10305(Q_d \div B^{5/2}) \tag{22}$$

$$\text{If} \quad 6\beta_1 > \frac{Q_d}{B^{5/2}}, \text{ use } \beta_1 = 0.46452 + 0.35468(T_w \div Y_b) + 0.02237(Q_d \div B^{5/2}) \tag{23}$$

$$\beta_2 = 1.02 \tag{24}$$

Table 11

Flow Type Variables*

Flow Type	H_w/D	d/d_c	Q_d/Q_f	$(S_oL+D)/T_w$	S_o/S_c	T_w/D	M_b/M_{TW}	d/D	d_c/T_w	d_c/D	Y_b
IA	<1.5	<1.0	<1.0	-	>1.0	<1.0	>1.0	<1.0	-	<1.0	d
IB	<1.5	<1.0	<1.0	>1.0	-	>1.0	<1.0	<1.0	-	<1.0	D
IC	<1.5	<1.0	<1.0	>1.0	>1.0	>1.0	>1.0	<1.0	-	<1.0	d
ID	>1.5	<1.0	<1.0	-	>1.0	<1.0	>1.0	<1.0		<1.0	d
IE	<1.5	<1.0	<1.0	>1.0	>1.0	>1.0	<1.0	<1.0	<1.0	<1.0	D
IF	>1.5	<1.0	<1.0	>1.0	>1.0	>1.0	>1.0	<1.0	<1.0	<1.0	d
IG	<1.5	<1.0	<1.0	-	>1.0	<1.0	<1.0	<1.0	>1.0	<1.0	T_w
IH	>1.5	<1.0	<1.0	-	>1.0	<1.0	<1.0	<1.0	>1.0	<1.0	T_w
IIA	<1.5	>1.0	<1.0	-	<1.0	<1.0	-	<1.0	>1.0	<1.0	d_c
IIB	>1.5	>1.0	<1.0	-	<1.0	<1.0	-	<1.0	>1.0	<1.0	d_c
IIIA	<1.5	>1.0	<1.0	-	<1.0	<1.0	-	<1.0	<1.0	<1.0	T_w
IIIB	>1.5	>1.0	<1.0	-	<1.0	<1.0	-	<1.0	<1.0	<1.0	T_w
IVA	>1.5	>1.0	<1.0	<1.0	<1.0	>1.0	-	-	<1.0	<1.0	D
IVB	<1.5	>1.0	<1.0	>1.0	<1.0	>1.0	-	-	<1.0	<1.0	D
V	-	-	>1.0	-	-	<1.0	-	-	-	<1.0	d_c
VIA	-	-	>1.0	-	-	<1.0	-	>1.0	-	>1.0	D
VIB	-	-	>1.0	-	-	>1.0	>1.0	>1.0	-	>1.0	D
VII	-	-	>1.0	-	-	<1.0	-	>1.0	>1.0	<1.0	say $(d_c+T_w)\div 2$

*Figure 8 illustrates these criteria for identifying flow types

H_w = Headwater pond, feet
D = Vertical culvert height, feet
d = Normal flow depth in culvert without tailwater influence, feet
d_c = Critical flow depth in culvert, feet
Q_d = Barrel discharge, cfs
Q_f = Discharge when barrel is full, cfs
S_o = Culvert slope, feet/feet
L = Culvert length
T_w = Flow depth in natural channel downstream
S_c = Critical culvert slope, feet/feet
M_b = Specific force at culvert outlet, lbs
M_{TW} = Specific force at culvert outlet due to tailwater, lbs
Y_b = Brink Depth, feet

Rectangular Culverts

Assume these coefficients are valid for arch and elliptical shapes also. β_1 can not be greater than 1.0 or less than zero; i.e., $0 < \beta_1 < 1.0$. If $S_o < S_c$, and $T_w < Y_b$, then

$$\beta_1 = \left(\frac{d_c}{Y_b}\right)^2 \left(3 - 2\frac{d_c}{Y_b}\right) \text{ ------------------------------------ } 25$$

Otherwise,

$$\beta_1 = 1.00 \text{ -- } 26a$$

$$\beta_2 = 1.00 \text{ -- } 26b$$

In accordance with Figure 8, the outlet (brink) depth, Y_b; corresponds to either the tailwater, T_w; the culvert's critical depth, d_c; the culvert's normal depth, d; or the culvert's vertical dimension, D; for full flow. As such, the appropriate depth applicable to a culvert operating under certain identifiable conditions is also identified in Table 11. The remaining geometric variables in Equations 18 through 21 are then identified in accordance with the appropriate brink depth, Y_b, as indicated in Table 11.

The geometric properties of culverts flowing partially full are computed using the following equations. The properties include culvert waterway areas, A_p; wetted perimeters, P_p; hydraulic radius, R_p; top width of waterway, T_p; and hydraulic depth, d_p.

Several flow types in Table 11 are so complex that only estimates can be used to define the outlet depth and related variables. These are Flow Types V and VII. The User may question whether certain flow types of Table 11 can physically occur. In answer, some of the flow types of Figure 8 were devised primarily in hopes of precluding program stoppages should the system ever encounter certain unique combinations of flow type variables. The questionable flow types are generally those associated with very high tailwaters with hydraulic jumps confined to the culvert barrel and are admittedly unlikely to occur.

Exact geometric properties for *circles* were computed using equations obtained from Marques' computer program (13), or

$$A_p = \left(Y_b - \frac{D}{2}\right)\sqrt{(D)(Y_b) - (Y_b)^2} + \frac{D^2}{4}\left|\pi \div 2 + \mathrm{Sin}^{-1}\left(\frac{2Y_b}{D} - 1\right)\right| \text{ ---- } 27$$

$$P_p = D\left|\pi/2 + \mathrm{Sin}^{-1}\left(\frac{2Y_b}{D} - 1\right)\right| \text{ ---------------------------- } 28$$

$$T_p = 2\sqrt{\frac{D^2}{4} - \left(\frac{D}{2} - Y_b\right)^2} \text{ ------------------------------- } 29$$

Geometric data by Zelensky (17) for riveted metal arch culverts having 2 2/3" x 1/2" corrugations (18" x 11" through 72" x 44" sizes) was regressed by the Wyoming Highway Department in order to obtain the following expressions used in *estimating* the geometric properties. The related statistical properties are included for reference.

$$A_p = BD(-0.03824 + 0.98591(Y_b \div D) - 0.15924(Y_b \div D)^2) \text{ -------- } 30$$

Multiple Regression Coefficient = 1.0000
Standard Error = 0.0010

$$R_p = D(-0.02894 + 1.01687(Y_b \div D) - 0.66163(Y_b \div D)^2) \text{ --------- } 31$$

Multiple Regression Coefficient = 0.9989
Standard Error = 0.0040

$$T_p = B(0.98406 - 0.80765(Y_b \div D)^4) \text{ ------------------------- } 32$$

Multiple Regression Coefficient = 0.9923
Standard Error = 0.0284

Similarly, regression techniques were again applied to data by Zelensky (17) for structural plate pipe arch culverts (SPPA) having 6" x 2" corrugations (73" x 55" through 247" x 158") resulting in the following expressions and related statistical properties. Again, these equations provide an *estimate* of the geometry properties and not an exact solution.

$$A_p = BD(-0.04938 + 0.99059(Y_b \div D) - 0.15349(Y_b \div D)^5) \text{ -------- } 33$$

Multiple Regression Coefficient = 1.0000
Standard Error = 0.0011

$$R_p = D(-0.03385 + 1.00955(Y_b \div D) - 0.65458(Y_b \div D)^2) \text{ --------- } 34$$

Multiple Regression Coefficient = 0.9988
Standard Error = 0.041

$$T_p = B(0.9636 - 0.82876(Y_b \div D)^5) \text{ ------------------------- } 35$$

Multiple Regression Coefficient = 0.9896
Standard Error = 0.0324

For the concrete ellipse (oval) culvert with the long axis horizontal, the regression analysis provided the following equations using the same data source. These expressions also provide only *estimates* of the geometric properties.

$$A_p = BD(-0.07462 + 0.96631(Y_b \div D] = 0.07636(Y_b \div D]^9) \text{ -------- } 36$$

Multiple Regression Coefficient = 0.9998
Standard Error = 0.0049

$$R_p = D(0.01645 + 0.59206(Y_b \div D) - 0.28286(Y_b \div D)^5) \text{ ---------- } 37$$

Multiple Regression Coefficient = 0.9989
Standard Error = 0.0047

$$T_p = B(0.47603 + 2.31817(Y_b \div D) - 2.59557(Y_b \div D)^2 \ldots$$

$$\ldots + 2.60422(Y_b \div D)^7 - 2.70755(Y_b \div D)^9 \text{ --------------- } 38$$

Multiple Regression Coefficient = 0.0075
Standard Error = 0.0165

The geometry of rectangular shapes result in relatively simple and exact geometrical relationships. These equations are:

$$A_p = BY_b \tag{39}$$

$$P_p = 2Y_b + B \tag{40}$$

$$T_p = B \tag{41}$$

Geometric properties for concrete arch culverts were unavailable for a regression analysis. As a temporary expedient, the concrete ellipse equations (Equations 36-38) were arbitrarily substituted.

A_p = currently unavailable, use Equation 36 -------------- 42

Multiple Regression Coefficient = NA
Standard Error = NA

R_p = currently unavailable, use Equation 37 -------------- 43

Multiple Regression Coefficient = NA
Standard Error = NA

T_p = currently unavailable, use Equation 38 -------------- 44

Multiple Regression Coefficient = NA
Standard Error = NA

From the foregoing geometric relationships, it was possible to identify the hydraulic depth, d_p, as

$$d_p = \frac{A_p}{T_p} \tag{45}$$

Where the hydraulic radius is not reflected in the foregoing equations for a specific geometric shape, it was computed using the following:

$$R_p = \frac{A_p}{P_p}$$

The foregoing expressions for hydraulic depth and hydraulic radius are commonly found in hydraulics texts (5,14).

By using regression equations to identify the geometric properties such as line abc on Figure 9 for circular culverts, it was necessary to set upper and lower limit controls. This was necessary for only arch and oval culvert types to preclude computing values less than zero and values greater than the maximum geometric properties which can occur due to the regression equations providing only a "best fit estimate." This limit control was accomplished by interpolating linearly between $Y_b \div D = 0$ and $(Y_b \div D) = 0.1$. Geometric limits corresponding to full barrel conditions were established as the maximum full barrel values.

At this point, discussion is warranted concerning a particular problem encountered in transposing the foregoing culvert geometry theory into computer logic. This can be illustrated by considering the curves of Figure 9. As the depth of flow increases in a culvert, the various geometrical properties increase in magnitude also. This process reverses for the part full hydraulic radius, R_p, in circular culverts at about the 80 per cent full point ($d/D \approx 0.81$) and a decrease occurs. Because the format of the foregoing regression equations reflect a statistical best fit of these geometrical properties, this reversal did not occur (see Figure 9). Instead, as an example, line gbc on Figure 9 would represent the part full hydraulic radius, R_p, relationship for a circular culvert. However, when a culvert was at or exceeding the full flow condition, the system used the true geometrical culvert properties (point f on Figure 9). This resulted in a discontinuity in the program that precluded the system from operating. The solution incorporated into the system logic was to allow the part full hydraulic radius, R_p, to increase in accordance with the regression equations until the culvert depth, d, exceeded 81 per cent of the culvert's vertical height ($d/D > 0.81$ on Figure 9). At this point, the part full hydraulic radius, R_p, was held constant at its maximum value; the part full cross sectional culvert area, A_p, continued to increase, however, avoiding computation of a constant discharge according to Manning's equation (Equation 2) in the region between $0.81 \leq d/D \leq 1.0$. This introduced some computational error into the system (about 0 to 10 per cent) as the part full hydraulic radius, R_p, now follows line ade which results in a full flow hydraulic radius, R_f, at point e which is a compromise between the true value at point f and the regression equation value at point c.

Two equations were developed for differentiating between the Type V and Type VI or VII flows found on Figure 8. These equations were derived from the graphs shown on Figure 10. Two equations were necessary; one for metal and one for concrete barrels (regardless of shape). Discussion of variables in this equation can be found in the report by Bodhaine (18) from which Figure 10 was obtained. The following two equations and related statistics were obtained through a regression analysis by the Wyoming Highway Department.

Concrete Culverts

$$S_o1 = 0.01490 + 0.05168 \ln (Y+1) \text{ ------------------------ } 47a$$

Multiple Regression Coefficient = 0.7017
Standard Error = 0.0103

The value of Y is defined by Equation 47b to be

$$Y = \frac{1.01\ell - 11.14022 + 102.008r/D}{\ell(169.151892e^{-65.517308r/D}) - 1356.899746e^{-69.947891r/D}} \text{ ------- } 47b$$

Metal Culverts

$$S_o1 = -0.01139 + 1.52602Y - 85.20076Y^3 + 2201.45435Y^5$$

Multiple Regression Coefficient = .9591
Standard Error = 0.0068

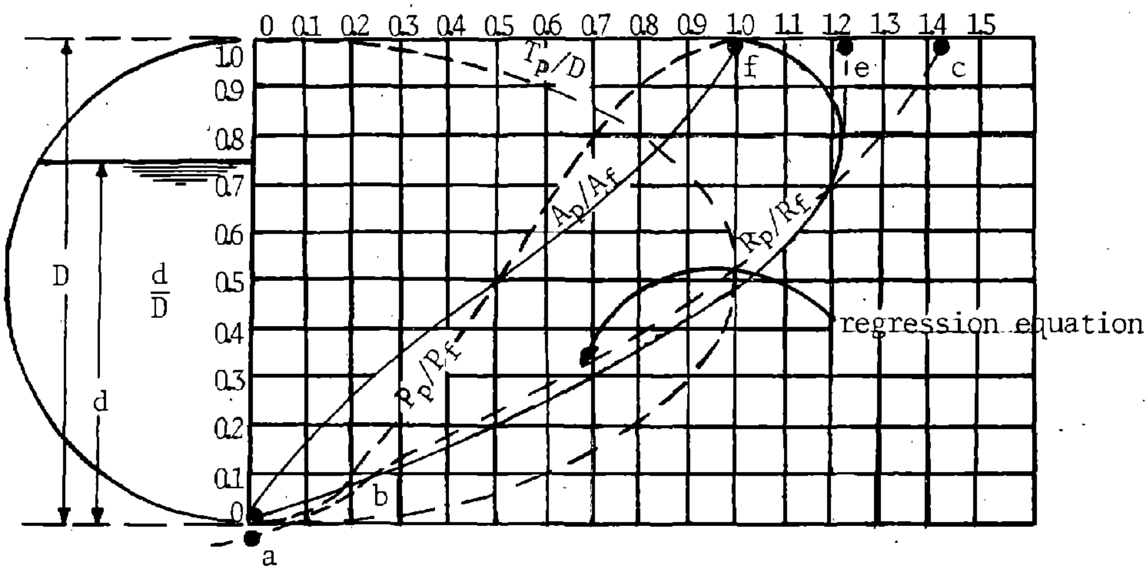


Figure 9

Geometric Elements of a Culvert Section

The value of Y in this polynominal is defined by Equation 48b and the constant F is defined by Equation 48c.

$$Y = 0.03789 + 0.98469\ell - 2.00115\ \mathrm{Sin}\left(\frac{(\ell-F)\pi}{70-2F}\right) -$$

$$0.6466(NHR)\mathrm{Sin}\left(\frac{(\ell-F)\pi}{70-2F}\right) \text{------------------------------} \quad 48b$$

$$F = (9.65429 - 28.65714\frac{r/D}{D}) - (13.89714 +$$

$$52.57143r/D)(N_{hr}) \text{----------------------------------} \quad 48c$$

$$N_{hr} = \frac{29n^2(H_w)}{R_f{}^{4/3}} \text{--} \quad 48d$$

The system computes a value for S_o1 using the foregoing equations depending on whether a concrete or metal culvert is being analyzed. The value of D is the greatest vertical dimension which may introduce some error with arch and oval culverts. The true culvert slope, S_o, is compared against S_o1 to determine if Type V or Types VI and VII flow are occurring; i.e., $S_o \geq S_o1$ results in Type V flow, whereas $S_o < S_o1$, then either Type VI or Type VII flow is probably occurring. Figure 8 shows Types V, VI, and VII flow and Figure 10 graphically portrays this selection process.

This system makes use of the critical flow properties of the culvert barrel. Critical flow properties of open channels are presented in detail in hydraulic texts (5,14) and will not be discussed here. This system uses an iterative process for all culverts *except boxes* to satisfy Equation 49 in order to determine the critical depth, d_c, corresponding to a given discharge, Q_d.

$$\frac{Q_d{}^2T_c}{gA_c{}^3} \text{---} \quad 49$$

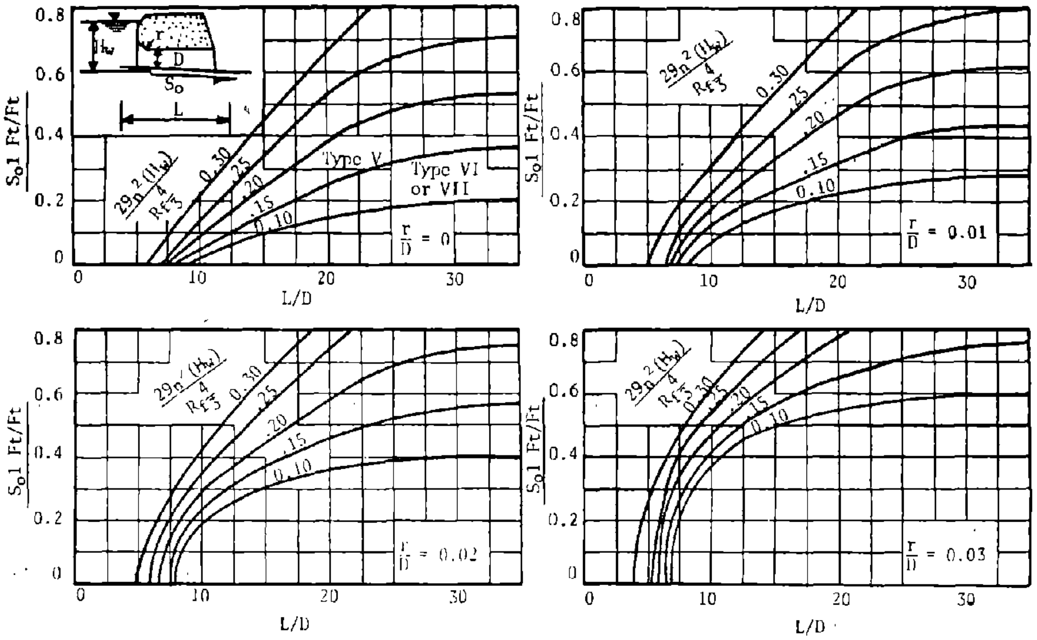
The system selects a trial critical depth, d_c. With this trial value, the top width, T_c, and area, A_c, are computed using Equations 27 to 41. With these values of T_c and A_c, Equation 49 can be solved. If the indicated identity does not result, the trial depth, d_c, is iterated until the balance indicated in Equation 49 occurs.

Rectangular shapes are unique in that the critical depth can be determined directly. This is done with Equation 50:

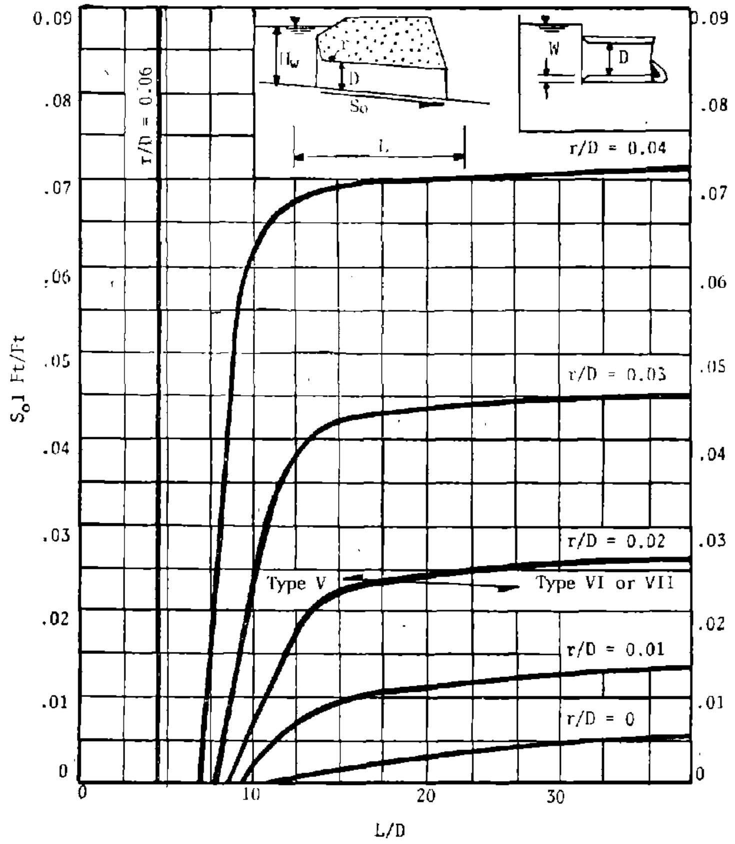
$$d_c = \left(\frac{(Q_d/B)^2}{g}\right)^{1/3} \text{--} \quad 50$$

With all culvert shapes, the critical depth, d_c, was necessarily limited to a maximum value equal to the culvert's vertical dimension, D.

Once the critical depth is determined, it is possible to determine other culvert properties corresponding to critical depth; i.e., algebraically manipulating Equation 2, Manning's equation, it is possible to



A. METAL CULVERTS



B. CONCRETE CULVERTS

Figure 10

Type V, VI, VII Flow Differentiation

compute the critical slope, S_c. Should the User encounter expressions in the program that are not presented in the foregoing, it is suggested an attempt be made to see if they are some form or combination of Equation 2 or 3. Hydraulic engineers use these two expressions quite frequently and they are not limited in this system to only the stage-discharge computation.

Flow-Distribution

The flow-distribution is a natural extension of the information generated by the stage-discharge analysis. At the outset, it must be stated that flow-distributions are not normally used or required in designing culverts. As such, this option may be used very seldom. In fact, the primary reason the flow-distribution option is in this system is to facilitate implementation of long range planning for hydraulic computer systems in the Wyoming Highway Department. At present, Wyoming uses flow-distribution to obtain input for hydraulic bridge analysis.

Flow-distribution data generated by this system allows the User to manually plot a flow-distribution. Figure 1 illustrates how this flow-distribution can be manually developed. Briefly, the stage-discharge analysis generates and accumulates incremental discharges across the typical cross section. These accumulated incremental discharges are plotted on a vertical scale vs. a lateral cross section distance on the horizontal scale as shown on Figure 1. Actually, it is less time consuming to plot the accumulated subsection discharges, q_{1-9}. No accuracy is sacrificed by this "shortcut." This vertical scale is then subdivided into equal parts (usually 20 for 5 per cent increments on the flow distribution). By projecting these subdivisions horizontally from the vertical scale until intercepting the plot of accumulated discharges and then proceeding vertically, a flow-distribution is generated. This system forestalls the need to manually plot the flow-distribution by providing flow per cents at intervals horizontally across the typical section.

Other information provided with the flow-distribution option for each of the incremental segments used in computing the stage-discharge relationship include Froude number, f_r; tractive shear, τ_i; velocity, v_i; and discharge, q_i. It should be remembered these are the hydraulic properties for each individual increment within a given subsection of the cross section (Figure 1). The flow-distribution also sums the incremental discharges, q_i, to obtain the total subsection and hence channel discharge, q. A little manual manipulation of this data will also provide the subsection discharge, q_{1-9}. In addition, the flow-distribution provides the average depth, d_a; average velocity, $\bar{V}$; and average Froude number, $\bar{F}_r$, for the channel. The non-uniform velocity coefficient, α, and non-uniform momentum coefficient, β, for the cross section are also provided by this option. In addition, flow-distribution option also identifies the maximum velocity occurring within the cross section, the specific forces of the cross section, and the cross section's specific head. Chow (5) discusses these variables in more detail.

As stated previously, the flow-distribution is not commonly used in *designing* or *reviewing* a culvert. However, in determining erosion protection requirements according to Schilling (3) and Wacker (7), it will be necessary to know the hydraulic properties of the natural channel--particularly the maximum values. In addition, the data on the flow-distribution provides some insight into the environmental aspects surrounding the stability of a channel (incremental tractive shear and velocities)--although similar information is available from the stage-discharge analysis. Another possibility would be to use the flow-distribution for identifying what portion of the approach flow should be allotted to culverts used for relief openings on wide floodplains. Experience with the system will best determine when the flow-distribution option can prove valuable to an individual User.

OUTPUT FORMATS

This system was developed to provide the User with a choice of four different printer outputs and a plotter output. Not all output formats are operational at this time. The User can select only one of the operational output formats plus the plotter output for a site with each computer run. The following will assist the User in determining which combination of outputs will best suit his needs for a given site.

As might be expected, the output formats vary from limited output to extensive output. Option 0.0 does not provide a printout. Option 1.0 provides a short summary, whereas Option 2.0 provides extensive information. Option 3.0 is a specialized form of output being considered by the Wyoming Highway Department to facilitate permanent file documentation of each drainage design and currently is not operational.

The reader is cautioned to read the following before selecting a design output format as different formats are necessary for different circumstances; i.e., flood hazards, whether the design is preliminary or final, environmental problems, outlet erosion economics, etc. It is possible to "generate a lot of paper" if care is not taken in wisely selecting the necessary output.

Plotter Output

This is not a printer plot, but actually a plotter operation. The most economical time to use this output format is after the site geometry is firm and the suitable culvert types have been reduced to one or two. Output consists of: (1) culvert performance curves (headwater and outlet velocity vs. discharge flows), (2) stage-discharge and velocity-discharge curves, and (3) inflow/outflow hydrograph. An information block will also be printed which will have to be filled out by the User. The plotter output is optional and may be requested with any of the following printer options by coding the proper values in the work option and printer option entries. Figure 23 reflects the plotter output.

Option 0.0 No Printout

If the design is completed and only a final plotter output is required, then this option should be used.

Option 1.0 Culvert Performance

The most commonly used output format will probably be the culvert performance option because it provides the concise hydraulic summary that is necessary to evaluate a site. This option should be used in studying site geometry alternatives and eliminating unsuitable culvert types. Quite often, this output option will be sufficient for selecting the final design for simple, uncomplicated sites.

Where the engineer feels a need to look more closely at the culvert's performance throughout the passage of a flood, it will be necessary to obtain the flood routing option. Sample Problems 1, 3, and 4 reflect typical Option 1.0 output.

Option 2.0 Flood Routing

This output is for drainage design only and should not be used for irrigation design.

Option 2.0 provides the maximum available flood routing detail. Sample Problem 2 shows this output format. The flood routing option provides the essential hydraulic data throughout the routing of a flood through a culvert site for each time interval.

In design, this format will be found useful when there are sensitive upstream improvements as it provides a detailed analysis of inundation depths, duration, and extent (area inundated). This format also allows the engineer to look more closely at outlet erosion problems; i.e., it may be considered uneconomical to provide erosion protection for the maximum outlet discharge, but by looking in more detail at what can be expected to occur at the outlet, it may be found that these severe outlet conditions occur only briefly. Under such circumstances, the engineer may wish to provide outlet protection for a less severe outlet condition. As an example, this might be for conditions occurring during 80 or 90 per cent of the time during the passage of a flood, or another example might be to accommodate the conditions occurring during all but a 15-20 minute period during the passage of the highest discharges. Debugging requirements also make this output useful.

Option 3.0 Design Summary

This is an optional output designed to facilitate documenting the essential hydraulic data at each site. This documentation format is used by the Wyoming Highway Department. Figure 22 shows the format used on the Flood Hazard Summary which is similar to the format appearing on the Wyoming Highway Department's E-65 drainage survey form.

The User should not request this output format when doing preliminary type designs. The proper time to request this output format is when preliminary analysis has reduced the culvert type selection to one or two and the site geometry has been firmly established.

Only part of this output format is completed by the system and includes station; culvert type, size, inlet type (for each culvert type on which a design or review is requested); hydrology (all items); design headwater; pond depth, structure velocity; natural channel depth; maximum velocity. This hydraulic information is provided for each of the review discharges input to the system (five maximum) and for the design discharge. These five review discharges are entered in one of the six column headings along with its corresponding frequency. The specified design discharge and frequency is entered in the remaining column heading and can be identified as such by the checkmark within the parenthesis found in each column heading.

The remaining output must be completed manually. A future enhancement that is being contemplated is to link the culvert erosion system into the culvert design system, thereby allowing the erosion protection portion of this output to be completed by the computer.

ENGINEERING USE OF THE SYSTEM

Sometimes a better appreciation of a system can be gained by understanding how the system may be used. Such discussion can also serve to generate new ideas on system use and enhancement.

The first and most obvious use of the system is that it *designs* culverts or *reviews* a predetermined culvert size. There are other more subtle uses that must not be overlooked.

The system was also designed for use in assessing flood hazards that might otherwise be overlooked. Besides the design discharge which sizes the culvert, it is possible to input five additional discharges to be used in reviewing this culvert size. Hydraulic engineers can be guilty of "tunnel vision"; i.e., the design flood is selected, the culvert sized to meet a design headwater, and the design is concluded. Federal Highway Administration directives (4) and current Wyoming Highway Department practices require the resulting culvert design be reviewed using a "super flood" commonly termed the basic flood. This flood has been arbitrarily selected as the 100-year event (5). This review is used to expand the engineer's vision and force him to consider what hazards may have been overlooked should a "super flood" occur. The procedure allows the engineer to consider not only upstream property damage, but property damage due to floodwaters being diverted to other previously unaffected areas. If the infiltration properties of the fill are available and knowing the pond duration, it may be desirable in some instances to determine if the highway fill could fail (through piping) and release a flood wave. Large, temporary impoundments might be subject to this type of rigorous analysis. If a "super flood" is noted to cause a severe flood hazard or catastrophic damage, then it may be prudent to redesign the culvert for a larger flood (but not necessarily the basic flood).

Several of the review floods input to the system should be smaller than the design flood. The mean annual flood ($Q \approx 2.33$ years) should always be used as it is often considered the bank full, "channel forming," or "dominant" discharge. Highways in the River Environment (19) pursues the use of the channel-forming discharge and its relationship to channel stability. While the larger design flood may satisfy an acceptable design headwater, a "nuisance" caused by smaller floods that occur more frequently may also justify a larger culvert. This may be particularly true in urban areas or adjacent to agricultural lands supporting high value crops.

Environmental assessments are possible with this system. The system provides not only the maximum temporary upstream pond depth, but incremental pond depths as the hydrograph is routed through the system. In addition to pond depths vs. time, the system also estimates the size of the inundated area occurring at each time increment. *The User is cautioned against over-reacting to this particular printout.* In many instances, the User will immediately envision a tremendous pond, deep and covering many acres for a long period of time. The User is urged instead to consider the resulting pond depths and inundated areas as a function of time. It may be that the envisioned pond occurs very briefly and that the average pond depth and inundation is relatively small. Similarly, while the total time to develop and then drain the pond may sometimes seem excessive, it may be the pond is quite shallow or unobtrusive for much of this time. These factors should be considered before rejecting a design. The plotter routine where the outflow hydrograph is displayed is particularly useful in evaluating this situation. The User has complete control of the pond through his input of D_{hw}, D_{in}, and D_{po}.

Another environmental impact is the effect of reducing the flood discharge released downstream. This could provide a very positive impact in the form of flood control benefits to downstream development. Conversely, in certain instances, it may be demonstrated that this reduced flood peak (not volume) may adversely affect channel morphology (19). In these latter instances, the User may wish to provide a culvert capable of passing the channel-forming discharge (about a 2-3 year event) with no significant ponding and storage.

This system provides the User with a wide choice of inlet types. In comparing the performance of different types of culvert barrels, the User should *compare inlets having similar inlet losses,* K_e, even though the inlet geometry may differ.

Another feature that should not be overlooked is the system's ability to evaluate beveled inlets. *Before resorting to a larger culvert, consider using a beveled or an improved inlet.* As an example, when a conventional culvert is operating in inlet control and the basic flood is creating an unacceptable flood hazard.

Through the internal stage-discharge logic, this system will also estimate certain environmental impacts on the channel. This evaluation is simplistic in nature as it only estimates the tractive shear a given flood exerts on the cross section bed within the limits of a specified subsection. Comparing this value with known values of tolerable tractive shear allows the User to determine what erosive impact a flood has on a channel bed and floodplain before a culvert is installed (the "before construction" case). This may aid in judging the necessity for extensive outlet protection.

This system currently does not provide an assessment of what will occur to the downstream channel bed after the culvert is constructed. This can be readily determined, however, by using this system in conjunction with the culvert erosion system (3,7). This culvert design system provides output compatible for use with this culvert erosion protection system.

The User may be surprised to find the culvert outlet velocities are lower than anticipated. This should not be surprising if the User realizes that pond storage had reduced the inflow discharge, Q_i, to a smaller discharge, Q_d, with a corresponding reduction in outlet velocity, V_b. This may not hold true, however, where very high heads can be tolerated with a correspondingly small culvert size. By identifying the true outlet conditions, the User can usually provide less outlet protection than would have been required if storage were ignored.

It is extremely important that the User be cognizant of sediment problems when using this culvert design system. Streams discharging clear water (unlikely) or containing only silt and clays will present less significant problems than discharges in the sand size range (particle size $\geq$ .05± mm). This system will, where considerable upstream storage is available and relatively high headwaters are tolerable, select very small culverts as being hydraulically acceptable. The culvert may be sufficiently small as to incur blockages from drift, debris, or sediment (either water or wind borne). An internal Wyoming Highway Department file report by Wacker (2) identifies a rationale for evaluating sediment problems at a culvert site and may be the source of a future enhancement. In any event, the User may elect to recommend a larger culvert to preclude sediment problems. This currently must be a judgement decision.

While intended primarily for highway culvert locations, the system can also evaluate flood retention ponds and other similar reservoir facilities commonly found on a highway system. The only requirement is that the "spillway" consist of a culvert type structure, and the temporary storage and stage-discharge relationships be quantified in accordance with the system's requirements.

Chapter 2

USER DOCUMENTATION

INTRODUCTION

As this computer program can perform several functions, either one at a time or grouped together, the following definitions will be used in this section:

Card - one line of data on the C-16 coding form which may be keypunched onto a computer card, a diskette, a magnetic tape, or a remote terminal

Deck - the lines of data which go together to provide input for a specific function

Group - a combination of decks which provide the input for a logical sequence of functions

Run - one or more groups input to the computer at the same time under one work order

The following describes the input requirements for each of the four data decks which constitute the culvert (hydrograph) program: STAGE-DISCHARGE DECK, STAGE-STORAGE DECK, CULVERT DECK, and FLOW-DISTRIBUTION DECK. All or combinations of the decks will be necessary depending upon the output desired as described in this documentation.

The universal coding form, C-16 (Figure 11), should be used in coding all data for this program. All decimal points must be coded in Entries 1 to 6 when using form C-16. As indicated on the form, the first card of each run must be the 100 or *COMMENT CARD*. Additional 100 *COMMENT CARDS* may be added at the beginning of the run or in front of any card which has work code, HF, HS or HC. For example, the user may add one or more 100 cards in front of the stage storage deck to describe the situation modeled. These comments will be printed on a page in front of the stage storage output to document what the user was doing. Also, the last card of each run must be the 999 or *TRAILER CARD*.

A schematic drawing showing each card type within each deck is provided in Figure 12. See Sample Problem section for examples.

FORM C-16
Rev. 3/11/69

WYOMING STATE HIGHWAY DEPARTMENT
CHEYENNE WYOMING
BRIDGE DIVISION

DESIGN SYSTEM

SHEET NO.__________ OF ________
BY ____________ DATE ________
CHECKED ________________

1 COMMENT CARD 64

1,0,0	

1 2 WORK CODE	3 5 DATA CODE	ENTRY 1 6 15	ENTRY 2 25	ENTRY 3 35	ENTRY 4 45	ENTRY 5 55	ENTRY 6 65	66 CONT

TRAILER CARD

9,9,9	

1 3

NOTE: A trailer card must follow the last structure card containing data

Figure 11
Form C-16

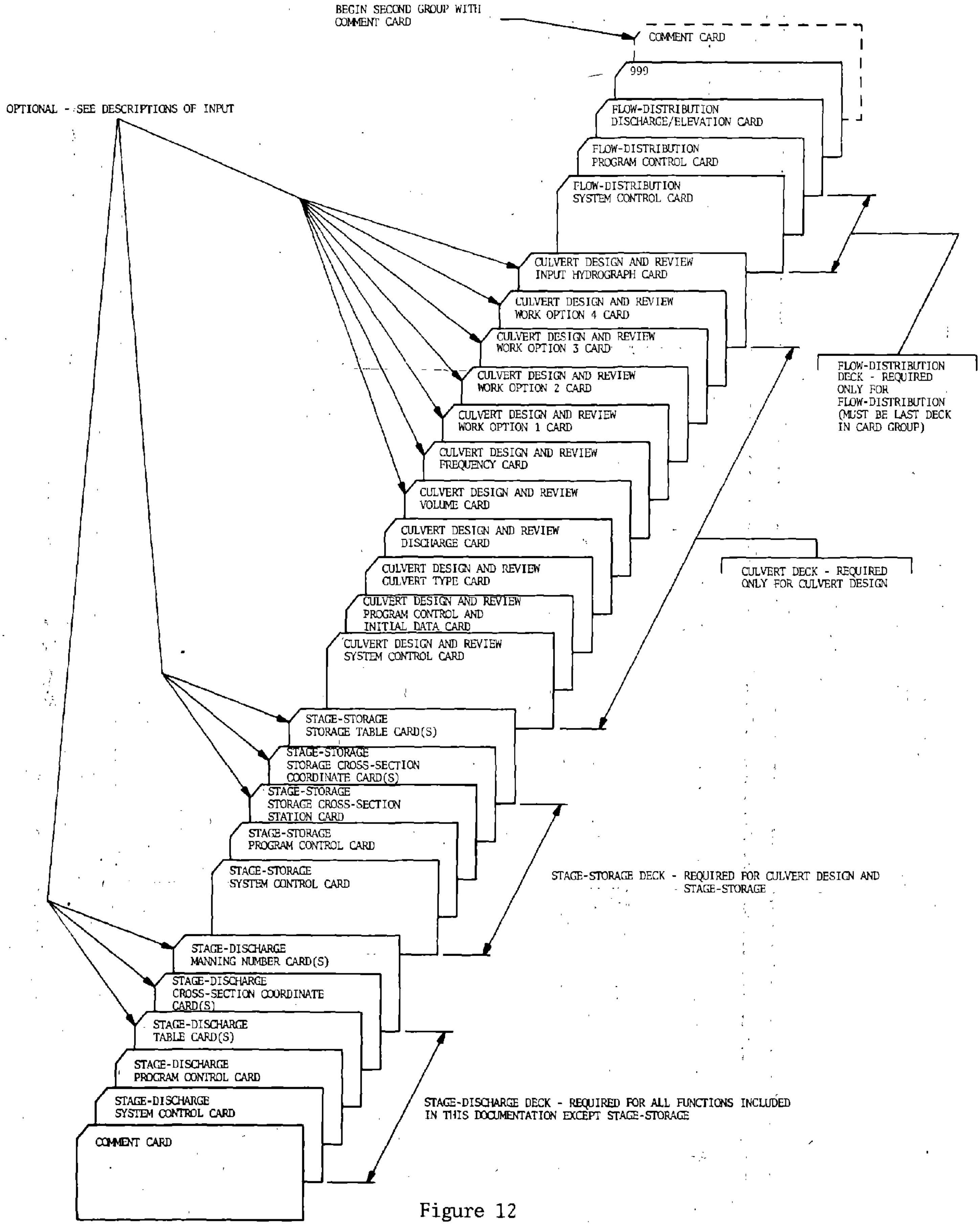


Figure 12

Card Sequence

Job Card Groups

The most common and simplest function in this program is the generation of the stage-discharge relationship from a typical cross section. Figure 13 indicates the necessary data group if this function is to be executed independent of a culvert design or review.

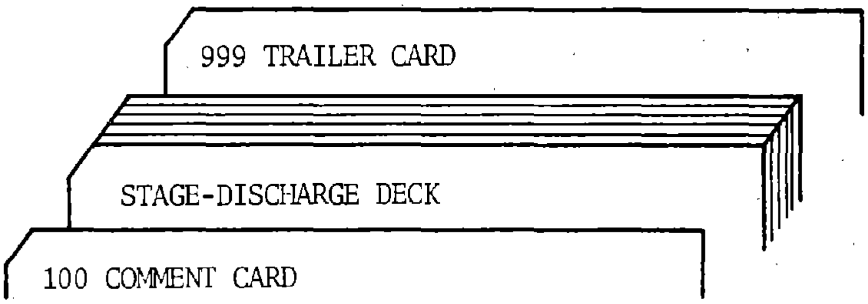


Figure 13

Stage-Discharge Function

To determine the volume of storage upstream of a culvert (independent of a culvert design or review) or behind a dam, the stage-storage deck is used according to Figure 14.

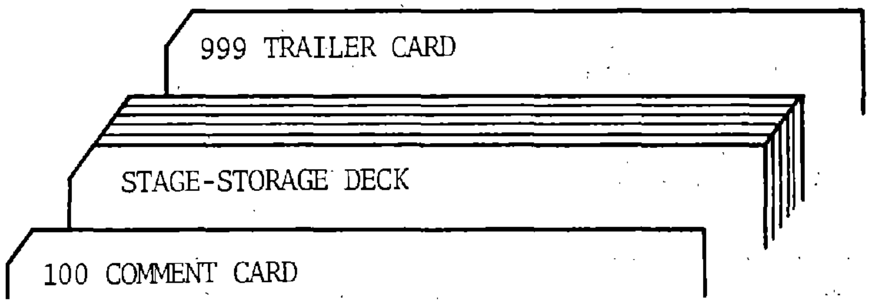


Figure 14

Stage-Storage Function

The design or review of a culvert with upstream storage *(the drainage design alternative)* requires a stage-discharge deck, a stage-storage deck, and a culvert deck, respectively, as shown in Figure 15. The *irrigation design or review* does not require a stage-storage deck.

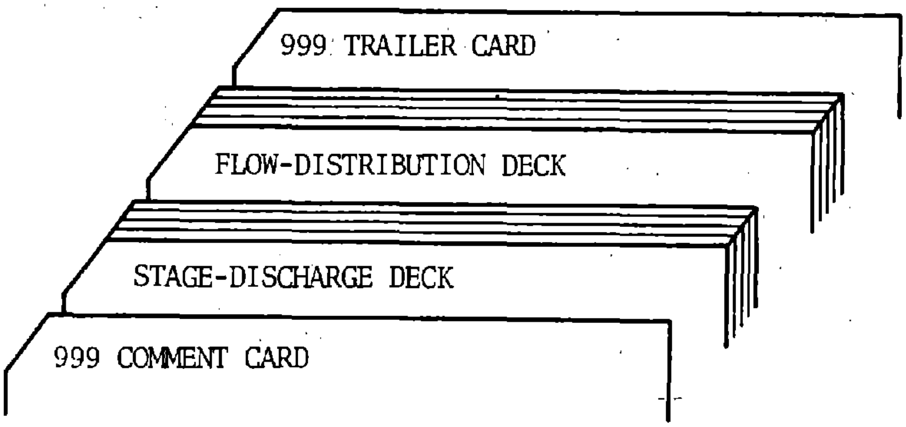


Figure 15

Culvert Function

To obtain the flow-distribution function independent of a culvert design or review requires that the stage-discharge deck precede the flow-distribution deck according to Figure 16.

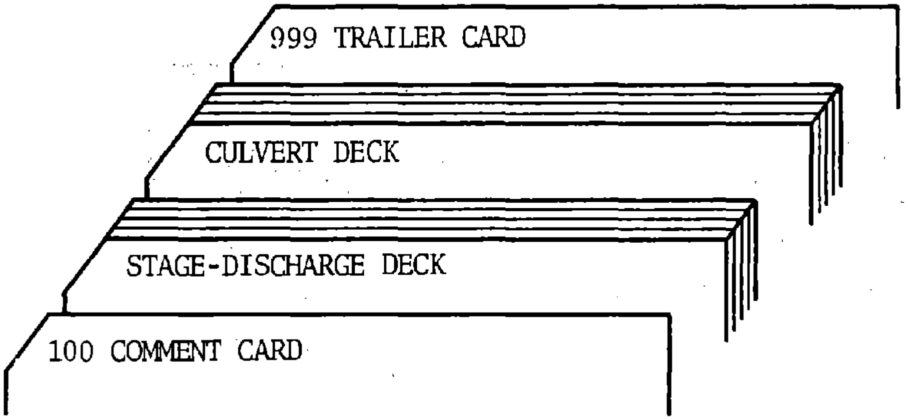


Figure 16

Flow-Distribution Function

The four main functions discussed in Figures 13, 14, 15, and 16 may be joined in any of the combinations illustrated in Figures 17, 18, 19, and 20.

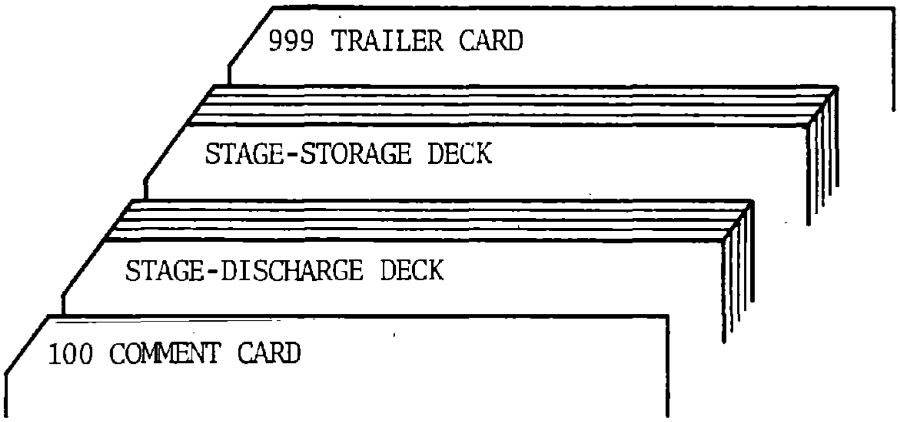


Figure 17

Stage-Discharge and Stage-Storage Function

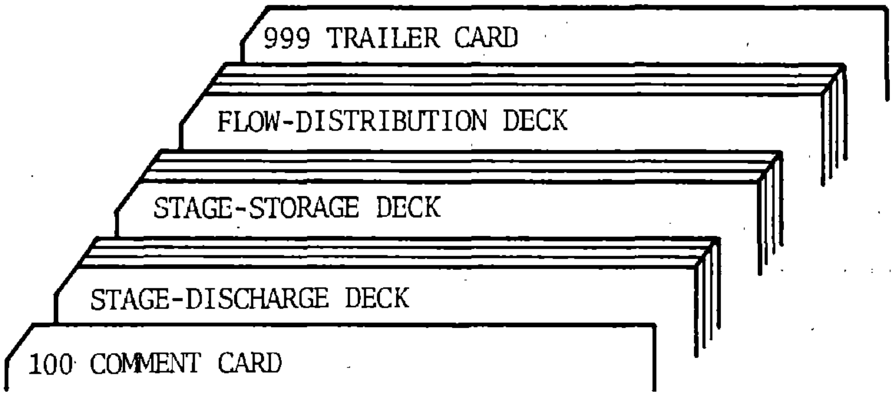


Figure 18

Stage-Discharge, Stage-Storage, and Flow-Distribution Function

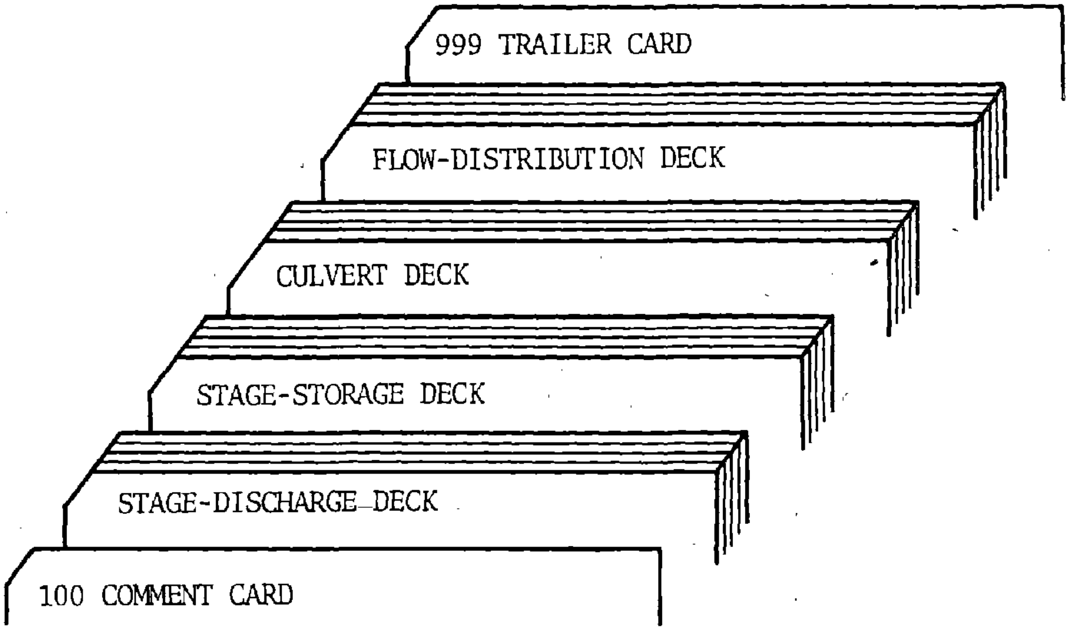


Figure 19

Stage-Discharge, Stage-Storage, Culvert
(*drainage design* or review), and
Flow-Distribution Function

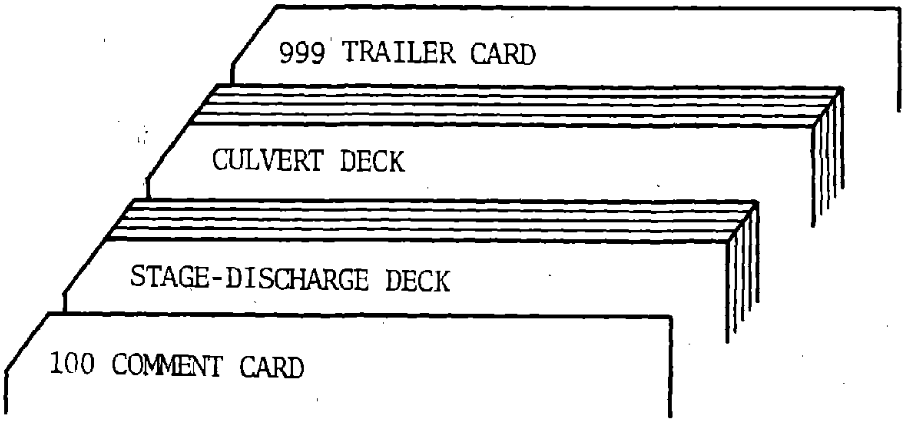


Figure 20

Stage-Discharge and Culvert Design or Review
Without Upstream Storage Function
(Irrigation Design)

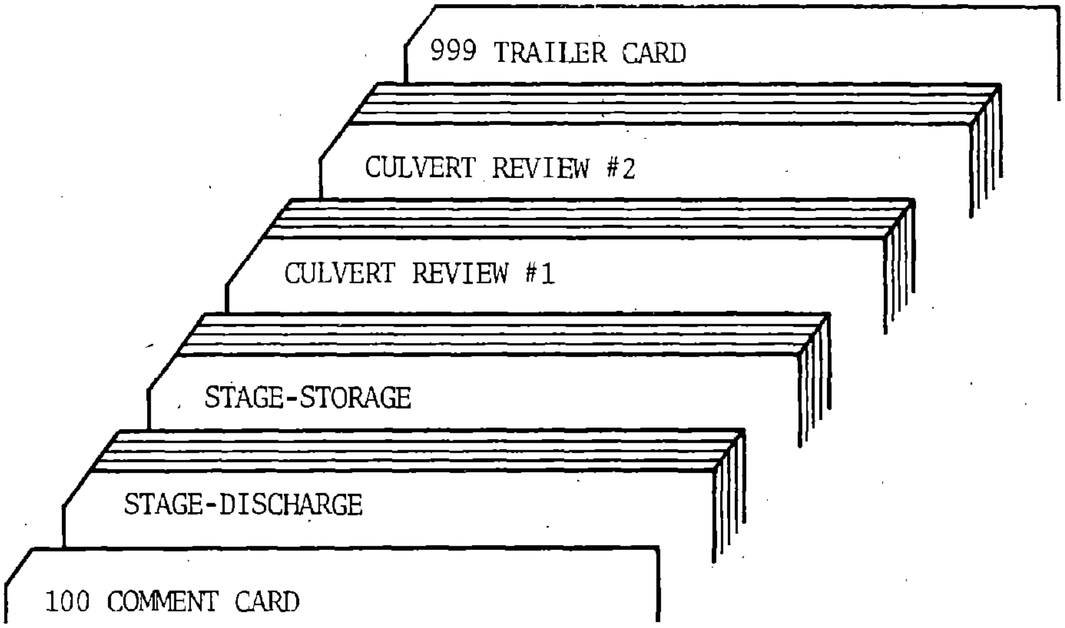


Figure 21

Reviewing More Than One Culvert Function

DESCRIPTION OF INPUT

Stage-Discharge

The Stage-Discharge deck must be included for all functions of this program except the Stage-Storage function.

1. SYSTEM CONTROL CARD: *Always include this card.*

   WORK CODE - Code HF

   DATA CODE - Code 002

2. PROGRAM CONTROL CARD: *Always include this card.*

   DATA CODE - Code 001

   ENTRY 1 - Printout option: Code 1.0 if a printed listing of the stage-discharge relationship is desired. Code 0.0 if no printed listing of the stage-discharge is desired.

   ENTRY 2 - Blank

   ENTRY 3 - Code 0.0 if a cross section will be input. Code 1.0 if a stage-storage table will be input.

   ENTRY 4 - Code the natural channel slope in feet/feet.

3. TABLE CARD(S) - *Include this card only when a stage-discharge relationship is input (Entry 3 of Program Control Card is 1.0). Do not include Cross Section Coordinate or Manning's n Cards when this card is used.*

DATA CODE - Code 010

ENTRY 1 - Code the depth in feet of the first stage (flow depth)

ENTRY 2 - Code the discharge in cfs associated with the first stage in Entry 1.

ENTRY 3 - Code the maximum channel velocity in fps associated with the first stage in Entry 1.

ENTRY 4 - Code the depth of the second stage

ENTRY 5 - Code the second discharge

ENTRY 6 - Code the second stage's maximum channel velocity.

CONT (Continuation) - Code 1 if another Table Card follows.

Use up to 183 Table Cards (or 366 stages) as necessary remembering all data codes are 010 and a 1 is required in the continuation column (66) for all but the last card.

4. CROSS SECTION COORDINATE CARD(S) - *Include this card only when inputting a cross section (Entry 3 of the Program Control Card is 0.0). Do not include Table Cards when this card is used.*

DATA CODE - Code 020

ENTRY 1 - Code the X coordinate of the left-most point in the cross section (X_1). See Figure 1 for a schematical explanation.

ENTRY 2 - Code the Y coordinate of the left-most point in the cross section (Y_1). Y coordinates may be either elevation or distance in feet above the lowest point in the cross section.

ENTRY 3 - Code the X coordinate of the second point in the cross section (X_2).

ENTRY 4 - Code the Y coordinate of the second point in the cross section (Y_2).

ENTRY 5 - Code X_3.

ENTRY 6 - Code Y_3.

CONT (Continuation) - Code 1 if another Cross Section Coordinate Card follows.

Use up to 21 Cross Section Coordinate Cards (63 points) remembering that data codes are 020 and a 1 is required in the continuation column (66) for all but the last Cross Section Coordinate Card. The last Y is the only elevation value that may exceed Y_1.

5. MANNING'S NUMBER CARD(S) - *Include this card only when inputting a cross section (Entry 1 of the Program Control Card is 0.0). Do not include Table Cards when this card is used.*

DATA CODE - Code 030

ENTRY 1 - Code the right-most X coordinate associated with the first Manning's n from the left. (Each X coordinate on a Manning's Number Card *must match* an X coordinate on a Cross Section Coordinate Card.) See subsection 1 on Figure 1 for a schematical explanation.

ENTRY 2 - Code the Manning's n that corresponds to the left-most roughness section which is bound on the right of Entry 1 of this card.

ENTRY 3 - Code the right-most X coordinate associated with the second Manning's n from the left.

ENTRY 4 - Code the Manning's n that corresponds to the section bound by the coordinate in Entry 3 of this card.

ENTRY 5 - Code the right-most X coordinate of the third Manning's n from the left.

ENTRY 6 - Code the Manning's n associated with Entry 5 of this card.

CONT (Continuation) - Code 1 if another Manning's card follows.

Use up to three Manning's n cards (or 9 n values) with all data codes 030 and a 1 is required in the continuation column (66) for all but the last Manning's n cards.

Remember that X coordinate points identifying Manning's n subsections must coincide with X coordinate points used to code the cross section in item 4 above. When the cross section being input has a small low flow channel and a large, flat floodplain, it is advisable to have a slightly different Manning's number for the floodplain than for the low flow channel, even if they have the same vegetation cover to prevent discontinuities in the stage-discharge relationship.

Stage-Storage

This section describes the input parameter requirements of the storage portion of the program. The Stage-Storage deck must be included after the Stage-Discharge deck and before the Culvert deck when obtaining a culvert drainage design or review. This deck is not required for the irrigation design or review.

1. SYSTEM CONTROL CARD: *Always include this card.*

   WORK CODE - Code HS

   DATA CODE - Code 001

2. PROGRAM CONTROL CARD: *Always include this card.*

   DATA CODE - Code 001

   ENTRY 1 - Code 1.0 if cross sections of the upstream storage pond will follow. *Storage Table Cards are not required with this option.* Code 2.0 if a table of the storage capacity will follow. *Cross Section Station and X-Section Coordinate Cards are not required with this option.*

   ENTRY 2 - Printout option: Code 1.0 if a printed listing of the storage table is desired. Code 0.0 if a printed storage table is not desired.

   ENTRY 3 - Blank

   ENTRY 4 - Leave blank if a storage table will be input (using Storage Table Cards and entering 2.0 in Entry 1 of this card). If cross sections will be input (using Cross Section Station and X-Section Coordinate Cards and entering 1.0 in Entry 1 of this card), then enter the channel slope upstream from the last cross section in feet/feet.

3. CROSS SECTION STATION CARD: *Include this card only when Entry 1 of the Program Control Card is 1.0.*

   DATA CODE - Code 005

   ENTRY 1 - Code the station of the first cross section in feet from the culvert inlet. If the first cross section is not at Station 0.0, then the program will assume that the section at Station 0.0 looks like the first cross section upstream of the toe of the fill.

4. X-SECTION COORDINATE CARD(S): *Include these cards only when Entry 1 of the Program Control Card is 1.0.*

   DATA CODE - Code 010 on each X-Section Coordinate Card. Entries 1 to 6 are similar to the coding procedure in item #4 of the Stage-Discharge deck.

   ENTRY 1 - Code the X coordinate of the first point from the left of the cross section in feet (X_1).

   ENTRY 2 - Code the Y coordinate of the first point from the left of the cross section in feet (Y_1).

ENTRY 3 - X_2

ENTRY 4 - Y_2

ENTRY 5 - X_3

ENTRY 6 - Y_3

CONT (continuation) - Code 1 if another Cross Section Coordinate Card follows. Use up to 21 Cross Section Coordinate Cards (or 63 points).

Note: A maximum of 10 cross sections may be input.

5. STORAGE TABLE CARD(S): *Include this card type only when Entry 1 of the Program Control Card is 2.0.*

DATA CODE - Code 020 on each Storage Table Card

ENTRY 1 - Enter the depth (feet) of the first level of the storage depression. If the first level is not coded at zero depth and zero volume, then the program will add an initial level at zero depth with zero volume and zero area inundated.

ENTRY 2 - Enter the storage volume (acre-feet) below the first level.

ENTRY 3 - Enter the area inundated (acres) at the first level.

ENTRY 4 - Enter the depth of the second level of storage (includes the depth of the first level).

ENTRY 5 - Enter the cumulative storage volume below the second level.

ENTRY 6 - Enter the area inundated at the second level.

CONT (continuation) - Enter 1 if more levels follow on the next card.

Use as many Storage Table Cards as necessary up to 32 cards (or 64 levels) remembering data codes are always 020 and a 1 is required in the continuation column (66) for all but the last Storage Table Card.

Include enough storage values so that at small depths the storage is small.

Culvert Design and Review

The following describes input for the culvert design and review option of the program. When designing or reviewing drainage structures, this deck must be preceded by the Stage-Discharge and Stage-Storage decks as indicated in Figure 15. When designing or reviewing irrigation structures, the deck must be preceded only by the Stage-Discharge deck according to Figure 20. The flow distribution input need not be included to obtain a culvert design.

1. SYSTEM CONTROL CARD: *Always include this card.*

WORK CODE - Code HC

DATA CODE - Code 001

2. PROGRAM CONTROL AND INITIAL DATA CARD: *Always include this card.*

DATA CODE - Code 001

ENTRY 1 - Code 10.0 if a culvert design by the irrigation design method is desired.

Code 20.0 if a culvert review by the irrigation design method is desired.

Code 30.0 if a culvert is to be designed for a drainage crossing using the drainage design. The internally generated hydrograph is considered valid for watershed areas of less than 15 square miles in semiarid regions of Wyoming. For larger watersheds or watersheds dissimilar to semiarid regions of Wyoming, it is necessary to input a hydrograph (Work Option 3 Card, Entry 4).

Code 40.0 if an existing or known culvert size is to be reviewed for a drainage crossing using the drainage review method. The limitations listed above for Code 30.0 are applicable to this code.

If the optional plotter output is desired, add 1 to each of the above codes; i.e., 11.0, 21.0, 31.0, 41.0.

ENTRY 2 - Printout option: Code 0.0 if no printed culvert output is desired.

Code 1.0 to obtain the short form printout showing just the time increment when the headwater is at its maximum. Refer to the output description (culvert performance option). See Figure 25a.

Code 2.0 to obtain printout similar to Figure 25b (flood routing).

Code 3.0 *(not available at this time)*. Refer to output description (design summary). See Figure 25c.

ENTRY 3 - Blank

ENTRY 4 - Code station of culvert site in feet (example: Station 214+31 would be coded as 21431.0).

ENTRY 5 - Code length of culvert in feet.

ENTRY 6 - Code slope of culvert in feet/feet.

3. CULVERT TYPE CARD: *Always include this card.*

DATA CODE - Code 002

ENTRY 1 - Code the desired inlet code from Table 9 if the design or review is for a circular concrete culvert (RCP).

ENTRY 2 - Code the desired inlet code from Table 8 if the design or review is for a circular metal pipe (CMP).

ENTRY 3 - Code the desired inlet code from Table 9 if the design or review is for an elliptical concrete pipe (ECP).

ENTRY 4 - Code the desired inlet code from Table 8 if the design or review is for a corrugated metal pipe arch (CMPA).

ENTRY 5 - Code the desired inlet code from Table 9 if the design or review is for a concrete pipe arch (RCPA).

ENTRY 6 - Code the desired inlet code from Table 10 if the design or review is for a concrete box (RCB).

NOTE: At least one of the inlet codes must be included for a successful run. If an entry is left blank, the program will ignore that particular culvert type. For reviewing a culvert (Work Option 4), only one entry should be coded for each culvert deck, with one exception: if the RCP and CMP pipes to be reviewed are the same size and require the same number of barrels, they both can be entered in the same Culvert Type Card in Entries 1 and 2.

4. DISCHARGE CARD: *Always include this card.*

DATA CODE - Code 004

ENTRY 1 - If Entry 1 of the Program Control and Initial Data Card is 10.0 or 30.0, code the design peak discharge or irrigation water right (Q_p) in cfs.

If Entry 1 of the Program Control and Initial Data Card is 2.0 or 4.0, code the peak discharge or irrigation water right (Q_p) to be reviewed in cfs.

ENTRIES 2 to 6 - Code optional discharges in cfs to be reviewed regardless of the code in Entry 1 of the Program Control and Initial Data Card. Specifically, if Entry 1 of the Program Control and Initial Data Card is 10.0 or 30.0, then the program will size the culvert for the design discharge (Entry 1 of this card) and then review that design size using the discharges provided in Entries 2 to 6 of this card. Also, if Entry 1 of the Program Control and Initial Data Card is 20.0 or 40.0, the program will review the specified culvert size for discharges in all entries of this card.

Leave Entries 2 to 6 blank if a hydrograph will be input (using Input Hydrograph Cards).

NOTES: 1. Entries 2 to 6 may be omitted if no additional discharges are to be reviewed.

2. If Entries 2 to 6 are used, the program will provide data for plotting a Performance Curve (Figure 7) and if one of the entries is the basic flood (100-year event), a flood hazard evaluation is obtained.

5. VOLUME CARD: *Always include this card except for irrigation design or review.*

DATA CODE - Code 005

ENTRY 1 - Code the volume, V_ℓ (in acre-feet), of runoff which corresponds to the peak discharge in Entry 1 of the Discharge Card. For semiarid drainage areas in Wyoming under 15 square miles and in USGS Regions 2 or 3, the following formulas give approximate values for 2, 5, 10, 25, and 100-year events.

$V_5 = 9.618\, A^{0.689}$ $V_{25} = 34.71\, A^{0.739}$

$V_5 = 18.08\, A^{0.713}$ $V_{50} = 42.82\, A^{0.748}$

$V_{10} = 24.87\, A^{0.727}$ $V_{100} = 51.58\, A^{0.756}$

Use Reference 1 to obtain more precise volume formulas for sites that are flood hazard sensitive and require more exact estimates. For watersheds over 15 square miles and/or not in semiarid regions, it is necessary to determine a more applicable flood volume and hydrograph shape.

ENTRIES 2 to 6 - Code volumes of runoff which correspond to the performance discharges on the Discharge Card. Details listed under Entry 1 of this card apply to Entries 2 to 6.

Leave Entries 2 to 6 blank if a hydrograph will be input.

6. FREQUENCY CARD: *Always include this card except for irrigation design and review.*

DATA CODE - Code 006

ENTRY 1 - Code the frequency in years that corresponds to the discharge in Entry 1 of the Discharge Card.

ENTRIES 2 to 6 - Code the frequencies which correspond to the discharges in Entries 2 to 6 of the Discharge Card, if any.

Leave Entries 2 to 6 blank if a hydrograph will be input.

7. WORK OPTION 1 CARD: *Include this card only for designing a culvert by the irrigation design method. Only one of the work option cards should exist for each group.*

   DATA CODE - Code 010

   ENTRY 1 - Code the design headwater in feet, if known. If left blank, the computer will calculate the tailwater, add 0.1 feet and set that value to be the design headwater.

   ENTRY 2 - Code the greatest allowable culvert height in feet.

8. WORK OPTION 2 CARD: *Include this card only for reviewing a culvert by the irrigation review method. Only one of the work option cards should exist for each group.*

   DATA CODE - Code 020

   ENTRY 1 - Code the number of barrels that comprise the culvert to be reviewed. Any number of barrels is allowed.

   ENTRY 2 - Code the width of a single barrel in feet.

   ENTRY 3 - Code the height of a single barrel in feet.

   Refer to Figure 21 and the note under 3. Culvert Design Review for reviewing more than one culvert per run.

9. WORK OPTION 3 CARD: *Include this card only when designing a culvert that has upstream storage (drainage design method).*

   DATA CODE - Code 030

   ENTRY 1 - Code the maximum allowable headwater in feet.

   ENTRY 2 - Code the greatest allowable culvert height in feet.

   ENTRY 3 - Leave blank unless a very detailed printout is required, or an input hydrograph is used, in which case code the desired time increment to be used in routing the flood through the culverts. The number of time increments from beginning to end of the inflow hydrograph must not exceed 200 and from beginning to end of the outflow hydrograph must not exceed 500.

   The total length of time for inflow runoff *of the computed hydrograph on Figure 5 only* can be found by:

$$\frac{70 \times 726 \times \mathrm{Vol}/970}{Q_p/60}$$

   For drainage areas less than 16 square miles, refer to Equation 8 and Table 2 when selecting Δt to insure the output includes a value close to the peak.

ENTRY 4 - Optional Input Hydrograph: Code 1.0 if a hydrograph will be input on Input Hydrograph Cards (for drainage areas larger than 15 square miles and/or not in semiarid regions of Wyoming).

Code 0.0 if the program's internal hydrograph is to be used (for drainage areas less than 15 square miles and in a semiarid region of Wyoming).

ENTRY 5 - (Optional) Code the maximum allowable pond size in acres.

ENTRY 6 - (Optional) Code the maximum allowable outflow runoff time in minutes.

10. WORK OPTION 4 CARD: *Include this card only for reviewing culverts where there is upstream pond storage (drainage design method).*

DATA CODE - Code 040

ENTRY 1 - Code the number of barrels that comprise the culvert to be reviewed. Any number of barrels is allowed.

ENTRY 2 - Code the width of a single barrel in feet.

ENTRY 3 - Code the height of a single barrel in feet.

ENTRY 4 - Leave blank unless a very detailed printout is required, in which case code the time increment to be used in routing the flood through the culverts. The number of time increments for the inflow hydrograph must not exceed 200 and for the outflow hydrograph must not exceed 500. For drainage areas less than 15 square miles, refer to Equation 8 and Table 2 when selecting Δt to insure that the output includes a value to the peak. Code if input hydrograph is used.

ENTRY 5 - Optional Input Hydrograph: Code 1.0 if a hydrograph will be input on Input Hydrograph Cards (for drainage areas larger than 15 square miles and/or not in semiarid regions of Wyoming).

Code 0.0 if the program's internal hydrograph is to be used (for drainage areas less than 15 square miles and in a semiarid region of Wyoming). Refer to Figure 21 for reviewing more than one culvert per run.

11. INPUT HYDROGRAPH CARD: *Include this card only when Entry 4 of Work Option 3 Card or Entry 5 of Work Option 4 Card is 1.0.*

DATA CODE - Code 050

ENTRY 1 - Code 0.0 as the beginning time of the input hydrograph (t_1).

ENTRY 2 - Code 0.0 as the beginning flow rate of the input hydrograph (Q_1).

ENTRY 3 - Code the second time along the hydrograph in minutes (t_2).

ENTRY 4 - Code the flow rate corresponding to t in Entry 3 (Q_2).

ENTRY 5 - t_3

ENTRY 6 - Q_3

CONT (Continuation) - Code 1 if another hydrograph card follows.

Use as many Input Hydrograph Cards up to 66 cards (or 198 points) as necessary remembering that all data codes are 050 and a 1 is required in the continuation column (66) for all but the last card.

Flow-Distribution

This section describes the input requirements of the flow-distribution option of this program. Flow-distribution relationships can be obtained for either known discharges or known elevations as detailed in item 3. A Flow-Distribution deck need be included only when it is desired to obtain the flow-distribution for a channel. (This option is not essential to obtain a culvert design or review.) Whenever the deck for this option is used, it must be placed at the end of the data set for a site and just in front of the 999 card (see Figure 12). This option will not function without a Stage-Discharge deck somewhere ahead of this deck.

1. SYSTEM CONTROL CARD: *Always include this card when obtaining a flow-distribution.*

   WORK CODE - Code HF

   DATA CODE - Code 005

2. PROGRAM CONTROL CARD: *Always include this card when obtaining a flow-distribution.*

   DATA CODE - Code 001

   ENTRY 1 - Printout option: Code 1.0 if a printed flow-distribution output is desired. Code 0.0 if no printout is desired.

   ENTRY 2 - Blank

3. DISCHARGE ELEVATION CARD: *Always include this card when obtaining a flow-distribution.*

   DATA CODE - Code 002

   ENTRIES 1 to 6 - To obtain the flow-distribution relationship for a particular discharge, code a minus sign (-) before the charge in cfs. To obtain the flow-distribution relationship for a particular elevation, code a positive elevation. This elevation should never be equal to or greater than the highest elevation in the cross section. (The elevation must be relative to the cross section elevations in the Stage-Discharge deck.) Any combination of ten discharges and/or elevations can be input.

NOTE: See Sample Problem section for examples.

INPUT STAGE-DISCHARGE

CONT				1	Code 1 if another Table card follows	1	Code 1 if another coordinate card follows
ENTRY 6					Max. Channel $Velocity_2$ fps		y_3
ENTRY 5					$Discharge_2$ cfs		x_3
ENTRY 4			Natural Channel Slope ft/ft		$Depth_2$ ft		y_2
ENTRY 3			Stage-Discharge Table coded 1.0 - yes 0.0 - no		Max. Channel $Velocity_1$ fps		x_2
ENTRY 2			Optional Subroutine Printout 1.0 - yes 0.0 - no (always) (debugging only)		$Discharge_1$ cfs		y_1
ENTRY 1			Printout Option 1.0 - yes 0.0 - no		$Depth_1$ ft Normally not used		x_1
DATA CODE	0 0 2	System Control Card	0 0 1	Program Control Card	0 1 0	Stage-Discharge Table Card Limit 182 cards. (Use only when Entry 3 of Program Control Card is 1.0)	0 2 0	X-Section Coordinate Card Limit 21 cards. (Use only when Entry 3 of the Program Control Card is 0.0)
WORK CODE	H F							

INPUT STAGE-DISCHARGE (Cont.)

CONT	1	Code 1 if another Manning's card follows			
ENTRY 6		n_3			
ENTRY 5		x coordinate associated with n_3			
ENTRY 4		n_2			
ENTRY 3		x coordinate associated with n_2			
ENTRY 2		Manning's Number n_1			
ENTRY 1		Rightmost x coordinate associated with the left subsection's Manning's number			
DATA CODE	0 3 0	Manning's Number Card Limit 3 cards. (Use only when Entry 1 of the Program Control Card is 0.0)			
WORK CODE					

INPUT STAGE-STORAGE

CONT				1 Code 1 if another coordinate card follows
ENTRY 6				y_3
ENTRY 5				x_3
ENTRY 4		Channel slope upstream from last cross section (ft/ft) Leave blank if storage table is input.		y_2
ENTRY 3		Optional Subroutine Printout 1.0 - yes 0.0 - no (always) (debugging only)		x_2
ENTRY 2		Printout Option 1.0 - yes 0.0 - no		y_1
ENTRY 1		Code 1.0 - cross section input Code 2.0 - storage table input	Station ft	x_1
DATA CODE	0 0 1 System Control Card	0 0 1 Program Control Card	0 0 5 Cross Section Station Card (Use only when Entry 1 of the Program Control Card is 1.0). Must be followed by X-Section Coordinate Cards	0 1 0 X-Section Coordinate Card Limit 21 cards. (Use only when Entry 1 of the Program Control Card is 1.0)
WORK CODE	H S			

← Repeat for up to ten cross sections. →

INPUT STAGE-STORAGE (Cont.)

CONT	1	Code 1 if another storage card follows
ENTRY 6		Area Inundated acre
ENTRY 5		$Storage_2$ ac-ft
ENTRY 4		$Depth_2$ ft
ENTRY 3		Area Inundated acre
ENTRY 2		$Storage_1$ ac-ft
ENTRY 1		$Depth_1$ ft
DATA CODE	0 2 0	Storage Table Card Limit 32 cards. (Use only when Entry 1 of the Program Control Card is 2.0)
WORK CODE		

INPUT CULVERT

WORK CODE	DATA CODE		ENTRY 1	ENTRY 2	ENTRY 3	ENTRY 4	ENTRY 5	ENTRY 6
H.C	0.01	System Control Card						
	0.01	Program Control and Initial Data Card	Work Option 10.0 - design irrigation 20.0 - review irrigation 30.0 - design to hydrograph 40.0 - review to hydrograph Code 11.0 for plotter op.	Printout Options 1.0 to 3.0 - see user documentation for printout option codes	Optional Subroutine Printout 1.0 - yes 0.0 - no (always) (debugging only)	Culvert Station ft	Culvert Length ft	Culvert Slope ft/ft
	0.02	Culvert Type Card	RCP Culvert Code an inlet code from Table 9 if the design or review of this culvert type is desired.	CMP Culvert Code an inlet code from Table 8 if the design or review of this culvert type is desired.	ECP Culvert Code an inlet code from Table 9 if the design or review of this culvert type is desired.	CMPA Culvert Code an inlet code from Table 8 if the design or review of this culvert type is desired.	RCPA Culvert Code an inlet code from Table 9 if the design or review of this culvert type is desired.	RCB Culvert Code an inlet code from Table 10 if the design or review of this culvert type is desired.
	0.04	Discharge Card	Design/Review Discharge cfs	Performance Discharge$_1$ cfs (Optional)	Performance Discharge$_2$ cfs (Optional)	Performance Discharge$_3$ cfs (Optional)	Performance Discharge$_4$ cfs (Optional)	Performance Discharge$_5$ cfs (Optional)

INPUT CULVERT (Cont.)

ENTRY 6	Performance Volume$_5$ ac-ft (Optional)	Performance Frequency$_5$ yr (Optional)		
ENTRY 5	Performance Volume$_4$ ac-ft (Optional)	Performance Frequency$_4$ yr (Optional)		
ENTRY 4	Performance Volume$_3$ ac-ft (Optional)	Performance Frequency$_3$ yr (Optional)		
ENTRY 3	Performance Volume$_2$ ac-ft (Optional)	Performance Frequency$_2$ yr (Optional)		Culvert Height ft
ENTRY 2	Performance Volume$_1$ ac-ft (Optional)	Performance Frequency$_1$ yr (Optional)	Greatest Allowable Culvert Height	Culvert Width ft
ENTRY 1	Design/Review Volume ac-ft	Design/Review Frequency yr	Design Headwater ft Leave blank if standard irrigation design (DHW = TW+.1)	Number of Culverts
DATA CODE	0 0 5 Volume Card	0 0 6 Frequency Card	0 1 0 Work Option 1 Card (Use only when Entry 1 of the Program Control and Initial Data Card is 10.0 or 11.0)	0 2 0 Work Option 2 Card (Use only when Entry 2 of the Program Control and Initial Data Card is 20.0 or 21.0)
WORK CODE				

			1 Code 1 if another hydrograph card follows	
ENTRY 6	Optional Max. Allowable Runoff Time min		Discharge$_3$ cfs	
ENTRY 5	Optional Max. Allowable Pond Size acres	Optional Input Hydrograph Code 1.0 - yes 0.0 - no	Time$_3$ min	
ENTRY 4	Optional Input Hydrograph Code 1.0 - yes 0.0 - no	Time Increment Δt for Flood Routing min	Discharge$_2$ cfs	
ENTRY 3	Time Increment Δt for Flood Routing (Optional) min	Culvert Height ft	Time$_2$ min	
ENTRY 2	Greatest Allowable Culvert Height ft	Culvert Width ft	0.0 Discharge$_1$ cfs	
ENTRY 1	Design Headwater ft	Number of Culverts	Time$_1$ min	
DATA CODE	0 3 0	0 4 0	0 5 0	
WORK CODE	Work Option 3 Card (Use only when Entry 1 of the Program Control and Initial Data Card is 30.0 or 31.0)	Work Option 4 Card (Use only when Entry 1 of the Program Control and Initial Data Card is 40.0 or 41.0)	Input Hydrograph Card Limit 66 cards. (Use only when Entry 4 of Work Option 3 Card or Entry 5 of Work Option 5 Card is 1.0)	

INPUT FLOW DISTRIBUTION

CONT					1	Code 1 if another discharge/elevation card follows		
ENTRY 6						Code minus values for discharge, cfs Code plus values for elevation, ft (Optional)		
ENTRY 5						Code minus values for discharge, cfs Code plus values for elevation, ft (Optional)		
ENTRY 4						Code minus values for discharge, cfs Code plus values for elevation, ft (Optional)		Code minus values for discharge, cfs Code plus values for elevation, ft (Optional)
ENTRY 3						Code minus values for discharge, cfs Code plus values for elevation, ft (Optional)		Code minus values for discharge, cfs Code plus values for elevation, ft (Optional)
ENTRY 2				Optional Subroutine Printout 1.0 - yes 0.0 - no (debugging only)		Code minus values for discharge, cfs Code plus values for elevation, ft (Optional)		Code minus values for discharge, cfs Code plus values for elevation, ft (Optional)
ENTRY 1				Printout Option 1.0 - yes 0.0 - no		Code minus values for discharge, cfs Code plus values for elevation, ft (Optional)		Code minus values for discharge, cfs Code plus values for elevation, ft (Optional)
DATA CODE	0 0 5	System Control Card	0 0 1	Program Control Card	0 0 2	Discharge/Elevation Card	0 0 2	Discharge/Elevation Card (Optional)
WORK CODE	H F							

DESCRIPTION OF OUTPUT

See the output from the Sample Problem section for examples of options listed in this section.

Stage-Discharge

If a 1.0 was coded in Entry 2 of the Program Control Card for the stage-discharge routine, the first page of the printer output for the stage-discharge program following the information listed above would consist of the title, the User's comment, the channel slope, and the stage-discharge input verification. A space has also been set aside for the designer's and checker's initials. If the stage-discharge table option was chosen, the input verification will consist of three columns containing the depth, discharge, and maximum velocity which were input. See Sample Problem 1. If a cross section was input, the input verification will consist of the distance (X), elevation (Y), and Manning's number associated with each coordinate point in the cross section being analyzed. Also a note may be printed: ***NOTE***LAST POINT WAS INTERPOLATED, or ***NOTE***LAST POINT WAS EXTRAPOLATED, which means that the last point in the cross section was either above or below the starting coordinate and the computer has either interpolated or extrapolated to make the elevations of both the same. If the last point was extrapolated, the real cross section should be checked as it may not be adequate to convey the 100-year discharge, in which case it should be determined how much will overflow and where it goes to see if this is a problem or not.

When a cross section is input, there will be a second page of printout containing the stage-discharge table. The standard title, User comment, and channel slope are at the top of the page followed by the calculated table. The table contains the elevation (stage), depth, discharge, average velocity, and the maximum velocity for the channel from the bottom of the cross section to the top at approximately .3 feet increments. See Sample Problem 2.

If a 0.0 was coded in Entry 2 of the Program Control Card, there will not be a stage-discharge printout. This is for use if the User already has a stage-discharge printout from a previous run and another copy is not needed.

Stage-Storage

If a 1.0 is coded in Entry 2 of the Program Control Card for the stage-storage routine, the stage-storage input verification will be printed. This consists of the date the run was made, the title, the User's comment, the input verification, and a space for the designer's and checker's initials. There are two possible forms of input to be verified; the cross section table input or the depth storage area table input.

The cross section input verification consists of the upstream slope followed by the cross section station (distance upstream from the roadway), and a table of the distance (X) and elevation (Y) coordinate listings for each cross section used. This is followed by a page consisting of the date, the title, the User's comments, and a table of the computational results showing the storage and the area inundated associated with various depths incremented from zero to the maximum depth of the cross section. See Sample Problem 2.

The depth storage area table input verification consists of a printed statement (Depth Storage Area Table Input) followed by a page with the date, the title, the User's comment, and the depth storage area table that the User input. See Sample Problem 1.

Culvert Design and Review

Printout Options 1, 2, and 3 will all have a common heading followed by a table as described in the subsections below. The heading will include a title on the first two lines followed by the printout option on line three; the station and User's comment on line four; the culvert description (number, size, type of pipe, and inlet details) on line five; the analysis type (work option), design Q, frequency (years or the water right) and the design headwater on line six; and the barrel geometry (length, slope, and BVD) on line seven.

Option 1.0 Culvert Performance. This option will be the one most often requested for culvert design and review. It contains a culvert performance table for the design/review discharge and up to five performance discharges. The table will include a summary of all important hydraulic performance data and corresponding natural channel conditions. See Sample Problems 1 and 3 for examples of this printout table.

1. Hydraulic Performance Properties

Column 1:	DES/REV Discharge (Q_p), the design/review or performance discharge
Column 2:	FLOOD FREQUENCY, the flood frequency in years if a drainage design/review or blank if an irrigation design/review
Column 3:	OUTFLOW DISCHARGE (Q_d), the maximum discharge passing through the culvert and into the downstream channel section
Column 4:	HEADWATER (H_w), this is the maximum headwater (feet) reached above the flow line of the culvert inlet
Column 5:	OUTLET VELOCITY (V_b), this is the average velocity at the culvert outlet for the outflow discharge
Column 6:	FROUDE NUMBER (F_r), this is the Froude number corresponding to the outflow discharge

Column 7: BRINK DEPTH (Y_b), the depth in the culvert at the outlet when it is carrying the outflow discharge

Column 8: FLOW TYPE (see Figure 8), the flow type at the time the culvert is carrying the maximum outflow discharge

Column 9: POND AREA (A_p), the maximum area in acres inundated by the water being stored behind the roadway fill

Column 10: POND DURATION, the length of time that water is being stored

2. Downstream Channel Performance

Column 11: TAILWATER (T_w), the depth of flow in the downstream channel section corresponding to the outflow discharge

Column 12: VEL MAX (V_{TW}), the maximum velocity in the downstream channel section corresponding to the outflow discharge

Column 13: VEL AVE ($\bar{V}$), the average velocity in the downstream channel section corresponding to the outflow discharge NOTE: If stage discharge table was input, this value will be **** since it can not be calculated without a cross section.

Column 14: BED SHEAR (τ_i), the bed shear in the downstream channel section corresponding to the outflow discharge NOTE: If stage discharge table was input, this value will be **** since it can not be calculated without a cross section.

Column 15: OUTFLOW DISCHARGE (Q_p), the maximum discharge passing through the culvert and into the downstream channel section

Option 2.0 Flood Routing. This option will be used only on hydrograph design or review where some special problem exists that requires a more detailed printout than Option 1.0. It will give the flood routing properties at each incremental hydrograph discharge for the design or review discharge and the performance discharges, if any are requested. See Sample Problem 2 for an example.

Column 1: ROUTING TIME, the flood routing time (minutes) is the accumulative total of the incremental routing time (Δt)

Column 2: DISCHARGE-INFLOW (Q_i), the incremental inflow discharge Q (cubic feet per second)

Column 3: DISCHARGE-OUTFLOW (Q_d), the incremental outflow discharge Q (cubic feet per second)

Column 4: VOLUME-IN (I_2, I_1), the incremental volume (acre-feet) of water coming to the site

Colume 5: VOLUME-OUT (O_2, O_1), the incremental volume (acre-feet) of water going through the culvert

Column 6: VOLUME-STORE (V_s), the volume (acre-feet) of water stored behind the roadway fill. This is equal to the VOL IN - VOL OUT plus the VOL STO from the previous incremental time increment.

Column 7: HEADWATER (H_w), the headwater (feet) reached above the flow line of the culvert inlet.

Column 8: OUTLET VELOCITY (V_b), the average velocity (feet per second) at the culvert outlet corresponding to the outflow discharge.

Column 9: FLOW TYPE, the flow type corresponding to the hydraulic properties at the outlet (see Figure 8).

Column 10: BRINK DEPTH (Y_b), the depth (feet) of flow in the culvert at the outlet corresponding to the outflow discharge.

Column 11: FROUDE NUMBER (F_r), the Froude number corresponding to the outflow discharge.

Column 12: TAILWATER (T_w), the depth of flow in the downstream channel section corresponding to the outflow discharge

Column 13: POND AREA (A_p), the incremental area (acres) inundated by the volume of water being stored behind the roadway fill.

Column 14: ROUTING TIME, the flood routing time is the accumulative total of the incremental routing time (Δt).

At the end of the table, there is a line with the VOL IN and VOL OUT totals followed by a line containing the time to peak, the time to maximum outflow, and the time to maximum headwater.

Option 3.0 Design Summary. *(Not available at this time.)* This option is a design summary table for use in conjunction with the Wyoming Highway Department's drainage survey form (E-65). It will contain three parts: hydrology and hydraulics, erosion protection, and cultural and environmental. This output will provide a brief but complete, permanent documentation of the selected culvert design or review formatted so as to be microfilmed along with the drainage survey details and "as built" geometry. See Figure 22.

1. Hydrology and Hydraulics

The hydrology and hydraulics section is a table with the design/review discharge and the performance discharge across the top (a total of six columns) and four performance sections (hydrology, structure, natural channel, and channel change) on the left side. The four performance sections contain several properties related to them. These properties are located in the second

SECTION 9. DESIGN SUMMARY

(To be completed by the Designer)

A. HYDROLOGY & HYDRAULICS *1		Q2.33 ☐	Q10 ☐	Q25 ☐	Q50 ☐	Q100 ☐	Q ☐
1. HYDROLOGY *2	DISCHARGE IN						
	DISCHARGE OUT						
	POND DURATION						
	AREA INUNDATED						
2. STRUCTURE	POND DEPTH						
	VELOCITY						
AHW = ____	STAGE ELEV.						
3. NATURAL CHANNEL	NATURAL DEPTH						
	MAXIMUM VEL.						
	STABILITY *3						
4. CHANNEL CHANGE	NATURAL DEPTH						
	MAXIMUM VEL.						
	STABILITY *3						

5. DESCRIBE INUNDATION DAMAGE VS. DEPTH ON TEMPLATE (THIS SHEET)

B. EROSION PROTECTION *1		TYPE	A	B	C	D	E	F	G	H	I	J	K	L	M	VOLUME
1. PERMANENT	INLET															
d_{mean}=___IN	OUTLET															

C. CULTURAL & ENVIRONMENTAL ☐ NONE ☐ STOCK ☐ LAND USE ☐ AQUATIC ☐ FISHERY ☐ GAME

1. REQUIREMENTS: ______________________________

____

*1 Indicate all units of measure.

*2 Check design discharge and indicate in plan view the reason for selection.

*3 Stability is based on Section 5 and tractive shear & velocity comparisons. Indicate allowable and actual S_0, τ, and V comparisons on corresponding profiles.

*4 Plot any channel change sections, lining, etc., on survey sheet.

*5 Designer will complete the appropriate items in Section 9 for the permanent files. Indicate inappropriate items as "Not Applicable" or "None Provided".

Figure 22

Design Summary

column from the left. The hydrology section contains the discharge in, discharge out, pond duration, and area inundated. The structure section contains pond depth, velocity (average velocity in the structure), and stage elevation. The natural channel section contains the natural depth, maximum velocity, and stability. The last section is for channel changes. It contains the natural depth (in the channel change section), maximum velocity, and stability. The computer will print out values for these properties across the table for the design/review discharge and all performance discharges requested except for the stage elevation, the natural channel and channel change stabilities, and either the natural channel properties or the channel change properties will be left blank depending on which cross section is coded in the stage-discharge input. These values will have to be filled in manually. To the right of the table is a column for remarks where additional information can be manually entered. The design headwater will also be printed out in the first column under structure. The hydrology and hydraulics section also contains an inundation damage table. This is located at the bottom of the printout page following the erosion protection and culvert and environmental sections. The inundation damage table contains columns for depth, time, delta depth, and damage descriptions which are also completed manually.

2. Erosion Protection

The erosion protection table contains dimensions and quantities for inlet and/or outlet protection structures or riprap.

3. Cultural and Environmental

The cultural and environmental table is to be filled in by the User. It contains a checklist of land and water uses and a section for any special requirement.

Flow-Distribution

If a 1.0 was coded in Entry 1 of the Program Control Card for the flow-distribution routine, the flow-distribution will be printed. It consists of the following statements: (1) an error statement which indicates that there is an error in the input data (see Error Messages), or (2) the User's flow-distribution which contains a title with the User's comment at the top of the page. The next two lines contain the elevation (or stage), the discharge for the stage, the starting and ending distance coordinates, and the maximum depth of the stage. Following this heading, the flow-distribution is printed for the User's selected elevation or discharge. The first two columns list the X and Y coordinates of the cross section. The following columns contain the Froude number, the average velocity and discharge in the incremental area between the X coordinates of the cross section, the accumulated discharge, and accumulated per cent of the total discharge (which may be slightly greater or less than 100 per cent due to rounding of numbers), and the tractive shear for the incremental area.

Below the flow-distribution is another set of values for the total accumulated discharge, average depth, average velocity, average Froude number, kinetic energy factor, α; momentum factor, β; specific head, total specific force for the whole cross section, and the maximum channel velocity. See Sample Problem 1.

Plotter Output

The program will output a plot if an 11.0, 21.0, 31.0, or 41.0 was coded in the work option entry of the Program Control and Initial Data Card of the Culvert Design and Review deck. This plot will provide graphic display of several characteristics of the drainage site and culvert under consideration. The plot also provides a data block where additional information about the site may be written manually. These curves and data can be used to document final culvert designs in the permanent file and to make various interpretations of the drainage design for the site. Some of these interpretations are included in the following plot descriptions. The engineer using this plot may discover others not included in the following. The plot descriptions are in the order normally used in designing a culvert. A reduced, black and white copy of the two-color 2'x3' plot is shown in Figure 23. For legibility, Figures 24a and 24c have been included to facilitate their description.

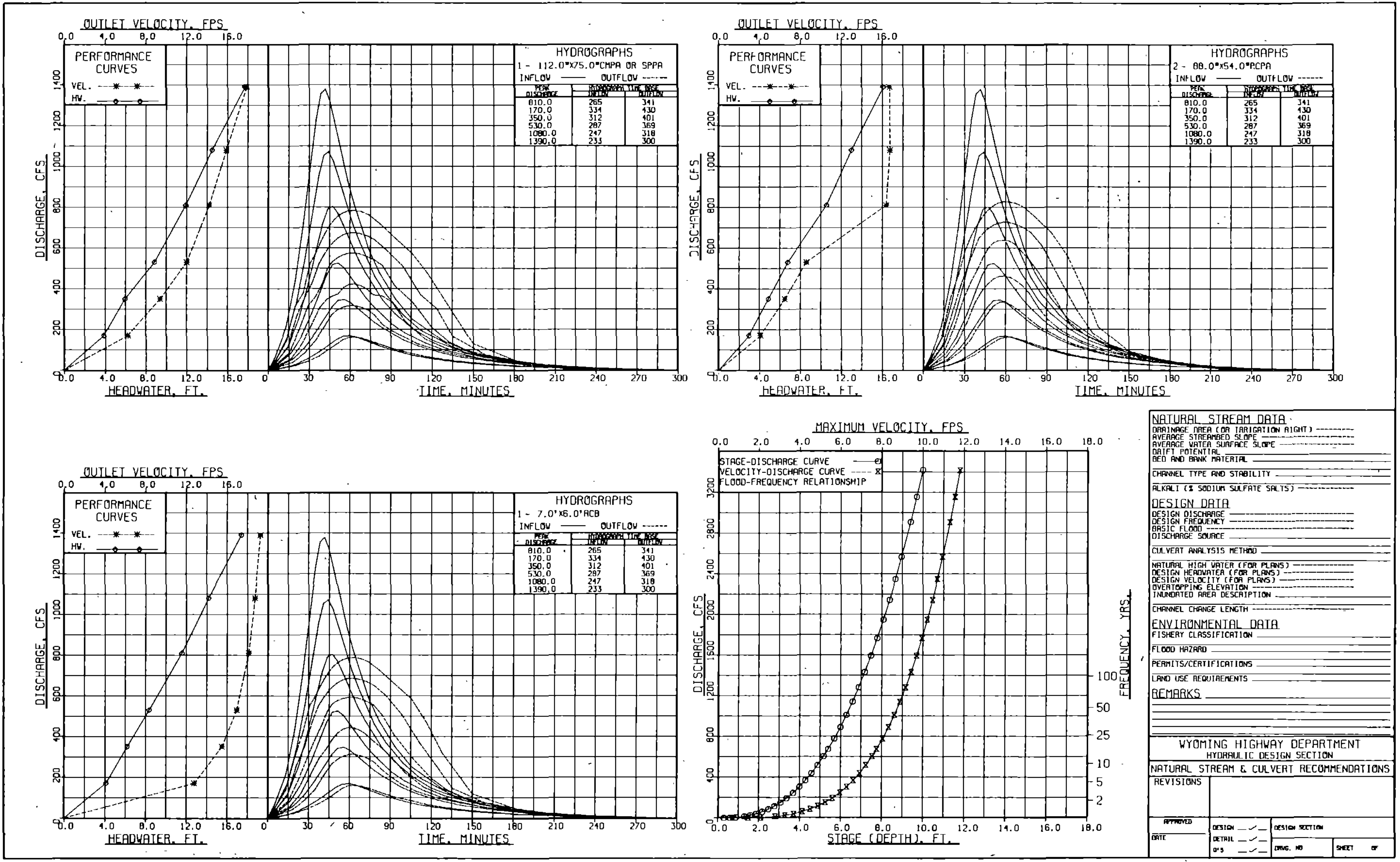
The first block (Figure 24a) shows two characteristics of channel reach through the site and in particular the downstream channel, depth, and maximum velocity plotted vs. discharge. It also marks the flood frequency so that the discharge, depth, and maximum channel velocity are readily found for a particular frequency.

These curves show the flood depth and maximum velocity occurring at the site prior to any highway construction. By including the frequency scale, it was also possible to illustrate the frequency or risk relationship. This type of information is valuable in ascertaining existing flood hazards prior to construction of a new highway and drainage facility. Having this type of information in the permanent file could be extremely important in the event of future legal actions due to alleged flood damage.

The second block (Figure 24b) of the plot is output for each type of culvert requested to be designed or reviewed. Therefore, the plot may contain from one to sic of these blocks. The left portion of this block shows performance curves for the type of culvert plotting peak hydrograph discharge in cfs vs. outlet velocity and headwater. A point for outlet velocity and headwater is plotted for the peak of each hydrograph called for by the designer. Note the headwater and velocity are still those maximums resulting from the hydrograph routing procedure even though they are plotted against the peak discharge for a given hydrograph.

These curves illustrated in Figure 24b show how the indicated culvert will affect the stage/velocity/discharge relationship in Figure 24a. Using both Figures 24a and 24b together allows the engineer to evaluate the risks caused by the selected culvert size. This is done by comparing the headwater with various discharges (which are related to frequency on Figure) to see if the design causes any unacceptable flood hazards. Additionally,

CULVERT HYDRAULIC PERFORMANCE



HYDROGRAPHS
1 - 112.0"X75.0"CMPA OR SPPA
INFLOW —— OUTFLOW ------

PEAK DISCHARGE	HYDROGRAPH TIME BASE	
	INFLOW	OUTFLOW
810.0	265	341
170.0	334	430
350.0	312	401
530.0	287	369
1080.0	247	318
1390.0	233	300

HYDROGRAPHS
2 - 88.0"x54.0"RCPA
INFLOW —— OUTFLOW ------

PEAK DISCHARGE	HYDROGRAPH TIME BASE	
	INFLOW	OUTFLOW
810.0	265	341
170.0	334	430
350.0	312	401
530.0	287	369
1080.0	247	318
1390.0	233	300

HYDROGRAPHS
1 - 7.0'x6.0'RCB
INFLOW —— OUTFLOW ------

PEAK DISCHARGE	HYDROGRAPH TIME BASE	
	INFLOW	OUTFLOW
810.0	265	341
170.0	334	430
350.0	312	401
530.0	287	369
1080.0	247	318
1390.0	233	300

NATURAL STREAM DATA
DRAINAGE AREA (OR IRRIGATION RIGHT) ---------
AVERAGE STREAMBED SLOPE ----------
AVERAGE WATER SURFACE SLOPE ----------
DRIFT POTENTIAL ______
BED AND BANK MATERIAL ______
CHANNEL TYPE AND STABILITY ______
ALKALI (% SODIUM SULFATE SALTS) ----------

DESIGN DATA
DESIGN DISCHARGE ----------
DESIGN FREQUENCY ----------
BASIC FLOOD ----------
DISCHARGE SOURCE ______
CULVERT ANALYSIS METHOD ______
NATURAL HIGH WATER (FOR PLANS) ----------
DESIGN HEADWATER (FOR PLANS) ----------
DESIGN VELOCITY (FOR PLANS) ----------
OVERTOPPING ELEVATION ----------
INUNDATED AREA DESCRIPTION ______
CHANNEL CHANGE LENGTH ----------

ENVIRONMENTAL DATA
FISHERY CLASSIFICATION ______
FLOOD HAZARD ______
PERMITS/CERTIFICATIONS ______
LAND USE REQUIREMENTS ______

REMARKS ______

WYOMING HIGHWAY DEPARTMENT
HYDRAULIC DESIGN SECTION
NATURAL STREAM & CULVERT RECOMMENDATIONS
REVISIONS
APPROVED
DATE
DESIGN ✓
DETAIL ✓
Q'S ✓
DESIGN SECTION
DRWG. NO
SHEET OF

DRY CREEK STATION 366+55+- (EXAMPLE NO.1)

Figure 23

Plotter Output

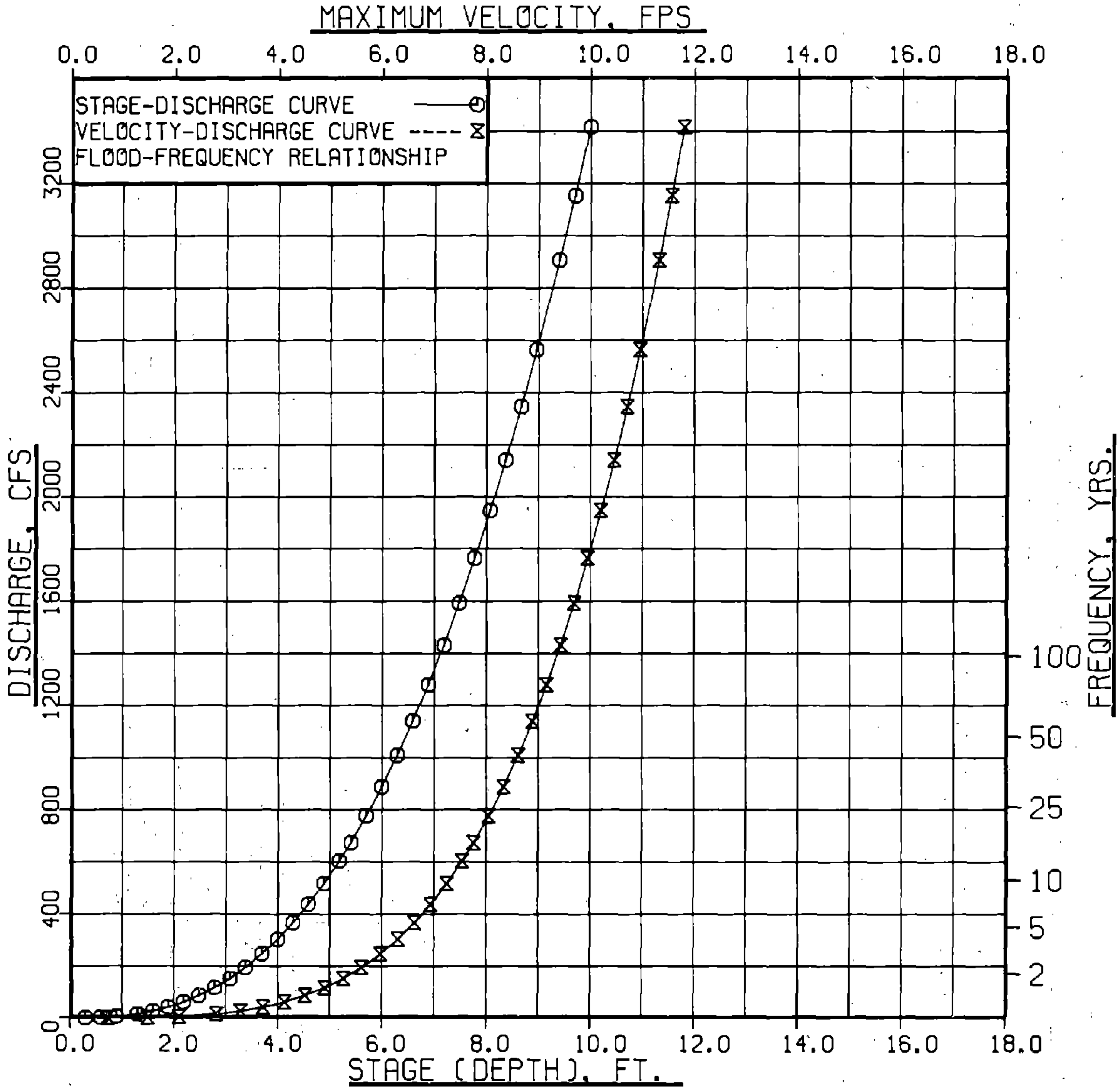
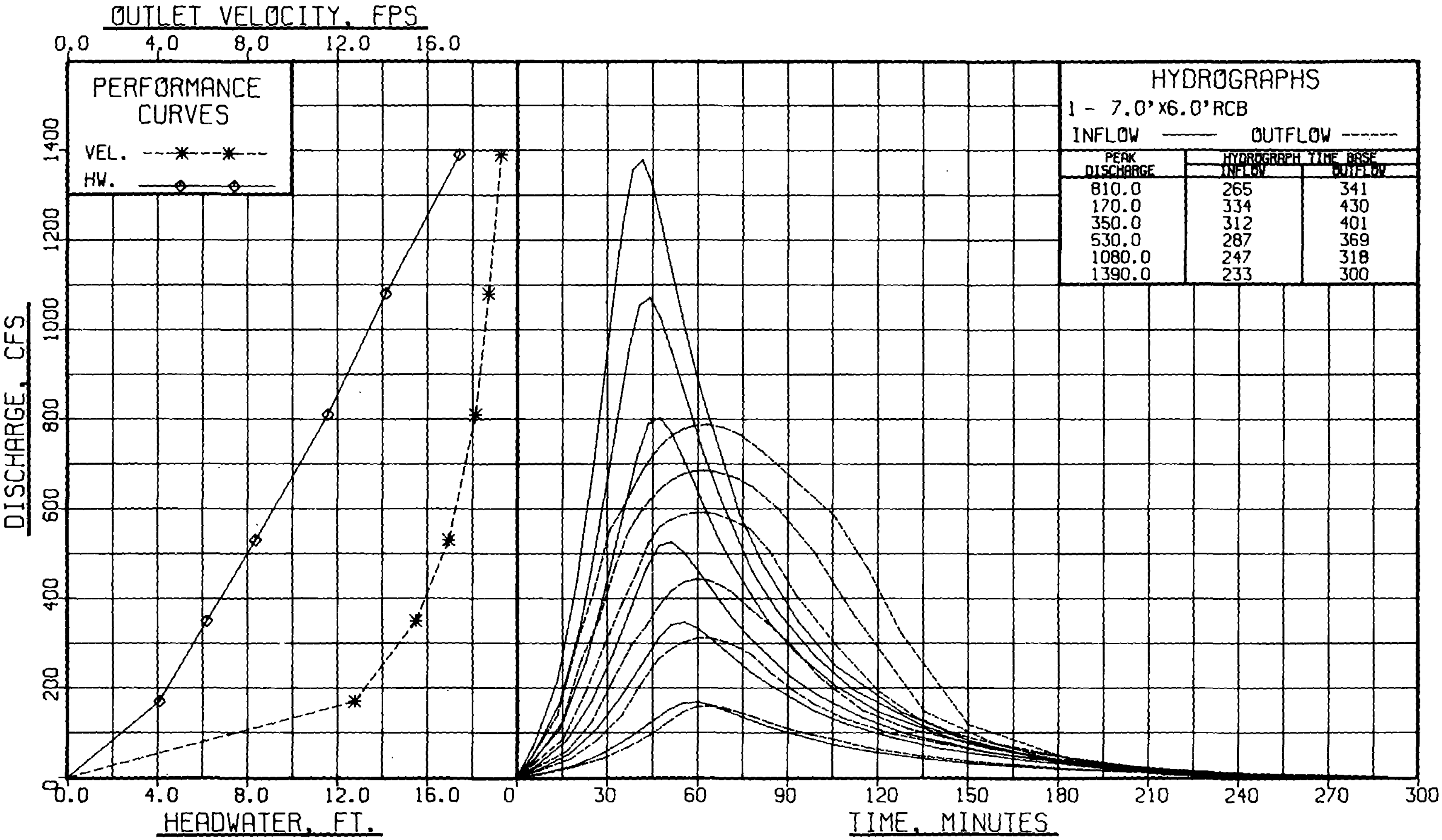


Figure 24a

Depth/Velocity vs. Discharge/Frequency Curves Plot



PEAK DISCHARGE	HYDROGRAPH TIME BASE	
	INFLOW	OUTFLOW
810.0	265	341
170.0	334	430
350.0	312	401
530.0	287	369
1080.0	247	318
1390.0	233	300

Figure 24b

Culvert Performance Curves

NATURAL STREAM DATA

DRAINAGE AREA (OR IRRIGATION RIGHT) ---------
AVERAGE STREAMBED SLOPE ----------------------
AVERAGE WATER SURFACE SLOPE ------------------
DRIFT POTENTIAL ______________________________
BED AND BANK MATERIAL ________________________
____
CHANNEL TYPE AND STABILITY ___________________
____
ALKALI (% SODIUM SULFATE SALTS) -------------

DESIGN DATA

DESIGN DISCHARGE -----------------------------
DESIGN FREQUENCY -----------------------------
BASIC FLOOD ----------------------------------
DISCHARGE SOURCE _____________________________
____
CULVERT ANALYSIS METHOD ______________________
____
NATURAL HIGH WATER (FOR PLANS) ---------------
DESIGN HEADWATER (FOR PLANS) -----------------
DESIGN VELOCITY (FOR PLANS) ------------------
OVERTOPPING ELEVATION ------------------------
INUNDATED AREA DESCRIPTION ___________________
____
CHANNEL CHANGE LENGTH ------------------------

ENVIRONMENTAL DATA

FISHERY CLASSIFICATION _______________________
____
FLOOD HAZARD _________________________________
____
PERMITS/CERTIFICATIONS _______________________
____
LAND USE REQUIREMENTS ________________________

REMARKS

WYOMING HIGHWAY DEPARTMENT

HYDRAULIC DESIGN SECTION

NATURAL STREAM & CULVERT RECOMMENDATIONS

REVISIONS

APPROVED
DATE

DESIGN __✓__
DETAIL __✓__
Q'S __✓__

DESIGN SECTION

DRWG. NO.

SHEET OF

Figure 24c

Design Documentation

comparing the outlet velocity-discharge relationship of Figure 24b with the maximum natural channel velocity using the same discharge on Figure 24a will qualitatively indicate the need for outlet erosion protection.

The right portion of the second block (Figure 24b) plots the inflow and outflow hydrographs for each requested hydrograph. In the upper right is the type, size, and number of the culverts for which the hydrographs are plotted. These culverts were selected using the design discharge and not necessarily the largest discharge that was input. For convenience, it also prints the peak discharge, inflow hydrograph time base, and outflow time base (in minutes). As the outflow time base may be very long in some cases, it is not plotted past the end of the inflow hydrograph. Therefore, the printed time base, either in the computer printout, Option 2, or on the plot will tell how long the outflow hydrograph lasts. By comparing the inflow and outflow hydrographs, the engineer can determine the storage volume generated at the site. A comparison of the inflow and outflow peaks also indicates the degree of "flood control" afforded by the selected culvert size. "Flood control" may prove beneficial to downstream property owners, however, if the culvert significantly influences floods in the mean annual range (bank full), there could be some unacceptable environmental effects such as adverse morphological and fish migration problems.

It is also possible to estimate the increase in time the upstream lands will be subjected to inundation for a given discharge from the hydrograph plots. By entering the stage/discharge/frequency curve (Figure 24a) and performance curve (Figure 24b) with the discharge from a given hydrograph occurring at a given point in time, it is also possible to identify the depth increase as caused by the selected culvert on the floodplains immediately upstream. These types of information allow for various environmental evaluations such as whether the increased time-depth would damage certain agricultural or natural vegetation, deny the use of certain facilities for long periods of time (including the selected drainage culvert which may also serve as a stockpass), etc.

The third block on the plot (Figure 24c) is to be used by the designer to document additional information about the drainage site and is self-explanatory for the most part. The Wyoming Highway Department currently uses this table to document certain essential design and site data for the permanent file. The actual data values must be entered manually. This table will be changed from time to time to reflect current documentation requirements.

NOTES AND ERROR MESSAGES

Stage-Discharge

```
***EXPECTING DATA CODE = 001, FOUND XXX RUN ABORTED
```

This message tells you that the Program Control Card has a Data Code of other than 001 or is missing. Solution: Either change Data Code to 001 or have a Program Control Card inserted if it is missing.

***EXPECTING DATA CODE = 010, FOUND XXX RUN ABORTED

This means that one of the Stage-Discharge Table Cards has a Data Code other than 010 or is missing. Solution: Check all of the Stage-Discharge Table Cards and if one has a code other than 010 or is in the wrong place, change it. If the last card is missing, have the card inserted in its proper place. If all the cards have the proper Data Code and none are missing, there is probably a 1 coded in the 66-CONT column on the last Stage-Discharge Table Card. This column should be blank on the last Stage-Discharge Table Card.

***EXPECTING DATA CODE = 020, FOUND XXX RUN ABORTED

This means that one of the Cross Section Coordinate Cards has a Data Code other than 020 or the last one is missing. Solution: Check all of the Cross Section Coordinate Cards to see if one has the wrong Data Code. If another card is in the wrong place, change it. Also the last Cross Section Coordinate Card could be missing or the 66-CONT column on the last card could have a 1 coded in it; if so, either insert the missing card or change the last coordinate card so that the 66-CONT column is blank.

***MORE THAN 63 SETS OF COORDINATES, FOUND XX RUN ABORTED

This means you have exceeded the maximum of 63 allowable coordinate points. Solution: Remove enough coordinates so that you have only 63 or less remaining.

***EXPECTING DATA CODE = 030, FOUND XXX RUN ABORTED

This means that one of the Manning's Number Cards has the wrong Data Code, another card is in the wrong place, the last Manning's card is missing, a 1 was left out of the 66-CONT column on one of the Cross Section Coordinate Cards, or a 1 was coded in the 66-CONT column on the last Manning's card. Solution: Check for Manning's cards with the wrong Data Dode or any cards that are out of order. If those are okay, check to see if the last Manning's card is missing or if it has a 1 coded in the 66-CONT column. If so, insert the missing card or change the last column so it is blank. If all of the above are okay, check the Cross Section Coordinate Cards to see if a 1 was left out of the 66-CONT column (except the last card): if so, code it in.

***MAXIMUM OF NINE MANNING'S NUMBERS EXCEEDED, FOUND XXX RUN ABORTED

This means that there are too many Manning's numbers coded. Solution: Remove enough Manning numbers so that there are only nine or less remaining. This may require redefining the subsections on the channel cross sections.

***COULD NOT FIND A MATCH FOR ALL X COORDINATES PERTAINING TO MANNING'S NUMBERS, RUN ABORTED

This means that one of the X coordinates on a Manning's Number Card does not match with any of the X coordinates in the cross section inputted on the Cross Section Coordinate Card. Solution: Either insert an additional point on the Cross Section Coordinate Card or change the X coordinate on the Manning's Card to match one of the X coordinates in the cross section.

***BAD CROSS SECTION, RUN ABORTED

This means that one or more of your Y coordinates other than the first one is over 90 feet greater than your lowest Y coordinate point. Solution: Change any points whose Y coordinate is over 90 feet greater than the lowest point.

***OVER 90 FEET DIFFERENCE IN ELEVATION BETWEEN POINT NO. 1 AND XXX

This means your cross section is too deep. Solution: Remove enough cross section points so that the difference between the first and lowest Y coordinate is 90 feet or less.

***POINT NO. XX IS GREATER THAN POINT NO. XX ON X SECTION

This means that one of the cross section points is greater than the starting or ending point and the cross section can not be extrapolated or interpolated to get a point higher than this. Solution: Change cross section so that the first point is higher than any other point except the last and the last point must have either a positive slope preceding it or be higher than all other points except the first. The first and last can be equal.

***FOUND HUMP IN X SECTION THAT PERTAINS TO A MANNING'S NUMBER AND CAN NOT ADJUST

This means that one or more points in your cross section are higher than the end points and the computer has truncated the hump and lost any associated Manning's numbers. Solution: Either make the end points higher than the hump in the cross section, change the Manning numbers on the hump so they are the same (if possible), or check to see if an elevation was coded wrong.

***SLOPE BETWEEN LAST TWO POINTS OF X SECTION IS NEGATIVE, EXTRAPOLATION IMPOSSIBLE, RUN ABORTED

This means that your last coordinate point was lower than the point preceding it and was also lower than your first coordinate point so that the computer would not extrapolate out to make the two end point elevations equal. Solution: Make your last coordiante point higher than the one preceding it.

***ONLY ONE POINT IN CROSS SECTION COORDINATE IS IN ERROR, RUN ABORTED

This means that the cross section input consists of only one point or the first coordinate point is lower than all the others. Solution: Cross section must have at least three points and the first point should be higher than all but the last point.

Stage-Storage

***PROGRAM WAS EXPECTING A 001 CONTROL CARD BUT READ A XXX CARD * ERROR JOB FLUSHED

This means that the Program Control Card is either missing, out of order, or has the wrong Data Code. Solution: Place a Program Control Card in the proper place or change the Data Code if it is wrong.

***NO PROPER CONTROL CARD FOUND, ALL DATA FLUSHED

This means that the Work Code on every System Control Card is blank. Solution: There must be a proper System Control Card for every part of the program requested. Place proper System Control Cards where needed.

***INPUT DATA CARDS NOT IN PROPER ORDER, FLUSHED

This means that your Data Cards are out of order. Solution: Put the cards in their proper place.

***CONTROL CARD HAS IMPROPER CODE FOR DATA TYPE SWITCH

This means that you coded either a cross section to be input or a storage table to be input and you used a 020 instead of 010 Data Code or 010 instead of 020. Solution: Change Data Code so that it matches the option selected.

***PROGRAM CAN NOT HANDLE OVER 63 DEPTHS, JOB FLUSHED

This means the Storage Table that was input has more than 62 depths. The computer adds one more set with all values initialized to zero for a total of 63. Solution: Remove as many cards as required to bring the total number of depths to 62 or less (31 cards).

***RAN OUT OF DATA CARDS

This means that the computer did not find another Control Card or a 999 card, so it stopped. Solution: Check for the missing Control Card or 999 card.

***NO UPSTREAM SLOPE INPUTTED, JOB FLUSHED

This means that Entry 4 in the Program Control Card is blank and a 1.0 was coded in Entry 1 (cross section input). Solution: The upstream channel slope must be entered in Entry 4 if a cross section is input.

***PROGRAM CAN NOT HANDLE OVER 10 CROSS SECTIONS, FLUSHED

This means that more than 10 cross sections have been input. Solution: Remove as many cross sections as are required to bring the total number down to 10 or less.

Culvert Design and Review

***INVALID CODE FOR INLET TYPE OR MANNING'S NUMBER

This means that one of the values in the Culvert Type Card is improper. Solution: Either the inlet code for one of the pipes was coded in the wrong column or one of the inlet codes used does not exist and must be changed.

***Q = XXX NOT IN RANGE OF DEPDIS TABLE, RUN STOPPED

This means that your Design/Review/Performance discharge is larger than the capacity of your cross section coded in the Stage-Discharge section. Solution: Input a larger cross section. If the terrain physically does not provide a larger cross section, then part of your flood is escaping the channel upstream and probably does not arrive at the site; re-evaluate your hydrology analysis to better identify the range of discharges arriving at the site.

***ERROR PIPE SIZE AND NUMBER AT MAXIMUM

This means that the required pipe installation is larger than the allowable. Solution: Try increasing the GVD and allowable headwater if possible. If this does not work, either a bridge design is required or more barrels than the system considers. If a culvert design or review is still desired, reduce the design/review discharge a specific amount (say half as an example), then proportionately increase (double) the number of required barrels.

***OUTFLOW HYDROGRAPH HAS OVER 500 VALUES

This means that the outflow hydrograph has exceeded 500 time increments. Solution: Change the time increment for flood routing in Work Option 3 or 4 to a larger value.

***DELTA T = XXX WILL NOT ALLOW HYDROGRAPH TO FIT IN 200 ENTRIES,
RUN STOPPED

This means that your inflow hydrograph has used more than 200 entries. Solution: Change the time increment for flood routing in Work Option 3 or 4 to a larger value.

***DELTA T = XXX WILL NOT WORK FOR INTERPOLATION, RUN STOPPED

This means that your time increment is greater than the flood hydrograph. Solution: Change the time increment for flood routing in Work Option 3 or 4 to a smaller value.

***DATA CODE = XXX WAS NOT A 050 CARD

This means that there is an improper Data Code or a mistake in the 66-CONT column. Solution: Check the input hydrograph card to see if its Data Code is 050 and change it if it is not. If you did not want to input a hydrograph, you may have coded a 1.0 in Entry 4 on the Work Option card or Entry 5 on the Work Option 4 card by mistake. This should be coded 0.0 if you are not inputting a hydrograph. Another possibility is that you coded a 1 in the 66-CONT column on the last Input Hydrograph Card. This should be left blank, otherwise the computer will attempt to read another 050 card.

```
***ERROR ENCOUNTERED NERROR = XXX
```

This means that you have error number XXX in a routing routine. This is usually printed at the end of the printout for the culvert being analyzed along with the last values calculated. It will be accompanied by another error message detailing the error.

```
***MORE THAN 30 ITERATIONS NEEDED TO BALANCE THE INFLOW-OUTFLOW
   STORAGE EQUATION A HEADWATER WAS CALCULATED TO MATCH THE QD
```

This is a warning statement. The program has forced a volume balance because, either the available storage is so large that even small changes in headwater result in large fluctuations in volume stored preventing the program from balancing within 30 iterations (See Chapter 1, SYSTEM OPERATION) or a discontinuity exists in the program logic. Check the storage table to see if there is a large amount of storage available at the headwater computed. If so, there is no problem. If not, bring this problem to the attention of the Data Services Division.

```
***RAN OUT OF DATA CARDS, RUN STOPPED
```

This means that you probably left out a 999 card at the end of the job. Solution: Your results should be all right, but put a 999 card at the end of the deck if you are going to run the deck again.

```
***DATA CARDS OUT OF SEQUENCE, CHECK CARD WITH CODES XXX
```

This means that one or more cards is missing or out of place. Solution: Add the missing XXX card or put the cards in the proper order.

```
***INVALID WORK OPTION
```

This means that the work option coded was other than a 1, 2, 3, or 4. Solution: Check input documentation for proper work option and change the card accordingly.

```
***APPROXIMATE OUTFLOW DISCHARGES OF XXX TOO LARGE FOR STAGE-DISCHARGE
   TABLE
```

This means that your downstream cross section coded in the stage-discharge section is too small. Solution: Code some additional higher elevation points to each end of your cross section.

```
***ERROR CHANGED KAPPA AND N WAS EQUAL TO 1
***ERROR KAPPA OUT OF RANGE
***ERROR N WAS NOT 0 or 1
```

The error statements indicate that an internal switching error was made. Solution: See Data Services Division as something could be wrong with the program itself.

***STAGE DISCHARGE TABLE INPUTED, AVERAGE VELOCITY AND BED SHEAR
CAN NOT BE CALCULATED

The program can not calculate average velocity and bed shear, without a cross section. If these values are needed a cross section will have to be input instead of a table for the stage discharge.

Flow-Distribution

***LIMIT OF 10 DISCHARGES OR ELEVATIONS, FOUND XX RUN ABORTED

This means that more than 10 discharges or elevations were asked for in the Flow-Distribution Section. Solution: Remove as many discharges or elevations as required to bring the total to 10 or less. A second run will be required for the ones removed.

***WAS EXPECTING DATA CODE = 001, FOUND XXX RUN ABORTED

This means that a card is in the wrong place or the Program Control Card is missing or has the wrong Data Code. Solution: Put a Program Control Card in the proper place or correct the Data Code if it is other than 001.

***WAS EXPECTED DATA CODE = 002, FOUND XXX RUN ABORTED

This means that the Discharge/Elevation Card is missing or has the wrong Data Code. Solution: Correct the Data Code or insert the Discharge/ Elevation Card in the proper place.

INSUFFICIENT CROSS SECTION TO CONTAIN DISCHARGE OF XXXX CFS

This means that the cross section coded in the Stage-Discharge section was too small. Solution: Add some higher points to each end of the cross section if possible.

Chapter 3

SAMPLE PROBLEMS

INTRODUCTION

The four examples in this chapter were chosen to illustrate each of the possible functions of the program. There is a brief description followed by the coded input on Form C-16. Following this are copies of the actual program output.

No attempt was made to provide interpretations of the design data provided as output in these examples. Interpretation of data from this system and the accuracy of this system in providing this data is the responsibility of the User and the Wyoming Highway Department assumes no liability or responsibility for either.

Example No. 1 - Culvert Design with Upstream Storage

This example uses a specified design flood, six culvert types, five performance curve floods, upstream and downstream cross sections and their profile slopes, culvert slope, allowable headwater, and maximum allowable culvert barrel height to determine six acceptable culvert sizes (one size for each specified type). The output consists of the stage-discharge relationship for the downstream cross section, available storage in the upstream cross section, and acceptable sizes and hydraulics for all six culvert types. The flow distribution alternative for the downstream cross section was selected for the requested discharges. The long form output format was selected which displays the flood routing properties at each incremental hydrograph discharge for the requested design and performance curve discharges.

FORM C-16
Rev. 3/11/69

WYOMING STATE HIGHWAY DEPARTMENT
CHEYENNE WYOMING
BRIDGE DIVISION

DESIGN SYSTEM

SHEET NO 1 OF 2
BY DB DATE 6/20/78
CHECKED JEK

I COMMENT CARD

1		64
100	DRY CREEK STATION 366+55± (EXAMPLE NO. 1)	

1 2 WORK CODE	3 5 DATA CODE	ENTRY 1 6 15	ENTRY 2 25	ENTRY 3 35	ENTRY 4 45	ENTRY 5 55	ENTRY 6 65	66 CONT
HF	002							
	001	1.0	0.0	0.0	0.0094			
	020	-125.0	5385.4	-77.0	5382.1	-35.0	5381.1	1
	020	-20.0	5376.5	-5.0	5372.4	0.0	5371.1	1
	020	15.0	5374.8	37.0	5380.5	50.0	5384.4	1
	020	90.0	5384.6	122.0	5385.7			
	030	-35.0	0.04	50.0	0.055	122.0	0.037	
HS	001							
	001	1.0	1.0	0.0	0.0106			
	005	100.0						
	010	-113.0	5389.1	-57.0	5387.7	-35.0	5388.2	1
	010	-12.0	5378.5	0.0	5377.4	26.0	5378.1	1
	010	55.0	5382.8	85.0	5387.8	100.0	5388.1	1
	010	134.0	5389.6					
HC	001							
	001	31.0	2.0	0.0	36655.0	103.0	0.01	
	002	11.0	53.0	11.0	83.0	11.0	11.0	

TRAILER CARD

1 3	
999	

NOTE: A trailer card must follow the last structure card containing data

FORM C-16
Rev. 3/11/69

WYOMING STATE HIGHWAY DEPARTMENT
CHEYENNE WYOMING
BRIDGE DIVISION

DESIGN SYSTEM

SHEET NO. 2 OF 2
BY DB DATE 6/20/78
CHECKED JEK

1 COMMENT CARD 64

~~+00~~

1 2 WORK CODE	3 5 DATA CODE	ENTRY 1 6 15	ENTRY 2 25	ENTRY 3 35	ENTRY 4 45	ENTRY 5 55	ENTRY 6 65	66 CONT
	004	810.0	170.0	350.0	530.0	1080.0	1390.0	
	005	68.32	18.08	34.75	48.41	84.98	103.12	
	006	25.0	2.0	5.0	10.0	50.0	100.0	
	030	12.0	9.0					
HF	015							
	001	1.0						
	002	-350.0	+53781.0	-810.0	+53782.5	-1390.0		

TRAILER CARD

999
1 3

NOTE: A trailer card must follow the last structure card containing data

```
                  WYOMING HIGHWAY DEPARTMENT
         PRECONSTRUCTION DIVISION      HYDRAULICS SECTION
              CHANNEL STAGE DISCHARGE RELATIONSHIP
    DRY CREEK           STATION 366+55+-         (EXAMPLE NO.1)
                CHANNEL SLOPE =  0.00940FT/FT

               STAGE DISCHARGE INPUT VERIFICATION

                                                             INPUT VERIFIED?
                                                     DESIGNER____    CHECKER____
       X( 1) = -125.0   Y( 1) = 5385.4   MANNINGS NUMBER = .040
       X( 2) =  -77.0   Y( 2) = 5382.1   MANNINGS NUMBER = .040
       X( 3) =  -35.0   Y( 3) = 5381.1   MANNINGS NUMBER = .040
       X( 4) =  -20.0   Y( 4) = 5376.5   MANNINGS NUMBER = .055
       X( 5) =   -5.0   Y( 5) = 5372.4   MANNINGS NUMBER = .055
       X( 6) =    0.0   Y( 6) = 5371.1   MANNINGS NUMBER = .055
       X( 7) =   15.0   Y( 7) = 5374.8   MANNINGS NUMBER = .055
       X( 8) =   37.0   Y( 8) = 5380.5   MANNINGS NUMBER = .055
       X( 9) =   50.0   Y( 9) = 5384.4   MANNINGS NUMBER = .055
       X(10) =   90.0   Y(10) = 5384.6   MANNINGS NUMBER = .037
       X(11) =  113.3   Y(11) = 5385.4   MANNINGS NUMBER = .037
*** NOTE *** LAST POINT WAS INTERPOLATED
```

```
                    WYOMING HIGHWAY DEPARTMENT
       PRECONSTRUCTION DIVISION       HYDRAULICS SECTION
                CHANNEL STAGE DISCHARGE RELATIONSHIP
    DRY CREEK           STATION 366+55+-         (EXAMPLE NO.1)
                  CHANNEL SLOPE =  0.00940FT/FT

ELEVATION           DEPTH        DISCHARGE        VELOCITY       MAX. VELOCITY

  5371.1             0.0              0.0            0.0              0.0
  5371.4             0.3              0.3            0.7              0.7
  5371.7             0.6              1.8            1.3              1.5
  5372.0             0.9              5.5            1.7              2.1
  5372.4             1.3             15.1            2.3              2.8
  5372.7             1.6             26.3            2.6              3.3
  5373.0             1.9             41.5            2.9              3.7
  5373.3             2.2             61.2            3.2              4.1
  5373.6             2.5             85.9            3.5              4.5
  5373.9             2.8            115.9            3.8              4.9
  5374.2             3.1            151.7            4.1              5.3
  5374.5             3.4            193.8            4.3              5.6
  5374.8             3.7            246.5            4.6              6.0
  5375.1             4.0            302.6            4.9              6.3
  5375.4             4.3            366.1            5.1              6.6
  5375.7             4.6            437.2            5.3              6.9
  5376.0             4.9            516.3            5.6              7.2
  5376.3             5.2            603.7            5.8              7.5
  5376.5             5.4            673.6            5.9              7.8
  5376.8             5.7            776.2            6.2              8.1
  5377.1             6.0            887.9            6.4              8.3
  5377.4             6.3           1009.0            6.6              8.6
  5377.7             6.6           1139.7            6.8              8.9
  5378.0             6.9           1280.4            7.0              9.2
  5378.3             7.2           1431.2            7.2              9.4
  5378.6             7.5           1592.4            7.4              9.7
  5378.9             7.8           1764.4            7.6             10.0
  5379.2             8.1           1947.3            7.8             10.2
  5379.5             8.4           2141.4            8.0             10.5
  5379.8             8.7           2347.0            8.2             10.7
  5380.1             9.0           2564.3            8.4             11.0
  5380.5             9.4           2906.3            8.6             11.3
  5380.8             9.7           3153.7            8.8             11.6
  5381.1            10.0           3417.0            9.0             11.8
  5381.4            10.3           3691.4            9.1             12.0
  5381.7            10.6           3987.9            9.2             12.3
  5382.1            11.0           4439.4            9.3             12.6
  5382.4            11.3           4808.4            9.4             12.8
  5382.7            11.6           5209.5            9.5             13.0
  5383.0            11.9           5642.7            9.6             13.3
  5383.3            12.2           6108.5            9.7             13.5
  5383.6            12.5           6607.5            9.8             13.7
  5383.9            12.8           7140.4           10.0             13.9
  5384.2            13.1           7708.0           10.1             14.1
  5384.4            13.3           8156.9           10.2             14.3
```

```
ELEVATION          DEPTH       DISCHARGE       VELOCITY      MAX. VELOCITY

 5384.6             13.5         8579.1           10.3            14.5
 5384.9             13.8         9264.9           10.3            14.7
 5385.2             14.1        10015.9           10.4            14.9
 5385.4             14.3        10578.9           10.5            15.0
```

```
                        WYOMING HIGHWAY DEPARTMENT                  PAGE    1
                                                                    12/31/79
        ENGINEERING DIRECTORATE  ********  HYDRAULICS SECTION
                             STAGE STORAGE
DRY CREEK           STATION 366+55+-        (EXAMPLE NO.1)
                           INPUT VERIFICATION
                                                     INPUT VERIFIED ?
                                               DESIGNER ____    CHECKER ____
      UPSTREAM SLOPE =     0.01060 FEET/FOOT
      CROSS SECTION STATION =       0.0
                 X (DISTANCE-FEET)     Y (ELEVATION-FEET)

                       -113.00              5389.10
                        -57.00              5387.70
                        -35.00              5388.20
                        -12.00              5378.50
                          0.0               5377.40
                         26.00              5378.10
                         55.00              5382.80
                         85.00              5387.80
                        100.00              5388.10
                        134.00              5389.60
      CROSS SECTION STATION =     100.00
                 X (DISTANCE-FEET)     Y (ELEVATION-FEET)

                       -113.00              5389.10
                        -57.00              5387.70
                        -35.00              5388.20
                        -12.00              5378.50
                          0.0               5377.40
                         26.00              5378.10
                         55.00              5382.80
                         85.00              5387.80
                        100.00              5388.10
                        134.00              5389.60
```

```
                     WYOMING HIGHWAY DEPARTMENT                  PAGE    2
                                                                 12/31/79
         ENGINEERING DIRECTORATE  *********  HYDRAULICS SECTION
                          STAGE STORAGE
DRY CREEK            STATION 366+55+-        (EXAMPLE NO.1)
                       COMPUTATIONAL RESULTS
          DEPTH (FT)       STORAGE (ACRE-FT)    AREA INUNDATED (ACRES)

              0.0               0.0                  0.0
              0.70              0.02                 0.06
              1.10              0.06                 0.09
              5.40              1.52                 0.54
             10.30              6.80                 1.74
             10.40              6.96                 1.81
             10.70              7.54                 2.20
             10.80              7.77                 2.30
             11.70             10.18                 3.26
```

```
                    WYOMING HIGHWAY DEPARTMENT
        ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
STATION:  366+55.00  PROJECT:  DRY CREEK          STATION 366+55+-        (EXAMPLE NO.1)
CULV SIZE: 1=  7.0X  7.0 ROUND CONCRETE/,SOCKET END PROJECTING INLET
ANALYSIS TYPE: DRAINAGE DESIGN     Q: 810CFS FREQ: 25YR DHW: 12.00FT
BARREL GEOMETRY: LENGTH: 103FT SLOPE: 1.00000% GVD: 9.0FT
* * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |  AREA  | TIME  |

   0MIN     0CFS     0CFS    0.0    0.0    0.0    0.0    0.0FPS    0.0   0.0FT          0.0FT    0.0AC     0MIN
   5MIN    37CFS    24CFS    0.6    0.4    0.2    1.6    3.9FPS    0.5   1.6FT    IG    1.6FT    0.1AC     5MIN
  15MIN   125CFS    78CFS    1.3    0.8    0.7    3.0    6.7FPS    0.8   2.4FT    IG    2.4FT    0.3AC    15MIN
  22MIN   256CFS   188CFS    2.7    2.0    1.4    5.1   14.4FPS    1.6   2.6FT    IA    3.3FT    0.5AC    22MIN
  29MIN   418CFS   276CFS    3.3    2.2    2.6    6.4   16.0FPS    1.6   3.2FT    IA    3.9FT    0.8AC    29MIN
  35MIN   580CFS   376CFS    4.5    2.9    4.2    7.9   17.3FPS    1.5   3.9FT    IA    4.3FT    1.1AC    35MIN
  39MIN   715CFS   450CFS    3.7    2.3    5.6    9.2   18.0FPS    1.5   4.3FT    IA    4.6FT    1.5AC    39MIN
  43MIN   789CFS   513CFS    4.1    2.7    7.1   10.5   18.5FPS    1.5   4.8FT    IA    4.9FT    1.9AC    43MIN
  47MIN   803CFS   540CFS    4.2    2.8    8.5   11.1   18.6FPS    1.5   4.9FT    ID    5.0FT    2.6AC    47MIN
  51MIN   769CFS   558CFS    4.0    2.9    9.6   11.5   18.7FPS    1.5   5.1FT    ID    5.0FT    3.0AC    51MIN
  54MIN   714CFS   570CFS    3.7    3.0   10.3   11.8   18.8FPS    1.5   5.2FT    ID    5.1FT    3.4AC    54MIN
  58MIN   656CFS   576CFS    3.4    3.0   10.8   11.9   18.8FPS    1.5   5.2FT    ID    5.1FT    3.8AC    58MIN
  62MIN   599CFS   578CFS    3.1    3.0   10.9   12.0   18.8FPS    1.5   5.2FT    ID    5.1FT    3.9AC    62MIN
  66MIN   542CFS   575CFS    2.8    3.0   10.7   11.9   18.8FPS    1.5   5.2FT    ID    5.1FT    3.8AC    66MIN
  71MIN   478CFS   564CFS    4.2    5.0    9.9   11.6   18.7FPS    1.5   5.1FT    ID    5.0FT    3.2AC    71MIN
  77MIN   411CFS   546CFS    3.4    4.6    8.8   11.2   18.7FPS    1.5   5.0FT    ID    5.0FT    2.7AC    77MIN
  83MIN   344CFS   517CFS    3.1    4.6    7.2   10.5   18.5FPS    1.5   4.8FT    ID    4.9FT    2.0AC    83MIN
  92MIN   278CFS   419CFS    4.4    6.6    5.0    8.6   17.7FPS    1.5   4.1FT    IA    4.5FT    1.3AC    92MIN
 106MIN   204CFS   300CFS    4.3    6.3    3.0    6.7   16.4FPS    1.6   3.4FT    IA    4.0FT    0.9AC   106MIN
 119MIN   147CFS   219CFS    2.5    3.8    1.7    5.6   15.1FPS    1.6   2.8FT    IA    3.5FT    0.6AC   119MIN
 132MIN   116CFS   144CFS    2.1    2.6    1.2    4.4   13.4FPS    1.6   2.3FT    IA    3.0FT    0.4AC   132MIN
 145MIN    85CFS   101CFS    1.5    1.7    0.9    3.6    7.6FPS    0.8   2.6FT    IG    2.6FT    0.4AC   145MIN
 170MIN    48CFS    55CFS    2.5    2.9    0.5    2.5    5.7FPS    0.7   2.1FT    IG    2.1FT    0.2AC   170MIN
 208MIN    16CFS    22CFS    0.9    1.2    0.2    1.5    3.8FPS    0.5   1.5FT    IG    1.5FT    0.1AC   208MIN
 246MIN     3CFS     6CFS    0.2    0.3    0.0    0.8    2.1FPS    0.4   0.9FT    IG    0.9FT    0.1AC   246MIN
 303MIN     0CFS     0CFS    0.0    0.0    0.0    0.1    0.5FPS    0.1   0.3FT    IG    0.3FT    0.0AC   303MIN

              TOTAL VOLUMES   71     71

TIME TO PEAK=   45MIN.  TIME TO MAX OUTFLO=   64MIN.   TIME TO MAX HW=   64MIN.
```

```
                         WYOMING HIGHWAY DEPARTMENT
           ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
 CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
 STATION: 366+55.00  PROJECT:  DRY CREEK            STATION 366+55+-         (EXAMPLE NO.1)
 CULV SIZE: 1= 7.0X 7.0 ROUND CONCRETE/,SOCKET END PROJECTING INLET
 ANALYSIS TYPE: PERFORM DISCHGE   Q: 170CFS FREQ:  2YR DHW:12.00FT
 BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
 * * * * * * * * *  C U L V E R T   F L O O D   R O U T I N G  * * * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *

|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO.  | DEPTH | TYPE |WATER |  AREA  | TIME  |

    0MIN     0CFS     0CFS    0.0     0.0    0.0    0.0    0.0FPS    0.0    0.0FT          0.0FT   0.0AC     0MIN
    7MIN     7CFS     5CFS    0.2     0.1    0.0    1.0    2.0FPS    0.4    0.9FT   IG     0.9FT   0.1AC     7MIN
   19MIN    26CFS    18CFS    0.3     0.2    0.2    1.4    3.4FPS    0.5    1.4FT   IG     1.4FT   0.1AC    19MIN
   28MIN    53CFS    38CFS    0.7     0.5    0.4    2.0    4.8FPS    0.6    1.8FT   IG     1.8FT   0.2AC    28MIN
   37MIN    87CFS    63CFS    0.9     0.6    0.6    2.7    6.1FPS    0.7    2.2FT   IG     2.2FT   0.3AC    37MIN
   44MIN   121CFS    95CFS    1.2     0.9    0.9    3.4    7.4FPS    0.8    2.6FT   IG     2.6FT   0.3AC    44MIN
   50MIN   150CFS   122CFS    1.0     0.8    1.0    4.0   12.8FPS    1.6    2.1FT   IA     2.8FT   0.4AC    50MIN
   54MIN   165CFS   144CFS    1.1     0.9    1.2    4.4   13.4FPS    1.6    2.3FT   IA     3.0FT   0.4AC    54MIN
   59MIN   168CFS   157CFS    1.1     1.0    1.3    4.6   13.7FPS    1.6    2.4FT   IA     3.1FT   0.5AC    59MIN
   64MIN   161CFS   159CFS    1.1     1.0    1.3    4.7   13.8FPS    1.6    2.4FT   IA     3.1FT   0.5AC    64MIN
   69MIN   149CFS   154CFS    1.0     1.0    1.2    4.6   13.7FPS    1.6    2.3FT   IA     3.1FT   0.5AC    69MIN
   74MIN   137CFS   145CFS    0.9     1.0    1.2    4.4   13.4FPS    1.6    2.3FT   IA     3.0FT   0.4AC    74MIN
   78MIN   125CFS   135CFS    0.8     0.9    1.1    4.2   13.2FPS    1.6    2.2FT   IA     2.9FT   0.4AC    78MIN
   83MIN   113CFS   124CFS    0.7     0.8    1.1    4.0   12.9FPS    1.6    2.1FT   IA     2.9FT   0.4AC    83MIN
   90MIN   100CFS   109CFS    1.1     1.2    1.0    3.7   12.4FPS    1.6    2.0FT   IA     2.7FT   0.4AC    90MIN
   97MIN    86CFS    95CFS    0.9     1.0    0.9    3.4    7.4FPS    0.8    2.6FT   IG     2.6FT   0.3AC    97MIN
  105MIN    72CFS    81CFS    0.8     0.9    0.7    3.1    6.9FPS    0.8    2.4FT   IG     2.4FT   0.3AC   105MIN
  117MIN    58CFS    65CFS    1.2     1.3    0.6    2.7    6.1FPS    0.7    2.2FT   IG     2.2FT   0.3AC   117MIN
  133MIN    42CFS    48CFS    1.1     1.3    0.5    2.3    5.3FPS    0.7    2.0FT   IG     2.0FT   0.2AC   133MIN
  151MIN    30CFS    36CFS    0.7     0.8    0.3    1.9    4.7FPS    0.6    1.8FT   IG     1.8FT   0.2AC   151MIN
  167MIN    24CFS    28CFS    0.5     0.6    0.3    1.7    4.1FPS    0.6    1.6FT   IG     1.6FT   0.2AC   167MIN
  183MIN    17CFS    21CFS    0.4     0.5    0.2    1.5    3.6FPS    0.5    1.5FT   IG     1.5FT   0.1AC   183MIN
  214MIN    10CFS    11CFS    0.7     0.8    0.1    1.2    2.8FPS    0.5    1.2FT   IG     1.2FT   0.1AC   214MIN
  262MIN     3CFS     3CFS    0.2     0.3    0.0    0.9    1.7FPS    0.3    0.8FT   IG     0.8FT   0.1AC   262MIN
  310MIN     0CFS     1CFS    0.0     0.1    0.0    0.5    1.0FPS    0.3    0.5FT   IG     0.5FT   0.0AC   310MIN
  382MIN     0CFS     0CFS    0.0     0.0    0.0    0.1    0.7FPS    0.3    0.1FT   IG     0.1FT   0.0AC   382MIN

             TOTAL VOLUMES     19      19

 TIME TO PEAK=   57MIN.  TIME TO MAX OUTFLO=   66MIN.   TIME TO MAX HW=   66MIN.
```

```
                         WYOMING HIGHWAY DEPARTMENT
          ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
 CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
 STATION: 366+55.00  PROJECT:  DRY CREEK            STATION 366+55+-        (EXAMPLE NO.1)
 CULV SIZE: 1- 7.0X  7.0 ROUND CONCRETE/,SOCKET END PROJECTING INLET
 ANALYSIS TYPE: PERFORM DISCHGE   Q: 350CFS FREQ:  5YR DHW:12.00FT
 BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
 * * * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO.  | DEPTH | TYPE-|WATER |  AREA  | TIME  |

    0MIN     0CFS     0CFS   0.0   0.0   0.0   0.0    0.0FPS    0.0   0.0FT          0.0FT   0.0AC     0MIN
    6MIN    16CFS    12CFS   0.3   0.2   0.1   1.2    2.9FPS    0.5   1.2FT   IG     1.2FT   0.1AC     6MIN
   17MIN    54CFS    34CFS   0.7   0.4   0.3   1.9    4.6FPS    0.6   1.8FT   IG     1.8FT   0.2AC    17MIN
   26MIN   110CFS    78CFS   1.4   1.0   0.7   3.1    6.7FPS    0.8   2.4FT   IG     2.4FT   0.3AC    26MIN
   34MIN   180CFS   136CFS   1.7   1.3   1.1   4.3   13.2FPS    1.6   2.2FT   IA     3.0FT   0.4AC    34MIN
   41MIN   250CFS   208CFS   2.3   1.9   1.6   5.4   14.9FPS    1.6   2.8FT   IA     3.5FT   0.5AC    41MIN
   46MIN   309CFS   237CFS   1.9   1.5   2.0   5.8   15.4FPS    1.6   3.0FT   IA     3.6FT   0.6AC    46MIN
   51MIN   341CFS   268CFS   2.1   1.6   2.5   6.3   15.9FPS    1.6   3.2FT   IA     3.8FT   0.8AC    51MIN
   55MIN   347CFS   290CFS   2.1   1.8   2.8   6.6   16.2FPS    1.6   3.3FT   IA     3.9FT   0.8AC    55MIN
   60MIN   332CFS   302CFS   2.0   1.9   3.0   6.8   16.4FPS    1.6   3.4FT   IA     4.0FT   0.9AC    60MIN
   64MIN   308CFS   304CFS   1.9   1.9   3.0   6.8   16.4FPS    1.6   3.4FT   IA     4.0FT   0.9AC    64MIN
   69MIN   283CFS   298CFS   1.7   1.8   2.9   6.7   16.3FPS    1.6   3.4FT   IA     4.0FT   0.9AC    69MIN
   73MIN   258CFS   287CFS   1.6   1.8   2.8   6.5   16.2FPS    1.6   3.3FT   IA     3.9FT   0.8AC    73MIN
   78MIN   234CFS   272CFS   1.4   1.7   2.5   6.3   15.9FPS    1.6   3.2FT   IA     3.8FT   0.8AC    78MIN
   84MIN   206CFS   245CFS   2.2   2.6   2.1   6.0   15.5FPS    1.6   3.0FT   IA     3.7FT   0.7AC    84MIN
   91MIN   177CFS   219CFS   1.7   2.2   1.7   5.6   15.1FPS    1.6   2.8FT   IA     3.5FT   0.6AC    91MIN
   98MIN   149CFS   177CFS   1.6   1.9   1.4   5.0   14.2FPS    1.6   2.5FT   IA     3.3FT   0.5AC    98MIN
  109MIN   120CFS   133CFS   2.2   2.5   1.1   4.2   13.1FPS    1.6   2.2FT   IA     2.9FT   0.4AC   109MIN
  124MIN    88CFS    98CFS   2.2   2.4   0.9   3.5    7.5FPS    0.8   2.6FT   IG     2.6FT   0.3AC   124MIN
  141MIN    63CFS    73CFS   1.3   1.5   0.7   2.9    6.5FPS    0.8   2.3FT   IG     2.3FT   0.3AC   141MIN
  156MIN    50CFS    56CFS   1.0   1.2   0.5   2.5    5.8FPS    0.7   2.1FT   IG     2.1FT   0.2AC   156MIN
  170MIN    36CFS    43CFS   0.7   0.9   0.4   2.1    5.0FPS    0.6   1.9FT   IG     1.9FT   0.2AC   170MIN
  200MIN    20CFS    24CFS   1.3   1.5   0.2   1.6    3.8FPS    0.5   1.5FT   IG     1.5FT   0.1AC   200MIN
  245MIN     7CFS     9CFS   0.4   0.6   0.1   1.1    2.6FPS    0.4   1.1FT   IG     1.1FT   0.1AC   245MIN
  289MIN     1CFS     2CFS   0.1   0.1   0.0   0.5    1.3FPS    0.3   0.6FT   IG     0.6FT   0.0AC   289MIN
  356MIN     0CFS     0CFS   0.0   0.0   0.0   0.1    0.7FPS    0.3   0.1FT   IG     0.1FT   0.0AC   356MIN

            TOTAL VOLUMES     36    36

 TIME TO PEAK=   53MIN.  TIME TO MAX OUTFLO=   66MIN.   TIME TO MAX HW=   66MIN.
```

```
                              WYOMING HIGHWAY DEPARTMENT
          ENGINEERING  DIRECTORATE  ********  HYDRAULICS SECTION
CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
STATION: 366+55.00  PROJECT:  DRY CREEK            STATION 366+55+-        (EXAMPLE NO.1)
CULV SIZE: 1= 7.0X 7.0 ROUND CONCRETE/,SOCKET END PROJECTING INLET
ANALYSIS TYPE: PERFORM DISCHGE   Q: 530CFS FREQ: 10YR DHW:12.00FT
BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
* * * * * * * *  C U L V E R T   F L O O D   R O U T I N G  * * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL= |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |  AREA  | TIME  |

    0MIN     0CFS      0CFS    0.0    0.0    0.0    0.0     0.0FPS    0.0    0.0FT          0.0FT   0.0AC     0MIN
    6MIN    24CFS     17CFS    0.4    0.3    0.1    1.4     3.3FPS    0.5    1.4FT    IG    1.4FT   0.1AC     6MIN
   16MIN    82CFS     51CFS    0.9    0.6    0.5    2.4     5.5FPS    0.7    2.0FT    IG    2.0FT   0.2AC    16MIN
   24MIN   167CFS    120CFS    1.9    1.4    1.0    3.9    12.7FPS    1.6    2.1FT    IA    2.8FT   0.4AC    24MIN
   31MIN   273CFS    211CFS    2.3    1.8    1.6    5.5    14.9FPS    1.6    2.8FT    IA    3.5FT   0.6AC    31MIN
   37MIN   379CFS    271CFS    3.2    2.3    2.5    6.3    15.9FPS    1.6    3.2FT    IA    3.8FT   0.8AC    37MIN
   43MIN   468CFS    324CFS    2.6    1.8    3.3    7.1    16.7FPS    1.6    3.5FT    IA    4.1FT   1.0AC    43MIN
   47MIN   516CFS    373CFS    2.9    2.1    4.1    7.8    17.2FPS    1.5    3.8FT    IA    4.3FT   1.1AC    47MIN
   51MIN   525CFS    410CFS    3.0    2.3    4.8    8.4    17.6FPS    1.5    4.1FT    IA    4.5FT   1.3AC    51MIN
   55MIN   503CFS    431CFS    2.8    2.4    5.2    8.8    17.8FPS    1.5    4.2FT    IA    4.6FT   1.4AC    55MIN
   59MIN   467CFS    439CFS    2.6    2.5    5.4    9.0    17.9FPS    1.5    4.3FT    IA    4.6FT   1.4AC    59MIN
   63MIN   429CFS    437CFS    2.4    2.5    5.3    8.9    17.9FPS    1.5    4.3FT    IA    4.6FT   1.4AC    63MIN
   67MIN   392CFS    427CFS    2.2    2.4    5.1    8.7    17.8FPS    1.5    4.2FT    IA    4.5FT   1.4AC    67MIN
   71MIN   354CFS    410CFS    2.0    2.3    4.8    8.4    17.6FPS    1.5    4.1FT    IA    4.5FT   1.3AC    71MIN
   77MIN   313CFS    376CFS    3.0    3.6    4.2    7.9    17.3FPS    1.5    3.9FT    IA    4.3FT   1.1AC    77MIN
   84MIN   269CFS    339CFS    2.4    3.1    3.6    7.3    16.8FPS    1.6    3.6FT    IA    4.2FT   1.0AC    84MIN
   90MIN   225CFS    296CFS    2.2    2.8    2.9    6.7    16.3FPS    1.6    3.3FT    IA    4.0FT   0.9AC    90MIN
  100MIN   182CFS    236CFS    3.1    4.0    2.0    5.8    15.4FPS    1.6    2.9FT    IA    3.6FT   0.6AC   100MIN
  114MIN   133CFS    162CFS    3.0    3.7    1.3    4.7    13.9FPS    1.6    2.4FT    IA    3.2FT   0.5AC   114MIN
  129MIN    96CFS    112CFS    1.8    2.1    1.0    3.8    12.5FPS    1.6    2.0FT    IA    2.8FT   0.4AC   129MIN
  143MIN    75CFS     86CFS    1.5    1.7    0.8    3.2     7.0FPS    0.8    2.5FT    IG    2.5FT   0.3AC   143MIN
  157MIN    55CFS     64CFS    1.0    1.2    0.6    2.7     6.1FPS    0.7    2.2FT    IG    2.2FT   0.3AC   157MIN
  184MIN    31CFS     36CFS    1.8    2.1    0.3    1.9     4.7FPS    0.6    1.8FT    IG    1.8FT   0.2AC   184MIN
  225MIN    11CFS     15CFS    0.6    0.8    0.1    1.3     3.1FPS    0.5    1.3FT    IG    1.3FT   0.1AC   225MIN
  266MIN     2CFS      3CFS    0.1    0.2    0.0    0.6     1.7FPS    0.3    0.7FT    IG    0.7FT   0.1AC   266MIN
  328MIN     0CFS      0CFS    0.0    0.0    0.0    0.1     0.5FPS    0.2    0.2FT    IG    0.2FT   0.0AC   328MIN

              TOTAL VOLUMES     50     50

TIME TO PEAK=   49MIN.   TIME TO MAX OUTFLO=   61MIN.   TIME TO MAX HW=   61MIN.
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```
                        WYOMING HIGHWAY DEPARTMENT
          ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
STATION: 366+55.00  PROJECT:  DRY CREEK           STATION 366+55+-        (EXAMPLE NO.1)
CULV SIZE: 1= 7.0X 7.0 ROUND CONCRETE/,SOCKET END PROJECTING INLET
ANALYSIS TYPE: PERFORM DISCHGE   Q:1080CFS FREQ: 50YR DHW:12.00FT
BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
* * * * * * * *  C U L V E R T   F L O O D   R O U T I N G  * * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |  AREA  | TIME  |

   0MIN      0CFS      0CFS     0.0     0.0     0.0     0.0     0.0FPS    0.0    0.0FT          0.0FT    0.0AC      0MIN
   5MIN     50CFS     31CFS     0.7     0.5     0.3     1.8     4.4FPS    0.6    1.7FT   IG     1.7FT    0.2AC      5MIN
  14MIN    167CFS    103CFS     1.6     1.0     0.9     3.6    12.2FPS    1.6    1.9FT   IA     2.7FT    0.4AC     14MIN
  21MIN    342CFS    236CFS     3.3     2.3     2.0     5.8    15.4FPS    1.6    3.0FT   IA     3.6FT    0.6AC     21MIN
  27MIN    558CFS    339CFS     4.1     2.5     3.6     7.3    16.8FPS    1.6    3.6FT   IA     4.2FT    1.0AC     27MIN
  32MIN    774CFS    462CFS     5.7     3.4     5.8     9.4    18.1FPS    1.5    4.4FT   IA     4.7FT    1.5AC     32MIN
  37MIN    954CFS    532CFS     4.6     2.6     8.0    10.9    18.6FPS    1.5    4.9FT   ID     4.9FT    2.4AC     37MIN
  40MIN   1053CFS    570CFS     5.1     2.8    10.3    11.8    18.8FPS    1.5    5.2FT   ID     5.1FT    3.4AC     40MIN
  44MIN   1071CFS    603CFS     5.2     2.9    12.6    12.6    18.9FPS    1.4    5.4FT   ID     5.2FT    5.7AC     44MIN
  47MIN   1026CFS    630CFS     5.0     3.1    14.6    13.3    18.9FPS    1.4    5.7FT   ID     5.3FT    7.6AC     47MIN
  51MIN    952CFS    650CFS     4.6     3.2    16.0    13.9    18.9FPS    1.4    5.9FT   ID     5.3FT    9.1AC     51MIN
  54MIN    875CFS    663CFS     4.3     3.2    17.1    14.3    18.9FPS    1.4    6.0FT   ID     5.4FT   10.1AC     54MIN
  58MIN    799CFS    671CFS     3.9     3.3    17.7    14.5    18.9FPS    1.4    6.1FT   ID     5.4FT   10.7AC     58MIN
  61MIN    722CFS    674CFS     3.5     3.3    17.9    14.6    18.9FPS    1.3    6.1FT   ID     5.4FT   11.0AC     61MIN
  66MIN    638CFS    671CFS     5.3     5.6    17.6    14.5    18.9FPS    1.4    6.1FT   ID     5.4FT   10.7AC     66MIN
  72MIN    548CFS    660CFS     4.3     5.1    16.8    14.2    18.9FPS    1.4    6.0FT   ID     5.4FT    9.9AC     72MIN
  78MIN    459CFS    640CFS     3.8     5.3    15.3    13.6    18.9FPS    1.4    5.8FT   ID     5.3FT    8.4AC     78MIN
  86MIN    371CFS    595CFS     5.4     8.7    12.0    12.4    18.9FPS    1.4    5.3FT   ID     5.2FT    5.1AC     86MIN
  98MIN    272CFS    517CFS     5.3    10.1     7.2    10.5    18.5FPS    1.5    4.8FT   ID     4.9FT    2.0AC     98MIN
 111MIN    196CFS    378CFS     3.2     6.1     4.2     7.9    17.3FPS    1.5    3.9FT   IA     4.3FT    1.2AC    111MIN
 123MIN    154CFS    264CFS     2.6     4.4     2.4     6.2    15.8FPS    1.6    3.1FT   IA     3.8FT    0.7AC    123MIN
 135MIN    113CFS    175CFS     1.8     2.8     1.4     4.9    14.2FPS    1.6    2.5FT   IA     3.3FT    0.5AC    135MIN
 159MIN     64CFS     77CFS     3.2     3.8     0.7     3.0     6.7FPS    0.8    2.4FT   IG     2.4FT    0.3AC    159MIN
 194MIN     22CFS     31CFS     1.1     1.5     0.3     1.8     4.3FPS    0.6    1.7FT   IG     1.7FT    0.2AC    194MIN
 229MIN      4CFS      9CFS     0.2     0.4     0.0     1.0     2.5FPS    0.4    1.0FT   IG     1.0FT    0.1AC    229MIN
 282MIN      0CFS      0CFS     0.0     0.0     0.0     0.1     0.7FPS    0.2    0.3FT   IG     0.3FT    0.0AC    282MIN

           TOTAL VOLUMES        88      88

TIME TO PEAK=   42MIN.  TIME TO MAX OUTFLO=   63MIN.   TIME TO MAX HW=   63MIN.
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```
                    WYOMING HIGHWAY DEPARTMENT
       ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
STATION: 366+55.00  PROJECT:  DRY CREEK             STATION 366+55+-          (EXAMPLE NO.1)
CULV SIZE: 1=  7.0X  7.0 ROUND CONCRETE/,SOCKET END PROJECTING INLET
ANALYSIS TYPE: PERFORM DISCHGE    Q:1390CFS FREQ:100YR DHW:12.00FT
BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
* * * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |  AREA  | TIME  |
    0MIN      0CFS      0CFS    0.0    0.0    0.0    0.0     0.0FPS     0.0    0.0FT          0.0FT    0.0AC     0MIN
    4MIN     64CFS     39CFS    0.9    0.5    0.4    2.0     4.8FPS     0.6    1.9FT   IG     1.9FT    0.2AC     4MIN
   13MIN    215CFS    134CFS    2.0    1.2    1.1    4.2    13.1FPS     1.6    2.2FT   IA     2.9FT    0.4AC    13MIN
   19MIN    440CFS    279CFS    4.0    2.6    2.6    6.4    16.0FPS     1.6    3.2FT   IA     3.9FT    0.8AC    19MIN
   25MIN    718CFS    408CFS    4.9    2.8    4.8    8.4    17.6FPS     1.5    4.1FT   IA     4.5FT    1.3AC    25MIN
   30MIN    996CFS    534CFS    6.9    3.7    8.1   10.9    18.6FPS     1.5    4.9FT   ID     4.9FT    2.4AC    30MIN
   34MIN   1227CFS    580CFS    5.6    2.7   11.0   12.0    18.8FPS     1.4    5.2FT   ID     5.1FT    4.1AC    34MIN
   38MIN   1355CFS    627CFS    6.2    2.9   14.4   13.3    18.9FPS     1.4    5.6FT   ID     5.3FT    7.4AC    38MIN
   41MIN   1378CFS    670CFS    6.3    3.1   17.6   14.5    18.9FPS     1.4    6.1FT   ID     5.4FT   10.7AC    41MIN
   44MIN   1320CFS    705CFS    6.1    3.2   20.4   15.5    18.9FPS     1.3    6.5FT   ID     5.5FT   13.5AC    44MIN
   48MIN   1225CFS    812CFS    5.6    3.7   22.3   16.2    21.4FPS     1.5    6.7FT  VII     5.8FT   15.4AC    48MIN
   51MIN   1127CFS    859CFS    5.2    3.9   23.6   16.7    22.5FPS     1.5    6.8FT  VII     5.9FT   16.6AC    51MIN
   54MIN   1028CFS    869CFS    4.7    4.0   24.3   17.0    22.8FPS     1.5    6.8FT  VII     5.9FT   17.4AC    54MIN
   58MIN    930CFS    873CFS    4.3    4.0   24.5   17.1    22.9FPS     1.5    6.8FT  VII     6.0FT   17.6AC    58MIN
   62MIN    821CFS    868CFS    6.4    6.8   24.2   16.9    22.8FPS     1.5    6.8FT  VII     5.9FT   17.3AC    62MIN
   68MIN    706CFS    852CFS    5.2    6.3   23.1   16.5    22.4FPS     1.5    6.8FT  VII     5.9FT   16.2AC    68MIN
   73MIN    591CFS    725CFS    4.6    5.7   22.1   16.1    19.3FPS     1.3    6.6FT  IIB     5.6FT   15.2AC    73MIN
   81MIN    478CFS    690CFS    6.6    9.5   19.2   15.0    18.9FPS     1.3    6.3FT   ID     5.5FT   12.2AC    81MIN
   93MIN    350CFS    624CFS    6.4   11.5   14.1   13.2    18.9FPS     1.4    5.6FT   ID     5.2FT    7.2AC    93MIN
  105MIN    252CFS    557CFS    3.8    8.4    9.5   11.5    18.7FPS     1.5    5.1FT   ID     5.0FT    3.0AC   105MIN
  116MIN    199CFS    447CFS    3.1    7.0    5.5    9.1    18.0FPS     1.5    4.3FT   IA     4.6FT    1.5AC   116MIN
  127MIN    145CFS    308CFS    2.2    4.7    3.1    6.8    16.4FPS     1.6    3.4FT   IA     4.0FT    0.9AC   127MIN
  149MIN     83CFS    126CFS    3.8    5.8    1.1    4.1    12.9FPS     1.6    2.1FT   IA     2.9FT    0.4AC   149MIN
  183MIN     28CFS     43CFS    1.3    2.0    0.4    2.1     5.0FPS     0.6    1.9FT   IG     1.9FT    0.2AC   183MIN
  216MIN      5CFS     12CFS    0.3    0.6    0.1    1.2     2.9FPS     0.5    1.2FT   IG     1.2FT    0.1AC   216MIN
  266MIN      0CFS      0CFS    0.0    0.1    0.0    0.2     0.8FPS     0.2    0.4FT   IG     0.4FT    0.0AC   266MIN
  349MIN      0CFS      0CFS    0.0    0.0    0.0    0.1     0.3FPS     0.2    0.1FT  IIA     0.0FT    0.0AC   349MIN

           TOTAL VOLUMES        107    107

TIME TO PEAK=   39MIN.   TIME TO MAX OUTFLO=   59MIN.   TIME TO MAX HW=   59MIN.
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                         WYOMING HIGHWAY DEPARTMENT
        ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
 CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
 STATION: 366+55.00  PROJECT:  DRY CREEK          STATION 366+55+-        (EXAMPLE NO.1)
 CULV SIZE: 1@  8.5X  8.5 ROUND METAL  (  SPP  )/          COMMERICAL END(FE) INLET
 ANALYSIS TYPE: DRAINAGE DESIGN   Q: 810CFS FREQ: 25YR DHW:12.00FT
 BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
 * * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * *  *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES****| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORF| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |  AREA  | TIME  |
    0MIN       0CFS      0CFS    0.0    0.0    0.0    0.0     0.0FPS    0.0   0.0FT        0.0FT   0.0AC     0MIN
    5MIN      37CFS     24CFS    0.6    0.4    0.2    1.6     3.4FPS    0.5   1.5FT  IIIA  1.5FT   0.1AC     5MIN
   15MIN     125CFS     83CFS    1.3    0.9    0.7    2.9     6.1FPS    0.7   2.5FT  IIIA  2.5FT   0.3AC    15MIN
   22MIN     256CFS    195CFS    2.7    2.0    1.3    4.8     9.1FPS    0.9   3.4FT   IIA  3.4FT   0.5AC    22MIN
   29MIN     418CFS    298CFS    3.3    2.3    2.3    6.1    10.4FPS    0.9   4.3FT   IIA  4.0FT   0.7AC    29MIN
   35MIN     580CFS    404CFS    4.5    3.2    3.7    7.4    11.6FPS    0.9   5.0FT   IIA  4.5FT   1.0AC    35MIN
   39MIN     715CFS    484CFS    3.7    2.5    4.9    8.5    12.4FPS    0.9   5.5FT   IIA  4.8FT   1.3AC    39MIN
   43MIN     789CFS    496CFS    4.1    2.6    6.4    9.9    12.6FPS    0.9   5.6FT   IIA  4.8FT   1.6AC    43MIN
   47MIN     803CFS    543CFS    4.2    2.8    7.9   10.8    13.1FPS    1.0   5.9FT     V  5.0FT   2.3AC    47MIN
   51MIN     769CFS    574CFS    4.0    3.0    8.9   11.2    13.4FPS    1.0   6.0FT     V  5.1FT   2.8AC    51MIN
   54MIN     714CFS    591CFS    3.7    3.1    9.5   11.5    13.6FPS    1.0   6.1FT     V  5.1FT   3.0AC    54MIN
   58MIN     656CFS    600CFS    3.4    3.1    9.9   11.6    13.6FPS    1.0   6.2FT     V  5.2FT   3.1AC    58MIN
   62MIN     599CFS    600CFS    3.1    3.1    9.9   11.6    13.6FPS    1.0   6.2FT     V  5.2FT   3.1AC    62MIN
   66MIN     542CFS    592CFS    2.8    3.1    9.6   11.5    13.6FPS    1.0   6.1FT     V  5.1FT   3.0AC    66MIN
   71MIN     478CFS    569CFS    4.2    5.1    8.8   11.2    13.3FPS    1.0   6.0FT     V  5.1FT   2.7AC    71MIN
   77MIN     411CFS    537CFS    3.4    4.5    7.7   10.8    13.0FPS    0.9   5.8FT     V  5.0FT   2.3AC    77MIN
   83MIN     344CFS    496CFS    3.1    4.4    6.3    9.8    12.6FPS    0.9   5.6FT   IIA  4.8FT   1.6AC    83MIN
   92MIN     278CFS    425CFS    4.4    6.7    4.0    7.7    11.8FPS    0.9   5.2FT   IIA  4.5FT   1.1AC    92MIN
  106MIN     204CFS    289CFS    4.3    6.0    2.2    6.0    10.3FPS    0.9   4.2FT   IIA  3.9FT   0.7AC   106MIN
  119MIN     147CFS    195CFS    2.5    3.4    1.3    4.8     9.1FPS    0.9   3.4FT   IIA  3.4FT   0.5AC   119MIN
  132MIN     116CFS    134CFS    2.1    2.4    1.0    3.8     7.7FPS    0.8   2.9FT  IIIA  2.9FT   0.4AC   132MIN
  145MIN      85CFS     97CFS    1.5    1.7    0.8    3.2     6.6FPS    0.7   2.6FT  IIIA  2.6FT   0.3AC   145MIN
  170MIN      48CFS     54CFS    2.5    2.8    0.5    2.3     5.0FPS    0.6   2.1FT  IIIA  2.1FT   0.2AC   170MIN
  208MIN      16CFS     21CFS    0.9    1.1    0.2    1.6     3.3FPS    0.5   1.5FT  IIIA  1.5FT   0.1AC   208MIN
  246MIN       3CFS      6CFS    0.2    0.3    0.0    0.9     1.9FPS    0.3   0.9FT  IIIA  0.9FT   0.1AC   246MIN
  303MIN       0CFS      0CFS    0.0    0.0    0.0    0.2     0.5FPS    0.2   0.3FT  IIIA  0.3FT   0.0AC   303MIN
             TOTAL VOLUMES        71     71
 TIME TO PEAK=   45MIN,  TIME TO MAX OUTFLO=   64MIN,   TIME TO MAX HW=   64MIN,
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```
                         WYOMING HIGHWAY DEPARTMENT
        ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
STATION:__366+55.00  PROJECT:  DRY CREEK           STATION 366+55+=        (EXAMPLE NO.1)
CULV SIZE:_1=__8.5X__8.5 ROUND METAL  (  SPP  )/         COMMERICAL END(FE) INLET
ANALYSIS TYPE: PERFORM_DISCHGE__  Q:_170CFS FREQ:__2YR DHW:12.00FT
BARREL GEOMETRY: LENGTH:_103FT SLOPE:1.00000% GVD:_9.0FT
* * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |  AREA  | TIME  |

    0MIN     0CFS     0CFS   0.0    0.0    0.0    0.0    0.0FPS    0.0    0.0FT         0.0FT    0.0AC     0MIN
    7MIN     7CFS     4CFS   0.2    0.1    0.1    1.2    1.7FPS    0.3    0.8FT  IIIA   0.8FT    0.1AC     7MIN
   19MIN    26CFS    18CFS   0.3    0.2    0.2    1.5    3.0FPS    0.5    1.4FT  IIIA   1.4FT    0.1AC    19MIN
   28MIN    53CFS    40CFS   0.7    0.5    0.4    2.0    4.4FPS    0.6    1.9FT  IIIA   1.9FT    0.2AC    28MIN
   37MIN    87CFS    67CFS   0.9    0.7    0.6    2.6    5.6FPS    0.7    2.3FT  IIIA   2.3FT    0.2AC    37MIN
   44MIN   121CFS   100CFS   1.2    1.0    0.8    3.2    6.7FPS    0.7    2.6FT  IIIA   2.6FT    0.3AC    44MIN
   50MIN   150CFS   126CFS   1.0    0.8    0.9    3.7    7.5FPS    0.8    2.9FT  IIIA   2.9FT    0.4AC    50MIN
   54MIN   165CFS   146CFS   1.1    1.0    1.0    4.0    8.0FPS    0.8    3.0FT  IIIA   3.0FT    0.4AC    54MIN
   59MIN   168CFS   158CFS   1.1    1.0    1.1    4.2    8.4FPS    0.8    3.1FT  IIIA   3.1FT    0.4AC    59MIN
   64MIN   161CFS   161CFS   1.1    1.1    1.1    4.2    8.4FPS    0.8    3.1FT  IIIA   3.1FT    0.4AC    64MIN
   69MIN   149CFS   154CFS   1.0    1.0    1.1    4.1    8.2FPS    0.8    3.1FT  IIIA   3.1FT    0.4AC    69MIN
   74MIN   137CFS   145CFS   0.9    1.0    1.0    4.0    8.0FPS    0.8    3.0FT  IIIA   3.0FT    0.4AC    74MIN
   78MIN   125CFS   134CFS   0.8    0.9    1.0    3.8    7.7FPS    0.8    2.9FT  IIIA   2.9FT    0.4AC    78MIN
   83MIN   113CFS   124CFS   0.7    0.8    0.9    3.6    7.4FPS    0.8    2.9FT  IIIA   2.9FT    0.4AC    83MIN
   90MIN   100CFS   108CFS   1.1    1.2    0.8    3.4    7.0FPS    0.7    2.7FT  IIIA   2.7FT    0.3AC    90MIN
   97MIN    86CFS    94CFS   0.9    1.0    0.7    3.1    6.5FPS    0.7    2.6FT  IIIA   2.6FT    0.3AC    97MIN
  105MIN    72CFS    80CFS   0.8    0.9    0.6    2.8    6.0FPS    0.7    2.4FT  IIIA   2.4FT    0.3AC   105MIN
  117MIN    58CFS    64CFS   1.2    1.3    0.5    2.5    5.4FPS    0.6    2.2FT  IIIA   2.2FT    0.2AC   117MIN
  133MIN    42CFS    47CFS   1.1    1.3    0.4    2.1    4.7FPS    0.6    2.0FT  IIIA   2.0FT    0.2AC   133MIN
  151MIN    30CFS    35CFS   0.7    0.8    0.3    1.9    4.1FPS    0.5    1.8FT  IIIA   1.8FT    0.2AC   151MIN
  167MIN    24CFS    27CFS   0.5    0.6    0.3    1.7    3.6FPS    0.5    1.6FT  IIIA   1.6FT    0.2AC   167MIN
  183MIN    17CFS    20CFS   0.4    0.4    0.2    1.5    3.2FPS    0.5    1.4FT  IIIA   1.4FT    0.1AC   183MIN
  214MIN    10CFS    11CFS   0.7    0.7    0.1    1.3    2.5FPS    0.4    1.1FT  IIIA   1.1FT    0.1AC   214MIN
  262MIN     3CFS     4CFS   0.2    0.3    0.1    1.1    1.6FPS    0.3    0.8FT  IIIA   0.8FT    0.1AC   262MIN
  310MIN     0CFS     1CFS   0.0    0.1    0.0    0.8    1.0FPS    0.2    0.5FT  IIIA   0.5FT    0.1AC   310MIN
  382MIN     0CFS     0CFS   0.0    0.0    0.0    0.1    0.5FPS    0.2    0.2FT  IIIA   0.2FT    0.0AC   382MIN

           TOTAL VOLUMES      19     19

TIME TO PEAK=   57MIN.  TIME TO MAX OUTFLO=   66MIN.   TIME TO MAX HW=   66MIN.
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                       WYOMING HIGHWAY DEPARTMENT
        ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
STATION: 366+55.00  PROJECT:  DRY CREEK            STATION 366+55+-        (EXAMPLE NO.1)
CULV SIZE: 1= 8.5X 8.5 ROUND METAL  (  SPP  )/           COMMERICAL END(FE) INLET
ANALYSIS TYPE: PERFORM DISCHGE   Q: 350CFS FREQ: 5YR DHW:12.00FT
BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
* * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |  AREA  | TIME  |

    0MIN      0CFS      0CFS    0.0    0.0    0.0    0.0    0.0FPS    0.0   0.0FT          0.0FT   0.0AC     0MIN
    6MIN     16CFS     10CFS    0.3    0.2    0.1    1.3    2.4FPS    0.4   1.1FT  IIIA    1.1FT   0.1AC     6MIN
   17MIN     54CFS     37CFS    0.7    0.5    0.3    1.9    4.2FPS    0.6   1.8FT  IIIA    1.8FT   0.2AC    17MIN
   26MIN    110CFS     83CFS    1.4    1.0    0.7    2.9    6.1FPS    0.7   2.5FT  IIIA    2.5FT   0.3AC    26MIN
   34MIN    180CFS    142CFS    1.7    1.3    1.0    3.9    7.9FPS    0.8   3.0FT  IIIA    3.0FT   0.4AC    34MIN
   41MIN    250CFS    211CFS    2.3    1.9    1.4    5.0    9.3FPS    0.9   3.6FT   IIA    3.5FT   0.5AC    41MIN
   46MIN    309CFS    257CFS    1.9    1.6    1.8    5.6    9.9FPS    0.9   4.0FT   IIA    3.8FT   0.6AC    46MIN
   51MIN    341CFS    284CFS    2.1    1.7    2.1    6.0   10.3FPS    0.9   4.2FT   IIA    3.9FT   0.7AC    51MIN
   55MIN    347CFS    303CFS    2.1    1.9    2.4    6.2   10.5FPS    0.9   4.3FT   IIA    4.0FT   0.7AC    55MIN
   60MIN    332CFS    312CFS    2.0    1.9    2.5    6.3   10.6FPS    0.9   4.4FT   IIA    4.0FT   0.8AC    60MIN
   64MIN    308CFS    311CFS    1.9    1.9    2.5    6.3   10.6FPS    0.9   4.4FT   IIA    4.0FT   0.8AC    64MIN
   69MIN    283CFS    302CFS    1.7    1.9    2.4    6.2   10.5FPS    0.9   4.3FT   IIA    4.0FT   0.7AC    69MIN
   73MIN    258CFS    288CFS    1.6    1.8    2.2    6.0   10.3FPS    0.9   4.2FT   IIA    3.9FT   0.7AC    73MIN
   78MIN    234CFS    272CFS    1.4    1.7    2.0    5.8   10.1FPS    0.9   4.1FT   IIA    3.8FT   0.6AC    78MIN
   84MIN    206CFS    242CFS    2.2    2.5    1.5    5.4    9.7FPS    0.9   3.8FT   IIA    3.7FT   0.5AC    84MIN
   91MIN    177CFS    198CFS    1.7    1.9    1.3    4.8    9.1FPS    0.9   3.5FT   IIA    3.4FT   0.5AC    91MIN
   98MIN    149CFS    165CFS    1.6    1.7    1.2    4.3    8.5FPS    0.8   3.2FT  IIIA    3.2FT   0.4AC    98MIN
  109MIN    120CFS    130CFS    2.2    2.4    1.0    3.8    7.6FPS    0.8   2.9FT  IIIA    2.9FT   0.4AC   109MIN
  124MIN     88CFS     96CFS    2.2    2.4    0.8    3.1    6.6FPS    0.7   2.6FT  IIIA    2.6FT   0.3AC   124MIN
  141MIN     63CFS     71CFS    1.3    1.5    0.6    2.7    5.7FPS    0.7   2.3FT  IIIA    2.3FT   0.3AC   141MIN
  156MIN     50CFS     55CFS    1.0    1.2    0.5    2.3    5.1FPS    0.6   2.1FT  IIIA    2.1FT   0.2AC   156MIN
  170MIN     36CFS     41CFS    0.7    0.8    0.4    2.0    4.4FPS    0.6   1.9FT  IIIA    1.9FT   0.2AC   170MIN
  200MIN     20CFS     23CFS    1.3    1.4    0.2    1.6    3.4FPS    0.5   1.5FT  IIIA    1.5FT   0.1AC   200MIN
  245MIN      7CFS      9CFS    0.4    0.6    0.1    1.3    2.3FPS    0.4   1.0FT  IIIA    1.0FT   0.1AC   245MIN
  289MIN      1CFS      2CFS    0.1    0.2    0.0    0.8    1.2FPS    0.3   0.6FT  IIIA    0.6FT   0.1AC   289MIN
  356MIN      0CFS      0CFS    0.0    0.0    0.0    0.1    0.5FPS    0.2   0.2FT  IIIA    0.2FT   0.0AC   356MIN
          TOTAL VOLUMES          36     36
TIME TO PEAK=   53MIN.  TIME TO MAX OUTFLO=   62MIN.   TIME TO MAX HW=   62MIN.
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                          WYOMING HIGHWAY DEPARTMENT
        ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
STATION: 366+55.00  PROJECT:  DRY CREEK            STATION 366+55+-         (EXAMPLE NO.1)
CULV SIZE: 1=  8.5X  8.5 ROUND METAL  (  SPP  )/          COMMERICAL END(FE) INLET
ANALYSIS TYPE: PERFORM DISCHGE    Q: 530CFS FREQ: 10YR DHW:12.00FT
BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
* * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |   POND   |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO.  | DEPTH | TYPE |WATER |   AREA   | TIME  |

   0MIN      0CFS     0CFS    0.0    0.0    0.0    0.0    0.0FPS    0.0   0.0FT         0.0FT    0.0AC      0MIN
   6MIN     24CFS    16CFS    0.4    0.3    0.2    1.4    2.9FPS    0.4   1.3FT  IIIA   1.3FT    0.1AC      6MIN
  16MIN     82CFS    55CFS    0.9    0.6    0.5    2.3    5.1FPS    0.6   2.1FT  IIIA   2.1FT    0.2AC     16MIN
  24MIN    167CFS   126CFS    1.9    1.4    0.9    3.7    7.5FPS    0.8   2.9FT  IIIA   2.9FT    0.4AC     24MIN
  31MIN    273CFS   217CFS    2.3    1.8    1.4    5.1    9.4FPS    0.9   3.6FT   IIA   3.5FT    0.5AC     31MIN
  37MIN    379CFS   291CFS    3.2    2.5    2.2    6.0   10.3FPS    0.9   4.2FT   IIA   3.9FT    0.7AC     37MIN
  43MIN    468CFS   345CFS    2.6    2.0    2.9    6.7   11.0FPS    0.9   4.6FT   IIA   4.2FT    0.9AC     43MIN
  47MIN    516CFS   398CFS    2.9    2.2    3.6    7.3   11.5FPS    0.9   5.0FT   IIA   4.4FT    1.0AC     47MIN
  51MIN    525CFS   434CFS    3.0    2.5    4.1    7.8   11.9FPS    0.9   5.2FT   IIA   4.6FT    1.1AC     51MIN
  55MIN    503CFS   454CFS    2.8    2.6    4.4    8.1   12.1FPS    0.9   5.3FT   IIA   4.7FT    1.2AC     55MIN
  59MIN    467CFS   457CFS    2.6    2.6    4.4    8.1   12.2FPS    0.9   5.4FT   IIA   4.7FT    1.2AC     59MIN
  63MIN    429CFS   449CFS    2.4    2.5    4.3    8.0   12.1FPS    0.9   5.3FT   IIA   4.6FT    1.2AC     63MIN
  67MIN    392CFS   434CFS    2.2    2.5    4.1    7.8   11.9FPS    0.9   5.2FT   IIA   4.6FT    1.1AC     67MIN
  71MIN    354CFS   411CFS    2.0    2.3    3.8    7.5   11.7FPS    0.9   5.1FT   IIA   4.5FT    1.0AC     71MIN
  77MIN    313CFS   368CFS    3.0    3.5    3.2    7.0   11.2FPS    0.9   4.8FT   IIA   4.3FT    0.9AC     77MIN
  84MIN    269CFS   328CFS    2.4    3.0    2.7    6.5   10.8FPS    0.9   4.5FT   IIA   4.1FT    0.8AC     84MIN
  90MIN    225CFS   284CFS    2.2    2.7    2.1    6.0   10.3FPS    0.9   4.2FT   IIA   3.9FT    0.7AC     90MIN
 100MIN    182CFS   220CFS    3.1    3.7    1.4    5.1    9.4FPS    0.9   3.7FT   IIA   3.5FT    0.5AC    100MIN
 114MIN    133CFS   149CFS    3.0    3.4    1.1    4.1    8.1FPS    0.8   3.1FT  IIIA   3.1FT    0.4AC    114MIN
 129MIN     96CFS   109CFS    1.8    2.0    0.8    3.4    7.0FPS    0.7   2.7FT  IIIA   2.7FT    0.3AC    129MIN
 143MIN     75CFS    84CFS    1.5    1.6    0.7    2.9    6.2FPS    0.7   2.5FT  IIIA   2.5FT    0.3AC    143MIN
 157MIN     55CFS    63CFS    1.0    1.2    0.5    2.5    5.4FPS    0.6   2.2FT  IIIA   2.2FT    0.2AC    157MIN
 184MIN     31CFS    35CFS    1.8    2.0    0.3    1.9    4.1FPS    0.5   1.8FT  IIIA   1.8FT    0.2AC    184MIN
 225MIN     11CFS    14CFS    0.6    0.8    0.2    1.4    2.7FPS    0.4   1.3FT  IIIA   1.3FT    0.1AC    225MIN
 266MIN      2CFS     3CFS    0.1    0.2    0.0    0.9    1.6FPS    0.3   0.8FT  IIIA   0.8FT    0.1AC    266MIN
 328MIN      0CFS     0CFS    0.0    0.0    0.0    0.2    0.4FPS    0.1   0.3FT  IIIA   0.3FT    0.0AC    328MIN

           TOTAL VOLUMES       50     50

TIME TO PEAK=   49MIN.  TIME TO MAX OUTFLO=   61MIN.   TIME TO MAX HW=   61MIN.
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                    WYOMING HIGHWAY DEPARTMENT
       ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
 CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
 STATION:  366+55.00  PROJECT:  DRY CREEK            STATION 366+55+-         (EXAMPLE NO.1)
 CULV SIZE: 1=  8.5X  8.5 ROUND METAL  (  SPP  )/          COMMERICAL END(FE) INLET
 ANALYSIS TYPE: PERFORM DISCHGE   Q:1080CFS FREQ: 50YR DHW:12.00FT
 BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
 * * * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |  AREA  | TIME  |

    0MIN       0CFS       0CFS     0.0     0.0     0.0    0.0      0.0FPS     0.0    0.0FT        0.0FT    0.0AC      0MIN
    5MIN      50CFS      31CFS     0.7     0.5     0.3    1.8      3.9FPS     0.5    1.7FT  IIIA  1.7FT    0.2AC      5MIN
   14MIN     167CFS     111CFS     1.6     1.1     0.8    3.4      7.0FPS     0.7    2.7FT  IIIA  2.7FT    0.3AC     14MIN
   21MIN     342CFS     256CFS     3.3     2.5     1.7    5.6      9.9FPS     0.9    4.0FT   IIA  3.8FT    0.6AC     21MIN
   27MIN     558CFS     362CFS     4.1     2.6     3.1    6.9     11.1FPS     0.9    4.7FT   IIA  4.3FT    0.9AC     27MIN
   32MIN     774CFS     495CFS     5.7     3.6     5.2    8.8     12.5FPS     0.9    5.6FT   IIA  4.8FT    1.4AC     32MIN
   37MIN     954CFS     524CFS     4.6     2.6     7.4   10.6     12.8FPS     0.9    5.7FT     V  4.9FT    2.1AC     37MIN
   40MIN    1053CFS     593CFS     5.1     2.9     9.6   11.5     13.6FPS     1.0    6.1FT     V  5.1FT    3.0AC     40MIN
   44MIN    1071CFS     648CFS     5.2     3.2    11.7   12.3     14.2FPS     1.0    6.4FT     V  5.3FT    4.8AC     44MIN
   47MIN    1026CFS     688CFS     5.0     3.4    13.3   12.9     14.6FPS     1.0    6.6FT     V  5.4FT    6.4AC     47MIN
   51MIN     952CFS     715CFS     4.6     3.5    14.5   13.3     14.9FPS     1.0    6.7FT     V  5.5FT    7.6AC     51MIN
   54MIN     875CFS     731CFS     4.3     3.6    15.2   13.6     15.1FPS     1.0    6.8FT     V  5.6FT    8.3AC     54MIN
   58MIN     799CFS     737CFS     3.9     3.6    15.5   13.7     15.2FPS     1.0    6.8FT     V  5.6FT    8.6AC     58MIN
   61MIN     722CFS     736CFS     3.5     3.6    15.4   13.7     15.2FPS     1.0    6.8FT     V  5.6FT    8.5AC     61MIN
   66MIN     638CFS     720CFS     5.3     6.0    14.7   13.4     15.0FPS     1.0    6.7FT     V  5.5FT    7.8AC     66MIN
   72MIN     548CFS     695CFS     4.3     5.4    13.6   13.0     14.7FPS     1.0    6.6FT     V  5.5FT    6.7AC     72MIN
   78MIN     459CFS     655CFS     3.8     5.4    12.0   12.4     14.2FPS     1.0    6.4FT     V  5.3FT    5.1AC     78MIN
   86MIN     371CFS     576CFS     5.4     8.4     9.0   11.3     13.4FPS     1.0    6.0FT     V  5.1FT    2.8AC     86MIN
   98MIN     272CFS     481CFS     5.3     9.4     4.8    8.5     12.4FPS     0.9    5.5FT   IIA  4.8FT    1.3AC     98MIN
  111MIN     196CFS     328CFS     3.2     5.3     2.7    6.5     10.8FPS     0.9    4.5FT   IIA  4.1FT    0.8AC    111MIN
  123MIN     154CFS     226CFS     2.6     3.7     1.5    5.2      9.5FPS     0.9    3.7FT   IIA  3.6FT    0.5AC    123MIN
  135MIN     113CFS     140CFS     1.8     2.3     1.0    3.9      7.9FPS     0.8    3.0FT  IIIA  3.0FT    0.4AC    135MIN
  159MIN      64CFS      73CFS     3.2     3.6     0.6    2.7      5.8FPS     0.7    2.3FT  IIIA  2.3FT    0.3AC    159MIN
  194MIN      22CFS      29CFS     1.1     1.4     0.3    1.7      3.8FPS     0.5    1.7FT  IIIA  1.7FT    0.2AC    194MIN
  229MIN       4CFS       8CFS     0.2     0.4     0.1    1.0      2.2FPS     0.4    1.0FT  IIIA  1.0FT    0.1AC    229MIN
  282MIN       0CFS       0CFS     0.0     0.0     0.0    0.2      0.6FPS     0.2    0.3FT  IIIA  0.3FT    0.0AC    282MIN
            TOTAL VOLUMES          88      88
 TIME TO PEAK=   42MIN,  TIME TO MAX OUTFLO=   60MIN,   TIME TO MAX HW=   60MIN,
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                     WYOMING HIGHWAY DEPARTMENT
      ENGINEERING  DIRECTORATE  ********  HYDRAULICS SECTION
CULVERT FLOOD ROUTING  PRINT OPTION NO, 2
STATION: 366+55.00  PROJECT:  DRY CREEK          STATION 366+55+-        (EXAMPLE NO.1)
CULV SIZE: 1- 8.5X 8.5 ROUND METAL  (  SPP  )/          COMMERICAL END(FE) INLET
ANALYSIS TYPE: PERFORM DISCHGE   Q:1390CFS FREQ:100YR DHW:12.00FT
BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
* * * * * * * * *  C U L V E R T   F L O O D   R O U T I N G  * * * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |  AREA  | TIME  |

    0MIN      0CFS      0CFS    0.0    0.0    0.0    0.0     0.0FPS    0.0    0.0FT         0.0FT   0.0AC     0MIN
    4MIN     64CFS     40CFS    0.9    0.6    0.4    2.0     4.3FPS    0.6    1.9FT IIIA    1.9FT   0.2AC     4MIN
   13MIN    215CFS    143CFS    2.0    1.3    1.0    4.0     8.0FPS    0.8    3.0FT IIIA    3.0FT   0.4AC    13MIN
   19MIN    440CFS    302CFS    4.0    2.8    2.4    6.2    10.5FPS    0.9    4.3FT  IIA    4.0FT   0.7AC    19MIN
   25MIN    718CFS    443CFS    4.9    3.1    4.2    7.9    12.0FPS    0.9    5.3FT  IIA    4.6FT   1.2AC    25MIN
   30MIN    996CFS    529CFS    6.9    3.6    7.5   10.7    12.9FPS    0.9    5.8FT    V    4.9FT   2.2AC    30MIN
   34MIN   1227CFS    613CFS    5.6    2.8   10.4   11.8    13.8FPS    1.0    6.2FT    V    5.2FT   3.5AC    34MIN
   38MIN   1355CFS    690CFS    6.2    3.2   13.4   12.9    14.6FPS    1.0    6.6FT    V    5.5FT   6.5AC    38MIN
   41MIN   1378CFS    755CFS    6.3    3.5   16.3   14.0    15.4FPS    1.0    6.9FT    V    5.6FT   9.4AC    41MIN
   44MIN   1320CFS    805CFS    6.1    3.7   18.7   14.9    16.0FPS    1.1    7.1FT    V    5.8FT  11.8AC    44MIN
   48MIN   1225CFS    839CFS    5.6    3.9   20.4   15.5    16.4FPS    1.1    7.2FT    V    5.9FT  13.5AC    48MIN
   51MIN   1127CFS    863CFS    5.2    4.0   21.6   16.0    16.7FPS    1.1    7.3FT    V    5.9FT  14.7AC    51MIN
   54MIN   1028CFS    876CFS    4.7    4.0   22.3   16.2    16.9FPS    1.1    7.3FT    V    6.0FT  15.4AC    54MIN
   58MIN    930CFS    880CFS    4.3    4.0   22.6   16.3    16.9FPS    1.1    7.3FT    V    6.0FT  15.7AC    58MIN
   62MIN    821CFS    873CFS    6.4    6.8   22.2   16.2    16.8FPS    1.1    7.3FT    V    6.0FT  15.3AC    62MIN
   68MIN    706CFS    852CFS    5.2    6.3   21.1   15.8    16.6FPS    1.1    7.2FT    V    5.9FT  14.2AC    68MIN
   73MIN    591CFS    818CFS    4.6    6.4   19.3   15.1    16.1FPS    1.1    7.1FT    V    5.8FT  12.4AC    73MIN
   81MIN    478CFS    742CFS    6.6   10.2   15.7   13.8    15.2FPS    1.0    6.8FT    V    5.6FT   8.8AC    81MIN
   93MIN    350CFS    622CFS    6.4   11.4   10.7   11.9    13.9FPS    1.0    6.3FT    V    5.2FT   3.8AC    93MIN
  105MIN    252CFS    500CFS    3.8    7.6    6.8   10.3    12.6FPS    0.9    5.6FT    V    4.8FT   1.8AC   105MIN
  116MIN    199CFS    403CFS    3.1    6.3    3.7    7.4    11.6FPS    0.9    5.0FT  IIA    4.4FT   1.0AC   116MIN
  127MIN    145CFS    264CFS    2.2    4.0    1.9    5.7    10.0FPS    0.9    4.0FT  IIA    3.8FT   0.6AC   127MIN
  149MIN     83CFS    104CFS    3.8    4.8    0.8    3.3     6.9FPS    0.7    2.7FT IIIA    2.7FT   0.3AC   149MIN
  183MIN     28CFS     38CFS    1.3    1.8    0.4    2.0     4.3FPS    0.6    1.8FT IIIA    1.8FT   0.2AC   183MIN
  216MIN      5CFS     11CFS    0.3    0.5    0.1    1.1     2.5FPS    0.4    1.1FT IIIA    1.1FT   0.1AC   216MIN
  266MIN      0CFS      0CFS    0.0    0.1    0.0    0.2     0.7FPS    0.2    0.4FT IIIA    0.4FT   0.0AC   266MIN
  349MIN      0CFS      0CFS    0.0    0.0    0.0    0.1     0.4FPS    0.2    0.1FT  IIA    0.0FT   0.0AC   349MIN

             TOTAL VOLUMES      107    107

TIME TO PEAK=   39MIN.  TIME TO MAX OUTFLO=   59MIN.   TIME TO MAX HW=   59MIN.
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                        WYOMING HIGHWAY DEPARTMENT
        ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
 CULVERT FLOOD ROUTING  PRINT OPTION NO, 2
 STATION:__366+55.00  PROJECT:  DRY CREEK          STATION 366+55+-        (EXAMPLE NO.1)
 CULV SIZE:_1=__8.9X__5.7 CONCRETE ELLIPSE(HORIZ AXIS)/,SOCKET END PROJECTING INLET
 ANALYSIS TYPE: DRAINAGE DESIGN__  Q:_810CFS FREQ:_25YR DHW:12.00FT
 BARREL GEOMETRY: LENGTH:_103FT SLOPE:1.00000% GVD:_9.0FT
 * * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |  AREA  | TIME  |

    0MIN      0CFS      0CFS    0.0    0.0    0.0    0.0    0.0FPS   0.0    0.0FT         0.0FT   0.0AC     0MIN
    5MIN     37CFS     28CFS    0.6    0.4    0.2    1.4    2.7FPS   0.4    1.6FT   IG    1.6FT   0.1AC     5MIN
   15MIN    125CFS     84CFS    1.3    0.9    0.6    2.7    4.8FPS   0.5    2.5FT   IG    2.5FT   0.3AC    15MIN
   22MIN    256CFS    198CFS    2.7    2.1    1.2    4.5   13.8FPS   1.7    2.1FT   IA    3.4FT   0.4AC    22MIN
   29MIN    418CFS    314CFS    3.3    2.5    2.1    5.9   16.0FPS   1.7    2.7FT   IA    4.0FT   0.7AC    29MIN
   35MIN    580CFS    403CFS    4.5    3.2    3.4    7.2   17.3FPS   1.7    3.1FT   IA    4.4FT   1.0AC    35MIN
   39MIN    715CFS    471CFS    3.7    2.5    4.7    8.4   18.2FPS   1.7    3.5FT   IA    4.7FT   1.3AC    39MIN
   43MIN    789CFS    533CFS    4.1    2.8    6.1    9.6   18.8FPS   1.7    3.7FT   ID    4.9FT   1.6AC    43MIN
   47MIN    803CFS    575CFS    4.2    3.0    7.3   10.6   19.1FPS   1.7    3.9FT   ID    5.1FT   2.0AC    47MIN
   51MIN    769CFS    592CFS    4.0    3.1    8.2   11.0   19.3FPS   1.7    4.0FT   ID    5.1FT   2.5AC    51MIN
   54MIN    714CFS    601CFS    3.7    3.1    8.8   11.2   19.3FPS   1.7    4.1FT   ID    5.2FT   2.7AC    54MIN
   58MIN    656CFS    605CFS    3.4    3.2    9.1   11.3   19.3FPS   1.7    4.1FT   ID    5.2FT   2.8AC    58MIN
   62MIN    599CFS    605CFS    3.1    3.2    9.1   11.3   19.3FPS   1.7    4.1FT   ID    5.2FT   2.8AC    62MIN
   66MIN    542CFS    600CFS    2.8    3.1    8.8   11.2   19.3FPS   1.7    4.1FT   ID    5.2FT   2.7AC    66MIN
   71MIN    478CFS    585CFS    4.2    5.2    7.8   10.8   19.2FPS   1.7    4.0FT   ID    5.1FT   2.3AC    71MIN
   77MIN    411CFS    553CFS    3.4    4.6    6.5   10.1   19.0FPS   1.7    3.8FT   ID    5.0FT   1.7AC    77MIN
   83MIN    344CFS    495CFS    3.1    4.4    5.2    8.8   18.4FPS   1.7    3.6FT   ID    4.8FT   1.4AC    83MIN
   92MIN    278CFS    397CFS    4.4    6.2    3.3    7.1   17.3FPS   1.7    3.1FT   IA    4.4FT   1.0AC    92MIN
  106MIN    204CFS    285CFS    4.3    6.0    1.7    5.5   15.5FPS   1.7    2.6FT   IA    3.9FT   0.6AC   106MIN
  119MIN    147CFS    177CFS    2.5    3.0    1.1    4.2    7.3FPS   0.7    3.3FT   IG    3.3FT   0.4AC   119MIN
  132MIN    116CFS    129CFS    2.1    2.3    0.9    3.5    6.1FPS   0.6    2.9FT   IG    2.9FT   0.3AC   132MIN
  145MIN     85CFS     95CFS    1.5    1.7    0.7    2.9    5.2FPS   0.6    2.6FT   IG    2.6FT   0.3AC   145MIN
  170MIN     48CFS     54CFS    2.5    2.8    0.4    2.1    3.8FPS   0.5    2.1FT   IG    2.1FT   0.2AC   170MIN
  208MIN     16CFS     22CFS    0.9    1.2    0.1    1.3    2.4FPS   0.4    1.5FT   IG    1.5FT   0.1AC   208MIN
  246MIN      3CFS      4CFS    0.2    0.3    0.0    0.5    1.4FPS   0.3    0.8FT   IG    0.8FT   0.0AC   246MIN
  303MIN      0CFS      0CFS    0.0    0.0    0.0    0.1    0.3FPS   0.1    0.2FT IIIA    0.2FT   0.0AC   303MIN

             TOTAL VOLUMES       71     71

 TIME TO PEAK=   45MIN,  TIME TO MAX OUTFLO=   60MIN,   TIME TO MAX HW=   60MIN,
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                      WYOMING HIGHWAY DEPARTMENT
        ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
STATION: 366+55.00  PROJECT:  DRY CREEK          STATION 366+55+-        (EXAMPLE NO.1)
CULV SIZE: 1=  8.9X  5.7 CONCRETE ELLIPSE(HORIZ AXIS)/,SOCKET END PROJECTING INLET
ANALYSIS TYPE: PERFORM DISCHGE    Q: 170CFS FREQ:  2YR DHW:12.00FT
BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
* * * * * * * *  C U L V E R T   F L O O D   R O U T I N G  * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES****| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |  AREA  | TIME  |
    0MIN     0CFS      0CFS    0.0     0.0     0.0    0.0     0.0FPS     0.0     0.0FT           0.0FT     0.0AC     0MIN
    7MIN     7CFS      6CFS    0.2     0.1     0.0    0.8     1.5FPS     0.3     0.9FT    IG     0.9FT     0.1AC     7MIN
   19MIN    26CFS     21CFS    0.3     0.3     0.1    1.2     2.4FPS     0.4     1.5FT    IG     1.5FT     0.1AC    19MIN
   28MIN    53CFS     40CFS    0.7     0.5     0.3    1.8     3.3FPS     0.4     1.9FT    IG     1.9FT     0.2AC    28MIN
   37MIN    87CFS     67CFS    0.9     0.7     0.5    2.4     4.3FPS     0.5     2.3FT    IG     2.3FT     0.2AC    37MIN
   44MIN   121CFS     99CFS    1.2     1.0     0.7    3.0     5.3FPS     0.6     2.6FT    IG     2.6FT     0.3AC    44MIN
   50MIN   150CFS    126CFS    1.0     0.8     0.9    3.5     6.0FPS     0.6     2.9FT    IG     2.9FT     0.3AC    50MIN
   54MIN   165CFS    148CFS    1.1     1.0     1.0    3.8     6.6FPS     0.7     3.1FT    IG     3.1FT     0.4AC    54MIN
   59MIN   168CFS    159CFS    1.1     1.1     1.0    3.9     6.9FPS     0.7     3.1FT    IG     3.1FT     0.4AC    59MIN
   64MIN   161CFS    160CFS    1.1     1.1     1.0    4.0     6.9FPS     0.7     3.1FT    IG     3.1FT     0.4AC    64MIN
   69MIN   149CFS    154CFS    1.0     1.0     1.0    3.9     6.7FPS     0.7     3.1FT    IG     3.1FT     0.4AC    69MIN
   74MIN   137CFS    145CFS    0.9     1.0     1.0    3.7     6.5FPS     0.7     3.0FT    IG     3.0FT     0.4AC    74MIN
   78MIN   125CFS    134CFS    0.8     0.9     0.9    3.6     6.2FPS     0.6     2.9FT    IG     2.9FT     0.4AC    78MIN
   83MIN   113CFS    122CFS    0.7     0.8     0.8    3.4     5.9FPS     0.6     2.8FT    IG     2.8FT     0.3AC    83MIN
   90MIN   100CFS    108CFS    1.1     1.2     0.8    3.1     5.5FPS     0.6     2.7FT    IG     2.7FT     0.3AC    90MIN
   97MIN    86CFS     94CFS    0.9     1.0     0.7    2.9     5.1FPS     0.6     2.6FT    IG     2.6FT     0.3AC    97MIN
  105MIN    72CFS     80CFS    0.8     0.9     0.6    2.6     4.7FPS     0.5     2.4FT    IG     2.4FT     0.3AC   105MIN
  117MIN    58CFS     64CFS    1.2     1.3     0.5    2.3     4.2FPS     0.5     2.2FT    IG     2.2FT     0.2AC   117MIN
  133MIN    42CFS     47CFS    1.1     1.3     0.3    1.9     3.6FPS     0.4     2.0FT    IG     2.0FT     0.2AC   133MIN
  151MIN    30CFS     35CFS    0.7     0.8     0.2    1.6     3.1FPS     0.4     1.8FT    IG     1.8FT     0.1AC   151MIN
  167MIN    24CFS     27CFS    0.5     0.6     0.2    1.4     2.7FPS     0.4     1.6FT    IG     1.6FT     0.1AC   167MIN
  183MIN    17CFS     20CFS    0.4     0.5     0.1    1.2     2.4FPS     0.3     1.5FT    IG     1.5FT     0.1AC   183MIN
  214MIN    10CFS     10CFS    0.7     0.7     0.0    0.9     1.8FPS     0.3     1.1FT    IG     1.1FT     0.1AC   214MIN
  262MIN     3CFS      3CFS    0.2     0.2     0.0    0.7     1.4FPS     0.3     0.8FT    IG     0.8FT     0.1AC   262MIN
  310MIN     0CFS      0CFS    0.0     0.1     0.0    0.4     0.9FPS     0.2     0.4FT  IIIA     0.4FT     0.0AC   310MIN
  382MIN     0CFS      0CFS    0.0     0.0     0.0    0.1     0.3FPS     0.2     0.1FT  IIIA     0.1FT     0.0AC   382MIN
             TOTAL VOLUMES      19      19
TIME TO PEAK=   57MIN,  TIME TO MAX OUTFLO=   66MIN,   TIME TO MAX HW=   66MIN.
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                         WYOMING HIGHWAY DEPARTMENT
          ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
STATION: 366+55.00  PROJECT:  DRY CREEK           STATION 366+55+-        (EXAMPLE NO.1)
CULV SIZE: 1=  8.9X  5.7 CONCRETE ELLIPSE(HORIZ AXIS)/,SOCKET END PROJECTING INLET
ANALYSIS TYPE: PERFORM DISCHGE   Q: 350CFS FREQ:  5YR DHW:12.00FT
BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
* * * * * * * *  C U L V E R T   F L O O D   R O U T I N G  * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |   POND   |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |   AREA   | TIME  |

    0MIN      0CFS      0CFS     0.0     0.0     0.0     0.0     0.0FPS    0.0     0.0FT           0.0FT    0.0AC      0MIN
    6MIN     16CFS     13CFS     0.3     0.2     0.1     1.0     2.0FPS    0.3     1.2FT    IG     1.2FT    0.1AC      6MIN
   17MIN     54CFS     38CFS     0.7     0.5     0.3     1.7     3.2FPS    0.4     1.8FT    IG     1.8FT    0.2AC     17MIN
   26MIN    110CFS     83CFS     1.4     1.0     0.6     2.7     4.8FPS    0.5     2.5FT    IG     2.5FT    0.3AC     26MIN
   34MIN    180CFS    142CFS     1.7     1.3     0.9     3.7     6.5FPS    0.7     3.0FT    IG     3.0FT    0.4AC     34MIN
   41MIN    250CFS    215CFS     2.3     2.0     1.3     4.7    14.2FPS    1.7     2.2FT    IA     3.5FT    0.5AC     41MIN
   46MIN    309CFS    271CFS     1.9     1.7     1.5     5.4    15.3FPS    1.7     2.5FT    IA     3.8FT    0.5AC     46MIN
   51MIN    341CFS    296CFS     2.1     1.8     1.8     5.7    15.7FPS    1.7     2.6FT    IA     4.0FT    0.6AC     51MIN
   55MIN    347CFS    312CFS     2.1     1.9     2.0     5.9    16.0FPS    1.7     2.7FT    IA     4.0FT    0.7AC     55MIN
   60MIN    332CFS    317CFS     2.0     2.0     2.1     6.0    16.1FPS    1.7     2.7FT    IA     4.1FT    0.7AC     60MIN
   64MIN    308CFS    315CFS     1.9     1.9     2.1     5.9    16.0FPS    1.7     2.7FT    IA     4.1FT    0.7AC     64MIN
   69MIN    283CFS    305CFS     1.7     1.9     1.9     5.8    15.9FPS    1.7     2.7FT    IA     4.0FT    0.6AC     69MIN
   73MIN    258CFS    291CFS     1.6     1.8     1.7     5.6    15.6FPS    1.7     2.6FT    IA     3.9FT    0.6AC     73MIN
   78MIN    234CFS    268CFS     1.4     1.6     1.5     5.3    15.2FPS    1.7     2.5FT    IA     3.8FT    0.5AC     78MIN
   84MIN    206CFS    224CFS     2.2     2.3     1.3     4.8    14.4FPS    1.7     2.3FT    IA     3.6FT    0.5AC     84MIN
   91MIN    177CFS    192CFS     1.7     1.9     1.2     4.4    13.7FPS    1.7     2.1FT    IA     3.4FT    0.4AC     91MIN
   98MIN    149CFS    162CFS     1.6     1.7     1.0     4.0     6.9FPS    0.7     3.2FT    IG     3.2FT    0.4AC     98MIN
  109MIN    120CFS    129CFS     2.2     2.4     0.9     3.5     6.1FPS    0.6     2.9FT    IG     2.9FT    0.3AC    109MIN
  124MIN     88CFS     96CFS     2.2     2.4     0.7     2.9     5.2FPS    0.6     2.6FT    IG     2.6FT    0.3AC    124MIN
  141MIN     63CFS     71CFS     1.3     1.5     0.5     2.4     4.4FPS    0.5     2.3FT    IG     2.3FT    0.2AC    141MIN
  156MIN     50CFS     55CFS     1.0     1.2     0.4     2.1     3.9FPS    0.5     2.1FT    IG     2.1FT    0.2AC    156MIN
  170MIN     36CFS     41CFS     0.7     0.9     0.3     1.8     3.3FPS    0.4     1.9FT    IG     1.9FT    0.2AC    170MIN
  200MIN     20CFS     23CFS     1.3     1.5     0.1     1.3     2.5FPS    0.4     1.5FT    IG     1.5FT    0.1AC    200MIN
  245MIN      7CFS      8CFS     0.4     0.5     0.0     0.9     1.7FPS    0.3     1.0FT    IG     1.0FT    0.1AC    245MIN
  289MIN      1CFS      1CFS     0.1     0.1     0.0     0.4     1.2FPS    0.3     0.6FT    IG     0.6FT    0.0AC    289MIN
  356MIN      0CFS      0CFS     0.0     0.0     0.0     0.1     0.3FPS    0.2     0.1FT  IIIA     0.1FT    0.0AC    356MIN

            TOTAL VOLUMES         36      36

TIME TO PEAK=    53MIN,  TIME TO MAX OUTFLO=    62MIN,   TIME TO MAX HW=    62MIN.
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```
                        WYOMING HIGHWAY DEPARTMENT
        ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
STATION: 366+55.00  PROJECT:  DRY CREEK           STATION 366+55+-        (EXAMPLE NO.1)
CULV SIZE: 1= 8.9X 5.7 CONCRETE ELLIPSE(HORIZ AXIS)/,SOCKET END PROJECTING INLET
ANALYSIS TYPE: PERFORM DISCHGE    Q: 530CFS FREQ: 10YR DHW:12.00FT
BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
* * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL= |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |  AREA  | TIME  |

    0MIN     0CFS      0CFS    0.0     0.0     0.0    0.0     0.0FPS     0.0     0.0FT          0.0FT     0.0AC      0MIN
    6MIN    24CFS     19CFS    0.4     0.3     0.1    1.2     2.3FPS     0.3     1.4FT   IG     1.4FT     0.1AC      6MIN
   16MIN    82CFS     55CFS    0.9     0.6     0.4    2.1     3.9FPS     0.5     2.1FT   IG     2.1FT     0.2AC     16MIN
   24MIN   167CFS    126CFS    1.9     1.4     0.9    3.4     6.0FPS     0.6     2.9FT   IG     2.9FT     0.3AC     24MIN
   31MIN   273CFS    221CFS    2.3     1.9     1.3    4.7    14.3FPS     1.7     2.2FT   IA     3.5FT     0.5AC     31MIN
   37MIN   379CFS    306CFS    3.2     2.6     2.0    5.8    15.9FPS     1.7     2.7FT   IA     4.0FT     0.6AC     37MIN
   43MIN   468CFS    352CFS    2.6     2.0     2.6    6.4    16.6FPS     1.7     2.9FT   IA     4.2FT     0.8AC     43MIN
   47MIN   516CFS    395CFS    2.9     2.2     3.3    7.1    17.2FPS     1.7     3.1FT   IA     4.4FT     0.9AC     47MIN
   51MIN   525CFS    426CFS    3.0     2.4     3.9    7.6    17.6FPS     1.7     3.2FT   IA     4.5FT     1.1AC     51MIN
   55MIN   503CFS    444CFS    2.8     2.5     4.2    7.9    17.9FPS     1.7     3.3FT   IA     4.6FT     1.1AC     55MIN
   59MIN   467CFS    450CFS    2.6     2.5     4.3    8.0    17.9FPS     1.7     3.4FT   IA     4.6FT     1.2AC     59MIN
   63MIN   429CFS    445CFS    2.4     2.5     4.2    7.9    17.9FPS     1.7     3.3FT   IA     4.6FT     1.1AC     63MIN
   67MIN   392CFS    433CFS    2.2     2.4     4.0    7.7    17.7FPS     1.7     3.3FT   IA     4.6FT     1.1AC     67MIN
   71MIN   354CFS    414CFS    2.0     2.3     3.6    7.4    17.5FPS     1.7     3.2FT   IA     4.5FT     1.0AC     71MIN
   77MIN   313CFS    377CFS    3.0     3.6     3.0    6.8    17.0FPS     1.7     3.0FT   IA     4.3FT     0.9AC     77MIN
   84MIN   269CFS    337CFS    2.4     3.1     2.4    6.2    16.4FPS     1.7     2.8FT   IA     4.2FT     0.7AC     84MIN
   90MIN   225CFS    292CFS    2.2     2.8     1.8    5.6    15.7FPS     1.7     2.6FT   IA     3.9FT     0.6AC     90MIN
  100MIN   182CFS    210CFS    3.1     3.6     1.2    4.6    14.1FPS     1.7     2.2FT   IA     3.5FT     0.5AC    100MIN
  114MIN   133CFS    146CFS    3.0     3.3     1.0    3.8     6.5FPS     0.7     3.0FT   IG     3.0FT     0.4AC    114MIN
  129MIN    96CFS    107CFS    1.8     2.0     0.7    3.1     5.5FPS     0.6     2.7FT   IG     2.7FT     0.3AC    129MIN
  143MIN    75CFS     83CFS    1.5     1.6     0.6    2.7     4.8FPS     0.5     2.5FT   IG     2.5FT     0.3AC    143MIN
  157MIN    55CFS     63CFS    1.0     1.2     0.5    2.3     4.1FPS     0.5     2.2FT   IG     2.2FT     0.2AC    157MIN
  184MIN    31CFS     35CFS    1.8     2.0     0.2    1.6     3.1FPS     0.4     1.8FT   IG     1.8FT     0.1AC    184MIN
  225MIN    11CFS     14CFS    0.6     0.8     0.1    1.0     2.0FPS     0.3     1.3FT   IG     1.3FT     0.1AC    225MIN
  266MIN     2CFS      2CFS    0.1     0.2     0.0    0.4     1.4FPS     0.3     0.7FT   IG     0.7FT     0.0AC    266MIN
  328MIN     0CFS      0CFS    0.0     0.0     0.0    0.1     0.3FPS     0.2     0.1FT IIIA     0.1FT     0.0AC    328MIN

           TOTAL VOLUMES        50      50

TIME TO PEAK=   49MIN,  TIME TO MAX OUTFLO=   61MIN,   TIME TO MAX HW=   61MIN,
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                         WYOMING HIGHWAY DEPARTMENT
       ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
CULVERT FLOOD ROUTING  PRINT OPTION NO, 2
STATION: 366+55.00  PROJECT:  DRY CREEK            STATION 366+55+=        (EXAMPLE NO.1)
CULV SIZE: 1= 8.9X 5.7 CONCRETE ELLIPSE(HORIZ AXIS)/,SOCKET END PROJECTING INLET
ANALYSIS TYPE: PERFORM DISCHGE   Q:1080CFS FREQ: 50YR DHW:12.00FT
BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
* * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL= |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO.  | DEPTH | TYPE |WATER |  AREA  | TIME  |

    0MIN      0CFS      0CFS    0.0    0.0    0.0    0.0     0.0FPS    0.0   0.0FT           0.0FT   0.0AC      0MIN
    5MIN     50CFS     35CFS    0.7    0.5    0.2    1.6     3.1FPS    0.4   1.8FT    IG     1.8FT   0.1AC      5MIN
   14MIN    167CFS    111CFS    1.6    1.1    0.8    3.2     5.6FPS    0.6   2.7FT    IG     2.7FT   0.3AC     14MIN
   21MIN    342CFS    267CFS    3.3    2.6    1.5    5.3    15.2FPS    1.7   2.5FT    IA     3.8FT   0.5AC     21MIN
   27MIN    558CFS    370CFS    4.1    2.7    2.9    6.7    16.9FPS    1.7   3.0FT    IA     4.3FT   0.9AC     27MIN
   32MIN    774CFS    484CFS    5.7    3.5    5.0    8.6    18.3FPS    1.7   3.5FT    ID     4.8FT   1.3AC     32MIN
   37MIN    954CFS    567CFS    4.6    2.8    6.9   10.4    19.1FPS    1.7   3.9FT    ID     5.1FT   1.8AC     37MIN
   40MIN   1053CFS    606CFS    5.1    3.0    9.1   11.3    19.4FPS    1.7   4.1FT    ID     5.2FT   2.8AC     40MIN
   44MIN   1071CFS    637CFS    5.2    3.1   11.3   12.1    19.5FPS    1.7   4.3FT    ID     5.3FT   4.3AC     44MIN
   47MIN   1026CFS    662CFS    5.0    3.2   13.0   12.8    19.6FPS    1.6   4.4FT    ID     5.4FT   6.1AC     47MIN
   51MIN    952CFS    679CFS    4.6    3.3   14.3   13.3    19.6FPS    1.6   4.5FT    ID     5.4FT   7.4AC     51MIN
   54MIN    875CFS    691CFS    4.3    3.4   15.2   13.6    19.6FPS    1.6   4.6FT    ID     5.5FT   8.3AC     54MIN
   58MIN    799CFS    698CFS    3.9    3.4   15.7   13.8    19.6FPS    1.6   4.6FT    ID     5.5FT   8.8AC     58MIN
   61MIN    722CFS    700CFS    3.5    3.4   15.9   13.8    19.6FPS    1.6   4.7FT    ID     5.5FT   8.9AC     61MIN
   66MIN    638CFS    693CFS    5.3    5.7   15.4   13.6    19.6FPS    1.6   4.6FT    ID     5.5FT   8.5AC     66MIN
   72MIN    548CFS    680CFS    4.3    5.3   14.4   13.3    19.6FPS    1.6   4.5FT    ID     5.4FT   7.5AC     72MIN
   78MIN    459CFS    658CFS    3.8    5.4   12.7   12.7    19.6FPS    1.6   4.4FT    ID     5.4FT   5.8AC     78MIN
   86MIN    371CFS    608CFS    5.4    8.9    9.3   11.4    19.4FPS    1.7   4.1FT    ID     5.2FT   2.9AC     86MIN
   98MIN    272CFS    486CFS    5.3    9.5    5.0    8.7    18.3FPS    1.7   3.5FT    ID     4.8FT   1.3AC     98MIN
  111MIN    196CFS    349CFS    3.2    5.6    2.6    6.4    16.6FPS    1.7   2.9FT    IA     4.2FT   0.8AC    111MIN
  123MIN    154CFS    227CFS    2.6    3.8    1.3    4.8    14.4FPS    1.7   2.3FT    IA     3.6FT   0.5AC    123MIN
  135MIN    113CFS    138CFS    1.8    2.2    0.9    3.6     6.3FPS    0.6   3.0FT    IG     3.0FT   0.4AC    135MIN
  159MIN     64CFS     72CFS    3.2    3.5    0.5    2.5     4.5FPS    0.5   2.3FT    IG     2.3FT   0.2AC    159MIN
  194MIN     22CFS     29CFS    1.1    1.4    0.2    1.5     2.8FPS    0.4   1.7FT    IG     1.7FT   0.1AC    194MIN
  229MIN      4CFS      7CFS    0.2    0.4    0.0    0.7     1.6FPS    0.3   1.0FT    IG     1.0FT   0.1AC    229MIN
  282MIN      0CFS      0CFS    0.0    0.0    0.0    0.1     0.3FPS    0.1   0.3FT  IIIA     0.3FT   0.0AC    282MIN

           TOTAL VOLUMES         88     88

TIME TO PEAK=   42MIN,  TIME TO MAX OUTFLO=   63MIN,   TIME TO MAX HW=   63MIN,
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                      WYOMING HIGHWAY DEPARTMENT
       ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
CULVERT FLOOD ROUTING  PRINT OPTION NO, 2
STATION:  366+55.00  PROJECT:  DRY CREEK          STATION 366+55+-        (EXAMPLE NO.1)
CULV SIZE: 1=  8.9X  5.7 CONCRETE ELLIPSE(HORIZ AXIS)/,SOCKET END PROJECTING INLET
ANALYSIS TYPE: PERFORM DISCHGE    Q:1390CFS FREQ:100YR DHW:12.00FT
BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
* * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)*****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |  AREA  | TIME  |

    0MIN      0CFS     0CFS    0.0    0.0    0.0   0.0    0.0FPS    0.0    0.0FT         0.0FT    0.0AC      0MIN
    4MIN     64CFS    43CFS    0.9    0.6    0.3   1.8    3.4FPS    0.4    1.9FT    IG   1.9FT    0.2AC      4MIN
   13MIN    215CFS   145CFS    2.0    1.3    1.0   3.7    6.5FPS    0.7    3.0FT    IG   3.0FT    0.4AC     13MIN
   19MIN    440CFS   317CFS    4.0    2.9    2.1   5.9   16.1FPS    1.7    2.7FT    IA   4.1FT    0.7AC     19MIN
   25MIN    718CFS   437CFS    4.9    3.0    4.0   7.7   17.8FPS    1.7    3.3FT    IA   4.6FT    1.1AC     25MIN
   30MIN    996CFS   569CFS    6.9    3.9    7.0  10.4   19.1FPS    1.7    3.9FT    ID   5.1FT    1.9AC     30MIN
   34MIN   1227CFS   616CFS    5.6    2.8    9.8  11.6   19.4FPS    1.7    4.2FT    ID   5.2FT    3.1AC     34MIN
   38MIN   1355CFS   662CFS    6.2    3.0   13.0  12.8   19.6FPS    1.6    4.4FT    ID   5.4FT    6.1AC     38MIN
   41MIN   1378CFS   703CFS    6.3    3.2   16.2  13.9   19.6FPS    1.6    4.7FT    ID   5.5FT    9.2AC     41MIN
   44MIN   1320CFS   737CFS    6.1    3.4   18.8  14.9   19.6FPS    1.6    4.9FT    ID   5.6FT   11.9AC     44MIN
   48MIN   1225CFS   763CFS    5.6    3.5   20.9  15.7   19.6FPS    1.5    5.1FT    ID   5.7FT   14.0AC     48MIN
   51MIN   1127CFS   782CFS    5.2    3.6   22.5  16.3   19.6FPS    1.5    5.3FT    IF   5.7FT   15.6AC     51MIN
   54MIN   1028CFS   795CFS    4.7    3.6   23.6  16.7   19.3FPS    1.4    5.7FT   IVA   5.7FT   16.7AC     54MIN
   58MIN    930CFS   801CFS    4.3    3.7   24.2  16.9   19.5FPS    1.4    5.7FT   IVA   5.8FT   17.3AC     58MIN
   62MIN    821CFS   803CFS    6.4    6.3   24.3  17.0   19.5FPS    1.4    5.7FT   IVA   5.8FT   17.4AC     62MIN
   68MIN    706CFS   795CFS    5.2    5.8   23.7  16.7   19.3FPS    1.4    5.7FT   IVA   5.8FT   16.7AC     68MIN
   73MIN    591CFS   778CFS    4.6    6.1   22.2  16.2   19.6FPS    1.5    5.3FT    IF   5.7FT   15.3AC     73MIN
   81MIN    478CFS   735CFS    6.6   10.1   18.7  14.9   19.6FPS    1.6    4.9FT    ID   5.6FT   11.8AC     81MIN
   93MIN    350CFS   661CFS    6.4   12.1   13.0  12.7   19.6FPS    1.6    4.4FT    ID   5.4FT    6.1AC     93MIN
  105MIN    252CFS   587CFS    3.8    8.9    7.9  10.9   19.2FPS    1.7    4.0FT    ID   5.1FT    2.4AC    105MIN
  116MIN    199CFS   438CFS    3.1    6.8    4.1   7.8   17.8FPS    1.7    3.3FT    IA   4.6FT    1.1AC    116MIN
  127MIN    145CFS   295CFS    2.2    4.5    1.8   5.7   15.7FPS    1.7    2.6FT    IA   4.0FT    0.6AC    127MIN
  149MIN     83CFS   105CFS    3.8    4.9    0.7   3.1    5.5FPS    0.6    2.7FT    IG   2.7FT    0.3AC    149MIN
  183MIN     28CFS    39CFS    1.3    1.8    0.3   1.7    3.2FPS    0.4    1.8FT    IG   1.8FT    0.2AC    183MIN
  216MIN      5CFS    10CFS    0.3    0.5    0.0   0.8    1.8FPS    0.3    1.1FT    IG   1.1FT    0.1AC    216MIN
  266MIN      0CFS     0CFS    0.0    0.0    0.0   0.1    0.4FPS    0.1    0.3FT  IIIA   0.3FT    0.0AC    266MIN

              TOTAL VOLUMES    107    107

TIME TO PEAK=   39MIN.  TIME TO MAX OUTFLO=   65MIN.   TIME TO MAX HW=   65MIN.
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                     WYOMING HIGHWAY DEPARTMENT
         ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
 CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
 STATION: 366+55.00  PROJECT:  DRY CREEK          STATION 366+55+-        (EXAMPLE NO.1)
 CULV SIZE: 1- 9.3X  6.3   METAL PIPE ARCH    / UNPAVED /MITERED-STEP BEVEL INLET
 ANALYSIS TYPE: DRAINAGE DESIGN    Q: 810CFS FREQ: 25YR DHW: 12.00FT
 BARREL GEOMETRY: LENGTH: 103FT SLOPE: 1.00000% GVD: 9.0FT
 * * * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO.  | DEPTH | TYPE |WATER |  AREA  | TIME  |

    0MIN      0CFS      0CFS    0.0    0.0    0.0    0.0    0.0FPS    0.0    0.0FT          0.0FT   0.0AC     0MIN
    5MIN     37CFS     28CFS    0.6    0.4    0.2    1.4    2.3FPS    0.3    1.6FT  IIIA    1.6FT   0.1AC     5MIN
   15MIN    125CFS     84CFS    1.3    0.9    0.6    2.7    4.2FPS    0.5    2.5FT  IIIA    2.5FT   0.3AC    15MIN
   22MIN    256CFS    197CFS    2.7    2.1    1.2    4.5    7.0FPS    0.7    3.4FT  IIIA    3.4FT   0.4AC    22MIN
   29MIN    418CFS    313CFS    3.3    2.5    2.1    5.9    9.4FPS    0.8    4.0FT  IIIA    4.0FT   0.7AC    29MIN
   35MIN    580CFS    363CFS    4.5    2.8    3.8    7.5   10.3FPS    0.9    4.3FT  IIIA    4.3FT   1.0AC    35MIN
   39MIN    715CFS    425CFS    3.7    2.2    5.3    8.9   12.0FPS    1.0    4.3FT     V    4.5FT   1.4AC    39MIN
   43MIN    789CFS    499CFS    4.1    2.6    6.8   10.3   13.1FPS    1.1    4.7FT     V    4.8FT   1.7AC    43MIN
   47MIN    803CFS    533CFS    4.2    2.8    8.3   11.0   13.6FPS    1.1    4.8FT     V    4.9FT   2.5AC    47MIN
   51MIN    769CFS    552CFS    4.0    2.9    9.4   11.4   13.9FPS    1.1    4.9FT     V    5.0FT   3.0AC    51MIN
   54MIN    714CFS    565CFS    3.7    3.0   10.2   11.7   14.1FPS    1.1    5.0FT     V    5.1FT   3.3AC    54MIN
   58MIN    656CFS    572CFS    3.4    3.0   10.7   11.9   14.2FPS    1.1    5.0FT     V    5.1FT   3.8AC    58MIN
   62MIN    599CFS    574CFS    3.1    3.0   10.8   11.9   14.2FPS    1.1    5.0FT     V    5.1FT   3.9AC    62MIN
   66MIN    542CFS    572CFS    2.8    3.0   10.6   11.9   14.2FPS    1.1    5.0FT     V    5.1FT   3.7AC    66MIN
   71MIN    478CFS    560CFS    4.2    5.0    9.9   11.6   14.0FPS    1.1    4.9FT     V    5.0FT   3.1AC    71MIN
   77MIN    411CFS    542CFS    3.4    4.5    8.8   11.2   13.7FPS    1.1    4.9FT     V    5.0FT   2.7AC    77MIN
   83MIN    344CFS    513CFS    3.1    4.6    7.3   10.6   13.3FPS    1.1    4.7FT     V    4.9FT   2.0AC    83MIN
   92MIN    278CFS    414CFS    4.4    6.5    5.1    8.7   11.9FPS    1.0    4.2FT     V    4.5FT   1.4AC    92MIN
  106MIN    204CFS    333CFS    4.3    7.0    2.4    6.2    9.7FPS    0.8    4.1FT  IIIA    4.1FT   0.7AC   106MIN
  119MIN    147CFS    211CFS    2.5    3.6    1.3    4.7    7.3FPS    0.7    3.5FT  IIIA    3.5FT   0.5AC   119MIN
  132MIN    116CFS    137CFS    2.1    2.4    0.9    3.5    5.7FPS    0.6    3.0FT  IIIA    3.0FT   0.3AC   132MIN
  145MIN     85CFS     97CFS    1.5    1.7    0.7    2.9    4.6FPS    0.5    2.6FT  IIIA    2.6FT   0.3AC   145MIN
  170MIN     48CFS     54CFS    2.5    2.8    0.4    2.0    3.3FPS    0.4    2.1FT  IIIA    2.1FT   0.2AC   170MIN
  208MIN     16CFS     22CFS    0.9    1.2    0.1    1.2    2.0FPS    0.3    1.5FT  IIIA    1.5FT   0.1AC   208MIN
  246MIN      3CFS      4CFS    0.2    0.2    0.0    0.5    0.9FPS    0.2    0.8FT  IIIA    0.8FT   0.0AC   246MIN
  303MIN      0CFS      0CFS    0.0    0.0    0.0    0.1    0.1FPS    0.1    0.2FT  IIIA    0.2FT   0.0AC   303MIN

             TOTAL VOLUMES       71     71

 TIME TO PEAK=   45MIN.  TIME TO MAX OUTFLO=   64MIN.   TIME TO MAX HW=   64MIN.
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                        WYOMING HIGHWAY DEPARTMENT
       ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION

CULVERT FLOOD ROUTING  PRINT OPTION NO. 2

STATION: 366+55.00  PROJECT:  DRY CREEK            STATION 366+55+-         (EXAMPLE NO.1)

CULV SIZE: 1- 9.3X 6.3     METAL PIPE ARCH     / UNPAVED /MITERED-STEP BEVEL INLET

ANALYSIS TYPE: PERFORM DISCHGE    Q: 170CFS FREQ:  2YR DHW:12.00FT

BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT

* * * * * * * *  C U L V E R T   F L O O D   R O U T I N G  * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *

|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |   POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |   AREA  | TIME  |

    0MIN      0CFS      0CFS    0.0     0.0     0.0    0.0    0.0FPS     0.0    0.0FT         0.0FT    0.0AC      0MIN
    7MIN      7CFS      6CFS    0.2     0.1     0.0    0.7    1.1FPS     0.2    0.9FT  IIIA   0.9FT    0.1AC      7MIN
   19MIN     26CFS     22CFS    0.3     0.3     0.1    1.2    2.0FPS     0.3    1.5FT  IIIA   1.5FT    0.1AC     19MIN
   28MIN     53CFS     40CFS    0.7     0.5     0.3    1.7    2.8FPS     0.4    1.9FT  IIIA   1.9FT    0.2AC     28MIN
   37MIN     87CFS     67CFS    0.9     0.7     0.5    2.3    3.7FPS     0.4    2.3FT  IIIA   2.3FT    0.2AC     37MIN
   44MIN    121CFS    100CFS    1.2     1.0     0.7    3.0    4.7FPS     0.5    2.6FT  IIIA   2.6FT    0.3AC     44MIN
   50MIN    150CFS    127CFS    1.0     0.8     0.8    3.4    5.4FPS     0.6    2.9FT  IIIA   2.9FT    0.3AC     50MIN
   54MIN    165CFS    149CFS    1.1     1.0     0.9    3.7    5.9FPS     0.6    3.1FT  IIIA   3.1FT    0.4AC     54MIN
   59MIN    168CFS    160CFS    1.1     1.1     1.0    3.9    6.2FPS     0.6    3.1FT  IIIA   3.1FT    0.4AC     59MIN
   64MIN    161CFS    161CFS    1.1     1.1     1.0    3.9    6.2FPS     0.6    3.2FT  IIIA   3.2FT    0.4AC     64MIN
   69MIN    149CFS    154CFS    1.0     1.0     1.0    3.8    6.1FPS     0.6    3.1FT  IIIA   3.1FT    0.4AC     69MIN
   74MIN    137CFS    144CFS    0.9     1.0     0.9    3.6    5.8FPS     0.6    3.0FT  IIIA   3.0FT    0.4AC     74MIN
   78MIN    125CFS    133CFS    0.8     0.9     0.9    3.5    5.6FPS     0.6    2.9FT  IIIA   2.9FT    0.3AC     78MIN
   83MIN    113CFS    122CFS    0.7     0.8     0.8    3.3    5.3FPS     0.6    2.8FT  IIIA   2.8FT    0.3AC     83MIN
   90MIN    100CFS    107CFS    1.1     1.2     0.7    3.1    4.9FPS     0.5    2.7FT  IIIA   2.7FT    0.3AC     90MIN
   97MIN     86CFS     93CFS    0.9     1.0     0.7    2.8    4.5FPS     0.5    2.6FT  IIIA   2.6FT    0.3AC     97MIN
  105MIN     72CFS     80CFS    0.8     0.9     0.6    2.6    4.1FPS     0.5    2.4FT  IIIA   2.4FT    0.2AC    105MIN
  117MIN     58CFS     64CFS    1.2     1.3     0.5    2.3    3.6FPS     0.4    2.2FT  IIIA   2.2FT    0.2AC    117MIN
  133MIN     42CFS     47CFS    1.1     1.3     0.3    1.9    3.1FPS     0.4    2.0FT  IIIA   2.0FT    0.2AC    133MIN
  151MIN     30CFS     35CFS    0.7     0.8     0.2    1.6    2.6FPS     0.3    1.8FT  IIIA   1.8FT    0.1AC    151MIN
  167MIN     24CFS     27CFS    0.5     0.6     0.2    1.4    2.3FPS     0.3    1.6FT  IIIA   1.6FT    0.1AC    167MIN
  183MIN     17CFS     20CFS    0.4     0.4     0.1    1.2    2.0FPS     0.3    1.4FT  IIIA   1.4FT    0.1AC    183MIN
  214MIN     10CFS     10CFS    0.7     0.7     0.0    0.9    1.4FPS     0.2    1.1FT  IIIA   1.1FT    0.1AC    214MIN
  262MIN      3CFS      3CFS    0.2     0.2     0.0    0.6    0.8FPS     0.2    0.8FT  IIIA   0.8FT    0.1AC    262MIN
  310MIN      0CFS      0CFS    0.0     0.1     0.0    0.3    0.3FPS     0.1    0.4FT  IIIA   0.4FT    0.0AC    310MIN
  382MIN      0CFS      0CFS    0.0     0.0     0.0    0.1    0.1FPS     0.1    0.1FT   IIA   0.1FT    0.0AC    382MIN

             TOTAL VOLUMES       19      19

TIME TO PEAK=   57MIN,  TIME TO MAX OUTFLO=   66MIN,   TIME TO MAX HW=   66MIN,
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                         WYOMING HIGHWAY DEPARTMENT
         ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
 CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
 STATION:__366+55.00  PROJECT:  DRY CREEK               STATION 366+55+-         (EXAMPLE NO.1)
 CULV SIZE:_1-  9.3X  6.3    METAL PIPE ARCH    / UNPAVED /MITERED-STEP BEVEL INLET
 ANALYSIS TYPE: PERFORM DISCHGE    Q:_350CFS FREQ:__5YR DHW:12.00FT
 BARREL GEOMETRY: LENGTH:_103FT SLOPE:1.00000% GVD:_9.0FT
 * * * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |  AREA  | TIME  |

    0MIN      0CFS      0CFS    0.0    0.0    0.0    0.0     0.0FPS    0.0    0.0FT          0.0FT   0.0AC      0MIN
    6MIN     16CFS     13CFS    0.3    0.3    0.0    1.0     1.6FPS    0.3    1.2FT  IIIA    1.2FT   0.1AC      6MIN
   17MIN     54CFS     38CFS    0.7    0.5    0.3    1.7     2.7FPS    0.4    1.8FT  IIIA    1.8FT   0.2AC     17MIN
   26MIN    110CFS     83CFS    1.4    1.0    0.6    2.7     4.2FPS    0.5    2.5FT  IIIA    2.5FT   0.3AC     26MIN
   34MIN    180CFS    144CFS    1.7    1.3    0.9    3.6     5.8FPS    0.6    3.0FT  IIIA    3.0FT   0.4AC     34MIN
   41MIN    250CFS    212CFS    2.3    2.0    1.3    4.7     7.3FPS    0.7    3.5FT  IIIA    3.5FT   0.5AC     41MIN
   46MIN    309CFS    272CFS    1.9    1.7    1.5    5.3     8.6FPS    0.8    3.8FT  IIIA    3.8FT   0.5AC     46MIN
   51MIN    341CFS    296CFS    2.1    1.8    1.8    5.7     9.0FPS    0.8    4.0FT  IIIA    4.0FT   0.6AC     51MIN
   55MIN    347CFS    310CFS    2.1    1.9    2.0    5.9     9.3FPS    0.8    4.0FT  IIIA    4.0FT   0.7AC     55MIN
   60MIN    332CFS    316CFS    2.0    1.9    2.1    6.0     9.4FPS    0.8    4.1FT  IIIA    4.1FT   0.7AC     60MIN
   64MIN    308CFS    314CFS    1.9    1.9    2.1    5.9     9.4FPS    0.8    4.1FT  IIIA    4.1FT   0.7AC     64MIN
   69MIN    283CFS    306CFS    1.7    1.9    2.0    5.8     9.2FPS    0.8    4.0FT  IIIA    4.0FT   0.6AC     69MIN
   73MIN    258CFS    293CFS    1.6    1.8    1.8    5.6     9.0FPS    0.8    3.9FT  IIIA    3.9FT   0.6AC     73MIN
   78MIN    234CFS    270CFS    1.4    1.7    1.5    5.3     8.5FPS    0.8    3.8FT  IIIA    3.8FT   0.5AC     78MIN
   84MIN    206CFS    222CFS    2.2    2.3    1.3    4.8     7.6FPS    0.7    3.6FT  IIIA    3.6FT   0.5AC     84MIN
   91MIN    177CFS    190CFS    1.7    1.9    1.2    4.4     6.9FPS    0.7    3.4FT  IIIA    3.4FT   0.4AC     91MIN
   98MIN    149CFS    165CFS    1.6    1.7    1.0    3.9     6.3FPS    0.6    3.2FT  IIIA    3.2FT   0.4AC     98MIN
  109MIN    120CFS    129CFS    2.2    2.4    0.8    3.4     5.5FPS    0.6    2.9FT  IIIA    2.9FT   0.3AC    109MIN
  124MIN     88CFS     95CFS    2.2    2.4    0.7    2.9     4.6FPS    0.5    2.6FT  IIIA    2.6FT   0.3AC    124MIN
  141MIN     63CFS     71CFS    1.3    1.4    0.5    2.4     3.9FPS    0.4    2.3FT  IIIA    2.3FT   0.2AC    141MIN
  156MIN     50CFS     55CFS    1.0    1.2    0.4    2.1     3.4FPS    0.4    2.1FT  IIIA    2.1FT   0.2AC    156MIN
  170MIN     36CFS     42CFS    0.7    0.9    0.3    1.8     2.9FPS    0.4    1.9FT  IIIA    1.9FT   0.2AC    170MIN
  200MIN     20CFS     23CFS    1.3    1.5    0.1    1.3     2.1FPS    0.3    1.5FT  IIIA    1.5FT   0.1AC    200MIN
  245MIN      7CFS      8CFS    0.4    0.5    0.0    0.8     1.3FPS    0.2    1.0FT  IIIA    1.0FT   0.1AC    245MIN
  289MIN      1CFS      1CFS    0.1    0.1    0.0    0.3     0.5FPS    0.1    0.6FT  IIIA    0.6FT   0.0AC    289MIN
  356MIN      0CFS      0CFS    0.0    0.0    0.0    0.1     0.1FPS    0.1    0.1FT   IIA    0.1FT   0.0AC    356MIN

               TOTAL VOLUMES     36     36

 TIME TO PEAK=   53MIN.  TIME TO MAX OUTFLO=   62MIN.   TIME TO MAX HW=   62MIN.
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```
                         WYOMING HIGHWAY DEPARTMENT
          ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
CULVERT FLOOD ROUTING  PRINT OPTION NO, 2
STATION:  366+55.00  PROJECT:  DRY CREEK               STATION 366+55+-        (EXAMPLE NO.1)
CULV SIZE: 1= 9.3X  6.3    METAL PIPE ARCH    / UNPAVED /MITERED-STEP BEVEL INLET
ANALYSIS TYPE: PERFORM DISCHGE    Q: 530CFS FREQ: 10YR DHW:12.00FT
BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
* * * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
!ROUTING! ***DISCHARGES***! ****VOLUMES(AF)****! HEAD ! OUTLET ! FROUDE! BRINK ! FLOW !TAIL- !  POND  !ROUTING!
! TIME  ! INFLOW ! OUTFLOW!  IN  !  OUT ! STORE! HW,FT!VELOCITY!  NO. ! DEPTH ! TYPE !WATER !  AREA  ! TIME  !

    0MIN      0CFS      0CFS    0.0    0.0    0.0    0.0     0.0FPS    0.0    0.0FT            0.0FT    0.0AC      0MIN
    6MIN     24CFS     20CFS    0.4    0.4    0.1    1.2     2.0FPS    0.3    1.4FT  IIIA      1.4FT    0.1AC      6MIN
   16MIN     82CFS     55CFS    0.9    0.6    0.4    2.1     3.3FPS    0.4    2.1FT  IIIA      2.1FT    0.2AC     16MIN
   24MIN    167CFS    127CFS    1.9    1.4    0.8    3.4     5.4FPS    0.6    2.9FT  IIIA      2.9FT    0.3AC     24MIN
   31MIN    273CFS    218CFS    2.3    1.9    1.3    4.7     7.5FPS    0.7    3.5FT  IIIA      3.5FT    0.5AC     31MIN
   37MIN    379CFS    307CFS    3.2    2.6    2.0    5.8     9.2FPS    0.8    4.0FT  IIIA      4.0FT    0.6AC     37MIN
   43MIN    468CFS    347CFS    2.6    2.0    2.7    6.5    10.0FPS    0.9    4.2FT  IIIA      4.2FT    0.8AC     43MIN
   47MIN    516CFS    362CFS    2.9    2.1    3.5    7.2    10.3FPS    0.9    4.3FT  IIIA      4.3FT    1.0AC     47MIN
   51MIN    525CFS    373CFS    3.0    2.1    4.4    8.0    11.4FPS    1.0    4.0FT     V      4.3FT    1.2AC     51MIN
   55MIN    503CFS    405CFS    2.8    2.3    4.9    8.6    11.8FPS    1.0    4.2FT     V      4.5FT    1.3AC     55MIN
   59MIN    467CFS    420CFS    2.6    2.4    5.2    8.8    12.0FPS    1.0    4.2FT     V      4.5FT    1.4AC     59MIN
   63MIN    429CFS    423CFS    2.4    2.4    5.2    8.9    12.0FPS    1.0    4.3FT     V      4.5FT    1.4AC     63MIN
   67MIN    392CFS    415CFS    2.2    2.3    5.1    8.7    11.9FPS    1.0    4.2FT     V      4.5FT    1.4AC     67MIN
   71MIN    354CFS    400CFS    2.0    2.3    4.8    8.5    11.7FPS    1.0    4.1FT     V      4.4FT    1.3AC     71MIN
   77MIN    313CFS    369CFS    3.0    3.5    4.3    8.0    11.3FPS    1.0    3.9FT     V      4.3FT    1.2AC     77MIN
   84MIN    269CFS    362CFS    2.4    3.3    3.5    7.2    10.3FPS    0.9    4.3FT  IIIA      4.3FT    1.0AC     84MIN
   90MIN    225CFS    334CFS    2.2    3.2    2.4    6.2     9.7FPS    0.8    4.1FT  IIIA      4.1FT    0.7AC     90MIN
  100MIN    182CFS    241CFS    3.1    4.1    1.4    5.0     7.9FPS    0.7    3.7FT  IIIA      3.7FT    0.5AC    100MIN
  114MIN    133CFS    152CFS    3.0    3.4    1.0    3.7     6.0FPS    0.6    3.1FT  IIIA      3.1FT    0.4AC    114MIN
  129MIN     96CFS    108CFS    1.8    2.0    0.7    3.1     4.9FPS    0.5    2.7FT  IIIA      2.7FT    0.3AC    129MIN
  143MIN     75CFS     83CFS    1.5    1.6    0.6    2.7     4.2FPS    0.5    2.5FT  IIIA      2.5FT    0.3AC    143MIN
  157MIN     55CFS     63CFS    1.0    1.2    0.4    2.2     3.6FPS    0.4    2.2FT  IIIA      2.2FT    0.2AC    157MIN
  184MIN     31CFS     35CFS    1.8    2.0    0.2    1.6     2.6FPS    0.3    1.8FT  IIIA      1.8FT    0.1AC    184MIN
  225MIN     11CFS     13CFS    0.6    0.8    0.0    1.0     1.6FPS    0.3    1.2FT  IIIA      1.2FT    0.1AC    225MIN
  266MIN      2CFS      2CFS    0.1    0.2    0.0    0.4     0.7FPS    0.1    0.7FT  IIIA      0.7FT    0.0AC    266MIN
  328MIN      0CFS      0CFS    0.0    0.0    0.0    0.1     0.1FPS    0.1    0.1FT  IIIA      0.1FT    0.0AC    328MIN

               TOTAL VOLUMES     50     50

TIME TO PEAK=   49MIN,  TIME TO MAX OUTFLO=   65MIN,   TIME TO MAX HW=   65MIN.
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                         WYOMING HIGHWAY DEPARTMENT
         ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
STATION: 366+55.00  PROJECT:  DRY CREEK            STATION 366+55+-        (EXAMPLE NO.1)
CULV SIZE: 1- 9.3X  6.3     METAL PIPE ARCH     / UNPAVED /MITERED-STEP BEVEL INLET
ANALYSIS TYPE: PERFORM DISCHGE    Q:1080CFS FREQ: 50YR DHW:12.00FT
BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
* * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |  AREA  | TIME  |

   0MIN      0CFS      0CFS    0.0    0.0    0.0    0.0    0.0FPS    0.0    0.0FT         0.0FT    0.0AC      0MIN
   5MIN     50CFS     36CFS    0.7    0.5    0.2    1.6    2.6FPS    0.3    1.8FT  IIIA   1.8FT    0.1AC      5MIN
  14MIN    167CFS    112CFS    1.6    1.1    0.8    3.2    5.0FPS    0.5    2.8FT  IIIA   2.8FT    0.3AC     14MIN
  21MIN    342CFS    268CFS    3.3    2.6    1.5    5.3    8.5FPS    0.8    3.8FT  IIIA   3.8FT    0.5AC     21MIN
  27MIN    558CFS    361CFS    4.1    2.6    2.9    6.7   10.3FPS    0.9    4.3FT  IIIA   4.3FT    0.9AC     27MIN
  32MIN    774CFS    433CFS    5.7    3.2    5.4    9.0   12.2FPS    1.0    4.3FT     V   4.6FT    1.4AC     32MIN
  37MIN    954CFS    519CFS    4.6    2.5    7.6   10.7   13.4FPS    1.1    4.8FT     V   4.9FT    2.2AC     37MIN
  40MIN   1053CFS    562CFS    5.1    2.7   10.0   11.6   14.0FPS    1.1    5.0FT     V   5.0FT    3.2AC     40MIN
  44MIN   1071CFS    598CFS    5.2    2.9   12.3   12.5   14.6FPS    1.1    5.1FT     V   5.2FT    5.4AC     44MIN
  47MIN   1026CFS    627CFS    5.0    3.1   14.3   13.2   15.1FPS    1.2    5.2FT     V   5.3FT    7.3AC     47MIN
  51MIN    952CFS    648CFS    4.6    3.2   15.7   13.8   15.4FPS    1.2    5.3FT     V   5.3FT    8.8AC     51MIN
  54MIN    875CFS    663CFS    4.3    3.2   16.8   14.2   15.7FPS    1.2    5.3FT     V   5.4FT    9.8AC     54MIN
  58MIN    799CFS    672CFS    3.9    3.3   17.4   14.4   15.8FPS    1.2    5.3FT     V   5.4FT   10.5AC     58MIN
  61MIN    722CFS    675CFS    3.5    3.3   17.6   14.5   15.9FPS    1.2    5.4FT     V   5.4FT   10.7AC     61MIN
  66MIN    638CFS    671CFS    5.3    5.6   17.4   14.4   15.8FPS    1.2    5.3FT     V   5.4FT   10.4AC     66MIN
  72MIN    548CFS    659CFS    4.3    5.1   16.5   14.1   15.6FPS    1.2    5.3FT     V   5.4FT    9.6AC     72MIN
  78MIN    459CFS    638CFS    3.8    5.3   15.0   13.5   15.3FPS    1.2    5.2FT     V   5.3FT    8.1AC     78MIN
  86MIN    371CFS    590CFS    5.4    8.6   11.8   12.3   14.5FPS    1.1    5.1FT     V   5.1FT    4.9AC     86MIN
  98MIN    272CFS    509CFS    5.3    9.9    7.2   10.5   13.2FPS    1.1    4.7FT     V   4.9FT    1.9AC     98MIN
 111MIN    196CFS    369CFS    3.2    5.9    4.3    8.0   11.3FPS    1.0    3.9FT     V   4.3FT    1.2AC    111MIN
 123MIN    154CFS    302CFS    2.6    5.0    1.9    5.7    9.1FPS    0.8    4.0FT  IIIA   4.0FT    0.6AC    123MIN
 135MIN    113CFS    164CFS    1.8    2.6    1.0    3.9    6.3FPS    0.6    3.2FT  IIIA   3.2FT    0.4AC    135MIN
 159MIN     64CFS     74CFS    3.2    3.6    0.5    2.5    4.0FPS    0.5    2.4FT  IIIA   2.4FT    0.2AC    159MIN
 194MIN     22CFS     29CFS    1.1    1.5    0.2    1.4    2.4FPS    0.3    1.7FT  IIIA   1.7FT    0.1AC    194MIN
 229MIN      4CFS      7CFS    0.2    0.4    0.0    0.6    1.2FPS    0.2    1.0FT  IIIA   1.0FT    0.1AC    229MIN
 282MIN      0CFS      0CFS    0.0    0.0    0.0    0.1    0.1FPS    0.1    0.2FT  IIIA   0.2FT    0.0AC    282MIN

          TOTAL VOLUMES        88     88

TIME TO PEAK=    42MIN,  TIME TO MAX OUTFLO=    63MIN,   TIME TO MAX HW=   63MIN,
```

```
                    WYOMING HIGHWAY DEPARTMENT
        ENGINEERING  DIRECTORATE  ********  HYDRAULICS SECTION
CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
STATION: 366+55.00  PROJECT:  DRY CREEK           STATION 366+55+-        (EXAMPLE NO.1)
CULV SIZE: 1- 9.3X  6.3    METAL PIPE ARCH    / UNPAVED /MITERED-STEP BEVEL INLET
ANALYSIS TYPE: PERFORM DISCHGE    Q:1390CFS FREQ:100YR DHW:12.00FT
BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
* * * * * * * *  C U L V E R T  F L O O D  R O U T I N G * * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |  AREA  | TIME  |
    0MIN      0CFS      0CFS    0.0    0.0    0.0   0.0    0.0FPS    0.0   0.0FT        0.0FT   0.0AC     0MIN
    4MIN     64CFS     44CFS    0.9    0.6    0.3   1.8    3.0FPS    0.4   1.9FT  IIIA  1.9FT   0.2AC     4MIN
   13MIN    215CFS    146CFS    2.0    1.3    0.9   3.7    5.9FPS    0.6   3.0FT  IIIA  3.0FT   0.4AC    13MIN
   19MIN    440CFS    315CFS    4.0    2.9    2.1   5.9    9.4FPS    0.8   4.1FT  IIIA  4.1FT   0.7AC    19MIN
   25MIN    718CFS    377CFS    4.9    2.6    4.4   8.1   11.4FPS    1.0   4.0FT     V  4.3FT   1.2AC    25MIN
   30MIN    996CFS    524CFS    6.9    3.6    7.8  10.8   13.4FPS    1.1   4.8FT     V  4.9FT   2.3AC    30MIN
   34MIN   1227CFS    574CFS    5.6    2.6   10.8  11.9   14.2FPS    1.1   5.0FT     V  5.1FT   3.9AC    34MIN
   38MIN   1355CFS    625CFS    6.2    2.9   14.1  13.2   15.0FPS    1.2   5.2FT     V  5.3FT   7.2AC    38MIN
   41MIN   1378CFS    671CFS    6.3    3.1   17.4  14.4   15.8FPS    1.2   5.3FT     V  5.4FT  10.4AC    41MIN
   44MIN   1320CFS    709CFS    6.1    3.3   20.2  15.4   16.5FPS    1.2   5.5FT     V  5.5FT  13.3AC    44MIN
   48MIN   1225CFS    737CFS    5.6    3.4   22.4  16.3   17.0FPS    1.3   5.5FT     V  5.6FT  15.5AC    48MIN
   51MIN   1127CFS    758CFS    5.2    3.5   24.1  16.9   17.4FPS    1.3   5.6FT     V  5.6FT  17.2AC    51MIN
   54MIN   1028CFS    772CFS    4.7    3.5   25.3  17.3   17.7FPS    1.3   5.6FT     V  5.7FT  18.4AC    54MIN
   58MIN    930CFS    780CFS    4.3    3.6   26.0  17.6   17.8FPS    1.3   5.6FT     V  5.7FT  19.1AC    58MIN
   62MIN    821CFS    784CFS    6.4    6.1   26.3  17.7   17.9FPS    1.3   5.6FT     V  5.7FT  19.4AC    62MIN
   68MIN    706CFS    777CFS    5.2    5.7   25.7  17.5   17.8FPS    1.3   5.6FT     V  5.7FT  18.8AC    68MIN
   73MIN    591CFS    762CFS    4.6    5.9   24.4  17.0   17.5FPS    1.3   5.6FT     V  5.7FT  17.5AC    73MIN
   81MIN    478CFS    720CFS    6.6    9.9   21.1  15.8   16.7FPS    1.3   5.5FT     V  5.5FT  14.2AC    81MIN
   93MIN    350CFS    647CFS    6.4   11.9   15.7  13.7   15.4FPS    1.2   5.3FT     V  5.3FT   8.7AC    93MIN
  105MIN    252CFS    574CFS    3.8    8.7   10.8  11.9   14.2FPS    1.1   5.0FT     V  5.1FT   3.9AC   105MIN
  116MIN    199CFS    478CFS    3.1    7.5    6.3   9.9   12.8FPS    1.1   4.6FT     V  4.7FT   1.6AC   116MIN
  127MIN    145CFS    362CFS    2.2    5.5    3.0   6.8   10.3FPS    0.9   4.3FT  IIIA  4.3FT   0.9AC   127MIN
  149MIN     83CFS    130CFS    3.8    6.0    0.9   3.4    5.5FPS    0.6   2.9FT  IIIA  2.9FT   0.3AC   149MIN
  183MIN     28CFS     41CFS    1.3    1.9    0.3   1.7    2.8FPS    0.4   1.9FT  IIIA  1.9FT   0.2AC   183MIN
  216MIN      5CFS     10CFS    0.3    0.5    0.0   0.8    1.5FPS    0.2   1.1FT  IIIA  1.1FT   0.1AC   216MIN
  266MIN      0CFS      0CFS    0.0    0.0    0.0   0.1    0.1FPS    0.0   0.3FT  IIIA  0.3FT   0.0AC   266MIN
           TOTAL VOLUMES        107    107
TIME TO PEAK=   39MIN.  TIME TO MAX OUTFLO=   65MIN.   TIME TO MAX HW=   65MIN.
```

```
                         WYOMING HIGHWAY DEPARTMENT
          ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
CULVERT FLOOD ROUTING  PRINT OPTION NO, 2
STATION:__366+55.00  PROJECT:  DRY CREEK              STATION 366+55+-          (EXAMPLE NO.1)
CULV SIZE:_2=__7.3X__4.5 CONCRETE ARCH /,SOCKET END PROJECTING INLET
ANALYSIS TYPE: DRAINAGE DESIGN__  Q:_810CFS FREQ:_25YR DHW:12.00FT
BARREL GEOMETRY: LENGTH:_103FT SLOPE:1.00000% GVD:_9.0FT
* * * * * * * *  C U L V E R T   F L O O D  R O U T I N G  * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |   POND   |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |   AREA   | TIME  |

    0MIN      0CFS      0CFS    0.0    0.0    0.0    0.0    0.0FPS    0.0   0.0FT           0.0FT   0.0AC      0MIN
    5MIN     37CFS     33CFS    0.6    0.5    0.1    1.1    1.7FPS    0.2   1.7FT   IG      1.7FT   0.1AC      5MIN
   15MIN    125CFS     94CFS    1.3    1.0    0.4    2.1    3.0FPS    0.3   2.6FT   IG      2.6FT   0.2AC     15MIN
   22MIN    256CFS    210CFS    2.7    2.2    0.9    3.5    4.8FPS    0.5   3.5FT   IG      3.5FT   0.3AC     22MIN
   29MIN    418CFS    349CFS    3.3    2.7    1.4    5.1    6.7FPS    0.6   4.2FT   IG      4.2FT   0.5AC     29MIN
   35MIN    580CFS    437CFS    4.5    3.4    2.6    6.4    8.1FPS    0.7   4.5FT   IE      4.6FT   0.8AC     35MIN
   39MIN    715CFS    497CFS    3.7    2.6    3.7    7.4    9.2FPS    0.8   4.5FT   IF      4.8FT   1.0AC     39MIN
   43MIN    789CFS    552CFS    4.1    2.9    4.9    8.5   15.8FPS    1.7   2.8FT   IF      5.0FT   1.3AC     43MIN
   47MIN    803CFS    598CFS    4.2    3.1    6.0    9.6   16.1FPS    1.6   3.0FT   IF      5.2FT   1.6AC     47MIN
   51MIN    769CFS    626CFS    4.0    3.3    6.7   10.2   16.3FPS    1.6   3.1FT   IF      5.3FT   1.7AC     51MIN
   54MIN    714CFS    636CFS    3.7    3.3    7.2   10.5   16.4FPS    1.6   3.1FT   IF      5.3FT   2.0AC     54MIN
   58MIN    656CFS    638CFS    3.4    3.3    7.3   10.6   16.4FPS    1.6   3.1FT   IF      5.3FT   2.0AC     58MIN
   62MIN    599CFS    634CFS    3.1    3.3    7.1   10.5   16.4FPS    1.6   3.1FT   IF      5.3FT   1.9AC     62MIN
   66MIN    542CFS    622CFS    2.8    3.2    6.7   10.2   16.3FPS    1.6   3.1FT   IF      5.2FT   1.7AC     66MIN
   71MIN    478CFS    585CFS    4.2    5.2    5.7    9.3   16.0FPS    1.6   2.9FT   IF      5.1FT   1.5AC     71MIN
   77MIN    411CFS    540CFS    3.4    4.5    4.6    8.3   15.7FPS    1.7   2.8FT   IF      5.0FT   1.2AC     77MIN
   83MIN    344CFS    483CFS    3.1    4.3    3.4    7.2    9.0FPS    0.7   4.5FT   IE      4.8FT   1.0AC     83MIN
   92MIN    278CFS    386CFS    4.4    6.0    1.7    5.6    7.3FPS    0.6   4.4FT   IG      4.4FT   0.6AC     92MIN
  106MIN    204CFS    238CFS    4.3    5.0    1.0    3.8    5.2FPS    0.5   3.7FT   IG      3.7FT   0.4AC    106MIN
  119MIN    147CFS    163CFS    2.5    2.8    0.7    3.0    4.1FPS    0.4   3.2FT   IG      3.2FT   0.3AC    119MIN
  132MIN    116CFS    124CFS    2.1    2.2    0.5    2.5    3.5FPS    0.4   2.9FT   IG      2.9FT   0.2AC    132MIN
  145MIN     85CFS     93CFS    1.5    1.6    0.4    2.1    3.0FPS    0.3   2.6FT   IG      2.6FT   0.2AC    145MIN
  170MIN     48CFS     52CFS    2.5    2.8    0.2    1.5    2.2FPS    0.3   2.1FT   IG      2.1FT   0.1AC    170MIN
  208MIN     16CFS     19CFS    0.9    1.0    0.0    0.8    1.3FPS    0.2   1.4FT   IG      1.4FT   0.1AC    208MIN
  246MIN      3CFS      3CFS    0.2    0.2    0.0    0.2    0.7FPS    0.1   0.8FT   IG      0.8FT   0.0AC    246MIN
  303MIN      0CFS      0CFS    0.0    0.0    0.0    0.0    0.2FPS    0.1   0.1FT IIIA      0.1FT   0.0AC    303MIN

              TOTAL VOLUMES      71     71

TIME TO PEAK=   45MIN,  TIME TO MAX OUTFLO=   60MIN,   TIME TO MAX HW=   60MIN,
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```
                    WYOMING HIGHWAY DEPARTMENT
       ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
 CULVERT FLOOD ROUTING  PRINT OPTION NO, 2
 STATION: 366+55.00  PROJECT:  DRY CREEK          STATION 366+55+-        (EXAMPLE NO.1)
 CULV SIZE: 2-  7.3X  4.5 CONCRETE ARCH /,SOCKET END PROJECTING INLET
 ANALYSIS TYPE: PERFORM DISCHGE    Q: 170CFS FREQ:  2YR DHW: 12.00FT
 BARREL GEOMETRY: LENGTH: 103FT SLOPE: 1.00000% GVD: 9.0FT
 * * * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET  | FROUDE| BRINK | FLOW |TAIL- |   POND   |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO.  | DEPTH | TYPE |WATER |   AREA   | TIME  |

    0MIN      0CFS      0CFS    0.0    0.0    0.0    0.0    0.0FPS    0.0    0.0FT           0.0FT     0.0AC      0MIN
    7MIN      7CFS      6CFS    0.2    0.1    0.0    0.6    0.8FPS    0.1    1.0FT    IG     1.0FT     0.1AC      7MIN
   19MIN     26CFS     24CFS    0.3    0.3    0.0    0.9    1.4FPS    0.2    1.6FT    IG     1.6FT     0.1AC     19MIN
   28MIN     53CFS     46CFS    0.7    0.6    0.1    1.3    2.0FPS    0.3    2.0FT    IG     2.0FT     0.1AC     28MIN
   37MIN     87CFS     72CFS    0.9    0.7    0.3    1.8    2.6FPS    0.3    2.3FT    IG     2.3FT     0.2AC     37MIN
   44MIN    121CFS    105CFS    1.2    1.0    0.5    2.3    3.2FPS    0.3    2.7FT    IG     2.7FT     0.2AC     44MIN
   50MIN    150CFS    132CFS    1.0    0.9    0.6    2.6    3.6FPS    0.4    2.9FT    IG     2.9FT     0.3AC     50MIN
   54MIN    165CFS    152CFS    1.1    1.0    0.7    2.9    3.9FPS    0.4    3.1FT    IG     3.1FT     0.3AC     54MIN
   59MIN    168CFS    162CFS    1.1    1.1    0.7    3.0    4.1FPS    0.4    3.2FT    IG     3.2FT     0.3AC     59MIN
   64MIN    161CFS    162CFS    1.1    1.1    0.7    3.0    4.1FPS    0.4    3.2FT    IG     3.2FT     0.3AC     64MIN
   69MIN    149CFS    153CFS    1.0    1.0    0.7    2.9    4.0FPS    0.4    3.1FT    IG     3.1FT     0.3AC     69MIN
   74MIN    137CFS    144CFS    0.9    1.0    0.6    2.8    3.8FPS    0.4    3.0FT    IG     3.0FT     0.3AC     74MIN
   78MIN    125CFS    132CFS    0.8    0.9    0.6    2.6    3.6FPS    0.4    2.9FT    IG     2.9FT     0.3AC     78MIN
   83MIN    113CFS    121CFS    0.7    0.8    0.5    2.5    3.5FPS    0.4    2.8FT    IG     2.8FT     0.2AC     83MIN
   90MIN    100CFS    106CFS    1.1    1.2    0.5    2.3    3.2FPS    0.3    2.7FT    IG     2.7FT     0.2AC     90MIN
   97MIN     86CFS     92CFS    0.9    1.0    0.4    2.1    3.0FPS    0.3    2.6FT    IG     2.6FT     0.2AC     97MIN
  105MIN     72CFS     78CFS    0.8    0.9    0.3    1.9    2.7FPS    0.3    2.4FT    IG     2.4FT     0.2AC    105MIN
  117MIN     58CFS     62CFS    1.2    1.2    0.2    1.6    2.4FPS    0.3    2.2FT    IG     2.2FT     0.1AC    117MIN
  133MIN     42CFS     46CFS    1.1    1.2    0.1    1.3    2.0FPS    0.3    2.0FT    IG     2.0FT     0.1AC    133MIN
  151MIN     30CFS     34CFS    0.7    0.7    0.1    1.1    1.7FPS    0.2    1.7FT    IG     1.7FT     0.1AC    151MIN
  167MIN     24CFS     25CFS    0.5    0.6    0.0    0.9    1.5FPS    0.2    1.6FT    IG     1.6FT     0.1AC    167MIN
  183MIN     17CFS     18CFS    0.4    0.4    0.0    0.8    1.3FPS    0.2    1.4FT    IG     1.4FT     0.1AC    183MIN
  214MIN     10CFS     10CFS    0.7    0.7    0.0    0.6    1.0FPS    0.2    1.1FT    IG     1.1FT     0.1AC    214MIN
  262MIN      3CFS      3CFS    0.2    0.2    0.0    0.5    0.7FPS    0.1    0.7FT    IG     0.7FT     0.0AC    262MIN
  310MIN      0CFS      0CFS    0.0    0.1    0.0    0.1    0.5FPS    0.1    0.4FT  IIIA     0.4FT     0.0AC    310MIN
  382MIN      0CFS      0CFS    0.0    0.0    0.0    0.0    0.2FPS    0.1    0.1FT  IIIA     0.1FT     0.0AC    382MIN

              TOTAL VOLUMES     19     19

 TIME TO PEAK=   57MIN,  TIME TO MAX OUTFLO=   62MIN,   TIME TO MAX HW=   62MIN,
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                          WYOMING HIGHWAY DEPARTMENT
         ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
 CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
 STATION: 366+55.00  PROJECT: DRY CREEK            STATION 366+55+-          (EXAMPLE NO.1)
 CULV SIZE: 2  7.3X  4.5 CONCRETE ARCH /,SOCKET END PROJECTING INLET
 ANALYSIS TYPE: PERFORM DISCHGE   Q: 350CFS FREQ:  5YR DHW:12.00FT
 BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
 * * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |  AREA  | TIME  |

    0MIN      0CFS      0CFS    0.0     0.0     0.0    0.0     0.0FPS     0.0    0.0FT          0.0FT    0.0AC      0MIN
    6MIN     16CFS     14CFS    0.3     0.3     0.0    0.7     1.1FPS     0.2    1.3FT    IG    1.3FT    0.1AC      6MIN
   17MIN     54CFS     46CFS    0.7     0.6     0.1    1.3     2.0FPS     0.3    2.0FT    IG    2.0FT    0.1AC     17MIN
   26MIN    110CFS     90CFS    1.4     1.1     0.4    2.1     2.9FPS     0.3    2.5FT    IG    2.5FT    0.2AC     26MIN
   34MIN    180CFS    151CFS    1.7     1.4     0.7    2.8     3.9FPS     0.4    3.1FT    IG    3.1FT    0.3AC     34MIN
   41MIN    250CFS    222CFS    2.3     2.0     0.9    3.6     5.0FPS     0.5    3.6FT    IG    3.6FT    0.4AC     41MIN
   46MIN    309CFS    275CFS    1.9     1.7     1.1    4.2     5.7FPS     0.5    3.9FT    IG    3.9FT    0.4AC     46MIN
   51MIN    341CFS    315CFS    2.1     1.9     1.3    4.7     6.2FPS     0.5    4.1FT    IG    4.1FT    0.5AC     51MIN
   55MIN    347CFS    334CFS    2.1     2.1     1.3    4.9     6.5FPS     0.6    4.1FT    IG    4.1FT    0.5AC     55MIN
   60MIN    332CFS    334CFS    2.0     2.1     1.3    4.9     6.5FPS     0.6    4.1FT    IG    4.1FT    0.5AC     60MIN
   64MIN    308CFS    318CFS    1.9     2.0     1.3    4.7     6.3FPS     0.5    4.1FT    IG    4.1FT    0.5AC     64MIN
   69MIN    283CFS    297CFS    1.7     1.8     1.2    4.5     6.0FPS     0.5    4.0FT    IG    4.0FT    0.4AC     69MIN
   73MIN    258CFS    275CFS    1.6     1.7     1.1    4.2     5.7FPS     0.5    3.9FT    IG    3.9FT    0.4AC     73MIN
   78MIN    234CFS    249CFS    1.4     1.5     1.0    3.9     5.3FPS     0.5    3.7FT    IG    3.7FT    0.4AC     78MIN
   84MIN    206CFS    217CFS    2.2     2.3     0.9    3.6     4.9FPS     0.5    3.5FT    IG    3.5FT    0.4AC     84MIN
   91MIN    177CFS    188CFS    1.7     1.9     0.8    3.3     4.5FPS     0.4    3.3FT    IG    3.3FT    0.3AC     91MIN
   98MIN    149CFS    159CFS    1.6     1.7     0.7    2.9     4.1FPS     0.4    3.1FT    IG    3.1FT    0.3AC     98MIN
  109MIN    120CFS    127CFS    2.2     2.4     0.6    2.6     3.6FPS     0.4    2.9FT    IG    2.9FT    0.2AC    109MIN
  124MIN     88CFS     94CFS    2.2     2.3     0.4    2.1     3.0FPS     0.3    2.6FT    IG    2.6FT    0.2AC    124MIN
  141MIN     63CFS     69CFS    1.3     1.4     0.3    1.7     2.5FPS     0.3    2.3FT    IG    2.3FT    0.2AC    141MIN
  156MIN     50CFS     54CFS    1.0     1.1     0.2    1.5     2.2FPS     0.3    2.1FT    IG    2.1FT    0.1AC    156MIN
  170MIN     36CFS     40CFS    0.7     0.8     0.1    1.2     1.9FPS     0.2    1.9FT    IG    1.9FT    0.1AC    170MIN
  200MIN     20CFS     21CFS    1.3     1.3     0.0    0.9     1.4FPS     0.2    1.5FT    IG    1.5FT    0.1AC    200MIN
  245MIN      7CFS      7CFS    0.4     0.5     0.0    0.6     0.8FPS     0.2    1.0FT    IG    1.0FT    0.1AC    245MIN
  289MIN      1CFS      1CFS    0.1     0.1     0.0    0.1     0.5FPS     0.1    0.6FT    IG    0.6FT    0.0AC    289MIN
  356MIN      0CFS      0CFS    0.0     0.0     0.0    0.0     0.2FPS     0.1    0.1FT  IIIA    0.1FT    0.0AC    356MIN

             TOTAL VOLUMES       36      36

 TIME TO PEAK=   53MIN.  TIME TO MAX OUTFLO=   57MIN.   TIME TO MAX HW=   57MIN.
```

```
                             WYOMING HIGHWAY DEPARTMENT
        ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
 CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
 STATION:__366+55.00  PROJECT:  DRY CREEK            STATION 366+55+-        (EXAMPLE NO.1)
 CULV SIZE:_2=__7.3X__4.5 CONCRETE ARCH /,SOCKET END PROJECTING INLET
 ANALYSIS TYPE: PERFORM DISCHGE__  Q:_530CFS FRFQ:_10YR DHW:12.00FT
 BARREL GEOMETRY: LENGTH:_103FT SLOPE:1.00000% GVD:_9.0FT
 * * * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO.  | DEPTH | TYPE |WATER |  AREA  | TIME  |

    0MIN     0CFS     0CFS    0.0     0.0    0.0    0.0    0.0FPS    0.0    0.0FT          0.0FT   0.0AC     0MIN
    6MIN    24CFS    22CFS    0.4     0.4    0.0    0.9    1.4FPS    0.2    1.5FT    IG    1.5FT   0.1AC     6MIN
   16MIN    82CFS    64CFS    0.9     0.7    0.2    1.7    2.4FPS    0.3    2.2FT    IG    2.2FT   0.2AC    16MIN
   24MIN   167CFS   137CFS    1.9     1.5    0.6    2.7    3.7FPS    0.4    3.0FT    IG    3.0FT   0.3AC    24MIN
   31MIN   273CFS   232CFS    2.3     2.0    1.0    3.7    5.1FPS    0.5    3.6FT    IG    3.6FT   0.4AC    31MIN
   37MIN   379CFS   332CFS    3.2     2.8    1.3    4.9    6.5FPS    0.6    4.1FT    IG    4.1FT   0.5AC    37MIN
   43MIN   468CFS   391CFS    2.6     2.2    1.8    5.7    7.3FPS    0.6    4.4FT    IG    4.4FT   0.6AC    43MIN
   47MIN   516CFS   423CFS    2.9     2.4    2.3    6.1    7.9FPS    0.7    4.5FT    IE    4.5FT   0.7AC    47MIN
   51MIN   525CFS   448CFS    3.0     2.5    2.8    6.5    8.3FPS    0.7    4.5FT    IE    4.6FT   0.8AC    51MIN
   55MIN   503CFS   461CFS    2.8     2.6    3.0    6.8    8.6FPS    0.7    4.5FT    IE    4.7FT   0.9AC    55MIN
   59MIN   467CFS   462CFS    2.6     2.6    3.0    6.8    8.6FPS    0.7    4.5FT    IE    4.7FT   0.9AC    59MIN
   63MIN   429CFS   455CFS    2.4     2.6    2.9    6.7    8.5FPS    0.7    4.5FT    IE    4.7FT   0.9AC    63MIN
   67MIN   392CFS   440CFS    2.2     2.5    2.6    6.4    8.2FPS    0.7    4.5FT    IE    4.6FT   0.8AC    67MIN
   71MIN   354CFS   419CFS    2.0     2.4    2.2    6.1    7.8FPS    0.6    4.5FT    IE    4.5FT   0.7AC    71MIN
   77MIN   313CFS   379CFS    3.0     3.6    1.6    5.5    7.2FPS    0.6    4.3FT    IG    4.3FT   0.6AC    77MIN
   84MIN   269CFS   307CFS    2.4     2.8    1.2    4.6    6.1FPS    0.5    4.0FT    IG    4.0FT   0.5AC    84MIN
   90MIN   225CFS   248CFS    2.2     2.4    1.0    3.9    5.3FPS    0.5    3.7FT    IG    3.7FT   0.4AC    90MIN
  100MIN   182CFS   194CFS    3.1     3.3    0.8    3.3    4.6FPS    0.4    3.4FT    IG    3.4FT   0.3AC   100MIN
  114MIN   133CFS   142CFS    3.0     3.2    0.6    2.7    3.8FPS    0.4    3.0FT    IG    3.0FT   0.3AC   114MIN
  129MIN    96CFS   105CFS    1.8     2.0    0.5    2.3    3.2FPS    0.3    2.7FT    IG    2.7FT   0.2AC   129MIN
  143MIN    75CFS    81CFS    1.5     1.6    0.3    1.9    2.8FPS    0.3    2.4FT    IG    2.4FT   0.2AC   143MIN
  157MIN    55CFS    61CFS    1.0     1.1    0.2    1.6    2.4FPS    0.3    2.2FT    IG    2.2FT   0.1AC   157MIN
  184MIN    31CFS    34CFS    1.8     2.0    0.1    1.1    1.7FPS    0.2    1.8FT    IG    1.8FT   0.1AC   184MIN
  225MIN    11CFS    11CFS    0.6     0.7    0.0    0.7    1.0FPS    0.2    1.2FT    IG    1.2FT   0.1AC   225MIN
  266MIN     2CFS     2CFS    0.1     0.1    0.0    0.2    0.6FPS    0.1    0.6FT    IG    0.6FT   0.0AC   266MIN
  328MIN     0CFS     0CFS    0.0     0.0    0.0    0.0    0.2FPS    0.1    0.1FT  IIIA    0.1FT   0.0AC   328MIN

           TOTAL VOLUMES       50      50

 TIME TO PEAK=   49MIN,  TIME TO MAX OUTFLO=   61MIN,   TIME TO MAX HW=   61MIN.
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                         WYOMING HIGHWAY DEPARTMENT
       ENGINEERING  DIRECTORATE  ********  HYDRAULICS SECTION
 CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
 STATION:  366+55.00  PROJECT:  DRY CREEK           STATION 366+55+-        (EXAMPLE NO.1)
 CULV SIZE: 2=  7.3X  4.5 CONCRETE ARCH /,SOCKET END PROJECTING INLET
 ANALYSIS TYPE: PERFORM DISCHGE    Q:1080CFS FREQ: 50YR DHW:12.00FT
 BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
 * * * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |  AREA  | TIME  |

    0MIN     0CFS      0CFS    0.0     0.0     0.0    0.0     0.0FPS    0.0    0.0FT          0.0FT    0.0AC      0MIN
    5MIN    50CFS     42CFS    0.7     0.6     0.1    1.3     1.9FPS    0.2    1.9FT   IG     1.9FT    0.1AC      5MIN
   14MIN   167CFS    124CFS    1.6     1.2     0.5    2.5     3.5FPS    0.4    2.9FT   IG     2.9FT    0.2AC     14MIN
   21MIN   342CFS    280CFS    3.3     2.7     1.1    4.3     5.8FPS    0.5    3.9FT   IG     3.9FT    0.4AC     21MIN
   27MIN   558CFS    416CFS    4.1     3.0     2.2    6.0     7.7FPS    0.6    4.5FT   IE     4.5FT    0.7AC     27MIN
   32MIN   774CFS    515CFS    5.7     3.8     4.1    7.8     9.6FPS    0.8    4.5FT   IE     4.9FT    1.1AC     32MIN
   37MIN   954CFS    590CFS    4.6     2.9     5.8    9.4    16.1FPS    1.6    3.0FT   IF     5.1FT    1.5AC     37MIN
   40MIN  1053CFS    648CFS    5.1     3.2     7.9   10.8    16.4FPS    1.6    3.1FT   IF     5.3FT    2.3AC     40MIN
   44MIN  1071CFS    676CFS    5.2     3.3     9.8   11.6    16.6FPS    1.6    3.2FT   IF     5.4FT    3.1AC     44MIN
   47MIN  1026CFS    698CFS    5.0     3.4    11.4   12.2    16.7FPS    1.6    3.3FT   IF     5.5FT    4.5AC     47MIN
   51MIN   952CFS    713CFS    4.6     3.5    12.6   12.6    16.7FPS    1.6    3.4FT   IF     5.5FT    5.6AC     51MIN
   54MIN   875CFS    722CFS    4.3     3.5    13.3   12.9    13.4FPS    1.1    4.5FT  IVA     5.5FT    6.4AC     54MIN
   58MIN   799CFS    727CFS    3.9     3.5    13.6   13.0    13.5FPS    1.1    4.5FT  IVA     5.6FT    6.7AC     58MIN
   61MIN   722CFS    727CFS    3.5     3.5    13.6   13.0    13.5FPS    1.1    4.5FT  IVA     5.6FT    6.7AC     61MIN
   66MIN   638CFS    718CFS    5.3     5.9    13.0   12.7    13.4FPS    1.1    4.5FT  IVA     5.9FT    6.1AC     66MIN
   72MIN   548CFS    702CFS    4.3     5.5    11.8   12.3    16.7FPS    1.6    3.3FT   IF     5.9FT    4.8AC     72MIN
   78MIN   459CFS    678CFS    3.8     5.6    10.0   11.6    16.6FPS    1.6    3.3FT   IF     5.4FT    3.2AC     78MIN
   86MIN   371CFS    612CFS    5.4     8.9     6.4    9.9    16.2FPS    1.6    3.0FT   IF     5.2FT    1.6AC     86MIN
   98MIN   272CFS    454CFS    5.3     8.8     2.9    6.6     8.4FPS    0.7    4.5FT   IE     4.7FT    0.8AC     98MIN
  111MIN   196CFS    297CFS    3.2     4.8     1.2    4.5     6.0FPS    0.5    4.0FT   IG     4.0FT    0.4AC    111MIN
  123MIN   154CFS    180CFS    2.6     3.0     0.8    3.2     4.4FPS    0.4    3.3FT   IG     3.3FT    0.3AC    123MIN
  135MIN   113CFS    126CFS    1.8     2.0     0.6    2.5     3.5FPS    0.4    2.9FT   IG     2.9FT    0.2AC    135MIN
  159MIN    64CFS     70CFS    3.2     3.4     0.3    1.7     2.5FPS    0.3    2.3FT   IG     2.3FT    0.2AC    159MIN
  194MIN    22CFS     26CFS    1.1     1.3     0.1    1.0     1.5FPS    0.2    1.6FT   IG     1.6FT    0.1AC    194MIN
  229MIN     4CFS      5CFS    0.2     0.3     0.0    0.3     0.7FPS    0.1    0.9FT   IG     0.9FT    0.0AC    229MIN
  282MIN     0CFS      0CFS    0.0     0.0     0.0    0.0     0.2FPS    0.1    0.1FT IIIA     0.1FT    0.0AC    282MIN

           TOTAL VOLUMES       88      88

 TIME TO PEAK=   42MIN.  TIME TO MAX OUTFLO=   63MIN.   TIME TO MAX HW=   63MIN.
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                    WYOMING HIGHWAY DEPARTMENT
     ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
STATION: 366+55.00  PROJECT:  DRY CREEK               STATION 366+55+-         (EXAMPLE NO.1)
CULV SIZE: 2- 7.3X  4.5 CONCRETE ARCH /,SOCKET END PROJECTING INLET
ANALYSIS TYPE: PERFORM DISCHGE    Q:1390CFS FREQ:100YR DHW:12.00FT
BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
* * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  | OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |  AREA  | TIME  |

    0MIN     0CFS      0CFS    0.0    0.0    0.0   0.0    0.0FPS   0.0    0.0FT          0.0FT    0.0AC      0MIN
    4MIN    64CFS     52CFS    0.9    0.7    0.2   1.5    2.2FPS   0.3    2.1FT   IG     2.1FT    0.1AC      4MIN
   13MIN   215CFS    159CFS    2.0    1.5    0.7   2.9    4.1FPS   0.4    3.1FT   IG     3.1FT    0.3AC     13MIN
   19MIN   440CFS    356CFS    4.0    3.3    1.4   5.2    6.8FPS   0.6    4.2FT   IG     4.2FT    0.5AC     19MIN
   25MIN   718CFS    471CFS    4.9    3.2    3.2   6.9    8.8FPS   0.7    4.5FT   IE     4.7FT    0.9AC     25MIN
   30MIN   996CFS    595CFS    6.9    4.1    5.9   9.5   16.1FPS   1.6    3.0FT   IF     5.2FT    1.5AC     30MIN
   34MIN  1227CFS    660CFS    5.6    3.0    8.6  11.1   16.5FPS   1.6    3.2FT   IF     5.4FT    2.6AC     34MIN
   38MIN  1355CFS    700CFS    6.2    3.2   11.6  12.2   16.7FPS   1.6    3.3FT   IF     5.5FT    4.7AC     38MIN
   41MIN  1378CFS    738CFS    6.3    3.4   14.5  13.3   13.7FPS   1.1    4.5FT  IVA     5.6FT    7.6AC     41MIN
   44MIN  1320CFS    769CFS    6.1    3.5   17.1  14.3   14.3FPS   1.2    4.5FT  IVA     5.7FT   10.1AC     44MIN
   48MIN  1225CFS    793CFS    5.6    3.6   19.0  15.0   14.7FPS   1.2    4.5FT  IVA     5.7FT   12.1AC     48MIN
   51MIN  1127CFS    810CFS    5.2    3.7   20.5  15.6   15.1FPS   1.3    4.5FT  IVA     5.8FT   13.6AC     51MIN
   54MIN  1028CFS    822CFS    4.7    3.8   21.5  15.9   15.3FPS   1.3    4.5FT  IVA     5.8FT   14.5AC     54MIN
   58MIN   930CFS    827CFS    4.3    3.8   21.9  16.1   15.4FPS   1.3    4.5FT  IVA     5.8FT   15.0AC     58MIN
   62MIN   821CFS    826CFS    6.4    6.4   21.9  16.1   15.4FPS   1.3    4.5FT  IVA     5.8FT   15.0AC     62MIN
   68MIN   706CFS    817CFS    5.2    6.0   21.1  15.8   15.2FPS   1.3    4.5FT  IVA     5.8FT   14.2AC     68MIN
   73MIN   591CFS    798CFS    4.6    6.2   19.5  15.2   14.8FPS   1.2    4.5FT  IVA     5.8FT   12.5AC     73MIN
   81MIN   478CFS    753CFS    6.6   10.4   15.7  13.8   14.0FPS   1.2    4.5FT  IVA     5.6FT    8.8AC     81MIN
   93MIN   350CFS    675CFS    6.4   12.4    9.7  11.5   16.6FPS   1.6    3.2FT   IF     5.4FT    3.1AC     93MIN
  105MIN   252CFS    558CFS    3.8    8.5    5.0   8.7   15.8FPS   1.7    2.8FT   IF     5.0FT    1.3AC    105MIN
  116MIN   199CFS    399CFS    3.1    6.2    1.9   5.8    7.5FPS   0.6    4.4FT   IG     4.4FT    0.6AC    116MIN
  127MIN   145CFS    212CFS    2.2    3.2    0.9   3.5    4.8FPS   0.5    3.5FT   IG     3.5FT    0.3AC    127MIN
  149MIN    83CFS     93CFS    3.8    4.3    0.4   2.1    3.0FPS   0.3    2.6FT   IG     2.6FT    0.2AC    149MIN
  183MIN    28CFS     36CFS    1.3    1.7    0.1   1.2    1.8FPS   0.2    1.8FT   IG     1.8FT    0.1AC    183MIN
  216MIN     5CFS      6CFS    0.3    0.3    0.0   0.4    0.8FPS   0.1    1.0FT   IG     1.0FT    0.0AC    216MIN
  266MIN     0CFS      0CFS    0.0    0.0    0.0   0.0    0.2FPS   0.1    0.1FT IIIA     0.1FT    0.0AC    266MIN

           TOTAL VOLUMES       107    107

TIME TO PEAK=   39MIN,  TIME TO MAX OUTFLO=   59MIN,   TIME TO MAX HW=   59MIN,
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                       WYOMING HIGHWAY DEPARTMENT
       ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
CULVERT FLOOD ROUTING  PRINT OPTION NO, 2
STATION:__366+55.00  PROJECT: DRY CREEK           STATION 366+55+-        (EXAMPLE NO,1)
CULV SIZE:_1=  7.0X  6.0 CONCRETE BOX/30 -75 DEGREE WINGWALL INLET & NO BEVEL
ANALYSIS TYPE: DRAINAGE DESIGN    Q:_810CFS FREQ:_25YR DHW:12.00FT
BARREL GEOMETRY: LENGTH:_103FT SLOPE:1.00000% GVD:_9.0FT
* * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |  AREA  | TIME  |

    0MIN      0CFS      0CFS   0.0    0.0    0.0   0.0    0.0FPS    0.0   0.0FT          0.0FT   0.0AC      0MIN
    5MIN     37CFS     31CFS   0.6    0.5    0.1   1.3    2.6FPS    0.4   1.7FT    IG    1.7FT   0.1AC      5MIN
   15MIN    125CFS     84CFS   1.3    0.9    0.5   2.5   10.4FPS    1.7   1.2FT    IA    2.5FT   0.2AC     15MIN
   22MIN    256CFS    190CFS   2.7    2.0    1.2   4.5   13.5FPS    1.7   2.0FT    IA    3.4FT   0.5AC     22MIN
   29MIN    418CFS    300CFS   3.3    2.4    2.2   6.0   15.3FPS    1.6   2.8FT    IA    4.0FT   0.7AC     29MIN
   35MIN    580CFS    390CFS   4.5    3.1    3.7   7.4   16.4FPS    1.6   3.4FT    IA    4.4FT   1.0AC     35MIN
   39MIN    715CFS    458CFS   3.7    2.4    5.0   8.6   17.1FPS    1.5   3.8FT    IA    4.7FT   1.3AC     39MIN
   43MIN    789CFS    522CFS   4.1    2.7    6.4  10.0   17.6FPS    1.5   4.2FT    ID    4.9FT   1.7AC     43MIN
   47MIN    803CFS    559CFS   4.2    2.9    7.8  10.8   17.9FPS    1.5   4.5FT    ID    5.0FT   2.3AC     47MIN
   51MIN    769CFS    575CFS   4.0    3.0    8.8  11.2   18.0FPS    1.5   4.6FT    ID    5.1FT   2.7AC     51MIN
   54MIN    714CFS    586CFS   3.7    3.1    9.5  11.4   18.1FPS    1.5   4.6FT    ID    5.1FT   3.0AC     54MIN
   58MIN    656CFS    591CFS   3.4    3.1    9.8  11.6   18.1FPS    1.5   4.7FT    ID    5.1FT   3.1AC     58MIN
   62MIN    599CFS    591CFS   3.1    3.1    9.8  11.6   18.1FPS    1.5   4.7FT    ID    5.1FT   3.1AC     62MIN
   66MIN    542CFS    587CFS   2.8    3.1    9.6  11.5   18.1FPS    1.5   4.6FT    ID    5.1FT   3.0AC     66MIN
   71MIN    478CFS    575CFS   4.2    5.1    8.8  11.2   18.0FPS    1.5   4.6FT    ID    5.1FT   2.7AC     71MIN
   77MIN    411CFS    554CFS   3.4    4.6    7.5  10.7   17.9FPS    1.5   4.4FT    ID    5.0FT   2.2AC     77MIN
   83MIN    344CFS    506CFS   3.1    4.5    6.0   9.6   17.5FPS    1.5   4.1FT    ID    4.8FT   1.6AC     83MIN
   92MIN    278CFS    407CFS   4.4    6.4    4.0   7.7   16.6FPS    1.6   3.5FT    IA    4.5FT   1.1AC     92MIN
  106MIN    204CFS    296CFS   4.3    6.2    2.1   6.0   15.3FPS    1.6   2.8FT    IA    4.0FT   0.7AC    106MIN
  119MIN    147CFS    194CFS   2.5    3.4    1.3   4.6   13.6FPS    1.7   2.1FT    IA    3.4FT   0.5AC    119MIN
  132MIN    116CFS    134CFS   2.1    2.4    0.9   3.7   12.1FPS    1.7   1.6FT    IA    2.9FT   0.4AC    132MIN
  145MIN     85CFS     97CFS   1.5    1.7    0.7   3.0    5.4FPS    0.6   2.6FT    IG    2.6FT   0.3AC    145MIN
  170MIN     48CFS     55CFS   2.5    2.9    0.3   1.9    3.8FPS    0.5   2.1FT    IG    2.1FT   0.2AC    170MIN
  208MIN     16CFS     21CFS   0.9    1.1    0.1   1.0    2.1FPS    0.3   1.5FT    IG    1.5FT   0.1AC    208MIN
  246MIN      3CFS      4CFS   0.2    0.2    0.0   0.3    0.8FPS    0.2   0.8FT    IG    0.8FT   0.0AC    246MIN
  303MIN      0CFS      0CFS   0.0    0.0    0.0   0.1    0.1FPS    0.1   0.1FT  IIIA    0.1FT   0.0AC    303MIN

           TOTAL VOLUMES        71     71

TIME TO PEAK=   45MIN,  TIME TO MAX OUTFLO=   64MIN,   TIME TO MAX HW=   64MIN,
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                         WYOMING HIGHWAY DEPARTMENT
            ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
      CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
      STATION: 366+55.00  PROJECT:  DRY CREEK            STATION 366+55+-          (EXAMPLE NO.1)
      CULV SIZE: 1= 7.0X 6.0 CONCRETE BOX/30 -75 DEGREE WINGWALL INLET & NO BEVEL
      ANALYSIS TYPE: PERFORM DISCHGE   Q: 170CFS FREQ: 2YR DHW:12.00FT
      BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
      * * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
     |ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
     | TIME  | INFLOW | OUTFLOW| IN  |  OUT | STORE| HW,FT|VELOCITY|  NO.  | DEPTH | TYPE |WATER |  AREA  | TIME  |

         0MIN      0CFS      0CFS    0.0    0.0    0.0   0.0     0.0FPS    0.0    0.0FT          0.0FT   0.0AC     0MIN
         7MIN      7CFS      6CFS    0.2    0.1    0.0   0.6     1.0FPS    0.2    0.9FT    IG    0.9FT   0.1AC     7MIN
        19MIN     26CFS     23CFS    0.3    0.3    0.1   1.1     2.2FPS    0.3    1.5FT    IG    1.5FT   0.1AC    19MIN
        28MIN     53CFS     42CFS    0.7    0.6    0.2   1.6     3.2FPS    0.4    1.9FT    IG    1.9FT   0.1AC    28MIN
        37MIN     87CFS     67CFS    0.9    0.7    0.4   2.2     9.7FPS    1.7    1.0FT    IA    2.3FT   0.2AC    37MIN
        44MIN    121CFS     94CFS    1.2    0.9    0.7   3.0     5.3FPS    0.6    2.6FT    IG    2.6FT   0.3AC    44MIN
        50MIN    150CFS    123CFS    1.0    0.8    0.9   3.5    11.8FPS    1.7    1.5FT    IA    2.8FT   0.3AC    50MIN
        54MIN    165CFS    145CFS    1.1    1.0    1.0   3.9    12.4FPS    1.7    1.7FT    IA    3.0FT   0.4AC    54MIN
        59MIN    168CFS    158CFS    1.1    1.0    1.1   4.1    12.7FPS    1.7    1.8FT    IA    3.1FT   0.4AC    59MIN
        64MIN    161CFS    159CFS    1.1    1.1    1.1   4.1    12.8FPS    1.7    1.8FT    IA    3.1FT   0.4AC    64MIN
        69MIN    149CFS    154CFS    1.0    1.0    1.0   4.0    12.7FPS    1.7    1.7FT    IA    3.1FT   0.4AC    69MIN
        74MIN    137CFS    145CFS    0.9    1.0    1.0   3.9    12.4FPS    1.7    1.7FT    IA    3.0FT   0.4AC    74MIN
        78MIN    125CFS    135CFS    0.8    0.9    0.9   3.7    12.1FPS    1.7    1.6FT    IA    2.9FT   0.4AC    78MIN
        83MIN    113CFS    123CFS    0.7    0.8    0.9   3.5    11.8FPS    1.7    1.5FT    IA    2.8FT   0.3AC    83MIN
        90MIN    100CFS    108CFS    1.1    1.2    0.8   3.2     5.7FPS    0.6    2.7FT    IG    2.7FT   0.3AC    90MIN
        97MIN     86CFS     95CFS    0.9    1.0    0.7   3.0     5.3FPS    0.6    2.6FT    IG    2.6FT   0.3AC    97MIN
       105MIN     72CFS     84CFS    0.8    0.9    0.5   2.5    10.4FPS    1.7    1.2FT    IA    2.5FT   0.2AC   105MIN
       117MIN     58CFS     65CFS    1.2    1.3    0.4   2.1     9.6FPS    1.7    1.0FT    IA    2.2FT   0.2AC   117MIN
       133MIN     42CFS     48CFS    1.1    1.3    0.3   1.7     3.4FPS    0.4    2.0FT    IG    2.0FT   0.2AC   133MIN
       151MIN     30CFS     35CFS    0.7    0.8    0.2   1.4     2.9FPS    0.4    1.8FT    IG    1.8FT   0.1AC   151MIN
       167MIN     24CFS     27CFS    0.5    0.6    0.1   1.2     2.4FPS    0.3    1.6FT    IG    1.6FT   0.1AC   167MIN
       183MIN     17CFS     19CFS    0.4    0.4    0.1   1.0     2.0FPS    0.3    1.4FT    IG    1.4FT   0.1AC   183MIN
       214MIN     10CFS     10CFS    0.7    0.7    0.0   0.7     1.4FPS    0.2    1.1FT    IG    1.1FT   0.1AC   214MIN
       262MIN      3CFS      3CFS    0.2    0.2    0.0   0.5     0.7FPS    0.1    0.7FT    IG    0.7FT   0.0AC   262MIN
       310MIN      0CFS      0CFS    0.0    0.1    0.0   0.3     0.3FPS    0.1    0.4FT    IG    0.4FT   0.0AC   310MIN
       382MIN      0CFS      0CFS    0.0    0.0    0.0   0.1     0.1FPS    0.1    0.1FT  IIIA    0.1FT   0.0AC   382MIN

                TOTAL VOLUMES        19     19

      TIME TO PEAK=   57MIN,  TIME TO MAX OUTFLO=   66MIN,   TIME TO MAX HW=   66MIN,
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                        WYOMING HIGHWAY DEPARTMENT
        ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
 CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
 STATION:__366+55.00  PROJECT:  DRY CREEK            STATION 366+55+-         (EXAMPLE NO.1)
 CULV SIZE:_1=  7.0X  6.0 CONCRETE BOX/30 -75 DEGREE WINGWALL INLET & NO BEVEL
 ANALYSIS TYPE: PERFORM DISCHGE    Q:_350CFS FREQ:__5YR DHW:12.00FT
 BARREL GEOMETRY: LENGTH:_103FT SLOPE:1.00000% GVD:_9.0FT
 * * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO.  | DEPTH | TYPE |WATER |  AREA  | TIME  |

    0MIN      0CFS      0CFS    0.0    0.0    0.0    0.0    0.0FPS    0.0    0.0FT          0.0FT   0.0AC     0MIN
    6MIN     16CFS     14CFS    0.3    0.3    0.0    0.8    1.6FPS    0.3    1.3FT   IG     1.3FT   0.1AC     6MIN
   17MIN     54CFS     41CFS    0.7    0.5    0.2    1.5    3.1FPS    0.4    1.9FT   IG     1.9FT   0.1AC    17MIN
   26MIN    110CFS     84CFS    1.4    1.0    0.5    2.5   10.4FPS    1.7    1.2FT   IA     2.5FT   0.2AC    26MIN
   34MIN    180CFS    136CFS    1.7    1.3    0.9    3.7   12.2FPS    1.7    1.6FT   IA     3.0FT   0.4AC    34MIN
   41MIN    250CFS    210CFS    2.3    1.9    1.3    4.8   13.9FPS    1.7    2.2FT   IA     3.5FT   0.5AC    41MIN
   46MIN    309CFS    263CFS    1.9    1.6    1.6    5.5   14.8FPS    1.6    2.5FT   IA     3.8FT   0.6AC    46MIN
   51MIN    341CFS    287CFS    2.1    1.8    2.0    5.8   15.2FPS    1.6    2.7FT   IA     3.9FT   0.6AC    51MIN
   55MIN    347CFS    303CFS    2.1    1.9    2.2    6.1   15.4FPS    1.6    2.8FT   IA     4.0FT   0.7AC    55MIN
   60MIN    332CFS    311CFS    2.0    1.9    2.4    6.2   15.5FPS    1.6    2.9FT   IA     4.0FT   0.7AC    60MIN
   64MIN    308CFS    310CFS    1.9    1.9    2.4    6.2   15.5FPS    1.6    2.9FT   IA     4.0FT   0.7AC    64MIN
   69MIN    283CFS    303CFS    1.7    1.9    2.2    6.1   15.4FPS    1.6    2.8FT   IA     4.0FT   0.7AC    69MIN
   73MIN    258CFS    290CFS    1.6    1.8    2.0    5.9   15.2FPS    1.6    2.7FT   IA     3.9FT   0.7AC    73MIN
   78MIN    234CFS    274CFS    1.4    1.7    1.8    5.7   15.0FPS    1.6    2.6FT   IA     3.8FT   0.6AC    78MIN
   84MIN    206CFS    235CFS    2.2    2.5    1.4    5.2   14.3FPS    1.6    2.3FT   IA     3.6FT   0.5AC    84MIN
   91MIN    177CFS    196CFS    1.7    1.9    1.3    4.6   13.6FPS    1.7    2.1FT   IA     3.4FT   0.5AC    91MIN
   98MIN    149CFS    164CFS    1.6    1.7    1.1    4.2   12.9FPS    1.7    1.8FT   IA     3.2FT   0.4AC    98MIN
  109MIN    120CFS    130CFS    2.2    2.4    0.9    3.6   12.0FPS    1.7    1.6FT   IA     2.9FT   0.4AC   109MIN
  124MIN     88CFS     96CFS    2.2    2.4    0.7    3.0    5.3FPS    0.6    2.6FT   IG     2.6FT   0.3AC   124MIN
  141MIN     63CFS     74CFS    1.3    1.5    0.5    2.3   10.0FPS    1.7    1.1FT   IA     2.4FT   0.2AC   141MIN
  156MIN     50CFS     56CFS    1.0    1.2    0.3    1.9    3.8FPS    0.5    2.1FT   IG     2.1FT   0.2AC   156MIN
  170MIN     36CFS     42CFS    0.7    0.9    0.2    1.6    3.2FPS    0.4    1.9FT   IG     1.9FT   0.1AC   170MIN
  200MIN     20CFS     23CFS    1.3    1.4    0.1    1.1    2.2FPS    0.3    1.5FT   IG     1.5FT   0.1AC   200MIN
  245MIN      7CFS      7CFS    0.4    0.5    0.0    0.7    1.1FPS    0.2    1.0FT   IG     1.0FT   0.1AC   245MIN
  289MIN      1CFS      1CFS    0.1    0.1    0.0    0.3    0.4FPS    0.1    0.6FT   IG     0.6FT   0.0AC   289MIN
  356MIN      0CFS      0CFS    0.0    0.0    0.0    0.1    0.1FPS    0.1    0.1FT IIIA     0.1FT   0.0AC   356MIN

           TOTAL VOLUMES         36     36

 TIME TO PEAK=   53MIN,  TIME TO MAX OUTFLO=   62MIN,   TIME TO MAX HW=   62MIN,
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                      WYOMING HIGHWAY DEPARTMENT
      ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
CULVERT FLOOD ROUTING  PRINT OPTION NO. 2
STATION: 366+55.00  PROJECT:  DRY CREEK            STATION 366+55+-        (EXAMPLE NO.1)
CULV SIZE: 1= 7.0X 6.0 CONCRETE BOX/30 -75 DEGREE WINGWALL INLET & NO BEVEL
ANALYSIS TYPE: PERFORM DISCHGE   Q: 530CFS FREQ: 10YR DHW:12.00FT
BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
* * * * * * * *  C U L V E R T   F L O O D   R O U T I N G  * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *

|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |   POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |   AREA  | TIME  |

    0MIN      0CFS      0CFS    0.0     0.0     0.0    0.0    0.0FPS     0.0    0.0FT          0.0FT    0.0AC      0MIN
    6MIN     24CFS     21CFS    0.4     0.4     0.1    1.0    2.1FPS     0.3    1.5FT    IG    1.5FT    0.1AC      6MIN
   16MIN     82CFS     57CFS    0.9     0.7     0.3    1.9    3.9FPS     0.5    2.1FT    IG    2.1FT    0.2AC     16MIN
   24MIN    167CFS    121CFS    1.9     1.4     0.9    3.5   11.7FPS     1.7    1.5FT    IA    2.8FT    0.3AC     24MIN
   31MIN    273CFS    216CFS    2.3     1.8     1.3    4.9   14.0FPS     1.7    2.2FT    IA    3.5FT    0.5AC     31MIN
   37MIN    379CFS    295CFS    3.2     2.5     2.1    5.9   15.3FPS     1.6    2.8FT    IA    4.0FT    0.7AC     37MIN
   43MIN    468CFS    340CFS    2.6     1.9     2.8    6.6   15.9FPS     1.6    3.1FT    IA    4.2FT    0.8AC     43MIN
   47MIN    516CFS    383CFS    2.9     2.2     3.6    7.3   16.4FPS     1.6    3.3FT    IA    4.4FT    1.0AC     47MIN
   51MIN    525CFS    416CFS    3.0     2.4     4.2    7.9   16.7FPS     1.6    3.6FT    IA    4.5FT    1.1AC     51MIN
   55MIN    503CFS    436CFS    2.8     2.5     4.6    8.2   16.9FPS     1.5    3.7FT    IA    4.6FT    1.2AC     55MIN
   59MIN    467CFS    443CFS    2.6     2.5     4.7    8.4   17.0FPS     1.5    3.7FT    IA    4.6FT    1.3AC     59MIN
   63MIN    429CFS    440CFS    2.4     2.5     4.7    8.3   16.9FPS     1.5    3.7FT    IA    4.6FT    1.3AC     63MIN
   67MIN    392CFS    429CFS    2.2     2.4     4.4    8.1   16.8FPS     1.6    3.6FT    IA    4.6FT    1.2AC     67MIN
   71MIN    354CFS    412CFS    2.0     2.3     4.1    7.8   16.7FPS     1.6    3.5FT    IA    4.5FT    1.1AC     71MIN
   77MIN    313CFS    378CFS    3.0     3.6     3.5    7.2   16.3FPS     1.6    3.3FT    IA    4.3FT    1.0AC     77MIN
   84MIN    269CFS    340CFS    2.4     3.1     2.8    6.6   15.9FPS     1.6    3.1FT    IA    4.2FT    0.8AC     84MIN
   90MIN    225CFS    297CFS    2.2     2.9     2.1    6.0   15.3FPS     1.6    2.8FT    IA    4.0FT    0.7AC     90MIN
  100MIN    182CFS    224CFS    3.1     3.8     1.4    5.0   14.1FPS     1.7    2.3FT    IA    3.6FT    0.5AC    100MIN
  114MIN    133CFS    150CFS    3.0     3.4     1.0    3.9   12.5FPS     1.7    1.7FT    IA    3.1FT    0.4AC    114MIN
  129MIN     96CFS    109CFS    1.8     2.0     0.8    3.2    5.7FPS     0.6    2.7FT    IG    2.7FT    0.3AC    129MIN
  143MIN     75CFS     87CFS    1.5     1.7     0.6    2.6   10.5FPS     1.7    1.2FT    IA    2.5FT    0.2AC    143MIN
  157MIN     55CFS     64CFS    1.0     1.2     0.4    2.1    9.5FPS     1.7    1.0FT    IA    2.2FT    0.2AC    157MIN
  184MIN     31CFS     35CFS    1.8     2.0     0.2    1.4    2.9FPS     0.4    1.8FT    IG    1.8FT    0.1AC    184MIN
  225MIN     11CFS     13CFS    0.6     0.7     0.0    0.8    1.5FPS     0.2    1.2FT    IG    1.2FT    0.1AC    225MIN
  266MIN      2CFS      2CFS    0.1     0.1     0.0    0.3    0.6FPS     0.1    0.7FT    IG    0.7FT    0.0AC    266MIN
  328MIN      0CFS      0CFS    0.0     0.0     0.0    0.1    0.1FPS     0.1    0.1FT  IIIA    0.1FT    0.0AC    328MIN

             TOTAL VOLUMES       50      50

TIME TO PEAK=   49MIN.  TIME TO MAX OUTFLO=   61MIN.   TIME TO MAX HW=   61MIN.
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                         WYOMING HIGHWAY DEPARTMENT
         ENGINEERING  DIRECTORATE  ********  HYDRAULICS SECTION
 CULVERT FLOOD ROUTING  PRINT OPTION NO, 2
 STATION: 366+55.00  PROJECT:  DRY CREEK           STATION 366+55+-        (EXAMPLE NO.1)
 CULV SIZE: 1= 7.0X  6.0 CONCRETE BOX/30 -75 DEGREE WINGWALL INLET & NO BEVEL
 ANALYSIS TYPE: PERFORM DISCHGE    Q:1080CFS FREQ: 50YR DHW:12.00FT
 BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
 * * * * * * * *  C U L V E R T  F L O O D  R O U T I N G  * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |  POND  |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO.  | DEPTH | TYPE |WATER |  AREA  | TIME  |

    0MIN     0CFS     0CFS    0.0    0.0    0.0    0.0     0.0FPS    0.0    0.0FT          0.0FT    0.0AC     0MIN
    5MIN    50CFS    38CFS    0.7    0.6    0.2    1.5     3.0FPS    0.4    1.8FT   IG     1.8FT    0.1AC     5MIN
   14MIN   167CFS   107CFS    1.6    1.0    0.8    3.2     5.7FPS    0.6    2.7FT   IG     2.7FT    0.3AC    14MIN
   21MIN   342CFS   260CFS    3.3    2.5    1.6    5.5    14.8FPS    1.6    2.5FT   IA     3.8FT    0.6AC    21MIN
   27MIN   558CFS   354CFS    4.1    2.6    3.1    6.8    16.0FPS    1.6    3.2FT   IA     4.2FT    0.9AC    27MIN
   32MIN   774CFS   471CFS    5.7    3.4    5.3    8.9    17.2FPS    1.5    3.9FT   IA     4.7FT    1.4AC    32MIN
   37MIN   954CFS   549CFS    4.6    2.7    7.3   10.6    17.8FPS    1.5    4.4FT   ID     5.0FT    2.0AC    37MIN
   40MIN  1053CFS   587CFS    5.1    2.9    9.6   11.5    18.1FPS    1.5    4.6FT   ID     5.1FT    3.0AC    40MIN
   44MIN  1071CFS   619CFS    5.2    3.0   11.8   12.3    18.3FPS    1.5    4.8FT   ID     5.2FT    4.9AC    44MIN
   47MIN  1026CFS   645CFS    5.0    3.1   13.7   13.0    18.5FPS    1.5    5.0FT   ID     5.3FT    6.8AC    47MIN
   51MIN   952CFS   663CFS    4.6    3.2   15.0   13.5    18.6FPS    1.5    5.1FT   ID     5.4FT    8.1AC    51MIN
   54MIN   875CFS   676CFS    4.3    3.3   16.0   13.9    18.7FPS    1.4    5.2FT   ID     5.4FT    9.1AC    54MIN
   58MIN   799CFS   683CFS    3.9    3.3   16.6   14.1    18.7FPS    1.4    5.2FT   ID     5.4FT    9.7AC    58MIN
   61MIN   722CFS   686CFS    3.5    3.3   16.8   14.2    18.7FPS    1.4    5.2FT   ID     5.4FT    9.9AC    61MIN
   66MIN   638CFS   681CFS    5.3    5.6   16.4   14.0    18.7FPS    1.4    5.2FT   ID     5.4FT    9.5AC    66MIN
   72MIN   548CFS   669CFS    4.3    5.2   15.5   13.7    18.6FPS    1.4    5.1FT   ID     5.4FT    8.6AC    72MIN
   78MIN   459CFS   648CFS    3.8    5.4   13.9   13.1    18.5FPS    1.5    5.0FT   ID     5.3FT    7.0AC    78MIN
   86MIN   371CFS   601CFS    5.4    8.8   10.6   11.8    18.2FPS    1.5    4.7FT   ID     5.2FT    3.6AC    86MIN
   98MIN   272CFS   503CFS    5.3    9.8    6.0    9.5    17.5FPS    1.5    4.1FT   ID     4.8FT    1.6AC    98MIN
  111MIN   196CFS   365CFS    3.2    5.9    3.3    7.0    16.2FPS    1.6    3.2FT   IA     4.3FT    0.9AC   111MIN
  123MIN   154CFS   257CFS    2.6    4.3    1.6    5.4    14.7FPS    1.6    2.5FT   IA     3.8FT    0.5AC   123MIN
  135MIN   113CFS   146CFS    1.8    2.3    1.0    3.9    12.4FPS    1.7    1.7FT   IA     3.0FT    0.4AC   135MIN
  159MIN    64CFS    75CFS    3.2    3.7    0.5    2.3    10.0FPS    1.7    1.1FT   IA     2.4FT    0.2AC   159MIN
  194MIN    22CFS    30CFS    1.1    1.5    0.1    1.3     2.6FPS    0.4    1.7FT   IG     1.7FT    0.1AC   194MIN
  229MIN     4CFS     6CFS    0.2    0.3    0.0    0.4     1.0FPS    0.2    0.9FT   IG     0.9FT    0.0AC   229MIN
  282MIN     0CFS     0CFS    0.0    0.0    0.0    0.1     0.1FPS    0.1    0.2FT IIIA     0.2FT    0.0AC   282MIN
             TOTAL VOLUMES     88     88
 TIME TO PEAK=   42MIN.  TIME TO MAX OUTFLO=   63MIN.   TIME TO MAX HW=   63MIN.
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                      WYOMING HIGHWAY DEPARTMENT
       ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
 CULVERT FLOOD ROUTING  PRINT OPTION NO, 2
 STATION: 366+55.00  PROJECT:  DRY CREEK           STATION 366+55+-        (EXAMPLE NO,1)
 CULV SIZE: 1- 7.0X 6.0 CONCRETE BOX/30 -75 DEGREE WINGWALL INLET & NO BEVEL
 ANALYSIS TYPE: PERFORM DISCHGE    Q:1390CFS FREQ:100YR DHW:12.00FT
 BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
 * * * * * * * * *  C U L V E R T   F L O O D   R O U T I N G  * * * * * * * * * * * * * * *CULVERT FLOOD ROUTING* * *
|ROUTING| ***DISCHARGES***| ****VOLUMES(AF)****| HEAD | OUTLET | FROUDE| BRINK | FLOW |TAIL- |   POND   |ROUTING|
| TIME  | INFLOW | OUTFLOW|  IN  |  OUT | STORE| HW,FT|VELOCITY|  NO. | DEPTH | TYPE |WATER |   AREA   | TIME  |

    0MIN     0CFS     0CFS    0.0    0.0    0.0    0.0    0.0FPS    0.0    0.0FT         0.0FT    0.0AC      0MIN
    4MIN    64CFS    47CFS    0.9    0.6    0.3    1.7    3.4FPS    0.4    2.0FT   IG    2.0FT    0.2AC      4MIN
   13MIN   215CFS   139CFS    2.0    1.3    1.0    3.8   12.2FPS    1.7    1.6FT   IA    3.0FT    0.4AC     13MIN
   19MIN   440CFS   303CFS    4.0    2.8    2.2    6.1   15.4FPS    1.6    2.8FT   IA    4.0FT    0.7AC     19MIN
   25MIN   718CFS   421CFS    4.9    2.9    4.3    8.0   16.8FPS    1.6    3.6FT   IA    4.5FT    1.2AC     25MIN
   30MIN   996CFS   551CFS    6.9    3.8    7.4   10.6   17.9FPS    1.5    4.4FT   ID    5.0FT    2.1AC     30MIN
   34MIN  1227CFS   598CFS    5.6    2.7   10.3   11.7   18.2FPS    1.5    4.7FT   ID    5.2FT    3.4AC     34MIN
   38MIN  1355CFS   644CFS    6.2    3.0   13.6   13.0   18.5FPS    1.5    5.0FT   ID    5.3FT    6.7AC     38MIN
   41MIN  1378CFS   685CFS    6.3    3.1   16.7   14.1   18.7FPS    1.4    5.2FT   ID    5.4FT    9.8AC     41MIN
   44MIN  1320CFS   719CFS    6.1    3.3   19.5   15.2   18.9FPS    1.4    5.4FT   ID    5.5FT   12.6AC     44MIN
   48MIN  1225CFS   745CFS    5.6    3.4   21.7   16.0   19.1FPS    1.4    5.6FT   ID    5.6FT   14.8AC     48MIN
   51MIN  1127CFS   764CFS    5.2    3.5   23.4   16.6   19.2FPS    1.4    5.7FT   ID    5.7FT   16.5AC     51MIN
   54MIN  1028CFS   777CFS    4.7    3.6   24.5   17.1   19.2FPS    1.4    5.8FT   ID    5.7FT   17.6AC     54MIN
   58MIN   930CFS   784CFS    4.3    3.6   25.2   17.3   19.3FPS    1.4    5.8FT   ID    5.7FT   18.3AC     58MIN
   62MIN   821CFS   787CFS    6.4    6.1   25.5   17.4   19.3FPS    1.4    5.8FT   ID    5.7FT   18.6AC     62MIN
   68MIN   706CFS   781CFS    5.2    5.7   24.9   17.2   19.2FPS    1.4    5.8FT   ID    5.7FT   18.0AC     68MIN
   73MIN   591CFS   766CFS    4.6    6.0   23.6   16.7   19.2FPS    1.4    5.7FT   ID    5.7FT   16.6AC     73MIN
   81MIN   478CFS   727CFS    6.6   10.0   20.1   15.4   19.0FPS    1.4    5.5FT   ID    5.6FT   13.2AC     81MIN
   93MIN   350CFS   657CFS    6.4   12.1   14.5   13.3   18.6FPS    1.5    5.1FT   ID    5.4FT    7.6AC     93MIN
  105MIN   252CFS   585CFS    3.8    8.9    9.5   11.4   18.1FPS    1.5    4.6FT   ID    5.1FT    3.0AC    105MIN
  116MIN   199CFS   467CFS    3.1    7.3    5.2    8.8   17.2FPS    1.5    3.9FT   IA    4.7FT    1.4AC    116MIN
  127MIN   145CFS   321CFS    2.2    4.9    2.5    6.3   15.6FPS    1.6    2.9FT   IA    4.1FT    0.8AC    127MIN
  149MIN    83CFS   119CFS    3.8    5.5    0.8    3.4   11.7FPS    1.7    1.5FT   IA    2.8FT    0.3AC    149MIN
  183MIN    28CFS    42CFS    1.3    2.0    0.2    1.6    3.2FPS    0.4    1.9FT   IG    1.9FT    0.1AC    183MIN
  216MIN     5CFS     9CFS    0.3    0.5    0.0    0.6    1.3FPS    0.2    1.1FT   IG    1.1FT    0.1AC    216MIN
  266MIN     0CFS     0CFS    0.0    0.0    0.0    0.1    0.1FPS    0.0    0.3FT IIIA    0.3FT    0.0AC    266MIN

            TOTAL VOLUMES     107    107

 TIME TO PEAK=   39MIN,  TIME TO MAX OUTFLO=   65MIN,   TIME TO MAX HW=   65MIN,


ALL CULVERT TYPES REQUESTED HAVE BEEN DESIGNED
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CHANNEL FLOW DISTRIBUTION FOR  DRY CREEK          STATION 366+55+-         (EXAMPLE NO.1)

                   ELEVATION          DISCHARGE        STARTING X          ENDING X           DEPTH

                     5375.3             350.0            -15.7               17.0               4.2
     X               Y             FROUDE          VELOCITY       DISCHARGE      ACCUMULATED     PERCENT         TRACTIVE
 COORDINATE      COORDINATE        NUMBER                                         DISCHARGE     OF  TOTAL         SHEAR

   -14.9           5375.1          0.3117             0.58            0.1            0.1            0.0          0.0642
   -13.8           5374.8          0.3814             1.31            0.5            0.6            0.2          0.2154
   -12.6           5374.5          0.4222             1.97            1.6            2.1            0.6          0.3964
   -11.5           5374.2          0.4495             2.53            2.7            4.8            1.4          0.5774
   -10.4           5373.9          0.4697             3.02            4.2            9.0            2.6          0.7515
    -9.3           5373.6          0.4863             3.47            5.9           15.0            4.3          0.9257
    -8.3           5373.3          0.5004             3.89            7.9           22.9            6.5          1.0998
    -7.2           5373.0          0.5129             4.29           10.1           33.0            9.4          1.2739
    -6.1           5372.7          0.5239             4.67           12.5           45.5           13.0          1.4481
    -5.0           5372.4          0.5339             5.04           15.1           60.7           17.3          1.6222
    -3.4           5372.0          0.5459             5.47           26.9           87.6           25.0          1.8296
    -2.3           5371.7          0.5558             5.88           23.3          110.8           31.7          2.0369
    -1.1           5371.4          0.5635             6.21           26.7          137.6           39.3          2.2111
     0.0           5371.1          0.5706             6.53           30.3          167.9           48.0          2.3852
     1.2           5371.4          0.5718             6.54           32.0          199.9           57.1          2.3852
     2.4           5371.7          0.5647             6.22           28.2          228.1           65.2          2.2111
     3.6           5372.0          0.5570             5.89           24.6          252.7           72.2          2.0369
     5.3           5372.4          0.5471             5.48           28.4          281.2           80.3          1.8296
     6.5           5372.7          0.5363             5.06           16.8          298.0           85.2          1.6222
     7.7           5373.0          0.5262             4.69           13.9          312.0           89.1          1.4481
     8.9           5373.3          0.5151             4.31           11.3          323.2           92.4          1.2739
    10.1           5373.6          0.5026             3.91            8.8          332.0           94.9          1.0998
    11.3           5373.9          0.4884             3.48            6.6          338.7           96.8          0.9257
    12.5           5374.2          0.4717             3.03            4.7          343.3           98.1          0.7515
    13.7           5374.5          0.4514             2.54            3.0          346.3           99.0          0.5774
    15.0           5374.8          0.4240             1.98            1.7          348.1           99.5          0.3964
    16.1           5375.1          0.3823             1.31            0.6          348.6           99.6          0.2154
 DISCHARGE         AVERAGE        VELOCITY         FROUDE          ALPHA          BETA          SPECIFIC        SPECIFIC
                    DEPTH                          NUMBER                                       HEAD(FT)       FORCE(LB)

    350.              2.1           5.03           0.6092         1.1807         1.0650          4.676           9725.
  MAXIMUM CHANNEL VELOCITY=           6.54
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CHANNEL FLOW DISTRIBUTION FOR  DRY CREEK          STATION 366+55+-          (EXAMPLE NO.1)

             ELEVATION          DISCHARGE          STARTING X          ENDING X          DEPTH

                5378.0             1288.3             -24.9               27.4              6.9

     X             Y            FROUDE          VELOCITY        DISCHARGE     ACCUMULATED      PERCENT        TRACTIVE
 COORDINATE    COORDINATE       NUMBER                                         DISCHARGE     OF   TOTAL        SHEAR

    -24.8        5378.0         0.1996            0.10             0.0             0.0            0.0          0.0046
    -23.9        5377.7         0.3315            0.76             0.1             0.1            0.0          0.0962
    -22.9        5377.4         0.3938            1.52             0.7             0.8            0.1          0.2704
    -21.9        5377.1         0.4278            2.11             1.6             2.3            0.2          0.4445
    -21.0        5376.8         0.4520            2.63             2.7             5.0            0.4          0.6186
    -20.0        5376.5         0.4711            3.11             4.1             9.1            0.7          0.7928
    -19.2        5376.3         0.4879            3.51             4.5            13.6            1.1          0.9440
    -18.1        5376.0         0.5001            3.88             7.9            21.5            1.7          1.0952
    -17.0        5375.7         0.5125            4.28            10.1            31.5            2.4          1.2694
    -15.9        5375.4         0.5236            4.66            12.5            44.0            3.4          1.4435
    -14.9        5375.1         0.5337            5.03            15.1            59.1            4.6          1.6176
    -13.8        5374.8         0.5429            5.38            17.9            76.9            6.0          1.7918
    -12.6        5374.5         0.5516            5.74            22.6            99.5            7.7          1.9728
    -11.5        5374.2         0.5598            6.09            24.3           123.8            9.6          2.1538
    -10.4        5373.9         0.5671            6.41            27.6           151.4           11.8          2.3279
     -9.3        5373.6         0.5739            6.73            31.2           182.6           14.2          2.5020
     -8.3        5373.3         0.5804            7.03            34.8           217.4           16.9          2.6762
     -7.2        5373.0         0.5865            7.34            38.7           256.1           19.9          2.8503
     -6.1        5372.7         0.5923            7.63            42.7           298.8           23.2          3.0244
     -5.0        5372.4         0.5979            7.92            46.9           345.8           26.8          3.1986
     -3.4        5372.0         0.6055            8.28            75.8           421.6           32.7          3.4059
     -2.3        5371.7         0.6115            8.61            60.5           482.1           37.4          3.6133
     -1.1        5371.4         0.6163            8.89            65.5           547.6           42.5          3.7874
      0.0        5371.1         0.6210            9.16            70.6           618.2           48.0          3.9616
      1.2        5371.4         0.6223            9.18            74.6           692.8           53.8          3.9616
      2.4        5371.7         0.6177            8.91            69.2           762.0           59.1          3.7874
      3.6        5372.0         0.6128            8.63            64.0           826.0           64.1          3.6133
      5.3        5372.4         0.6068            8.30            80.1           906.1           70.3          3.4059
      6.5        5372.7         0.6005            7.96            52.2           958.4           74.4          3.1986
      7.7        5373.0         0.5949            7.67            47.6          1006.0           78.1          3.0244
      8.9        5373.3         0.5891            7.37            43.1          1049.1           81.4          2.8503
     10.1        5373.6         0.5829            7.07            38.8          1087.9           84.4          2.6762
     11.3        5373.9         0.5764            6.76            34.7          1122.6           87.1          2.5020
     12.5        5374.2         0.5695            6.44            30.8          1153.3           89.5          2.3279
     13.7        5374.5         0.5622            6.11            27.0          1180.3           91.6          2.1538
     15.0        5374.8         0.5540            5.77            25.2          1205.5           93.6          1.9728
     16.1        5375.1         0.5441            5.40            18.9          1224.4           95.0          1.7918
     17.3        5375.4         0.5349            5.04            15.9          1240.3           96.3          1.6176
     18.4        5375.7         0.5249            4.67            13.2          1253.5           97.3          1.4435
     19.6        5376.0         0.5138            4.29            10.6          1264.1           98.1          1.2694
     20.7        5376.3         0.5013            3.89             8.3          1272.4           98.8          1.0952
     21.6        5376.5         0.4890            3.52             4.8          1277.2           99.1          0.9440
     22.7        5376.8         0.4750            3.13             4.9          1282.1           99.5          0.7928
     23.9        5377.1         0.4558            2.66             3.2          1285.3           99.8          0.6186
     25.0        5377.4         0.4313            2.13             1.8          1287.1           99.9          0.4445
     26.2        5377.7         0.3970            1.53             0.8          1287.9          100.0          0.2704
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     X              Y            FROUDE       VELOCITY     DISCHARGE    ACCUMULATED     PERCENT       TRACTIVE
COORDINATE     COORDINATE        NUMBER                                  DISCHARGE     OF   TOTAL       SHEAR

    27.3          5378.0          0.3342          0.77          0.1        1288.1         100.0         0.0962
 DISCHARGE       AVERAGE        VELOCITY        FROUDE        ALPHA          BETA        SPECIFIC       SPECIFIC
                  DEPTH                         NUMBER                                   HEAD(FT)       FORCE(LB)
   1288.            3.5           7.01          0.6586        1.1797        1.0647         7.801         45219.
    MAXIMUM CHANNEL VELOCITY=         9.18
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   CHANNEL FLOW DISTRIBUTION FOR  DRY CREEK          STATION 366+55+-        (EXAMPLE NO.1)

              ELEVATION          DISCHARGE        STARTING X           ENDING X            DEPTH

                 5376.9              810.0             -21.2              23.0               5.8
       X             Y            FROUDE        VELOCITY      DISCHARGE    ACCUMULATED     PERCENT        TRACTIVE
  COORDINATE    COORDINATE        NUMBER                                    DISCHARGE     OF   TOTAL        SHEAR

     -21.0         5376.8         0.2651          0.31           0.0           0.0           0.0          0.0252
     -20.0         5376.5         0.3518          0.97           0.2           0.2           0.0          0.1375
     -19.2         5376.3         0.4004          1.59           0.6           0.9           0.1          0.2887
     -18.1         5376.0         0.4296          2.11           1.7           2.6           0.3          0.4399
     -17.0         5375.7         0.4541          2.64           3.0           5.6           0.7          0.6141
     -15.9         5375.4         0.4734          3.11           4.5          10.1           1.2          0.7882
     -14.9         5375.1         0.4894          3.56           6.3          16.4           2.0          0.9623
     -13.8         5374.8         0.5032          3.97           8.4          24.8           3.1          1.1365
     -12.6         5374.5         0.5157          4.39          11.5          36.3           4.5          1.3175
     -11.5         5374.2         0.5269          4.78          13.3          49.6           6.1          1.4985
     -10.4         5373.9         0.5367          5.14          15.9          65.5           8.1          1.6726
      -9.3         5373.6         0.5456          5.49          18.8          84.3          10.4          1.8467
      -8.3         5373.3         0.5538          5.83          21.8         106.1          13.1          2.0209
      -7.2         5373.0         0.5615          6.16          25.0         131.2          16.2          2.1950
      -6.1         5372.7         0.5687          6.49          28.4         159.6          19.7          2.3692
      -5.0         5372.4         0.5755          6.80          32.0         191.6          23.7          2.5433
      -3.4         5372.0         0.5843          7.18          53.1         244.7          30.2          2.7506
      -2.3         5371.7         0.5915          7.54          43.4         288.1          35.6          2.9580
      -1.1         5371.4         0.5971          7.83          47.7         335.8          41.5          3.1321
       0.0         5371.1         0.6025          8.12          52.2         388.0          47.9          3.3063
       1.2         5371.4         0.6038          8.13          55.2         443.2          54.7          3.3063
       2.4         5371.7         0.5984          7.85          50.4         493.6          60.9          3.1321
       3.6         5372.0         0.5927          7.55          45.9         539.5          66.6          2.9580
       5.3         5372.4         0.5856          7.20          56.1         595.6          73.5          2.7506
       6.5         5372.7         0.5780          6.83          35.6         631.3          77.9          2.5433
       7.7         5373.0         0.5712          6.51          31.7         662.9          81.8          2.3692
       8.9         5373.3         0.5640          6.19          27.9         690.8          85.3          2.1950
      10.1         5373.6         0.5563          5.86          24.3         715.1          88.3          2.0209
      11.3         5373.9         0.5480          5.52          20.9         736.0          90.9          1.8467
      12.5         5374.2         0.5390          5.16          17.7         753.8          93.1          1.6726
      13.7         5374.5         0.5292          4.80          14.8         768.5          94.9          1.4985
      15.0         5374.8         0.5180          4.41          12.9         781.4          96.5          1.3175
      16.1         5375.1         0.5044          3.98           8.8         790.2          97.6          1.1365
      17.3         5375.4         0.4906          3.57           6.7         796.9          98.4          0.9623
      18.4         5375.7         0.4745          3.12           4.8         801.7          99.0          0.7882
      19.6         5376.0         0.4552          2.64           3.2         804.9          99.4          0.6141
      20.7         5376.3         0.4306          2.12           1.8         806.7          99.6          0.4399
      21.6         5376.5         0.4014          1.60           0.7         807.4          99.7          0.2887
      22.7         5376.8         0.3547          0.97           0.3         807.6          99.7          0.1375
  DISCHARGE       AVERAGE        VELOCITY        FROUDE         ALPHA          BETA        SPECIFIC       SPECIFIC
                   DEPTH                         NUMBER                                    HEAD(FT)       FORCE(LB)

     810.             2.9           6.22         0.6403         1.1816        1.0654         6.492         26084.
     MAXIMUM CHANNEL VELOCITY=         8.13
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CHANNEL FLOW DISTRIBUTION FOR  DRY CREEK          STATION 366+55+-        (EXAMPLE NO.1)

                ELEVATION         DISCHARGE         STARTING X          ENDING X          DEPTH

                  5382.5            4950.9             -82.9              43.7             11.4

     X              Y            FROUDE         VELOCITY       DISCHARGE    ACCUMULATED     PERCENT       TRACTIVE
 COORDINATE     COORDINATE       NUMBER                                       DISCHARGE    OF  TOTAL        SHEAR

   -81.3          5382.4         0.3881            0.51            0.0            0.0          0.0         0.0309
   -77.0          5382.1         0.5043            1.44            1.6            1.6          0.0         0.1489
   -59.9          5381.7         0.5837            2.58           26.6           28.2          0.6         0.3551
   -47.5          5381.4         0.6300            3.50           41.7           70.0          1.4         0.5614
   -35.0          5381.1         0.6590            4.19           65.5          135.4          2.7         0.7355
   -34.0          5380.8         0.4821            3.41            5.2          140.6          2.8         0.9108
   -33.1          5380.5         0.4965            3.83            6.9          147.5          3.0         1.0861
   -31.6          5380.1         0.5117            4.32           13.7          161.2          3.3         1.3014
   -30.7          5379.8         0.5249            4.79           12.0          173.2          3.5         1.5168
   -29.7          5379.5         0.5345            5.15           14.4          187.6          3.8         1.6909
   -28.7          5379.2         0.5433            5.50           16.9          204.5          4.1         1.8651
   -27.7          5378.9         0.5514            5.83           19.6          224.2          4.5         2.0392
   -26.8          5378.6         0.5590            6.16           22.5          246.7          5.0         2.2133
   -25.8          5378.3         0.5661            6.48           25.6          272.2          5.5         2.3875
   -24.8          5378.0         0.5728            6.79           28.7          301.0          6.1         2.5616
   -23.9          5377.7         0.5791            7.10           32.1          333.0          6.7         2.7358
   -22.9          5377.4         0.5851            7.39           35.5          368.6          7.4         2.9099
   -21.9          5377.1         0.5908            7.69           39.1          407.7          8.2         3.0840
   -21.0          5376.8         0.5962            7.97           42.9          450.6          9.1         3.2582
   -20.0          5376.5         0.6014            8.26           46.8          497.4         10.0         3.4323
   -19.2          5376.3         0.6093            8.55           41.8          539.2         10.9         3.5835
   -18.1          5376.0         0.6135            8.79           60.7          599.9         12.1         3.7347
   -17.0          5375.7         0.6182            9.06           65.5          665.4         13.4         3.9089
   -15.9          5375.4         0.6227            9.32           70.5          735.9         14.9         4.0830
   -14.9          5375.1         0.6271            9.59           75.5          811.4         16.4         4.2571
   -13.8          5374.8         0.6313            9.85           80.8          892.2         18.0         4.4313
   -12.6          5374.5         0.6355           10.11           93.1          985.3         19.9         4.6123
   -11.5          5374.2         0.6396           10.38           92.1         1077.4         21.8         4.7933
   -10.4          5373.9         0.6434           10.62           97.7         1175.1         23.7         4.9674
    -9.3          5373.6         0.6471           10.87          103.5         1278.5         25.8         5.1416
    -8.3          5373.3         0.6507           11.12          109.4         1387.9         28.0         5.3157
    -7.2          5373.0         0.6542           11.36          115.4         1503.3         30.4         5.4898
    -6.1          5372.7         0.6576           11.60          121.6         1624.9         32.8         5.6640
    -5.0          5372.4         0.6610           11.83          127.9         1752.8         35.4         5.8381
    -3.4          5372.0         0.6663           12.14          197.2         1950.0         39.4         6.0455
    -2.3          5371.7         0.6700           12.41          151.0         2101.0         42.4         6.2528
    -1.1          5371.4         0.6731           12.64          158.1         2259.1         45.6         6.4270
     0.0          5371.1         0.6761           12.87          165.3         2424.4         49.0         6.6011
     1.2          5371.4         0.6776           12.90          174.7         2599.1         52.5         6.6011
     2.4          5371.7         0.6746           12.67          167.1         2766.3         55.9         6.4270
     3.6          5372.0         0.6715           12.44          159.6         2925.9         59.1         6.2528
     5.3          5372.4         0.6677           12.16          208.5         3134.4         63.3         6.0455
     6.5          5372.7         0.6639           11.88          142.4         3276.8         66.2         5.8381
     7.7          5373.0         0.6605           11.65          135.4         3412.2         68.9         5.6640
     8.9          5373.3         0.6571           11.41          128.5         3540.7         71.5         5.4898
    10.1          5373.6         0.6536           11.16          121.8         3662.5         74.0         5.3157
```

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     X             Y          FROUDE      VELOCITY    DISCHARGE   ACCUMULATED    PERCENT     TRACTIVE
 COORDINATE    COORDINATE     NUMBER                               DISCHARGE    OF  TOTAL     SHEAR

    11.3         5373.9       0.6499       10.92        115.2       3777.7         76.3        5.1416
    12.5         5374.2       0.6462       10.67        108.8       3886.5         78.5        4.9674
    13.7         5374.5       0.6424       10.42        102.5       3989.0         80.6        4.7933
    15.0         5374.8       0.6383       10.16        103.7       4092.8         82.7        4.6123
    16.1         5375.1       0.6328        9.87         85.4       4178.1         84.4        4.4313
    17.3         5375.4       0.6286        9.61         79.9       4258.0         86.0        4.2571
    18.4         5375.7       0.6242        9.35         74.5       4332.5         87.5        4.0830
    19.6         5376.0       0.6197        9.08         69.3       4401.8         88.9        3.9089
    20.7         5376.3       0.6150        8.81         64.2       4466.0         90.2        3.7347
    21.6         5376.5       0.6108        8.57         44.2       4510.1         91.1        3.5835
    22.7         5376.8       0.6064        8.32         55.8       4565.9         92.2        3.4323
    23.9         5377.1       0.6012        8.04         51.1       4617.1         93.3        3.2582
    25.0         5377.4       0.5957        7.75         46.7       4663.7         94.2        3.0840
    26.2         5377.7       0.5899        7.46         42.4       4706.1         95.1        2.9099
    27.3         5378.0       0.5839        7.16         38.2       4744.3         95.8        2.7358
    28.4         5378.3       0.5775        6.85         34.3       4778.6         96.5        2.5616
    29.6         5378.6       0.5708        6.53         30.5       4809.0         97.1        2.3875
    30.7         5378.9       0.5636        6.21         26.8       4835.9         97.7        2.2133
    31.9         5379.2       0.5560        5.88         23.4       4859.3         98.1        2.0392
    33.0         5379.5       0.5478        5.54         20.2       4879.5         98.6        1.8651
    34.2         5379.8       0.5389        5.19         17.1       4896.6         98.9        1.6909
    35.3         5380.1       0.5292        4.83         14.3       4910.9         99.2        1.5168
    37.0         5380.5       0.5159        4.36         16.3       4927.2         99.5        1.3014
    38.0         5380.8       0.4971        3.84          7.0       4934.3         99.7        1.0861
    39.0         5381.1       0.4827        3.41          5.3       4939.6         99.8        0.9108
    40.0         5381.4       0.4658        2.96          3.7       4943.3         99.8        0.7355
    41.0         5381.7       0.4453        2.47          2.3       4945.6         99.9        0.5614
    42.3         5382.1       0.4126        1.82          1.5       4947.1         99.9        0.3551
    43.3         5382.4       0.3569        1.02          0.3       4947.3         99.9        0.1489
 DISCHARGE      AVERAGE      VELOCITY     FROUDE       ALPHA        BETA       SPECIFIC     SPECIFIC
                 DEPTH                    NUMBER                               HEAD(FT)    FORCE(LB)

   4951.          4.2          9.41       0.8134       1.2565      1.0933       13.129      217633.
   MAXIMUM CHANNEL VELOCITY=      12.90
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CHANNEL FLOW DISTRIBUTION FOR  DRY CREEK          STATION 366+55+-        (EXAMPLE NO.1)

             ELEVATION         DISCHARGE        STARTING X          ENDING X           DEPTH

                5378.2           1390.0            -25.5              28.1              7.1
     X            Y           FROUDE        VELOCITY       DISCHARGE     ACCUMULATED      PERCENT       TRACTIVE
COORDINATE    COORDINATE      NUMBER                                      DISCHARGE     OF  TOTAL       SHEAR

    -24.8        5378.0       0.3089            0.57            0.0            0.0           0.0        0.0630
    -23.9        5377.7       0.3784            1.29            0.5            0.5           0.0        0.2131
    -22.9        5377.4       0.4181            1.93            1.2            1.7           0.1        0.3872
    -21.9        5377.1       0.4447            2.47            2.3            4.0           0.3        0.5614
    -21.0        5376.8       0.4652            2.96            3.6            7.6           0.5        0.7355
    -20.0        5376.5       0.4820            3.41            5.1           12.7           0.9        0.9096
    -19.2        5376.3       0.4974            3.80            5.5           18.2           1.3        1.0608
    -18.1        5376.0       0.5086            4.15            9.3           27.5           2.0        1.2121
    -17.0        5375.7       0.5201            4.54           11.6           39.2           2.8        1.3862
    -15.9        5375.4       0.5305            4.91           14.2           53.3           3.8        1.5603
    -14.9        5375.1       0.5399            5.27           16.9           70.3           5.1        1.7345
    -13.8        5374.8       0.5486            5.62           19.8           90.1           6.5        1.9086
    -12.6        5374.5       0.5569            5.97           24.9          115.0           8.3        2.0896
    -11.5        5374.2       0.5647            6.30           26.5          141.5          10.2        2.2706
    -10.4        5373.9       0.5717            6.62           30.0          171.5          12.3        2.4448
     -9.3        5373.6       0.5783            6.93           33.6          205.1          14.8        2.6189
     -8.3        5373.3       0.5845            7.24           37.4          242.5          17.4        2.7930
     -7.2        5373.0       0.5905            7.54           41.4          283.9          20.4        2.9672
     -6.1        5372.7       0.5961            7.83           45.5          329.4          23.7        3.1413
     -5.0        5372.4       0.6015            8.11           49.8          379.2          27.3        3.3154
     -3.4        5372.0       0.6089            8.47           80.2          459.4          33.0        3.5228
     -2.3        5371.7       0.6148            8.80           63.8          523.2          37.6        3.7302
     -1.1        5371.4       0.6195            9.07           68.9          592.1          42.6        3.9043
      0.0        5371.1       0.6240            9.34           74.1          666.2          47.9        4.0784
      1.2        5371.4       0.6253            9.36           78.3          744.5          53.6        4.0784
      2.4        5371.7       0.6208            9.09           72.8          817.3          58.8        3.9043
      3.6        5372.0       0.6161            8.82           67.5          884.8          63.7        3.7302
      5.3        5372.4       0.6102            8.49           84.8          969.6          69.8        3.5228
      6.5        5372.7       0.6041            8.15           55.5         1025.0          73.7        3.3154
      7.7        5373.0       0.5987            7.86           50.7         1075.7          77.4        3.1413
      8.9        5373.3       0.5930            7.57           46.1         1121.8          80.7        2.9672
     10.1        5373.6       0.5871            7.27           41.7         1163.5          83.7        2.7930
     11.3        5373.9       0.5808            6.96           37.4         1200.9          86.4        2.6189
     12.5        5374.2       0.5742            6.65           33.4         1234.3          88.8        2.4448
     13.7        5374.5       0.5672            6.33           29.5         1263.8          90.9        2.2706
     15.0        5374.8       0.5594            5.99           27.7         1291.5          92.9        2.0896
     16.1        5375.1       0.5499            5.63           21.0         1312.5          94.4        1.9086
     17.3        5375.4       0.5412            5.28           17.9         1330.4          95.7        1.7345
     18.4        5375.7       0.5317            4.92           15.0         1345.4          96.8        1.5603
     19.6        5376.0       0.5213            4.55           12.3         1357.7          97.7        1.3862
     20.7        5376.3       0.5098            4.16            9.8         1367.5          98.4        1.2121
     21.6        5376.5       0.4986            3.81            5.8         1373.3          98.8        1.0608
     22.7        5376.8       0.4860            3.43            6.1         1379.4          99.2        0.9096
     23.9        5377.1       0.4691            2.98            4.3         1383.7          99.5        0.7355
     25.0        5377.4       0.4484            2.49            2.7         1386.4          99.7        0.5614
     26.2        5377.7       0.4215            1.94            1.5         1387.9          99.8        0.3872
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     X            Y           FROUDE       VELOCITY     DISCHARGE   ACCUMULATED    PERCENT      TRACTIVE
 COORDINATE   COORDINATE      NUMBER                                 DISCHARGE    OF  TOTAL      SHEAR

    27.3         5378.0       0.3816         1.31          0.5        1388.5         99.9        0.2131
 DISCHARGE     AVERAGE       VELOCITY      FROUDE        ALPHA         BETA        SPECIFIC     SPECIFIC
                DEPTH                      NUMBER                                  HEAD(FT)     FORCE(LB)

   1390.         3.6           7.15        0.6622        1.1784       1.0642        8.035        49409.
   MAXIMUM CHANNEL VELOCITY=      9.36
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Example No. 2 - Culvert Design for Irrigation (Peak) Discharge

This example uses a specified design discharge, a downstream cross section and profile slope, culvert slope, allowable headwater, and maximum allowable culvert barrel height to determine six acceptable culvert sizes (one size for each type). The output shows the stage-discharge relationship for the downstream cross section and culvert sizes and hydraulics for all six culvert types. The short form output format was selected which displays only the culvert performance data for the requested design and performance curve discharges.

FORM C-16
Rev. 3/11/69

WYOMING STATE HIGHWAY DEPARTMENT
CHEYENNE WYOMING
BRIDGE DIVISION

SHEET NO 1 OF 1
BY JEK DATE 6-16-78
CHECKED WRB

DESIGN SYSTEM

1 COMMENT CARD 64

100 DRY CREEK STATION 362+55± (EXAMPLE NO. 2)

1 2 WORK CODE	3 5 DATA CODE	ENTRY 1 6 15	ENTRY 2 25	ENTRY 3 35	ENTRY 4 45	ENTRY 5 55	ENTRY 6 65	66 CONT
HF	002							
	001	1.0	0.0	0.0	0.0056			
	020	-80.0	5323.2	-44.0	5323.0	-30.0	5314.6	1
	020	-12.0	5314.5	-21.0	5311.7	0.0	5312.0	1
	020	5.5	5315.4	11.0	5319.6	50.0	5319.9	1
	020	134.0	5324.6					
	030	-44.0	0.033	-12.0	0.045	11.0	0.04	
HC	001							
	001	1.0	1.0	0.0	36255.0	90.0	0.0075	
	002	11.0	53.0	11.0	83.0	11.0	11.0	
	004	485.0	120.0	260.0	395.0	705.0	970.0	
	010	8.0	7.0					

TRAILER CARD

999
1 3

NOTE: A trailer card must follow the last structure card containing data

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                         WYOMING HIGHWAY DEPARTMENT
                PRECONSTRUCTION DIVISION      HYDRAULICS SECTION
                     CHANNEL STAGE DISCHARGE RELATIONSHIP
       DRY CREEK      STATION 362+55+-       (EXAMPLE NO.2)
                        CHANNEL SLOPE =  0.00560FT/FT

                     STAGE DISCHARGE INPUT VERIFICATION
                                                                  INPUT VERIFIED?
                                                          DESIGNER____    CHECKER____
            X( 1) =   -80.0   Y( 1) = 5323.2   MANNINGS NUMBER = .033
            X( 2) =   -44.0   Y( 2) = 5323.0   MANNINGS NUMBER = .033
            X( 3) =   -30.0   Y( 3) = 5314.6   MANNINGS NUMBER = .045
            X( 4) =   -12.0   Y( 4) = 5314.5   MANNINGS NUMBER = .045
            X( 5) =    -2.0   Y( 5) = 5311.7   MANNINGS NUMBER = .040
            X( 6) =     0.0   Y( 6) = 5312.0   MANNINGS NUMBER = .040
            X( 7) =     5.5   Y( 7) = 5315.4   MANNINGS NUMBER = .040
            X( 8) =    11.0   Y( 8) = 5319.6   MANNINGS NUMBER = .040
            X( 9) =    50.0   Y( 9) = 5319.9   MANNINGS NUMBER = .040
            X(10) =   109.0   Y(10) = 5323.2   MANNINGS NUMBER = .040
*** NOTE *** LAST POINT WAS INTFRPOLATED
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                     WYOMING HIGHWAY DEPARTMENT
             PRECONSTRUCTION DIVISION      HYDRAULICS SECTION
                 CHANNEL STAGE DISCHARGE RELATIONSHIP
  DRY CREEK        STATION 362+55+-       (EXAMPLE NO.2)
                    CHANNEL SLOPE =  0.00560FT/FT

ELEVATION               DEPTH          DISCHARGE           VELOCITY            MAX. VELOCITY
 5311.7                  0.0               0.0                0.0                  0.0
 5312.0                  0.3               0.4                0.8                  0.8
 5312.3                  0.6               2.4                1.5                  1.6
 5312.6                  0.9               6.4                2.0                  2.3
 5312.9                  1.2              12.7                2.4                  2.8
 5313.2                  1.5              21.7                2.8                  3.4
 5313.5                  1.8              33.8                3.1                  3.8
 5313.8                  2.1              49.1                3.5                  4.3
 5314.1                  2.4              68.1                3.8                  4.7
 5314.5                  2.8             101.8                4.2                  5.3
 5314.6                  2.9             111.2                4.1                  5.4
 5314.9                  3.2             148.6                4.0                  5.8
 5315.2                  3.5             196.6                4.1                  6.2
 5315.4                  3.7             235.7                4.3                  6.4
 5315.7                  4.0             299.1                4.5                  6.8
 5316.0                  4.3             371.0                4.8                  7.1
 5316.3                  4.6             451.0                5.1                  7.5
 5316.6                  4.9             539.1                5.3                  7.8
 5316.9                  5.2             635.0                5.6                  8.1
 5317.2                  5.5             738.7                5.9                  8.4
 5317.5                  5.8             850.2                6.2                  8.7
 5317.8                  6.1             969.4                6.4                  9.0
 5318.1                  6.4            1096.3                6.7                  9.3
 5318.4                  6.7            1230.9                6.9                  9.6
 5318.7                  7.0            1373.2                7.2                  9.9
 5319.0                  7.3            1523.1                7.4                 10.2
 5319.3                  7.6            1680.8                7.7                 10.5
 5319.6                  7.9            1870.9                7.9                 10.8
 5319.9                  8.2            2052.2                8.0                 11.1
 5320.2                  8.5            2258.5                7.9                 11.4
 5320.5                  8.8            2489.8                8.0                 11.6
 5320.8                  9.1            2745.5                8.0                 11.9
 5321.1                  9.4            3025.8                8.0                 12.1
 5321.4                  9.7            3331.3                8.1                 12.4
 5321.7                 10.0            3662.7                8.2                 12.7
 5322.0                 10.3            4020.6                8.3                 12.9
 5322.3                 10.6            4405.9                8.4                 13.2
 5322.6                 10.9            4819.2                8.5                 13.4
 5323.0                 11.3            5468.4                8.7                 13.8
 5323.2                 11.5            5793.3                8.8                 13.9
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                    WYOMING HIGHWAY DEPARTMENT
        ENGINEERING  DIRECTORATE  ********  HYDRAULICS SECTION
 CULVERT PERFORMANCE    PRINT OPTION NO. 1
 STATION:__362+55.00  PROJECT: DRY CREEK      STATION 362+55+-      (EXAMPLE NO.2)
 CULV SIZE:_2=__5.5X__5.5 ROUND CONCRETE/,SOCKET END PROJECTING INLET
 ANALYSIS TYPE: IRRIGATION DESIGN  Q:_485CFS FREQ:___WR DHW:_8.00FT
 BARREL GEOMETRY: LENGTH:__90FT SLOPE:0.75000% GVD:_7.0FT
 * * * * * * * *  C U L V E R T   P E R F O R M A N C E  * * * * * * * * *   ****DOWNSTREAM CHANNEL PERFORMANCE****
| INFLOW   |FLOOD| OUTFLOW   |HEAD | OUTLET |FROUDE|BRINK |FLOW|*****POND****** |  TAIL- | *VEL(FPS)* |  BED   | OUTFLOW |
|DISCHARGE|FREQ |DISCHARGE |HW,FT|VELOCITY|  NO. |DEPTH |TYPE| AREA |DURATION |  WATER | MAX | AVE  | SHEAR  |DISCHARGE|
  485 CFS   25YR  485 CFS   7.2   13.7FPS   1.2   3.8FT   IA*****AC*******MIN    4.7FT   7.6   5.2   1.59PSF  485.0 CFS

                 ***** REVIEW Q =  120 *****
  120 CFS    2YR  120 CFS   2.9    4.6FPS   0.5   3.0FT   IG*****AC*******MIN    3.0FT   5.5   4.1   0.99PSF  120.0 CFS

                 ***** REVIEW Q =  260 *****
  260 CFS    5YR  260 CFS   4.9    7.4FPS   0.7   3.8FT   IG*****AC*******MIN    3.8FT   6.6   4.4   1.28PSF  260.0 CFS

                 ***** REVIEW Q =  395 *****
  395 CFS   10YR  395 CFS   6.3   13.2FPS   1.3   3.3FT   IA*****AC*******MIN    4.4FT   7.2   4.9   1.48PSF  395.0 CFS

                 ***** REVIEW Q =  705 *****
  705 CFS   50YR  705 CFS  10.0   15.5FPS   1.2   5.0FT  VII*****AC*******MIN    5.4FT   8.3   5.8   1.83PSF  705.0 CFS

                 ***** REVIEW Q =  970 *****
  970 CFS  100YR  970 CFS  14.6   20.4FPS   1.5   5.5FT  VIB*****AC*******MIN    6.1FT   9.0   6.4   2.07PSF  970.0 CFS
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                         WYOMING HIGHWAY DEPARTMENT
          ENGINEERING  DIRECTORATE  ********  HYDRAULICS SECTION
 CULVERT PERFORMANCE    PRINT OPTION NO, 1
 STATION:__362+55,00  PROJECT: DRY CREEK      STATION 362+55+-      (EXAMPLE NO,2)
 CULV SIZE:_2-__6,5X__6,5 ROUND METAL  (  SPP  )/         COMMERICAL END(FE) INLET
 ANALYSIS TYPE: IRRIGATION_DESIGN  Q:_485CFS FREQ:___WR DHW:_8,00FT
 BARREL GEOMETRY: LENGTH:___90FT SLOPE:0,75000% GVD:_7,0FT
 * * * * * * * *  C U L V E R T   P E R F O R M A N C E  * * * * * * * * * *   ****DOWNSTREAM CHANNEL PERFORMANCE****
| INFLOW   |FLOOD| OUTFLOW   |HEAD | OUTLET |FROUDE|BRINK |FLOW|*****POND****** |  TAIL- | *VEL(FPS)* |  BED    | OUTFLOW |
|DISCHARGE|FREQ |DISCHARGE  |HW,FT|VELOCITY|  NO, |DEPTH |TYPE| AREA |DURATION |  WATER | MAX | AVE  | SHEAR   |DISCHARGE|
  485 CFS    25YR    485 CFS    8,0    10,8FPS    0,9    4,2FT    V*****AC*******MIN    4,7FT    7,6    5,2    1,59PSF  485,0 CFS

                  ***** REVIEW Q =  120 *****
  120 CFS     2YR    120 CFS    2,9     4,1FPS    0,4    3,0FT IIIA*****AC*******MIN    3,0FT    5,5    4,1    0,99PSF  120,0 CFS

                  ***** REVIEW Q =  260 *****
  260 CFS     5YR    260 CFS    4,5     6,4FPS    0,6    3,8FT IIIA*****AC*******MIN    3,8FT    6,6    4,4    1,28PSF  260,0 CFS

                  ***** REVIEW Q =  395 *****
  395 CFS    10YR    395 CFS    5,8     8,3FPS    0,7    4,4FT IIIA*****AC*******MIN    4,4FT    7,2    4,9    1,48PSF  395,0 CFS

                  ***** REVIEW Q =  705 *****
  705 CFS    50YR    705 CFS   10,4    12,8FPS    1,0    5,0FT    V*****AC*******MIN    5,4FT    8,3    5,8    1,83PSF  705,0 CFS

                  ***** REVIEW Q =  970 *****
  970 CFS   100YR    970 CFS   14,4    15,6FPS    1,1    5,8FT    V*****AC*******MIN    6,1FT    9,0    6,4    2,07PSF  970,0 CFS
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                      WYOMING HIGHWAY DEPARTMENT
      ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
CULVERT PERFORMANCE    PRINT OPTION NO, 1
STATION: 362+55.00  PROJECT: DRY CREEK      STATION 362+55+-      (EXAMPLE NO.2)
CULV SIZE: 1= 9.4X 6.0 CONCRETE ELLIPSE(HORIZ AXIS)/,SOCKET END PROJECTING INLET
ANALYSIS TYPE: IRRIGATION DESIGN  Q: 485CFS FREQ:   WR DHW: 8.00FT
BARREL GEOMETRY: LENGTH:  90FT SLOPE:0.75000% GVD: 7.0FT
* * * * * * * * *  C U L V E R T   P E R F O R M A N C E  * * * * * * * * * *   ****DOWNSTREAM CHANNEL PERFORMANCE****
| INFLOW  |FLOOD| OUTFLOW  |HEAD | OUTLET |FROUDE|BRINK |FLOW|*****POND****** |  TAIL- | *VEL(FPS)* |  BED    | OUTFLOW |
|DISCHARGE|FREQ |DISCHARGE |HW,FT|VELOCITY| NO,  |DEPTH |TYPE| AREA |DURATION |  WATER | MAX | AVE  | SHEAR   |DISCHARGE|
  485 CFS   25YR   485 CFS   7.9   16.4FPS   1.5   3.7FT   IA*****AC*******MIN    4.7FT   7.6   5.2   1.59PSF   485.0 CFS

                *****_REVIEW_Q = 120 *****
  120 CFS    2YR   120 CFS   3.3    5.3FPS   0.5   3.0FT   IG*****AC*******MIN    3.0FT   5.5   4.1   0.99PSF   120.0 CFS

                *****_REVIEW_Q = 260 *****
  260 CFS    5YR   260 CFS   5.1   13.5FPS   1.5   2.6FT   IA*****AC*******MIN    3.8FT   6.6   4.4   1.28PSF   260.0 CFS

                *****_REVIEW_Q = 395 *****
  395 CFS   10YR   395 CFS   6.7   15.5FPS   1.5   3.3FT   IA*****AC*******MIN    4.4FT   7.2   4.9   1.48PSF   395.0 CFS

                *****_REVIEW_Q = 705 *****
  705 CFS   50YR   705 CFS  12.1   17.7FPS   1.4   4.9FT   ID*****AC*******MIN    5.4FT   8.3   5.8   1.83PSF   705.0 CFS

                *****_REVIEW_Q = 970 *****
  970 CFS  100YR   970 CFS  14.9   21.1FPS   1.5   6.0FT  VIB*****AC*******MIN    6.1FT   9.0   6.4   2.07PSF   970.0 CFS
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                 WYOMING HIGHWAY DEPARTMENT
       ENGINEERING  DIRECTORATE  ********  HYDRAULICS SECTION
CULVERT PERFORMANCE    PRINT OPTION NO. 1
STATION: 362+55.00  PROJECT: DRY CREEK      STATION 362+55+-      (EXAMPLE NO.2)
CULV SIZE: 2- 7.0X 5.1    METAL PIPE ARCH    / UNPAVED /MITERED-STEP BEVEL INLET
ANALYSIS TYPE: IRRIGATION DESIGN  Q: 485CFS FREQ:   WR DHW: 8.00FT
BARREL GEOMETRY: LENGTH: 90FT SLOPE:0.75000% GVD: 7.0FT
* * * * * * * *  C U L V E R T   P E R F O R M A N C E  * * * * * * * * * *    ****DOWNSTREAM CHANNEL PERFORMANCE****
| INFLOW   |FLOOD| OUTFLOW  |HEAD | OUTLET |FROUDE|BRINK |FLOW|*****POND****** |  TAIL- | *VEL(FPS)* |  BED    | OUTFLOW |
|DISCHARGE|FREQ |DISCHARGE |HW,FT|VELOCITY| NO.  |DEPTH |TYPE| AREA |DURATION |  WATER | MAX | AVE  | SHEAR   |DISCHARGE|
 485 CFS    25YR   485 CFS   7.8   11.1FPS   1.0    3.5FT    V*****AC*******MIN    4.7FT   7.6   5.2   1.59PSF  485.0 CFS

                   ***** REVIEW Q =  120 *****
 120 CFS     2YR   120 CFS   2.7    3.3FPS   0.3    3.0FT IIIA*****AC*******MIN    3.0FT   5.5   4.1   0.99PSF  120.0 CFS

                   ***** REVIEW Q =  260 *****
 260 CFS     5YR   260 CFS   4.5    5.6FPS   0.5    3.8FT IIIA*****AC*******MIN    3.8FT   6.6   4.4   1.28PSF  260.0 CFS

                   ***** REVIEW Q =  395 *****
 395 CFS    10YR   395 CFS   6.7   10.1FPS   1.0    3.2FT    V*****AC*******MIN    4.4FT   7.2   4.9   1.48PSF  395.0 CFS

                   ***** REVIEW Q =  705 *****
 705 CFS    50YR   705 CFS  11.9   12.6FPS   1.0    5.1FT  VIB*****AC*******MIN    5.4FT   8.3   5.8   1.83PSF  705.0 CFS

                   ***** REVIEW Q =  970 *****
 970 CFS   100YR   970 CFS  19.0   17.3FPS   1.4    5.1FT  VIB*****AC*******MIN    6.1FT   9.0   6.4   2.07PSF  970.0 CFS
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                         WYOMING HIGHWAY DEPARTMENT
         ENGINEERING  DIRECTORATE  ********  HYDRAULICS SECTION
CULVERT PERFORMANCE     PRINT OPTION NO. 1
STATION:__362+55.00  PROJECT: DRY CREEK       STATION 362+55+-       (EXAMPLE NO.2)
CULV SIZE:_2=  7.3X  4.5 CONCRETE ARCH /,SOCKET END PROJECTING INLET
ANALYSIS TYPE: IRRIGATION DESIGN  Q:_485CFS FREQ:___WR DHW:_8.00FT
BARREL GEOMETRY: LENGTH:__90FT SLOPE:0.75000% GVD:_7.0FT
* * * * * * * * *  C U L V E R T   P E R F O R M A N C E  * * * * * * * * * * *   ****DOWNSTREAM CHANNEL PERFORMANCE****
| INFLOW   |FLOOD| OUTFLOW  |HEAD | OUTLET |FROUDE|BRINK |FLOW|*****POND****** |  TAIL- | *VEL(FPS)* |  BED    | OUTFLOW |
|DISCHARGE|FREQ |DISCHARGE |HW,FT|VELOCITY|  NO. |DEPTH |TYPE| AREA |DURATION |  WATER | MAX | AVE  | SHEAR   |DISCHARGE|
  485 CFS    25YR    485 CFS    7.2     9.0FPS   0.7    4.5FT    IE*****AC*******MIN     4.7FT    7.6    5.2    1.59PSF   485.0 CFS

                  ***** REVIEW Q =  120 *****

  120 CFS     2YR    120 CFS    2.5     3.2FPS   0.3    3.0FT    IG*****AC*******MIN     3.0FT    5.5    4.1    0.99PSF   120.0 CFS

                  ***** REVIEW Q =  260 *****

  260 CFS     5YR    260 CFS    4.0     5.4FPS   0.5    3.8FT    IG*****AC*******MIN     3.8FT    6.6    4.4    1.28PSF   260.0 CFS

                  ***** REVIEW Q =  395 *****

  395 CFS    10YR    395 CFS    5.7     7.4FPS   0.6    4.4FT    IG*****AC*******MIN     4.4FT    7.2    4.9    1.48PSF   395.0 CFS

                  ***** REVIEW Q =  705 *****

  705 CFS    50YR    705 CFS   12.4    13.1FPS   1.1    4.5FT   IVA*****AC*******MIN     5.4FT    8.3    5.8    1.83PSF   705.0 CFS

                  ***** REVIEW Q =  970 *****

  970 CFS   100YR    970 CFS   14.7    18.0FPS   1.5    4.5FT   VIB*****AC*******MIN     6.1FT    9.0    6.4    2.07PSF   970.0 CFS
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                              WYOMING HIGHWAY DEPARTMENT
          ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
 CULVERT PERFORMANCE     PRINT OPTION NO, 1
 STATION:__362+55.00  PROJECT: DRY CREEK      STATION 362+55+-      (EXAMPLE NO.2)
 CULV SIZE:_1=__9.0X__5.0 CONCRETE BOX/30 -75 DEGREE WINGWALL INLET & NO BEVEL
 ANALYSIS TYPE: IRRIGATION DESIGN  Q:_485CFS FREQ:___WR DHW:_8.00FT
 BARREL GEOMETRY: LENGTH:__90FT SLOPE:0.75000% GVD:_7.0FT
 * * * * * * * * *  C U L V E R T    P E R F O R M A N C E  * * * * * * * * * * *   ****DOWNSTREAM CHANNEL PERFORMANCE****
| INFLOW   |FLOOD| OUTFLOW  |HEAD | OUTLET |FROUDE|BRINK |FLOW|*****POND****** |  TAIL- | *VEL(FPS)* |  BED    | OUTFLOW |
|DISCHARGE|FREQ |DISCHARGE |HW,FT|VELOCITY|  NO, |DEPTH |TYPE| AREA |DURATION |  WATER | MAX | AVE  | SHEAR   |DISCHARGE|
  485 CFS   25YR   485 CFS   7.8   15.5FPS   1.5   3.5FT   ID*****AC********MIN    4.7FT   7.6   5.2   1.59PSF  485.0 CFS

                 ***** REVIEW Q =  120 *****
  120 CFS    2YR   120 CFS   2.8    4.5FPS   0.5   3.0FT   IG*****AC********MIN    3.0FT   5.5   4.1   0.99PSF  120.0 CFS

                 ***** REVIEW Q =  260 *****
  260 CFS    5YR   260 CFS   5.4   12.9FPS   1.5   2.2FT   IA*****AC********MIN    3.8FT   6.6   4.4   1.28PSF  260.0 CFS

                 ***** REVIEW Q =  395 *****
  395 CFS   10YR   395 CFS   6.7   14.6FPS   1.5   3.0FT   IA*****AC********MIN    4.4FT   7.2   4.9   1.48PSF  395.0 CFS

                 ***** REVIEW Q =  705 *****
  705 CFS   50YR   705 CFS  12.7   17.1FPS   1.4   4.6FT   IF*****AC********MIN    5.4FT   8.3   5.8   1.83PSF  705.0 CFS

                 ***** REVIEW Q =  970 *****
  970 CFS  100YR   970 CFS  16.5   21.6FPS   1.7   5.0FT  VIB*****AC********MIN    6.1FT   9.0   6.4   2.07PSF  970.0 CFS
ALL CULVERT TYPES REQUESTED HAVE BEEN DESIGNED
```

Example No. 3 - Culvert Design from Stage-Discharge and Stage-Storage Tables

This example is similar to Example No. 1 except that a stage-discharge relationship table and stage-storage table were input to override the system's internal logic for using the downstream and upstream cross section to compute these relationships. The output consists of a stage-discharge relationship, a stage-storage table, and acceptable sizes and hydraulics for all six specified culvert types. The short form output format was selected which provides the culvert performance table for the requested design and performance curve discharges.

FORM C-16
Rev. 3/11/69

WYOMING STATE HIGHWAY DEPARTMENT
CHEYENNE WYOMING
BRIDGE DIVISION

DESIGN SYSTEM

SHEET NO. 1 OF 2
BY WRB DATE 6/21/78
CHECKED db

1 COMMENT CARD 64

100 DRY CREEK STATION 366+55± (EXAMPLE NO. 3)

WORK CODE (1–2)	DATA CODE (3–5)	ENTRY 1 (6–15)	ENTRY 2 (16–25)	ENTRY 3 (26–35)	ENTRY 4 (36–45)	ENTRY 5 (46–55)	ENTRY 6 (56–65)	CONT (66)
HF	002							
	001	1.0	0.0	1.0	0.0094			
	010	0.0	0.0	0.0	0.3	0.3	0.7	1
	010	1.3	12.9	2.4	2.5	72.4	3.8	1
	010	3.7	207.5	5.0	5.2	508.6	6.4	1
	010	6.3	852.3	7.3	7.5	1345.7	8.2	1
	010	9.0	2165.3	9.3	10.3	3149.4	10.3	1
	010	11.9	4958.6	11.7				
HS	001							
	001	2.0	1.0	0.0				
	020	0.7	0.02	0.06	1.1	0.06	0.09	1
	020	5.4	1.52	0.54	10:3	6.8	1.04	1
	020	10.4	6.96	1.81	10.7	7.54	2.2	1
	020	10.8	7.77	2.3	11.7	10.18	3.26	
HC	001							
	001	3.0	1.0	0.0	36655.0	103.0	0.01	
	002	11.0	53.0	11.0	83.0	11.0	11.0	

TRAILER CARD

~~999~~ (1–3)

NOTE: A trailer card must follow the last structure card containing data

FORM C-16
Rev. 3/11/69

WYOMING STATE HIGHWAY DEPARTMENT
CHEYENNE WYOMING
BRIDGE DIVISION

DESIGN SYSTEM

SHEET NO. 2 OF 2
BY WRB DATE 6/21/78
CHECKED db

1 COMMENT CARD 64

~~100~~

1 2 WORK CODE	3 5 DATA CODE	ENTRY 1 6 15	ENTRY 2 25	ENTRY 3 35	ENTRY 4 45	ENTRY 5 55	ENTRY 6 65	66 CONT
	004	810.0	170.0	350.0	530.0	1080.0	1390.0	
	005	68.32	18.08	34.75	48.41	94.98	103.12	
	006	25.0	2.0	5.0	10.0	50.0	100.0	
	030	12.0	9.0					

TRAILER CARD

999
1 3

NOTE: A trailer card must follow the last structure card containing data

```
                    WYOMING HIGHWAY DEPARTMENT
           PRECONSTRUCTION DIVISION      HYDRAULICS SECTION
                CHANNEL STAGE DISCHARGE RELATIONSHIP
      DRY CREEK            STATION 366+55+-       (EXAMPLE NO.3)
                   CHANNEL SLOPE =  0.00940FT/FT

                 STAGE DISCHARGE INPUT VERIFICATION

                                                       INPUT VERIFIED?
                                                  DESIGNER____     CHECKER____

          DEPTH            DISCHARGE          MAX. VELOCITY
          0.0                 0.0                0.0
          0.30                0.30               0.70
          1.30               12.90               2.40
          2.50               72.40               3.80
          3.70              207.50               5.00
          5.20              508.60               6.40
          6.30              852.30               7.30
          7.50             1345.70               8.20
          9.00             2165.30               9.30
         10.30             3149.40              10.30
```

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                    WYOMING HIGHWAY DEPARTMENT                   PAGE    1
          ENGINEERING DIRECTORATE  ********  HYDRAULICS SECTION  12/31/79
                              STAGE STORAGE
 DRY CREEK            STATION 366+55+-       (EXAMPLE NO.3)
                         INPUT VERIFICATION
                                                 o INPUT VERIFIED ?
                                             DESIGNER ___    CHECKER ___
DEPTH STORAGE AREA TABLE INPUTED
```

```
                    WYOMING HIGHWAY DEPARTMENT                      PAGE    2
                                                                    12/31/79
         ENGINEERING DIRECTORATE  ********  HYDRAULICS SECTION
                              STAGE STORAGE
DRY CREEK            STATION 366+55+-        (EXAMPLE NO.3)
                          COMPUTATIONAL RESULTS
            DEPTH (FT)         STORAGE (ACRE-FT)    AREA INUNDATED (ACRES)

                 0.0                 0.0                  0.0
                 0.70                0.02                 0.06
                 1.10                0.06                 0.09
                 5.40                1.52                 0.54
                10.30                6.80                 1.04
                10.40                6.96                 1.81
                10.70                7.54                 2.20
                10.80                7.77                 2.30
                11.70               10.18                 3.26
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                       WYOMING HIGHWAY DEPARTMENT
         ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
CULVERT PERFORMANCE    PRINT OPTION NO. 1
STATION: 366+55.00  PROJECT:  DRY CREEK           STATION 366+55+-        (EXAMPLE NO.3)
CULV SIZE: 1-  7.0X  7.0 ROUND CONCRETE/,SOCKET END PROJECTING INLET
ANALYSIS TYPE: DRAINAGE DESIGN    Q: 810CFS FREQ: 25YR DHW:12.00FT
BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
* * * * * * * * *  C U L V E R T    P E R F O R M A N C E  * * * * * * * * * *    ****DOWNSTREAM CHANNEL PERFORMANCE****
| INFLOW   |FLOOD| OUTFLOW   |HEAD | OUTLET  |FROUDE|BRINK  |FLOW|*****POND****** |  TAIL- | *VEL(FPS)* |  BED    | OUTFLOW |
|DISCHARGE|FREQ |DISCHARGE  |HW,FT|VELOCITY| NO.  |DEPTH  |TYPE| AREA |DURATION |  WATER | MAX  | AVE |  SHEAR  |DISCHARGE|
  599 CFS    25YR   578 CFS  12.0   18.8FPS   1.5   5.2FT   ID  4.0AC    340MIN    5.4FT   6.6  ****  *****PSF  578.3 CFS

                    ***** REVIEW Q =  170 *****
  161 CFS     2YR   159 CFS   4.7   13.8FPS   1.6   2.4FT   IA  0.5AC    429MIN    3.3FT   4.6  ****  *****PSF  159.5 CFS

                    ***** REVIEW Q =  350 *****
  308 CFS     5YR   303 CFS   6.8   16.4FPS   1.6   3.4FT   IA  0.7AC    401MIN    4.2FT   5.4  ****  *****PSF  304.0 CFS

                    ***** REVIEW Q =  530 *****
  467 CFS    10YR   439 CFS   9.0   17.9FPS   1.5   4.3FT   IA  0.9AC    369MIN    4.9FT   6.1  ****  *****PSF  439.6 CFS

                    ***** REVIEW Q = 1080 *****
  722 CFS    50YR   689 CFS  15.0   18.9FPS   1.3   6.3FT   ID 12.1AC    355MIN    5.8FT   6.9  ****  *****PSF  689.3 CFS

                    ***** REVIEW Q = 1390 *****
  930 CFS   100YR   874 CFS  17.1   22.9FPS   1.5   6.8FT  VII 17.6AC    399MIN    6.4FT   7.3  ****  *****PSF  874.1 CFS
***** NOTE:
         STAGE DISCHARGE TABLE INPUTED, AVERAGE VELOCITY AND BED SHEAR CAN NOT BE CALCULATED
```

```
                         WYOMING HIGHWAY DEPARTMENT
       ENGINEERING  DIRECTORATE  ********  HYDRAULICS SECTION
CULVERT PERFORMANCE     PRINT OPTION NO. 1
STATION: 366+55.00  PROJECT:  DRY CREEK              STATION 366+55+-       (EXAMPLE NO.3)
CULV SIZE: 1- 8.5X  8.5 ROUND METAL  (  SPP  )/          COMMERICAL END(FE) INLET
ANALYSIS TYPE: DRAINAGE DESIGN    Q: 810CFS FREQ: 25YR DHW:12.00FT
BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 9.0FT
* * * * * * * * *  C U L V E R T   P E R F O R M A N C E  * * * * * * * * * * *    ****DOWNSTREAM CHANNEL PERFORMANCE****
| INFLOW   |FLOOD| OUTFLOW   |HEAD | OUTLET |FROUDE|BRINK |FLOW|*****POND****** |  TAIL- | *VEL(FPS)* |  BED    | OUTFLOW |
|DISCHARGE|FREQ |DISCHARGE |HW,FT|VELOCITY| NO.  |DEPTH |TYPE| AREA |DURATION |  WATER | MAX | AVE  | SHEAR  |DISCHARGE|
 599 CFS    25YR   600 CFS  11.6   13.6FPS   1.0    6.2FT    V  3.1AC    340MIN    5.5FT   6.6  ****  *****PSF  600.2 CFS

                   ***** REVIEW Q =  170 *****
 161 CFS     2YR   160 CFS   4.2    7.9FPS   0.8    3.3FT IIIA  0.4AC    429MIN    3.3FT   4.6  ****  *****PSF  160.3 CFS

                   ***** REVIEW Q =  350 *****
 332 CFS     5YR   312 CFS   6.3   10.6FPS   0.9    4.4FT  IIA  0.6AC    401MIN    4.2FT   5.5  ****  *****PSF  312.5 CFS

                   ***** REVIEW Q =  530 *****
 467 CFS    10YR   457 CFS   8.1   12.2FPS   0.9    5.4FT  IIA  0.8AC    369MIN    4.9FT   6.2  ****  *****PSF  457.7 CFS

                   ***** REVIEW Q = 1080 *****
 799 CFS    50YR   756 CFS  14.0   15.4FPS   1.0    6.9FT    V  9.4AC    355MIN    6.0FT   7.0  ****  *****PSF  756.4 CFS

                   ***** REVIEW Q = 1390 *****
 930 CFS   100YR   880 CFS  16.3   16.9FPS   1.1    7.3FT    V 15.6AC    399MIN    6.4FT   7.4  ****  *****PSF  880.6 CFS
***** NOTE:
         STAGE DISCHARGE TABLE INPUTED, AVERAGE VELOCITY AND BED SHEAR CAN NOT BE CALCULATED
```

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                   WYOMING HIGHWAY DEPARTMENT
      ENGINEERING  DIRECTORATE  ********  HYDRAULICS SECTION
CULVERT PERFORMANCE    PRINT OPTION NO. 1
STATION:__366+55.00  PROJECT:   DRY CREEK          STATION 366+55+-       (EXAMPLE NO.3)
CULV SIZE:_1=__8.9X__5.7 CONCRETE ELLIPSE(HORIZ AXIS)/,SOCKET END PROJECTING INLET
ANALYSIS TYPE: DRAINAGE DESIGN__   Q:_810CFS FREQ:_25YR DHW:12.00FT
BARREL GEOMETRY: LENGTH:_103FT SLOPE:1.00000% GVD:_9.0FT
* * * * * * * *  C U L V E R T   P E R F O R M A N C E  * * * * * * * * * *   ****DOWNSTREAM CHANNEL PERFORMANCE****
| INFLOW   |FLOOD| OUTFLOW  |HEAD | OUTLET |FROUDE|BRINK |FLOW|*****POND****** |  TAIL- | *VEL(FPS)* |  BED    | OUTFLOW |
|DISCHARGE|FREQ |DISCHARGE |HW,FT|VELOCITY|  NO. |DEPTH |TYPE| AREA |DURATION |  WATER |  MAX | AVE |  SHEAR  |DISCHARGE|
 656 CFS   25YR   605 CFS  11.3   19.3FPS   1.7   4.1FT   ID  2.8AC    340MIN    5.5FT   6.7  ****  *****PSF  605.8 CFS

                 *****_REVIEW_Q =  170 *****
 161 CFS    2YR   160 CFS   4.0    6.6FPS   0.6   3.3FT   IG  0.4AC    429MIN    3.3FT   4.6  ****  *****PSF  161.0 CFS

                 *****_REVIEW_Q =  350 *****
 332 CFS    5YR   318 CFS   6.0   16.1FPS   1.7   2.7FT   IA  0.6AC    401MIN    4.3FT   5.5  ****  *****PSF  318.8 CFS

                 *****_REVIEW_Q =  530 *****
 467 CFS   10YR   450 CFS   8.0   17.9FPS   1.7   3.4FT   IA  0.8AC    369MIN    4.9FT   6.1  ****  *****PSF  450.2 CFS

                 *****_REVIEW_Q = 1080 *****
 722 CFS   50YR   713 CFS  14.2   19.6FPS   1.6   4.7FT   IF  9.9AC    355MIN    5.9FT   6.9  ****  *****PSF  713.1 CFS

                 *****_REVIEW_Q = 1390 *****
 821 CFS  100YR   803 CFS  17.0   19.5FPS   1.4   5.7FT  IVA 17.4AC    299MIN    6.1FT   7.2  ****  *****PSF  803.6 CFS
***** NOTE:
        STAGE DISCHARGE TABLE INPUTED, AVERAGE VELOCITY AND BED SHEAR CAN NOT BE CALCULATED
```

```
                    WYOMING HIGHWAY DEPARTMENT
     ENGINEERING  DIRECTORATE  ********  HYDRAULICS SECTION
CULVERT PERFORMANCE    PRINT OPTION NO. 1
STATION:  366+55.00  PROJECT:  DRY CREEK           STATION 366+55+-       (EXAMPLE NO.3)
CULV SIZE: 1- 9.3X 6.3    METAL PIPE ARCH    / UNPAVED /MITERED-STEP BEVEL INLET
ANALYSIS TYPE: DRAINAGE DESIGN    Q: 810CFS FREQ: 25YR DHW: 12.00FT
BARREL GEOMETRY: LENGTH: 103FT SLOPE: 1.00000% GVD: 9.0FT
* * * * * * * *  C U L V E R T   P E R F O R M A N C E  * * * * * * * * * *   ****DOWNSTREAM CHANNEL PERFORMANCE****
| INFLOW  |FLOOD| OUTFLOW  |HEAD | OUTLET |FROUDE|BRINK |FLOW|*****POND****** |  TAIL- | *VEL(FPS)* |  BED   | OUTFLOW |
|DISCHARGE|FREQ |DISCHARGE |HW,FT|VELOCITY| NO.  |DEPTH |TYPE| AREA |DURATION |  WATER | MAX | AVE  | SHEAR  |DISCHARGE|
  599 CFS   25YR   574 CFS  11.9   14.2FPS   1.1   5.0FT    V  3.9AC    340MIN    5.4FT   6.6  ****  *****PSF  574.5 CFS

                  ***** REVIEW Q =  170 *****
  161 CFS    2YR   161 CFS   3.9    5.9FPS   0.6   3.3FT IIIA 0.4AC    429MIN    3.3FT   4.6  ****  *****PSF  161.4 CFS

                  ***** REVIEW Q =  350 *****
  332 CFS    5YR   317 CFS   6.0    9.0FPS   0.8   4.2FT IIIA 0.6AC    401MIN    4.2FT   5.5  ****  *****PSF  317.4 CFS

                  ***** REVIEW Q =  530 *****
  429 CFS   10YR   423 CFS   8.9   12.0FPS   1.0   4.3FT    V  0.9AC    369MIN    4.8FT   6.0  ****  *****PSF  423.2 CFS

                  ***** REVIEW Q = 1080 *****
  722 CFS   50YR   690 CFS  14.9   16.2FPS   1.2   5.4FT    V 11.9AC    355MIN    5.8FT   6.9  ****  *****PSF  690.8 CFS

                  ***** REVIEW Q = 1390 *****
  821 CFS  100YR   784 CFS  17.7   17.9FPS   1.3   5.6FT    V 19.3AC    299MIN    6.1FT   7.1  ****  *****PSF  784.1 CFS
***** NOTE:
        STAGE DISCHARGE TABLE INPUTED, AVERAGE VELOCITY AND BED SHEAR CAN NOT BE CALCULATED
```

```
                        WYOMING HIGHWAY DEPARTMENT
      ENGINEERING  DIRECTORATE  ********  HYDRAULICS SECTION
CULVERT PERFORMANCE     PRINT OPTION NO. 1
STATION: 366+55.00  PROJECT:   DRY CREEK           STATION 366+55+-        (EXAMPLE NO.3)
CULV SIZE: 2-  7.3X  4.5 CONCRETE ARCH /,SOCKET END PROJECTING INLET
ANALYSIS TYPE: DRAINAGE DESIGN    Q: 810CFS FREQ: 25YR DHW: 12.00FT
BARREL GEOMETRY: LENGTH: 103FT SLOPE: 1.00000% GVD: 9.0FT
* * * * * * * * *  C U L V E R T   P E R F O R M A N C E  * * * * * * * * * *   ****DOWNSTREAM CHANNEL PERFORMANCE****
| INFLOW   |FLOOD| OUTFLOW  |HEAD | OUTLET |FROUDE|BRINK |FLOW|*****POND****** |  TAIL- | *VEL(FPS)* |  BED   | OUTFLOW |
|DISCHARGE|FREQ |DISCHARGE |HW,FT|VELOCITY| NO.  |DEPTH |TYPE| AREA |DURATION |  WATER | MAX | AVE  | SHEAR  |DISCHARGE|
 656 CFS   25YR   638 CFS  10.6   11.9FPS   1.0   4.5FT  IVA  2.0AC    340MIN    5.6FT    6.7  ****  *****PSF  638.7 CFS

              ***** REVIEW Q =  170 *****
 168 CFS    2YR   162 CFS   3.0    3.9FPS   0.4   3.3FT   IG  0.3AC    429MIN    3.3FT    4.6  ****  *****PSF  163.0 CFS

              ***** REVIEW Q =  350 *****
 347 CFS    5YR   335 CFS   4.9    6.3FPS   0.5   4.3FT   IG  0.5AC    401MIN    4.3FT    5.6  ****  *****PSF  335.4 CFS

              ***** REVIEW Q =  530 *****
 467 CFS   10YR   462 CFS   6.8    8.6FPS   0.7   4.5FT   IE  0.7AC    369MIN    5.0FT    6.2  ****  *****PSF  462.7 CFS

              ***** REVIEW Q = 1080 *****
 799 CFS   50YR   739 CFS  13.3   13.7FPS   1.1   4.5FT  IVA  7.7AC    355MIN    5.9FT    7.0  ****  *****PSF  739.2 CFS

              ***** REVIEW Q = 1390 *****
 930 CFS  100YR   827 CFS  16.1   15.4FPS   1.3   4.5FT  IVA 15.0AC    299MIN    6.2FT    7.2  ****  *****PSF  827.6 CFS
***** NOTE:
        STAGE DISCHARGE TABLE INPUTED, AVERAGE VELOCITY AND BED SHEAR CAN NOT BE CALCULATED
```

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                      WYOMING HIGHWAY DEPARTMENT
       ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
  CULVERT PERFORMANCE    PRINT OPTION NO. 1
  STATION: 366+55.00  PROJECT:   DRY CREEK            STATION 366+55+-       (EXAMPLE NO.3)
  CULV SIZE: 1- 7.0X  6.0 CONCRETE BOX/30 -75 DEGREE WINGWALL INLET & NO BEVEL
  ANALYSIS TYPE: DRAINAGE DESIGN    Q: 810CFS FREQ: 25YR DHW: 12.00FT
  BARREL GEOMETRY: LENGTH: 103FT SLOPE: 1.00000% GVD: 9.0FT
  * * * * * * * * *  C U L V E R T    P E R F O R M A N C E  * * * * * * * * * *    ****DOWNSTREAM CHANNEL PERFORMANCE****
 | INFLOW   |FLOOD| OUTFLOW   |HEAD  | OUTLET |FROUDE|BRINK |FLOW|*****POND****** |   TAIL- | *VEL(FPS)* |  BED    | OUTFLOW |
 |DISCHARGE|FREQ |DISCHARGE |HW,FT|VELOCITY|  NO.  |DEPTH |TYPE| AREA |DURATION |   WATER | MAX | AVE  | SHEAR   |DISCHARGE|
   599 CFS    25YR    591 CFS  11.6   18.1FPS   1.5    4.7FT   ID  3.1AC     340MIN    5.5FT    6.6  ****  *****PSF  591.8 CFS

                      ***** REVIEW Q =  170 *****
   161 CFS     2YR    159 CFS   4.2   12.8FPS   1.7    1.8FT   IA  0.4AC     429MIN    3.3FT    4.6  ****  *****PSF  159.6 CFS

                      ***** REVIEW Q =  350 *****
   332 CFS     5YR    313 CFS   6.3   15.5FPS   1.6    2.9FT   IA  0.6AC     401MIN    4.2FT    5.5  ****  *****PSF  313.7 CFS

                      ***** REVIEW Q =  530 *****
   467 CFS    10YR    444 CFS   8.4   17.0FPS   1.5    3.7FT   IA  0.8AC     369MIN    4.9FT    6.1  ****  *****PSF  444.2 CFS

                      ***** REVIEW Q = 1080 *****
   722 CFS    50YR    699 CFS  14.6   18.8FPS   1.4    5.3FT   ID 11.0AC     355MIN    5.8FT    6.9  ****  *****PSF  699.9 CFS

                      ***** REVIEW Q = 1390 *****
   821 CFS   100YR    788 CFS  17.4   19.3FPS   1.4    5.8FT   IF 18.6AC     299MIN    6.1FT    7.1  ****  *****PSF  788.2 CFS
  ***** NOTE:
             STAGE DISCHARGE TABLE INPUTED, AVERAGE VELOCITY AND BED SHEAR CAN NOT BE CALCULATED


 ALL CULVERT TYPES REQUESTED HAVE BEEN DESIGNED
```

Example No. 4 - Culvert Review with Upstream Storage

This example reviews two specified culvert sizes for a designated discharge. The input consists of the same type of site data used in Example No. 1 . The output is similar to Example No. 2 . The short form output format was selected which displays the culvert performance data for the requested design and performance curve discharges.

FORM C-16
Rev. 3/11/69

WYOMING STATE HIGHWAY DEPARTMENT
CHEYENNE WYOMING
BRIDGE DIVISION

SHEET NO 1 OF 2
BY JEK DATE 6/19/78
CHECKED DB

DESIGN SYSTEM

1 COMMENT CARD 64

100 DRY CREEK STATION 366+55± (EXAMPLE NO. 4)

WORK CODE 1 2	DATA CODE 3 5	ENTRY 1 6 15	ENTRY 2 25	ENTRY 3 35	ENTRY 4 45	ENTRY 5 55	ENTRY 6 65	CONT 66
HF	002							
	001	1.0	0.0	0.0	0.0094			
	020	-125.0	5385.4	-77.0	5382.1	-35.0	5381.1	1
	020	-20.0	5376.5	-5.0	5372.4	0.0	5371.1	1
	020	15.0	5374.8	37.0	5380.5	50.0	5384.4	1
	020	90.0	5384.6	122.0	5385.7			
	030	-35.0	0.09	50.0	0.055	122.0	0.037	
HS	001							
	001	1.0	1.0	0.0	0.0106			
	005	100.0						
	010	-113.0	5389.1	-57.0	5387.7	-35.0	5388.2	1
	010	-12.0	5378.5	0.0	5377.4	26.0	5378.1	1
	010	55.0	5382.8	85.0	5387.8	100.0	5388.1	1
	010	134.0	5389.6					
HC	001							
	001	4.0	1.0	0.0	36655.0	103.0	0.01	
	002	11.0	0.0	0.0	0.0	0.0	0.0	

TRAILER CARD

~~999~~

1 3

NOTE: A trailer card must follow the last structure card containing data

FORM C-16
Rev. 3/11/69

WYOMING STATE HIGHWAY DEPARTMENT
CHEYENNE WYOMING
BRIDGE DIVISION

DESIGN SYSTEM

SHEET NO. 2 OF 2
BY JEK DATE 6/19/78
CHECKED DB

1 COMMENT CARD 64

~~100~~

1 2 WORK CODE	3 5 DATA CODE	ENTRY 1 6 15	ENTRY 2 25	ENTRY 3 35	ENTRY 4 45	ENTRY 5 55	ENTRY 6 65	66 CONT
	004	810.0	170.0	350.0	530.0	1080.0	1390.0	
	005	68.32	18.08	34.75	48.41	4.98	103.12	
	006	25.0	2.0	5.0	10.0	50.0	100.0	
	040	1.0	7.0	7.0				
HC	001							
	001	4.0	1.0	0.0	36655.0	103.0	0.01	
	002	0.0	83.0	0.0	0.0	0.0	0.0	
	004	810.0	170.0	350.0	530.0	1080.0	1390.0	
	005	68.32	18.08	34.75	48.41	84.98	103.12	
	006	25.0	2.0	5.0	10.0	50.0	100.0	
	040	1.0	8.0	8.0				

TRAILER CARD

999
1 3

NOTE: A trailer card must follow the last structure card containing data

```
                    WYOMING HIGHWAY DEPARTMENT
          PRECONSTRUCTION DIVISION      HYDRAULICS SECTION
                CHANNEL STAGE DISCHARGE RELATIONSHIP
      DRY CREEK         STATION 366+55+-       (EXAMPLE NO.4)
                    CHANNEL SLOPE =  0.00940FT/FT

                 STAGE DISCHARGE INPUT VERIFICATION

                                                                     INPUT VERIFIED?
                                                              DESIGNER____     CHECKER____
        X( 1) = -125.0   Y( 1) = 5385.4   MANNINGS NUMBER = .040
        X( 2) =  -77.0   Y( 2) = 5382.1   MANNINGS NUMBER = .040
        X( 3) =  -35.0   Y( 3) = 5381.1   MANNINGS NUMBER = .040
        X( 4) =  -20.0   Y( 4) = 5376.5   MANNINGS NUMBER = .055
        X( 5) =   -5.0   Y( 5) = 5372.4   MANNINGS NUMBER = .055
        X( 6) =    0.0   Y( 6) = 5371.1   MANNINGS NUMBER = .055
        X( 7) =   15.0   Y( 7) = 5374.8   MANNINGS NUMBER = .055
        X( 8) =   37.0   Y( 8) = 5380.5   MANNINGS NUMBER = .055
        X( 9) =   50.0   Y( 9) = 5384.4   MANNINGS NUMBER = .055
        X(10) =   90.0   Y(10) = 5384.6   MANNINGS NUMBER = .037
        X(11) =  113.3   Y(11) = 5385.4   MANNINGS NUMBER = .037
*** NOTE *** LAST POINT WAS INTERPOLATED
```

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                         WYOMING HIGHWAY DEPARTMENT
              PRECONSTRUCTION DIVISION      HYDRAULICS SECTION
                     CHANNEL STAGE DISCHARGE RELATIONSHIP
      DRY CREEK        STATION 366+55+-      (EXAMPLE NO.4)
                       CHANNEL SLOPE =  0.00940FT/FT

ELEVATION          DEPTH        DISCHARGE        VELOCITY        MAX. VELOCITY

 5371.1             0.0             0.0             0.0             0.0
 5371.4             0.3             0.3             0.7             0.7
 5371.7             0.6             1.8             1.3             1.5
 5372.0             0.9             5.5             1.7             2.1
 5372.4             1.3            15.1             2.3             2.8
 5372.7             1.6            26.3             2.6             3.3
 5373.0             1.9            41.5             2.9             3.7
 5373.3             2.2            61.2             3.2             4.1
 5373.6             2.5            85.9             3.5             4.5
 5373.9             2.8           115.9             3.8             4.9
 5374.2             3.1           151.7             4.1             5.3
 5374.5             3.4           193.8             4.3             5.6
 5374.8             3.7           246.5             4.6             6.0
 5375.1             4.0           302.6             4.9             6.3
 5375.4             4.3           366.1             5.1             6.6
 5375.7             4.6           437.2             5.3             6.9
 5376.0             4.9           516.3             5.6             7.2
 5376.3             5.2           603.7             5.8             7.5
 5376.5             5.4           673.6             5.9             7.8
 5376.8             5.7           776.2             6.2             8.1
 5377.1             6.0           887.9             6.4             8.3
 5377.4             6.3          1009.0             6.6             8.6
 5377.7             6.6          1139.7             6.8             8.9
 5378.0             6.9          1280.4             7.0             9.2
 5378.3             7.2          1431.2             7.2             9.4
 5378.6             7.5          1592.4             7.4             9.7
 5378.9             7.8          1764.4             7.6            10.0
 5379.2             8.1          1947.3             7.8            10.2
 5379.5             8.4          2141.4             8.0            10.5
 5379.8             8.7          2347.0             8.2            10.7
 5380.1             9.0          2564.3             8.4            11.0
 5380.5             9.4          2906.3             8.6            11.3
 5380.8             9.7          3153.7             8.8            11.6
 5381.1            10.0          3417.0             9.0            11.8
 5381.4            10.3          3691.4             9.1            12.0
 5381.7            10.6          3987.9             9.2            12.3
 5382.1            11.0          4439.4             9.3            12.6
 5382.4            11.3          4808.4             9.4            12.8
 5382.7            11.6          5209.5             9.5            13.0
 5383.0            11.9          5642.7             9.6            13.3
 5383.3            12.2          6108.5             9.7            13.5
 5383.6            12.5          6607.5             9.8            13.7
 5383.9            12.8          7140.4            10.0            13.9
 5384.2            13.1          7708.0            10.1            14.1
 5384.4            13.3          8156.9            10.2            14.3
```

```
 ELEVATION             DEPTH       DISCHARGE          VELOCITY         MAX. VELOCITY

  5384.6               13.5          8579.1             10.3               14.5
  5384.9               13.8          9264.9             10.3               14.7
  5385.2               14.1         10015.9             10.4               14.9
  5385.4               14.3         10578.9             10.5               15.0
```

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                        WYOMING HIGHWAY DEPARTMENT                  PAGE    1
        ENGINEERING DIRECTORATE  ********  HYDRAULICS SECTION       01/03/80
                             STAGE STORAGE
DRY CREEK       STATION 366+55+-      (EXAMPLE NO.4)
                           INPUT VERIFICATION
                                                     INPUT VERIFIED ?
                                               DESIGNER ____    CHECKER ____
      UPSTREAM SLOPE =    0.01060 FEET/FOOT
      CROSS SECTION STATION =      0.0
                 X (DISTANCE-FEET)     Y (ELEVATION-FEET)
                       -113.00               5389.10
                        -57.00               5387.70
                        -35.00               5388.20
                        -12.00               5378.50
                          0.0                5377.40
                         26.00               5378.10
                         55.00               5382.80
                         85.00               5387.80
                        100.00               5388.10
                        134.00               5389.60
      CROSS SECTION STATION =    100.00
                 X (DISTANCE-FEET)     Y (ELEVATION-FEET)
                       -113.00               5389.10
                        -57.00               5387.70
                        -35.00               5388.20
                        -12.00               5378.50
                          0.0                5377.40
                         26.00               5378.10
                         55.00               5382.80
                         85.00               5387.80
                        100.00               5388.10
                        134.00               5389.60
```

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                      WYOMING HIGHWAY DEPARTMENT                    PAGE    2
                                                                    01/03/80
          ENGINEERING DIRECTORATE  ********  HYDRAULICS SECTION
                               STAGE STORAGE
    DRY CREEK      STATION 366+55+-      (EXAMPLE NO.4)
                            COMPUTATIONAL RESULTS
            DEPTH (FT)        STORAGE (ACRE-FT)     AREA INUNDATED (ACRES)

                  0.0                0.0                   0.0
                  0.70               0.02                  0.06
                  1.10               0.06                  0.09
                  5.40               1.52                  0.54
                 10.30               6.80                  1.74
                 10.40               6.96                  1.81
                 10.70               7.54                  2.20
                 10.80               7.77                  2.30
                 11.70              10.18                  3.26
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                       WYOMING HIGHWAY DEPARTMENT
         ENGINEERING  DIRECTORATE  ********  HYDRAULICS SECTION
 CULVERT PERFORMANCE     PRINT OPTION NO. 1
 STATION:__366+55.00  PROJECT:  DRY CREEK        STATION 366+55+-       (EXAMPLE NO.4)
 CULV SIZE:_1=__7.0X__7.0 ROUND CONCRETE/,SOCKET END PROJECTING INLET
 ANALYSIS TYPE: DRAINAGE REVIEW__  Q:_810CFS FREQ:_25YR DHW:_0.0_FT
 BARREL GEOMETRY: LENGTH:_103FT SLOPE:1.00000% GVD:_0.0FT
 * * * * * * * *  C U L V E R T   P E R F O R M A N C E  * * * * * * * * * *    ****DOWNSTREAM CHANNEL PERFORMANCE****
| INFLOW   |FLOOD| OUTFLOW   |HEAD | OUTLET |FROUDE|BRINK |FLOW|*****POND****** |  TAIL- | *VEL(FPS)* |  BED     | OUTFLOW |
|DISCHARGE|FREQ |DISCHARGE |HW,FT|VELOCITY| NO.  |DEPTH |TYPE| AREA |DURATION |  WATER | MAX | AVE  | SHEAR    |DISCHARGE|
  599 CFS    25YR    578 CFS  12.0   18.8FPS    1.5    5.2FT    ID  3.9AC      340MIN     5.1FT    7.5    5.7    2.91PSF  578.0 CFS

                     ***** REVIEW Q =  170 *****
  161 CFS     2YR    159 CFS   4.7   13.8FPS    1.6    2.4FT    IA  0.5AC      429MIN     3.1FT    5.3    4.1    1.76PSF  159.5 CFS

                     ***** REVIEW Q =  350 *****
  308 CFS     5YR    304 CFS   6.8   16.4FPS    1.6    3.4FT    IA  0.9AC      401MIN     4.0FT    6.3    4.9    2.27PSF  304.8 CFS

                     ***** REVIEW Q =  530 *****
  467 CFS    10YR    439 CFS   9.0   17.9FPS    1.5    4.3FT    IA  1.4AC      369MIN     4.6FT    7.0    5.3    2.61PSF  439.6 CFS

                     ***** REVIEW Q = 1080 *****
  722 CFS    50YR    674 CFS  14.6   18.9FPS    1.3    6.1FT    ID 11.0AC      318MIN     5.4FT    7.8    5.9    3.09PSF  674.6 CFS

                     ***** REVIEW Q = 1390 *****
  930 CFS   100YR    873 CFS  17.1   22.9FPS    1.5    6.8FT   VII 17.6AC      399MIN     6.0FT    8.3    6.4    3.41PSF  873.6 CFS


ALL CULVERT TYPES REQUESTED HAVE BEEN REVIEWED
```

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                   WYOMING HIGHWAY DEPARTMENT
       ENGINEERING  DIRECTORATE  *********  HYDRAULICS SECTION
CULVERT PERFORMANCE    PRINT OPTION NO. 1
STATION: 366+55.00  PROJECT:  DRY CREEK       STATION 366+55+-      (EXAMPLE NO.4)
CULV SIZE: 1- 8.0X  8.0 ROUND METAL  (  SPP  )/          MITERED-STEP BEVEL INLET
ANALYSIS TYPE: DRAINAGE REVIEW    Q: 810CFS FREQ: 25YR DHW: 0.0 FT
BARREL GEOMETRY: LENGTH: 103FT SLOPE:1.00000% GVD: 0.0FT
* * * * * * * *  C U L V E R T   P E R F O R M A N C E  * * * * * * * * * *   ****DOWNSTREAM CHANNEL PERFORMANCE****
| INFLOW   |FLOOD| OUTFLOW  |HEAD | OUTLET |FROUDE|BRINK |FLOW|*****POND****** |  TAIL- | *VEL(FPS)* |  BED    | OUTFLOW |
|DISCHARGE|FREQ |DISCHARGE |HW,FT|VELOCITY| NO.  |DEPTH |TYPE| AREA |DURATION |  WATER | MAX | AVE  | SHEAR   |DISCHARGE|
 599 CFS   25YR   568 CFS  12.2   13.9FPS   1.0   6.1FT    V  4.7AC    340MIN    5.1FT   7.4   5.7   2.89PSF  568.8 CFS

                  ***** REVIEW Q =  170 *****
 161 CFS    2YR   159 CFS   4.6    8.7FPS   0.9   3.1FT  IIA  0.5AC    429MIN    3.1FT   5.3   4.1   1.76PSF  159.7 CFS

                  ***** REVIEW Q =  350 *****
 308 CFS    5YR   306 CFS   6.7   10.7FPS   0.9   4.4FT  IIA  0.8AC    401MIN    4.0FT   6.3   4.9   2.27PSF  306.4 CFS

                  ***** REVIEW Q =  530 *****
 429 CFS   10YR   421 CFS   9.0   12.1FPS   0.9   5.2FT  IIA  1.4AC    369MIN    4.5FT   6.9   5.3   2.57PSF  422.0 CFS

                  ***** REVIEW Q = 1080 *****
 722 CFS   50YR   688 CFS  14.7   15.4FPS   1.1   6.6FT    V 11.2AC    318MIN    5.4FT   7.8   6.0   3.11PSF  688.5 CFS

                  ***** REVIEW Q = 1390 *****
 821 CFS  100YR   808 CFS  17.6   17.2FPS   1.1   7.1FT    V 19.0AC    399MIN    5.8FT   8.1   6.2   3.31PSF  808.6 CFS


ALL CULVERT TYPES REQUESTED HAVE BEEN REVIEWED
```

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APPENDIX A

XYNETICS TO CALCOMP PLOTTER CONVERSION

Modifications made to Wyoming's Culvert/Design/Plot program by Kansas to use Calcomp software and hardware for plotting.

1. Replaced CALL DIMTAB with CALL PLOTS in subroutine H80PLT.
2. Modified CALL GRID in subroutines H80PLT and H80GBT due to the fact that CALCOMP looks for different arguments than XYNETICS.
3. Modified CALL SYMBOL in subroutines H80PLT, H80PLI, H80GBT, and H80TTB because CALCOMP spaces its lettering differently than XYNETICS.
4. Modified CALL DASHLN extensively in subroutines H80PLT, H80PLI, H80TTB and H80TTI. Due to spacing before using CALL DASHP, we had to CALL PLOT to set coordinate. Arguments passed were totally different.
5. Commented CALL MESAGE in subroutine H80GBT. CALCOMPS CALL OPMES different, didn't modify, relay message via PLOT request sheet.
6. Modified CALL PLOT in subroutines H80TTB and H80TTI to adjust spacing.
7. Modified the variable PLOTS to PLOTTS due to inserting a CALL PLOTS.
8. Modified plot routine to move pen to new coordinate if second plan sheet is to be plotted, subroutine H80GBT. Second sheet was plotting on top of first sheet.
9. Split out a BAL subroutine called GEN4 and placed it in SUBRTLIB and renamed it HYRD30. It modified alphabetic characters for plotting plan sheet title.

APPENDIX B

UNITS CONVERSION

Length	1 inch = 25.4 mm
	1 ft = 0.3048 m
	1 mile = 1.609 km
Area	1 ft^2 = 0.09290 m^2
	1 acre = 4047 m^2
	1 mi^2 = 2.590 km^2
Volume	1 gallon = 0.003785 m^3 = 3.785 liters = 0.1337 ft^3
	1 acre-ft = 1233.53 m^3
Velocity	1 ft/sec = 0.3048 m/sec
	1 mph = 1.609 km/hr = 0.4470 m/sec
Acceleration	1 ft/sec^2 = 0.3048 m/sec^2
Flow Rate	1 ft^3/sec = 0.02832m^3/sec
	1 gallon/min = 0.003785 m^3/min = 3.785 liters
	1 MGD = 11.57 gallons/sec = 1.55 ft^3/sec
Weight	1 oz = 28.35 g
	1 lb = 453.6 g
	1 ton = 2000 lbs
Pressure	1 lb/ft^2 = 47.88026 Pa
Density	1 lb/ft^3 = 16.01846 kg/m^3

*U.S. GOVERNMENT PRINTING OFFICE : 1981 0-725-260/1068