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Soil Conservation Service
Engineering Division

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TR-59B

WATER SURFACE PROFILES AND TRACTIVE STRESSES FOR RIPRAP GRADIENT CONTROL STRUCTURES

PREFACE

TR-59 procedure may be used as a design tool to design a riprap gradient control structure for a design discharge and a tailwater condition. The structure will satisfy both capacity and stability requirements. However, an analytical procedure is needed to investigate the effects, if any, of other discharge-tailwater conditions or other parameters on the structure. This supplement contains such a procedure.

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TECHNICAL RELEASE NO. 59, SUPPLEMENT 2

WATER SURFACE PROFILES AND TRACTIVE STRESSES FOR RIPRAP GRADIENT CONTROL STRUCTURES

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NOMENCLATURE

This supplement uses the same nomenclature as contained in Technical Release No. 59. Usually, each new term used in the supplement is defined where it first appears in the text. Not all nomenclature is listed. For any nomenclature or symbols not listed, the meaning may be ascertained from this supplement or Technical Release No. 59. The symbols used for input and output data are defined in the "Computer Program" section of this supplement.

a ≡ Flow area, ft^2

C_n = CN ≡ Coefficient relating Manning's n to riprap D_{50} size, $n = C_n[D_{50}]^{EXPN}$

d ≡ Depth of flow, ft

D_{50} = D50 ≡ Size of rock in riprap of which 50 percent by weight is finer, ft

DS ≡ Depth of flow corresponding to the discharge, Q, at the ends of the riprap structure, ft

EXPN ≡ Value of the exponent in the equation for computing Manning's roughness coefficient, $n = C_n[D_{50}]^{EXPN}$

FS ≡ Factor of safety

g ≡ Acceleration of gravity, ft/sec^2

h_f ≡ Friction head loss, $\frac{ft\text{-}lb}{lb}$

ℓ ≡ Horizontal length of a portion of a channel or length of a computational reach, ft

n = N ≡ Manning's coefficient of roughness

p ≡ Wetted perimeter, ft

Q ≡ Discharge through the riprap structure, cfs

s ≡ Energy gradient, ft/ft

v ≡ Velocity corresponding to the discharge, Q, ft/sec

TECHNICAL RELEASE NO. 59, SUPPLEMENT 2

WATER SURFACE PROFILES AND TRACTIVE STRESSES FOR RIPRAP GRADIENT CONTROL STRUCTURES

Introduction

A riprap gradient control structure can be used to dissipate excess energy and establish a stable gradient in a channel where the gradient without some such control would be too steep and would cause erosive velocities. The procedures for the hydraulic design and proportioning of such structures are given in TR-59.

Technical Release No. 59

Technical Release No. 59, "Hydraulic Design of Riprap Gradient Control Structures," presents a detailed discussion of the concept of the riprap gradient control structure, procedures for the hydraulic design and proportioning of the structures, and procedures used in the associated computer program to obtain the design of the structure.

Purpose of Supplement

Technical Release No. 59 procedure provides the design of a riprap structure for a given design discharge and tailwater condition. However, by use of this technical release, the capacity and stability of the riprap structure are not investigated for discharges other than the design discharge nor for other tailwater conditions. A water surface profile program is needed which will evaluate the depth of flow and tractive stress at various locations throughout the structure for any combination of discharge and downstream starting depth. Therefore, the purpose of this supplement is to: (1) present procedures for the computation of water surface profiles for various parameters, and (2) investigate the effect of various parameters on the capacity and stability of the riprap structure.

Computer Program

A computer program, written in FORTRAN for IBM equipment, determines the water surface profile, maximum tractive stresses, and various other hydraulic parameters associated with the riprap structure under investigation.

Input and output data information is discussed under the "Computer Program" section. Computer runs may be obtained by request to

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Riprap Gradient Control Structure

The purpose of a riprap gradient control structure is channel gradient control. The concept and the hydraulic design of the riprap gradient control structure are contained in TR-59. For brevity, riprap gradient control structures will be referred to in this supplement as riprap structures or simply as structures.

Discharges and Starting Depths

The design of a riprap structure obtained from TR-59 procedure is for a design discharge and tailwater condition; in the design, both capacity and stability of the structure are satisfied. The design discharge is equal to the discharge used in evaluating the stability of both the upstream and downstream channels adjacent to the structure.

Generally, riprap structures that are stable for the design discharge will also be stable for all discharges less than the design discharge. However, if a rating curve is such that the tailwater decreases very rapidly with small decreases in discharge, such a discharge-tailwater combination may cause tractive stress greater than those associated with the design discharge. Further, if the actual tailwater depth corresponding to the design discharge is subsequently determined to be less than the starting depth, DS, used in the riprap structure design, the water depth in the structure, especially in the downstream transition, will be lower than normal depth. Thus, velocity and tractive stress in the structure will be increased.

The procedure in this supplement may be used to compute water surface profiles and tractive stresses at various locations throughout the riprap structure for any combination of discharge-tailwater conditions. If the tractive stress at any location in the structure is greater than the allowable tractive stress, the riprap structure should be redesigned using TR-59 procedures for the controlling discharge-tailwater condition. Locations most likely to experience tractive stresses that are larger than the allowable value are usually the most downstream end of the prismatic channel and the upstream half of the downstream transition.

If a discharge greater than the design discharge occurs, the structure may not function properly; the structure may be overtopped and tractive stress greater than allowable may occur. Therefore, as stated in TR-59, the design discharge should be selected sufficiently large and the lowest tailwater depth corresponding to the design discharge should always be used.

Size of Riprap, D_{50}

Since the value of the roughness coefficient, n, and the critical tractive stress, τ_{bc} or τ_{sc} are functions of the size of riprap, D_{50}, any variation of D_{50} size will have some effect on the performance of the riprap structure. The procedures in this supplement may be used to check the capacity and stability of the structure if the actual D_{50} size used in the construction differs somewhat from the design value of D_{50}.

Manning's Roughness Coefficient

The coefficient of roughness, n, for the riprap has been experimentally evaluated as

$$n = C_n (D_{50})^{EXPN}$$

where (from Report 108 and used as default values in TR-59)

$C_n = 0.0395$

$EXPN = 1/6$

A constant n value based on the above equation was used in the design procedure of TR-59. However, the procedure in this supplement may be used to investigate what effects the various roughness coefficients may have on the capacity and stability of the riprap structure. Water depths and tractive stresses at various preselected sections of the riprap structure will be computed corresponding to the desired n value.

Prismatic Channel

Generally, the most critical section for stability is that section where the velocity and tractive stress are the greatest. For flow conditions other than the discharge-tailwater condition used in the riprap structure design, the most critical section is usually at the most downstream end of the prismatic channel. However, if supercritical flow exists in the downstream transition, the most critical section may be in the transition.

For a discharge less than the design discharge and/or a starting depth less than the DS used in the design, the depth at the most downstream end of the prismatic channel could be as low as critical depth; and the water surface profile in the structure upstream from this section will approach normal depth. For a discharge greatly exceeding the design discharge, it is theoretically possible to have supercritical flow in the prismatic channel.

Water Surface Profile

The water surface profile (WSP) in a riprap structure depends on the discharge and the starting depth. Thus, for every discharge-starting depth combination, there is a corresponding water surface profile which can be used to obtain the capacity and maximum tractive stress values in the riprap structure. The starting depth at the most downstream section of the riprap structure must be predetermined before profile computations can be started. The water surface profile is merely the determination of the depth of flow at preselected sections throughout the structure. These preselected sections are the ten equally spaced sections within each element of the structure. These elements are the downstream transition, upstream transition, and the prismatic channel. The preselected sections in the transitions may be obtained from the computer output of TR-59.

Hydraulic Theory

The theory and assumptions used in the determination of water surface profiles are taken from NEH-5, Hydraulics. It is assumed that the law of conservation of energy (Bernoulli's Theorem) is valid for varied flow and that Manning's formula defines the slope of the energy line.

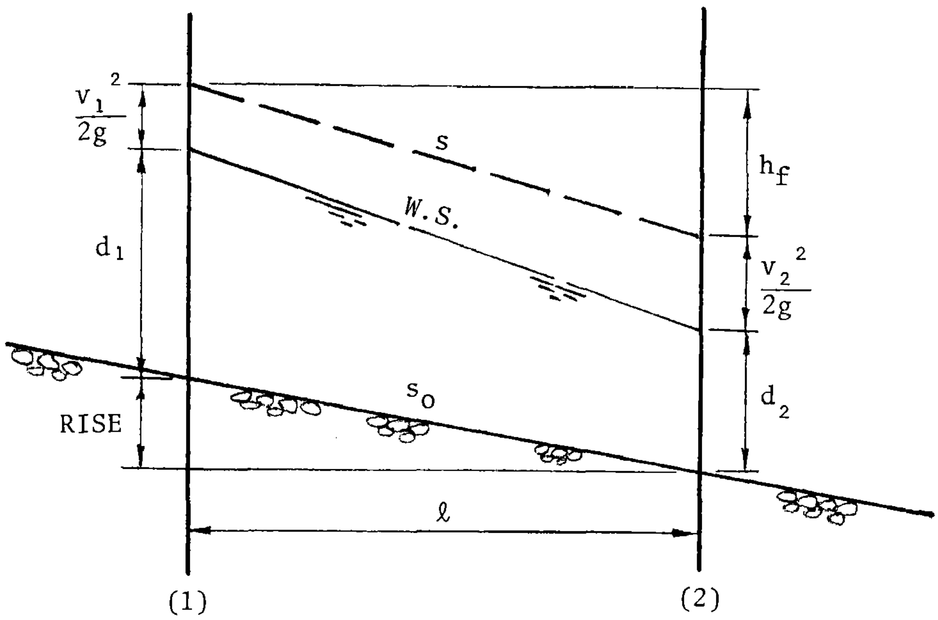


Figure 1. Energy in varied flow

From Figure 1.

$$RISE + d_1 + \frac{v_1^2}{2g} = d_2 + \frac{v_2^2}{2g} + h_f$$

The total head loss, h_f, between sections 1 and 2 is equal to the rate of friction loss, s, times the distance, ℓ, between sections 1 and 2 or

$$h_f = s\ell$$

$$s = \frac{1}{\ell}\left[(d_1 - d_2) + \frac{Q^2}{2g}\left(\frac{1}{a_1^2} - \frac{1}{a_2^2}\right) + RISE\right] \quad \text{- - - - - - - - - - (1)}$$

It is further assumed that conversion losses in the transitions and the correction for non-uniform velocity distribution are negligible; thus they are ignored. The rate of friction loss, s, between sections 1 and 2 is taken as the arithmetical average of the instantaneous rate of friction loss of section 1, (s_1), and section 2, (s_2), or

$$s = \frac{1}{2}(s_1 + s_2)$$

From Manning's Formula

$$s_1 = \left(\frac{nQ}{1.486}\right)^2 \frac{p_1^{4/3}}{a_1^{10/3}}$$

$$s_2 = \left(\frac{nQ}{1.486}\right)^2 \frac{p_2^{4/3}}{a_2^{10/3}}$$

$$s = \frac{1}{2}\left(\frac{nQ}{1.486}\right)^2 \left[\frac{p_1^{4/3}}{a_1^{10/3}} + \frac{p_2^{4/3}}{a_2^{10/3}}\right] \text{- - - - - - - - - - - - - - - - -} \quad (2)$$

Setting equation (1) equal to equation (2)

$$d_1 + \frac{Q^2}{2a_1^2}\left[\frac{1}{g} - \ell\left(\frac{n}{1.486}\right)^2 \left(\frac{p_1}{a_1}\right)^{4/3}\right]$$

$$= d_2 - \text{RISE} + \frac{Q^2}{2a_2^2}\left[\frac{1}{g} + \ell\left(\frac{n}{1.486}\right)^2 \left(\frac{p_2}{a_2}\right)^{4/3}\right] \text{- - - -} \quad (3)$$

Computations

The computation of the water surface profile merely determines the depth of flow at one end of a computational reach when the depth of the other end is known. Thus, the length of a computational reach is equal to the distance between any two consecutive sections. In the case of subcritical flow where computation of WSP is in an upstream direction, the depth at section 2 (see Figure 1) is known; thus, every term on the right hand side of equation (3) is known. The depth at section 1, d_1, is determined by assuming a depth, d_1, and stepping d_1 until equation (3) is balanced within the degree of accuracy desired. The degree of accuracy may be achieved when the computational reaches are "sufficiently short." The lengths of computational reaches used in the computer program are set equal to the distance between preselected consecutive sections of the riprap structure divided by ten. In other words, the length between any two preselected consecutive sections is divided into ten equal sub-lengths; each sub-length contains two subsections where WSP is computed. The depths at these subsections are computed to an accuracy of $\pm$ 0.001 ft, but they are not part of the output. Only depths at preselected sections are output.

A flow chart of the procedure used in the WSP computer program is given in Figure 2. Water surface profile computation commences at the most downstream section of the riprap structure. The program examines to see if the starting depth, DS, is equal to or greater than critical depth corresponding to the discharge, Q. If the starting depth is less than critical depth, critical depth will be used as the starting depth. Computations proceed in an upstream direction. The computer examines whether subcritical flows exist. When the flow is critical or supercritical, computation ceases and a message, "CRITICAL DEPTH," will be printed to indicate that critical depth will be used as the starting depth for the next upstream computational reach. This process continues upstream until flow changes back to subcritical at some section of the downstream transition or until the most downstream section of the prismatic channel has been reached.

If the flow changes back to subcritical before reaching the prismatic channel, both of the following computations occur:

1. Computation of WSP continues upstream for subcritical flow and

2. A message, "SUPERCRICAL FLOW," will be printed to indicate that computation of WSP is in a downstream direction for supercritical flow; using critical depth as the starting depth and commencing at the last preselected section where flow changes back to subcritical flow to the preselected section where supercritical flow first occurred.

However, if the flow did not change back to subcritical flow when the prismatic channel is reached, both of the following computations occur:

1. A message, "SUPERCRITICAL FLOW," will be printed to indicate that computation of WSP is in a downstream direction for supercritical flow. Using critical depth as the starting depth and commencing at the most downstream section of the prismatic channel, compute WSP to the preselected section in the downstream transition where supercritical flow first occurred and

2. Compute the WSP in an upstream direction commencing at the most downstream section of the prismatic channel using critical depth as the starting depth. Flow will approach normal depth in the prismatic channel.

The critical slope, $s_{c,Q}$, is associated with a discharge, Q, and when the discharge is changed, the critical slope is changed. The critical slope usually increases as the discharge decreases. Therefore, for discharges less than or equal to the design discharge, the lowest possible depth at the most downstream section of the prismatic channel is critical depth; flow in the prismatic channel will never be supercritical. The WSP in the prismatic channel and the upstream transition will approach normal depth in an upstream direction.

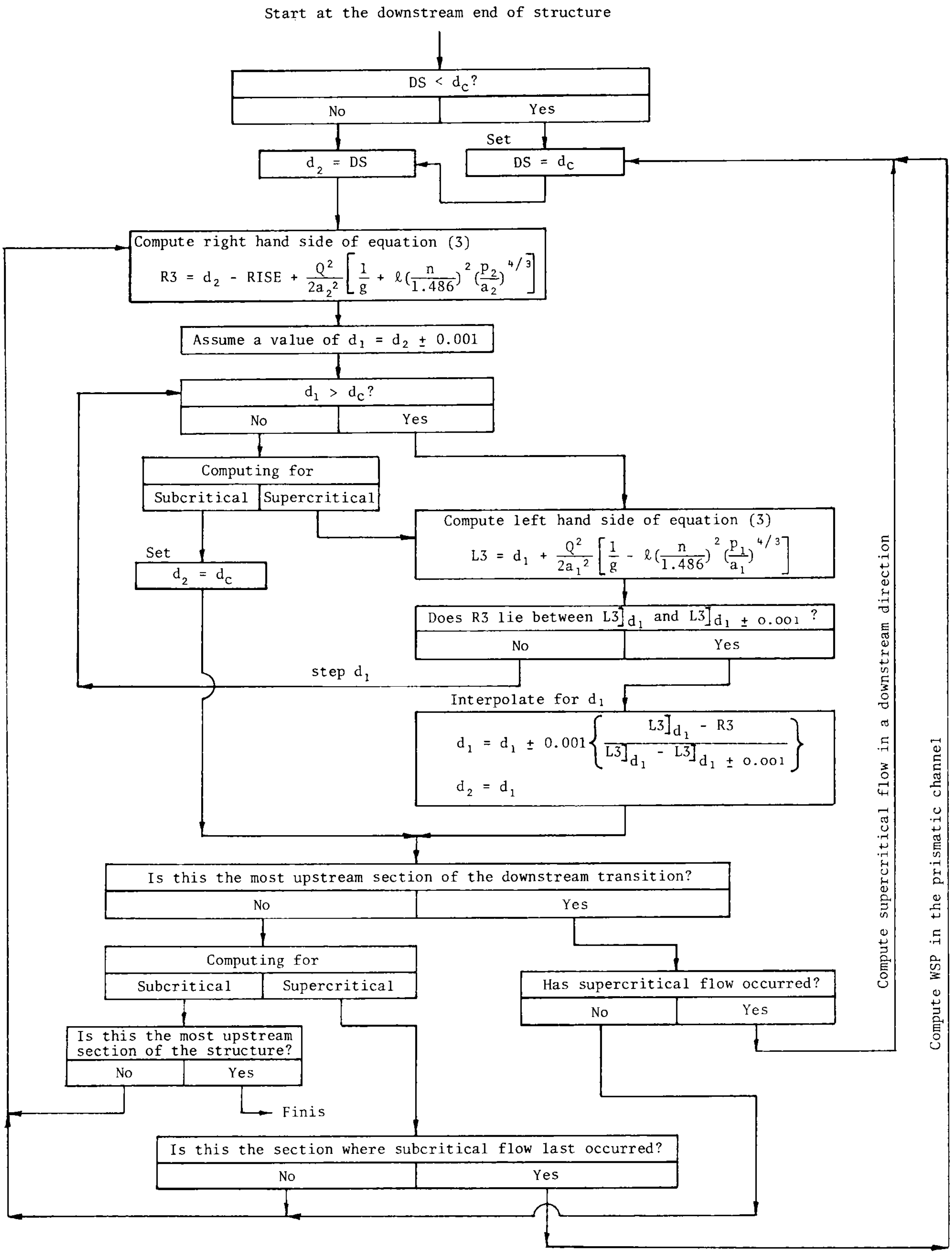


Figure 2. Flow chart of procedure used in computer program to compute WSP

Computer Program

A computer program has been prepared which computes water surface profiles, maximum tractive stresses and other hydraulic parameters for the purpose of comparing and analyzing the design of a riprap gradient control structure obtained from TR-59. The program examines if the flow is subcritical, critical, or supercritical. The water surface profile corresponding to a discharge will be computed for subcritical as well as supercritical flow. It will readily show the effect on the profile and tractive stress of changes in: the tailwater condition, D_{50} size of riprap, or Manning's roughness coefficient.

Input Data

Each computer job requires two lines of heading information. Each line consists of 80 or less alphanumeric characters. This information must be placed ahead of the other input data and is used for identification.

The line arrangement of input data and their order are given in Table 1. All values indicated must be included except the value of n, see below.

Line No.	Order of Input Parameters						
0	Q	n	D_{50}	DIV	CONV	ZL	ZR
1	DS	BSD	R_1	R_2	R_3	R_4	R_5
2	R_6	R_7	R_8	R_9	R_{10}	-	-
3	ZU	BU	LPC	SN	THETA	-	-
4	BSU	R_{11}	R_{12}	R_{13}	R_{14}	R_{15}	R_{16}
5	R_{17}	R_{18}	R_{19}	R_{20}	-	-	-

Table 1. Input Data

Line 0

Q ≡ Discharge for which WSP is desired, cfs

n ≡ Manning's coefficient of roughness. $n = 0.0395\ D_{50}{}^{1/6}$ unless user specified

D_{50} ≡ Size of rock in riprap of which 50 percent by weight is finer, ft

DIV ≡ Rate of divergence of the bottom width of the downstream transition, ft/ft

CONV ≡ Rate of convergence of the bottom width of the downstream transition, ft/ft

ZL ≡ Side slope of the left bank at the ends of riprap structure (looking downstream), ft/ft

ZR ≡ Side slope of the right bank of the ends of riprap structure, ft/ft

Lines 1 and 2

DS ≡ Starting depth at the most downstream end of the riprap structure, ft

BSD ≡ Bottom width at the most downstream end of the riprap structure, ft

R_j = $[RISE]_j$ ≡ The vertical distance from the bottom of the channel, at the downstream end of the transition, to the bottom of the channel at any section j in the transition, ft. The subscript, j, is numbered from 1 to 10 inclusive; 1 being the first preselected section upstream from the most downstream end section of the transition and 10 being the 10th or the last section (most upstream end section) of the transition. The values of $(RISE)_j$ are obtained from the computer output design of TR-59.

Line 3

ZU ≡ Side slope of the prismatic channel, ft/ft

BU ≡ Bottom width of the prismatic channel, ft

LPC ≡ Length of the prismatic channel, ft

SN ≡ Slope of the prismatic channel, ft/ft

THETA ≡ Angle of repose of the riprap, degrees

Lines 4 and 5

BSU ≡ Bottom width of the most upstream end of the riprap structure, ft

R_j = $[RISE]_j$ ≡ See definition above; except that j is numbered from 11 to 20 for the upstream transition, ft

Output Data

The alphanumeric heading information in the first two lines of input is printed in each computer run. The printed alphanumeric information is followed by the data used for analyzing the design.

The output data for the WSP, parameters, and dimensions of the structure are given in the following order:

1. Downstream Transition
2. Prismatic Channel
3. Upstream Transition.

The headings used for the output for the transitions and prismatic channel are:

LENGTH FT ≡ Length from the downstream end of the transition/prismatic channel to any section j of the transition/prismatic channel, ft

RISE FT ≡ The vertical distance from the bottom of the channel, at the downstream end of the transition/prismatic channel, to the bottom of the channel at any section j in the transition/prismatic channel, ft

WIDTH FT ≡ The bottom width at any section j, ft

ZL ≡ The left side slope (looking downstream) at any section j, ft/ft

ZR ≡ The right side slope at any section j, ft/ft

DEPTH FT ≡ The depth at any section j, ft

NORMAL DEPTH ≡ The normal depth at any section j, ft

CRITICAL DEPTH ≡ The critical depth at any section j, ft

VELOCITY FT/SEC ≡ The velocity at any section j, ft/sec

FRIC SLOPE FT/FT ≡ The instantaneous slope of the energy grade line at any section j, ft/ft

TAUBM LB/SQ.FT = (CTAUB)(γ)(RN)(SN) ≡ The maximum tractive stress along the riprap lining on the bottom of any section j, lb/ft^2

FS BOTTOM = $\frac{4\ D_{50}}{TAUBM}$ ≡ Factor of safety of the riprap lining on the bottom of any section j

TAUSM LB/SQ.FT = (CTAUS)(γ)(RN)(SN) ≡ The maximum tractive stress along the riprap lining on the side slope of any section j, lb/ft^2

FS SIDES = $\frac{K\ 4\ D_{50}}{TAUSM}$ ≡ Factor of safety of the riprap lining on the side slope of any section j

TAUO LB/SQ.FT ≡ Mode 4 type structure only (see TR-59); the average tractive stress at any section j in the transition. The maximum tractive stress cannot be obtained, because the value of $C_{\tau b}$ or $C_{\tau s}$ is unknown for trapezoidal cross sections having unequal side slopes, lb/ft^2

In computing the normal depth of flow in the various sections of the riprap structure, the bottom slope, s_o, used in the computations are as follows:

1. Downstream Transition

   a. the slope of the most downstream section has not been defined, therefore normal depth cannot be computed

   b. the average slope of the upstream and downstream computational reach is used to compute DN for all sections except end sections

   c. the slope of the prismatic channel is used to compute DN for the most upstream section

2. Prismatic Channel - the slope of the prismatic channel is used to compute DN for all sections of the prismatic channel

3. Upstream Transition

a. the slope of the prismatic channel is used to compute DN for the most downstream section

b. the average slope of the upstream and downstream computational reach is used to compute DN for all sections except end sections

c. the slope of the most upstream section has not been defined, therefore normal depth cannot be computed.

Example

Given: The riprap structure design used in this example is taken from Example No. 2 of TR-59. This example is repeated in this supplement on pages 14 and 15.

Required:

1. Determine the stability and factor of safety of the riprap structure for the design discharge if the tailwater depth was 6.7 ft instead of 7.0 ft.

2. Determine the stability of the riprap structure for the following discharge-tailwater conditions:

   a. Q = 2600 cfs, DS = 6.75 ft

   b. Q = 2400 cfs, DS = 6.50 ft

   c. Q = 2000 cfs, DS = 6.00 ft.

3. Determine the stability, factor of safety, and capacity of the riprap structure if the design D_{50} = 1.0' was not used in the construction, but the following D_{50} sizes were used.

   a. D_{50} = 1.25 ft

   b. D_{50} = 0.75 ft.

4. Determine the stability, factor of safety, and capacity of the riprap structure if the following CN values were used instead of 0.0395 in the equation $n = CN(D_{50})^{1/6}$

   a. CN = 0.042

   b. CN = 0.035.

5. Determine if the following discharge-tailwater combinations would actually control the design

   a. Q = 2650 cfs, DS = 5.5 ft

   b. Q = 2550 cfs, DS = 6.75 ft.

Solution:

1. The water surface profile elevation, corresponding to the design discharge and a lower starting depth of 6.7 ft, will be lower than the original design where DS = 7.0 ft was used. Therefore, the velocity and tractive stresses will be increased in the downstream transition and the downstream end of the prismatic channel. From the WSP computer output (page 20):

   TAUBM = 4.046 lb/ft^2

   TAUSM = 3.391 lb/ft^2

Example No. 2 (From TR-59)

Given:

Design discharge, Q = 2750 cfs
Side slopes, ZU = 2.5 and ZS = 3.0
Riprap size, D50 = 1.0 ft
Bottom width, BS = 100.0 ft
Starting depth, DS = 7.0 ft
Factor of safety, FS = 1.25

Required:

Design a riprap structure and determine the length of the structure if the total vertical drop desired for gradient control is 6.0 ft.

Solution:

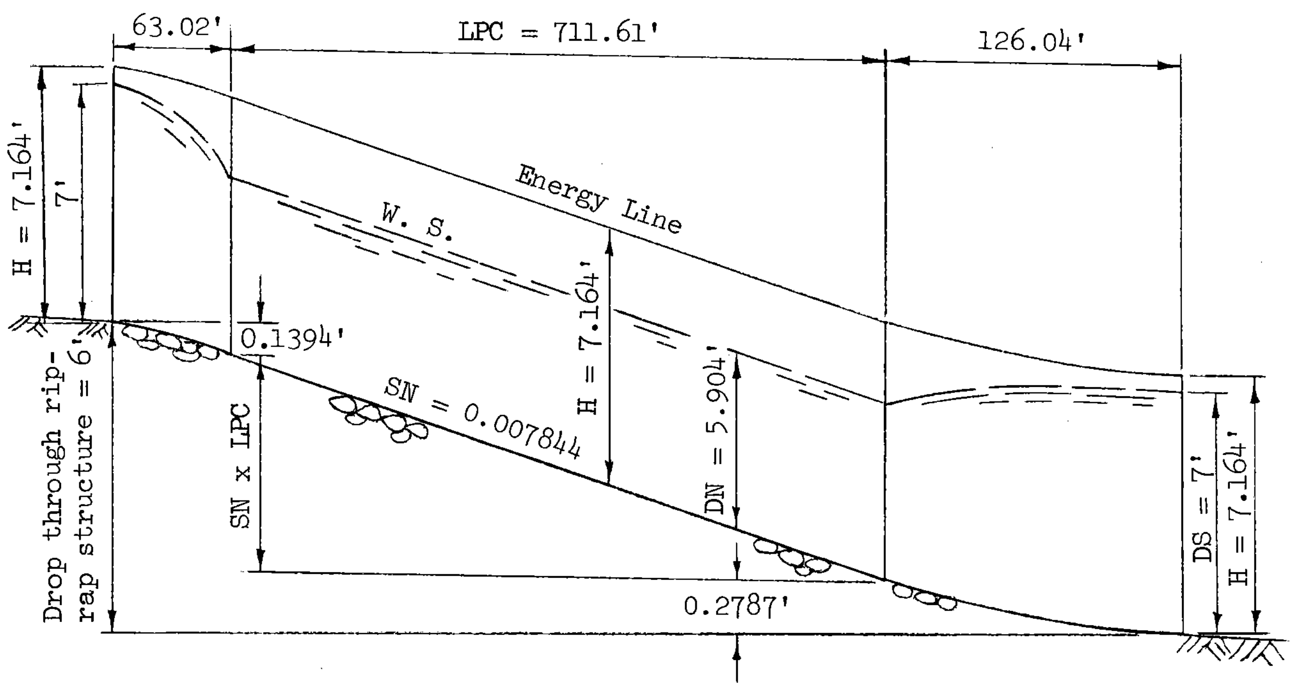
The design obtained from the computer using mode 2 is given on the next page.

The vertical drop in the prismatic channel is equal to the drop through the riprap structure minus the vertical drop contained in both transitions. The length of the prismatic channel, LPC, is equal to the vertical drop in the prismatic channel divided by the bottom slope of the prismatic channel, or

$$LPC = \frac{6.0 - 0.2787 - 0.1394}{0.007844} = 711.61 \text{ ft}$$

The total length of the structure is equal to the length of the prismatic channel plus the lengths of both transitions or

the total length = 711.61 + 126.04 + 63.02 = 900.67 ft



ELEVATION

DESIGN OF RIPRAP GRADIENT CONTROL STRUCTURE
FOR A CONSTANT SPECIFIC ENERGY HEAD

SPECIAL DESIGN PREPARED BY THE DESIGN UNIT AT HYATTSVILLE, MD.
FOR
EXAMPLE DESIGN NO. 2
JANUARY 23, 1976

DIMENSIONS AND PARAMETERS UPSTREAM AND DOWNSTREAM OF THE RIPRAP STRUCTURE

Q= 2750.00 CFS	H= 7.164 FT	ZS= 3.00 FT/FT
BS= 100.000 FT	DS= 7.000 FT	VS= 3.247 FT/SEC

ADDITIONAL DESIGN PARAMETERS EITHER SPECIFIED OR OBTAINED BY DEFAULT

D50= 1.000 FT	CS= 0.7000	THETA= 35.0 DEGREES
C50= 4.00 LB/CU.FT.	CN= 0.0395	CONV= 2.000
FS= 1.250	EXPN= 0.1667	DIV= 4.000

DIMENSIONS AND PARAMETERS ASSOCIATED WITH THE TRANSITION AT THE
DOWNSTREAM END OF THE RIPRAP PRISMATIC CHANNEL

LENGTH FT	RISE FT	WIDTH FT	Z	DEPTH FT	TAU LB/SQ.FT.	VELOCITY FT/SEC	FRIC SLOPE FT/FT
0.0	0.0	100.00	3.00	7.000	0.278	3.247	7.03E-04
12.60	0.0095	93.70	2.95	6.979	0.322	3.448	8.03E-04
25.21	0.0204	87.40	2.90	6.954	0.377	3.677	9.27E-04
37.81	0.0331	81.09	2.85	6.923	0.446	3.940	1.08E-03
50.42	0.0480	74.79	2.80	6.883	0.533	4.247	1.28E-03
63.02	0.0658	68.49	2.75	6.833	0.646	4.611	1.55E-03
75.62	0.0876	62.19	2.70	6.767	0.799	5.051	1.91E-03
88.23	0.1150	55.89	2.65	6.677	1.011	5.598	2.43E-03
100.83	0.1507	49.58	2.60	6.545	1.325	6.309	3.23E-03
113.44	0.2002	43.28	2.55	6.334	1.838	7.305	4.62E-03
126.04	0.2787	36.98	2.50	5.904	2.910	9.003	7.84E-03

DIMENSIONS AND PARAMETERS ASSOCIATED WITH THE PRISMATIC CHANNEL
OF THE RIPRAP STRUCTURE

D50U= 1.000 FT	SN= 0.007844	SC= 0.014965	CTAUB = 1.339
CSU= 0.5242	HN= 7.164 FT	HC= 6.920 FT	TAUBM= 2.910 LB/SQ.FT.
FSU= 1.25	DN= 5.904 FT	DC= 4.943 FT	TAUBA= 3.200 LB/SQ.FT.
BU= 36.98 FT	VN= 9.00 FPS	N= 0.0395	CTAUS = 1.122
ZU= 2.50	RN= 4.44 FT	K= 0.7621	TAUSM= 2.439 LB/SQ.FT.
		KPS= 8.77E+03	TAUSA= 2.439 LB/SQ.FT.

DIMENSIONS AND PARAMETERS ASSOCIATED WITH THE TRANSITION AT THE
UPSTREAM END OF THE RIPRAP PRISMATIC CHANNEL

LENGTH FT	RISE FT	WIDTH FT	Z	DEPTH FT	TAU LB/SQ.FT.	VELOCITY FT/SEC	FRIC SLOPE FT/FT
0.0	0.0	36.98	2.50	5.904	2.910	9.003	7.84E-03
6.30	0.0393	43.28	2.55	6.334	1.838	7.305	4.62E-03
12.60	0.0640	49.58	2.60	6.545	1.325	6.309	3.23E-03
18.91	0.0819	55.89	2.65	6.677	1.011	5.598	2.43E-03
25.21	0.0955	62.19	2.70	6.767	0.799	5.051	1.91E-03
31.51	0.1064	68.49	2.75	6.833	0.646	4.611	1.55E-03
37.81	0.1154	74.79	2.80	6.883	0.533	4.247	1.28E-03
44.11	0.1228	81.09	2.85	6.923	0.446	3.940	1.08E-03
50.42	0.1292	87.40	2.90	6.954	0.377	3.677	9.27E-04
56.72	0.1346	93.70	2.95	6.979	0.322	3.448	8.03E-04
63.02	0.1394	100.00	3.00	7.000	0.278	3.247	7.03E-04

TRANSITION CONVERSION LOSSES

THE CONVERSION LOSS IN THE DOWNSTREAM TRANSITION MAY BE AS MUCH AS 0.15 FT

THE CONVERSION LOSS IN THE UPSTREAM TRANSITION MAY BE AS MUCH AS 0.05 FT

From the original design (page 15):

TAUBA = 3.200 lb/ft^2

TAUSA = 2.439 lb/ft^2

The maximum tractive stress for both the bottom and side slopes of the channel is greater than their allowable tractive stress, i.e.,

TAUBM > TAUBA

TAUSM > TAUSA

Factor of safety: From the computer output (page 20) or may be computed as follows:

bottom; $FS = \frac{C_{50}D_{50}}{TAUBM} = \frac{4.0(1.0)}{4.046} = 0.99 < 1.25$ N.G.

side slopes; $FS = \frac{K\ C_{50}D_{50}}{TAUSM} = \frac{0.7621(4.0)(1.0)}{3.391} = 0.90 < 1.25$ N.G.

For the design discharge, the lowest tailwater condition should be used for the design. Therefore, the structure should be redesigned using the lower starting depth. The redesign is given on page 21.

2. a. The computer output is given on page 22.

TAUBM	= 2.922 < 3.2 = TAUBA	OK
FS	= 1.37 > 1.25	OK
TAUSM	= 2.449 ≃ 2.439 = TAUSA	OK
FS	= 1.24 ≃ 1.25	OK

b. The computer output is given on page 23.

TAUBM	= 2.701 < 3.2 = TAUBA	OK
TAUSM	= 2.263 < 2.439 = TAUSA	OK
FS > 1.25		OK

c. The computer output is given on page 24.

TAUBM	= 2.436 < 3.2 = TAUBA	OK
TAUSM	= 2.042 < 2.439 = TAUSA	OK
FS > 1.25		OK

The original design is considered stable for this rating curve.

3. a. Since the riprap size D_{50} = 1.25' was used instead of the design D_{50} = 1.0 ft, Manning's roughness coefficient, n, is increased. Thus, the water surface elevation throughout the entire structure will be higher. However, the increase in depths are considered small in this case, and the usual freeboard provided will be adequate.

Since a larger riprap size was used, stability will not be a problem. From WSP computer output (page 25):

TAUBM = 3.092 lb/ft^2

TAUSM = 2.591 lb/ft^2

$$TAUBA = \frac{C_{50}D_{50}}{FS} = \frac{4(1.25)}{1.25} = 4 > 3.092 = TAUBM \qquad OK$$

$$TAUSA = \frac{K\ C_{50}D_{50}}{FS} = 0.7621(4) = 3.05 > 2.591 = TAUSM \qquad OK$$

Factor of safety for bottom

FS = 1.62 > 1.25 OK

Factor of safety for side slopes

FS = 1.47 > 1.25 OK

b. Since the smaller size riprap D_{50} = 0.75' was used, the value of n is decreased. Thus, the water surface profile elevation throughout the entire structure will be lower so that capacity will not be a problem.

Since a smaller riprap size was used, stability may be a problem and the factor of safety will be decreased. From WSP computer output (page 26):

TAUBM = 2.835 lb/ft^2

TAUSM = 2.376 lb/ft^2

$$TAUBA = \frac{C_{50}D_{50}}{FS} = \frac{4(0.75)}{1.25} = 2.4 < 2.835 = TAUBM \qquad N.G.$$

$$TAUSA = \frac{K\ C_{50}D_{50}}{FS} = \frac{0.7621(4)(0.75)}{1.25} = 1.83 < 2.376 = TAUSM \qquad N.G.$$

Factor of safety for bottom

FS = 1.06 < 1.25 N.G.

Factor of safety for side slopes

FS = 0.96 < 1.25 N.G.

4. a. Since the value of CN = 0.042 was used instead of 0.0395, Manning's roughness coefficient is increased. Thus the water surface profile elevation throughout the entire structure will be higher. (See DEPTH column of WSP computer output, page 27).

From Example Design No. 2 (page 15) the maximum allowable tractive stress for the bottom and side slopes are:

TAUBA = 3.200 lb/ft^2

TAUSA = 2.439 lb/ft^2

From the WSP computer output (page 27) the maximum tractive stress occurred at the most downstream end of the prismatic channel.

TAUBM = 3.260 > 3.200 = TAUBA

TAUSM = 2.686 > 2.439 = TAUSA N.G.

Factor of safety at bottom

FS = 1.25

Factor of safety at side slopes

FS < 1.25

If the factor of safety = 1.25 is desired, the structure should be redesigned using the higher CN value.

b. The smaller value of CN = 0.035 would result in a smaller value of n. Thus, the water surface profile elevation throughout the entire structure will be lower. (See DEPTH column of WSP computer output, page 28). The maximum tractive stress occurred at the upstream end of the prismatic channel.

TAUBM = 2.724 < 3.200 = TAUBA OK

TAUSM = 2.282 < 2.439 = TAUSA OK

Factor of safety at the bottom

FS = 1.47 > 1.25 OK

Factor of safety at the side slopes

FS = 1.34 > 1.25 OK

5. a. The WSP computer output is given on page 29. Computation of water surface profile commences at the most downstream section, Sta. 0.0, in an upstream direction with a starting depth of 5.5 ft. Flow remains subcritical to Sta. 100.83, but supercritical flow occurred before reaching Sta. 113.44. Therefore, computation ceases and critical depth of 4.454 ft was used as the starting depth for the next computational reach. However, flow remains supercritical to the most upstream section (Sta. 126.04) of the downstream transition.

Computation of water surface profile for supercritical flow in a downstream direction using d_c = 4.835 ft as the starting depth commencing at Sta. 126.04 to Sta. 100.83 where subcritical flow last occurred. Note that actually a hydraulic jump occurs between Sta. 113.44 and Sta. 100.83.

Computation of water surface profile in an upstream direction resumes commencing at Sta. 126.04 using critical depth as the starting depth. The WSP approaches normal depth in the prismatic channel and the upstream transition.

In this case, the tailwater is considered to be decreasing very rapidly with a small decrease in discharge. The lesser discharge causes higher tractive stresses than the design discharge. For example, at Sta. 113.44;

TAUBM = 6.304 > 1.838 = TAU

TAUSM = 5.304 > 1.838 = TAU

where TAU is the maximum tractive stress at Sta. 113.44 for the design discharge-tailwater condition (see page 15).

Thus, the lesser discharge actually controls the design.

b. As can be seen from the WSP computer output given on page 30, this discharge-tailwater condition does not control the design and the original design is good for this condition.

WATER SURFACE PROFILES AND TRACTIVE STRESSES FOR RIPRAP GRADIENT CONTROL STRUCTURES

SPECIAL ANALYSIS PREPARED BY THE DESIGN UNIT AT HYATTSVILLE, MD.
FOR
DESIGN UNIT, ENGINEERING DIVISION, HYATTSVILLE, MARYLAND
EXAMPLE DESIGN NO. 1 - - - - - - - - - - JANUARY 23, 1978

PARAMETERS USED IN THE WSP ANALYSIS

Q = 2750.00 CFS   N = 0.0395   D50 = 1.00 FT   DIV = 4.00   CONV = 2.00   SN = 0.007844   THETA = 35.0 DEGREES

DOWNSTREAM TRANSITION

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	100.00	3.00	3.00	6.700	******	2.784	3.418	0.000820	0.305	13.12	0.266	12.55
12.60	0.0095	93.70	2.95	2.95	6.678	6.964	2.899	3.631	0.000938	0.355	11.27	0.308	10.75
25.21	0.0204	87.40	2.90	2.90	6.651	6.934	3.027	3.875	0.001084	0.417	9.60	0.361	9.13
37.81	0.0331	81.09	2.85	2.85	6.618	6.901	3.170	4.157	0.001269	0.494	8.09	0.426	7.67
50.42	0.0480	74.79	2.80	2.80	6.577	6.862	3.330	4.486	0.001508	0.593	6.74	0.509	6.36
63.02	0.0658	68.49	2.75	2.75	6.523	6.805	3.511	4.878	0.001826	0.723	5.53	0.618	5.20
75.62	0.0876	62.19	2.70	2.70	6.451	6.727	3.717	5.355	0.002267	0.898	4.45	0.765	4.16
88.23	0.1150	55.89	2.65	2.65	6.350	6.623	3.954	5.956	0.002911	1.146	3.49	0.972	3.24
100.83	0.1507	49.58	2.60	2.60	6.200	6.465	4.230	6.751	0.003931	1.522	2.63	1.286	2.43
113.44	0.2002	43.28	2.55	2.55	5.945	6.172	4.555	7.915	0.005820	2.170	1.84	1.826	1.69
126.04	0.2787	36.98	2.50	2.50	5.211	5.904	4.943	10.554	0.012370	4.046	0.99	3.391	0.90

PRISMATIC CHANNEL

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	36.98	2.50	2.50	5.211	5.904	4.943	10.554	0.012370	4.046	0.99	3.391	0.90
71.20	0.5585	36.98	2.50	2.50	5.717	5.904	4.943	9.381	0.008822	3.170	1.26	2.656	1.15
142.40	1.1170	36.98	2.50	2.50	5.827	5.904	4.943	9.155	0.008229	3.013	1.33	2.525	1.21
213.60	1.6755	36.98	2.50	2.50	5.870	5.904	4.943	9.070	0.008012	2.955	1.35	2.476	1.23
284.80	2.2340	36.98	2.50	2.50	5.888	5.904	4.943	9.033	0.007920	2.930	1.37	2.456	1.24
356.00	2.7925	36.98	2.50	2.50	5.897	5.904	4.943	9.017	0.007879	2.919	1.37	2.446	1.25
427.20	3.3510	36.98	2.50	2.50	5.900	5.904	4.943	9.009	0.007860	2.914	1.37	2.442	1.25
498.40	3.9094	36.98	2.50	2.50	5.902	5.904	4.943	9.006	0.007851	2.912	1.37	2.440	1.25
569.60	4.4679	36.98	2.50	2.50	5.903	5.904	4.943	9.004	0.007848	2.911	1.37	2.439	1.25
640.80	5.0264	36.98	2.50	2.50	5.903	5.904	4.943	9.004	0.007846	2.910	1.37	2.439	1.25
712.00	5.5849	36.98	2.50	2.50	5.904	5.904	4.943	9.003	0.007845	2.910	1.37	2.439	1.25

UPSTREAM TRANSITION

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	36.98	2.50	2.50	5.904	5.904	4.943	9.003	0.007845	2.910	1.37	2.439	1.25
6.30	0.0393	43.28	2.55	2.55	6.331	6.172	4.555	7.309	0.004628	1.841	2.17	1.549	1.99
12.60	0.0640	49.58	2.60	2.60	6.542	6.465	4.230	6.312	0.003238	1.327	3.02	1.121	2.78
18.91	0.0819	55.89	2.65	2.65	6.674	6.626	3.954	5.601	0.002435	1.012	3.95	0.858	3.67
25.21	0.0955	62.19	2.70	2.70	6.764	6.735	3.717	5.053	0.001914	0.799	5.00	0.681	4.68
31.51	0.1064	68.49	2.75	2.75	6.830	6.796	3.511	4.613	0.001550	0.647	6.18	0.553	5.81
37.81	0.1154	74.79	2.80	2.80	6.880	6.856	3.330	4.249	0.001285	0.534	7.50	0.458	7.08
44.11	0.1228	81.09	2.85	2.85	6.920	6.901	3.170	3.942	0.001084	0.446	8.96	0.385	8.49
50.42	0.1292	87.40	2.90	2.90	6.951	6.934	3.027	3.679	0.000928	0.378	10.59	0.327	10.07
56.72	0.1346	93.70	2.95	2.95	6.976	6.964	2.899	3.450	0.000805	0.323	12.40	0.280	11.83
63.02	0.1394	100.00	3.00	3.00	6.997	******	2.784	3.248	0.000704	0.278	14.39	0.242	13.77

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DESIGN OF RIPRAP GRADIENT CONTROL STRUCTURE
FOR A CONSTANT SPECIFIC ENERGY HEAD

SPECIAL DESIGN PREPARED BY THE DESIGN UNIT AT HYATTSVILLE, MD.
FOR
DESIGN UNIT, ENGINEERING DIVISION, HYATTSVILLE, MARYLAND
EXAMPLE DESIGN NO. 1 - - - - - - - - - - JANUARY 23, 1978

DIMENSIONS AND PARAMETERS UPSTREAM AND DOWNSTREAM OF THE RIPRAP STRUCTURE

Q=	2750.00 CFS	H=	6.882 FT	ZS=	3.00 FT/FT
BS=	100.000 FT	DS=	6.700 FT	VS=	3.418 FT/SEC

ADDITIONAL DESIGN PARAMETERS EITHER SPECIFIED OR OBTAINED BY DEFAULT

D50=	1.000 FT	CS=	0.7000	THETA=	35.0 DEGREES
C50=	4.00 LB/CU.FT.	CN=	0.0395	CONV=	2.000
FS=	1.250	EXPN=	0.1667	DIV=	4.000

DIMENSIONS AND PARAMETERS ASSOCIATED WITH THE TRANSITION AT THE
DOWNSTREAM END OF THE RIPRAP PRISMATIC CHANNEL

LENGTH FT	RISE FT	WIDTH FT	Z	DEPTH FT	TAU LB/SQ.FT.	VELOCITY FT/SEC	FRIC SLOPE FT/FT
0.0	0.0	100.00	3.00	6.700	0.305	3.418	8.20E-04
11.98	0.0105	94.01	2.95	6.678	0.353	3.622	9.32E-04
23.95	0.0225	88.02	2.90	6.651	0.411	3.853	1.07E-03
35.93	0.0363	82.03	2.85	6.618	0.483	4.118	1.24E-03
47.91	0.0525	76.05	2.80	6.577	0.574	4.426	1.46E-03
59.89	0.0718	70.06	2.75	6.525	0.691	4.789	1.75E-03
71.86	0.0951	64.07	2.70	6.457	0.847	5.226	2.14E-03
83.84	0.1241	58.08	2.65	6.365	1.061	5.765	2.70E-03
95.82	0.1615	52.09	2.60	6.233	1.374	6.461	3.54E-03
107.80	0.2125	46.10	2.55	6.024	1.878	7.428	4.98E-03
119.77	0.2919	40.11	2.50	5.603	2.910	9.069	8.27E-03

DIMENSIONS AND PARAMETERS ASSOCIATED WITH THE PRISMATIC CHANNEL
OF THE RIPRAP STRUCTURE

D50U=	1.000 FT	SN=	0.008275	SC=	0.015036	CTAUB =	1.306
CSU=	0.5503	HN=	6.882 FT	HC=	6.678 FT	TAUBM=	2.910 LB/SQ.FT.
FSU=	1.25	DN=	5.603 FT	DC=	4.746 FT	TAUBA=	3.200 LB/SQ.FT.
BU=	40.11 FT	VN=	9.07 FPS	N=	0.0395	CTAUS =	1.095
ZU=	2.50	RN=	4.31 FT	K=	0.7621	TAUSM=	2.438 LB/SQ.FT.
				KPS=	8.49E+03	TAUSA=	2.439 LB/SQ.FT.

DIMENSIONS AND PARAMETERS ASSOCIATED WITH THE TRANSITION AT THE
UPSTREAM END OF THE RIPRAP PRISMATIC CHANNEL

LENGTH FT	RISE FT	WIDTH FT	Z	DEPTH FT	TAU LB/SQ.FT.	VELOCITY FT/SEC	FRIC SLOPE FT/FT
0.0	0.0	40.11	2.50	5.603	2.910	9.069	8.27E-03
5.99	0.0397	46.10	2.55	6.024	1.878	7.428	4.98E-03
11.98	0.0652	52.09	2.60	6.233	1.374	6.461	3.54E-03
17.97	0.0839	58.08	2.65	6.365	1.061	5.765	2.70E-03
23.95	0.0984	64.07	2.70	6.457	0.847	5.226	2.14E-03
29.94	0.1100	70.06	2.75	6.525	0.691	4.789	1.75E-03
35.93	0.1197	76.05	2.80	6.577	0.574	4.426	1.46E-03
41.92	0.1278	82.03	2.85	6.618	0.483	4.118	1.24E-03
47.91	0.1347	88.02	2.90	6.651	0.411	3.853	1.07E-03
53.90	0.1407	94.01	2.95	6.678	0.353	3.622	9.32E-04
59.89	0.1459	100.00	3.00	6.700	0.305	3.418	8.20E-04

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TRANSITION CONVERSION LOSSES

THE CONVERSION LOSS IN THE DOWNSTREAM TRANSITION MAY BE AS MUCH AS 0.15 FT

THE CONVERSION LOSS IN THE UPSTREAM TRANSITION MAY BE AS MUCH AS 0.05 FT

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WATER SURFACE PROFILES AND TRACTIVE STRESSES FOR RIPRAP GRADIENT CONTROL STRUCTURES

SPECIAL ANALYSIS PREPARED BY THE DESIGN UNIT AT HYATTSVILLE, MD.
FOR
DESIGN UNIT, ENGINEERING DIVISION, HYATTSVILLE, MARYLAND
EXAMPLE DESIGN NO. 1 - - - - - - - - - - JANUARY 23, 1978

PARAMETERS USED IN THE WSP ANALYSIS

Q = 2600.00 CFS N = 0.0395 D50 = 1.00 FT DIV = 4.00 CONV = 2.00 SN = 0.007844 THETA = 35.0 DEGREES

DOWNSTREAM TRANSITION

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	100.00	3.00	3.00	6.750	******	2.684	3.203	0.000714	0.268	14.91	0.234	14.26
12.60	0.0095	93.70	2.95	2.95	6.730	6.745	2.796	3.402	0.000816	0.312	12.82	0.271	12.23
25.21	0.0204	87.40	2.90	2.90	6.705	6.717	2.920	3.629	0.000942	0.366	10.93	0.317	10.39
37.81	0.0331	81.09	2.85	2.85	6.675	6.685	3.058	3.891	0.001101	0.433	9.23	0.373	8.75
50.42	0.0480	74.79	2.80	2.80	6.636	6.648	3.213	4.196	0.001305	0.519	7.71	0.446	7.27
63.02	0.0658	68.49	2.75	2.75	6.587	6.594	3.388	4.557	0.001576	0.631	6.34	0.540	5.95
75.62	0.0876	62.19	2.70	2.70	6.523	6.519	3.588	4.995	0.001948	0.781	5.12	0.665	4.78
88.23	0.1150	55.89	2.65	2.65	6.434	6.419	3.818	5.541	0.002483	0.992	4.03	0.841	3.75
100.83	0.1507	49.58	2.60	2.60	6.304	6.267	4.086	6.252	0.003310	1.304	3.07	1.102	2.83
113.44	0.2002	43.28	2.55	2.55	6.094	5.985	4.402	7.254	0.004755	1.819	2.20	1.530	2.02
126.04	0.2787	36.98	2.50	2.50	5.652	5.726	4.780	9.001	0.008227	2.922	1.37	2.449	1.24

PRISMATIC CHANNEL

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	36.98	2.50	2.50	5.652	5.726	4.780	9.001	0.008227	2.922	1.37	2.449	1.24
71.20	0.5585	36.98	2.50	2.50	5.693	5.726	4.780	8.917	0.008008	2.865	1.40	2.401	1.27
142.40	1.1170	36.98	2.50	2.50	5.711	5.726	4.780	8.882	0.007917	2.842	1.41	2.381	1.28
213.60	1.6755	36.98	2.50	2.50	5.719	5.726	4.780	8.866	0.007877	2.831	1.41	2.373	1.28
284.80	2.2340	36.98	2.50	2.50	5.723	5.726	4.780	8.859	0.007859	2.827	1.42	2.369	1.29
356.00	2.7925	36.98	2.50	2.50	5.724	5.726	4.780	8.855	0.007851	2.824	1.42	2.367	1.29
427.20	3.3510	36.98	2.50	2.50	5.725	5.726	4.780	8.854	0.007847	2.823	1.42	2.366	1.29
498.40	3.9094	36.98	2.50	2.50	5.725	5.726	4.780	8.853	0.007846	2.823	1.42	2.366	1.29
569.60	4.4679	36.98	2.50	2.50	5.726	5.726	4.780	8.853	0.007845	2.823	1.42	2.365	1.29
640.80	5.0264	36.98	2.50	2.50	5.726	5.726	4.780	8.853	0.007844	2.823	1.42	2.365	1.29
712.00	5.5849	36.98	2.50	2.50	5.726	5.726	4.780	8.853	0.007844	2.823	1.42	2.365	1.29

UPSTREAM TRANSITION

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	36.98	2.50	2.50	5.726	5.726	4.780	8.853	0.007844	2.823	1.42	2.365	1.29
6.30	0.0393	43.28	2.55	2.55	6.140	5.985	4.402	7.185	0.004628	1.784	2.24	1.501	2.06
12.60	0.0640	49.58	2.60	2.60	6.344	6.267	4.086	6.203	0.003235	1.283	3.12	1.084	2.88
18.91	0.0819	55.89	2.65	2.65	6.471	6.422	3.818	5.501	0.002432	0.978	4.09	0.829	3.80
25.21	0.0955	62.19	2.70	2.70	6.559	6.527	3.588	4.962	0.001910	0.771	5.19	0.657	4.85
31.51	0.1064	68.49	2.75	2.75	6.623	6.584	3.388	4.528	0.001547	0.623	6.42	0.533	6.03
37.81	0.1154	74.79	2.80	2.80	6.671	6.643	3.213	4.170	0.001282	0.513	7.80	0.440	7.36
44.11	0.1228	81.09	2.85	2.85	6.709	6.685	3.058	3.867	0.001081	0.428	9.34	0.369	8.85
50.42	0.1292	87.40	2.90	2.90	6.739	6.717	2.920	3.608	0.000925	0.362	11.05	0.313	10.51
56.72	0.1346	93.70	2.95	2.95	6.763	6.745	2.796	3.383	0.000802	0.309	12.96	0.268	12.36
63.02	0.1394	100.00	3.00	3.00	6.783	******	2.685	3.185	0.000702	0.265	15.07	0.232	14.41

WATER SURFACE PROFILES AND TRACTIVE STRESSES FOR RIPRAP GRADIENT CONTROL STRUCTURES

SPECIAL ANALYSIS PREPARED BY THE DESIGN UNIT AT HYATTSVILLE, MD.
FOR
DESIGN UNIT, ENGINEERING DIVISION, HYATTSVILLE, MARYLAND
EXAMPLE DESIGN NO. 1 - - - - - - - - - - JANUARY 23, 1978

PARAMETERS USED IN THE WSP ANALYSIS

Q = 2400.00 CFS N = 0.0395 D50 = 1.00 FT DIV = 4.00 CONV = 2.00 SN = 0.007844 THETA = 35.0 DEGREES

DOWNSTREAM TRANSITION

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	100.00	3.00	3.00	6.500	******	2.549	3.090	0.000694	0.247	16.16	0.216	15.46
12.60	0.0095	93.70	2.95	2.95	6.481	6.444	2.655	3.283	0.000793	0.288	13.87	0.251	13.23
25.21	0.0204	87.40	2.90	2.90	6.457	6.417	2.773	3.502	0.000916	0.339	11.80	0.293	11.22
37.81	0.0331	81.09	2.85	2.85	6.429	6.387	2.904	3.755	0.001070	0.402	9.95	0.346	9.43
50.42	0.0480	74.79	2.80	2.80	6.393	6.354	3.052	4.050	0.001270	0.483	8.29	0.414	7.82
63.02	0.0658	68.49	2.75	2.75	6.346	6.303	3.219	4.400	0.001533	0.587	6.81	0.502	6.40
75.62	0.0876	62.19	2.70	2.70	6.285	6.232	3.410	4.824	0.001894	0.729	5.49	0.620	5.13
88.23	0.1150	55.89	2.65	2.65	6.201	6.138	3.631	5.351	0.002413	0.926	4.32	0.785	4.01
100.83	0.1507	49.58	2.60	2.60	6.079	5.994	3.888	6.037	0.003213	1.219	3.28	1.030	3.03
113.44	0.2002	43.28	2.55	2.55	5.883	5.726	4.192	6.999	0.004603	1.698	2.36	1.429	2.16
126.04	0.2787	36.98	2.50	2.50	5.481	5.480	4.556	8.640	0.007839	2.700	1.48	2.262	1.35

PRISMATIC CHANNEL

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	36.98	2.50	2.50	5.481	5.480	4.556	8.640	0.007839	2.700	1.48	2.262	1.35
71.20	0.5585	36.98	2.50	2.50	5.480	5.480	4.556	8.641	0.007842	2.700	1.48	2.263	1.35
142.40	1.1170	36.98	2.50	2.50	5.480	5.480	4.556	8.641	0.007843	2.701	1.48	2.263	1.35
213.60	1.6755	36.98	2.50	2.50	5.480	5.480	4.556	8.642	0.007844	2.701	1.48	2.263	1.35
284.80	2.2340	36.98	2.50	2.50	5.480	5.480	4.556	8.642	0.007844	2.701	1.48	2.263	1.35
356.00	2.7925	36.98	2.50	2.50	5.480	5.480	4.556	8.642	0.007844	2.701	1.48	2.263	1.35
427.20	3.3510	36.98	2.50	2.50	5.480	5.480	4.556	8.642	0.007844	2.701	1.48	2.263	1.35
498.40	3.9094	36.98	2.50	2.50	5.480	5.480	4.556	8.642	0.007844	2.701	1.48	2.263	1.35
569.60	4.4679	36.98	2.50	2.50	5.480	5.480	4.556	8.642	0.007844	2.701	1.48	2.263	1.35
640.80	5.0264	36.98	2.50	2.50	5.480	5.480	4.556	8.642	0.007844	2.701	1.48	2.263	1.35
712.00	5.5849	36.98	2.50	2.50	5.480	5.480	4.556	8.642	0.007844	2.701	1.48	2.263	1.35

UPSTREAM TRANSITION

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	36.98	2.50	2.50	5.480	5.480	4.556	8.642	0.007844	2.701	1.48	2.263	1.35
6.30	0.0393	43.28	2.55	2.55	5.875	5.726	4.192	7.012	0.004627	1.704	2.35	1.434	2.15
12.60	0.0640	49.58	2.60	2.60	6.070	5.994	3.888	6.049	0.003231	1.224	3.27	1.034	3.02
18.91	0.0819	55.89	2.65	2.65	6.191	6.141	3.631	5.362	0.002427	0.930	4.30	0.789	4.00
25.21	0.0955	62.19	2.70	2.70	6.275	6.240	3.410	4.833	0.001905	0.731	5.47	0.623	5.11
31.51	0.1064	68.49	2.75	2.75	6.336	6.294	3.219	4.409	0.001542	0.590	6.78	0.504	6.37
37.81	0.1154	74.79	2.80	2.80	6.382	6.348	3.052	4.058	0.001277	0.484	8.26	0.416	7.79
44.11	0.1228	81.09	2.85	2.85	6.418	6.388	2.904	3.763	0.001077	0.404	9.91	0.348	9.39
50.42	0.1292	87.40	2.90	2.90	6.446	6.417	2.773	3.509	0.000921	0.340	11.76	0.294	11.18
56.72	0.1346	93.70	2.95	2.95	6.470	6.444	2.655	3.289	0.000798	0.290	13.82	0.251	13.18
63.02	0.1394	100.00	3.00	3.00	6.489	******	2.549	3.096	0.000698	0.248	16.10	0.217	15.41

WATER SURFACE PROFILES AND TRACTIVE STRESSES FOR RIPRAP GRADIENT CONTROL STRUCTURES

SPECIAL ANALYSIS PREPARED BY THE DESIGN UNIT AT HYATTSVILLE, MD.
FOR
DESIGN UNIT, ENGINEERING DIVISION, HYATTSVILLE, MARYLAND
EXAMPLE DESIGN NO. 1 - - - - - - - - - - JANUARY 23, 1978

PARAMETERS USED IN THE WSP ANALYSIS

Q = 2000.00 CFS N = 0.0395 D50 = 1.00 FT DIV = 4.00 CONV = 2.00 SN = 0.007844 THETA = 35.0 DEGREES

DOWNSTREAM TRANSITION

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	100.00	3.00	3.00	6.000	******	2.264	2.825	0.000637	0.204	19.61	0.178	18.76
12.60	0.0095	93.70	2.95	2.95	5.983	5.804	2.359	3.002	0.000728	0.237	16.88	0.206	16.11
25.21	0.0204	87.40	2.90	2.90	5.962	5.781	2.464	3.204	0.000841	0.280	14.31	0.242	13.60
37.81	0.0331	81.09	2.85	2.85	5.937	5.756	2.582	3.437	0.000983	0.333	12.01	0.287	11.38
50.42	0.0480	74.79	2.80	2.80	5.906	5.728	2.715	3.708	0.001165	0.401	9.97	0.344	9.41
63.02	0.0658	68.49	2.75	2.75	5.865	5.684	2.865	4.030	0.001406	0.490	8.16	0.419	7.66
75.62	0.0876	62.19	2.70	2.70	5.812	5.623	3.038	4.418	0.001736	0.610	6.56	0.520	6.13
88.23	0.1150	55.89	2.65	2.65	5.739	5.541	3.237	4.901	0.002209	0.777	5.15	0.659	4.78
100.83	0.1507	49.58	2.60	2.60	5.634	5.414	3.470	5.526	0.002931	1.024	3.91	0.865	3.61
113.44	0.2002	43.28	2.55	2.55	5.469	5.174	3.747	6.390	0.004161	1.422	2.81	1.197	2.58
126.04	0.2787	36.98	2.50	2.50	5.148	4.956	4.081	7.794	0.006837	2.209	1.81	1.851	1.65

PRISMATIC CHANNEL

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	36.98	2.50	2.50	5.148	4.956	4.081	7.794	0.006837	2.209	1.81	1.851	1.65
71.20	0.5585	36.98	2.50	2.50	5.048	4.956	4.081	7.988	0.007340	2.324	1.72	1.947	1.57
142.40	1.1170	36.98	2.50	2.50	4.997	4.956	4.081	8.090	0.007611	2.385	1.68	1.998	1.53
213.60	1.6755	36.98	2.50	2.50	4.974	4.956	4.081	8.137	0.007741	2.414	1.66	2.023	1.51
284.80	2.2340	36.98	2.50	2.50	4.964	4.956	4.081	8.158	0.007800	2.427	1.65	2.034	1.50
356.00	2.7925	36.98	2.50	2.50	4.959	4.956	4.081	8.168	0.007825	2.432	1.64	2.038	1.50
427.20	3.3510	36.98	2.50	2.50	4.957	4.956	4.081	8.172	0.007836	2.435	1.64	2.040	1.49
498.40	3.9094	36.98	2.50	2.50	4.956	4.956	4.081	8.173	0.007841	2.436	1.64	2.041	1.49
569.60	4.4679	36.98	2.50	2.50	4.956	4.956	4.081	8.174	0.007843	2.436	1.64	2.042	1.49
640.80	5.0264	36.98	2.50	2.50	4.956	4.956	4.081	8.174	0.007844	2.436	1.64	2.042	1.49
712.00	5.5849	36.98	2.50	2.50	4.956	4.956	4.081	8.174	0.007844	2.436	1.64	2.042	1.49

UPSTREAM TRANSITION

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	36.98	2.50	2.50	4.956	4.956	4.081	8.174	0.007844	2.436	1.64	2.042	1.49
6.30	0.0393	43.28	2.55	2.55	5.310	5.174	3.747	6.629	0.004628	1.533	2.61	1.290	2.39
12.60	0.0640	49.58	2.60	2.60	5.485	5.414	3.470	5.711	0.003225	1.094	3.66	0.924	3.37
18.91	0.0819	55.89	2.65	2.65	5.595	5.543	3.237	5.055	0.002418	0.827	4.84	0.701	4.50
25.21	0.0955	62.19	2.70	2.70	5.670	5.629	3.038	4.552	0.001895	0.647	6.18	0.551	5.78
31.51	0.1064	68.49	2.75	2.75	5.724	5.676	2.865	4.148	0.001532	0.519	7.71	0.443	7.25
37.81	0.1154	74.79	2.80	2.80	5.765	5.723	2.715	3.815	0.001268	0.423	9.45	0.364	8.91
44.11	0.1228	81.09	2.85	2.85	5.797	5.756	2.582	3.534	0.001068	0.351	11.40	0.302	10.80
50.42	0.1292	87.40	2.90	2.90	5.823	5.781	2.464	3.294	0.000913	0.294	13.61	0.254	12.94
56.72	0.1346	93.70	2.95	2.95	5.843	5.804	2.359	3.085	0.000790	0.249	16.09	0.216	15.35
63.02	0.1394	100.00	3.00	3.00	5.860	******	2.264	2.903	0.000691	0.217	18.45	0.189	17.65

WATER SURFACE PROFILES AND TRACTIVE STRESSES FOR RIPRAP GRADIENT CONTROL STRUCTURES

SPECIAL ANALYSIS PREPARED BY THE DESIGN UNIT AT HYATTSVILLE, MD.
FOR
DESIGN UNIT, ENGINEERING DIVISION, HYATTSVILLE, MARYLAND
EXAMPLE DESIGN NO. 1 - - - - - - - - - - JANUARY 23, 1978

PARAMETERS USED IN THE WSP ANALYSIS

Q = 2750.00 CFS N = 0.0410 D50 = 1.25 FT DIV = 4.00 CONV = 2.00 SN = 0.007844 THETA = 35.0 DEGREES

DOWNSTREAM TRANSITION

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	100.00	3.00	3.00	7.000	******	2.784	3.247	0.000758	0.299	16.72	0.261	15.99
12.60	0.0095	93.70	2.95	2.95	6.980	7.113	2.899	3.447	0.000865	0.347	14.40	0.302	13.74
25.21	0.0204	87.40	2.90	2.90	6.955	7.082	3.027	3.676	0.000998	0.406	12.31	0.351	11.71
37.81	0.0331	81.09	2.85	2.85	6.925	7.048	3.170	3.938	0.001165	0.480	10.42	0.413	9.87
50.42	0.0480	74.79	2.80	2.80	6.887	7.008	3.330	4.244	0.001380	0.573	8.72	0.492	8.23
63.02	0.0658	68.49	2.75	2.75	6.839	6.949	3.511	4.606	0.001663	0.695	7.19	0.594	6.76
75.62	0.0876	62.19	2.70	2.70	6.774	6.868	3.717	5.044	0.002050	0.858	5.83	0.731	5.45
88.23	0.1150	55.89	2.65	2.65	6.686	6.761	3.954	5.588	0.002605	1.085	4.61	0.920	4.28
100.83	0.1507	49.58	2.60	2.60	6.558	6.599	4.230	6.293	0.003457	1.420	3.52	1.200	3.25
113.44	0.2002	43.28	2.55	2.55	6.353	6.300	4.555	7.277	0.004925	1.965	2.54	1.654	2.33
126.04	0.2787	36.98	2.50	2.50	5.934	6.025	4.943	8.944	0.008294	3.092	1.62	2.591	1.47

PRISMATIC CHANNEL

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	36.98	2.50	2.50	5.934	6.025	4.943	8.944	0.008294	3.092	1.62	2.591	1.47
71.20	0.5585	36.98	2.50	2.50	5.981	6.025	4.943	8.853	0.008054	3.027	1.65	2.536	1.50
142.40	1.1170	36.98	2.50	2.50	6.004	6.025	4.943	8.811	0.007945	2.997	1.67	2.511	1.52
213.60	1.6755	36.98	2.50	2.50	6.014	6.025	4.943	8.791	0.007894	2.983	1.68	2.499	1.52
284.80	2.2340	36.98	2.50	2.50	6.019	6.025	4.943	8.781	0.007869	2.976	1.68	2.494	1.53
356.00	2.7925	36.98	2.50	2.50	6.022	6.025	4.943	8.776	0.007856	2.972	1.68	2.491	1.53
427.20	3.3510	36.98	2.50	2.50	6.023	6.025	4.943	8.774	0.007850	2.971	1.68	2.489	1.53
498.40	3.9094	36.98	2.50	2.50	6.024	6.025	4.943	8.772	0.007847	2.970	1.68	2.489	1.53
569.60	4.4679	36.98	2.50	2.50	6.024	6.025	4.943	8.772	0.007846	2.969	1.68	2.488	1.53
640.80	5.0264	36.98	2.50	2.50	6.024	6.025	4.943	8.771	0.007845	2.969	1.68	2.488	1.53
712.00	5.5849	36.98	2.50	2.50	6.024	6.025	4.943	8.771	0.007845	2.969	1.68	2.488	1.53

UPSTREAM TRANSITION

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	36.98	2.50	2.50	6.024	6.025	4.943	8.771	0.007845	2.969	1.68	2.488	1.53
6.30	0.0393	43.28	2.55	2.55	6.417	6.300	4.555	7.186	0.004748	1.914	2.61	1.611	2.39
12.60	0.0640	49.58	2.60	2.60	6.618	6.599	4.230	6.222	0.003345	1.387	3.60	1.172	3.33
18.91	0.0819	55.89	2.65	2.65	6.745	6.764	3.954	5.527	0.002525	1.061	4.71	0.900	4.38
25.21	0.0955	62.19	2.70	2.70	6.833	6.876	3.717	4.991	0.001988	0.840	5.95	0.715	5.56
31.51	0.1064	68.49	2.75	2.75	6.898	6.939	3.511	4.558	0.001613	0.681	7.35	0.582	6.90
37.81	0.1154	74.79	2.80	2.80	6.947	7.002	3.330	4.200	0.001338	0.562	8.90	0.482	8.40
44.11	0.1228	81.09	2.85	2.85	6.985	7.048	3.170	3.898	0.001130	0.470	10.63	0.405	10.07
50.42	0.1292	87.40	2.90	2.90	7.016	7.082	3.027	3.638	0.000968	0.398	12.56	0.345	11.94
56.72	0.1346	93.70	2.95	2.95	7.041	7.113	2.899	3.412	0.000839	0.341	14.68	0.296	14.01
63.02	0.1394	100.00	3.00	3.00	7.062	******	2.784	3.214	0.000735	0.293	17.04	0.256	16.30

WATER SURFACE PROFILES AND TRACTIVE STRESSES FOR RIPRAP GRADIENT CONTROL STRUCTURES

SPECIAL ANALYSIS PREPARED BY THE DESIGN UNIT AT HYATTSVILLE, MD.
FOR
DESIGN UNIT, ENGINEERING DIVISION, HYATTSVILLE, MARYLAND
EXAMPLE DESIGN NO. 1 - - - - - - - - - - JANUARY 23, 1978

PARAMETERS USED IN THE WSP ANALYSIS

Q = 2750.00 CFS   N = 0.0377   D50 = 0.75 FT   DIV = 4.00   CONV = 2.00   SN = 0.007844   THETA = 35.0 DEGREES

DOWNSTREAM TRANSITION

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	100.00	3.00	3.00	7.000	******	2.784	3.247	0.000639	0.252	11.89	0.220	11.38
12.60	0.0095	93.70	2.95	2.95	6.978	6.777	2.899	3.448	0.000730	0.293	10.24	0.254	9.77
25.21	0.0204	87.40	2.90	2.90	6.952	6.748	3.027	3.678	0.000843	0.343	8.75	0.297	8.32
37.81	0.0331	81.09	2.85	2.85	6.919	6.716	3.170	3.942	0.000985	0.405	7.40	0.349	7.01
50.42	0.0480	74.79	2.80	2.80	6.878	6.679	3.330	4.251	0.001169	0.485	6.18	0.416	5.84
63.02	0.0658	68.49	2.75	2.75	6.826	6.624	3.511	4.616	0.001412	0.589	5.10	0.503	4.79
75.62	0.0876	62.19	2.70	2.70	6.758	6.549	3.717	5.059	0.001745	0.728	4.12	0.620	3.85
88.23	0.1150	55.89	2.65	2.65	6.664	6.448	3.954	5.611	0.002224	0.923	3.25	0.783	3.02
100.83	0.1507	49.58	2.60	2.60	6.527	6.295	4.230	6.331	0.002967	1.213	2.47	1.024	2.28
113.44	0.2002	43.28	2.55	2.55	6.306	6.011	4.555	7.346	0.004267	1.690	1.77	1.422	1.63
126.04	0.2787	36.98	2.50	2.50	5.842	5.751	4.943	9.125	0.007407	2.719	1.10	2.279	1.00

PRISMATIC CHANNEL

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	36.98	2.50	2.50	5.842	5.751	4.943	9.125	0.007407	2.719	1.10	2.279	1.00
71.20	0.5585	36.98	2.50	2.50	5.791	5.751	4.943	9.228	0.007648	2.784	1.08	2.333	0.98
142.40	1.1170	36.98	2.50	2.50	5.768	5.751	4.943	9.275	0.007761	2.813	1.07	2.357	0.97
213.60	1.6755	36.98	2.50	2.50	5.758	5.751	4.943	9.296	0.007809	2.826	1.06	2.368	0.97
284.80	2.2340	36.98	2.50	2.50	5.754	5.751	4.943	9.304	0.007830	2.831	1.06	2.373	0.96
356.00	2.7925	36.98	2.50	2.50	5.752	5.751	4.943	9.308	0.007838	2.834	1.06	2.375	0.96
427.20	3.3510	36.98	2.50	2.50	5.752	5.751	4.943	9.309	0.007842	2.835	1.06	2.375	0.96
498.40	3.9094	36.98	2.50	2.50	5.751	5.751	4.943	9.310	0.007843	2.835	1.06	2.376	0.96
569.60	4.4679	36.98	2.50	2.50	5.751	5.751	4.943	9.310	0.007844	2.835	1.06	2.376	0.96
640.80	5.0264	36.98	2.50	2.50	5.751	5.751	4.943	9.310	0.007844	2.835	1.06	2.376	0.96
712.00	5.5849	36.98	2.50	2.50	5.751	5.751	4.943	9.310	0.007844	2.835	1.06	2.376	0.96

UPSTREAM TRANSITION

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	36.98	2.50	2.50	5.751	5.751	4.943	9.310	0.007844	2.835	1.06	2.376	0.96
6.30	0.0393	43.28	2.55	2.55	6.231	6.011	4.555	7.458	0.004456	1.744	1.72	1.467	1.58
12.60	0.0640	49.58	2.60	2.60	6.454	6.295	4.230	6.421	0.003090	1.248	2.40	1.054	2.22
18.91	0.0819	55.89	2.65	2.65	6.591	6.451	3.954	5.689	0.002314	0.949	3.16	0.805	2.94
25.21	0.0955	62.19	2.70	2.70	6.684	6.556	3.717	5.128	0.001814	0.748	4.01	0.637	3.75
31.51	0.1064	68.49	2.75	2.75	6.752	6.615	3.511	4.678	0.001468	0.605	4.96	0.517	4.66
37.81	0.1154	74.79	2.80	2.80	6.803	6.673	3.330	4.307	0.001215	0.498	6.03	0.427	5.69
44.11	0.1228	81.09	2.85	2.85	6.843	6.716	3.170	3.995	0.001025	0.416	7.21	0.358	6.83
50.42	0.1292	87.40	2.90	2.90	6.875	6.748	3.027	3.727	0.000877	0.352	8.53	0.304	8.11
56.72	0.1346	93.70	2.95	2.95	6.901	6.777	2.899	3.494	0.000759	0.300	9.99	0.261	9.53
63.02	0.1394	100.00	3.00	3.00	6.922	******	2.784	3.290	0.000665	0.258	11.61	0.225	11.11

WATER SURFACE PROFILES AND TRACTIVE STRESSES FOR RIPRAP GRADIENT CONTROL STRUCTURES

SPECIAL ANALYSIS PREPARED BY THE DESIGN UNIT AT HYATTSVILLE, MD.
FOR
DESIGN UNIT, ENGINEERING DIVISION, HYATTSVILLE, MARYLAND
EXAMPLE DESIGN NO. 1 - - - - - - - - - - JANUARY 23, 1978

PARAMETERS USED IN THE WSP ANALYSIS

Q = 2750.00 CFS N = 0.0420 D50 = 1.00 FT DIV = 4.00 CONV = 2.00 SN = 0.007844 THETA = 35.0 DEGREES

DOWNSTREAM TRANSITION

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	100.00	3.00	3.00	7.000	******	2.784	3.247	0.000795	0.314	12.74	0.274	12.19
12.60	0.0095	93.70	2.95	2.95	6.980	7.212	2.899	3.447	0.000908	0.364	10.98	0.316	10.48
25.21	0.0204	87.40	2.90	2.90	6.956	7.180	3.027	3.675	0.001047	0.426	9.39	0.369	8.93
37.81	0.0331	81.09	2.85	2.85	6.927	7.144	3.170	3.937	0.001221	0.503	7.95	0.434	7.53
50.42	0.0480	74.79	2.80	2.80	6.890	7.104	3.330	4.242	0.001446	0.601	6.65	0.516	6.28
63.02	0.0658	68.49	2.75	2.75	6.843	7.044	3.511	4.603	0.001742	0.728	5.49	0.623	5.16
75.62	0.0876	62.19	2.70	2.70	6.780	6.962	3.717	5.039	0.002146	0.899	4.45	0.765	4.16
88.23	0.1150	55.89	2.65	2.65	6.694	6.852	3.954	5.580	0.002724	1.136	3.52	0.963	3.27
100.83	0.1507	49.58	2.60	2.60	6.568	6.688	4.230	6.281	0.003608	1.485	2.69	1.254	2.49
113.44	0.2002	43.28	2.55	2.55	6.367	6.384	4.555	7.256	0.005125	2.050	1.95	1.725	1.79
126.04	0.2787	36.98	2.50	2.50	5.961	6.104	4.943	8.891	0.008558	3.205	1.25	2.686	1.13

PRISMATIC CHANNEL

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	36.98	2.50	2.50	5.961	6.104	4.943	8.891	0.008558	3.206	1.25	2.686	1.13
71.20	0.5585	36.98	2.50	2.50	6.035	6.104	4.943	8.751	0.008180	3.101	1.29	2.599	1.17
142.40	1.1170	36.98	2.50	2.50	6.070	6.104	4.943	8.687	0.008010	3.054	1.31	2.559	1.19
213.60	1.6755	36.98	2.50	2.50	6.087	6.104	4.943	8.656	0.007928	3.031	1.32	2.540	1.20
284.80	2.2340	36.98	2.50	2.50	6.095	6.104	4.943	8.640	0.007887	3.020	1.32	2.530	1.20
356.00	2.7925	36.98	2.50	2.50	6.100	6.104	4.943	8.632	0.007866	3.014	1.33	2.526	1.21
427.20	3.3510	36.98	2.50	2.50	6.102	6.104	4.943	8.628	0.007856	3.011	1.33	2.523	1.21
498.40	3.9094	36.98	2.50	2.50	6.103	6.104	4.943	8.626	0.007850	3.009	1.33	2.522	1.21
569.60	4.4679	36.98	2.50	2.50	6.104	6.104	4.943	8.625	0.007847	3.008	1.33	2.521	1.21
640.80	5.0264	36.98	2.50	2.50	6.104	6.104	4.943	8.624	0.007846	3.008	1.33	2.521	1.21
712.00	5.5849	36.98	2.50	2.50	6.104	6.104	4.943	8.624	0.007845	3.008	1.33	2.521	1.21

UPSTREAM TRANSITION

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	36.98	2.50	2.50	6.104	6.104	4.943	8.624	0.007845	3.008	1.33	2.521	1.21
6.30	0.0393	43.28	2.55	2.55	6.475	6.384	4.555	7.103	0.004821	1.961	2.04	1.650	1.87
12.60	0.0640	49.58	2.60	2.60	6.670	6.688	4.230	6.160	0.003412	1.426	2.80	1.205	2.59
18.91	0.0819	55.89	2.65	2.65	6.795	6.855	3.954	5.477	0.002581	1.093	3.66	0.927	3.40
25.21	0.0955	62.19	2.70	2.70	6.881	6.970	3.717	4.948	0.002035	0.866	4.62	0.738	4.31
31.51	0.1064	68.49	2.75	2.75	6.945	7.034	3.511	4.521	0.001652	0.703	5.69	0.601	5.35
37.81	0.1154	74.79	2.80	2.80	6.993	7.098	3.330	4.167	0.001372	0.580	6.89	0.498	6.50
44.11	0.1228	81.09	2.85	2.85	7.031	7.145	3.170	3.868	0.001159	0.486	8.23	0.419	7.80
50.42	0.1292	87.40	2.90	2.90	7.061	7.180	3.027	3.610	0.000993	0.412	9.71	0.356	9.23
56.72	0.1346	93.70	2.95	2.95	7.086	7.212	2.899	3.386	0.000861	0.352	11.35	0.306	10.83
63.02	0.1394	100.00	3.00	3.00	7.106	******	2.784	3.190	0.000754	0.304	13.16	0.265	12.60

WATER SURFACE PROFILES AND TRACTIVE STRESSES FOR RIPRAP GRADIENT CONTROL STRUCTURES

SPECIAL ANALYSIS PREPARED BY THE DESIGN UNIT AT HYATTSVILLE, MD.
FOR
DESIGN UNIT, ENGINEERING DIVISION, HYATTSVILLE, MARYLAND
EXAMPLE DESIGN NO. 1 - - - - - - - - - - JANUARY 23, 1978

PARAMETERS USED IN THE WSP ANALYSIS

Q = 2750.00 CFS   N = 0.0350   D50 = 1.00 FT   DIV = 4.00   CONV = 2.00   SN = 0.007844   THETA = 35.0 DEGREES

DOWNSTREAM TRANSITION

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	100.00	3.00	3.00	7.000	******	2.784	3.247	0.000552	0.218	18.35	0.190	17.56
12.60	0.0095	93.70	2.95	2.95	6.977	6.500	2.899	3.449	0.000631	0.253	15.79	0.220	15.07
25.21	0.0204	87.40	2.90	2.90	6.949	6.473	3.027	3.680	0.000730	0.297	13.48	0.257	12.82
37.81	0.0331	81.09	2.85	2.85	6.915	6.443	3.170	3.945	0.000854	0.351	11.40	0.302	10.80
50.42	0.0480	74.79	2.80	2.80	6.872	6.408	3.330	4.256	0.001013	0.420	9.52	0.361	8.99
63.02	0.0658	68.49	2.75	2.75	6.817	6.357	3.511	4.624	0.001226	0.510	7.84	0.436	7.36
75.62	0.0876	62.19	2.70	2.70	6.745	6.286	3.717	5.071	0.001518	0.632	6.33	0.538	5.91
88.23	0.1150	55.89	2.65	2.65	6.647	6.191	3.954	5.629	0.001940	0.803	4.98	0.681	4.63
100.83	0.1507	49.58	2.60	2.60	6.503	6.045	4.230	6.360	0.002597	1.058	3.78	0.894	3.49
113.44	0.2002	43.28	2.55	2.55	6.271	5.774	4.555	7.399	0.003764	1.482	2.70	1.247	2.47
126.04	0.2787	36.98	2.50	2.50	5.768	5.526	4.943	9.275	0.006706	2.431	1.65	2.037	1.50

PRISMATIC CHANNEL

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	36.98	2.50	2.50	5.768	5.526	4.943	9.275	0.006706	2.431	1.65	2.037	1.50
71.20	0.5585	36.98	2.50	2.50	5.622	5.526	4.943	9.584	0.007364	2.602	1.54	2.180	1.40
142.40	1.1170	36.98	2.50	2.50	5.559	5.526	4.943	9.723	0.007675	2.681	1.49	2.247	1.36
213.60	1.6755	36.98	2.50	2.50	5.536	5.526	4.943	9.774	0.007789	2.710	1.48	2.271	1.34
284.80	2.2340	36.98	2.50	2.50	5.529	5.526	4.943	9.790	0.007827	2.719	1.47	2.279	1.34
356.00	2.7925	36.98	2.50	2.50	5.527	5.526	4.943	9.795	0.007839	2.722	1.47	2.281	1.34
427.20	3.3510	36.98	2.50	2.50	5.526	5.526	4.943	9.797	0.007843	2.723	1.47	2.282	1.34
498.40	3.9094	36.98	2.50	2.50	5.526	5.526	4.943	9.797	0.007844	2.724	1.47	2.282	1.34
569.60	4.4679	36.98	2.50	2.50	5.526	5.526	4.943	9.797	0.007844	2.724	1.47	2.282	1.34
640.80	5.0264	36.98	2.50	2.50	5.526	5.526	4.943	9.798	0.007844	2.724	1.47	2.282	1.34
712.00	5.5849	36.98	2.50	2.50	5.526	5.526	4.943	9.798	0.007844	2.724	1.47	2.282	1.34

UPSTREAM TRANSITION

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	36.98	2.50	2.50	5.526	5.526	4.943	9.798	0.007844	2.724	1.47	2.282	1.34
6.30	0.0393	43.28	2.55	2.55	6.102	5.774	4.555	7.659	0.004157	1.592	2.51	1.340	2.30
12.60	0.0640	49.58	2.60	2.60	6.341	6.045	4.230	6.564	0.002846	1.129	3.54	0.953	3.27
18.91	0.0819	55.89	2.65	2.65	6.485	6.193	3.954	5.804	0.002120	0.854	4.68	0.724	4.35
25.21	0.0955	62.19	2.70	2.70	6.582	6.293	3.717	5.225	0.001657	0.671	5.96	0.572	5.57
31.51	0.1064	68.49	2.75	2.75	6.652	6.348	3.511	4.764	0.001337	0.541	7.39	0.463	6.94
37.81	0.1154	74.79	2.80	2.80	6.705	6.403	3.330	4.384	0.001106	0.445	8.99	0.382	8.48
44.11	0.1228	81.09	2.85	2.85	6.746	6.443	3.170	4.064	0.000931	0.371	10.77	0.320	10.20
50.42	0.1292	87.40	2.90	2.90	6.778	6.473	3.027	3.790	0.000796	0.314	12.75	0.271	12.13
56.72	0.1346	93.70	2.95	2.95	6.805	6.500	2.899	3.552	0.000689	0.268	14.95	0.232	14.26
63.02	0.1394	100.00	3.00	3.00	6.826	******	2.784	3.344	0.000603	0.230	17.38	0.201	16.63

WATER SURFACE PROFILES AND TRACTIVE STRESSES FOR RIPRAP GRADIENT CONTROL STRUCTURES

SPECIAL ANALYSIS PREPARED BY THE DESIGN UNIT AT HYATTSVILLE, MD.
FOR
DESIGN UNIT, ENGINEERING DIVISION, HYATTSVILLE, MARYLAND
EXAMPLE DESIGN NO. 1 - - - - - - - - - JANUARY 23, 1978

PARAMETERS USED IN THE WSP ANALYSIS

Q = 2650.00 CFS   N = 0.0395   D50 = 1.00 FT   DIV = 4.00   CONV = 2.00   SN = 0.007844   THETA = 35.0 DEGREES

DOWNSTREAM TRANSITION

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	100.00	3.00	3.00	5.500	******	2.718	4.136	0.001512	0.449	8.92	0.391	8.53
12.60	0.0095	93.70	2.95	2.95	5.475	6.819	2.831	4.406	0.001740	0.511	7.83	0.444	7.47
25.21	0.0204	87.40	2.90	2.90	5.444	6.790	2.956	4.718	0.002027	0.593	6.75	0.513	6.42
37.81	0.0331	81.09	2.85	2.85	5.403	6.757	3.095	5.083	0.002397	0.715	5.59	0.617	5.30
50.42	0.0480	74.79	2.80	2.80	5.350	6.720	3.252	5.518	0.002892	0.876	4.57	0.752	4.31
63.02	0.0658	68.49	2.75	2.75	5.276	6.665	3.429	6.051	0.003580	1.094	3.66	0.935	3.44
75.62	0.0876	62.19	2.70	2.70	5.171	6.589	3.631	6.730	0.004603	1.405	2.85	1.196	2.66
88.23	0.1150	55.89	2.65	2.65	5.003	6.487	3.864	7.661	0.006305	1.891	2.12	1.604	1.97
100.83	0.1507	49.58	2.60	2.60	4.655	6.334	4.134	9.229	0.010140	2.854	1.40	2.411	1.29
CRITICAL DEPTH													
113.44	0.2002	43.28	2.55	2.55	4.454	6.048	4.454						
CRITICAL DEPTH													
126.04	0.2787	36.98	2.50	2.50	4.835	5.786	4.835						
SUPERCRITICAL FLOW													
126.04	0.2787	36.98	2.50	2.50	4.835	5.786	4.835	11.169	0.015051	4.556	0.88	3.818	0.80
113.44	0.2002	43.28	2.55	2.55	3.720	6.048	4.454	13.500	0.028091	6.304	0.63	5.304	0.58
100.83	0.1507	49.58	2.60	2.60	3.343	6.334	4.134	13.600	0.031625	5.924	0.68	5.005	0.62

PRISMATIC CHANNEL

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
CRITICAL DEPTH													
0.0	0.0	36.98	2.50	2.50	4.835	5.786	4.835	13.600	0.015051	4.557	0.88	3.818	0.80
71.20	0.5585	36.98	2.50	2.50	5.595	5.786	4.835	9.292	0.008864	3.117	1.28	2.612	1.17
142.40	1.1170	36.98	2.50	2.50	5.708	5.786	4.835	9.058	0.008239	2.956	1.35	2.477	1.23
213.60	1.6755	36.98	2.50	2.50	5.752	5.786	4.835	8.971	0.008014	2.897	1.38	2.428	1.26
284.80	2.2340	36.98	2.50	2.50	5.770	5.786	4.835	8.934	0.007920	2.872	1.39	2.407	1.27
356.00	2.7925	36.98	2.50	2.50	5.779	5.786	4.835	8.917	0.007879	2.861	1.40	2.398	1.27
427.20	3.3510	36.98	2.50	2.50	5.782	5.786	4.835	8.910	0.007860	2.856	1.40	2.394	1.27
498.40	3.9094	36.98	2.50	2.50	5.784	5.786	4.835	8.906	0.007851	2.854	1.40	2.392	1.27
569.60	4.4679	36.98	2.50	2.50	5.785	5.786	4.835	8.905	0.007847	2.853	1.40	2.391	1.28
640.80	5.0264	36.98	2.50	2.50	5.785	5.786	4.835	8.904	0.007846	2.852	1.40	2.390	1.28
712.00	5.5849	36.98	2.50	2.50	5.785	5.786	4.835	8.904	0.007845	2.852	1.40	2.390	1.28

UPSTREAM TRANSITION

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	36.98	2.50	2.50	5.785	5.786	4.835	8.904	0.007845	2.852	1.40	2.390	1.28
6.30	0.0393	43.28	2.55	2.55	6.204	6.048	4.454	7.227	0.004628	1.803	2.22	1.517	2.03
12.60	0.0640	49.58	2.60	2.60	6.410	6.334	4.134	6.240	0.003236	1.298	3.08	1.097	2.85
18.91	0.0819	55.89	2.65	2.65	6.539	6.490	3.864	5.535	0.002433	0.989	4.04	0.839	3.76
25.21	0.0955	62.19	2.70	2.70	6.628	6.597	3.631	4.993	0.001911	0.781	5.12	0.665	4.79
31.51	0.1064	68.49	2.75	2.75	6.693	6.655	3.429	4.557	0.001548	0.631	6.34	0.540	5.95
37.81	0.1154	74.79	2.80	2.80	6.741	6.714	3.252	4.197	0.001283	0.520	7.70	0.446	7.26
44.11	0.1228	81.09	2.85	2.85	6.780	6.757	3.095	3.893	0.001082	0.434	9.21	0.374	8.73
50.42	0.1292	87.40	2.90	2.90	6.810	6.790	2.956	3.632	0.000926	0.367	10.89	0.318	10.36
56.72	0.1346	93.70	2.95	2.95	6.835	6.819	2.831	3.405	0.000803	0.313	12.76	0.272	12.18
63.02	0.1394	100.00	3.00	3.00	6.855	******	2.718	3.206	0.000703	0.270	14.83	0.235	14.19

WATER SURFACE PROFILES AND TRACTIVE STRESSES FOR RIPRAP GRADIENT CONTROL STRUCTURES

SPECIAL ANALYSIS PREPARED BY THE DESIGN UNIT AT HYATTSVILLE, MD.
FOR
DESIGN UNIT, ENGINEERING DIVISION, HYATTSVILLE, MARYLAND
EXAMPLE DESIGN NO. 1 - - - - - - - - - - JANUARY 23, 1978

PARAMETERS USED IN THE WSP ANALYSIS

Q = 2550.00 CFS N = 0.0395 D50 = 1.00 FT DIV = 4.00 CONV = 2.00 SN = 0.007844 THETA = 35.0 DEGREES

DOWNSTREAM TRANSITION

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	100.00	3.00	3.00	6.750	******	2.651	3.142	0.000687	0.258	15.50	0.225	14.83
12.60	0.0095	93.70	2.95	2.95	6.730	6.671	2.761	3.337	0.000785	0.300	13.33	0.261	12.71
25.21	0.0204	87.40	2.90	2.90	6.706	6.643	2.884	3.559	0.000906	0.352	11.37	0.304	10.81
37.81	0.0331	81.09	2.85	2.85	6.676	6.611	3.020	3.815	0.001058	0.417	9.60	0.359	9.10
50.42	0.0480	74.79	2.80	2.80	6.639	6.576	3.173	4.113	0.001254	0.499	8.02	0.428	7.57
63.02	0.0658	68.49	2.75	2.75	6.592	6.522	3.346	4.466	0.001513	0.606	6.60	0.518	6.20
75.62	0.0876	62.19	2.70	2.70	6.529	6.448	3.544	4.894	0.001867	0.750	5.33	0.639	4.98
88.23	0.1150	55.89	2.65	2.65	6.443	6.350	3.772	5.425	0.002376	0.951	4.21	0.806	3.91
100.83	0.1507	49.58	2.60	2.60	6.318	6.200	4.037	6.115	0.003158	1.248	3.21	1.054	2.96
113.44	0.2002	43.28	2.55	2.55	6.118	5.921	4.350	7.078	0.004508	1.732	2.31	1.457	2.12
126.04	0.2787	36.98	2.50	2.50	5.713	5.665	4.725	8.707	0.007607	2.731	1.46	2.289	1.33

PRISMATIC CHANNEL

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	36.98	2.50	2.50	5.713	5.665	4.725	8.707	0.007607	2.731	1.46	2.289	1.33
71.20	0.5585	36.98	2.50	2.50	5.688	5.665	4.725	8.757	0.007732	2.764	1.45	2.316	1.32
142.40	1.1170	36.98	2.50	2.50	5.675	5.665	4.725	8.781	0.007792	2.779	1.44	2.329	1.31
213.60	1.6755	36.98	2.50	2.50	5.670	5.665	4.725	8.792	0.007821	2.787	1.44	2.335	1.31
284.80	2.2340	36.98	2.50	2.50	5.667	5.665	4.725	8.797	0.007833	2.790	1.43	2.338	1.30
356.00	2.7925	36.98	2.50	2.50	5.666	5.665	4.725	8.799	0.007839	2.791	1.43	2.339	1.30
427.20	3.3510	36.98	2.50	2.50	5.666	5.665	4.725	8.800	0.007842	2.792	1.43	2.340	1.30
498.40	3.9094	36.98	2.50	2.50	5.665	5.665	4.725	8.801	0.007843	2.792	1.43	2.340	1.30
569.60	4.4679	36.98	2.50	2.50	5.665	5.665	4.725	8.801	0.007844	2.793	1.43	2.340	1.30
640.80	5.0264	36.98	2.50	2.50	5.665	5.665	4.725	8.801	0.007844	2.793	1.43	2.340	1.30
712.00	5.5849	36.98	2.50	2.50	5.665	5.665	4.725	8.801	0.007844	2.793	1.43	2.340	1.30

UPSTREAM TRANSITION

LENGTH FT	RISE FT	WIDTH FT	ZL	ZR	DEPTH FT	NORMAL DEPTH	CRITICAL DEPTH	VELOCITY FT/SEC	FRIC SLOPE FT/FT	TAUBM LB/SQ.FT	FS BOTTOM	TAUSM LB/SQ.FT	FS SIDES
0.0	0.0	36.98	2.50	2.50	5.665	5.665	4.725	8.801	0.007844	2.793	1.43	2.340	1.30
6.30	0.0393	43.28	2.55	2.55	6.074	5.921	4.350	7.143	0.004627	1.764	2.27	1.484	2.08
12.60	0.0640	49.58	2.60	2.60	6.276	6.200	4.037	6.165	0.003234	1.269	3.15	1.072	2.91
18.91	0.0819	55.89	2.65	2.65	6.402	6.353	3.772	5.467	0.002430	0.966	4.14	0.819	3.85
25.21	0.0955	62.19	2.70	2.70	6.489	6.456	3.544	4.930	0.001909	0.761	5.25	0.648	4.91
31.51	0.1064	68.49	2.75	2.75	6.552	6.513	3.346	4.499	0.001546	0.615	6.51	0.526	6.11
37.81	0.1154	74.79	2.80	2.80	6.600	6.570	3.173	4.142	0.001280	0.506	7.91	0.434	7.46
44.11	0.1228	81.09	2.85	2.85	6.637	6.611	3.020	3.842	0.001080	0.422	9.47	0.364	8.98
50.42	0.1292	87.40	2.90	2.90	6.667	6.643	2.884	3.584	0.000924	0.357	11.22	0.308	10.67
56.72	0.1346	93.70	2.95	2.95	6.691	6.671	2.761	3.360	0.000801	0.304	13.16	0.264	12.55
63.02	0.1394	100.00	3.00	3.00	6.711	******	2.651	3.163	0.000701	0.261	15.31	0.228	14.65