UMTRA - GEN

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON-KNUDSEN COMPANY

INFORMATION ADVISORY

No. 4005-GEN-A-01-02808-00

Contract No. ______

To: Thomas T. Olsen
NRC - Denver

Project: UMTRA PROJECT - GEN

Subject: UMTRA Design Procedures, Revision 2

Enclosed is Copy No. 54 of Revision 2 to the MKE UMTRA Design Procedures. This revision updates Chapters 4 and 5 of the manual. Please replace Chapters 4 and 5 of the manual with these revisions and destroy or mark "void" the previous revisions to these chapters.

This manual is an MKE Controlled Document. Please acknowledge receipt of the above by signing and dating in the lower right-hand corner and returning this to the following address:

Morrison Knudsen Engineers
UMTRA Project Office
180 Howard Street
San Francisco, CA 94105

RECEIVED
NOV 21 1986
U.S. Nuclear Regulatory Commission
Mail Station

DOCKETED
USNRC
NOV 22 1986
MAIL SECTION
DOCKET CLERK

T. R. Wathen
Title Engineering and Design Manager
Date 20 May 1986

ACKNOWLEDGED AND ACCEPTED

87-126

OFFICIAL DOCKET COPY

9801070367 860520
PDR WASTE
WM-3 PDR

MKE UMTRA DESIGN PROCEDURES

CONTENTS

MKE UMTRA DESIGN PROCEDURES

CHAPTER 4
SITE DRAINAGE
REVISION 2
17 APRIL 1986

CONTENTS

TABLES

Table

FIGURE

Figure

APPENDIX

Appendix

CHAPTER 4

SITE DRAINAGE

4.1 INTRODUCTION

This chapter includes:

- the types of drainage facilities to be designed for UMTRA sites;

- The types of data required for design of drainage facilities; and,

- Details of the procedures to be used for design of ditches and retention basins.

Procedures are presented for determining capacity requirements for ditches, retention basins, and emergency spillways. Site drainage includes all necessary facilities to 1) control runoff and construction wastewater at the site and 2) divert off-site flows away from the site. Primary considerations are to control all runoff and wastewater that may be contaminated, to limit erosion and prevent sediment transport to offsite locations.

Design criteria are expected to vary from site to site, because different federal, state and Indian nation regulations will apply. An important source of site drainage criteria will be the permit guidance documents provided by the permitting agencies. Therefore, site drainage design should be coordinated with the permitting task. Minimum criteria for all sites have been established by the DOE (Ref. 4-1). The type and number of facilities required at each site also will vary, depending on site conditions and design criteria.

4.2 FACILITIES

Drawings and specifications will be required for one or more of the following types of drainage facilities:

A. Permanent Drainage Facilities
   1. Ditches (sections, locations, grades ...)
   2. Outlet to natural drainage course
   3. Crossings for maintenance vehicles
   4. Fence or barrier crossings
   5. Permanent diversion facilities

B. Construction Drainage Facilities
   1. Ditches (contaminated water directed to retention basin, uncontaminated water diverted away from site)
   2. Silt fences
   3. Sumps and pumps (where gravity drainage is infeasible)

4. Dewatering facilities for excavations
5. Retention basin
   a. Inlet
   b. Basin
   c. Emergency spillway
   d. Outlet to natural drainage course
6. Wastewater treatment facilities
7. Flood control berms
8. Vehicle crossings (e.g., culverts)
9. Fence crossings

4.3 DATA REQUIREMENTS

The following data will be needed for the design of drainage facilities:

A. Permanent Drainage Facilities

1. Conceptual design site plan and grading plan (with contours) [see Remedial Action Plan (RAP) and coordinate with final design of site plan and grading plan.]
2. Design criteria [to be presented in Design Basis Memorandum (DBM)]
   (1) UMTRA general (see Refs. 4-1 and 4-15)
   (2) Site-specific (e.g., State or COE Requirements) [see RAP and coordinate with permitting task.]
3. Probable Maximum Precipitation (PMP) intensity and rainfall distribution [see Processing Site Characterization Report (PSCR), and check PMP using appropriate Hydrometeorological Report by NOAA (See Fig. 4-1, Ref's. 4-2 through 4-7, Table 4-1, and Chapter 5, Sec. 5.1.C1.)]
4. Location of outlet(s) to natural drainage course (see PSCR and RAP)
5. Locations of drainage courses with a potential for the Probable Maximum Flood (PMF) and PMF data for site (average velocity, water surface elevation, mean channel slope). (See PSCR and RAP)
6. Proposed embankment cover material (i.e., rock or grass) and cover type in areas outside of embankment (usually native grasses)
7. Soil type and vegetation cover in drainage area.

B. Construction Drainage Facilities

1. Design criteria (to be presented in DBM)
   a. UMTRA general (see Refs. 4-1 and 4-15)
   b. Site-specific (e.g., State or COE requirements) [see RAP and coordinate with permitting task.]
2. Existing topography (contours)
3. Required construction facilities and interim and final grading plans (with contours) (see RAP and coordinate with final design)
4. Site design storms (Ref. 4-17)
   When duration of a storm is specified, it is important to define the site-specific rainfall distribution.

a. 10-year, 24-hour precipitation - minimum retention basin criteria (Ref. 4-1) - Check site specific requirements also.
b. 10-year precipitation intensity versus duration, for events ' the range of anticipated times of concer ion. Use for ditch capacity determinations.
c. 25-ye storm data, use for minimum retention basin spillwa capacity, (Ref. 4-1). Also, c ck site specific requirem ts.
d. Other storms required by any site-specific requirements.

5. Design floods (water surface elevations which could affect the site).
   a. 10-year, 24-hour, flood - minimum requirement for construction protection (Ref. 4-1).
   b. Other site-specific requirements.
6. Dewatering data (if excavation dewatering is anticipated).
   a. Excavation plan
   b. Ground-water levels (see PSCR)
   c. Subsurface and material data (e.g., material types, structures, pump test results)
7. Construction schedule (see RAP and coordinate with final design). Use for estimating volume of sediment that will accumulate in retention basin
8. Construction facilities and layout requirements (for coordination of all facilities; i.e., access may be restricted to one side of site, certain areas may require excavation of contaminated material, certain areas could be used as borrow sources, etc.).
9. Evaporation data, direct precipitation, runoff and snowmelt (preferably monthly averages), and soil type in basin area. Possibly necessary in sizing retention basin and determining feasibility of pumping basin dry between storms. (See PSCR)

4.4 DESIGN PROCEDURES FOR DITCHES AND RETENTION BASINS

Procedures to be used for design of ditches and retention basins are:

A. Ditches

1. Calculate required ditch capacities using one of the following methods to calculate peak runoff:

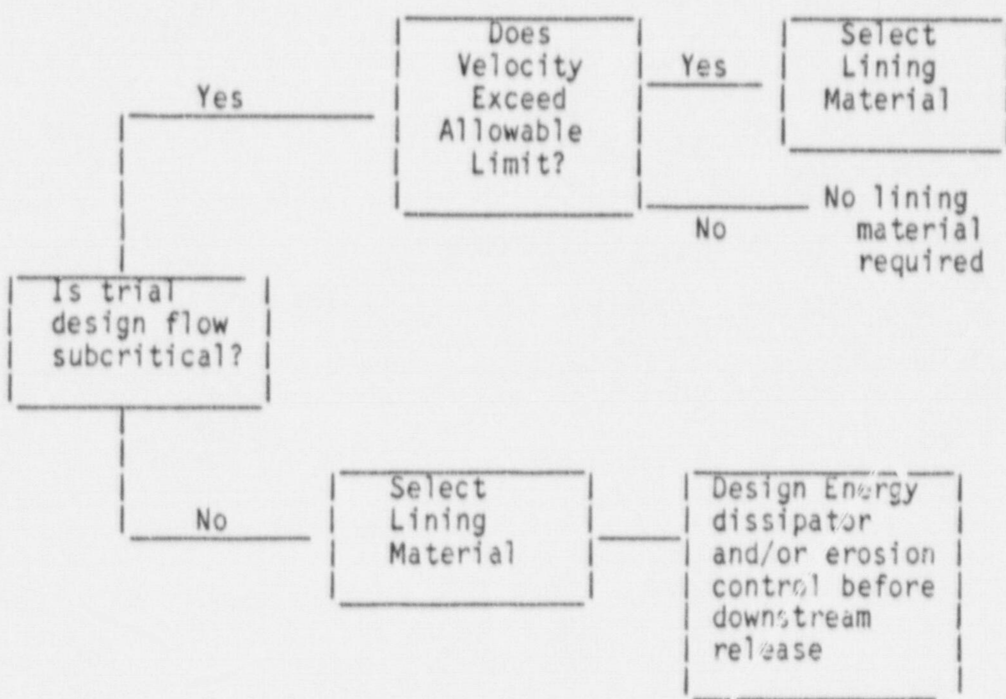
Drainage Area	Run-off Calculation Procedure
Up to 200 acres	Rational Method
Up to 500 acres	Santa Barbara Method (Ref. 4-16)
Up to 20 sq. mi.	SCS Method (Tabular, Graphical, or Unit Hydrograph Method (Ref. 4-11)
Any drainage area	HEC-1 (Ref. 4-18)

Tables and formulas similar to those shown in Table 4-2 (Rational Method) should be used.

The HEC-1 program uses the following methods for synthesizing unit Hydrographs:

Method	Drainage Area
SCS	up to 100 sq. mi.
Clark	up to 100 sq. mi.
Snyder	10 - 10,000 sq. mi.

2. Determine cross-section shape (triangular or trapezoidal). If discharge (Q) $\leq$ 10 cfs, use triangular ditch, otherwise use trapezodial ditch with initial bottom width = 10'.
3. Using trial side slope(s) and Manning's formula (e.g., see Ref. 4-8), design ditch for subcritical flow where practical by adjusting channel slope. Also, may optimize ditch dimensions for site-specific conditions. Use site-specific information (e.g. soil type, vegetation, and channel slope) to select allowable channel velocities. Allowable velocity guidance is available in References 4-8 and 4-20.
4. Determine final cross-section dimensions and lining, as follows:
   a. General - Proceed as follows:



   b. Riprap-lined - Perform iterative calculations relating depth of flow, riprap size and Manning's n, as outlined in Chapter 5.

4. Check superelevation and riprap size requirements where ditches change direction and at ditch intersections.
5. Summarize results in a format similar to that shown in Table 4-3.
6. Draw typical sections for construction drawings.

B. Retention Basins

Retention Basins associated with Temporary Drainage Facilities:

1. Basic criteria - minimum storage of 10-year, 24-hour storm or minimum retention time (24 hr.) for runoff plus 3-year sediment storage or storage of sediment from a 10-year, 24-hour storm.
2. Runoff volume - Perform hydrologic calculations to determine volume required to store runoff, using the Santa Barbara Urban Hydrograph Computer Model (Ref. 4-9) as modified by T. J. Ward (Ref. 4-16) (available in MKE computer program library)*, the SCS method (Ref. 4-11), or HEC-1 (Ref. 4-18).
   Note: The MKE program assumes initial obstruction loss equal to zero to account for possibility that antecedent conditions have saturated the obstruction capacity.
   a. Input for Santa Barbara Method
      (1) Name of the site
      (2) Total drainage area (acres)
      (3) Portion of total area assumed to be impervious (acres)
      (4) Time of concentration (t_c) (minutes). Suggested methods for determining t_c are Figure 30, Method C (Ref. 4-10) and SCS Velocity Method (Ref. 4-11).
      (5) Time increment (minutes) and rainfall depth (inches). Time increment duration and number of increments [See (9) below] are chosen as necessary to accurately define rainfall distribution with time.
      (6) Initial and saturated volumetric soil moisture contents, each expressed as a fraction. (Volumetric moisture content is defined as volume of water divided by total volume.) The volumetric soil moisture contents should be determined from data given in the site specific documents, if possible, or from information presented in Ref. 4-21.
      (7) Soil suction head (inches) should be based on (a) USDA textural classification and information in Ref. 4-12, (b) data in the site specific documents, or (c) both.
      ( ) The effective hydraulic conductivity, which is taken as one-half the saturated hydraulic conductivity. Site specific hydraulic conductivity data should be used, if possible, or hydraulic conductivity can be based on the USDA textural classification and information in Ref. 4-12.
      (9) Number of rainfall increments (as needed to accurately model rainfall distribution with time, up to a maximum of 100 increments). The time increment for the rain should be approximately equal to 1/5 of time of concentration.

* See Appendix 4-1 for comments on the use of the Santa Barbara Method.

(10) Number of output steps (as needed to accurately model the outflow hydrograph, up to a maximum of 200 steps).

b. Output

(1) The outflow hydrograph (flowrate versus time).

(2) The total volume of outflow (acre-ft.)

3. Sediment storage volume

a. Sufficient volume should be provided to store total sediment to be collected during entire construction period, if feasible, to avoid need for cleaning.

b. Use Universal Soil Loss Equation (USLE) or modified form given in Ref. 4-13 to estimate volume of sediment.

4. Spillway Capacity - Spillway design flood depends on regulatory agency-requirements and should not be less than 25-year, 24-hour. Perform hydrologic and hydraulic calculations to determine the required size of emergency spillway using the modified version of Santa Barbara Model (see 1. above), with the reservoir routing routine.

a. Input

(1) Retention basin area capacity curve.*

(2) Rating curve for trial design dimensions.

b. Output

(1) Maximum depth of water in the retention basin (feet).

(2) Maximum depth of flow in V - ditch (feet), or depth of flow across weir (feet).

4.5 WATER QUALITY

Provide monitoring systems for surface and ground water if required.

*Model currently assumes vertical side slopes; to be modified to include actual side slopes.

4.6 REFERENCES

4-1 U. S. Department of Energy, Design Criteria for Stabilization of Inactive Uranium Mill Tailings Sites, UMTRA-DOE/AL-050424.0049, June 1984.

4-2 U. S. Weather Bureau, Probable Maximum Precipitation, Northwest States, Hydrometeorological Report No. 43, NOAA, U.S. Dept. of Commerce, April, 1981.

4-3 Hansen, E. M., Schwarz, F. K., and Riedel, J. T., Probable Maximum Precipitation Estimates, Colorado River and Great Basin Drainages, Hydrometeorological Report No. 49, National Weather Service, NOAA, U.S. Dept. of Commerce, 1977.

4-4 Schreiner, L. G. and Riedel, J. T., Probable Maximum Precipitation Estimates, United States East of the 105th Meridian, Hydrometeorological Report No. 51, National Weather Service, NOAA, U.S. Dept. of Commerce, 1978.

4-5 Hansen, E. M., et. al., Probable Maximum Precipitation Estimates, United States East of the 105th Meridian (Application Report), Hydrometeorological Report No. 52, National Weather Service, NOAA, U.S. Dept. of Commerce, 1982.

4-6 Ho and Riedel, Probable Maximum Precipitation Estimates, United States East of 103rd Meridian Hydrometeorological Report No. 53, National Weather Service, NOAA, U.S. Dept. of Commerce, 1980.

4-7 Miller, J. F., et. al., Probable Maximum Precipitation Estimates, U.S. Between Continental Divide and 103rd Meridian, Hydrometeorological Report No. 55, National Weather Service, NOAA, U.S. Dept. of Commerce, 1984.

4-8 Chow, V. T., Open-Channel Hydraulics, McGraw-Hill Book Company, New York, 1959.

4-9 Stubacher, J., The Santa Barbara Urban Hydrograph Method, presented at the National Symposium on Urban Hydrology and Sediment control, University of Kentuck, Lexington, Kentucky, 1975.

4-10 U. S. Department of the Interior, Design of Small Dams, Second Edition, Bureau of Reclamation, U. S. Government Printing Office, Washington, D. C., 1973.

4-11 U. S. Department of Agriculture, Urban Hydrology for Small Watersheds, Technical Release No. 55 (TR-55), Soil Conservation Service, Washington, D. C., 1975.

4-12 Rawls, W. J., Brakensiek, D. L. and Miller, N., "Green-Ampt Infiltration Parameters for Soil Data," J. of the Hydraulics Division, Vol. 109, No. 1, ASCE, New York, January 1983.

4-13 Israelsen, C. E., Clyde, C. G., Fletcher, J. E., Israelsen, E. K., Haws, F. W., Packer, P. E., and Farmer, E. E., Erosion Control During Highway Construction, National Cooperative Highway Research Program Report 221, National Academy of Sciences, Washington, D. C., April 1980.

4-14 U. S. Department of the Interior, Surface Mining Water Diversion Manual, OSM/TR-82/2, Office of Surface Mining, U. S. Government Printing Office, Washington, D. C., September 1982.

4-15 U. S. Department of Energy, Plan for Implementing EPA Standards for UMTRA Sites, UMTRA-DOE/AL-163, January 1984.

4-16 Ward, T. J., "Modifications to the Santa Barbara Urban Hydrograph Method," Proceedings, Symposium on Watershed Management in the Eighties, ASCE, 1985.

4-17 U. S. Department of Commerce, "Precipitation Frequency Atlas of The Western United States," U. S. Government Printing Office, Washington, D. C., (specific atlas and date depend on area covered).

4-18 U.S. Army Corps of Engineers, "HEC-1, Flood Hydrograph Package Users' Manual," The Hydraulic Engineering Center, Davis, California, 95616, Revised January 1985.

4-19 Brater, E. F. and King, H. W., Handbook of Hydraulics, Sixth Edition, McGraw-Hill, 1976.

4-20 U.S. Army Corps of Engineers, 1 July 1970, "Hydraulic Design of Flood Control Channels", Changes 1 through 4 included, EM 1110-2-1601, Washington, D.C.

4-21 Israelsen, O.W. and Hanson, V.E., Irrigation Principles and Practices, 1962, John Wiley and Son, Inc., P. 168

TABLE 4-1

Generalized PMP Studies for Conterminous United States, Ref. 4-7, Page 2 2

Hydrometeorological Report	Geographical Region	Scope
No. 36 (U.S. Weather Bureau 1961 Revision, U.S. Weather Bureau 1969)	Pacific coast drainage of California	General-storm PMP; areas to to 5,000 mi^2, 6 to 72 hr., seasonal values October through April
No. 43 (U.S. Weather Bureau 1966 addendum 1981)	Columbia River and coastal drainages of Oregon and Washington	General-storm PMP, areas up to 5,000 mi^2, west of Cascades Ridge, areas up to 1,000 mi^2 east of Cascades Ridge, 6 to 72 hr., seasonal values October through June. Local-storm PMP east of Cascades Ridge, areas up to 500 mi^2, durations to 6 hr., seasonal values May through September.
No. 49 (Hansen et al. 1977)	Colorado River and Great Basin drainage. Also provides local storm for all of California	General-storm PMP, areas up to 5,000 mi^2, 6 to 72 hr., monthly values. Local-storm PMP, areas up to 500 mi^2, durations up to 6 hr., all season values.
No. 51 (Schreiner and Riedel 1978)	U.S. east of 105th meridian*	PMP from 10 to 20,000 mi^2, 6 to 72 hr., all season values.
No. 52 (Hansen et al. 1982)	U.S. east of 105th meridian*	PMP from 10 to 20,000 mi^2, durations $\leq$ 6 hr. all season values (Application Report).
No. 53 (Ho and Riedel 1980)	U.S. east of 103rd meridian*	PMP for 10 mi^2, 6 to 72 hr., monthly values.
No. 55 (Miller et al. 1984)	U.S. between Continental Divide and 103rd meridian	General-storm PMP, areas 10 to 20,000 mi^2 in nonorographic regions and 10 to 5,000 mi^2 in orographic regions, 1 to 72 hr., all-season values. Local-storm PMP, for selected portions of study region, up to 500 mi^2, durations <6 hr., all season values.

*Reports 51, 52, and 53 originally provided PMP for the U.S. east of the 105th meridian, PMP between the 103rd and 105th meridian from these reports are now superseded by HMR 55. Application portion of HMR 52 is valid for Eastern U.S. out to the 105th meridian.

TABLE 4-2

REQUIRED DITCH CAPACITIES BY RATIONAL METHOD

(EXAMPLE FORMAT FOR CALCULATIONS)

Ditch No.	Drainage Area Characteristics						Time of Concentration[2] (min)		Rainfall Intensity[3] (in/hr) i	Average Runoff Coefficient[4] C	Total Area A (ac)	Required Ditch Capacity Q = CiA, (cfs)
	Subarea No. j	Area A_j (ac)	Runoff Coefficient[1] C_j	Flow Path Data			Method 1	Method 2				
				Segment No.	Length (ft)	Elev. Diff. (ft)						

NOTES:

1. Use Table 3.3, Ref. 4-14 for temporary ditches. Assume C = 1 for permanent ditches.

2. For time of concentration for temporary ditches, Method 1 = Figure 30, Method C, Ref. 4-10; Method 2 = SCS Velocity Method (Ref. 4-11). For permanent ditches, See Chapter 5, Section 5.1.C.4.

3. Use rainfall intensity for duration equal to smallest values for T_c for each ditch.

4. $C = \frac{A_j C_j}{A_j}$ (i.e., area-weighted average C).

TABLE 4-3
SUMMARY OF DITCH DESIGN RESULTS
(EXAMPLE FORMAT)

Ditch No.	Slope	Required Ditch Capacity cu.ft/sec	Flow Depth (ft)	Ditch Depth (ft)	Lining Type

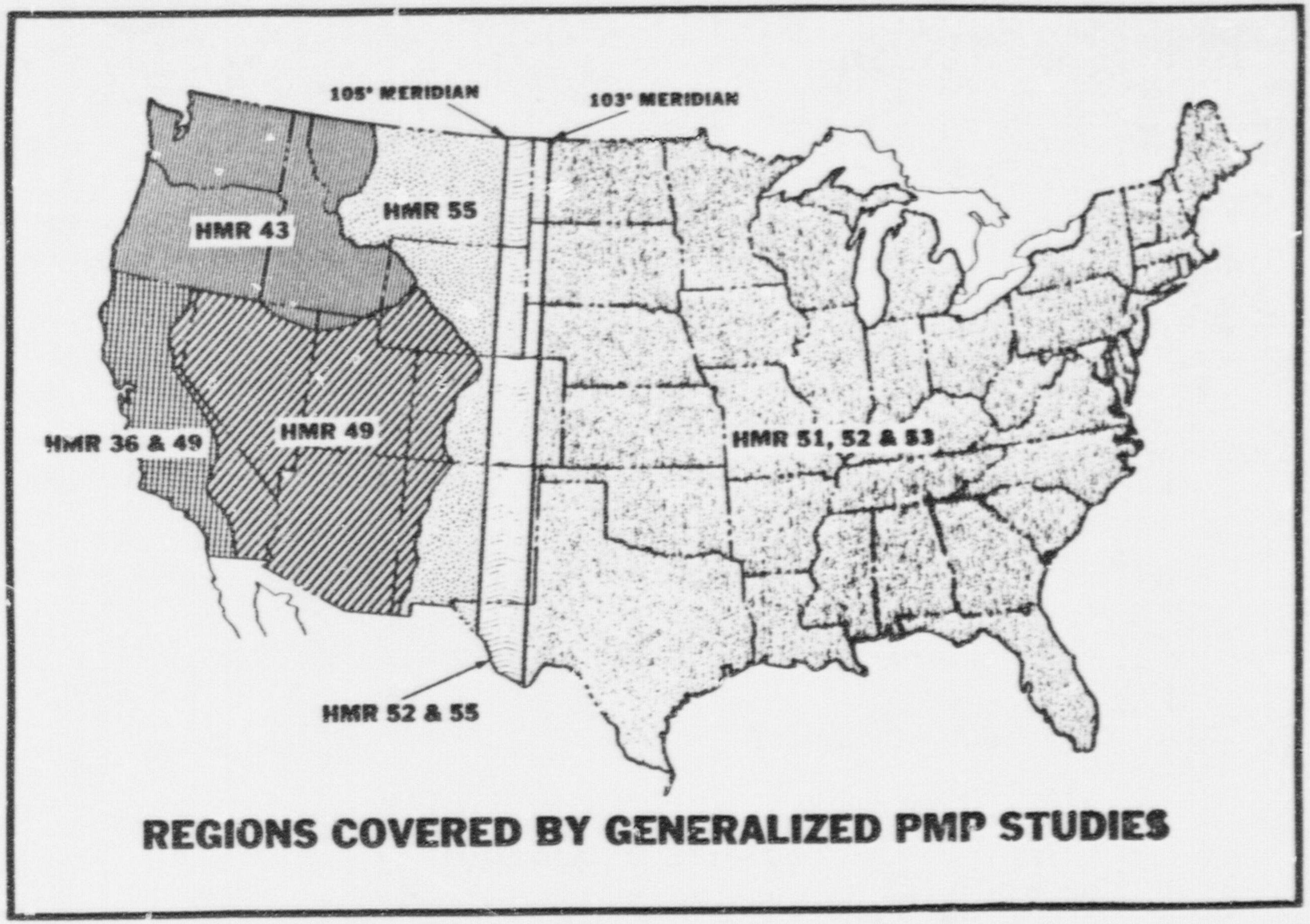


Figure 4-1.—Regions of the conterminous United States for which PMP estimates are provided in indicated Hydrometeorological Reports. See Table 4-1 for description of geographical region covered and scope of each report. (Ref. 4-7, Page 3).

APPENDIX 4 - 1

COMMENTS ON THE USE OF THE SANTA BARBARA URBAN HYDROGRAPH METHOD

- Limitation of the method

  The Santa Barbara Urban Hydrograph method is subject to the following restrictions in application:

  - For watershed less that 500 Acres
  - For time of concentration less than 1 hour
  - For rainfall duration less than about 10 hours

  Violation of any of the above requirements may render the results unreliable.

- Limitation on time increment, Δt, for rainfall and hydrograph during simulation.

  The value of Δt should be restricted to either (a) or (b) as follows, whichever is smaller.

  (a) Δt should not be more than one fifth of the time of concentration.

  (b) In the case of modeling infiltration for pervious area, Δt should be reduced to Dt when the hourly rainfall intensity is equal to or greater than:

  $$\frac{k}{2} \times \frac{Dt}{60} \times \frac{1}{FRAC}$$

  Where k = hydraulic conductivity (in/hr)
  Dt = time duration with highest known rainfall intensity (min)
  FRAC = Fraction of hourly rainfall during Dt when the most intensive rainfall occurs

- Vegetation Cover is not considered in the runoff-infiltration relationship

- Green and Ampt Infiltration

  (a) The Green and Ampt infiltration equation used in the program assumes homogeneous condition for the soil. If non-homogeneity occurs close to the ground surface, the equation should be modified to account for a composite hydraulic conductivity for the layered system.

(b) The porosity and effective porosity values listed in Table 2 of Rawls, et.al.[1], are not reliable and should be used with caution. Other values seem to be reasonable and may be used in modeling for values of porosity and effective porosity for different textural soils. Other references (e.g., Israelsen & Hansen[2]) should be consulted.

- Reservoir Routing

(a) The computer program assumes the water surface area in the retention basin is always constant. This will be conservative if the area selected is the minimum during the routing period. To model accurately the rise of water in the basin during a storm, the area-capacity curve should be used to iterate the stage in the reservoir during each time step until a water balance is achieved, consistent with the spillway rating curve (conventional modified Puls method).

(b) In general, when the spillway channel has a mild slope, Manning's equation may be used to describe the flow. However, when the channel slope is increased to or beyond the critical slope, a control will be created at the outlet of the reservoir in which case weir-flow will be controlling. Thus specifying the channel slope in the program without checking critical flow may introduce error in the outflow. A spillway rating curve should be derived after checking the control and considering the velocity of approach. This, then, would be in the form usable for reservoir routing in the computer program. This check can be done by hand calculation.

Recommendation

The computer program SHUHYD should be used as suggested above, especially in the reservoir routing routine.

When use of the Santa Barbara Method is not appropriate, the SCS Unitgraph Method should be used.

---

1. Rawls, W.J. Brakensiek, D.L. and Miller, N., "Green-Ampt Infiltration Parameters for Soil Data" J. of the Hydraulics Division, Vol. 109, No. 1, ASCE, New York, January 1983.

2. Israelsen, O.W. & V.E. Hansen, "Irrigation Principles and Practices", 1962, John Wiley & Son, Inc., P. 168

UMTRA DESIGN PROCEDURES

CHAPTER 5
EROSION PROTECTION
REVISION 2
24 APRIL 1986

CONTENTS

87-126

TABLES

FIGURES

CHAPTER 5

EROSION PROTECTION

5.1 RIPRAP DESIGN

A. Introduction

1. Use of Riprap - Riprap is required for erosion protection of the following site features:

- o The top and sides of the covered tailings pile.

- o Drainage swales and ditches.

2. Design Methods - The design methods presented herein are:

a. The Stephenson's Method (Ref. 5-9), used for slopes equal to or steeper than 10 percent subjected to sheet flow [top and sides of embankment where no topsoil is provided (topsoil will develop gulleys, and sheet flow assumption will no longer apply)],

b. The Safety Factors Method (Ref. 5-10), used for ditches, swales and gulleys, including gulleys formed on top or sides of embankment when topsoil is provided, and for sheet flow conditions for slopes flatter than 10 percent.

The Stephenson's Method referred to herein is a method by D. Stephenson for stability of stones on the downstream face of a rockfill embankment subjected to overflow (Ref. 5-9). It has been shown to be satisfactory for sheet flow on slopes of 10% or greater and mean rock sizes of 1.5 inches or greater (Ref. 5-14 and 5-20). A minimum mean rock size of 1.5 inches has been adopted for protection against effects of rainsplash impact, wind concentrations, and irregularities in the finished surface. Interstitial flow is included in the Stephenson formula, and should not be subtracted from total flow.

Key details for applying the Safety Factors Method are as follows:

- o The riprap is to have a minimum safety factor of 1.0 against flows due to the design storm.

- o The safety factor is determined as the available shear resistance divided by the peak local shear stress due to runoff from the design storm.

- o Flow in the riprap voids is deducted from the total runoff to give the flow used to size the riprap.

- o Manning's formula is used to calculate the average velocity.

o The Corps of Engineer's formula (Ref. 5.11) is used to compute Manning's n. This formula accounts for depth of flow and average rock size so that iteration involving these parameters is required.

o Peak local shear stress for triangular ditches with 5H:1V side slopes is computed from

$$\tau = 0.9\ \gamma_w y S,$$

where γ_w = unit weight of water,
y = depth of flow, and
S = slope.

o Peak local shear stress for trapezoidal ditches is computed from:

$$\tau = C_{Rs}\ \gamma_w\ RS \text{ for sides, and:}$$

$$\tau = C_{Rb}\ \gamma_w\ RS \text{ for bottom,}$$

where C_{Rs} and C_{Rb} are functions of side slope and width/depth ratio, and R is the hydraulic radius.

o Rill and gully formation is assumed on the top and sides of the pile when topsoil is provided over the riprap.

The design methods give minimum D_{50} for a given condition. The remaining gradation limits, $D_{100})_{min}$, $D_{100})_{max}$, $D_{25})_{min}$ and layer thickness are then determined using the Corps of Engineer's method (Ref. 5-11).

B. Input Data and Parameters

1. Runoff Calculations - The following input is required to calculate design runoff parameters:

o Plan view of tailings pile, adequately dimensioned or to a scale that is satisfactory for determining areas and lengths, with contours, and elevations of key points.

- o Plan view of ditches, swales, and area contributing to runoff, meeting the same requirements as specified for the plan of the tailings pile.

- o Cross-sections of tailings pile, cover, swales and ditches.

- o Ground cover and topographic characteristics in sufficient detail for determination of roughness coefficients in contributory drainage areas and erodibility of ground beyond outlets.

- o Location of the site (latitude and longitude).

2. Riprap Size Calculations - The following input is required to determine optimum riprap sizes:

- o Specific gravity (G_s) of available stone of adequate durability.

- o Angle of internal friction (Ø) of riprap. Design values of Ø can be obtained as a function of rock size (Ref. 5-2, Fig. 16). A value greater than 40 degrees, as suggested by the USCE (Ref. 5-11, p. 41) should not be used without site-specific data indicating a larger value.

- o Porosity (p) of the in-place riprap layer. The degree to which porosity can affect rock stability and throughflow determinations can vary depending on the situation. A value of 0.3 has been used, based on data for rockfill (Ref. 5-22) and relatively uniform-sized, clean gravel (Ref. 5-23).

C. Methodology

1. Precipitation Intensity

a. Probable Maximum Precipitation (PMP) - The PMP is determined as follows:

(1) Plot location of site on Figure 4-1.

(2) Use appropriate Hydrometeorological Report (HMR) by NOAA (see Figure 4-1 and Table 4-1) tc determine precipitation intensity vs. time of concentration. For sites near boundaries shown in Figure 4-1, compare PMP estimates from HMR's applicable to areas near site, and use more conservative HMR results.

(3) Obtain design rainfall intensity compatible with time of concentration by interation as described below.

b. <u>Time of Concentration</u> - Time of concentration (Tc) estimates are based on hydraulic flow computations using Manning's formula for riprap-covered slopes and ditches. At some sites, significant overland flow from natural ground contributes to design flows. Time of concentration for such flow should be estimated by more than one method, since such estimates can vary significantly and be limited in their applicability. One estimate should be obtained by the Soil Conservation Service (SCS) Velocity Chart method (Figure 5-5). This method provides very good estimates for Tc for overland flow as long as flow paths exceed approximately 300-400 feet (Ref. 5-21). Other methods are available (e.g. several are given in Ref. 5-4 and Ref. 4-9), but their applicability to the design case under study should be considered in selecting a design Tc value.

2. <u>Top and Sides of Pile With No Topsoil Provided</u>

a. The sheet flow approach is used; i.e., calculations are performed for a 1-foot wide strip of slope length, L.

b. Assume a trial mean rock size, D_{50}.

c. Compute $q_t = q$ at critical (design) section from:

$$q_t = \frac{K^{3/2} C g^{1/2} [(1-p)(G_s-1)\cos\theta(\tan\emptyset - \tan\theta)]^{5/3}}{(\tan\theta)^{7/6}\,(p)^{1/6}}$$

Where $K = D_{50}$

C = 0.22 for gravel and pebbles, 0.27 for crushed granite

g = gravitational constant = 32.2 ft/sec^2 = 9.81 m/s^2

p = porosity

G_s = specific gravity

θ = embankment slope

and $\emptyset$ = angle of internal friction.

d. The intensity of rainfall for a strip 1-foot wide by length L_t, in inches, is:

$$I_{PMP} = \frac{43{,}560\ q_t}{L_t}$$ (Ref. 5.15, page 15).

e. Compute through-flow in the riprap voids, q_v, using

$$q_v = pA\ v_v$$

where p = porosity,

A = cross-sectional area,

= $t \times 1$ for 1-foot wide strip,

$t = 1.9D_{50}$ or minimum allowable thickness, whichever is larger,

and v_v = velocity in voids,

= $Wm^{0.5} S^{0.54}$ (Ref. 5-5 p. 90),

where W = empirical constant,

m = mean hydraulic radius,

and S = slope.

Figure 5-1 gives values of $Wm^{0.5}$.

f. Compute $q_{tn} = q_t$ at end of each segment n, and $L_n = L$ for each segment n, where the total number of segements n_t is such that L_n is no greater than about 100 feet, as follows:

$$q_{tn} = \frac{n\, q_t}{n_t},$$

$$L_n = \frac{L_t}{n_t}$$

g. Compute $q_{rn} = q_{runoff}$ for each segment n as $q_{rn} = q_{tn} - q_v$.

h. Select trial value of depth of flow, y, at end of segment n.

i. Compute trial value of Manning's Coefficient, n, from:

$n = y^{1/6}/[23.85 + 21.95 \log_{10} (y/D_{50})]$

(Ref. 5-11, p. III-7)

j. Check depth of flow assumed using:

$y = (q_{rn}\, n/1.486)^{0.6}/(\tan \theta)^{0.3}$

(based on Ref. 5-15, pp. 15-16).

k. Repeat Steps h through j until resolution is achieved for y for each segment.

l. Compute $v_{rn} = q_{rn}/y$.

m. Compute $t_{rn} = t_{runoff}$ for segment n from

$$t_{rn} = \frac{2 L_n}{V_{r(n-1)} + V_{rn}}$$

n. Compute T_r = sum of t_{rn}.

o. Repeat Steps b through n until resolution is achieved for I_{PMP} from T_r (using Tc versus i curve for site) and I_{PMP} from q_t and L_t (step d). Resolve I_{PMP} for each design section (e.g. ends of top slope and side slope).

3. <u>Top and Sides of Pile With Topsoil Provided</u>:

a. The gully development approach is used, with the Safety Factors Method.

b. The length of a given slope, L, defines the maximum length of potential gully for that slope.

c. The ratio W/L, where W = spacing of potential gullies on the slope, is determined from Figure 5-2. Then W = (W/L) X L.

d. The drainage area for a top slope gully is W X L. Side slope gullies may have a different spacing. The worst case for a side will be a gully which crosses the top and extends down the side, having a total drainage area = $W_t L_t + W_s L_s$ (t and s indicate top and sides, respectively).

e. The design flow rate, Q, is given by the Rational Formula:

Q = C i A,

where C = 1.0,

i = PMP intensity

and A = drainage area.

f. Estimate time of concentration T_c. Determine i from PMP versus time curve for site and calculate Q.

. Assume a trial mean rock size, D_{50}.

h. Assume gully base width $B = 2 X D_{50}$, gully side slopes = 2 horizontal to 1 vertical.

i. Compute flow in the riprap voids from:

$$Q_v = pA_v v_v$$

where p = porosity,

$A_v = Bt$, and

$t = 1.9D_{50}$ or minimum allowable thickness, whichever is larger, and

$v_v = Wm^{0.5} S^{0.54}$ (Ref. 5-5, p. 90)

where $Wm^{0.5}$ = factor from Figure 5-1,

and S = slope.

j. Compute net flow $Q_{net} = Q - Q_{th}$.

k. Select trial value of flow depth, y.

l. Compute area of flow, $A = 2y^2 + 0.5y$, and hydraulic radius, $R = (2y^2 + 0.5y)/4.5y + 0.5)$.

m. Compute Manning's coefficient, n, from:
$n = R^{1/6} [23.85 + 21.95 \log_{10}(R/D_{50})]$

n. Solve $Q_{net} = 1.486 AR^{0.67} S^{0.5}/n$ for y by trial.

o. Repeat steps j through n until resolution is achieved for y and Q_{net}.

p. Compute peak local shear stress on riprap. The riprap is at the base of a trapezoidal channel. The peak local shear stress on the base, $\tau_b)_{max}$, is determined from:

$$\tau_b)_{max} = C_{Rb}\ \gamma_w RS,$$

where C_{Rb} = factor given by Figure 5-3 (Ref. 5-2, p. 13).

q. Compute $n_s = 21\ \tau_b)_{max}/[(G_s - 1)\ \gamma_w D_{50}]$
(Ref. 5.10, p. 641).

r. Compute $SF = \cos\theta \tan\emptyset/(n_s \tan\emptyset + \sin\theta)$
(Ref. 5.10, p. 643).

s. If SF ≠ 1.0, repeat Steps f through q until resolution is achieved; i.e., SF = 1.0 for trial D_{50}.

t. Calculate T_c by averaging 1) time of concentration assuming overland flow for entire slope and 2) time of concentration assuming flow velocity in gully for entire slope. Compare estimated T_c (step f) with calculated T_c.

u. Repeat steps f through t until resolution is achieved for PMP intensity, i, and T_c.

4. Swales and Ditches

a. Design flow rate for a given swale is given by:

$$Q = C\ i\ A$$

where C = 1.0
i = intensity (PMP)
and A = drainage area.

b. Estimate time of concentration T_c. Determine i from PMP versus time (duration) curve for site and calculate Q.

c. Assume a trial mean rock size D_{50}. Determine thickness of riprap layer, t, for throughflow calculations by:

$t = 1.9D_{50}$ or minimum allowable thickness, whichever is larger.

d. Compute through flow from

$Q_{th} = p\, A_{th} v_{th}$

where p = porosity,

A_{th} = area of through flow,

and $v_{th} = Wm^{0.5}\, S^{0.54}$ (Ref. 5-5, pg 90),

where $Wm^{0.5}$ = factor from Figure 5-1

and S = slope.

e. Compute net flow $Q_{net} = Q-Q_{th}$.

f. Compute area of flow, A, wetted perimeter, P, and hydraulic radius, R = A/P for a trial value of y.

g. Compute Manning's coefficient, n, from

$n = R^{1/6}/[23.85+21.95 \log_{10} (R/D_{50})]$

h. Solve $Q_{net} = 1.486\, AR^{0.67}S^{0.5}/n$ for y by trial, and compute R.

i. Repeat steps e through h until resolution is achieved for y and Q_{net}.

j. Compute peak local shear stress as follows:

For triangular ditch with 5H:1V side slopes,

$\tau_{max} = 0.9\ \gamma S$ (Ref. 5-2, p. 12, Fig. 10).

For trapezoidal ditch,

$\tau_{max.} = C_{Rs}\, \gamma_w\, RS$ (for sides)

$\tau_{max.} = C_{Rb}\, \gamma_w\, RS$ (for bottom)

where C_{Rs} and C_{Rb} are given in Ref. 5-2, (Fig. 11 and 12, respectively).

k. Compute $n_s = 21\ \tau_{max}/[(G_s-1)\ \gamma_w D_{50}]$ (Ref. 5-8, p. 641).

l. Compute SF from:

$$SF = \frac{\cos\theta\ \tan\emptyset}{0.5\ [1+\sin(\lambda + B)]\ n_s \tan\emptyset + \sin\theta\ \cos B},$$

$$B = \tan^{-1} \frac{\cos\lambda}{[2\ \sin\theta/(n_s \tan\emptyset)] + \sin\lambda}$$

$$\lambda = \cos^{-1} \frac{a^2 + e^2 - c^2}{2\ a\ e}$$

$a = 1/\sin\alpha$, $b = 1/\tan\alpha$, $c = 1/\sin\theta$,

$d = 1/\tan\theta$, $e = (b^2 + d^2)^{1/2}$, and $\alpha = \tan^{-1} S$.

m. If SF $\neq$ 1.0, repeat Steps b through l until resolution is achieved, where SF = 1 for trial D_{50}.

n. Calculate T_c and compare to estimated T_c, if necessary. Incremental times of concentration T_{cn} for flow in ditches are obtained from ditch flow velocity V_n as follows:

$$T_{cn} = L_n/V_n.$$

o. Repeat steps b through n until resolution is achieved for intensity i and T_c.

5. Gradation

a. Compute $W_{50})_{min} = \pi G_s\ \gamma_w D_{50}^3/6$ (assuming spherical rock pieces).

b. Compute $W_{100})_{min} = 2\ W_{50})_{min}$ (Ref. 5-11, p. 42).

$W_{100})_{max} = 5\ W_{50})_{min}$

$W_{25})_{min} = W_{100})_{max}/16$

c. Compute $D_{100})_{min}$, $D_{100})_{max}$ and $D_{25})_{min}$ from

$$D = [6W/(\pi \ G_s \gamma_w)]^{1/3}.$$

d. Plot upper and lower bound gradation curves, adjust if necessary to utilize gradations already produced locally, and determine ranges for a minimum number of commonly-used sieve sizes that will ensure minimum and maximum size requirements. The following format should be used:

Sieve Size	Percent Finer By Weight
$D_{100})_{max}$	100
(sufficient sizes to	___ to ___
define curves, in even	___ to ___
inches)	___ to ___
1 inch	___ to ___
1/2 inch	___ to ___
No. 4	___ to ___

6. Thickness

The minimum thickness of a riprap layer, T_{min}, should be the greater thickness as determined by the following:

a. $T_{min} \geq 1.9\ D_{50})_{min}$

b. $T_{min} \geq 1.5\ D_{50})_{max}$

c. $T_{min} \geq 12$ inches

These requirements are based on USCE recommendations (Ref. 5-11). The first requirement is derived from the USCE minimum as follows:

$D_{100})_{max} = (5)^{1/3}\ D_{50})_{min}$ (after Ref. 5-11)

$T_{min} \geq 1.1\ D_{100})_{max} = 1.9\ D_{50})_{min}$

7. Filters and Bedding Material

a. Filters beneath riprap protect subgrade materials from migrating through voids. Bedding layers usually function as filters for underlying soils. Governing filter sizes for preventing migration of subgrade materials should be determined as follows (after Ref. 5-18, p. 10 and 11):

Subgrade Soil		Design Criteria**
Group No.	Percent Fines*	
1	40 - 100	$D_{15})_f \leq 0.7$ mm, except where base soil is dispersive or cohesionless, for which special study is required
2	0 - 15	$D_{15})_f/D_{85})_b \leq 4$ where base material is radon barrier, or ≤ 7.5 otherwise+
3	15 - 40	Interpolate linearly with percent fines between sizes required by criteria for groups 1 and 2

Notes:

* By weight, smaller than No. 200 sieve.

** D_{15} and D_{85} are sizes for which 15 percent and 85 percent of the particles are smaller, respectively. "f" denotes filter and "b" denotes base.

\+ Page 10 of the reference recommends $D_{15})_f/D_{85})_b \leq 4$, but p. 14 states that this results in a factor of safety of about 2, whereas $D_{15})_f/D_{85})_b \leq 7.5$ still results in a factor of safety ≥ 1.

b. If conditions require provision for adequate flow capacity, in addition to prevention of base material migration, the following criterion applies:

$D_{15})_f \geq 5D_{15})_b$ (Ref. 5-16, p. 59)

c. Filter $D_{max} \leq 3$ inch (Ref. 5-12, p. 236).

d. To avoid internal movement of fines, filter material should have no more than 5% passing No. 200 sieve (Ref. 5-12, p. 235).

e. Check need for second stage filter by considering first stage (from a.) as base and overlying riprap as filter in equations (1) through (4) above. Design 2nd stage filter, if required.

f. Plot upper and lower bound gradation curves for filter(s), adjust if necessary to utilize gradations already produced locally, and determine ranges for the following sieve sizes:

Sieve Size	Percent Finer By Weight
$D_{100})_{max}$	100
2 inches	___ to ___
1 inch	___ to _
1/2 inch	___ to
No. 4	___
No. 4	___ to ___
No. 16	___ to ___
No. 30	___ to ___
No. 50	___ to ___
No. 100	___ to ___
No. 200	___ to ___

g. The minimum thickness of a filter or bedding layer should be $1.1 \times D_{100})_{max}$ or 6 inches, whichever is larger.

8. Special Problems

a. Ditch Bends: Increased shear at the outside of ditch bends should be accounted for by USCE guidelines for maximum shear in channel bends for rough channels (Ref. 5-11, Plate 34). Bends with longer radii will not require as large an increase in rock size, so longer radii should be used where practicable.

b. Slope Decrease Transitions: Turbulence and increased shear stress results when slopes change from steeper to flatter, due to non-uniform flow in the transition area (Ref. 5-24). Rock sizes should be increased in such transition areas above rock sizes required for uniform flow. Increased rock sizes should be determined by several methods and the results compared before a final determination of design rock size is made. The following methods give rock sizes which are larger than those computed from methods for uniform flow:

1. USCE shear stress method [Ref. 5-11 with increased shear factor of 1.5 (Ref. 5-24)].

2. USCE method for design of riprap in turbulent areas beyond stilling basins. See Ref. 5-25, p. 44 and Ref. 5-26, Sheet 712-1 for guidelines for this method.

3. Stephenson's method for design of stones in flowing water (Ref. 5-9, p. 41).

4. Safety Factor Method with design shear stress greater than shear stress for uniform flow.

Considerable judgment must be used in applying these methods and selecting appropriate rock sizes, due to insufficiency of information on reliability for particular design situations.

c. Emergent Throughflow: When the throughflow capacity of a downstream layer is less than the upstream layer capacity, some throughflow will emerge above the section with the reduced capacity. This emergent throughflow should be included as runoff in flowrate determinations (for methods that subtract throughflow to obtain runoff).

5.2 RIPRAP MATERIALS SELECTION

A. Introduction

Before completing specifications for erosion protection elements, the Site Design Engineer should review the potentially available quantities and the durability characteristics of local materials. It may be necessary to modify the computed gradation limits and thickness requirements in order to develop a balanced, practical design. Guidelines for the investigation of available materials are presented herein.

B. Input Data

In the beginning of the investigation, it is necessary to know:

1. Quantities and Sizes of Material - Approximate required quantities and sizes of erosion protection material can be estimated from thickness of rock protection required for similar sites and from rough calculations for the site in question.

2. Riprap Durability - The data presented in Tables 5-2 and 5-3 are included as guidelines to judge the suitability of a rock source for use as riprap.

C. Methodology

The material selection process is divided into two phases: 1) Data Collection and 2) Data Analysis.

1. Data Collection - Much available data can be obtained via telephone and written correspondence with local quarry operators. Most operating local quarries have test results and quantity estimates on file. In addition, independent sources such as local highway departments, U.S. Army Corps of Engineers, and local governments may have valuable data for local sources. Generally, only results for tests one through five in Table 5-2, and petrographic analysis will be available. Communications regarding existing data should include inquiries into past local use of each type of rock in question, especially regarding length of exposure. Such data can be extremely valuable in judging long-term durability.

After an initial screening of the data available by telephone and mail, potential borrow sites should be visited. A site visit will permit visual examination, testing with a geologist's hammer, and independent selection of samples for gradation and rock quality testing. Tests one through four in Table 5-2 and petrographic analyses should be performed at a reputable laboratory. In addition, the search for cases where each rock type has been subjected to long-term exposure should be extended and these sites visited to evaluate the rock's performance. It is important to identify during the early stages of design any potential problem in obtaining suitable erosion protection materials within an economic hauling distance from the site.

2. Data Analysis - Gradation requirements determined, using the procedures presented in Section 5.1, should be plotted and compared with

gradations commercially produced. Without compromising performance, the gradation limits should be adjusted to make maximum use of available gradations. When necessary to ensure satisfactory results, layer thicknesses may be increased, if economically justified.

Presented below are guidelines for assessing the suitability of rock sources as erosion protection material.

- o Wherever possible, a particular source of riprap should be specified. Priority should be given to specific rock types that have been exposed for periods of more than 50 years and have suffered essentially no deterioration. As a quality control measure, the minimum specific gravity, maximum absorption, sulphate soundness weight loss, and abrasion loss values should be specified as acceptance criteria at each site. This will ensure that acceptable rock continues to be supplied from the source.

- o Specifications for materials, for which observable evidence regarding long-term performance is not available, should be selected using the third column in Table 5-2 (good quality rock), and then modified to allow for unusual characteristics of particular rock types. For example, the specific gravity of certain rock types (gabbro, gneiss, etc.) is consistently greater than 2.9. Therefore gabbro with a value of 2.65, while acceptable according to Table 5-2, could perform in an unsatisfactory manner.

- o Because there are currently no physical tests that can predict the performance of rock or gravel after 200 to 1000 years exposure, some judgment will have to be used to supplement the test data in selecting acceptable quality rock. Petrographic analysis provides an important basis in forming a judgment.

3. Form of Specifications - The gradation limits developed in Section 5.1 should be included in the technical Specifications.

Rock quality criteria used for the acceptance of riprap, bedding, and filter materials may be prescribed in the following format:

- o Representative samples of riprap material shall meet the following requirements:

Tests	Designation	Requirements	
Specific Gravity and Absorption	ASTM C127	S.G. (SSD) not less than Absorption not more than	___ ___%
Soundness (sodium-sulfate method)	ASTM C88-76	Maximum weight loss	___%
Abrasion	ASTM C131 or ASTM C535	Not more than ___% loss of weight after ___ revolutions. Ratio of loss after ___ revolutions to loss after ___ revolutions shall not exceed ___ percent	

o Samples of bedding and filter materials shall meet the following requirements:

Tests	Designation	Requirements
Specific Gravity (SSD):	ASTM C127 or ASTM C128	Greater than ____
Soundness (sodium-sulfate method):	ASTM C88	Less than __ percent loss of weight after 5 cycles
Abrasion	ASTM C131 or ASTM C535	Not more than ___ percent loss of weight after ___ revolutions. Ratio of weight loss after ___ revolutions to loss after ___ revolutions shall not exceed ___ percent.

5.3 REFERENCES

5-1 American Iron and Steel Institute, Handbook of Steel Drainage & Highway Construction Products, 2nd Edition, 1971.

5-2 Anderson, A. G., Paintal, A. S., and Davenport, J. T., Tentative Design Procedure for Riprap - Lined Channels, Highway Research Board, National Cooperative Highway Research Program, Report 108, 1970.

5-3 Ecker, R. M., Effects of Rock Riprap Design Parameters on Flood Protection Costs for Uranium Tailings Impoundments, U.S. Nuclear Regulatory Commission, NUREG/CR-3751, July 1984.

5-4 Gray, D. H., Handbook on the Principles of Hydrology, 1970.

5-5 Leps, Thomas M., "Flow Through Rockfill", Embankment-Dam Engineering, John Wiley & Sons, 1973, pp. 87-107.

5-6 Leonards, G. A., Foundation Engineering, McGraw-Hill Book Co., Inc., New York, 1962, page 134.

5-7 Nelson, J. D., Volpe, R. L., Wardwell, R. E., Schumm, S.A., and Staub, W. P., Design Considerations for Long-Term Stabilization of Uranium Mill Tailings Impoundments, U.S. Nuclear Regulatory Commission, NUREG/CR-3397, October 1983.

5-8 Rouse, H., Editor, Engineering Hydraulics, 1950.

5-9 Stephenson, David, Rockfill in Hydraulic Engineering, Elsevier Scientific Publishing Company, New York, 1979.

5-10 Stevens, M. A., Simons, D. B., and Lewis, G. L., "Safety Factors for Riprap Protection", ASCE Journal of the Hydraulics Division, Vol. 102, No. HY5, May 1976, pp. 637-655.

5-11 U.S. Army Corps of Engineers (USCE), Hydraulic Design of Flood Control Channels, EM 1110-2-1601, including Changes 1 through 4, U.S. Army, July 1, 1970.

5-12 U.S. Bureau of Reclamation, Design of Small Dams, Second Edition, Revised Reprint, 1977.

5-13 U.S. Department of Commerce, Rainfall Frequency Atlas of the U.S.

5-14 Abt, Steve, telephone conversation with G.R Thiers, 21 March 1986.

5-15 Walters, W. H., Overland Erosion of Uranium Mill Tailings Impoundments: Physical Processes and Computational Methods, U.S. Nuclear Regulatory Commission, NUREG/CR-3027, March 1983.

5-16 Walters, W. H., Rock Riprap Design Methods and Their Applicability to Long-Term Protection of Uranium Mill Tailings Impoundments, U.S. Nuclear Regulatory Commission, NUREG/CR-2684, August 1982.

5-17 U.S. Navy, Design Manual, Soil Mechanics, Foundations and Earth Structures, NAVFAC DM-7, March 1971.

5-18 Sherard, J.L., and Dunnigan, L.P., (5 May 1985), "Filters and Leakage Control in Embankment Dams", in Seepage and Leakage from Dams and Impoundments, Volpe and Kelley, Eds., Proceedings of ASCE Symposium, American Society of Civil Engineers, New York.

5-19 Lindsey, C.G., Long, L.W., and Begej, C.W. (1982), Long-Term Survivability of Riprap for Armoring Uranium Mill Tailings and Covers: A Literature Review, U.S. Nuclear Regulatory Commission, NUREG/CR-2642.

5-20 Abt, Steve "Data from CSU Studies", 28 January 1986

5-21 Kibler, D.F., and Aron, G. (1983), "Evaluation of Tc Methods for Urban Watersheds", in Frontiers in Hydraulic Engineering, Hung Tao Shen, Editor, ASCE Conference Proceedings, New York.

5-22 Marsal, R. J. (1973), "Mechanical Properties of Rockfill", in Embankment-Dam Engineering, Hirschfield and Poulos, (eds.), John Wiley and Sons, New York.

5-23 Winterkorn, H.F., and Fan, H-Y, (Editors), (1975), Foundation Engineering Handbook, Van Nostrand Rheinhold Co., New York

5-24 U.S. Army Corps of Engineers (USCE), (14 May 1971), "Engineering and Design: Additional Guidance for Riprap Channel Protection", Engineering Technical Letter (ETL) No. 1110-2-120, Washington, D.C.

5-25 U.S. Army Corps of Engineers (USCE), (31 March 1965), Hydraulic Design of Spillways, EM 1110-2-1603, Washington, D.C. (Reprint with Change 1, 21 April 1969).

5-26 U.S. Army Corps of Engineers (USCE), 1959 (Revised), Hydraulic Design Criteria, Vol. 2, Washington, D.C.

TABLE 5-1

CHECK LIST - AREA DRAINAGE AND EROSION PROTECTION DESIGN
(Sheet 1 of 2)

1. Name of site, state:

2. Approximate Coordinates: Processing Site
   Disposal Site

3. Basic Data:	Available	Not Available
a) Correct Base Map/Topo (1" = 200')		
b) Hydro-Met Data (Precipitation, Evaporation, Temp, etc.)		
c) Information on Nature of Vegetation		
d) Stream Flow Data		
e) Drainage Area Topo (1" = 200')		

4. Slope Protection Materials	Bedding or Filter	Riprap
a) Potential Sources		
b) Required Quantities (c.y)		
c) Available Quantities (c.y)		
d) Test Data Attached		

5. Reference Showing Contamiated Material Boundary

6. Reference Showing Geometry of Tailings Piles

7. Reference Showing Site Layout (Plan and X-Section)

TABLE 5-1
(Sheet 2 of 2)

8. Review of Conceptual Design in RAP	Yes	No
a) Design Sufficiently Detailed for Review Purposes		
b) All Supportive Data & Docs. Available		
c) Minor Change from Draft RAP, Need Not Redesign		
d) Major Change from Draft RAP, Need to Redesign		

9. a) If Redesigning, State Reasons ____________________
____

b) Schedule for Redesign: Start __________ Finish __________

c) Proposed Method or Methods of Design ____________________
____

d) Manual Computation/Computer Solution ____________________
____

10. Other Data

11. Comments

TABLE 5-2

U.S. BUREAU OF RECLAMATION STANDARDS
FOR JUDGING RIPRAP DURABILITY
(REF. 5-19)

Test	Quality		
	Poor	Fair	Good
1. Bulk specific gravity	2.5	2.5 to 2.65	2.65
2. Absorption, %	1.0	0.5 to 1.0	0.5
3. Na_2SO_4 weight loss, %	10	5 to 10	5
4. Los Angeles abrasion loss, %[b]	10	5 to 10	5
5. Freeze-thaw weight loss, %[a]	5	0.5	0 to 0.5
6. Ultrasonic cavitation rating	0 to 5	5 to 7	7 to 10
7. Schmidt impact hammer	40	40 to 60	60
8. Scleroscope	30	30 to 50	50
9. Coefficient of restitution[c]	0.5	0.5 to 0.7	0.7
10. Tensile strength, psi	500	500 to 1,000	1,000
11. Compressive strength, psi	15,000	15,000 to 20,000	20,000
12. Sonic velocity, ft/sec	15,000	15,000 to 17,000	17,000

(a) 250 cycles

(b) 100 revolutions

(c) rebound hardness

TABLE 5-3

COMPRESSIVE STRENGTH OF VARIOUS ROCKS
(REF. 5-19)

Rock Type	Strength, psi
Diabase and some basalts and quartzites	Over 40,000
Fine-grained granite, diorite, basalt, quartzite, well-cemented sandstone and limestone	25,000 to 40,000
Average sandstone and limestone, coarse-grained granite and gneiss	10,000 to 25,000
Porous sandstone and limestone, shales	5,000 to 10,000
Tuff, talc, siltstone, very porous sandstone	Under 5,000

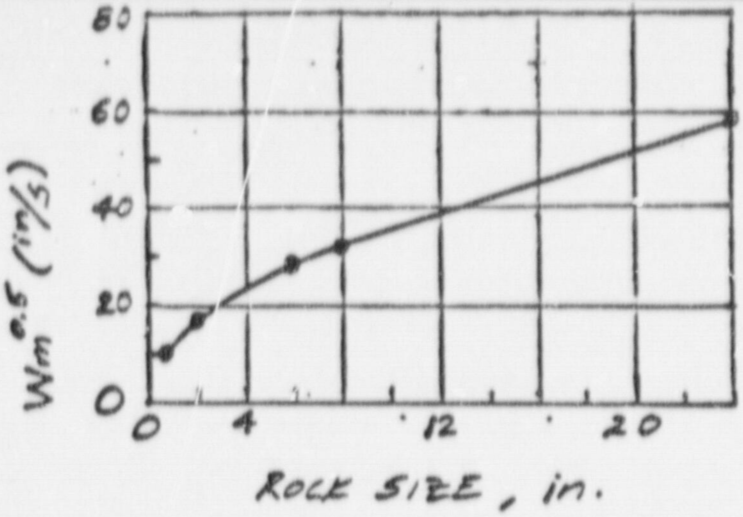


FIGURE 5-1 Mean hydraulic radius function versus rock size for the computation of turbulent flow velocity (After Ref. 5-5, Table 2, page 90)

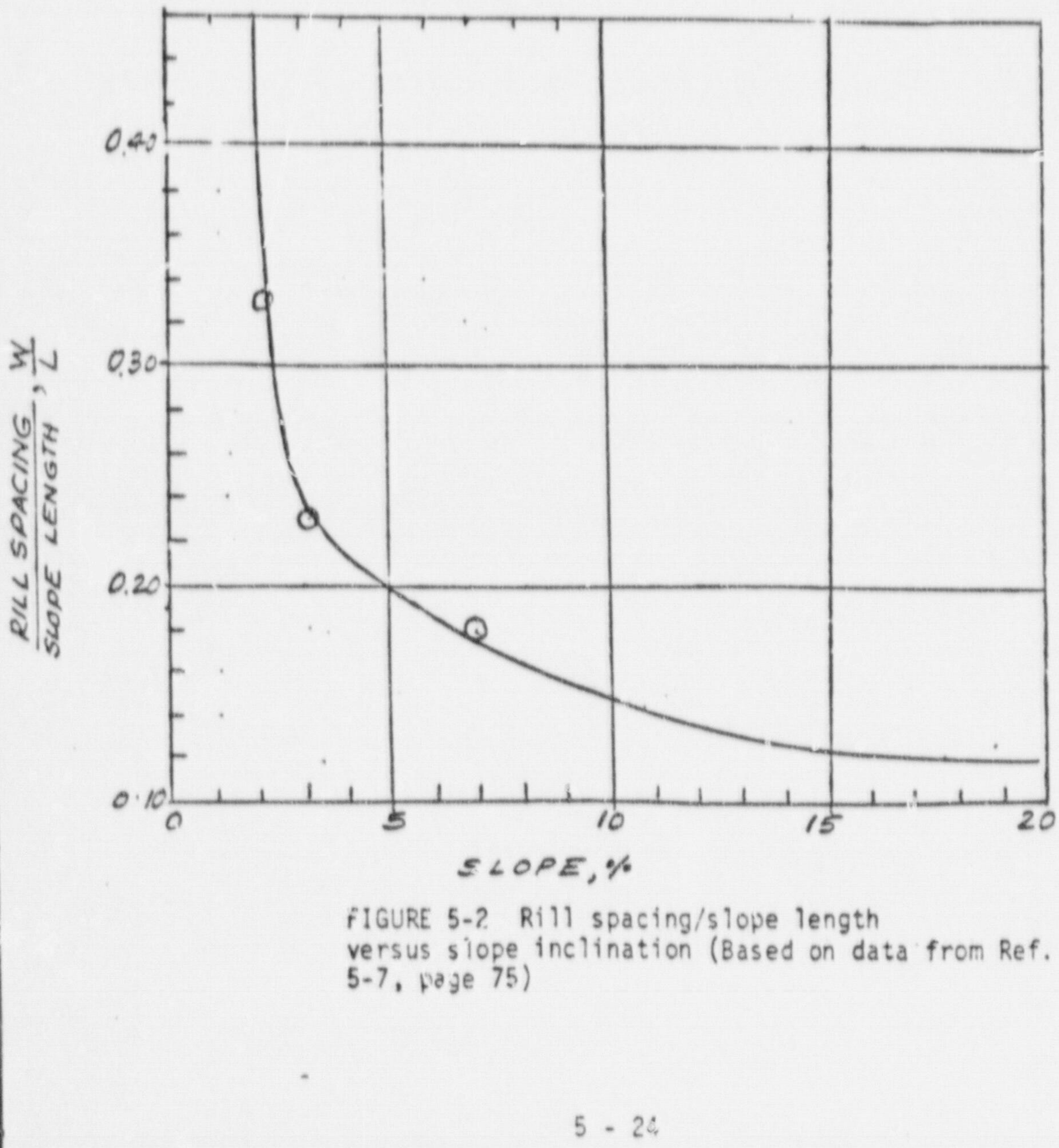


FIGURE 5-2 Rill spacing/slope length versus slope inclination (Based on data from Ref. 5-7, page 75)

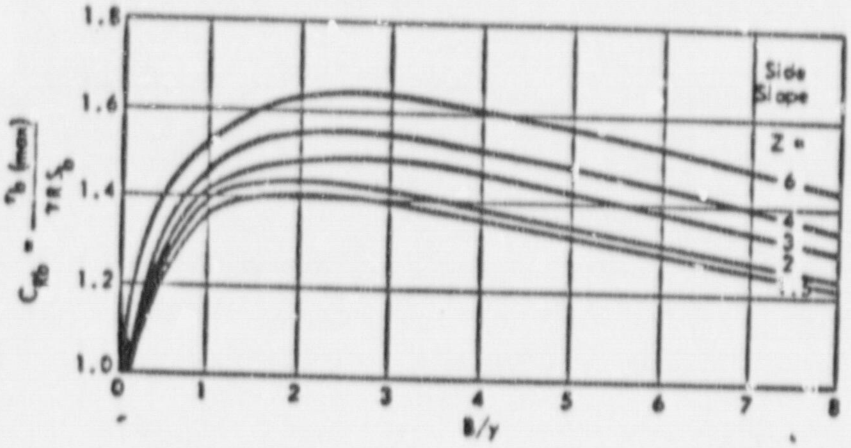


FIGURE 5-3 Maximum boundary shear stress on bottom of trapezoidal channels. (Ref. 5-2, page 13)

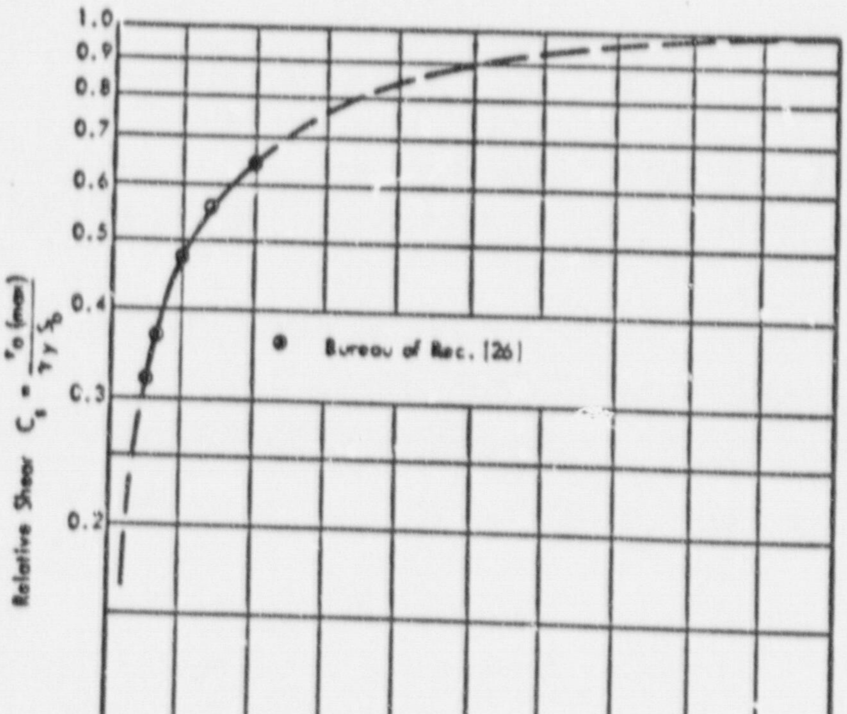


FIGURE 5-4 Maximum boundary shear stress on sides of triangular channels. (Ref. 5-2, page 12)

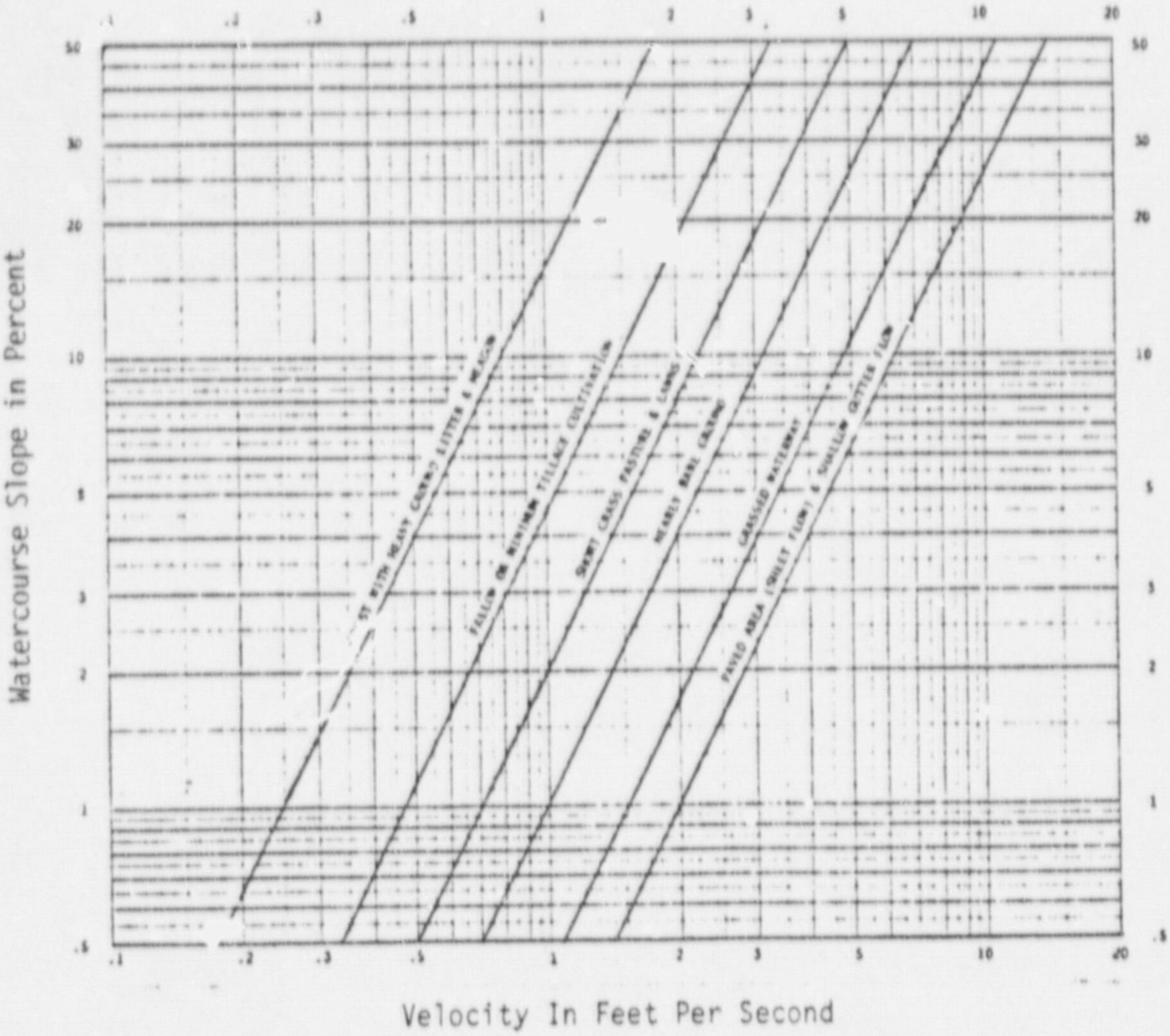


Figure 5-5 -- Average Velocities for Estimating Travel Time for Overland Flow. (Soil Conservation Service Method Ref. 4-6)