VENTURA COUNTY FLOOD CONTROL DISTRICT

DESIGN MANUAL

ADOPTED BY THE BOARD OF SUPERVISORS

VENTURA COUNTY FLOOD CONTROL DISTICT

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A number of changes in design requirements and policy matters have been made since the publication of this manual. Also, there are some minor errors. Please contact District staff prior to initiation of any final design.

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INTRODUCTION

This manual establishes uniform policies and procedures for planning and design of drainage facilities on water-courses designated to be under the jurisdiction of the Ventura County Flood Control District.

The material in the manual has been organized to provide the user with various design approaches as well as basic minimum requirements established by the District. The design approaches are presented to guide and assist the user in performing the planning and design function and should not be considered as a substitute for sound engineering practice. Design policies and standards are not inflexible. Higher standards may be used within reasonable economic limits. To insure uniform practice on a county-wide basis, lower standards may not be used without approval from the District.

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PREPARATION OF PLANS AND SPECIFICATIONS

110. PRELIMINARY ENGINEERING AND ECONOMIC STUDIES

111. Prior to the start of preparation of plans for a project, such engineering and economic studies as may be necessary shall be made to determine that the alignment, type of structure and limits of the project are those that will best and most economically serve the area to be drained.

In performing economic studies, comparative estimates of combined right of way, construction, operation and maintenance costs for both open and covered sections shall be made. As an aid in preparing these estimates, the District will furnish right of way costs for both open and covered channels. In all cases the implication of constructing a certain facility on the adjacent property shall be investigated.

In planning the project, careful consideration shall be given to aligning the project so that adequate working area is available for the contractor's operations and to avoid proximity to buildings that might be damaged by construction activities. Wherever economically and hydraulically practicable, the facility shall be aligned so as to stay out of business districts and State Highways.

120. DATA TO BE SUBMITTED IN ADVANCE OF PRELIMINARY DRAWINGS

121. GENERAL

The requirements presented herein are intended primarily for other agencies and consulting engineers performing design of flood control facilities. However, similar procedure may be used by the Design Section in coordinating the preliminary steps prior to starting the design.

122. REQUESTS FOR CHANGES OF ALIGNMENTS, LIMITS OR TYPES OF STRUCTURES

When, as a result of economic studies or for other reasons, it appears that a change of alignment, limits of the project or type of structures from those determined by the District should be considered, comparative plans, hydrology, right of way requirements and cost estimates, as applicable, for the proposed revision shall be submitted for District approval prior to use.

123. RAILROAD CROSSINGS

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The District will arrange for conferences between the designing agency, the District and the railroad companies; and subsequently obtain approval from said companies in cases where drains encroach or cross railroad property or tracks.

Prior to the conferences, transparencies of drawings on standard size sheets showing plan, profile and section of crossings, vicinity sketch, loading factors and structural details and calculations will be submitted to the District.

124. SOIL INVESTIGATION REPORT

Three copies of the soil investigation report (original and duplicates) prepared in accordance with the following requirements shall be furnished the District.

.10 GENERAL

Sufficient subsurface exploratory borings and sample analyses shall be made to permit the District to make an adequate assessment of the soil problems which may be encountered in the construction of the project. The soil investigation report shall contain findings and supporting information on (a) the relative density, type and extent of material to be encountered, (b) excavation problems, (c) location and extent of over-excavation required, (d) the stability of proposed excavations and of fill and backfill slopes, (e) the bearing capacity and settlement characteristics of the individual soil types relative to their use as fill or backfill, (f) the ground water condition, (g) the presence of substances in ground water or in the native soils deleterious to concrete and steel, and (h) information on lateral earth pressures.

Recommendations with supporting information shall be made for special problems such as, but not limited to, construction in expansive soils; construction in soil which has hydrocarbons; water control and, if dewatering is considered, the method to be used and what effects might be expected on structures or other improvements adjacent to the construction; use of project excavation material for fill and backfill which has an excess of moisture; if and where piling should be used.

Field observations of items which can affect the construction operations, such as bedrock out-
17 croppings between the borings, shall be recorded.

The District will analyze and use information from the soils investigation report in reviewing plans and specifications for construction.

.20 *LOCATION, SPACING AND DEPTHS OF EXPLORATORY BORINGS*

Exploratory borings shall be identified with the numbering sequence increasing upstream with each line of a project having its own sequence numbers. Borings shall be spaced at intervals not to exceed 600 feet, and their locations shall be shown and identified on a location map to be bound in the report. The scale of the location map shall be not less than one inch equals 600 feet. One boring shall be located at the downstream end of a project line, or at its confluence with another line of the project. The interval between borings shall be reduced if necessary so as to locate borings in areas in which topography or other evidence indicates a probability of soil conditions differing from those of surrounding areas or so as to locate borings adjacent to existing structures where special construction measures may be necessary. Borings shall be drilled in the bottom of natural channels when necessary to be truly indicative of field conditions on the project alignment. The location maps shall show the location and length of the proposed storm drain. Each log of a boring shall have the elevation of the existing ground graphically indicated. Boring locations may be selected at any point within the rights of way or easements in which the conduit or structure is to be located. Except in unusual situations, borings need not be located in paved street areas, but may be located in back of the curbs in the parkway areas. In order that the stability of the foundation may be adequately determined, soil borings having a diameter sufficient for obtaining adequate samples for testing and analyses shall be carried to the following depths: 18

.21 Where no ground water is encountered, test holes shall be carried to a depth of at least two feet below the proposed storm drain invert.

.22 Where ground water is encountered in vicinity of subgrade, or above, test holes shall be carried to a depth of ten feet or twice the structure width, whichever is less, below the proposed storm drain invert.

.23 If unsuitable material for support of the drain is encountered near subgrade, test holes shall be carried through to the bottom of the unsuitable material or to a depth of ten feet below the proposed invert, whichever is less.

.24 Where the construction will involve structural foundations such as footings or piles, the test holes shall be carried sufficiently below the footing subgrade or pile tip elevation to furnish bearing capacity and settlement information for proper design of the foundation.

.25 In the event a project is so redesigned subsequent to the soil consultant's report that the subgrade is lowered or the alignment is changed, additional borings shall be made as necessary to conform to the above requirements for those portions of the alignments which have been redesigned.

.30 LOGS OF BORINGS

The logs of borings shall give the soil classifications and descriptions together with all pertinent observations made in connection with the drilling of the borings.

In addition, the group symbol according to the Unified Soil Classification System shall be affixed either on the log of the boring or in parentheses following the soil classification. Selection of the group symbol shall be based on the Field Identification Procedures and on the criteria given on Table I of the Corps of Engineers Technical Memorandum No. 3-357, Volume I, dated March, 1953 (Revised April, 1960) entitled Unified Soil Classification System, and Earth Manual, published by the United States Department of Interior, Bureau of Reclamation. The field classification group symbols shown on the boring logs should be compared with the results of mechanical analyses, where available, and corrected if not compatible with the laboratory test data.

.40 *SOIL SAMPLES AND REQUIRED ANALYSES*

Representative undisturbed and bulk soil samples shall be taken from each major soil type encountered in the borings. The type and depth of sample shall be indicated on the logs of borings. Laboratory analyses shall be made on the soil samples as indicated in Table 124.40.

19 Prior to disposing of the soil samples and after receipt by the District of the consultant's soil report, the District shall be advised in writing or by telephone at least 15 days in advance of date of disposal. In unusual soil situations where soil characteristics may seriously affect design, District personnel may examine the samples, or may arrange for storage by the District in lieu of disposal. Furthermore, in such situations should additional tests be necessary, in the opinion of the District, they shall be furnished by the designing agency when requested in writing by the District.

.50 *GROUND WATER*

The logs of the exploratory borings should indicate the ground or perched water table as of the date the boring was made. If no water was encountered, a statement to that effect shall be included in the logs of borings. In every case where it is deemed possible that seepage, ground water or free water of any kind may be present, the boring shall be left open overnight or a minimum of 8 hours or, if free water is detected, until the depth to water becomes stabilized, but not to exceed 24 hours. The length of time and the depths to which and from which the water rose, shall be noted on the log of the boring. In certain locations, substantial quantities of

TABLE 124.40

LABORATORY ANALYSIS

Type	Method	Purpose
Gradation	Test Method No. Calif. 202.	Evaluation of project excavation material for use as fill, backfill or bedding.
Sand Equivalent Determinations	Test Method No. Calif. 217.	
Laboratory Maximum Density	ASTM D1557-58T modified by using three layers instead of five.	Establishing the in situ soil dry density and relative density of major soil types to be encountered.
Field Density	ASTM D1556-58T, with base plate.	
Shear Strength Characteristics Expressed in Terms of Ultimate Values of ϕ and C	Direct shear or triaxial test. Use ASTM D2166-63T when above methods are impractical.	Evaluation of foundation and slope stability.
Consolidation Characteristics	Settlement and rebound.	
Chemical Analyses	Analyses of a distilled water extract of soil (1 part soil : 5 parts water by weight) or the ground water in accordance with: ASTM D516 - Sulfate ASTM D1884- Acidity ASTM D512 - Chloride	Determination of the presence of sulfates, acids and chlorides in ground water or in the native soil (as percent dry weight of soil) which are deleterious to concrete and steel.

sulfates, acids and chlorides may be present in the ground water, all of which are considered deleterious to steel and concrete if found in sufficient quantities. Chemical analyses shall be made of ground water encountered in each boring, to determine the quantities of these deleterious substances present. The existence of these substances in damaging concentrations may justify the use of special cements or additives.

.60 *EXPLORATORY BORINGS, LABORATORY RECORDS AND ANALYSES*

All field, laboratory, and office information shall be submitted on 8 1/2" x 11" sheets. Boring locations shall be given in terms of distances from street centerlines, curbs or other permanent improvements. The elevation of the ground surface at each boring location shall be given. The date each boring was drilled shall be given.

.70 *USE OF EXISTING EXPLORATORY BORING DATA*

In many locations, exploratory boring data have been taken previously for the soil information required in the design of storm drains, sanitary sewers, bridge foundations, or other structures. This information, where available, adequate, and when taken in reasonable proximity to the storm drain, may be used in lieu of new exploratory boring data, except for the determination of the existing ground water table. These existing exploratory data shall comply with all the conditions set forth in subparagraph .40 above. In the event that the existing exploratory data do not fully meet all of the requirements herein outlined, new exploratory boring information will be required to supplement the existing data. Ground water tables must, however, in all cases, be up to date where said water table may influence the design or affect the contractor's operations.

.80 *SOILS INVESTIGATIONS FOR DEBRIS BASINS*

The soil investigation and report shall meet the following minimum requirements.

.81 *Locations of Borings* - Borings shall be drilled at least in the following areas:

a. In the foundation under proposed dam.

b. At dam abutments

c. Along alignment of outlet works.

d. In borrow areas.

e. At locations of proposed structures such as inlet chutes, outlet towers, spillways, etc.

f. Along proposed cuts such as for access roads, basin inlets.

It may be that some boring sites can be selected so as to furnish information for more than one of the areas listed above, dependent on the site and the proposed design. Under some conditions, it may be necessary to drill in other areas, such as in natural slopes of questionable stability.

.82 *Depth of Borings* - The minimum depths of borings shall be as follows, except that if firm bedrock is encountered at shallower depths, depths may be reduced accordingly:

a. Borings in the foundation under the proposed dam should have a depth at least equal to the height of the dam; if soft or loose materials are found to exist at that depth, drilling should be continued until firm material, not necessarily bedrock, is reached.

b. Borings at the abutments shall extend at least into firm material, not necessarily bedrock, suitable for support of the dam.

c. Borings in borrow areas or along proposed cuts should go at least as deep as the proposed excavation.

d. Borings at locations for structures should extend at least five feet below structure subgrade. If water is encountered, the boring should be drilled at least ten feet below the structure subgrade.

Reduction of boring depths due to presence of firm bedrock will be permitted only in igneous materials such as granite, decomposed granite, and similar massive rock in which it may be necessary to excavate by jackhammer, blasting, or similar methods. The depth of drilling shall not be reduced in soft, stratified, or fractured materials such as shale, slate, or weak sandstone.

.83 *Number and Frequency of Borings* - The number of borings shall be sufficient to allow obtaining all necessary information for proper design, as described below. The number necessary will depend on the design

and on site conditions, and cannot be specified in these recommendations; in addition, a need for additional borings may be disclosed during the soil investigation.

It may be possible to minimize the number of borings by the use of supplemental information obtained by geophysical methods such as seismic or electrical resistivity measurements. The results of such measurements shall be verified by and correlated with borings at the site; it will not be permissible to eliminate borings entirely and depend only on geophysical information.

.84 *Type of Exploratory Excavations* - The term "boring" as used in these recommendations is intended to include borings by drill rigs; auger holes; pits dug by hand or by equipment such as bulldozer, backhoe or clam bucket; tunnels; or other excavations as may be suited to the type of material encountered and the conditions of the site.

Borings by drill rigs should, if possible, be done dry by using buckets, helical augers or similar tools to facilitate examining, sampling and logging the materials encountered. Wash borings, cable tool borings, or use of drilling mud should be avoided if other means of advancing the boring (such as use of casing, if needed) are feasible.

.85 *Samples* - Samples should be obtained in each boring, so that each type of material encountered at the site is presented. Both undisturbed and bulk samples of each type of material shall be obtained if reasonably possible.

If ground water is encountered, samples shall be obtained for chemical analysis. Water samples shall also be obtained of any surface water flowing at the site.

Samples other than water samples shall not be disposed of until after notification of the District. District personnel may examine the samples, and may elect to store them on District premises in lieu of having them discarded.

.86 *Design Recommendations* - It is suggested that the designer familiarize himself with the book prepared by the Bureau of Reclamation, United States Department of the Interior, entitled "Design of Small Dams" and State "Rules and Regulations Pertaining to Supervision of Dams in California".

Recommendations shall be submitted by the soil engineer for all phases of the work related to soil mechanics and foundation engineering, including but not limited to the following:

a. Treatment of the abutments of the dam, so as to prevent cracking, differential settlement, piping, or excessive seepage.

b. Necessary depth of stripping in areas to be covered by fills, in order to minimize settlement, piping, or excessive seepage.

c. Treatment of foundation for dam and structures to minimize post-construction settlement, cracking, or leakage.

d. Needs for subdrainage systems or toe drains, to prevent saturation failures of slopes or uplift of structures.

e. Stability of proposed fill slopes for the dam, under the various conditions which may exist following construction. Due allowance shall be made for seismic loading, seepage, and drawdown.

f. In the event that subdrains or toe drains are needed, gradation requirements for filter and drain materials so as to prevent failure by clogging or by piping.

g. Needs for erosion-resistant inlet structures, to prevent unacceptable erosion of stream bed material upstream of the basin.

h. Stability of proposed fill slopes for access roads, housing areas, or other purposes. Due allowance shall be made for surcharges and live loads.

i. Suitability of proposed borrow materials, with relation to compressibility after placement and compaction, expansiveness, stability, presence of soluble or decomposable materials, and permeability, so as to prevent post-construction shrinkage cracking, excessive settlement or saturation, slope failure, excessive seepage, or progressive removal of solids by solution.

j. Relative density (or relative compaction, or per cent compaction) necessary in compacted fills, and the test procedure for determining laboratory maximum density.

k. Proposed location of concrete structures (particularly the spillway) with respect to suitability of the foundation to support the loads without undue or differential settlement which could cause cracking or leaking of the structures.

l. Need for special cements in concrete, to resist high sulfates or other deleterious materials in water or soil which might cause deterioration or loss of strength of concrete.

m. Stability of proposed cut slopes in order to prevent sloughing which might extend outside the right of way, block the access road, or reduce the available capacity of the basin.

25 n. Stability of natural slopes which may become inundated, in order to prevent sloughing which would reduce the available capacity of the basin or extend outside the right of way.

o. Stability and bearing capacity of material (in cut or fill) at grade for the access road, with respect to support of traffic loads as necessary during the after storms. Due consideration shall be given to possible erosion of the access road as related to the proposed grade. If surfacing is found to be needed, recommendations shall be made as to the type, thickness, subgrade preparation, need for base or subbase, and related matters.

p. Treatment of the upstream face of the dam as necessary to control erosion by wave action or rainfall, saturation of the dam by water in the basin, and as related to possible effects of drawdown and cleanout operations.

q. Needs for erosion prevention treatments, including planting, drainage devices, or erosion resistant covers such as rock blankets, for cut and fill slopes including the downstream face of the dam, and for the crest of the dam.

r. Treatment of excavations, subgrade, and backfill in connection with outlet conduits, with respect to prevention of piping or erosion along the conduits.

s. Need for and required depth of any cutoff to prevent or control seepage through the foundation of the dam, to prevent failure by piping, uplift, or removal of soluble materials.

t. Need for special construction methods of backfilling behind spillway walls, so as to minimize shrinkage of spillway backfill away from the main mass of the fill.

.87 *Supporting Information* - The design recommendations shall be accompanied by supporting information, including but not limited to the following:

a. Logs of borings, showing in addition to the location and surface elevation of each boring so referenced that the relationship with the proposed design can be evaluated. Each log should describe the material encountered and the depth thereof; the depth to ground water if any; the occurrence of sloughing, ravelling or seepage; the site of the boring and the method and date of drilling, including any use of casing, drilling mud, or other pertinent features, and the depths at which samples were obtained. The soil classification system used in logging the borings shall be identified in the soil investigation report. If the soil classification system is not widely used, it 26
shall be described in the soil investigation report.

b. Results of any geophysical measurements which were made.

c. Reports and interpretation of any geologic studies which were made. If conditions warrant, the District may require an engineering geologic investigation.

d. Results of laboratory analyses as follows:

(1) Consolidation test, particularly of dam fill and foundation materials, of undisturbed and remolded samples, with water being added during the test.

(2) Strength tests (direct shear, unconfined compression, or triaxial compression as applicable) as natural moisture or saturated, as applicable. A description of the test conditions (drainage, strain rate, etc.) shall be included. Results shall be presented in terms of internal friction angle and cohesion.

(3) Mechanical analyses.

(4) Any classification tests such as Sand Equivalent or Atterberg Limits which may have been performed.

(5) Any tests for shrinkage, expansion, or expansion pressure which may have been performed.

(6) Permeability, particularly of dam fill and foundation materials.

(7) Organic content, particularly of dam fill and foundation materials.

(8) Chemical analyses for materials deleterious to steel or concrete, in water or soil.

(9) Native density and moisture content.

(10) Laboratory maximum density and optimum moisture content with the method of determination being identified.

e. Results of calculation such as factors of safety against sliding for proposed slopes and amounts of settlement to be expected under various anticipated situations.

f. Results of any field observations of pertinent matters such as bedrock outcrops, overhangs, springs and seeps, presence of existing wells, and
27 evidence of previous accelerated erosion.

.88 *Supplemental Information and Recommendations* - If it should prove necessary to make changes in the design or construction which may affect the operation or maintenance of the basin, supplemental information and recommendations shall be submitted. For example, if an unexpected shortage of borrow material should require the use of a new borrow area or pit, the materials in the new source shall be investigated by the soil engineer and approved by the District prior to use.

125. INDUSTRIAL WASTE

Where it is evident that the project drain will be subjected in any way to industrial waste, the chemical analyses thereof shall be furnished the District.

126. SURVEY DATA

Survey data such as survey controls, cross sections, aerial surveys and other pertinent information shall be generally furnished by the District. Any errors found in the survey data or need for any additional survey information shall be brought to the attention of District prior to commencement of the preliminary design.

130. PRELIMINARY DRAWINGS AND SUPPORTING DATA

131. DRAWINGS

.10 *GENERAL*

Preliminary drawings shall consist of sepia transparencies of the original tracings. Detailed design for reinforced concrete structures shall not be submitted with preliminary drawings. All preliminary drawings shall be on District standard size sheets with the District title block thereon. The size of the drawing sheets is 21" wide x 42" long, measured inside of borders, and is available in half plan and half profile, blank, and 10 x 10 cross section. Drawing sheets will be provided by the District.

The following general requirements shall be applicable to the preliminary drawings.

.11 Since contract drawings are reduced to half scale for inclusion in the specifications, all lettering on such drawings shall be equivalent to, and/or larger than, the #5 setting on the Ames Lettering Guide.

.12 Plans and profiles shall be stationed upstream from left to right and each sheet shall be plotted with limits identical and no overlaps on adjacent sheets.

.13 The sheets shall be used entirely.

.20 *TITLE SHEET*

The first sheet of the drawings shall be the title sheet and shall have shown thereon:

.21 Location map, north arrow, and numerical and graphic scale. Decals will not be acceptable.

.22 Index to sheets of drawings.

.23 Structural and hydraulic criteria used in design.

.24 Location and length of project.

.25 Key map.

.26 General notes. See Appendix A for a listing of generally applicable general notes.

.27 Project and specification numbers. If a Bond Program Project, the year of the Bond Program and Bond Program number shall also be indicated.

.28 *Title Block* - The title block shall contain the project name. The title block shall not include the words "Title Sheet".

.30 *PLAN*

The following information shall be indicated on plans for storm drains and conveyance structures, for other types of flood control structures appropriate data shall be provided:

.31 *Scale* - 1" = 40', show numerically and graphically

.32 North arrow.

.33 Show outline of main channel or conduit and other flood control facilities. Show center-line of main facility with appropriate ties to survey control line and right of way lines. Indicate the dimensions of the facility as viewed on the plan. Show contour of existing ground, or outline of existing channel at toe and top of bank. A separate tie sheet may be used, if the inclusion of tie information on the plan affects clarity. 30

.34 Show railroad property lines and tracks.

.35 Show location of test borings in accordance with subparagraph .60.

.36 *Utilities, Sewers and Drains* - Indicate the type, size and ownership of all existing utilities, sewers, house connections, power and telephone poles affected by the project. Utilities to be abandoned in place or relocated by owner shall be shown by the appropriate note.

.37 *Existing Improvements and Culture* - Indicate on plans all existing improvements which will be affected by construction, or which will affect the contractor's operations. Show all culture and trees within the right of way as well as those outside the right of way affected by the construction. Indicate on the drawings the approximate size of trunk measured 3 feet above ground. Show all trees which must be removed or replaced by appropriate symbol or note.

.38 Show right of way or easement lines, street centerline, street improvements, driveways, structures and other improvements which will be existing at the time of the construction. Right of way lines shall be shown with sufficient ties and details to allow for use in right of way acquisition. Also show temporary work areas.

.40 *PROFILE*

.41 *Scale*: Vertical 1" = 4', horizontal 1" = 40'. Indicate numerically. A vertical scale of 1" = 8' may be used when the steepness of terrain or depth of drain below ground surface makes a scale of 1" = 4' impractical. A change in scale within a set of drawings shall be noted, directing attention to said change.

.42 Show ground line over centerline of drain, and
31 in the case of open channels, show ground line at centerline of construction.

.43 Indicate size of conduit or channel by reach, such as pipe diameter, width and height of open channels or box conduits. In case of alternate designs (pipe or box), indicate both including D - load for pipe. The height of box conduits shall be defined as the vertical distance from the base of the wall to the soffit. In rectangular or trapezoidal open channels, the height shall be defined as the vertical distance from base of wall to top of wall.

.44 Show invert (grade line) and soffit of closed conduit or top of wall. The invert elevation shown shall be at the centerline of the drain or at the lowest point in a multibarrel boxes.

.45 Show hydraulic grade line and the energy grade line. Abbreviate as HGL and EGL respectively.

.46 Show with dashed lines the outlines of existing structures which may affect or be affected by the construction.

.47 Show location and vertical position of all utilities traversing the right of way, which may be affected by the construction. Indicate the correct numerical elevation of all underground utilities three inches or greater in diameter in case of pipe conduits, and all telephone conduits or ducts. The numerical

elevation shall be substantiated by exploratory excavation when possible. Also on profile show encasement and protection of utilities, where required.

.50 CROSS SECTIONS

.51 Scale not less than 1" = 10' No distorted scale.

.52 Show sufficient cross section based on recent field survey. Accurately calculated earthwork, structural excavation, and structural backfill quantities shall be indicated at each cross section in cubic feet. Pay lines and cross sections shall be shown in pencil. Cross section of the structure shall be shown in pencil on the preliminary plans, and shall be inked on the final drawings.

.53 Cross sections shall be at intervals required by the topography of the specific area, however, in no case shall the interval be greater than 100 feet. 32

.60 SOILS INVESTIGATION DRAWINGS

The location of the test borings shall be shown by symbol on the plan portion of the storm drain plan and profile sheets. The logs of the borings, however, shall be plotted on separate standard size sheets showing all information given for the logs in the soils report and indicating the grade line for the proposed facility on each boring log.

A note shall be placed on said drawings indicating those test borings in which ground water was encountered. If no ground water was encountered in any of the borings, a statement to that affect will be made.

132. SUPPORTING DATA AND RIGHT OF WAY REQUIREMENTS

.10 GENERAL

One complete set of all calculations shall be submitted for review. The calculations shall be bound in separate folders with title on cover, pages numbered, and indexed. Each sheet of calculations shall be dated and have name or initials of individual making the calculations. All calculations submitted by consulting engineers shall be affixed with the name and number of a registered engineer, indicating that the calculations have been checked.

Calculations pertaining to hydrology, hydraulics, quantities and cost estimates, and other supporting data shall be in separate folders.

.20 HYDROLOGY CALCULATIONS AND DRAINAGE MAPS

Two separate drainage maps shall be furnished. One map shall show the watershed for the main channel and shall include the 50 yr. 24 hr. isohyetal lines, sub-areas colored and numbered, soil types, cover types, concentration points, contours and pertinent elevations. The scale of this map shall be not less than 1 inch = 2000 feet.

A second map shall be primarily for the developed areas adjacent to the main channel and shall indicate the sub-areas, direction of surface flow, location of existing drainage structures, concentration points of the surface flow and other pertinent data necessary for proper disposal of surface flow. The map shall show the latest developments and the scale shall be not less than 1 inch = 600 feet.

33

.30 HYDRAULIC CALCULATIONS

Hydraulic calculations for the main channel and appurtenant structures as well as hydraulic calculations for side drains, catch basins and other minor facilities, when included in the design.

.40 COST ESTIMATES AND QUANTITY SHEETS

.41 All construction cost estimates shall be submitted on the Districts' Engineers' Estimate Summary Sheets, accompanied by appropriate detailed quantity computations. Prices used in Cost Estimates shall be based upon the Districts' Cost Estimating data presented in this manual. All Quantity and Cost Estimates shall be submitted in single copy and shall be neat and legible.

.42 Quantities shall be completely and independently checked by the consulting engineer or designing agency.

.43 If revisions to drawings result in changed quantities, revised cost and quantity estimates shall be submitted together with revised drawings.

.50 RIGHT OF WAY REQUIREMENTS

.51 Transparencies of drawings and/or sketches showing right of way requirements shall be submitted. The preliminary drawings as described above may serve as right of way drawings provided all of the necessary information is clearly presented, or if desired, separate right of way sketches may be submitted. The drawings and sketches shall include the following information.

a. Correct title, project number and date.

b. North arrow and scale

c. Location of right of way to be acquired, including ties to control lines.

d. Legal identification of tracts and lots in which right of way is required.

e. Field survey notebook references.

.52 The sketches shall be on standard size sheets.

.53 Additional sketches shall be submitted for each revision in right of way requirements, including the correct identification of the portion to be superseded or added. 34

.54 *Right of Way for Covered Conduits* - Right of way dimensions for covered conduits, in general, shall be equal to the inside dimensions of the box or pipe conduit plus three feet on each side of the conduit, but in no case shall the width be less than 15 feet.

.55 *Right of Way for Open Channels* - Open channels will require widths of right of way to meet ground surface conditions and access road requirements. Right of way dimensions shall be as follows:

a. When the inside top width of a channel section is less than 40 feet, the width of the right of way shall be equal to said top width plus 18 feet (3 feet on one side of the channel and 15 feet on other side for access road) and such additional width as may be necessary for cut or fill slopes to daylight (cut slopes 1 1/2 : 1 and fill slopes 2 : 1 unless soil conditions require flatter slopes).

b. When top width of channel section is 40 feet or more, an additional 12 feet over the width shown in a. above shall be required in order to provide for access roads on both sides of the channel.

c. When possible, it will be attempted to obtain slope right for cut or fill slopes and to maintain the right of way or easement lines at the toe or top of bank, respectively.

d. When a parallel public street is adjacent to the right of way, thereby providing access for maintenance of the channel, each of the total widths shown in a. and b. above may be reduced.

e. Access shall be provided to the access roads from all cross streets.

35 f. Suitable access ramps shall be provided for access to open channel bottom in accordance with District Standards.

g. In addition to the above requirements for permanent rights of way, temporary construction easements or work areas shall be provided as necessary to encompass a sloped excavation of 3/4 to 1 (or flatter where the safe angle of repose is less steep) in conformance with the "Construction Safety Orders" of the State Division of Industrial Safety.

.56 Right of Way Requirements for Debris Basins

a. Sufficient right of way shall be provided for economical maintenance and access for cleanout equipment and shall include sufficient area to provide for a 15 foot wide access road from a dedicated public street to the debris basin.

b. To establish the required right of way limits, based on the maximum expected debris deposit, the theoretical debris slope, facing upstream from the spillway crest, shall be assumed at 75% of the average slope of the original streambed for the total length of the basin site.

c. In general, the contours of the debris surface shall be assumed as straight lines at right angles to the centerline of the spillway and/or the basin streambed, depending on the shape of the basin involved.

d. A disposal area, of sufficient storing capacity subject to District approval shall be provided within an economical hauling distance from the debris basin.

.57 *Survey Notes* - All additional surveys performed by the consulting engineer or designing agency other than those performed by the District shall be in accordance with recognized good surveying practice. All survey notes must be neat, technically correct, accurate, legible and clear enough to reproduce. Notes shall include sketches oriented by a north arrow pointing up the page, preferably. Date of survey, field book page number, party's personnel, cross references to adjoining pages, and references to all District field books must be shown.

Two copies each of all pages of horizontal control, vertical control, and calculations shall be furnished. Horizontal control, vertical control, and design survey notes shall be submitted on separate pages. All notes shall be on 8 1/2" x 11" sheets.

.58 *Comparative Cost Estimates to Justify Utility Relocations* - Economic studies shall be made during preliminary design of the project with respect to the cost of relocation or reconstruction of existing street or other surface improvements, utilities and storm drains. Where the alignment is such as to require the relocation of a utility, a comparative cost study shall be made to determine the possibility of realignment of the drain or other modification, which may result in cost saving to the District.

Comparative cost estimates shall be furnished to the District with the preliminary drawings where it is proposed to relocate a utility or modify the flood control facility.

140. FINAL DRAWINGS AND SUPPORTING DATA

141. DRAWINGS

.10 *GENERAL*

Final drawings shall be on District standard size sheets having District title block, complete with name of project, signature and approval of project engineer, name of consulting engineer and designing agencies, if any, and all other information as required under "Preliminary Drawings and Supporting Data".

.20 *DRAFTING*

All drafting shall be in pencil, with the following exceptions:

.21 Outline of pipe or box conduit and open channel shall be inked on the plan and profile sheets.

.22 Outline of all major details or cross sections on the detail sheets shall be inked. Standard symbols for concrete or steel or other materials shall be shown on the cross sections.

.23 All the lettering on the title sheet and in the title blocks shall be Leroyed in ink.

.24 All sections of the structure on the cross section sheet shall be in ink.

.30 *DETAILS*

All structural details shall be no less than 1" = 4' in scale and shall indicate sufficient details for construction purposes. The title block on the detail sheets shall indicate the type of detail shown thereon.

142. SUPPORTING DATA

.10 *PRELIMINARY DATA*

Furnish all supporting data as required under "Preliminary Drawings and Supporting Data", if not previously furnished.

.20 *STRUCTURAL CALCULATIONS*

Furnish two complete sets of structural calculations. Structural calculations may be submitted after the preliminary data but prior to the final supporting data, for review by the District, particularly when special problems are encountered in the structural design.

.30 SPECIFICATIONS

.31 Furnish a complete set of Special Provisions to accompany the standard specifications used by the District. Special Provisions shall cover all items of construction by bid item, both for the materials and the construction methods view point. Standard Special Provision forms shall be provided by the District upon request. Special Provisions not covered by standard District forms shall be written specially for the purpose.

.32 A final Cost Estimate Summary on District standard form shall be furnished. Where separate construction schedules are used, the Cost Estimate Summary shall be according to schedule.

.33 All above items shall be typewritten in final form on 8 1/2" x 11" sheets, for reproduction by Xerox.

.40 FINAL REPORT

Two complete packages, original and one copy, consisting of all final calculations, notes and other data pertinent to the design of the project shall be furnished in report form. Depending on the number of sheets, the reports may be separated into hydrology, hydraulic, structural and other reports and shall be bound in a cover with the title of the project and other pertinent data shown thereon.

200
HYDROLOGY

210. METHODS

Methods outlined in the Ventura County Flood Control District, Hydrology Manual shall be used for hydrologic design for flood control improvements.

220. FREQUENCY CRITERIA

Storm frequency criteria to be used for the determination of the design storm runoff is presented in the following table.

Table 220.

Type of Improvement	Frequency of Occurrence in Years
Channels under VCFCD jurisdiction and appurtenant structures	50
Channels intended for future VCFCD jurisdiction and appurtenant structures	50
Small dams - Spillway*	100
Dams not meeting requirements of small dams (Subject to the jurisdiction of the Dept. of Water Resources, State of California.)	1000
Levees and Channels where the H.G.L. is above surrounding ground	500
Catch basins and minor side inlets	10

** Small dams include any dam which falls into one of the following classifications.*

- *a. Impounds less than 15-acre feet, regardless of height.*
- *b. Is less than 6 feet high, regardless of capacity.*
- *c. Is less than 25 feet high and impounds less than 50 acre-feet.*

Height of dam is measured from spillway crest elevation to natural streambed elevation at downstream toe of dam. Capacity of dam is measured to spillway crest elevation.

300

HYDRAULIC DESIGN

310. CONVEYANCE STRUCTURES

311. The term conveyance structure as used herein is generally intended to describe a facility that conveys flow from one point to another, such as an open channel or pipe. The word channel is used indiscriminately for open channels, conduits with freeboard or pipes flowing partly full. In areas when application is limited to a closed conduit flowing under pressure, specific reference is made.

312. MAXIMUM PERMISSIBLE SIDE SLOPES

Maximum side slopes for trapezoidal open channel shall conform to the following requirements:

.10 UNLINED CHANNEL

Side slopes shall be limited to the natural angle of repose of the material, or maximum of 2:1. Divergence from this requirement may be allowed based on materials investigation of the soil and the ability of the soil under
15 saturated conditions to remain stable and resist erosion.

.20 LINED CHANNEL

Side slopes shall be limited to 1½ : 1 or flatter for unformed concrete lining. Formed concrete sides shall be limited to vertical wall, rectangular channels. Maximum permissible side slopes for rock riprap reveted channels shall be 2:1.

313. ROUGHNESS COEFFICIENT

The following values of "n" for use in Manning's equation are for average conditions. Modification of listed values should be made in case of tortuous channel alignment, variation of material, excessive vegetation, etc.

.10 UNIFORM SECTIONS

The values of "n" presented in Table 313.10 shall be used for channel cross sections with material of the same roughness.

Table 313.10

Manning Roughness Coefficient, "n"

Corrugated Aluminum Pipe - 1" x 6" Corrugation	0.027
Corrugated Metal Pipe - 1/2" x 2 2/3" Corrugation	0.024
Corrugated Metal Pipe - 1" x 3" Corrugation	0.027
Corrugated Metal Pipe - 2" x 6" Corrugation	0.030
Reinforced Concrete Channel - formed or wood floated finish. Also cast-in-place pipe	0.015
Reinforced Concrete Pipe - spun or cast	0.012
Rock Riprap Revetment - grouted or ungrouted	0.035
Unlined - graded earth, regularly maintained	0.030
Natural Streams, Regular Section - grass and weeds	0.035
Natural Streams, Regular Section - light brush	0.050
Natural Streams, Regular Section - heavy brush	0.070

46

(for Natural Streams, Irregular Section add 0.02 to above)

.20 COMPOSITE SECTIONS

A weighted value of Manning's roughness coefficient "n" shall be used for channel cross sections when the perimeter is made of several types of material of different roughness coefficient. The equivalent coefficient is expressed by the following equation:

$$n = \left[\frac{p_1 (n_1)^{3/2} + p_2 (n_2)^{3/2} + p_3 (n_3)^{3/2}}{P} \right]^{2/3}$$

where n = equivalent coefficient

n_1, n_2, etc. = roughness coefficient of individual lining material.

p_1, p_2, etc. = wetted perimeter associated with roughness coefficient n_1, n_2. etc.

P = Total wetted perimeter ($p_1 + p_2 + p_3 + \ldots$)

314. PERMISSIBLE VELOCITIES

.10 UNLINED CHANNELS

Allowable non-erodible velocities for a variety of earth channel material types is presented in Table 314.10. All velocity determination shall be substantiated by a soils investigation of the area.

Table 314.10

Allowable Mean Velocities for Unlined Channel *

Lining Material	Mean Velocity ft. per sec.
Very light loose sand	1.00
Coarse sand	1.50
Average sandy soil	2.00
Sandy loam	2.50
Average loam, alluvial soil, volcanic ash soil	2.75
Clay loam	3.00
Stiff clay	4.00
Ordinary gravel soil	4.00
Coarse gravel, cobbles, shingles	5.00
Cemented gravel, conglomerates	6.00
Tough hardpan, soft slate	6.00
Soft sedimentary rock	6.00
Hard rock	10.00

In the design of major Flood Control channels and when a more exact solution is desired, the Method of Tractive Force shall be used. The allowable unit tractive force presented in the references** shall be reduced by 20% to allow for occasional peak flow conditions prevalent in Ventura County.

* *For allowable mean velocities in earth channel with vegetative cover see Reference 12.*

** *Reference 4 and 11.*

.20 LINED CHANNELS

No velocity limitation for reinforced concrete lined channels. Velocity for a rock riprap revetted channel shall be based on Table 314.10 and the Method of Tractive Force.

315. CHANNEL DEPTH

Depth of the channel section shall be computed by the use of the following criteria and shall be the sum of the depth of flow and freeboard as applicable. In order to allow side drainage to enter, it is desirable to keep required top of bank at or below ground surface as required by existing or future development.

316. DEPTH OF FLOW

Determine the water surface profile for uniform, gradually varied steady continuous flow using Bernoulli's Theorem, working upstream with $F < 1$ and downstream with $F > 1$.

Bernoulli's equation:

$$V_1^2/2g + d_1 = V_2^2/2g + d_2 \pm L\,(S_o - S_f) + h_T \qquad 316(a)$$

where

d = depth

$$F = \text{Froude Number} = \frac{V}{\sqrt{g\,\frac{A}{T}}}$$

V = velocity

S_o = bottom slope

S_f = friction slope, from Manning Equation:

$$Q = \frac{1.486}{n}\;A\,(R)^{2/3}\;(S_f)^{1/2} \qquad 316(b)$$

h_T = various head losses due to impact and eddies, obstructions, junctions, etc.

Hydraulic Work Form #1 presented in Appendix B shall be used for water surface computation.

317. BENDS

.10 *CLOSED CONDUITS*

Head loss due to bends shall be used in all pipe conduits, and in box conduits designed as open channels when sufficient freeboard as required in 323.20 is not provided; and shall be included in the solution of the Bernoulli equation, in addition to the normal friction loss.

$$h_B = K_B \left(\frac{V^2}{2g}\right) \qquad 317.10$$

Determine K_B by using Figure 317.10

49 ### .20 *OPEN CHANNELS*

Head loss due to bends shall be used in all open channels in accordance with the procedure outlined on page 441 of Reference 4.

318. TRANSITIONS

Transition structures shall be provided whenever there is a change in the shape and/or size of a conveyance structure. The material presented below shall be used as the criteria in the design of transitions for sub-critical and supercritical flow conditions. This material is not applicable to sudden expansion or contraction.

.10 *SUBCRITICAL FLOW*

In the design of transitions for subcritical flow conditions, sharp angles either in the water surface or in the structure shall be avoided. The maximum angle between the channel axis and a line connecting the channel sides between entrance and exit sections shall be 12.5°. The energy losses shall be computed from the following equations:

Accelerating flow $V_2 > V_1$

$$h_t = 0.1 \quad (V_2^2 / 2g - V_1^2 / 2g) \qquad 318.10(A)$$

Decelerating flow $V_1 > V_2$

$$h_t = 0.2 \quad (V_1^2 / 2g - V_2^2 / 2g) \qquad 318.10(b)$$

.20 *SUPERCRITICAL FLOW*

The approach presented herein shall be used in the design of transitions in supercritical flow.

.21 *Contractions* - When supercritical flow is introduced through a contraction* with symmetrical converging walls, cross waves will appear. In order to minimize disturbances downstream of the transition the method presented shall be used with straight, not curved contraction. In this approach the shock waves which emanate at the beginning of the contraction are directed to the opposite walls at the end of the contraction, thus cancelling off the newly created negative disturbances, Figure 318.21(a).

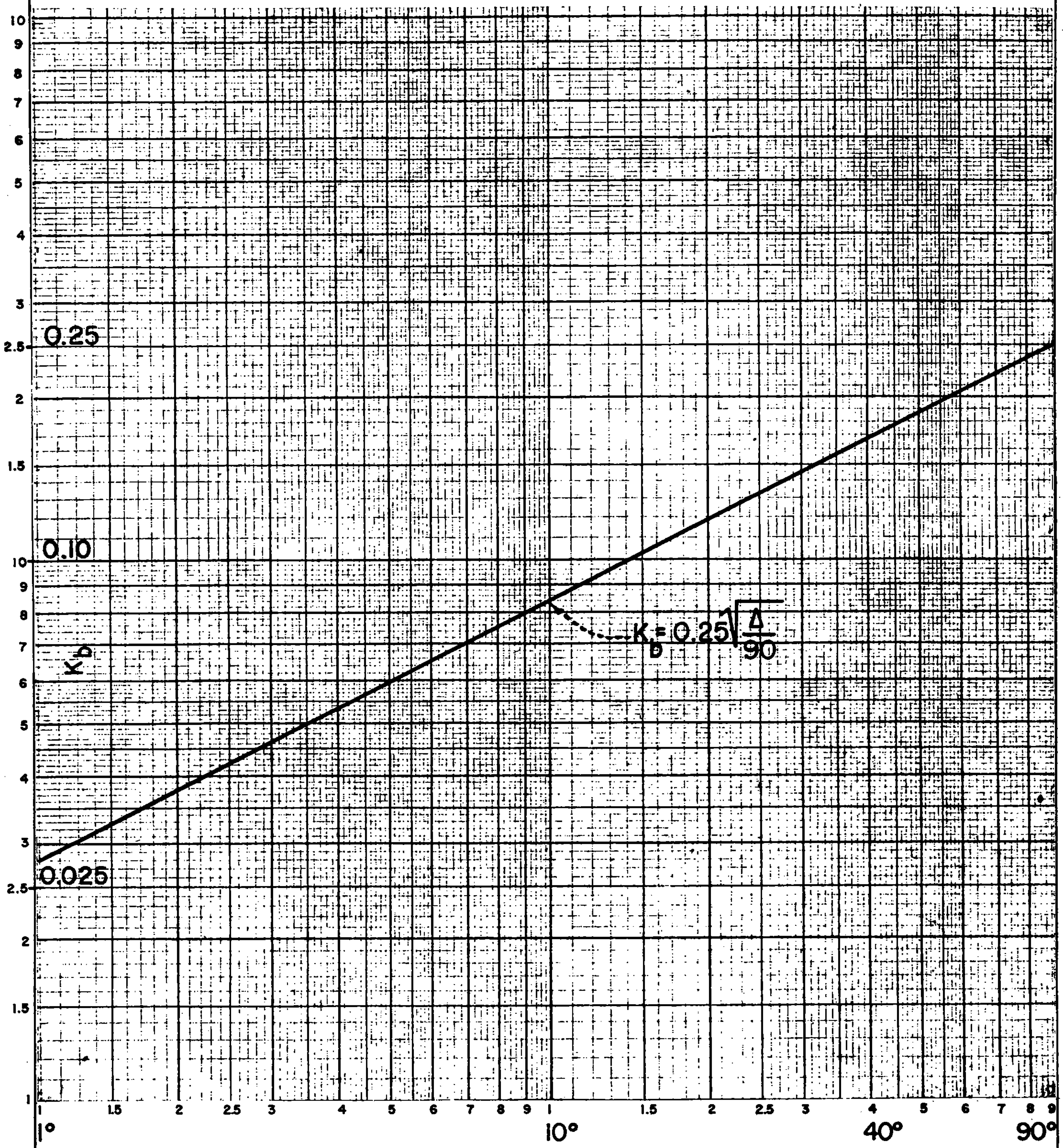
Equations 318.21(a) and (b) and Figure 318.21(b) shall be used to design a straight contraction.

$$\frac{b_1}{b_3} = \left(\frac{d_3}{d_1}\right)^{3/2} \left(\frac{F_3}{F_1}\right) \qquad 318.21(a)$$

$$L = \frac{b_1 - b_3}{2 \tan \theta} \qquad 318.21(b)$$

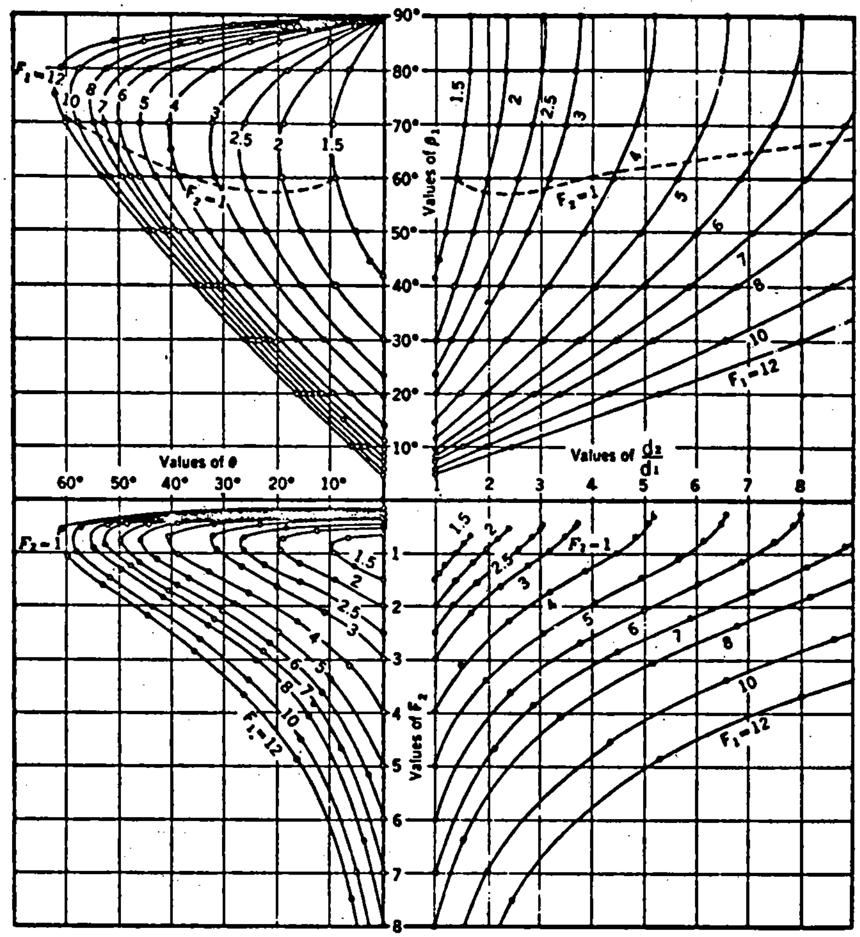
Figure 318.21(b) is used by entering the flow conditions at the entrance to the transition characterized by F_1 and the angle θ in the lower left hand quadrant and determining b_1, F_2, and d_2/d_1 at the point of intersection of the first shock front shown in Figure 318.21(a) as point B. Downstream of point B the flow conditions as given by F_2 will determine the further progress of the front. Thus due to symmetry the intersecting front will deflect through the angle θ and condition at F_3 can be determined by entering F_2 and θ into Figure 318.21(b) in the manner used above. The length L of the contraction is adjusted by repeated assumption of wall angle θ and application of Figure 318.21(b) until the affected shock point and the end of the transition coincide. The value of F_3 should be held well within the supercritical range, since otherwise a jump might be produced which will drown the contraction. 50

* *For expanded discussion see Reference 7.*



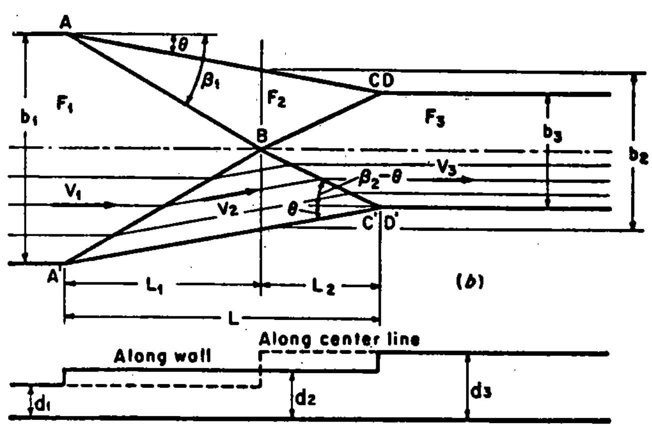
Reference	Ventura County Flood Control District DESIGN MANUAL	Figure
Hydrology and Hydraulic Design Manual, Los Angeles County Flood Control District, 1964.	BEND LOSSES IN CLOSED CONDUITS	317.10

(b)



General Relations for F_1 Versus θ, β, $\frac{d_2}{d_1}$ and F_2

(a)



Reference: Wrees Program II Engineering Extension University Of California, Berkley	Ventura County Flood Control District DESIGN MANUAL	Figure
	DESIGN OF CONTRACTIONS IN SUPERCRITICAL FLOW	318.21

Generally, high values of F_1 and low values of d_3/d_1 will produce a long contraction. The length of the contraction may be reduced by using a ratio d_3/d_1 between 2 and 3, provided the F_3 stays well above the critical values. Although the above approach was developed primarily for rectangular channels, it may be used in the design of trapezoidal channels by using b_1 and b_3 as the width at the water surface at the corresponding locations, and θ as the deflection angle produced by connecting the two ends of the transition at the hydraulic grade line.

For low values of F_1 when above approach is impractical, use Bernoulli's Equation and Equation 318.10(a).

55 .22 *Expansions* - In order to minimize disturbance and to insure that the major part of the flow will follow the boundaries, the criteria presented here for the design of expansions in supercritical flow shall be complied with:

a. The length of the approach channel preceding the transition shall be a minimum $5d_1$, in length, where d_1 is the approach depth of flow.

b. The maximum permissible side-wall divergence shall be 1 in $3F_1$, however, in no case shall the transition be less than 10 feet in length.

c. The flow conditions at the end of transition shall be determined by the use of Bernoulli's Equation and Equation 318.10(b).

.30 *CLOSED CONDUITS UNDER PRESSURE*

Transition losses in conduits under pressure may be determined using the following criteria:

Accelerating flow: $V_2 > V_1$

$$h_t = 0.1 \quad (V_2{}^2/2g - V_1{}^2/2g) \qquad 318.30(a)$$

Decelerating flow: $V_1 > V_2$

$$h_t = 0.2\ (V_1{}^2/2g - V_2{}^2/2g) \qquad 318.20(b)$$

319. JUNCTIONS

A junction is defined as a condition when two conveyance structures converge into one, or where a side inlet is made into a conveyance structure.

Hydraulic analysis shall be performed for all junctions involving converging channels and whenever the flow in the side inlet exceeds 10% of the flow in the main channel. Hydraulic analysis shall also be performed for all junctions of circular pipe conduits flowing under pressure. The hydraulic analysis of junctions as presented herein requires the evaluation of the pressure and momentum at various locations in the junction. See Fig. 319.90 for junction of two channels.

.10 *GENERAL EQUILIBRIUM EQUATIONS* *

The general equilibrium equation for all cases is:

$$P_2 + M_2 = P_1 + M_1 + M_3 \cos\theta + P_i + P_w - P_f \qquad 319.10$$

Where P_1 = hydrostatic pressure on section 1

P_2 = hydrostatic pressure on section 2

P_i = horizontal component of hydrostatic pressure on invert

P_w = axial component of hydrostatic pressure on walls

P_f = retardation force of friction (S_1 and S_2 are friction slopes see Kings Hdbk.)

M_1 = momentum of moving mass of water entering junction at section 1

M_2 = momentum of moving mass of water leaving junction at section 2

$M_3 \cos\theta$ = axial component of momentum of the moving mass of water entering the junction at section 3.

In the following equations:

(1) "w", the unit weight of water, has been

* *See Appendix B*

omitted since it appears in all terms.

(2) The assumptions are made that the cosines of the invert slopes equal unity and that the tangents and sines of the friction slopes are equal.

.20 OPEN TRAPEZOIDAL CHANNEL

$$M_1 = \frac{Q_1^2}{(b_1 + z_1 d_1)\ g d_1}$$

$$M_2 = \frac{Q_2^2}{(b_2 + z_2 d_2)\ g d_2}$$

57

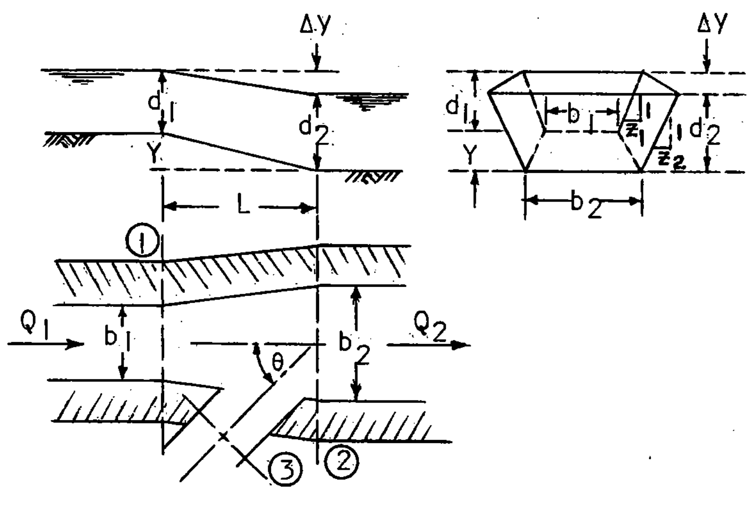


Fig. 319.20

$$M_3 \cos\theta = \frac{(Q_2 - Q_1)^2}{\Delta_3 g}\ (\cos\theta)$$

$$P_1 = \frac{d_1^2}{6}\ (3b_1 + 2z_1\ d_1)$$

$$P_2 = \frac{d_2^2}{6}\ (3b_2 + 2z_2\ d_2)$$

$$P_i = \left(\frac{b_1 + b_2}{2}\right) \gamma \left[d_1 + \frac{(d_2 - d_1)(b_1 + 2b_2)}{3(b_1 + b_2)}\right]$$

$$P_w = \frac{d_1 + d_2}{4} \left[\frac{b_1 + b_2}{2} (d_1 - d_2) + \right.$$

$$\left. \Delta y\ (z_1 d_1 + z_2 d_2) + (b_2 + z_2 d_2)d_2 - (b_1 + z_1 d_1)\ d_1 \right]$$

$$P_f = \frac{L(s_1 + s_2)}{4} \left[(b_1 + z_1 d_1)\ d_1 + (b_2 + z_2 d_2)\ d_2\right]$$

where A_3 = water area at section 3

$\Delta y = Y + d_1 - d_2$ S_1 & S_2 = Friction Slope

.30 OPEN RECTANGULAR CHANNEL

58

$$M_1 = \frac{Q_1^2}{b_1 d_1 g}$$

$$M_2 = \frac{Q_2^2}{b_2 d_2 g}$$

$$M_3 \cos\theta = \frac{(Q_2 - Q_1)^2}{A_3 g} (\cos\theta)$$

$$P_1 = \frac{b_1 d_1^2}{2}$$

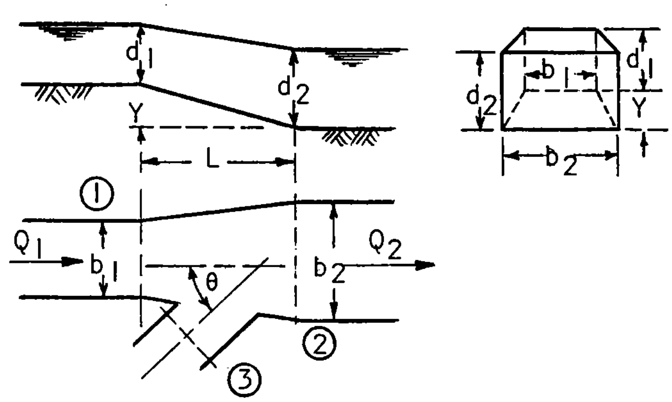


Fig. 319.30

$$P_2 = \frac{b_2 d_2^2}{2}$$

$$P_i = \left(\frac{b_1 + b_2}{2}\right) Y \left[d_1 + \frac{(d_2 - d_1)\ (b_1 + 2b_2)}{3\ (b_1 + b_2)}\right]$$

$$P_w = \frac{d_1 + d_2}{4}\ (b_2 - b_1) \left[d_1 + \frac{(d_2 - d_1)(d_1 + 2d_2)}{3\ (d_1 + d_2)}\right]$$

$$P_f = \frac{L(s_1 + s_2)}{4}\ (b_1 d_1 + b_2 d_2)$$

.40 RECTANGULAR BOX UNDER PRESSURE

$$M_1 = \frac{Q_1^2}{b_1 D_1 g}$$

59

$$M_2 = \frac{Q_2^2}{b_2 D_2 g}$$

$$M_3 \cos\theta = \frac{(Q_2 - Q_1)^2}{A_3\ g}\ (\cos\theta)$$

$$P_1 = b_1 D_1 \left(d_1 - \frac{D_1}{2}\right)$$

$$P_2 = b_2 D_2 \left(d_2 - \frac{D_2}{2}\right)$$

$$P_i = \frac{b_1 + b_2}{2}\ (D_2 - D_1) \left[d_1 + \frac{(d_2 - d_1)(b_1 + 2b_2)}{3(b_1 + b_2)}\right]$$

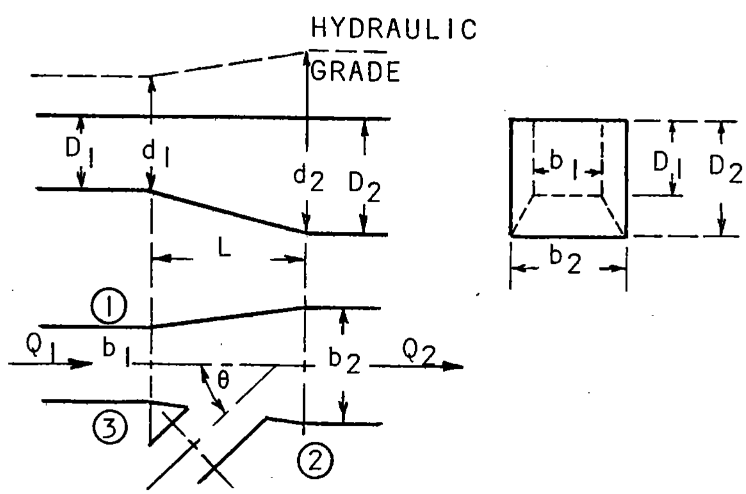


Fig. 319.40

$$P_w = \frac{D_1 + D_2}{4} (b_2 - b_1) \left[d_1 + d_2 - \frac{D_1 + D_2}{2} \right]$$

$$P_f = \frac{L(s_1 + s_2)}{4} \quad (b_1 D_1 + b_2 D_2),$$

$$\text{where } s = \left[\frac{Qn(b+D)^{2/3}}{.936(bD)^{5/3}} \right]^2$$

.50 *CIRCULAR CONDUIT UNDER PRESSURE, PIPE INLET*

$$M_1 = \frac{Q_1^2}{25.2\ D_1^2}$$

$$M_2 = \frac{Q_2^2}{25.2\ D_2^2}$$

$$M_3 \cos \theta = \frac{(Q_2 - Q_1)^2}{25.2\ D_3^2} (\cos \theta)$$

$$P_1 = .784\ D_1^2 \ (d_1 - \frac{D_1}{2})$$

$$P_2 = .784\ D_2^2 \ (d_2 - \frac{D_2}{2})$$

$$P_i = o$$

$$P_w = .392 \left[(D_2^3 - D_1^3) + (D_2^2 - D_1^2) \right.$$
$$\left. (d_1 + d_2 - D_1 - D_2) \right]$$

$$P_f = .196\ L(s_1 + s_2)\ (D_1^2 + D_2^2),$$

$$\text{where } s = \left[\frac{Qn}{.463\ D^{8/3}} \right]^2$$

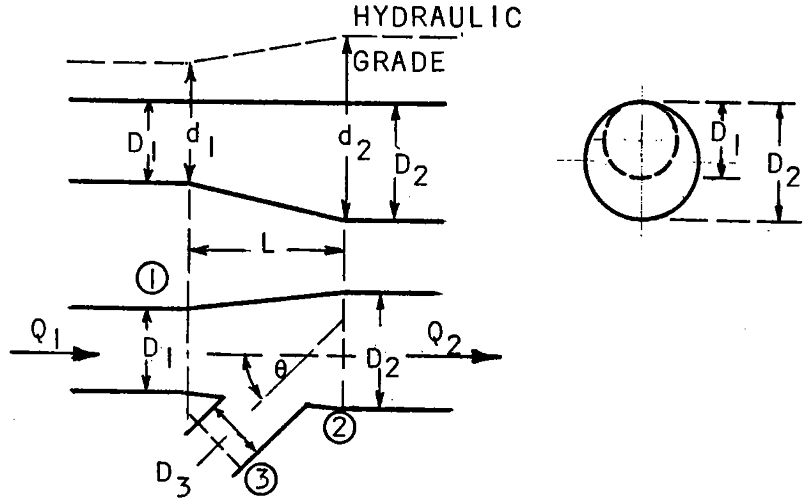


Fig. 319.50

61 *.60 CIRCULAR CONDUIT FLOWING PARTIALLY FULL. PIPE INLET*

$$M_1 = K_1\left(\frac{Q_1}{D_1}\right)^2$$

$$M_2 = K_2\left(\frac{Q_2}{D_2}\right)^2$$

$$M_3 \cos\theta = \frac{(Q_2 - Q_1)^2}{25.2\ D_3^{\,2}}(\cos\theta)$$

$$P_1 = C_1\ D_1^{\,3}$$

$$P_2 = C_2\ D_2^{\,3}$$

$$P_i = o$$

$${}^*P_w = A_2\bar{y}_2 - A_1\bar{y}_1 + \frac{\Delta y}{2}(A_2 + A_1) + \frac{(\Delta y)^2}{12}(T_2 - T_1)$$

$$P_f = \frac{L(s_1 + s_2)}{4}(A_1 + A_2)$$

* $\frac{(\Delta y)^2}{12}(T_2 - T_1)$ *is usually small and may be neglected*

Where $\Delta y = Y + d_1 - d_2$

For tabulated values of C and K, see Table 319.60. See King "Handbook of Hydraulics", for A_1, $\bar{y}$ and T.

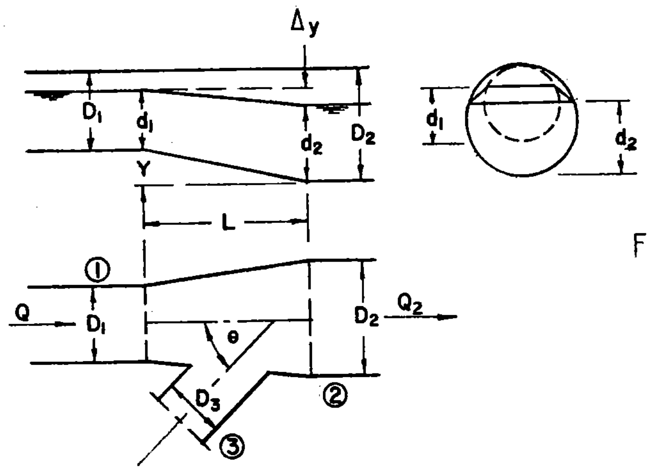


Figure 319.60

.70 *LENGTH OF TRANSITION*

In all of the above junctions the length of the transition shall be a minimum of

$$L = \frac{b_3}{\sin\theta} \quad (a) \quad \text{or} \quad L = 5\,(b_2 - b_1) \quad (b) \qquad 319.70$$

whichever is greater.

.80 *ANGLE OF CONFLUENCE*

The angle of confluence θ of side inlets shall not be greater than 30° for the following cases:

.81 Lateral flow exceeds 10% of the main line flow.

.82 Lateral flow velocities are 20 fps or greater.

.83 Hydraulic analysis of the junction indicates excessive losses in the main channel.

A confluence angle of 45° may be used if none of the above conditions exist.

TABLE 319.60

FACTORS FOR CIRCULAR CONDUITS FLOWING PARTLY FULL

d/D	K	C	d/D	K	C	d/D	K	C	d/D	K	C
.00	00	.0000	.25	.2026	.0157	.50	.0792	.0833	.75	.0492	.2121
.01	23.919	.0000	.26	.1916	.0173	.51	.0773	.0873	.76	.0485	.2185
.02	8.403	.0000	.27	.1817	.0190	.52	.0753	.0914	.77	.0479	.2249
.03	4.507	.0001	.28	.1727	.0207	.53	.0736	.0956	.78	.0473	.2314
.04	2.961	.0002	.29	.1645	.0226	.54	.0719	.0998	.79	.0467	.2380
.05	2.115	.0003	.30	.1569	.0255	.55	.0703	.1042	.80	.0462	.2447
.06	1.620	.0005	.31	.1493	.0266	.56	.0687	.1087	.81	.0456	.2515
.07	1.285	.0007	.32	.1435	.0287	.57	.0672	.1133	.82	.0451	.2584
.08	1.058	.0010	.33	.1376	.0309	.58	.0658	.1179	.83	.0446	.2653
.09	0.888	.0013	.34	.1320	.0332	.59	.0645	.1227	.84	.0441	.2723
.10	0.760	.0017	.35	.1269	.0356	.60	.0632	.1276	.85	.0437	.2794
.11	0.662	.0021	.36	.1221	.0381	.61	.0620	.1326	.86	.0433	.2865
.12	0.582	.0026	.37	.1177	.0407	.62	.0608	.1376	.87	.0429	.2938
.13	0.518	.0032	.38	.1135	.0434	.63	.0597	.1428	.88	.0425	.3011
.14	0.466	.0038	.39	.1096	.0462	.64	.0586	.1481	.89	.0421	.3084
.15	0.421	.0045	.40	.1060	.0491	.65	.0575	.1534	.90	.0418	.3158
.16	0.383	.0053	.41	.1026	.0520	.66	.0565	.1589	.91	.0414	.3233
.17	0.351	.0061	.42	.0993	.0551	.67	.0559	.1644	.92	.0411	.3308
.18	0.324	.0070	.43	.0963	.0583	.68	.0547	.1700	.93	.0408	.3384
.19	0.299	.0080	.44	.0934	.0616	.69	.0538	.1758	.94	.0406	.3460
.20	0.278	.0091	.45	.0907	.0650	.70	.0530	.1816	.95	.0403	.3537
.21	0.259	.0103	.46	.0882	.0684	.71	.0521	.1875	.96	.0401	.3615
.22	0.243	.0115	.47	.0857	.0720	.72	.0514	.1935	.97	.0399	.3692
.23	0.228	.0128	.48	.0834	.0757	.73	.0506	.1996	.98	.0398	.3770
.24	0.215	.0143	.49	.0813	.0795	.74	.0499	.2058	.99	.0397	.3938
									1.00	.0396	.3927

d = depth of water
D = diameter of conduit

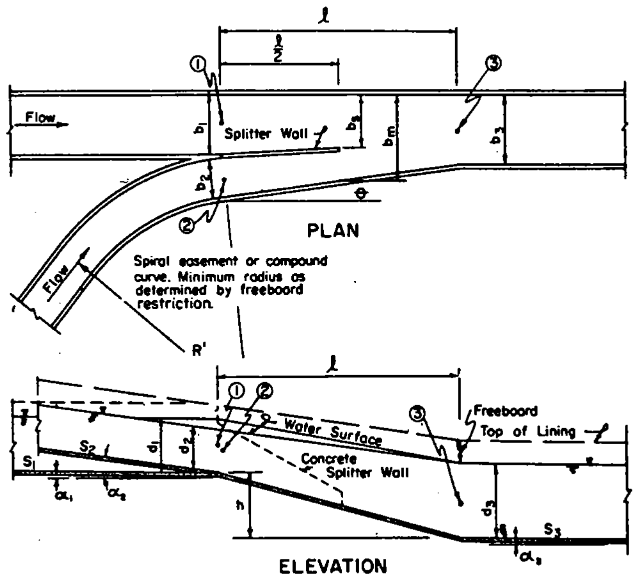
$$K = \frac{\text{momentum}}{(Q/D)^2}$$

$$C = \frac{\text{pressure}}{D^3}$$

NOMENCLATURE

A	=	cross-sectional area of water prism	ft.^{2}
b	=	base width of channel section	ft.
c	=	constant - see Chart A	--
d	=	vertical depth of water	ft.
g	=	acceleration due to gravity (32.2)	fps.^{2}
h	=	difference in invert elevation between any two sections	ft.
ℓ	=	length of channel reach	ft.
n	=	coefficient of roughness in Manning's formula	--
P_a	=	average wetted perimeter between two sections	ft.
P_m	=	wetted perimeter at middle section	ft.
Q	=	rate of discharge	cfs.
R_a	=	average hydraulic radius between two sections	ft.
R_m	=	hydraulic radius at middle section	ft.
R'	=	radius of curve to centerline	ft.
S_c	=	critical slope of channel invert	--
S	=	channel invert slope	--
V_a	=	average velocity between two sections	fps.
V_m	=	velocity at middle section	fps.
Z	=	side slope of trapezoidal section (horizontal to vertical)	--
θ	=	angle of merging channels	deg.
α	=	invert slope angle	deg.
F	=	Froude number	--

Numerical subscripts refer to appropriate channel members.



1. TRAPEZOIDAL CHANNELS

Constant Width Main Channel

$$\frac{Q_3^2}{gA_3}\cos\alpha_3+\left(\frac{b_3}{2}+\frac{Zd_3}{3}\right)\left(d_3^2\right)\cos^2\alpha_3=\frac{Q_1^2}{gA_1}\cos\alpha_1+\frac{Q_2^2}{gA_2}\cos\alpha_2\cos\theta+\left(\frac{b_1}{2}+\frac{Zd_1}{3}\right)\left(d_1^2\right)\cos^2\alpha_1+A_ah-\frac{P_a\ell n^2V_a^2}{2.21\,R_a^{1/3}}$$

Unequal Width Main Channel

$$\frac{Q_3^2}{gA_3}\cos\alpha_3+\left(\frac{b_3}{2}+\frac{Zd_3}{3}\right)\left(d_3^2\right)\cos^2\alpha_3=\frac{Q_1^2}{gA_1}\cos\alpha_1+\frac{Q_2^2}{gA_2}\cos\alpha_2\cos\theta+\left(\frac{b_3}{2}+\frac{Zd_1}{3}\right)\left(d_1^2\right)\cos^2\alpha_1+(b_3+Zd_m)\,d_mh-\frac{P_m\ell n^2V_m^2}{2.21\,R_m^{1/3}}$$

Note: For flows at supercritical velocities these equations may be used only for preliminary design. Final design must be based on results of supplemental hydraulic model studies.

2. RECTANGULAR CHANNELS

Constant Width Main Channel

$$\frac{Q_3^2}{gA_3}\cos\alpha_3+\frac{b_3d_3^2}{2}\cos^2\alpha_3-\frac{b_3d_3h}{2}=\frac{Q_1^2}{gA_1}\cos\alpha_1+\frac{Q_2^2}{gA_2}\cos\alpha_2\cos\theta+\frac{b_3d_1h}{2}+\frac{b_3d_1^2}{2}\cos^2\alpha_1-\frac{P_a\ell n^2V_a^2}{2.21\,R_a^{1/3}}$$

Unequal Width Main Channel

$$\frac{Q_3^2}{gA_3}\cos\alpha_3+\frac{b_3d_3^2}{2}\cos^2\alpha_3-\frac{b_3d_3h}{2}=\frac{Q_1^2}{gA_1}\cos\alpha_1+\frac{Q_2^2}{gA_2}\cos\alpha_2\cos\theta+\frac{b_3d_1h}{2}+\frac{b_1d_1^2}{2}\cos^2\alpha_1+\frac{(b_3-b_1)}{2}\left(d_2^2\right)\cos^2\alpha_2-\frac{P_m\ell n^2V_m^2}{2.21\,R_m^{1/3}}$$

SPECIAL CASE

Limiting Criteria - Rectangular Channels
Supercritical Velocity Flow in All Branches.

Constant Width Main Channel

$$\frac{Q_3^2}{gA_3}+\frac{b_3d_3^2}{2}-\frac{b_3d_3h}{2}=\frac{Q_1^2}{gA_1}+\frac{Q_2^2}{gA_2}+\frac{b_3d_1h}{2}+\frac{b_3d_1^2}{2}-\frac{P_a\ell n^2V_a^2}{2.21\,R_a^{1/3}}$$

Unequal Width Main Channel

$$\frac{Q_3^2}{gA_3}+\frac{b_3d_3^2}{2}-\frac{b_3d_3h}{2}=\frac{Q_1^2}{gA_1}+\frac{Q_2^2}{gA_2}+\frac{b_3d_1h}{2}+\frac{b_1d_1^2}{2}+\frac{(b_3-b_1)}{2}\left(d_2^2\right)-\frac{P_m\ell n^2V_m^2}{2.21\,R_m^{1/3}}$$

Criteria

$\tan\alpha < 0.1$

Convergence angle θ less than 10°

$F=\frac{V}{\sqrt{gd}}\geq 1.2$

$\theta \leq 10°$

$1.2 \geq \frac{d_1}{d_2} \geq 0.8$

Height of sidewall at ③ $= 1.2\,d_3 + 0.25\,d_{c_3}\left[1-11.1\left(\frac{S_3}{S_{c_3}}-1\right)^2\right]+1.2\,\frac{V_2^2 b_2}{gZ_2}$

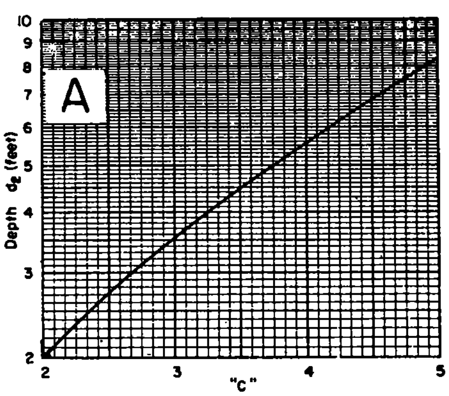
Height of splitter wall
upstream = $d_{1,2}$ max.
downstream = 6" min.

$\ell = cV_2\left[b_1+b_2-b_3\right]^{1/3}$

$b_3 \geq 0.8\,(b_1+b_2)$

$b_s = \frac{b_1\,(b_1+b_2+b_3)}{2(b_1+b_2)}$ when $b_1 > b_2$

$b_s = \frac{b_2\,(b_1+b_2+b_3)}{2(b_1+b_2)}$ when $b_1 < b_2$



Reference ENGINEERING DESIGN STDS. Far West States, United States Dept. of Agriculture, Soil Conservation Service, Sept. 1958	Ventura County Flood Control District DESIGN MANUAL JUNCTION ANALYSIS OF CHANNELS	Figure 319.90

Catch basin connector pipes are generally excluded from the confluence angle requirements unless the conditions stated in .71 through .73 exist.

320. OBSTRUCTIONS

.10 *PIERS*

Consideration of pier losses and effects of same on open channel design is important not only at bridge crossings, and splitter walls, but also when an open channel discharges into a length of multi-barreled box. It is especially important when the flow is supercritical, and when the flows could be transporting debris which could impinge on the piers. The area of the piers shall be increased to three feet for the entire depth of flow to allow for bulking due to debris in the stream.

Pier losses may be determined by the solution of the pressure-momentum equation, with the following assumptions:

a. The water surface is level across a section normal to flow.

b. The velocity distribution is uniform.

c. Friction losses are compensated for by the gravity component of the bottom slope.

d. Air entrainment is negligible.

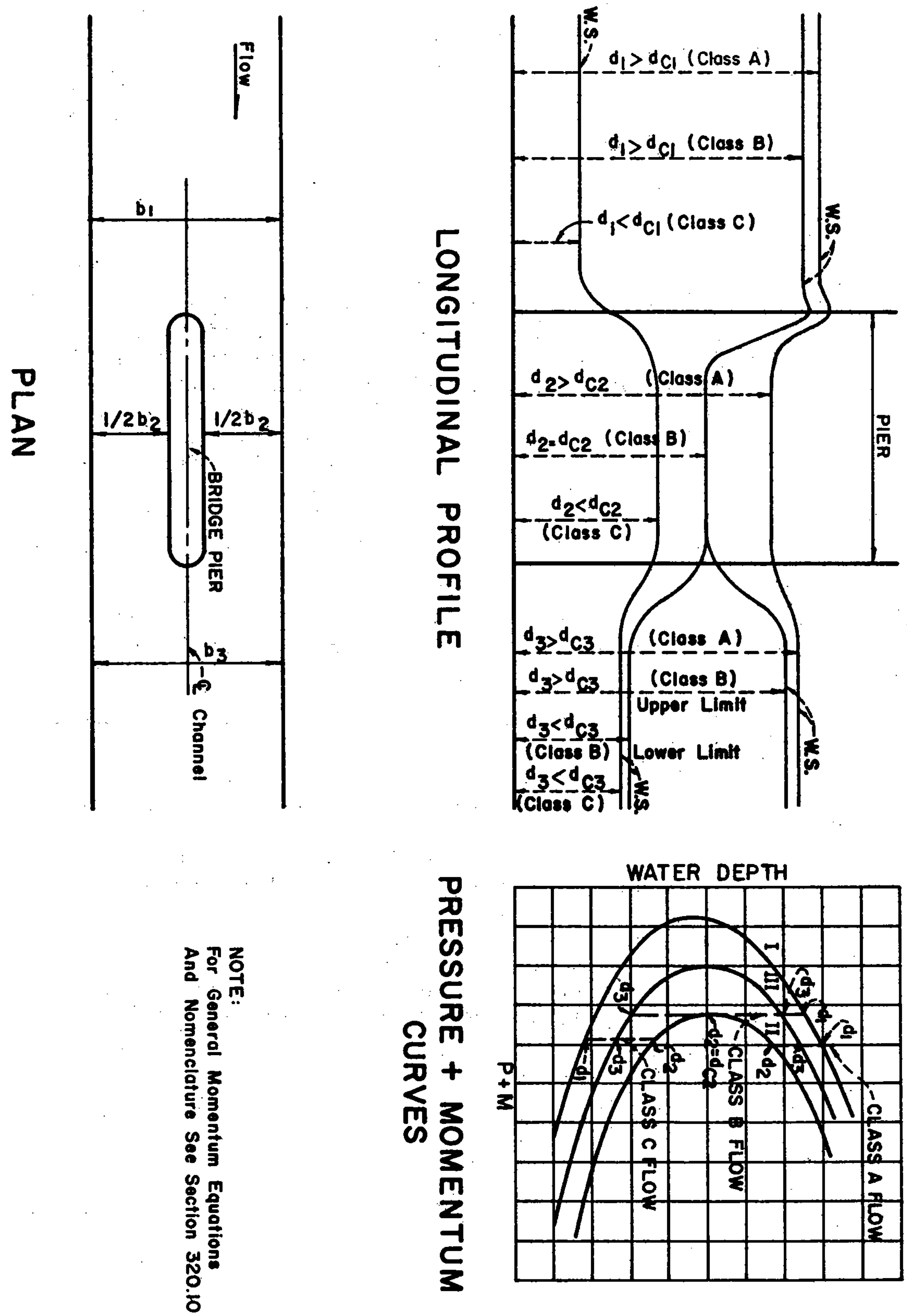
The pressure-momentum equation at each of the three longitudinal sections along centerline of channel is:

$$P_1 - P_p + \frac{Q^2}{gA_1^2}(A_1 - A_p) \qquad \text{Equation I}$$

$$P_1 - P_p + \frac{Q^2}{g\,(A_2 - A_p)} \qquad \text{Equation II}^*$$

$$P_3 - P_p + \frac{Q^2}{g\,A_3} \qquad \text{Equation III}$$

* If Equation I & II or II & III are equated for solution by trial, without the use of the table the term $P_1 - P_2$ and $A_1 - A_p$ in Equation II shall be replaced by P_2^1 & A_2^2 respectively.



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Reference: Hydrology and Hydraulic Design Manuel —— Los Angeles County Flood Control District, 1964	Ventura County Flood Control District DESIGN MANUEL	Figure 320.10(a)
	BRIDGE PIER LOSSES BY MOMENTUM METHOD	

where

P_1 & P_3 = Hydrostatic pressure in unobstructed channel

P_p = Hydrostatic pressure of bridge piers

A_1 & A_3 = Area of unobstructed channel

A_2 = Area at Section 2

A_p = Area of bridge piers (Use 2/3 A_p for round nose piers

Q = Discharge

g = Acceleration of gravity - 32.2 feet per second^2. 70

The general equation for the pier analysis is:

$$P_1 - P_p + \frac{Q^2}{g\ A_1{}^2}\ (A_1 - A_p) = P_1 - P_p +$$

$$\frac{Q^2}{g(A_1 - A_p)} = P_3 - P_p + \frac{Q^2}{gA_3}$$

The values of Equations I, II, and III are determined for various depths, both subcritical and supercritical. A curve using hydrostatic pressure plus momentum as the abscissa and depth as the ordinate is plotted for each equation as shown in Figure 320.10(a).

A vertical line passed through the three curves gives a solution of the general equation. This vertical line must intersect a minimum of five depth values, and preferably six, two values each on the upper and lower portions of Curve I and III and one or two values on Curve II. If only one value is intersected on Curve II, the flow in Section 2 is critical.

Since water surface profile computations will determine either a flow depth at Section I or Section 3, depending on the type of flow conditions, the curves give a direct solution to the problem because the vertical line must pass through the known depth on either Curve I or Curve III as well as Curve II. In the event that this vertical line does not intersect Curve II, it is an indication that the momentum plus pressure of the known depth is too small to pass the flow past the obstruction, and a change in the known or computed flow depth must be made. The flow should then be critical at Section 2, since the critical depth is the depth at which the sum of pressure and momentum is the minimum.

Curves presented in Figure 320.10(b) and (c) may be used as approximate solutions for Bridge Pier Losses.

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Use Hydraulic Work Form Number 3 in Appendix B for the solution of the pier losses.

.20 TRASH RACKS AND PROTECTIVE BARRIERS

The primary consideration for flow through trash racks is the amount of head loss due to the resistance of the rack. The nomograph presented in Figure 320.20 shall be used in determining the head loss through trash racks when the velocity of flow downstream of trash rack is known. For supercritical flow the downstream velocity may be determined by trial, using an assumed loss through the trash rack.*

321. LOSSES DUE TO SUDDEN CHANGE IN AREA

Entrance and exit losses due to sudden change in area shall be considered in addition to any transition losses.

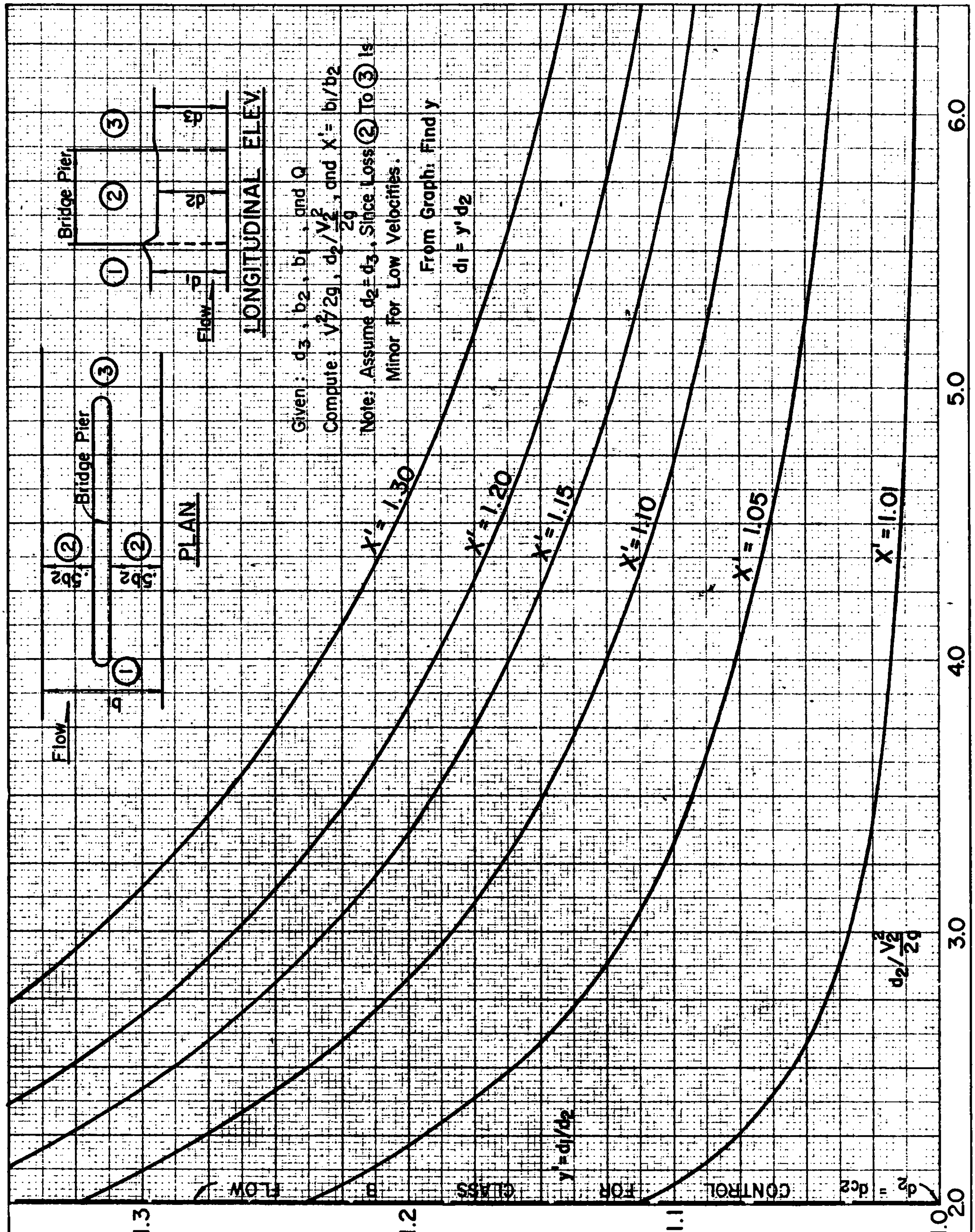
.10 CLOSED CONDUITS UNDER PRESSURE

Entrance losses for closed conduits flowing under pressure shall be determined by the following criteria:

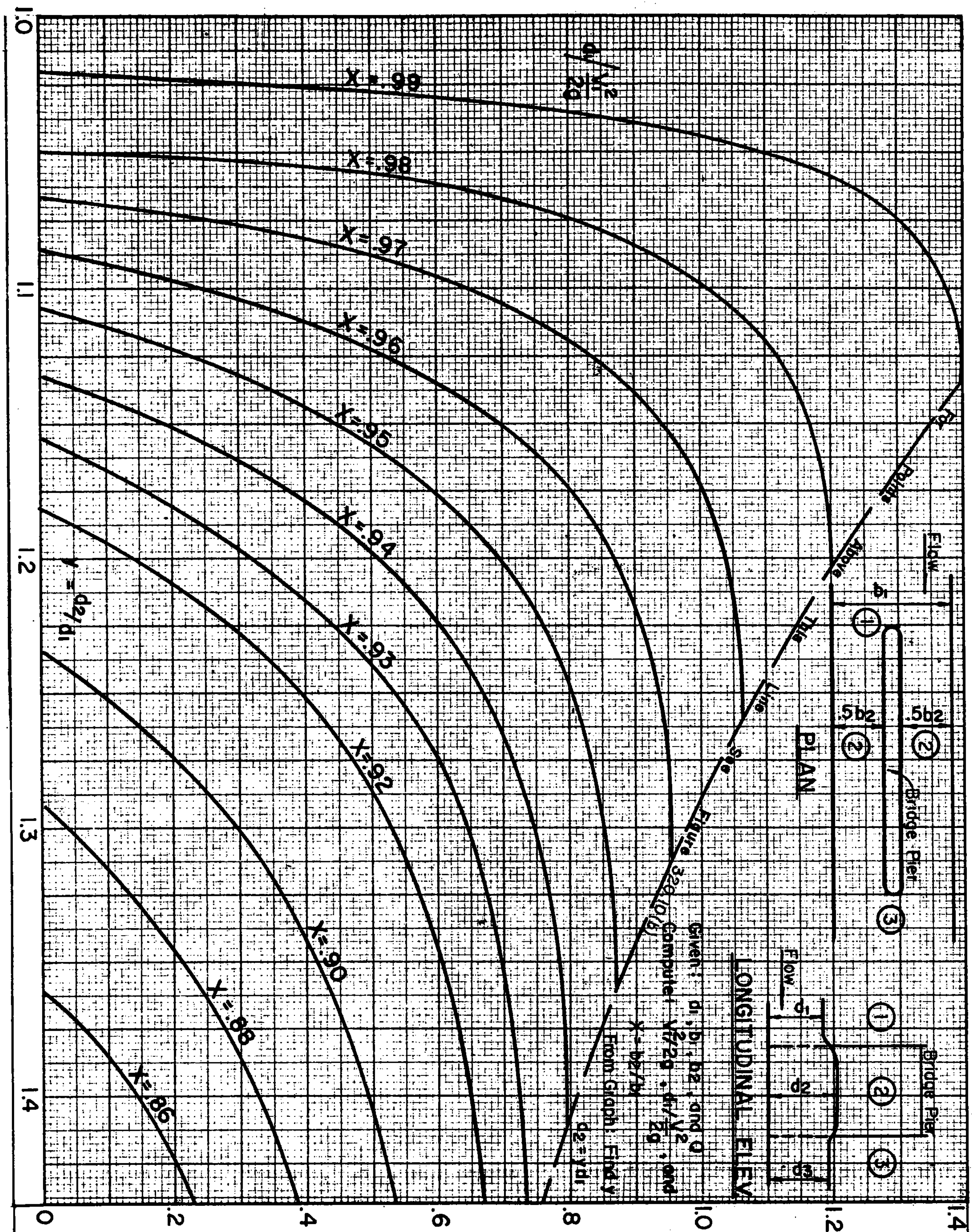
Rounded Entrance

$$h_e = 0.2\left(\frac{V^2}{2g}\right) \qquad 321.10(a)$$

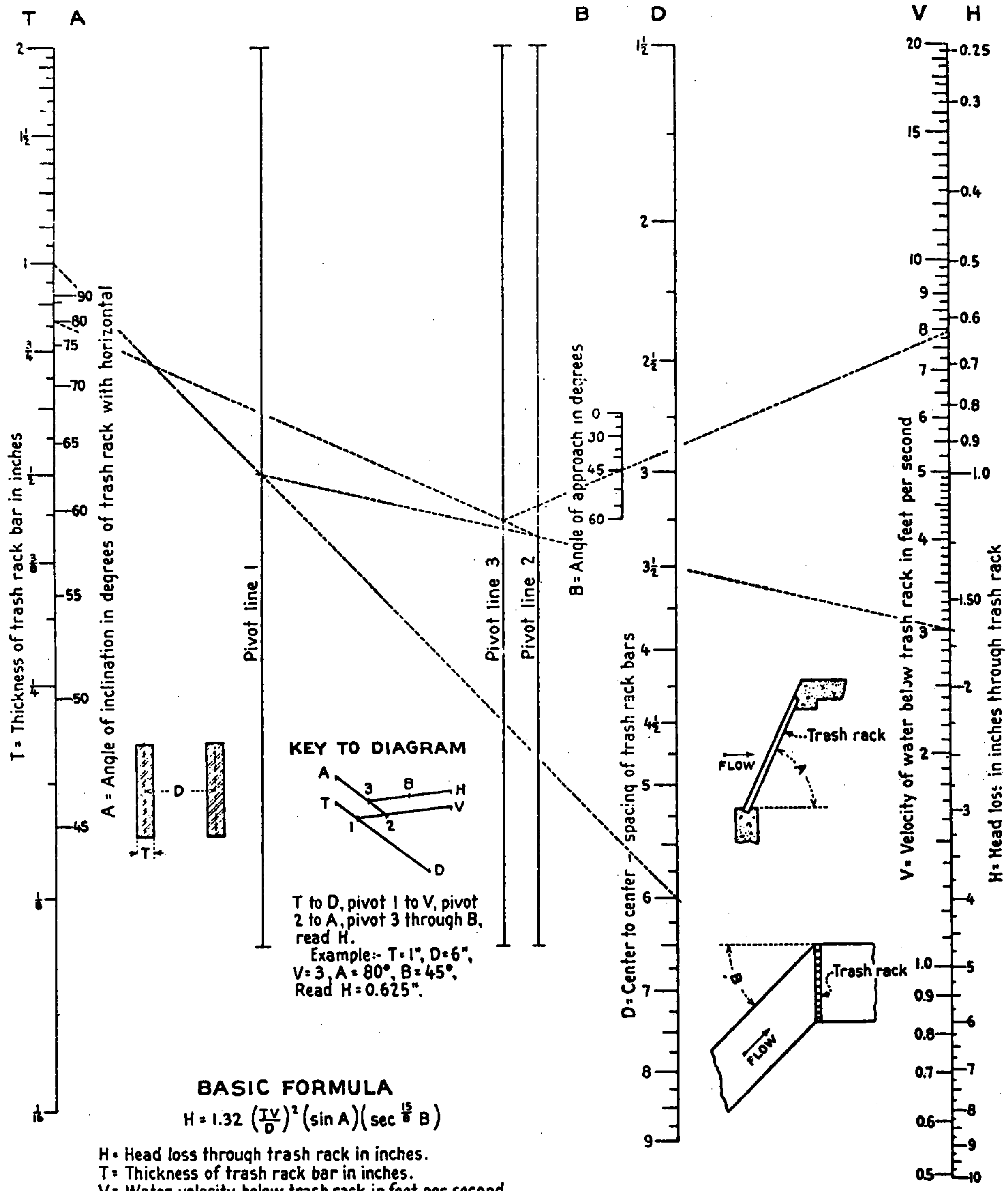
* *For a more detailed and accurate approach see Page 506 of Reference 4.*



Reference	Ventura County Flood Control District DESIGN MANUAL	Figure
Hydrology And Hydraulic Design Manuel —— Los Angeles County Flood Control District, 1964	APPROXIMATE BRIDGE PIER LOSSES BY MOMENTUM METHOD CLASS A&B FLOW RECTANGULAR CHANNELS	320.10 (b)



Reference	Ventura County Flood Control District DESIGN MANUAL	Figure
Hydrology And Hydraulic Design Manuel —— Los Angeles County Flood Control District, 1964	APPROXIMATE BRIDGE PIER LOSSES BY MOMENTUM METHOD CLASS C FLOW RECTANGULAR CHANNELS	320.10(c)



BASIC FORMULA

$$H = 1.32 \left(\frac{TV}{D}\right)^2 (\sin A)(\sec^{\frac{15}{8}} B)$$

H = Head loss through trash rack in inches.
T = Thickness of trash rack bar in inches.
V = Water velocity below trash rack in feet per second.
A = Angle of inclination of rack with horizontal.
B = Angle of approach.
D = Center to center spacing of trash rack bars in inches.

Reference:	Ventura County Flood Control District DESIGN MANUAL	Figure
Reclamation Manual U.S. Department Of Interior Bureau Of Reclamation	HEAD LOSS THROUGH TRASH RACKS	320.20

Square Entrance

$$h_e = 0.5 \left(\frac{V^2}{2g}\right) \qquad 321.10(b)$$

Exit losses shall be determined by the following criteria:*

$$h_o = 1.0 \left(\frac{V^2}{2g}\right) \qquad 321.20$$

.20 OPEN CHANNELS

Energy losses due to sudden changes in area in open channels shall be determined by the following criteria:*

Contraction

$$h_c = .5 \left(\frac{V_2^2}{2g} - \frac{V_1^2}{2g}\right)$$

Expansion

$$h_e = 1.0\left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right)$$

.30 SUDDEN EXPANSION OR CONTRACTION IN PIPES

Sudden changes in pipe area without transition shall be avoided when possible. However, if used the criteria presented in Chapter 6 of Reference 8 shall be applied.

322. ANGLE POINTS

Deflection angles up to 6^o may be used in closed conduits. Deflection angles greater than 6^o shall not be used without the prior approval from the District.

Angle point loss shall be determined using the following criteria:

$$h_{A.pt.} = K_{A.pt.} \left(\frac{V^2}{2g}\right) \qquad 322.$$

where

$K_{A.pt.}$ = 0.02 for 6^o deflection angle and varies uniformly down to zero for 0^o.

* *For additional information see Reference 8*

323. MANHOLES

Manholes shall be provided in all closed conduits and their location shall be governed by the following criteria:

.10 If the design velocity is less than 10 feet per second, manholes shall be spaced at approximately 400 feet.

.20 If the design velocity is greater than 10 feet per second, manholes shall be spaced at approximately 500 feet.

.30 Immediately downstream of all major changes in
77 grade of pipe conduit.

.40 Where there is a sudden change in size of conduit.

.50 At all junctions where the following conditions exist:

.51 Two converging closed conduits of approximately the same size.

.52 Whenever the diameter of side inlet is one-half or greater than one-half of the main line diameter or height.

.53 Whenever the flow from the side inlet is greater than one-half of the main line flow.

Special care shall be exercised not to locate manholes in heavily traveled street intersections. However, when possible, manholes shall be located in streets rather than in easements where access to manholes is difficult to maintain.

324. FREEBOARD

Freeboard or additional wall height shall be added above all water surfaces.

.10 *CLOSED CONDUITS*

Pipe conduits shall be generally designed to carry the design discharge at a depth equal or less than 0.7 of the diameter, and shall be maintained at a minimum slope of 0.003 feet per foot. Closed conduits may be designed as flowing full and may be allowed to go under pressure if by so doing, the number and size of grade changes can be reduced. If designed under pressure, the hydraulic or pressure gradient shall not rise above the ground surface or restrict the capacity of inlets. District approval shall be obtained for design of pipe under pressure.

Closed box conduits shall be designed as open channels with the minimum of one foot of freeboard, with the exception of curved sections where the freeboard shall be equal to the superelevation allowance, but shall not be less than one foot, or the freeboard required for open channels.

.20 OPEN CHANNELS

Freeboard requirement for open channels shall be determined using the sum of the following:*

.21 Air Entrainment - Allowance for air entrainment shall be used with $F > 2$ and shall be determined from:

$$H_1 = 0.15\, d(F-2) \qquad 324.21$$

.22 Flow in the Unstable Zone - For flow in the unstable zone defined as being in the range of $.7 < F^2 < 1.3$, calculate height of wave above the normal depth of flow. Allowance for waves in unstable zone is equal to the wave height:

$$H_2 = 0.25\, d_c \left[1 - 11.1\,(F^2-1)^2\right] \qquad 324.22$$

.23 Superelevation - For curvilinear flow in open channels in order to provide sufficient wall height for the water surface transverse slope due to centrifugal force, an allowance shall be made for superelevation on both sides of the channel.

Curves shall be designed in such a manner as to limit superelevation to one foot above the normal depth of flow or 10% of water surface width, whichever is the least. Compound curves shall be employed to reduce superelevation in accordance with the following criteria:

a. Subcritical flow

1. Rectangular Channels - For subcritical flow $F < 1$, or for supercritical flow $F > 1$, where a stable transverse slope

* *See Hydraulic Work Form Number 2 in Appendix B*

has been attained by an upstream easement curve, the allowance for superelevation is determined by the formula:

$$H_3 = \frac{3V^2 b}{4\ Rg} \qquad 324.23(a)$$

where

b = bottom width

V = velocity

R = radius of curve

g = 32.2 fps^2

2. Trapezoidal Channels

$$H_3 = \frac{V^2\ (b + 2\ Zd)}{2\ (gR - 2Z\ V^2)} \qquad 324.23(b)$$

81 where

Z = cotangent of bank slope

d = normal depth

b. Supercritical Flow

For supercritical flow F > 1, in the absence of an upstream easement curve use the formula:

1. Rectangular Channels

$$H_3 = 1.2\ \frac{V^2 b}{Rg} \qquad 324.23(c)$$

2. Trapezoidal Channels

$$H_3 = \frac{V^2\ (b + 2\ Zd)}{gR - 2\ Z\ V^2} \qquad 324.23(d)$$

c. Compound Curve Criteria

The complete compound curve shall consist of three sections; a central section with radius R_c and terminal easement curves each with a radius R_t, equal to twice R_c.

The purpose of the easement curve is to alter the cross slope of the water surface in order to keep the water prism in constant static equilibrium around the curve. The minimum length, L' and the central angle of θ of the easement curve shall be computed from:

$$L' = \frac{T}{\tan \beta} \qquad 324.23(e)$$

$$\theta = \tan^{-1}\left(\frac{T}{R_T \tan \beta}\right) \qquad 324.23(f)$$

where

T = top width of channel

$\beta = \sin^{-1}\left(\frac{\sqrt{gd_m}}{V}\right)$ = wave angle 82

$R_t = 2\ R_c$ = Radius of curvature of easement curves

R_c = Radius of curvature of central section

d_m = Mean depth

The main central curve shall be a circular curve with the radius R_c.

d. Superelevation Allowance

Allowance for superelevation shall begin at the B.C. of the easement curve with no allowance, taper to full allowance at the end of the easement curve, carry full allowance to the end of the main curve and taper to no superelevation at the end of the upstream easement curve.

In the absence of easement curves, begin with no superelevation allowance 5 L' downstream of B.C. of curve taper to full allowance at point 3 L' downstream of B.C., carry full allowance to E.C. of curve and taper to no allowance 2 L' upstream of E.C.

.24 *Residual Freeboard* - A minimum freeboard above the calculated water surface shall be provided in accordance with the following criteria:

a. Reinforced concrete lined channels

$$H_4 = 0.5' + 0.1d \qquad 324.24(a)$$

b. Uniformly shaped unlined or revetted channels

$$H_4 = 1.0' + 0.2d \qquad 324.24(b)$$

c. Irregularly shaped revetted channels

$$H_4 = 1.0' + 0.4d \qquad 324.24(c)$$

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325. GRADE CHANGES

Vertical curves shall be provided at all grade changes of 2 percent or greater, in the channel profile. The minimum radius of curvature of the vertical curve shall be determined from the following criteria, except that the curve length shall not be less than 10 feet.

*.10 CONCAVE CURVES**

$$R = \frac{2d\ V^2}{100} \qquad 325.10$$

where

R = radius of curvature, not less than 10 d

d = depth of flow

v = velocity

*.20 CONVEX CURVES***

$$R = \frac{V^2}{g \cos \phi} \qquad 325.20$$

where

ϕ = slope angle of floor upstream of curves

g = 32.2 fps^2

* *Reference 5*
** *Reference 7*

340. SPILLWAYS

341. GENERAL

Spillways may be defined as structures used to transfer water from one level to a lower level. Spillways are provided for dams to release surplus of flood water which cannot be contained in the allotted storage space. Spillways are also provided in natural or man-made channels to provide variation in the flow conditions of a channel for the purpose of providing physical characteristics beneficial to best hydraulic performance.

Selection of spillway type and its design is greatly influenced by the location, function, size and overall economy.

342. SPILLWAY COMPONENTS

85

The components of a spillway and common types of spillways are described and discussed herein. Hydraulic design criteria and procedures are covered in 344. and 345.

.10 *CONTROL STRUCTURE*

A major component of a spillway is the control device, since it controls and limits the flow. The control structure may consist of a sill, weir, orifice, tube, or pipe.

.20 *DISCHARGE CHANNEL*

Flow passing through the control structure usually is conveyed to the stream bed below in a discharge channel. Exceptions are where the discharge falls free from an arch dam crest or drop spillway. The conveyance structure may be a channel on the downstream face of an earth fill dam, an open channel excavated along the ground surface, or a closed conduit placed through or under the dam.

.30 *TERMINAL STRUCTURE*

When spillway flows fall to downstream channel level, the static head is converted to kinetic energy. This energy manifests itself in the form of high velocities, which if unimpeded result in serious erosion in the stream bed or damage to the adjacent structure. Where serious erosion to the stream bed is to be avoided, the high energy of the flow must be dissipated before the discharge is returned to the stream channel.. This can be accomplished by the use of an energy dissipating device, such as a hydraulic jump basin, a sill block apron, a basin incorporating baffles and walls, or some similar energy absorber or dissipator. A description of energy dissipators and a discussion of their hydraulic design is given in 344. More complete information is available in the references.

.40 *ENTRANCE AND OUTLET CHANNELS*

Entrance channels serve to convey the flow to the control structure. When the spillway is located in a stream the approach channel or the transition immediately upstream of the control structure would be considered as the entrance channel. Similarly, in earth dams the open channel conveying the flow from the reservoir to the control structure would be considered as the entrance channel.

Outlet channels convey the spillway flow from the terminal structure to the channel downstream. The outlet channel dimensions and its need for protection by lining or riprap will depend on the influences and conditions of the tailwater.

343. SPILLWAY TYPES

.10 *CHUTE (OPEN CHANNEL) SPILLWAYS*

A spillway whose discharge is conveyed through an open channel to the downstream level is called a chute spillway. Chute spillways are primarily used with earth fill dams, however, they may also be used as grade stabilization structures. Factors influencing the selection of chute spillways are the simplicity of their design and construction, their adaptability to almost any foundation condition, and overall economy.

.20 *FREE OVERFALL (STRAIGHT DROP) SPILLWAYS*

A free overfall or straight drop (drop structure) spillway is one in which the flow drops freely from the crest. This type of structure is not adaptable for high drops and shall be limited to hydraulic drops from head pool to tailwater of 20 feet. As discussed herein, drop spillways are primarily intended to establish permanent control elevations below which an eroding stream cannot lower the channel floor. When placed at intervals along a channel these structures can be used to change the profile from a steep gradient to a series of stable reaches separated by artificial falls. When used for this purpose they are sometimes referred to as grade stabilization structures.

.30 CONDUIT AND TUNNEL SPILLWAYS

Where a closed conduit is used to convey the discharge around or under a dam, the spillway is often called a tunnel or conduit spillway, as appropriate. The closed conduit may take the form of a vertical or inclined shaft or a horizontal tunnel. Most forms of control structures can be used with conduit and tunnel spillways.

87 *.40 DROP INLET (SHAFT OR MORNING GLORY) SPILLWAYS*

A drop inlet or shaft spillway, as the name implies, is one in which the water enters over a horizontally positioned lip, drops through a vertical or sloping shaft, and then flows to the downstream channel through a horizontal or near horizontal discharge conduit. Where the inlet is funnel-shaped, this type of structure is often called a "morning glory" or "glory hole" spillway.

.50 OGEE SPILLWAYS

The ogee spillway has a control weir which is ogee or S-shaped in profile. The upper curve of the ogee ordinarily is made to conform closely to the profile of the lower nappe of a ventilated sheet falling from a sharp crested weir. An ogee crest and apron may comprise an entire spillway such as the overflow portion of a concrete gravity dam, or the ogee crest may only be the control structure for some other type of spillway.

344. CHUTE SPILLWAYS

.10 CONTROL

The control structure for a chute spillway shall be designed as a broad-crested weir. When used in streams the upper end of the crest or sill shall be the continuation of the stream invert. The cross section of the control shall be rectangular with rounded abutments to increase the crest efficiency.

The capacity of the inlet control structure without freeboard shall be determined by the formula:

$$Q = C\ L\ H_e^{3/2} \qquad 344.10(a)$$

where

Q = discharge, cfs

C = discharge coefficient = 2.80

L = effective length of crest, feet

H_e= total head on the crest, including velocity of approach head

The total head on the crest, $H_e = d + \frac{V^2}{2g}$ shall be determined at a point upstream meeting one or all of the following criteria:

(a) Shall be 3d or more upstream from the crest.

(b) Shall be upstream of any constrictions of the approach channel.

(c) Flow is sub-critical.

The effective length, L, shall be determined from the following formula:

$$L = L' - 2\ (NK_p + K_a)\ H_e \qquad 344.10(b)$$

where

L = effective length of crest, feet

L'= net length of crest, shall always be equal or greater than 2d, feet

N = number of contractions

H_e= total head on the crest

K_p = pier contraction coefficient, and

K_a = abutment contraction coefficient

The average pier coefficients are as follows: K_p

For square-nosed piers with rounded corners 0.02

For round-nosed piers 0.01

For pointed-nosed piers 0

The average abutment contraction coefficients
89 are as follows: K_a

For square abutments with headwall at 90° to direction of flow 0.10

For rounded abutments with headwall at 90° to direction of flow when

$$0.5\ H_e \geqq r \geqq 0.15\ H_e$$

For rounded abutments where $r > 0.5\ H_e$ and headwall is placed not more than 45° to direction of flow 0

where r = radius of abutment rounding

.20 *DISCHARGE CHANNEL*

.21 *Flow* - Discharge generally passes through the critical stage in the spillway control structure and enters the discharge channel as supercritical or shooting flow. The velocities and depths of free surface flow in the channel conform to the principle of Bernoulli's Theorem. As applied to Figure 344.21(a) the theorem may be expressed as follows:

$$Z + d_1 + h_{v1} = d_2 + h_{v2} + \Delta h_L \qquad 344.21(a)$$

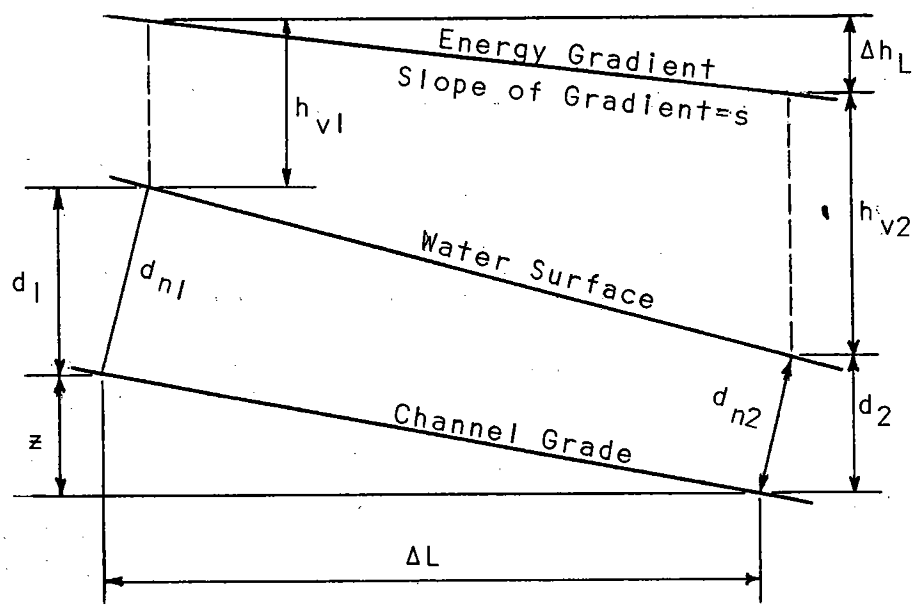
The term Δh_L includes all losses which occur in ΔL, however, since in most channels changes are made gradually, ordinary losses except those due to friction can be neglected, therefore:

$$\Delta h_L = \frac{(s_1 + s_2)\ \Delta L}{2} \qquad 344.21(b)$$

where $s = \left(\frac{Vn}{1.486 r^{2/3}}\right)^2$

Friction losses in chute channels may be approximated from nomograph in Figure 344.21(b)

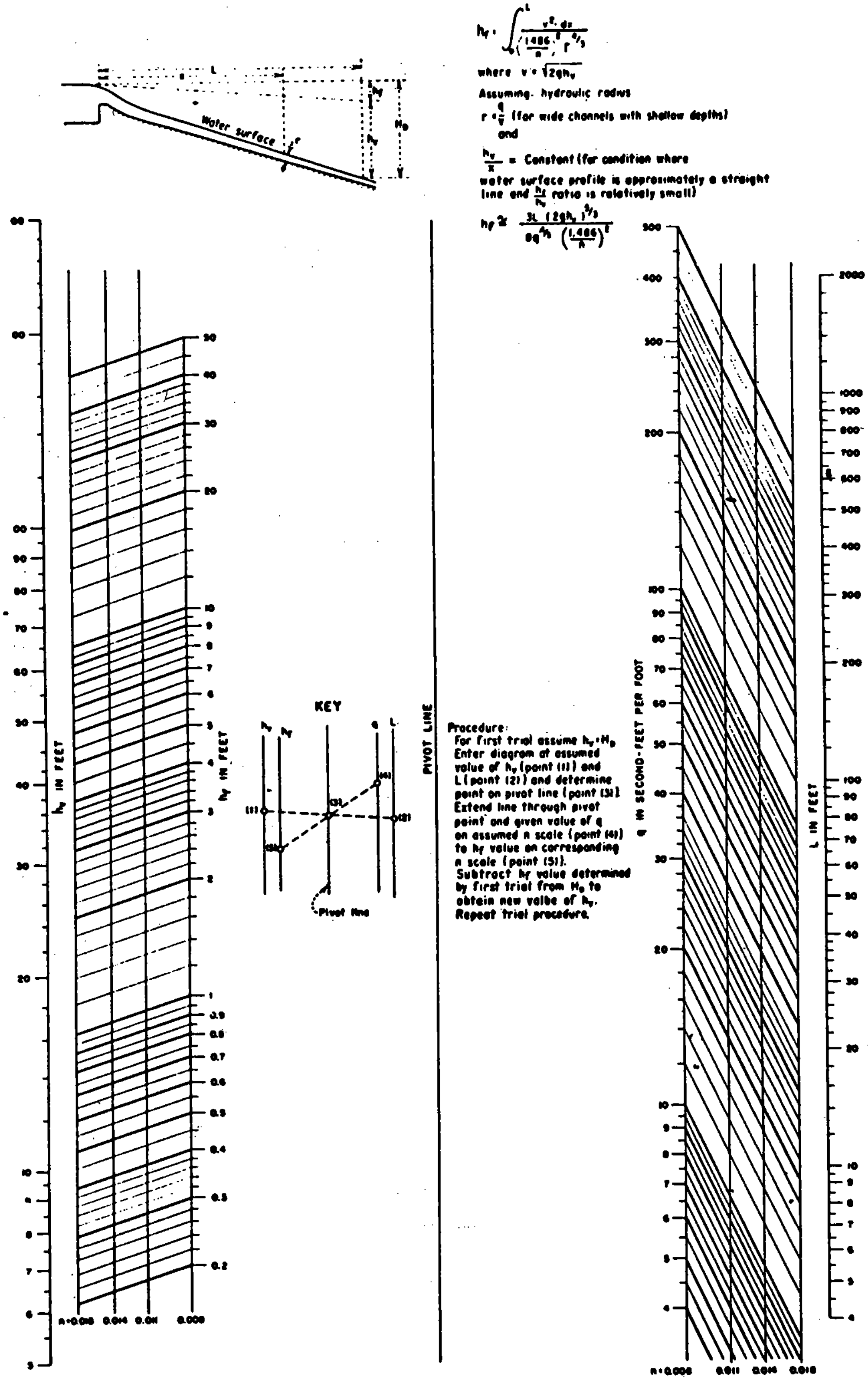
Figure 344.21(a)



For determining depths of flow a value of n of 0.018 shall be assumed in order to account for air swell, wave action, etc. For determining specific energies of flow needed for designing the dissipating device, a value of n of 0.008 shall be assumed.

.22 *Profile* - The profile of discharge channel is generally defined by straight reaches joined by vertical curves. Sharp convex and concave vertical curves shall be avoided to prevent unsatisfactory flows in the channel. Convex curves shall be flat enough to maintain positive pressures and thus avoid the tendency of separation of flow from the floor. The curvature shall approximate a shape defined by the equation:

$$-y = x \tan \theta + \frac{x^2}{[4\ (d + h_v)\ \cos^2 \theta]} \qquad 344.22(a)$$



Reference:
Hydraulic Design Of Stilling Basins And Energy Dissipators
Engineering Nomograph 25, 1964
U.S. Department Of Interior
Bureau Of Reclamation

Ventura County Flood Control District
DESIGN MANUAL

APPROXIMATE LOSSES IN CHUTES FOR VARIOUS VALUES OF WATER DROP AND CHANNEL LENGTH

Figure
344.21 (b)

where:

y = vertical coordinate defining the channel profile

x = horizontal coordinate defining the channel

θ = slope angle of floor upstream from the curve

d = depth of flow, feet

h_v = velocity head, feet

K = factor, shall be equal to or greater than 1.5 to assure positive pressure.

Concave curves shall have a sufficiently long radius of curvature to minimize the dynamic forces on the floor brought about by the centrifugal force which results from a change in the direction of flow. An approximate relationship is expressed by the equation:

$$R = \frac{2qV}{p} \quad \text{or} \quad R = \frac{2d\ V^2}{p} \qquad 344.22(b)$$

where:

R = minimum radius of curvature, feet

q = discharge in cfs per foot of width

V = velocity, fps

d = depth of flow, feet

p = normal dynamic pressure exerted on the floor, pounds per square foot.

An assumed value of p = 100 will normally produce an acceptable radius; however, in no event shall the radius be less than 10d.

.23 *Convergence and Divergence* - The best hydraulic performance in a discharge channel is obtained when the confining side walls are parallel and the distribution of flow across the channel is maintained uniform. If necessary, the covergence or divergence shall be gradual and shall not exceed the angular variation produced by the equation:

$$\tan \alpha = \frac{1}{3F} \qquad 344.23$$

where:

α = angular variation of the sidewall with respect to the channel center line.

F = Froude Number based on average velocities and depths at the beginning and the end of the channel.

.24 *Channel Freeboard* - The freeboard in the discharge channel shall be determined from the following relationship.

$$\text{Freeboard (in feet)} = 2.0 + 0.025\ V \sqrt[3]{d} \qquad 344.24$$

.30 *TERMINAL STRUCTURES*

.31 *Hydraulic Jump Basins* - The hydraulic jump basin is an effective device for dissipating the energy of flow in a spillway and reducing the exit velocity to a tranquil state. The jump form and the flow characteristics can be related to the kinetic flow factor $\frac{V^2}{gd}$, of the discharge entering the basin; to the critical depth of flow, d_c; or to the Froude number parameter, $\frac{V}{\sqrt{gd}}$. For good hydraulic performance, the side walls of stilling basins shall be vertical.

The following expession shall be used to determine the freeboard in hydraulic jump type stilling basins.

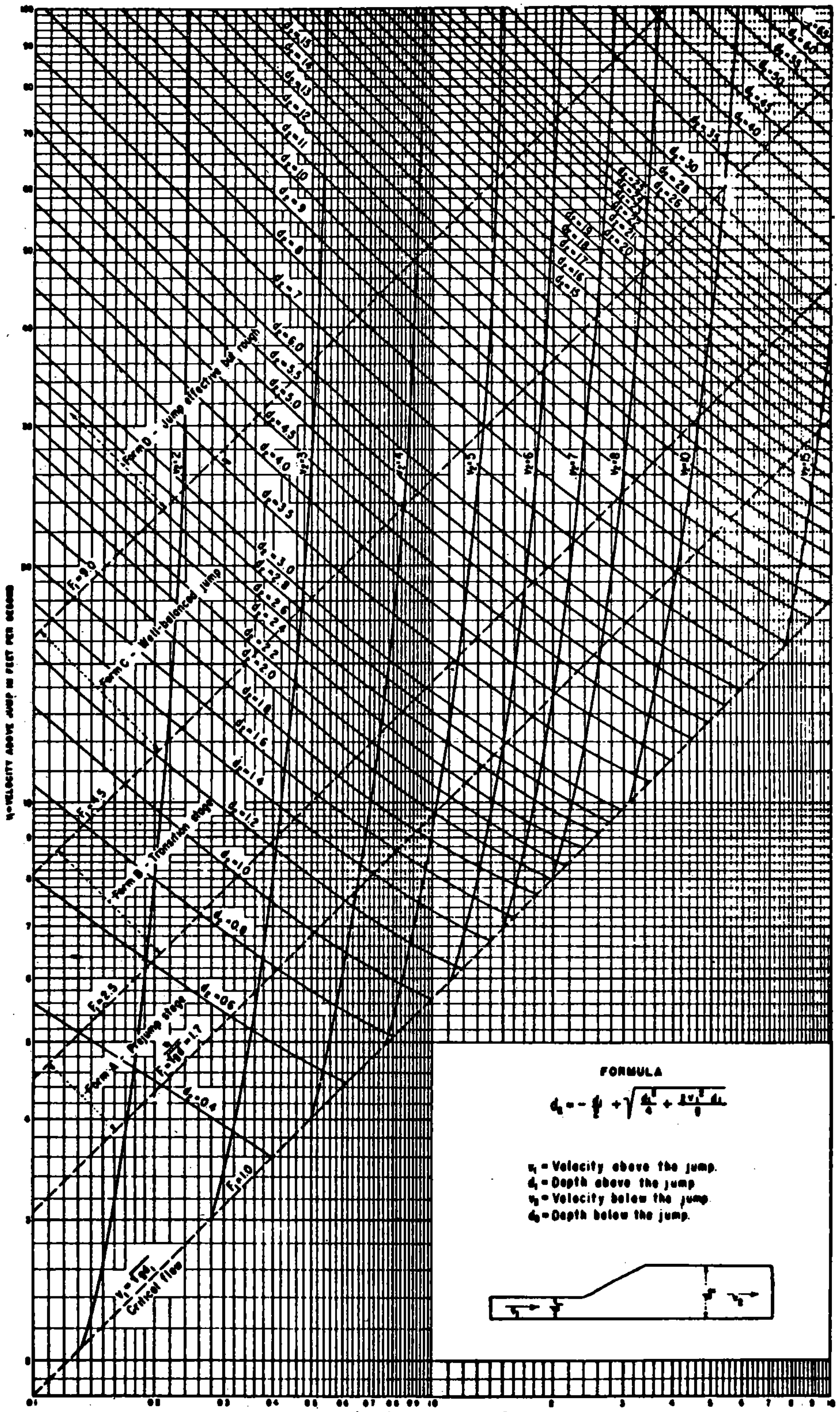
$$\text{Freeboard in feet} = 0.1\ (V_1 + d_2). \qquad 344.31$$

Relations between variables in hydraulic jump for rectangular channels are shown in Figure 344.31(a).

Stilling basin design suitable to provide stilling action for various ranges of Froude numbers are presented below.

(a) Froude numbers less than 1.7

For Froude number of 1.7 the conjugate depth d_2 is about twice the incoming depth,



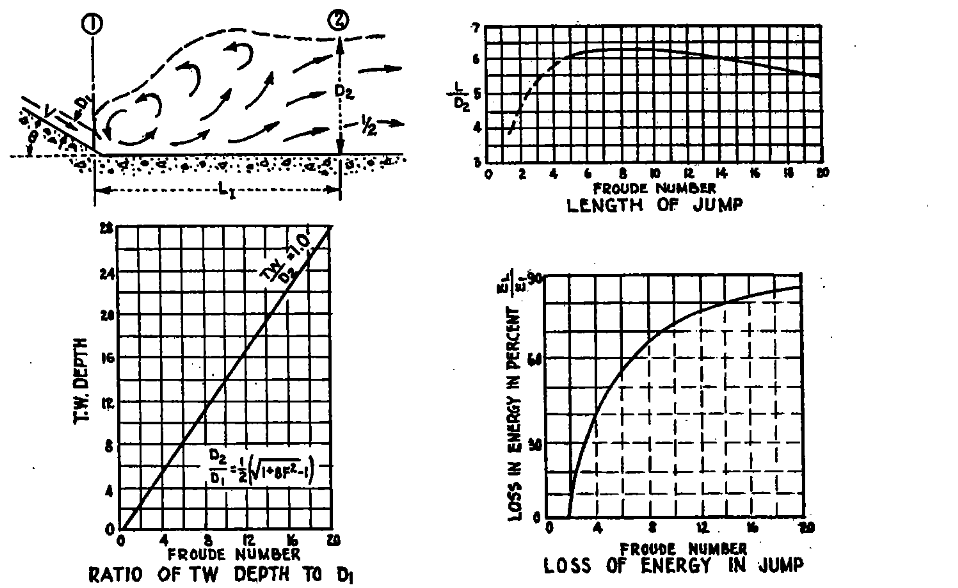
Reference:	Ventura County Flood Control District DESIGN MANUAL	Figure
Design Of Small Dams U.S. Department Of Interior Bureau Of Reclamation 1960	RELATIONS BETWEEN VARIABLES IN HYDRAULIC JUMP FOR RECTANGULAR CHANNEL	344.31(a)

and the exit velocity is about half the incoming velocity. No buffer or special dissipating devices are needed, except the apron length beyond the point where the depth starts to change shall not be less than about $4d_2$.

(b) The USBR Basin I

Flow phenomena for basins where Froude number for incoming flow is in the range of $F_1 = 1.7$ to $F_1 = 2.5$, flows are not attended by active turbulence and are designated as the pre-jump stage. The basin shall be sufficiently long to contain the flow prism, however, baffles or sills are not required. Conjugate depths and basin lengths shown in
95 Figure 344.31(b) shall be used in design.

Figure 344.31(b) - Stilling basin characteristics for Froude numbers between 1.7 and 2.5



(c) The USBR Basin II

Basins in which the Froude number value of the incoming flow is higher than 4.5 a true hydraulic jump will form. Basin II shall be used whenever $F_1 > 4.5$ and the incoming velocities exceed 50 fps, Figure 443.31(c).

(d) The USBR Basin III

This basin shall be used whenever $F_1 > 4.5$ and incoming velocities are under 50 fps, Figure 344.31(d)

(e) The USBR Basin IV

Flows in the range of Froude number $F_1 = 2.5$ to 4.5 are designated as transition stage flows, since a true hydraulic jump does not fully develop. Criteria presented in Figure 344.31(e) shall be used in design.

(f) The St. Anthony Falls (SAF) Stilling Basin

This basin shall be used on small structures such as small spillways, outlet works, and small channel structures intended to lower the gradient or dissipate the energy where the incoming Froude number $F_1 = 1.7$ to 17. Through the addition of stilling basin appurtenances the SAF basin has reduced the length of a conventional hydraulic jump-type stilling basin by approximately 80%. The proportions of the SAF basins are shown in Figure 344.31(f).

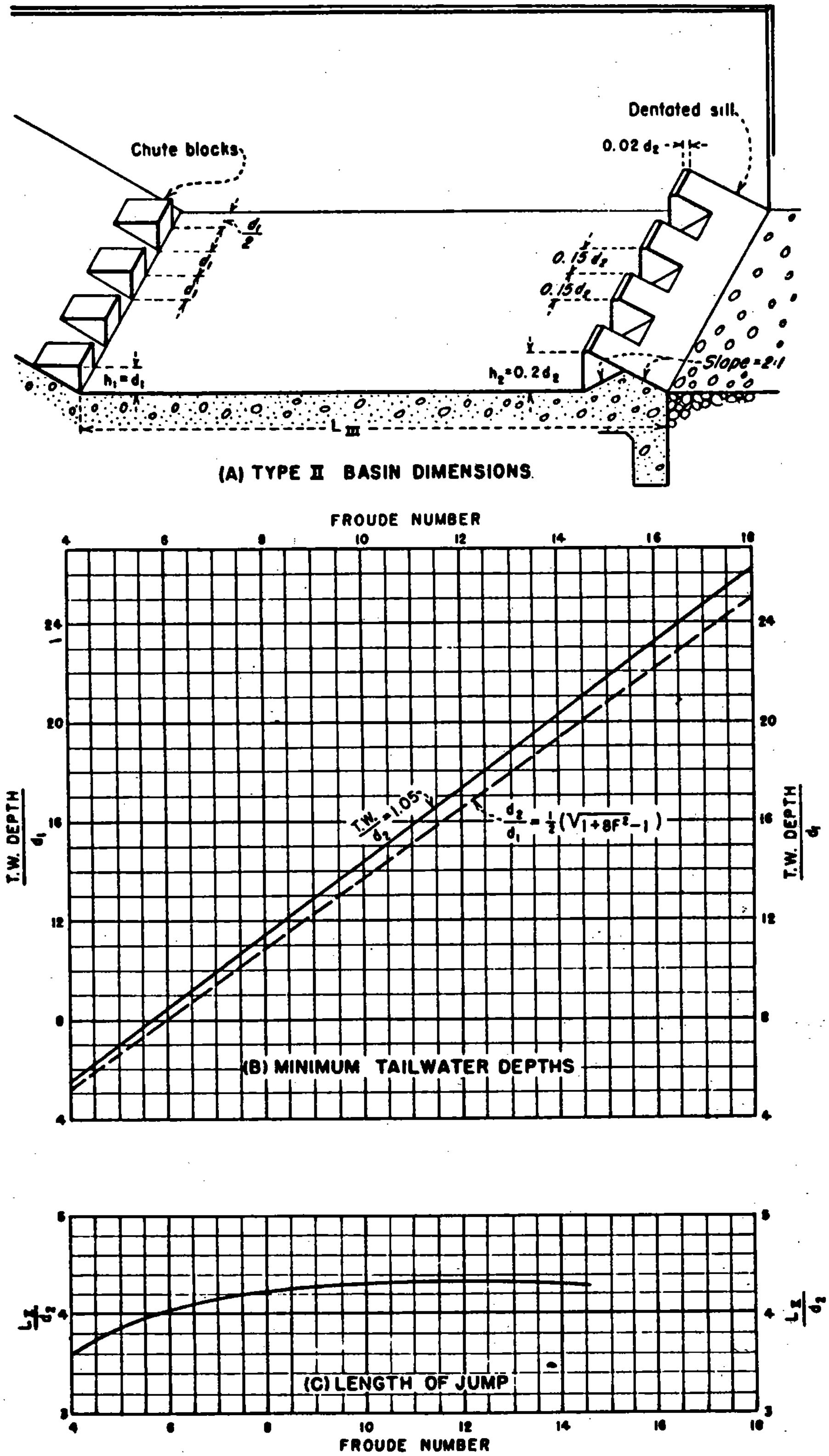
The design rules and data not shown in Figure 344.31(f) are as follows:

1. The floor blocks shall be placed downstream from the openings between the chute blocks.

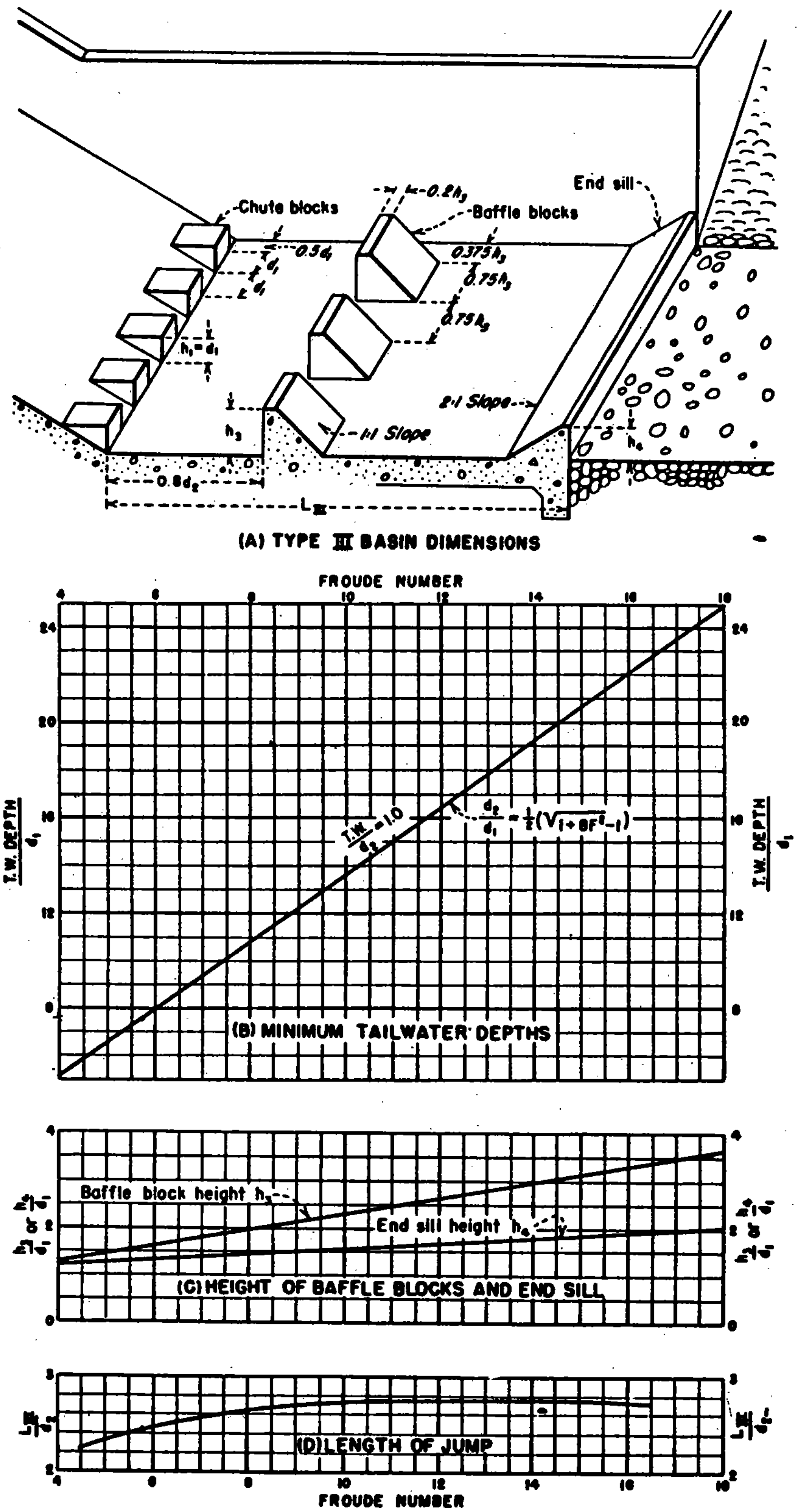
2. Stilling basin side walls may be parallel (as in a rectangular stilling basin) or they may diverge as an extension of the transition side walls (as in a trapezoidal stilling basin).

3. The widths and spacings of the floor blocks for diverging stilling basins shall be increased in proportion to the increase in stilling basin width at the floor block location.

4. Wing walls shall be equal in height to the stilling basin side walls. The top of the wing walls shall have a slope of 1 to 1.



Reference:	Ventura County Flood Control District DESIGN MANUAL	Figure
Hydraulic Design Of Stilling Basins And Energy Dissipators Engineering Nomograph 25, 1964 U S Department Of Interior Bureau Of Reclamation	USBR BASIN II $F_1 > 4.5$ AND $V_1 > 50$ fps	344.31(c)



Reference: Hydraulic Design Of Stilling Basins And Energy Dissipators Engineering Nomograph 25, 1964 U.S. Department Of Interior Bureau Of Reclamation	Ventura County Flood Control District DESIGN MANUAL	Figure
	USBR BASIN III $F_1 > 4.5$ AND $V_1 < 50$ fps	344.31 (d)

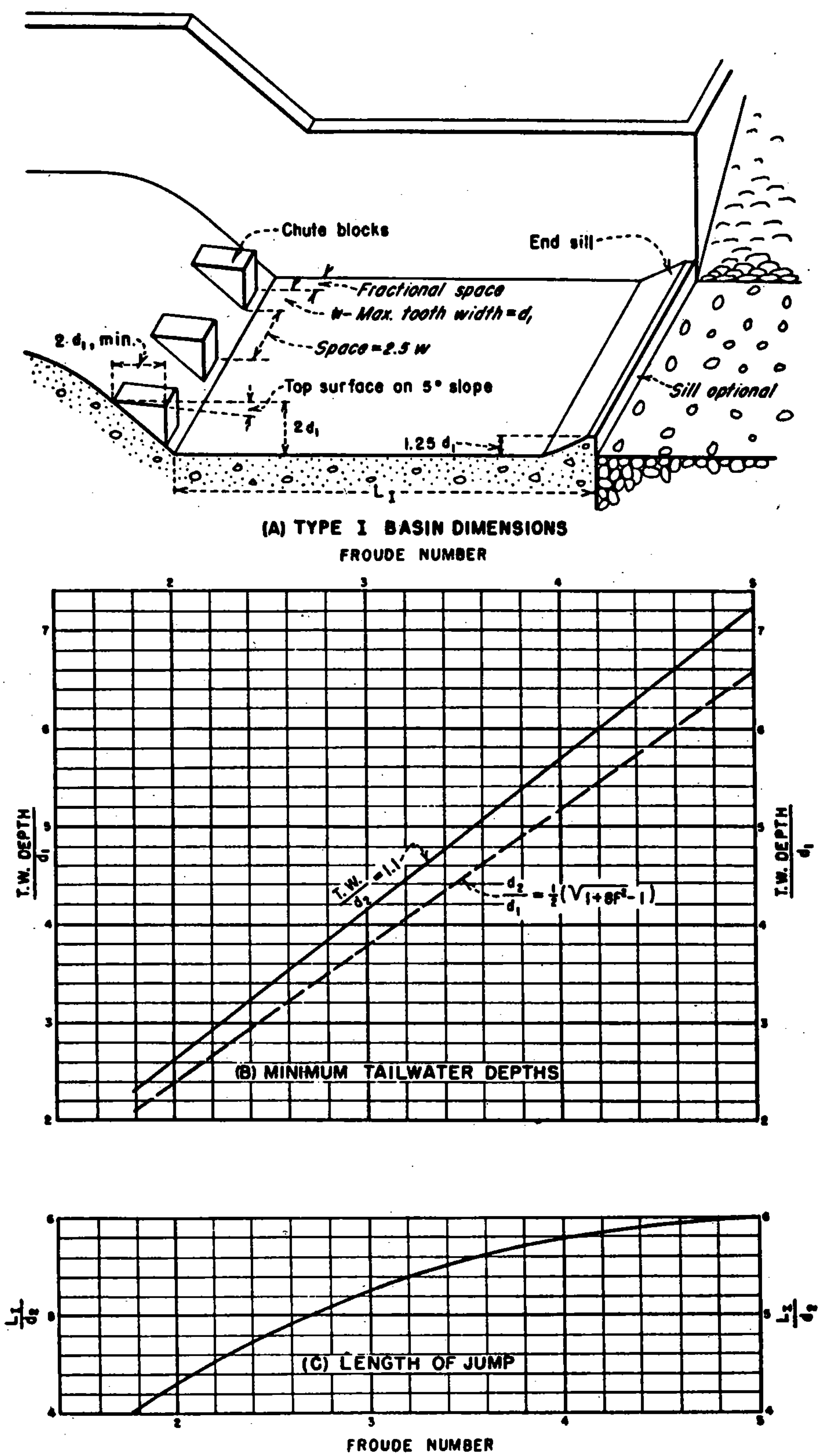
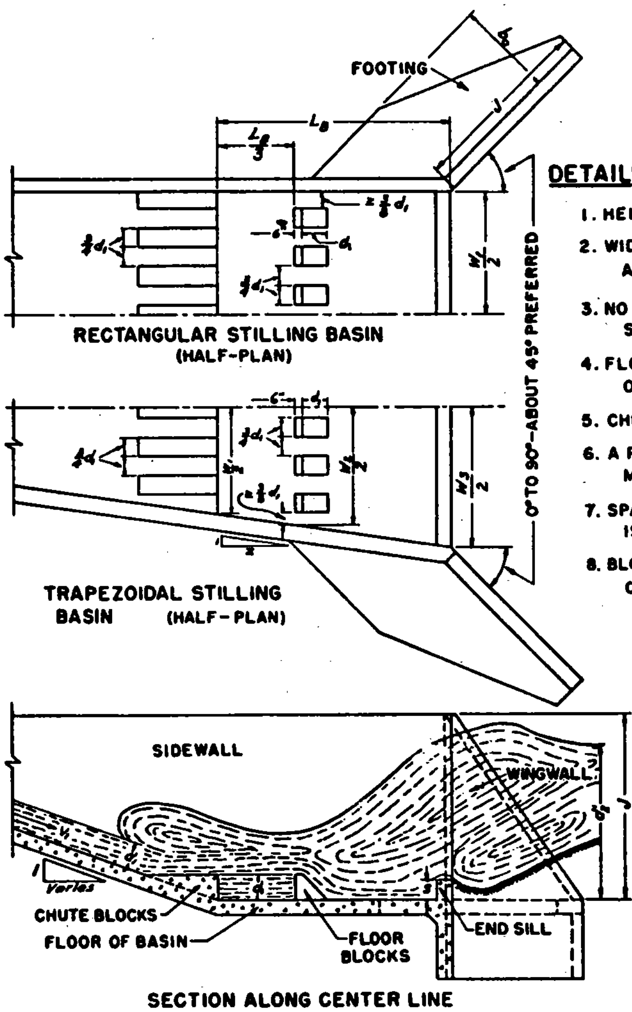


Figure 205. **Stilling basin characteristics for Froude numbers between 2.5 and 4.5.**

Reference Hydraulic Design Of Stilling Basins And Energy Dissipators Engineering Nomograph 25, 1964 U.S. Department Of Interior Bureau Of Reclamation.	Ventura County Flood Control District DESIGN MANUAL USBR BASIN IV FROUDE NUMBER 2.5 TO 4.5	Figure 344.31(e)



DETAILS OF LAYOUT FOR FLOOR AND CHUTE BLOCKS

1. HEIGHT OF FLOOR AND CHUTE BLOCKS IS d_1
2. WIDTH AND SPACING OF FLOOR AND CHUTE BLOCKS APPROXIMATELY $\frac{3d_1}{4}$
3. NO FLOOR BLOCK SHOULD BE PLACED CLOSER TO SIDEWALL THAN $\frac{3d_1}{8}$
4. FLOOR BLOCKS OCCUPY BETWEEN 40 AND 55 PERCENT OF STILLING BASIN WIDTH AT BLOCKS
5. CHUTE BLOCKS TO BE STAGGERED WITH FLOOR BLOCKS
6. A PORTION OF A CHUTE BLOCK OR A WHOLE CHUTE BLOCK MAY BE ADJACENT TO A SIDEWALL
7. SPACE BETWEEN SIDEWALL AND FIRST CHUTE BLOCK IS NOT TO BE GREATER THAN APPROXIMATELY $\frac{3d_1}{4}$
8. BLOCKS ARE TO BE SYMMETRICAL ABOUT STILLING BASIN CENTER LINE

DESIGN FORMULAS

$$3 \leq F_1 \leq 300$$

1. $F_1 = \frac{v_1^2}{g d_1}$
2. $d_2 = \frac{d_1}{2}\left(-1 + \sqrt{8F_1 + 1}\right)$
3. $d_2' = 1.4 d_1 F_1^{0.46}$
4. $L_B = \frac{4.5 d_2}{F_1^{0.38}}$
5. $J = \frac{d_2}{3} + d_2'$
6. $s = 0.07 d_2$
7. $z \geq 3\sqrt{F_1}$

DEFINITION OF SYMBOLS

F_1 = FROUDE'S NUMBER $= \frac{v_1^2}{g d_1}$ (DIMENSIONLESS NUMBER)

v_1 = ENTRANCE VELOCITY OF WATER TO SAF STILLING BASIN — FT./SEC.

d_1 = ENTRANCE DEPTH OF WATER TO SAF STILLING BASIN — FEET

L_B = LENGTH OF SAF STILLING BASIN — FEET

J = HEIGHT OF SIDEWALLS OF SAF STILLING BASIN — FEET

s = HEIGHT OF TRANSVERSE END SILL OF SAF STILLING BASIN — FEET

d_2' = REQUIRED HEIGHT OF TAILWATER OVER SAF STILLING BASIN — FEET

d_2 = SEQUENT DEPTH OF FLOW TO DEPTH d_1 — FEET

g = ACCELERATION DUE TO GRAVITY — 32.16 FT./SEC.^{2}

W_1 = WIDTH OF SAF STILLING BASIN AT DOWNSTREAM END OF CHUTE BLOCKS - FEET

W_2 = WIDTH OF SAF STILLING BASIN AT UPSTREAM END OF FLOOR BLOCKS - FEET

W_3 = WIDTH OF SAF STILLING BASIN AT DOWNSTREAM END — FEET

Z = DIVERGENCE OF SIDEWALL (RATIO)

Reference: Chute Spillways Engineering Handbook Section 14 Soil Conservation Service	Ventura County Flood Control District DESIGN MANUAL — SAF STILLING BASIN HYDRAULIC DESIGN CRITERIA	Figure 344.31(f)

.32 *Bucket-type Energy Dissipator* - Whenever the stream bed is composed of non-erodible material, or whenever the tailwater depth is too great for the formation of a hydraulic jump, bucket-type energy dissipators may be used. For additional information see Reference 1, 3 and 4.

345. DROP SPILLWAYS

.10 *CONTROLS*

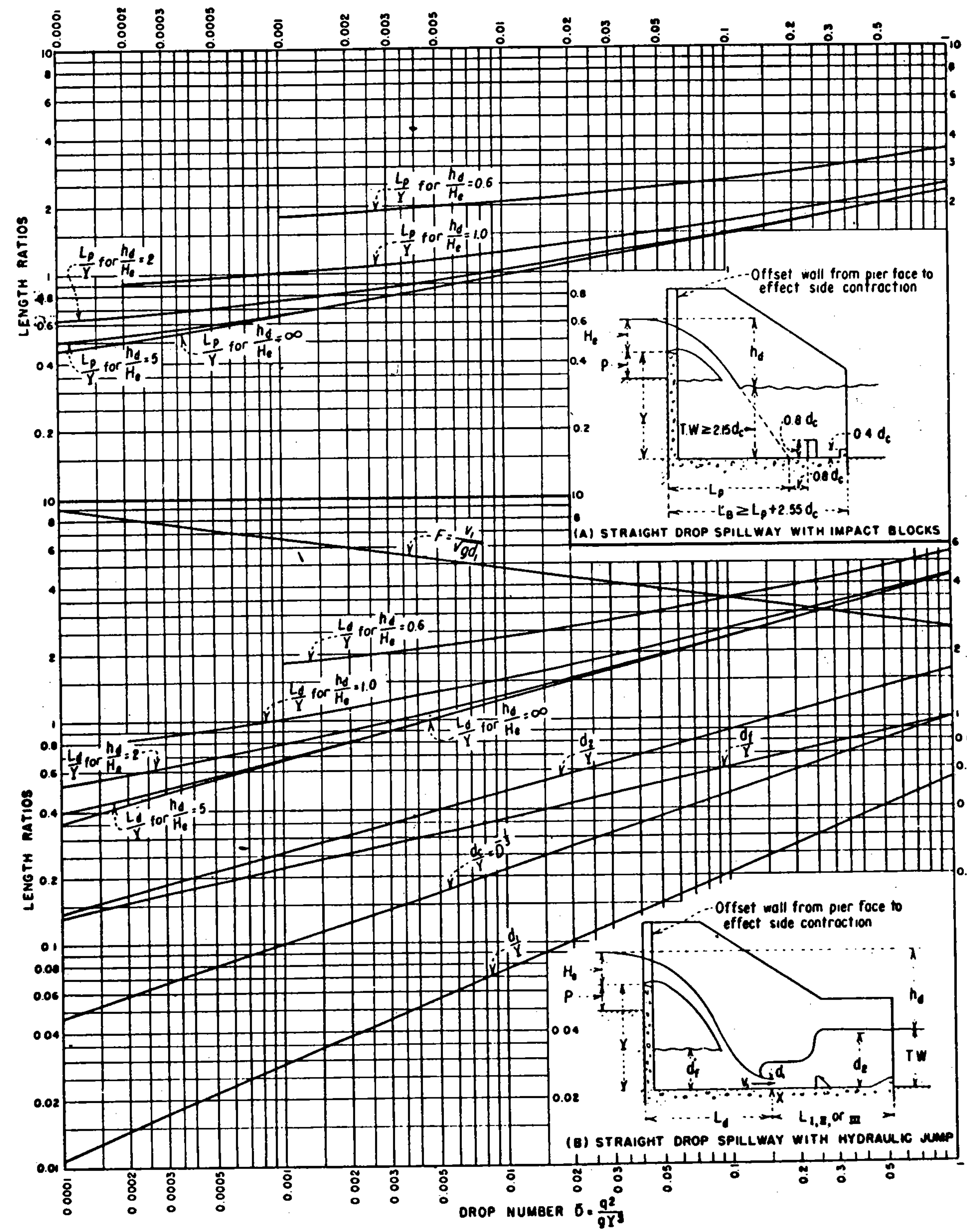
The control for a drop spillway shall be designed as a broad crested weir to effect a fully suppressed jet. The capacity of the control without freeboard shall be determined using Equation 344.10(a). The sides of the control shall be vertical and shall be arranged to allow for full side contraction, in order to provide side space for the access of air to the underside of the nappe. This contraction is effected by providing square abutment headwalls or by installing square-cornered vertical offsets along the piers or headwalls opposite the crest. The effective length of the crest is then determined according to Equation 344.10(b) with $K_p = K_a = 0.20$. If a 0.5 foot offset wall from pier face is used on each side in a single control the value of $2\ K_p\ H_e$ shall be replaced by $2\ (.5)=1.0$.

.20 *STILLING BASIN*

The dimensions for two types of stilling basins as related to the Froude number and the drop number $D = \frac{q^2}{g\ Y^3}$, are presented in Figure 345.20.

.21 *Impact Block Type Basin* - The dissipation of energy in an impact block basin is principally by turbulence induced by the impingement of the incoming flow upon the impact block. Therefore, the required tailwater depths are independent of the drop height. The value of $d_c = \sqrt[3]{\frac{q^2}{g}}$, where q is the unit discharge.

.22 *Hydraulic Jump Basin* - In this type of basin the energy is dissipated by a hydraulic jump. The start of the jump, point X, will vary with the vertical drop distance, Y , and is influenced by the under nappe pool depth, d_p. Values of the depth, d_1, and the Froude number, F_1, at the start of the jump in relation to the drop number, D, are shown in Figure 345.20. These relations shall be used for determining the basin dimensions. The basin design downstream from point X shall be governed by the criteria for terminal structures for Chute Spillways, Section 344.31



Reference: Design Of Small Dams U.S. Department Of Interior Bureau Of Reclamation 1960	Ventura County Flood Control District DESIGN MANUAL HYDRAULIC CHARACTERISTICS OF STRAIGHT DROP SPILLWAYS	Figure 345.20

350. DEBRIS DAMS AND BASINS

351. DEBRIS CAPACITY

.10 The debris basin shall, in general, be designed for minimum debris capacity. The design capacity shall represent 1½ times the amount of debris from a 100 year storm in a burned watershed. "Debris Production Curves", developed by the Los Angeles County Flood Control District, and "A New Method of Estimating Debris Storage Requirements for Debris Basins", by Fred E. Tatum, U. S. Army Engineers District, Los Angeles, may be used as references in debris capacity studies. However, due to possibility of unusual conditions which may affect any individual watershed, specific confirmation as to applicability of the data shall be obtained from the District.

105

.20 For basin capacity calculations, the theoretical debris slope, fanning upstream from the spillway crest, shall be assumed at 60% of the average slope of the original stream bed for the total length of the basin site.

.30 The bottom of the basin shall generally be established at the average slope of the original stream bed. In the event of extensive excavation below stream bed level, a well stabilized inlet structure shall be provided to prevent erosion of the stream beds upstream of the basin.

352. SPILLWAYS

.10 *LENGTH*

The length of spillway crest and height of spillway walls shall be designed to pass as far as the downstream toe of the dam, with freeboard as specified below, the District's 100 year Q for a burned watershed condition.

.20 *FREEBOARD*

The minimum freeboard at spillway crest shall be 2 feet or equal to 25% of the head differential from weir crest to the water surface in the basin, whichever is greater.

.30 *HYDRAULICS OF SPILLWAYS*

The hydraulics of the spillways and appurtenant structures shall be performed in accordance with the requirements of Section 340, "Spillways".

353. OUTLET WORKS

.10 *COMPONENT PARTS*

The outlet works shall consist of an outlet tower or riser, pipe conduit through the embankment and an outlet consisting of a spillway or other satisfactory outlet structure. The pipe conduit may outlet directly into the emergency spillway channel if conditions permit.

.20 *TOWER OR RISER*

Generally, the tower shall be a rectangular or circular structure.

.21 Circular concrete towers shall generally be avoided, due to the difficulty of attaching anti-vortex and safety collars to, and providing ports for, precast pipes. In addition, precast concrete pipe elbows of the required dimensions to transmit flow from the riser to the outlet conduit are not ordinarily manufactured. Rectangular cast-in-place structures with circular interior may be used.

.22 Rectangular risers shall have an inside cross-sectional area equal to at least 1½ times that of the conduit to insure that the outlet conduit will flow full under design conditions.

.30 *OUTLET CONDUIT*

.31 The outlet conduit shall consist of circular or rectangular conduit. The outlet conduit shall be connected to the tower with a smooth transition.

.40 *HYDRAULICS*

.41 Outlet works shall be designed in such a manner as to prevent orifice control in the riser or short-tube control in the outlet conduit. The structure shall generally be designed for weir control. For best hydraulic functioning, the tower crest shall be at least 5 conduit diameters above the flow line of the conduit. Anti-vortex devices and trash rack structures shall be provided on the tower when necessary.

.42 The outlet conduit shall be on a slope not less than 5% unless otherwise permitted by the District.

The publication "Design Memorandum EWP-5", U. S. Department of Agriculture, S. C. S., 1959 provide excellent design information and may be used as a guide.

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STRUCTURAL DESIGN

410. ALLOWABLE STRESSES

411. HYDRAULIC STRUCTURES

Allowable concrete and reinforcing steel unit stresses shall be as shown in Table 411. For splices use a minimum of 30 bar diameters for reinforcing steel in tension zone, and 20 bar diameters for reinforcing steel in compression zone and other reinforcing steel, such as temperature or shrinkage steel. Bars shall be extended a
111 minimum of 15 bar diameters beyond the point where they are no longer needed to resist stresses, but not less than the effective depth of the member.

Unless otherwise specified, all reinforced concrete structures shall be designed for a 28-day compressive strength of 3000 psi. Any deviation from the allowable stresses indicated herein shall be subject to approval by the District.

All reinforcing steel shall comply with the requirements of the standard specifications.

The maximum spacing of bars carrying calculated stress shall be no more than three times the wall or slab thickness nor more than 18 inches.

Table 411.

CONCRETE	ALLOWABLE STRESS For $f'_c = 3000$	ALLOWABLE STRESS Any Strength
Flexure, f_c		
Extreme fiber in compression	1350 psi	$0.45\ f'_c$
Extreme fiber in tension, in plain concrete	90 psi	$0.03\ f'_c$
Shear, v		
113 Beams without web reinforcing	60 psi	$0.02\ f'_c$
Reinforced concrete footings	75 psi	$0.03\ f'_c$
Plain concrete footings	60 psi	$0.02\ f'_c$
Beams with web reinforcing	180 psi	$0.06\ f'_c$
Horizontal shear in shear keys	300 psi	$0.10\ f'_c$
Bond, u		
Top bars *	180 psi	$0.06\ f'_c$
Two way footings (ex. top bars)	240 psi	$0.08\ f'_c$
All others	300 psi	$0.10\ f'_c$
Bearing, f_c		
On full area	750 psi	$0.25\ f'_c$
On 1/3 area or less	1125 psi	$0.375\ f'_c$

REINFORCING STEEL	UNIT STRESS	
Tension - Flexural members and web reinforcing	fy	fs
Intermediate Grade (ASTM 15)	40,000 psi	20,000 psi
60 Ksi Yield Grade (ASTM 432)	60,000 psi	24,000 psi
Compression - combined flexure and axial stress		0.4 fy

* *Top bars are horizontal bars having more than 12 inches of concrete cast in the member below the bar.*

420. RECTANGULAR OPEN CHANNELS

421. ECONOMY OF DESIGN

Consideration shall be given in each individual project to the soil conditions, ground water level, slope of adjacent ground and other factors that may affect the overall economy of a project. Generally whenever conditions permit, the ratio of height to width shall be held within the range of 0.5 to 0.6.

In areas of projected ultimate commercial or industrial development consideration shall be given to provide rigid "U" channels capable of accepting cover. Economic conditions specified for box conduits shall be considered applicable for such cases.

422. METHOD OF DESIGN

For ordinary conditions rectangular channels shall be designed as rigid "U" channels. For wide channels and whenever economic conditions indicate relative merit, "L" channels shall be used. "U" channel is the designation used to describe a rectangular channel designed as a rigid frame. "L" channel consists of retaining walls with a nominal thickness central invert connecting slab.

423. DESIGN LOADS

Horizontal and vertical loads used in the design of rectangular open channels shall be in accordance with the following criteria:

.10 HORIZONTAL LOADS

Channel walls shall be designed to sustain the lateral pressure from the outside and the inside due to the dead load as well as live loads which transmit lateral pressure on the walls.

.11 Dead Load - Channel walls 13 feet or less in height shall be designed for an equivalent fluid pressure of 62.5 psf applied on the earth face of the wall, except when the earth load due to the sloping surcharge exceeds this, or where the wall is adjacent to or within a street or highway easement. The lateral earth pressure due to sloping

surcharge shall be based on soil data. Charts presented in Figure 423.11(a) may be used for estimating surcharge due to sloping backfill.*

Proper consideration shall also be given to increased pressure due to structures and other loads which produce a uniformly distributed surcharge. In this case the uniform load may be converted into an equivalent depth of earth and the wall shall be designed as though the top of the earth was the equivalent depth above the actual surface.

For wall heights greater than 13 feet, a careful study of the soil types, excavation and backfill conditions, ground water levels, subdrainage systems, topography and other pertinent items shall be performed to determine the design loading.

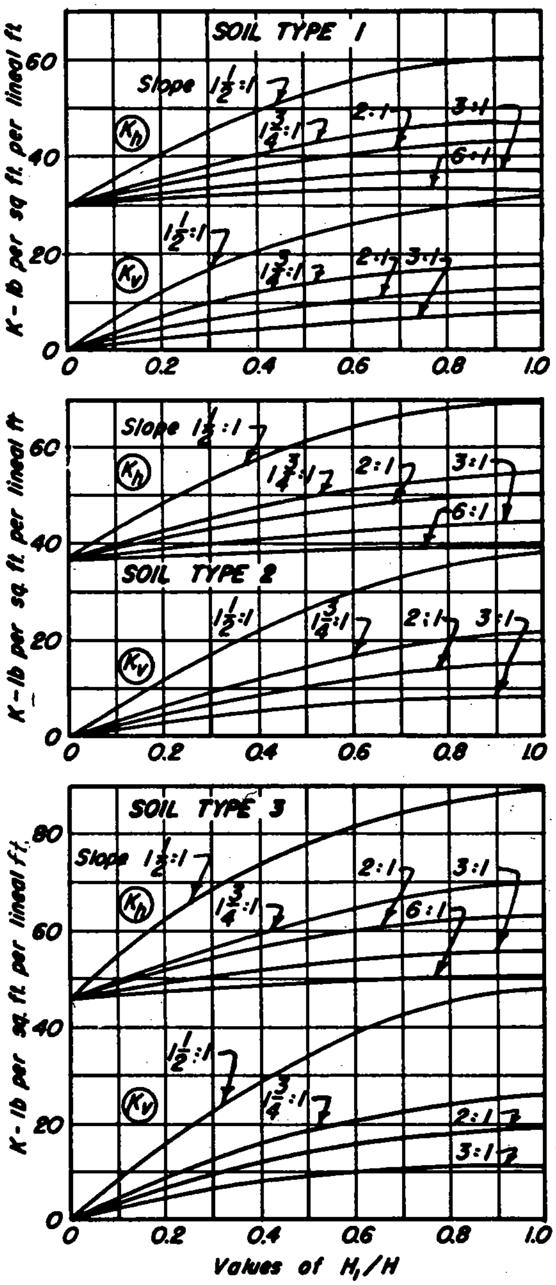
Channel walls regardless of height shall also be designed for 40 psf. equivalent fluid pressure applied on the waterside to top of wall. This assumes active resistance from soil outside the walls or allows an increase in stresses for infrequent overloading of approximately 150 percent of allowable stresses based on full hydrostatic pressure, should active pressure not exist.

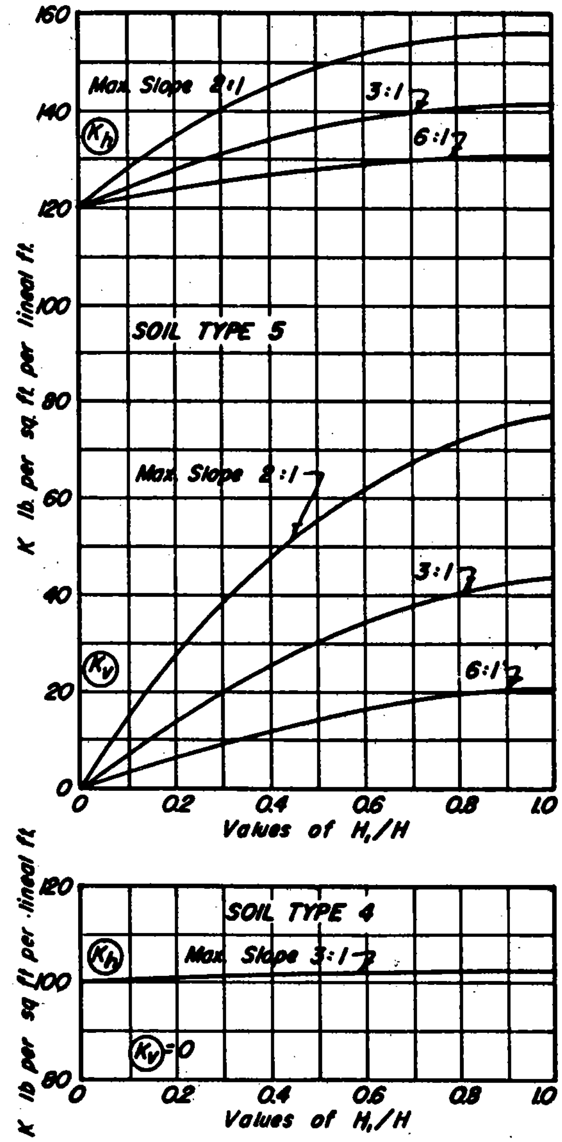
Moment and shear curves for 62.5 psf. and 40 psf. equivalent fluid pressure are presented in Figure 423.11(b).

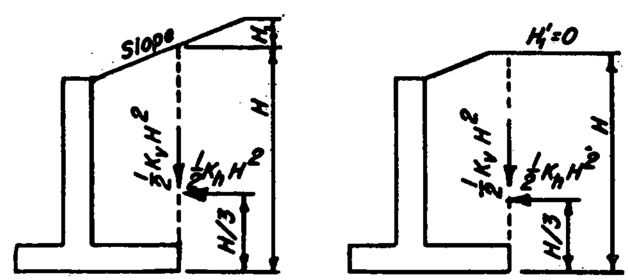
.12 *Live Loads* - Channel walls regardless of height adjacent to or within street or highway easements shall be designed for a loading of 30 psf. equivalent fluid pressure combined with the lateral pressure produced by one HS20-44 truck. The lateral load shall be computed on the basis of the distance measured from the centerline of the wheel to the outer edge of the wall, determined from the best available information as to the location of the right of way, sidewalk width, etc.*

Walls over 13 feet in height adjacent to maintenance access roads shall be designed for lateral loading of 30 psf. equivalent fluid pressure combined with the loads produced by one HS15-44 truck with wheels 2 feet from the wall, measured from centerline of wheel to outer edge of wall.

* *The lateral load computed in this manner shall not be less than that using E.F.P. of 62.5 psf.*



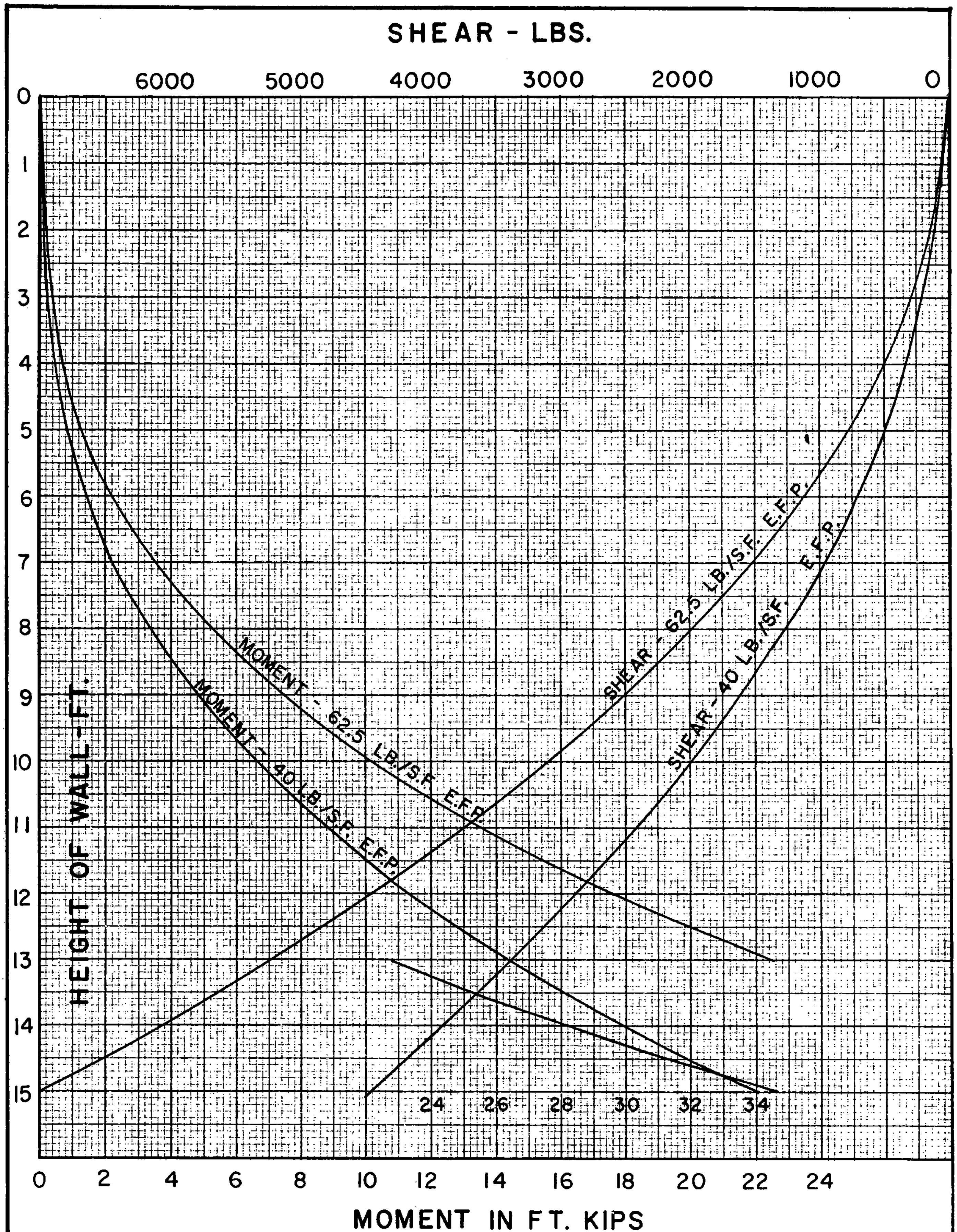




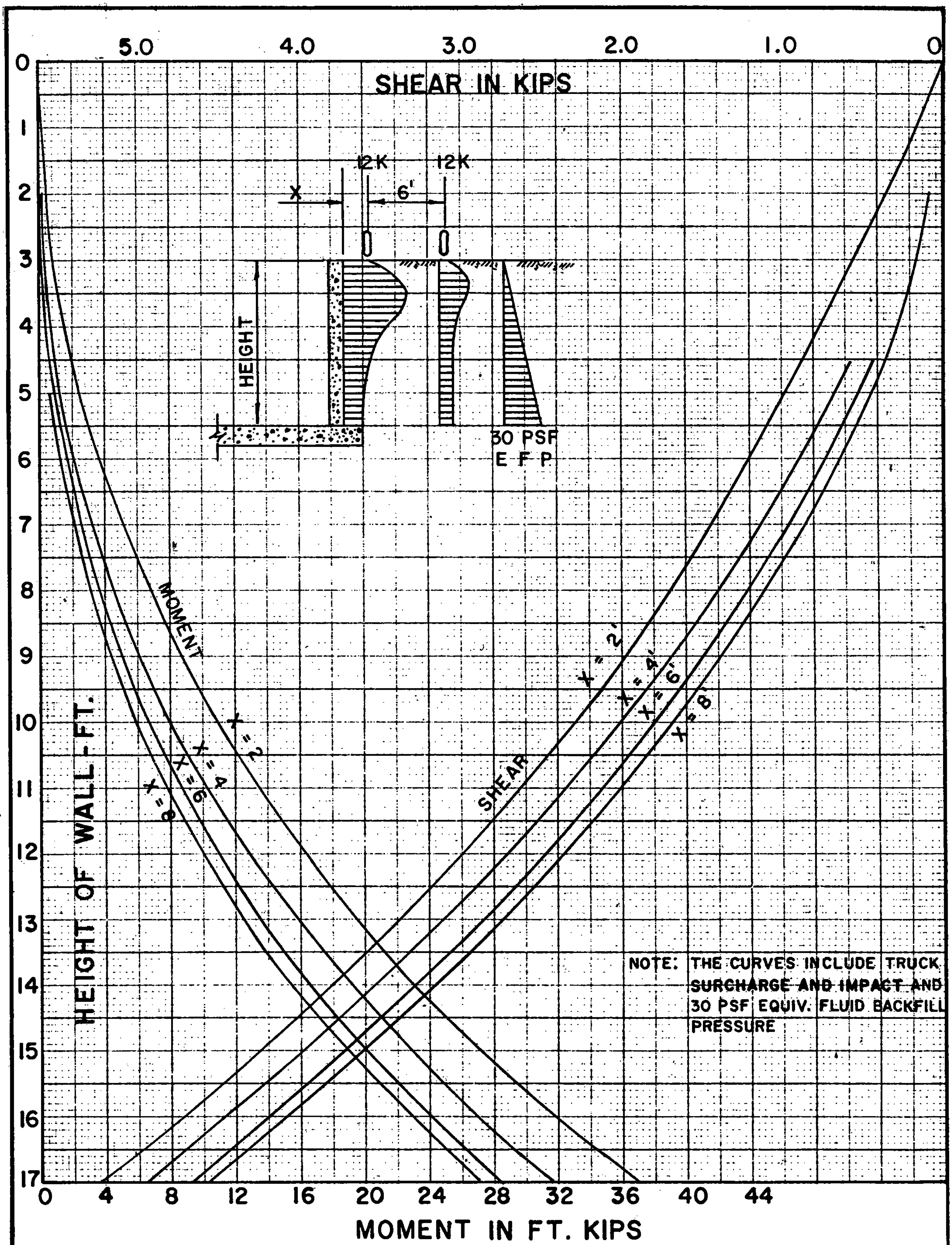
TYPES OF BACKFILL

1. Clean sand or gravels
2. Coarse grained soil of low permeability
3. Residual soil with stones, fine silty sand, and granular materials with conspicuous clay content
4. Soft clay, organic silt, or silty clays.
5. Medium or stiff clay protected in such a way that a negligible amount of water enters the voids.

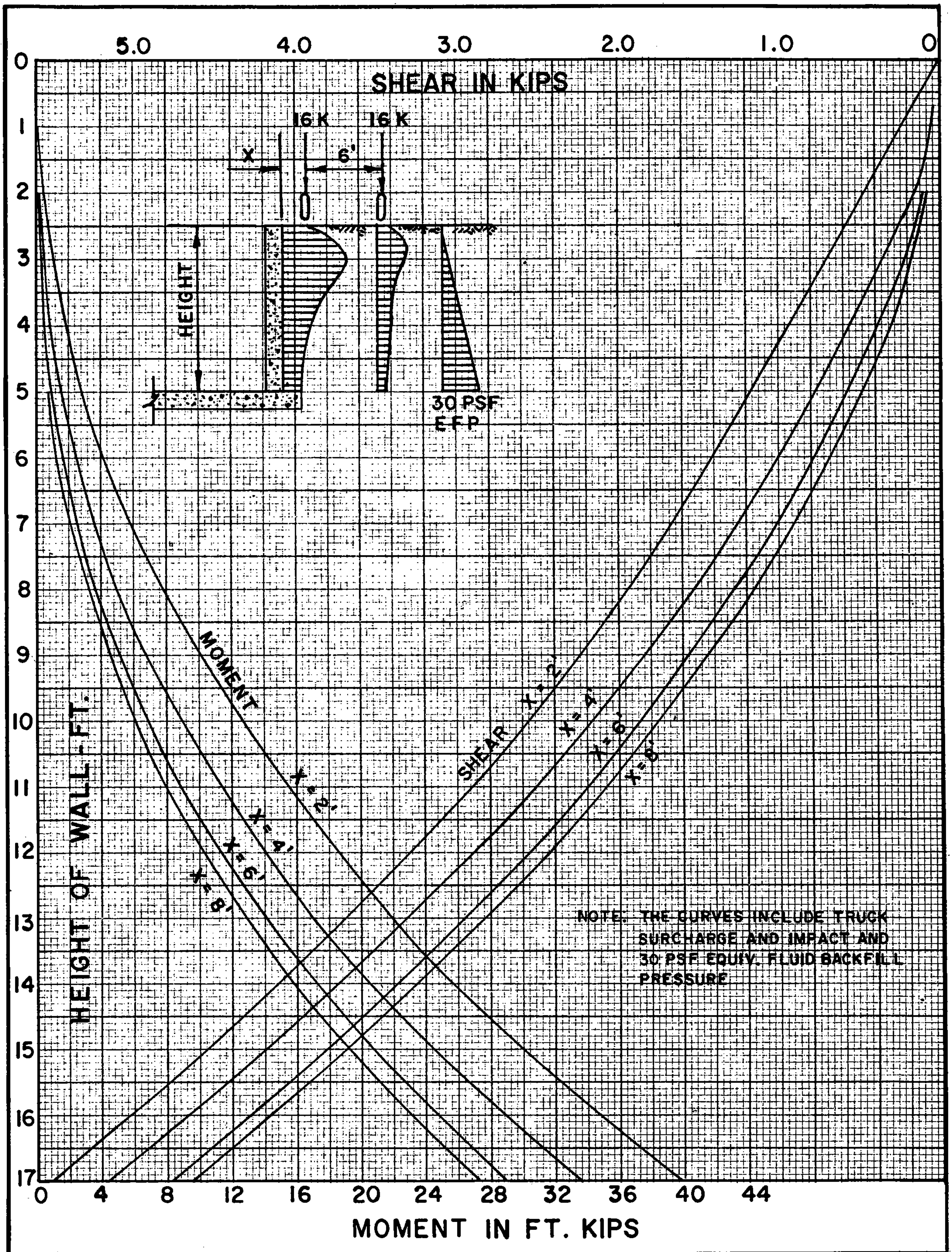
Reference	Ventura County Flood Control District DESIGN MANUAL	Figure
ENGINEERING DESIGN STDS. Far West States, United States Dept. of Agriculture, Soil Conservation Service, Sept. 1958	SURCHARGE DUE TO SLOPING BACKFILL	423.11(a)



Reference: Structural Design Manual Los Angeles County Flood Control District, 1964	Ventura County Flood Control District DESIGN MANUAL / MOMENTS AND SHEARS FOR CANTILEVER WALLS	Figure 423.11 (b)



Reference:	Ventura County Flood Control District DESIGN MANUAL	Figure
Theory And Practice Of Reinf. Conc. By C.W. Dunham Structural Design Manual Los Angeles County F.C. Dist.	MOMENTS & SHEARS AT BASE OF CHANNEL WALLS FOR H-15 TRUCKS TRAVELING PARALLEL TO ℄ OF CHANNEL	423.12 (a)



Reference:
Theory And Practice Of Reinf. Conc. By C.W. Dunham
Structural Design Manual
Los Angeles County F.C. Dist.

Ventura County Flood Control District
DESIGN MANUAL

MOMENTS & SHEARS AT BASE OF CHANNEL WALLS FOR H-20 TRUCKS TRAVELING PARALLEL TO ℄ OF CHANNEL

Figure
423.12(b)

Curves showing the moments and shears produced by 30 psf. equivalent fluid pressure and H15 and H20 truck loads on rectangular open channel walls are presented in Figures 423.12(a) and 423.12(b).

.13 *Stability and Sliding* - Channel sections subject to differential lateral loads shall be checked for stability, soil reaction and sliding. In "L" channels the central invert slab shall also be checked for buckling forces transmitted by the walls. The thrust delivered to the central invert slab shall be the total horizontal force minus the product of the effective vertical force and the coefficient of sliding friction. The factor of safety
121 against sliding shall be 1.5.

.14 *Open Channel Designed for Future Cover* - Open channels may be designed to receive future cover as directed by the District. Channel designed for future cover shall be analysed as rigid frames as prescribed in 430, "Box Conduits", and at the same time shall meet all requirements of open channels as indicated herein.

.20 *VERTICAL LOADS*

.21 *Soil Pressure* - Soil pressure on rectangular channels shall be computed considering the invert slab as a slab on an elastic foundation. See "Beams on Elastic Foundations" by M. Hetenyi, University of Michigan Press, Ann Arbor Michigan, 1946. Curves showing soil pressure and moments in "U" channels are shown in Figure 423.21(a) through (h). When the width of channel is less than the minimum values shown on the curves, uniform soil pressure shall be assumed. Typical channel section, nomenclature and formulas used in the derivation of the curves are presented in Appendix C.

.22 *Uplift Pressure* - See discussion of methods of design for ground water forces under Section 470, "Subdrain Systems".

424. STRUCTURAL SECTION

.10 *THICKNESS OF MEMBERS*

Channel walls with one curtain of reinforcing steel shall be a minimum of 6 inches thick.

Walls with two curtains of reinforcing shall have a minimum thickness of 8 inches.

Invert slab of "U" and "L" channels shall have a minimum thickness exceeding the wall thickness by 1 inch. Thickness of the invert slabs shall be measured at the wall. Central invert connecting slabs for "L" channels shall be no less than 6 inches thick. The invert slab thickness for "U" channels may be constant or sloping to the center, as long as the necessary minimum thickness is provided at the center. A heel a minimum of 6 inches in length shall be provided at the base of open channel walls.

.20 *LONGITUDINAL REINFORCEMENT* 122

Longitudinal steel area shall be 0.001 times the gross concrete area but not less than #4 bars at 18 inch centers, and shall be discontinued at the construction joints.

.30 *STEEL CLEARANCE*

Steel clearance shall be shown on project drawings from the edge of the bar to the face of the concrete. Said clearance shall not be less than that specified below:

Side walls, inside and outside faces - 1½ inches

Top of invert slab - 2 inches for velocities less than 15 fps.
2½ inches for velocities of 15 fps or greater.

Bottom of invert slab - 3 inches.

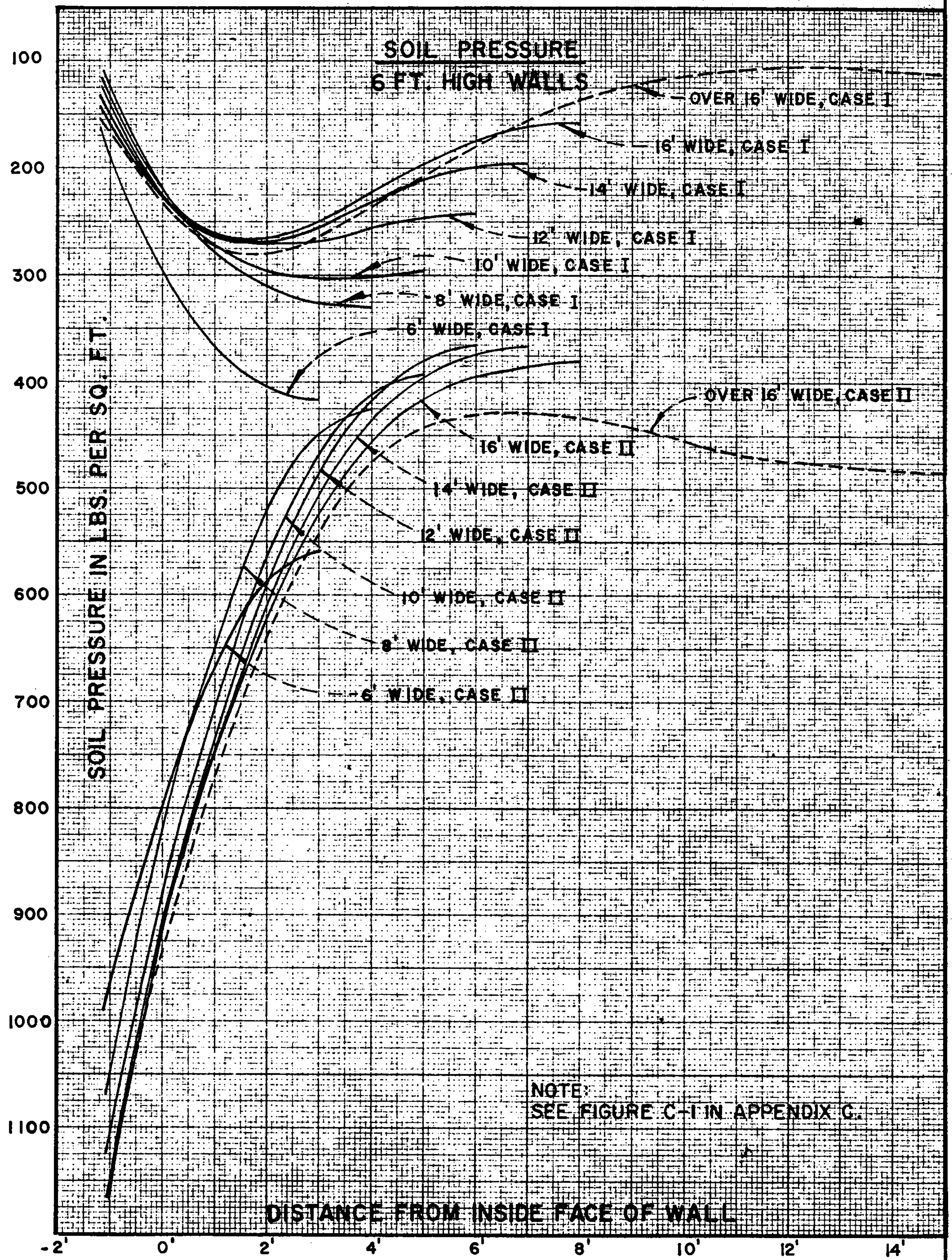
When concrete is subject to the action of sea water, harmful ground water, etc., an additional cover of ½ inch shall be provided on the inside.

Structures subject to harmful industrial wastes may require the use of special cement in the concrete.

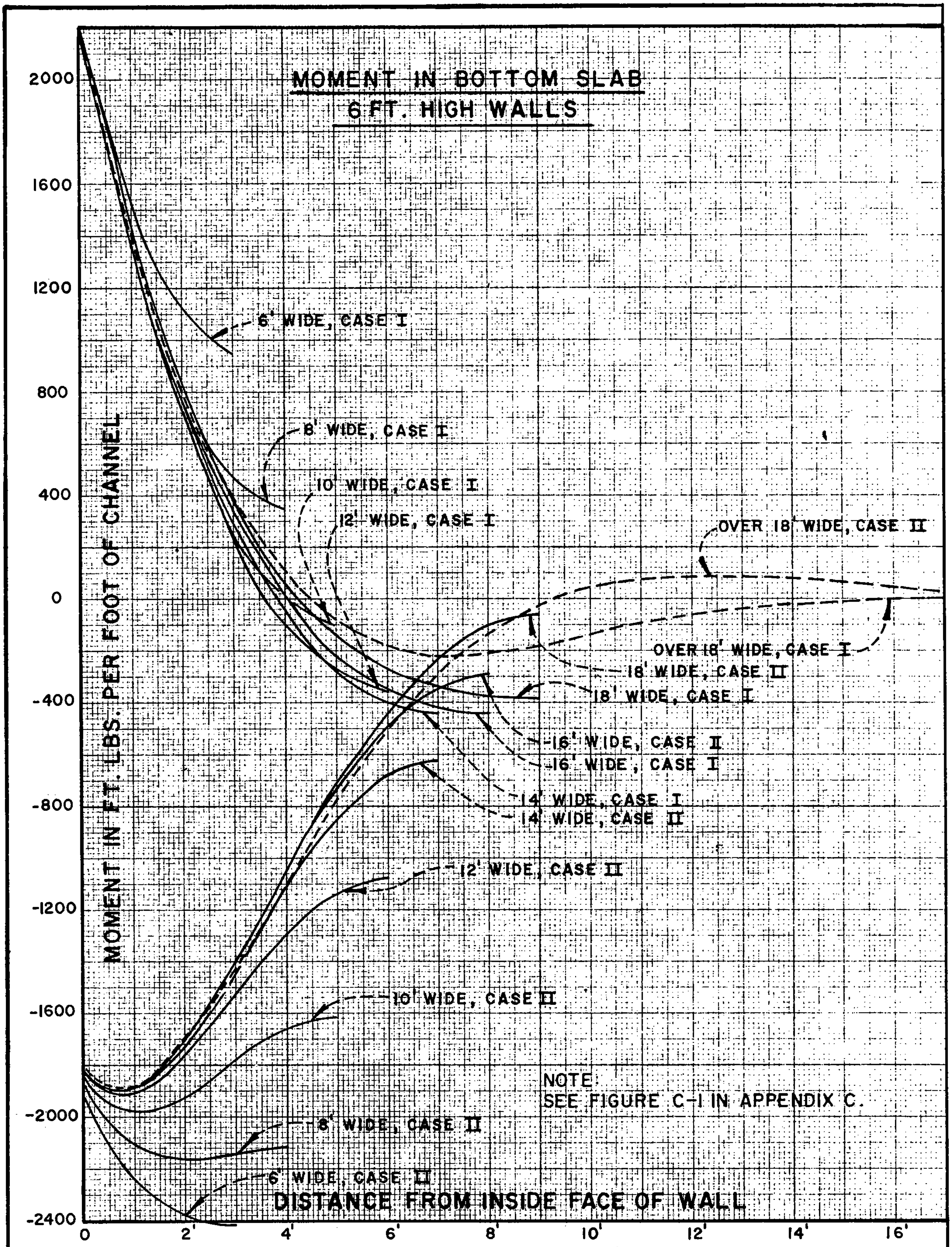
.40 *TRANSVERSE SLOPE OF INVERT SLAB*

The following criteria shall be used to determine the drop in the invert slab from the wall to the center of the channel.

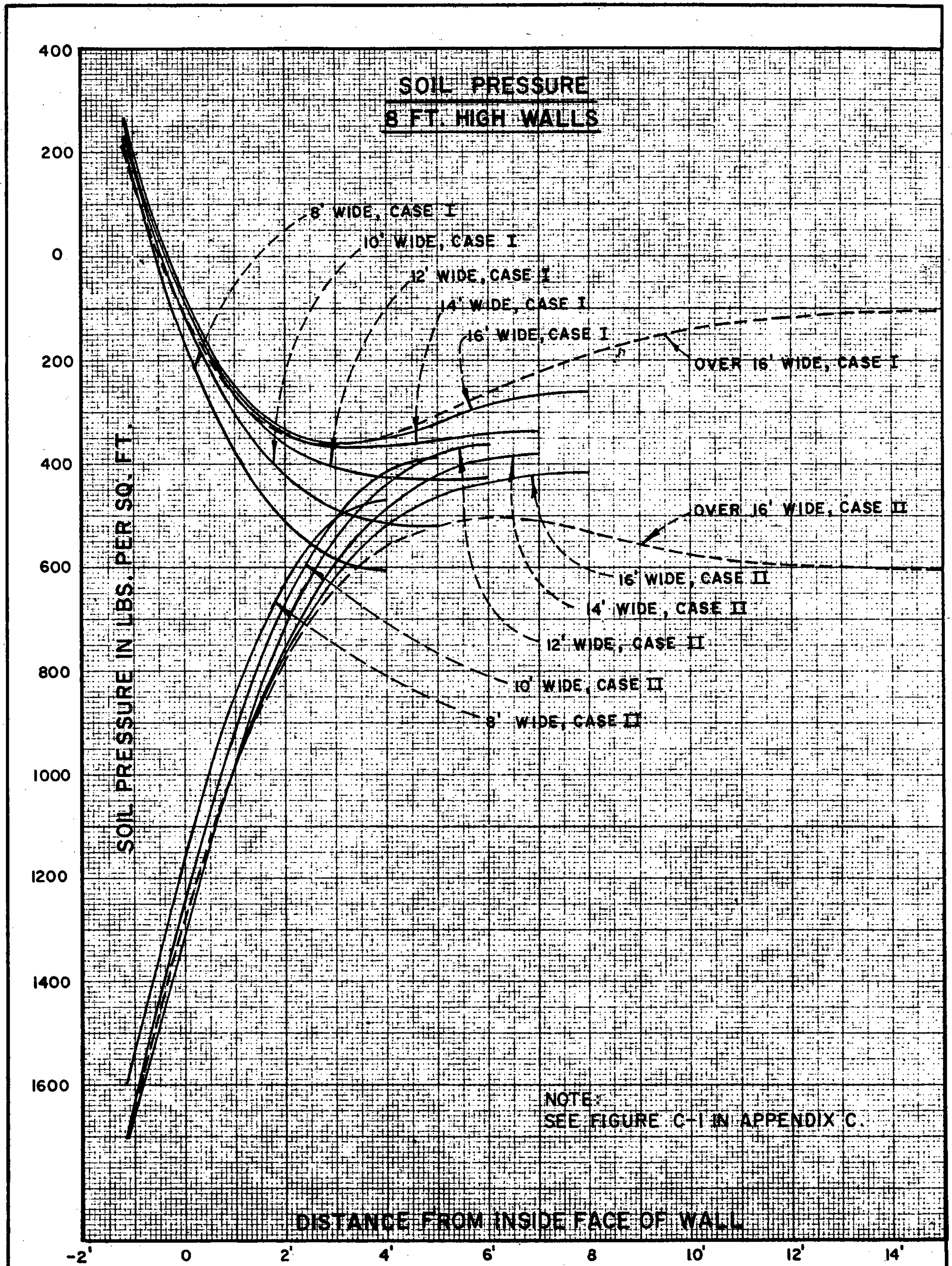
b = 0' - 10'	flat
b = 11' - 20'	drop = 2"
b = 21' or greater	drop = 3"



Reference: Structural Design Manual Los Angeles County Flood Control District, 1964	Ventura County Flood Control District DESIGN MANUAL DESIGN OF FLOOR SLABS IN RECTANGULAR CHANNELS	Figure 423.21(a)



Reference:	Ventura County Flood Control District DESIGN MANUAL	Figure
Structural Design Manual Los Angeles County Flood Control District, 1964	DESIGN OF FLOOR SLABS IN RECTANGULAR CHANNELS	423.21(b)

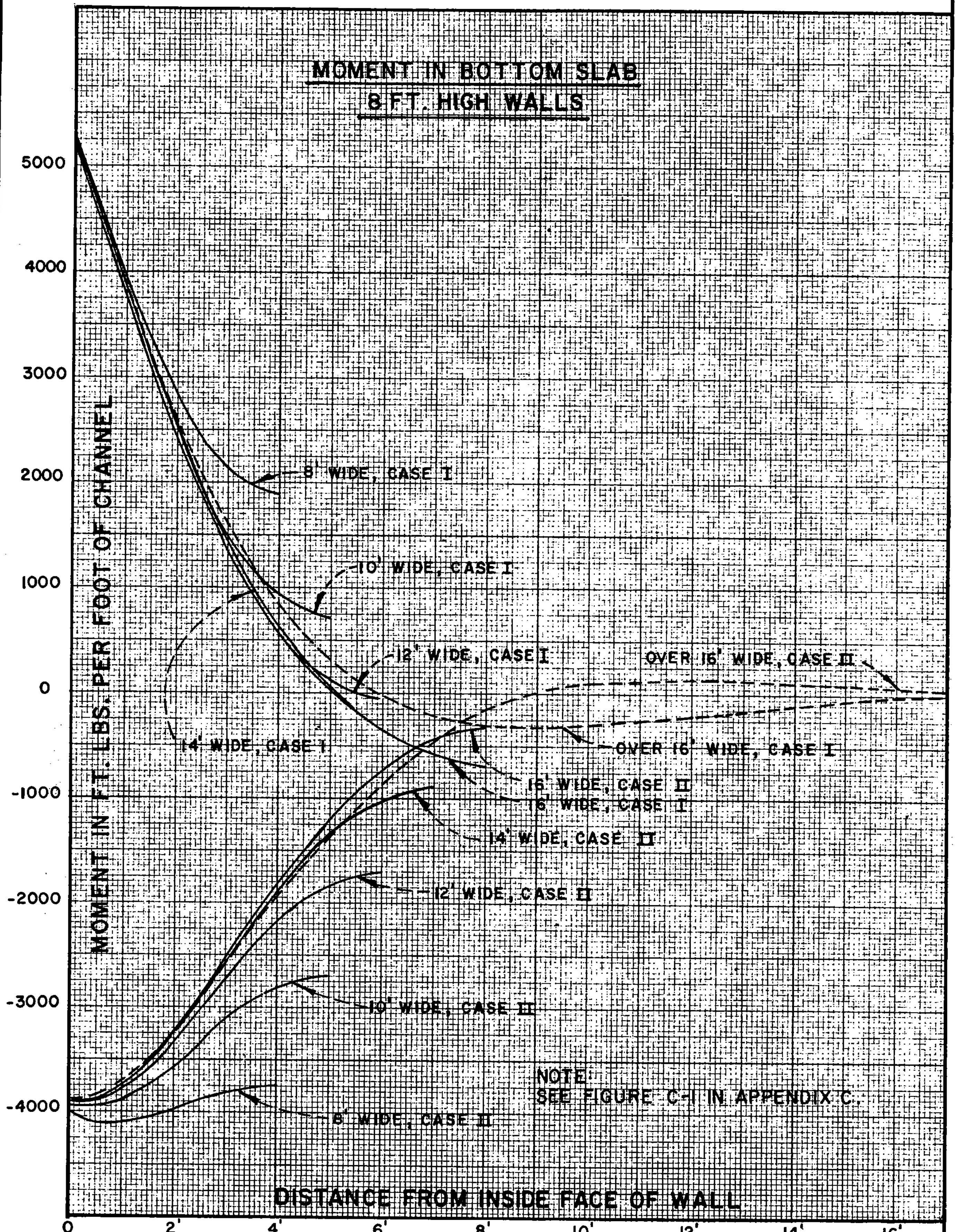


Reference:
Structural Design Manual
Los Angeles County Flood
Control District, 1964

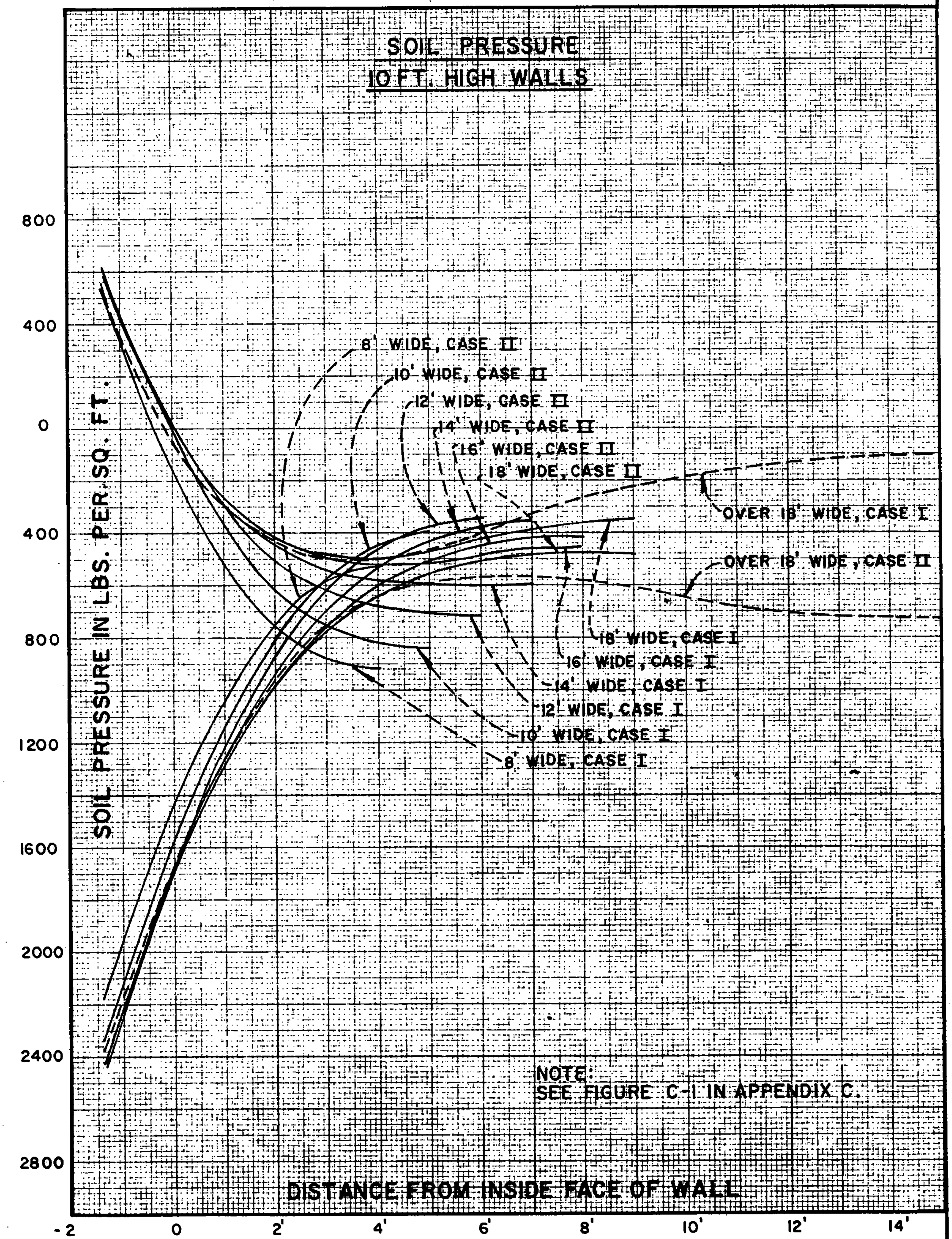
Ventura County Flood Control District
DESIGN MANUAL

DESIGN OF FLOOR SLABS IN
RECTANGULAR CHANNELS

Figure
423.21 (c)



Reference: Structural Design Manual Los Angeles County Flood Control District, 1964	Ventura County Flood Control District DESIGN MANUAL DESIGN OF FLOOR SLABS IN RECTANGULAR CHANNELS	Figure 423.21 (d)

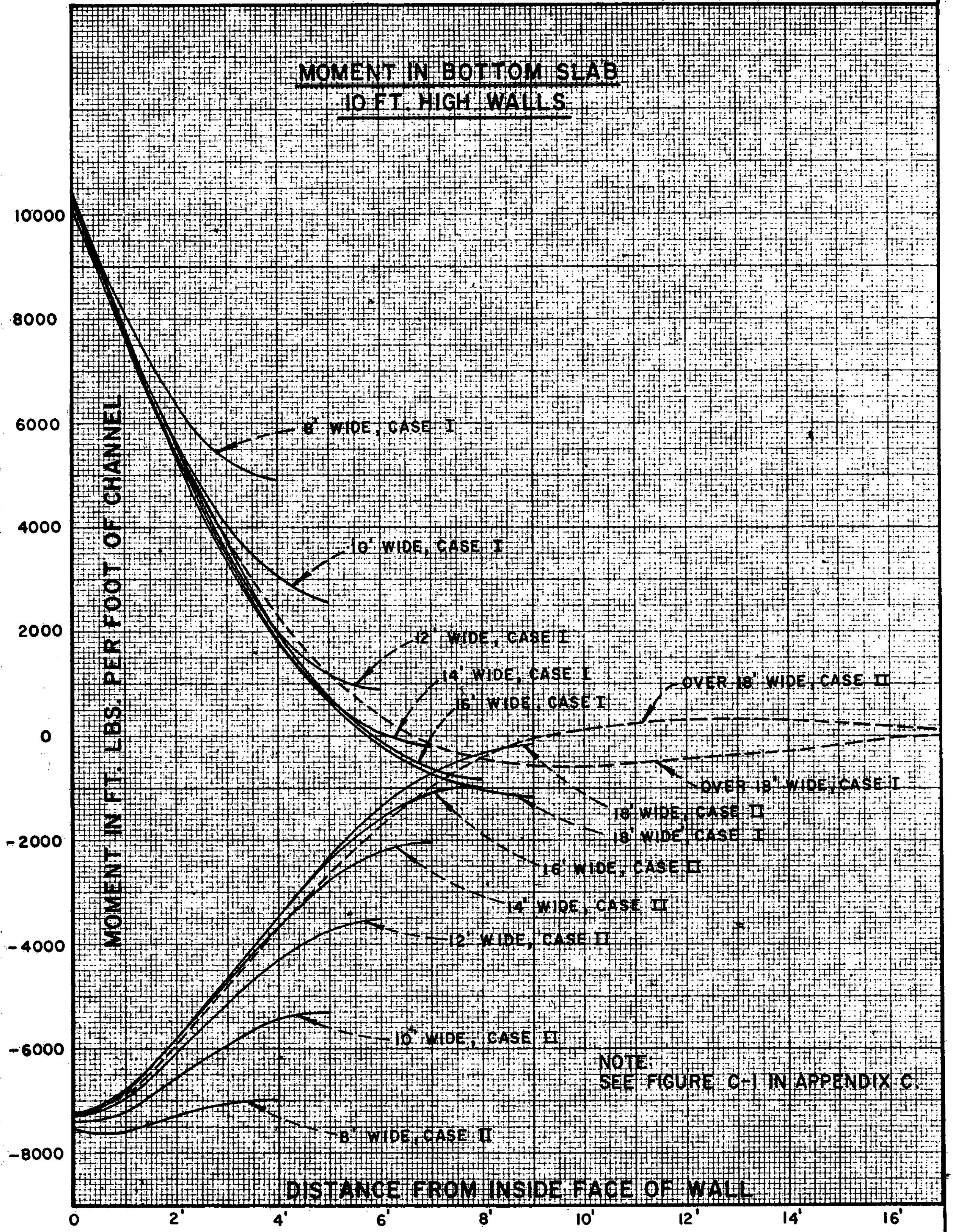


Reference :
Structural Design Manual
Los Angeles County Flood
Control District, 1964

Ventura County Flood Control District
DESIGN MANUAL

DESIGN OF FLOOR SLABS IN
RECTANGULAR CHANNELS

Figure
423.21(e)

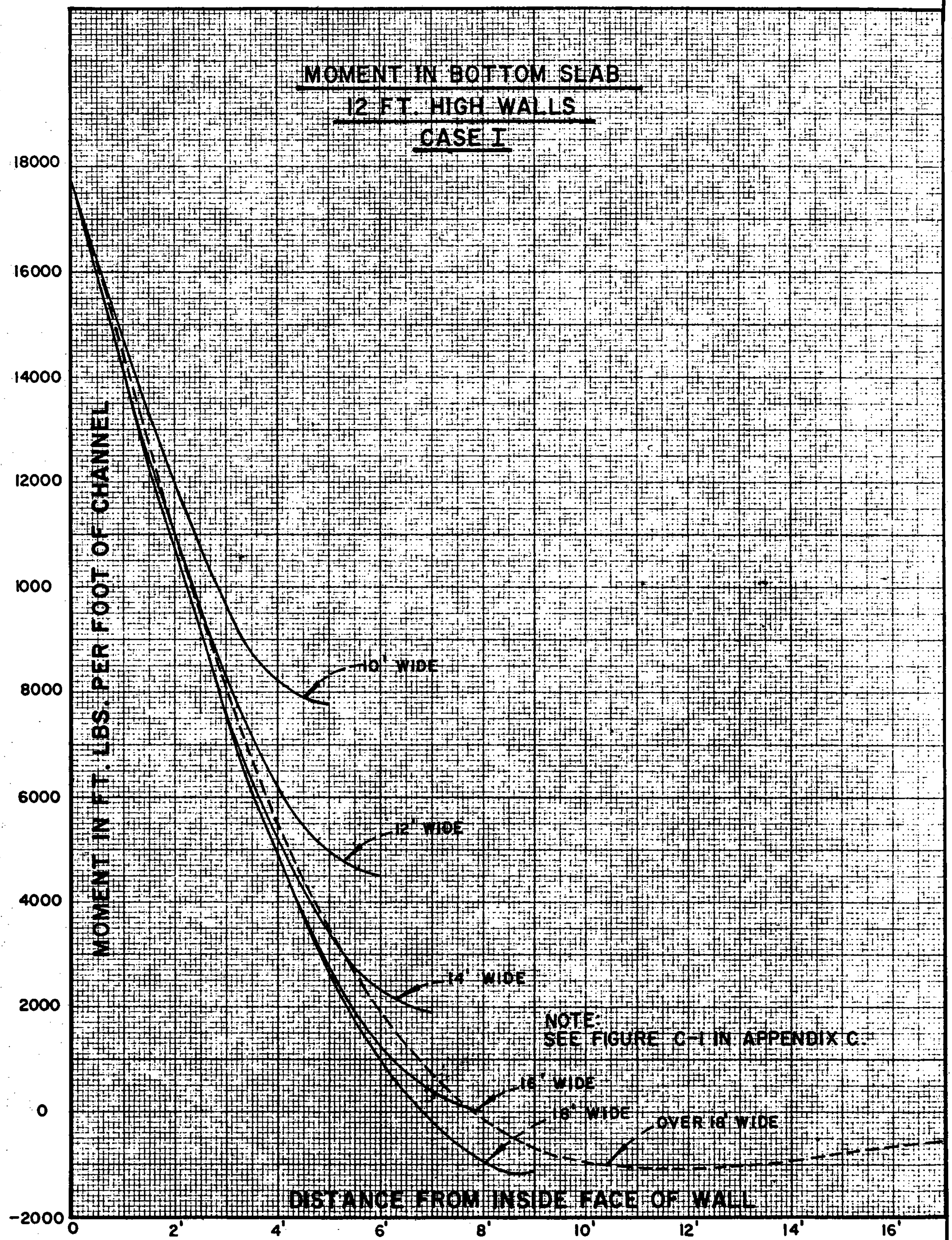


Reference:
Structural Design Manual
Los Angeles County Flood
Control District, 1964

Ventura County Flood Control District
DESIGN MANUAL

DESIGN OF FLOOR SLABS IN
RECTANGULAR CHANNELS

Figure
423.21(f)

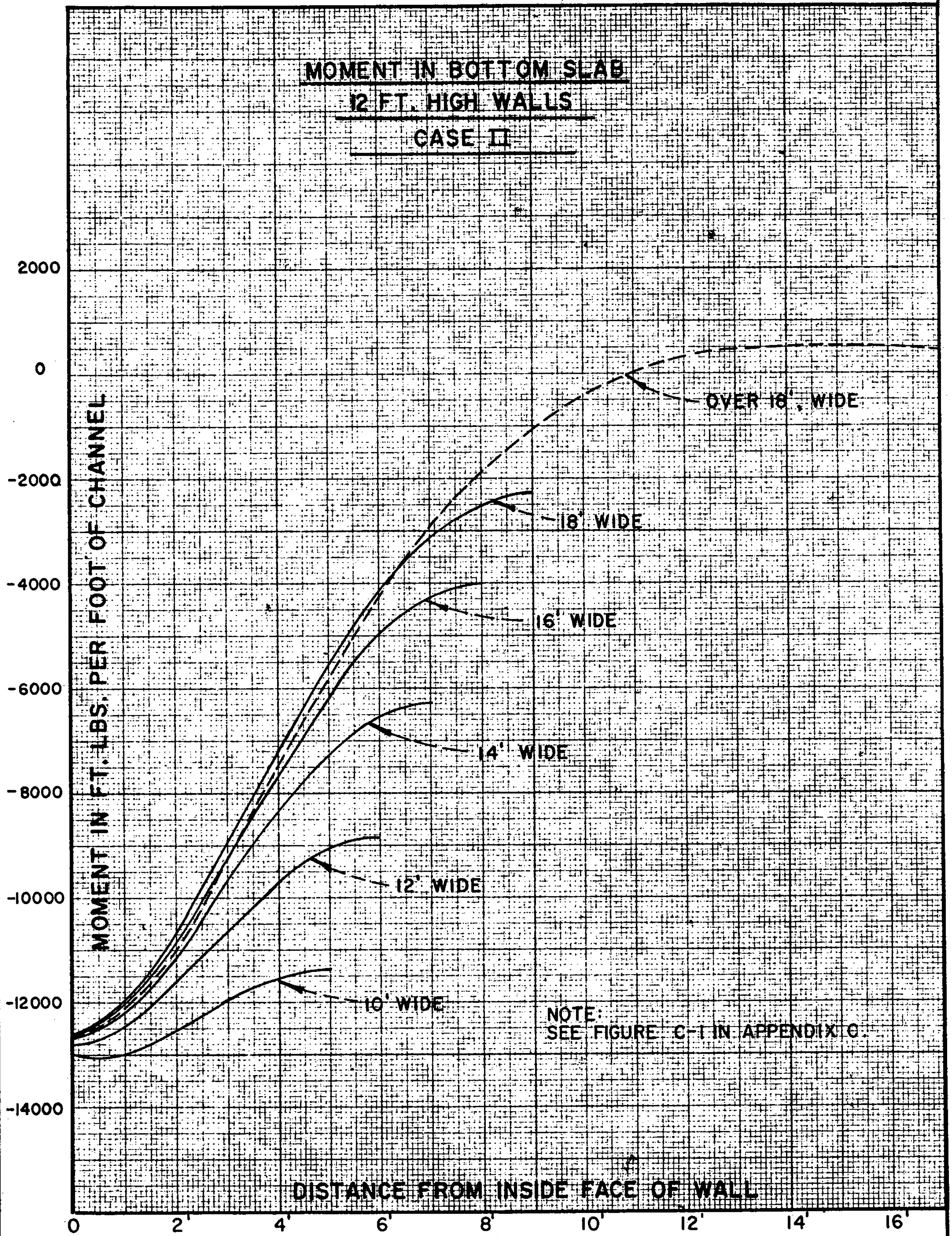


Reference :
Structural Design Manual
Los Angeles County Flood Control District, 1964

Ventura County Flood Control District
DESIGN MANUAL

DESIGN OF FLOOR SLABS IN RECTANGULAR CHANNELS

Figure
423.21(g)



Reference: Structural Design Manual Los Angeles County Flood Control District, 1964	Ventura County Flood Control District DESIGN MANUAL	Figure
	DESIGN OF FLOOR SLABS IN RECTANGULAR CHANNELS	423.21(h)

The earth face of the floor slab shall be sloped to provide the required thickness at the inside face of the wall and at the center of the slab.

425. CONSTRUCTION JOINTS

Construction joint details shall be shown on project drawings.

.10 *LONGITUDINAL OONSTRUCTION JOINTS*

.11 *Wall Joint* - Longitudinal wall joints shall be optional roughened or keyed joints, and shall be located 0 to 8 inches above the top of the invert slab, at contractor's option. However, the longitudinal wall joints located at the base of the wall shall always be formed.

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.12 *Floor Joints* - Longitudinal floor joints shall be formed with keys 1 inch deep and one-third of the slab thickness in width centered in the invert slab. The central invert connecting slabs shall be dowelled to wall bases with a minimum of #4 at 12 inches by 4 foot dowels. If the channel is subject to the action of sea water, the joints shall be sealed with epoxy.

.20 *TRANSVERSE CONSTRUCTION JOINTS*

Transverse construction joints shall be provided in the walls and floor of open channels. Transverse joints in walls and slabs shall be in the same plane, except where floor joints are not required, as specified below. Where floor joints are not specified, tooled contraction joints shall be provided in the same plane as the wall joint. Contraction joint shall be 3/8 inch wide and extend a minimum of 1 inch into the slab. All transverse construction joints shall be painted with a tack coat of asphalt paint. Reinforcing steel shall not be continuous through the construction joints.

.21 *Wall Joints* - Vertical wall joints shall be spaced at intervals not exceeding 50 feet and not less than 10 feet.

.22 *Floor Joints* - Transverse floor joints shall be spaced at intervals not exceeding those indicated below, and not less than 10 feet:

b = 0' - 10'	none
b = 11' - 20'	spacing = 100'
b = 21' or greater	spacing = 50'

426. SECURITY FENCING

.10 OPEN CHANNELS

Standard District security fences shall be constructed along all rectangular open channels and shall be located a minimum of 6 inches inside the right of way line. Standard vehicular gates shall be provided at all intersections of the access road with public roads. Standard commercial type driveways shall be provided wherever the intersection street is paved and has a curb and gutter.

427. ACCESS

Normal channel design shall provide for an access road at the level of the top of the channel walls. If a cut slope is provided between the access road and channel wall, it shall be located a minimum of 1 foot away from the outside edge of the wall. Cut slopes shall have a maximum slope of 2:1.

The surface of the access road shall be paved with 4 inch aggregate base, or 4 inch aggregate base and oil penetration treatment, depending on the ability of the soil to bear traffic in a saturated condition. Prior to paving of the access road, the entire right of way shall be treated with soil sterilants in accordance with District requirements.

A minimum channel width of 8 feet shall be maintained whenever economically feasible to allow for access in the channel for maintenance purposes. Access ramps shall be sloped down in the direction of the flow and shall have a grade not exceeding 10%. The junction of the access ramp to the channel shall consist of a curved section with a minimum outside radius of 40 feet.

The need for access ramps shall be determined by the District.

430. BOX CONDUITS

431. ECONOMY OF DESIGN

Careful economic studies shall be performed in the preliminary engineering stage of a project to determine the need and justification for a box conduit, and the benefit derived by substituting the box conduit for an open channel.

.10 HEIGHT TO WIDTH RATIO

A curve, "Concrete Quantity Comparison Curve for Box Conduit Section", Figure 431.10, is included as an aid to determine the most economic ratio of height to width, based on volume of concrete. When topography and hydraulic conditions allow, it will be attempted to use the most economical section.

.20 MAXIMUM SPAN

Where the clear span of box culverts exceeds 16 feet, a cost study should be initiated to determine the advisability of using additional cell(s) with shorter span.

432. METHOD OF DESIGN

Box conduits shall be designed for the dead weight of the structure, and vertical and horizontal earth loads together with the combination of live load and impact that produce the greatest stresses in the various parts of the structure. See Figure 433.00 for standard loading conditions.

Box conduits shall be designed as rigid frames. In analysis where the members are assumed to be of constant cross-section, the stiffness of the invert slab shall be calculated using the thickness at the center of the span. Where nominal haunches or fillets are used in construction of the conduit, they shall be neglected in all phases of the design, such as in calculating unit shear, bond, area of steel and stiffness of members. In large structures where structural considerations indicate substantial haunches are required, they may be considered in the design.

Where box conduits are of relatively short length, such as are used for channel crossings, and the centerline of the roadway is not normal to the centerline of the channel, a skew analysis shall be made.* The angle of skew is defined as the angle between a line perpendicular to the roadway centerline and a line parallel to the supporting walls.

Edge beams shall be provided at the termination of all cast-in-place box conduits.

Where a large portion of a structure is poured at one time, consideration should be given to utilization of details that will prevent shrinkage stresses. The effects of shrinkage may be greatly reduced by leaving a small portion at the center span for a later pour.

Where the structure is subject to unbalanced lateral load, a sideway analysis shall be required.

433. DESIGN LOADS

Loads used in the design of box conduits shall be in accordance with the following criteria. Refer to Figure 433.00.

.10 *HORIZONTAL LOADS*

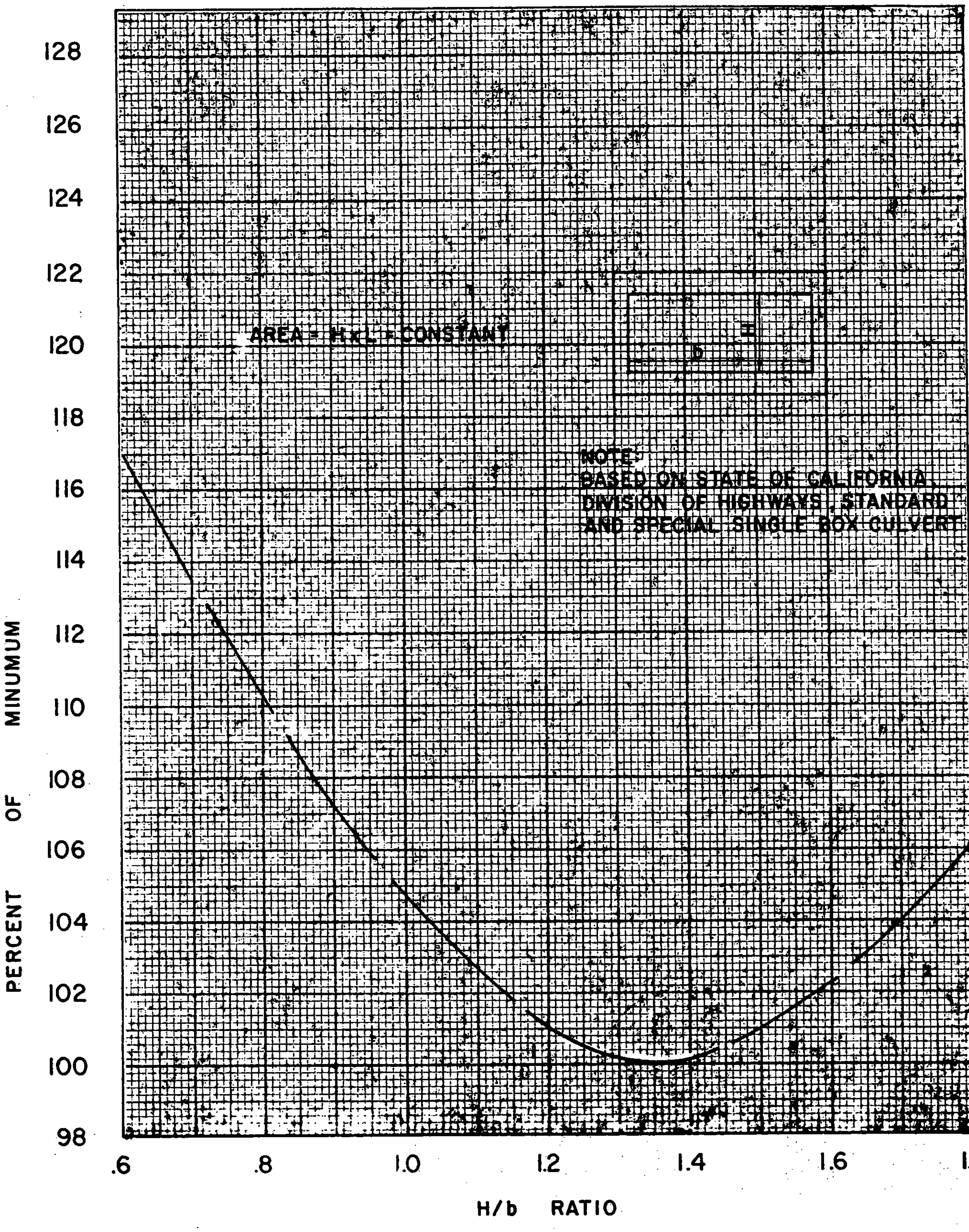
.11 *Dead Load* - Box conduits shall be designed for active horizontal earth pressure of 36 psf equivalent fluid pressure. For extreme conditions of saturation, or when soils tests indicate considerable variation, the lateral earth pressure shall be computed in accordance with acceptable methods. Horizontal loads due to existing structures shall be considered in the design of box conduits, however, no provision shall be allowed for support of future structures, such as buildings, abutments, footings, etc. without prior approval by the District.

.12 *Live Load* - Up to 8 feet of cover, a minimum live load surcharge of two feet distributed uniformly on the earth surface over and adjacent to the conduit shall be used in determining the lateral loading due to live loads, except when located adjacent to the railroads, in which case railroad loading shall be used. The 8 feet of cover does not apply to railroad loading.

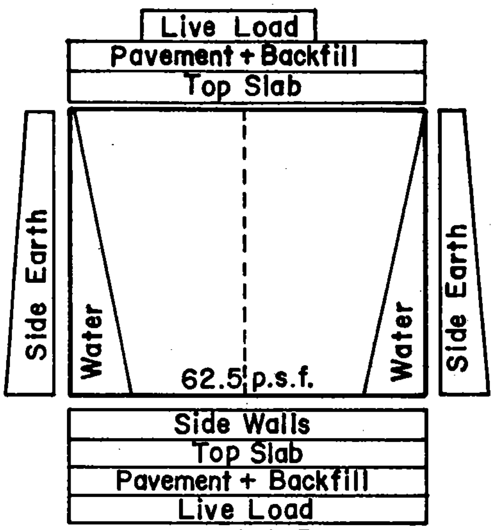
.20 *VERTICAL LOADS*

.21 *Dead Load* - Vertical dead load shall consist of the weight of part of the structure considered, any other structure exerting a vertical load and the weight of the over-burden soil. Unit weight of concrete shall

* *Reference 18*

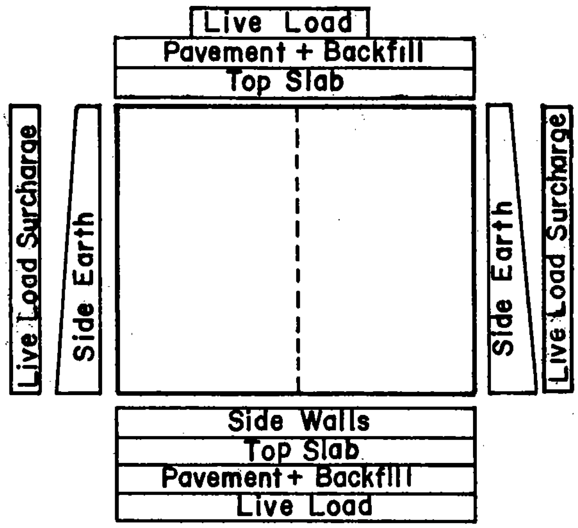


Reference:	Ventura County Flood Control District DESIGN MANUAL CONCRETE QUANTITY COMPARISON CURVE FOR BOX CONDUIT SECTION	Figure: 431.10



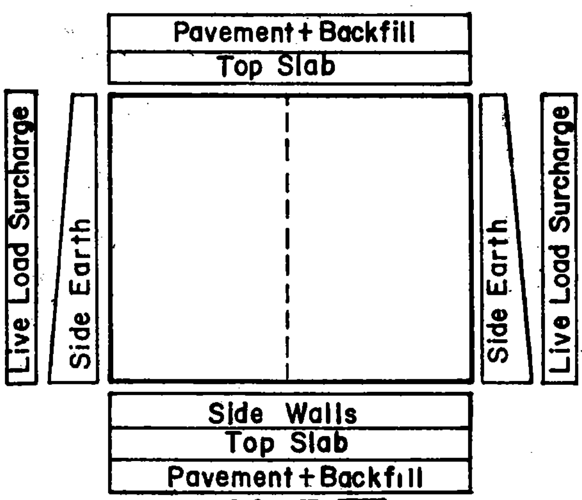
CASE I

Max. (+) Moment, Top And Bottom Slabs
Max. (-) Moment, Side Walls



CASE II

Max. (-) Moment Corners
Max. Shears



CASE III

Max. (+) Moment, Side Walls

Reference : Structural Design Manual Los Angeles County Flood Control Dist.	Ventura County Flood Control District DESIGN MANUAL **STANDARD LOADING CONDITIONS FOR BOX CONDUITS**	Figure 433.00

be 150 pcf. 120 pcf shall be used for the weight of the overburden soil, in accordance with A.A.S.H.O. 1.2.2.

The weight of the earth shall be taken at 70% of the actual weight, in accordance with A.A.S.H.O. 1.2.2.(A).

.22 *Live Load* - Except where passing beneath railroad tracks, public roads and access roads to commercial or industrual sites, box conduits shall be designed for HS15-14 truck loading in accordance with the requirements of the Standard Specifications for Highway Bridges, A.A.S.H.O.

Box conduits constructed under existing or proposed public roads shall be designed for HS20-44 truck per lane.

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Box conduits passing under railroads shall be designed in accordance with A.R.E.A. specifications and the particular railroad. Cooper Loading E72 shall be used for all Southern Pacific Railroad crossings.

Vertical live loads shall be distributed in the box conduit in accordance with the following criteria:

a. Top Slab - Where the earth cover is 1'-11" or less, the wheel load per foot width of slab shall be distributed over a width E=4+.06S, regardless of whether the main reinforcing is parallel or perpendicular to traffic, see A.A.S.H.O. 1.3.2. The bending moment shall be computed using the concentrated load as computed from above. Where the depth of fill is over 2 feet, but not greater than 8 feet or the span length, concentrated loads shall be considered as uniformly distributed over a square, the sides of which are equal to 1.75F, in accordance with A.A.S.H.O. 1.3.3. In the above equations

   S = Effective Span Length

   F = Depth of Fill

   Impact shall be provided in accordance with A.A.S.H.O. 1.2.12.

b. Bottom Slab - Wheel loads on the bottom slab shall be distributed uniformly in the longitudinal direction over a length, 1.75F + H, but not less than the distribution width on the top slab. H is height of box from invert at base of wall to soffit.

In the transverse direction, the wheel loads shall be distributed over the outside width of the box conduit, B_c, when $B_c \geqslant 1.75F$. However, when $B_c < 1.75F$, only that portion of the distributed load that falls within the limits of B_c at the top of the box shall be distributed in the bottom slab. Impact due to live load shall not be distributed to the bottom slab.

For all loading conditions whether main reinforcing is parallel or perpendicular to traffic, consideration shall be given to overlap of the distributed loads in both the top and bottom slabs, as specified in A.A.S.H.O. 1.3.3.

.30 *INTERNAL WATER PRESSURE*

Internal water pressure shall be calculated for the conduit flowing just full in combination with other loading conditions at standard allowable unit stresses. An additional structural analysis shall be made if the hydraulic gradient is above the top of the conduit. The analysis shall be made using the pressure due to the hydraulic load from the soffit of the conduit to the gradient in addition to other loadings, assuming the conduit flowing just full. The hydraulic gradient shall be assumed at the maximum elevation possible.

.40 *CONSTRUCTION LOADS*

Structures shall be checked for loads sustained during construction. Construction loads heavier than legal load shall not be permitted until concrete has reached a strength of 3,000 psi and structure has been strutted and cushioned as directed by the District.

434. STRUCTURAL SECTION

.10 *STEEL CLEARANCE*

Steel clearance shall be shown on the project drawings from the edge of the bar to the face of the concrete. Said clearance shall not be less than the following distances:

Top slab and side walls, inside and outside	- 1½ inches
Top of invert slab	- 2 inches for velocities less than 15 fps
	2½ inches for velocities of 15 fps or greater
Bottom of invert slab	- 3 inches

Where concrete is subject to the action of sea water, harmful ground water, etc., an additional cover of ½ inch shall be provided.

Structures subject to harmful industrial wastes may require the use of special cement.

.20 *LONGITUDINAL REINFORCEMENT*

Longitudinal reinforcement shall consist of #4 bars at 18" o.c. in each face of slabs and walls except when analysis of the box conduit indicates otherwise, but shall not be less than #4 bars at 18" o.c. Longitudinal reinforcement shall be continuous through joints.

.30 *REINFORCEMENT PATTERN*

In general, transverse reinforcement for single 140
barrel boxes should consist of straight bars in the inner faces of the top and bottom slab and side walls, L-bars running from the outer face of the top slab into the outer face of the side walls and resting on the bottom construction joint and lapping with L-bars continuing into the outer face of the bottom slab. Alternate top L-bars should be cut off if possible. An optional lap may be used at the base of the wall for the lapping of the L-bars. Bars shall generally be spaced on a common spacing or a multiple thereof, but nonuniform spacing may be used if economy is thereby affected.

.40 *THICKNESS OF MEMBERS*

The minimum thickness of vertical walls shall be eight inches where two curtains of steel are used and six inches where one curtain is used.

.50 *DISTRIBUTION REINFORCEMENT*

Distribution reinforcement shall be placed in the bottom of all slabs in accordance with the provisions of A.A.S.H.O. 1.3.2 (E).

.60 *FILLETS*

Fillets shall be placed at the junction of vertical walls and top slab. These fillets shall be a minimum of 3/4 inches.

.70 TRANSVERSE SLOPE OF INVERT SLAB

A transverse slope shall be provided in all single and multi-barrel box conduits. The criteria presented in 424.40, "Transverse Slope of Invert Slabs, Rectangular Open Channels", shall be applied, using the equivalent open channel width for single or multi-barrel box conduit.

.80 DESIGN TABLES FOR REINFORCED CONCRETE BOX CONDUITS

Ventura County Standard Drawings, "Standard Box Culverts", may be used for design as long as the loading conditions correspond to those discussed herein above. The design is based on A.A.S.H.O. "Standard Specifications", 1957, for main reinforcing parallel to traffic and shall not be used for other conditions without a check. If concrete thicknesses are increased because of high velocity, sea water, etc., the lengths of the reinforcing bars, and concrete and steel quantities indicated in the tables must also be correspondingly increased. 142

A structural detail of the box conduit shall be shown on the project drawings, reference to standards shall not be acceptable.

435. JOINTS

.10 CONSTRUCTION JOINTS

.11 Longitudinal - The bottom wall joint shall be located 0 to 8 inches, at the contractor's option, above the top of the invert slab. Longitudinal construction joints at the bottom of the vertical exterior walls shall be formed into keys 1½ inches deep and one third of the wall thickness in width centered into the wall, unless a starter wall is used, in which case the joint shall be roughened. The longitudinal construction joint at the top of walls shall also be roughened. Longitudinal construction joints at the top and bottom of vertical interior walls of multi-barrel box conduits shall be roughened joints without keys. If the box conduit is designed to withstand pressure load, water stops shall be incorporated in the construction joints, and a special joint detail shall be required.

.12 *Transverse* - Transverse construction joint shall be located at all transitions, changes in cross section, connection of old and new construction, and end of pours. Longitudinal reinforcing shall be continuous through the transverse construction joints.

If the box conduit is subject to the action of sea water, the construction joints must be sealed with epoxy. If the box conduit is designed to withstand pressure head, water stops shall be incorporated in the construction joints. Special longitudinal and transverse construction joint details will be required.

436. ACCESS STRUCTURES

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Access shafts or manholes shall be provided in box conduits at minimum intervals of 500 feet and at all street crossings. Access shaft shall meet minimum requirements of District Standards.

The District reserves the right to require vehicle access structures to permit the entrance of vehicles and/or equipment into box conduits where the conduit is equal or greater than 8' x 7'. The need for vehicle access structures shall be determined by the District.

In multi-barrel boxes, windows should be placed in interior walls to equalize flows; however the interval shall not exceed 500 feet. Windows shall be 5 feet wide and as deep as possible.

437. PROTECTIVE BARRIERS

Provisions for installation of protective barriers at entrance and exit to box conduits in residential and developed areas shall be made in the design of box conduits. The need for protective barriers shall be determined by the District.

438. PIER EXTENSION WALL

Pier extension walls shall be provided for the center wall at the inlet to multiple box conduits. The pier extension shall have a height equal to the height of the center wall, and shall slope to the channel slab at 3:1 slope. The minimum height of the pier extension shall be 1 foot. Pier extension walls shall be designed as an integral part of the invert slab.

440. REINFORCED CONCRETE PIPE

441. DESIGN OF REINFORCED CONCRETE PIPE 96 INCHES IN DIAMETER AND UNDER *

.10 *METHOD OF DESIGN*

.*11* D-Load = $\frac{\text{(Total Vert. Load per Lin. Ft.)(S.F.)}}{\text{(Internal Diameter) (Load Factor)}}$

Safety Factor (S.F.) = 1.25

Load Factor depends upon bedding conditions and upon whether conduit is in trench or embankment, See Section 441.30.

Specific consideration shall be given to future grade over the pipe when determining the total vertical load.

Variation in D-Load shall be kept to within a reasonable limit in any reach. Minimum length of pipe for any one D-Load shall be 100 feet.

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.*12* The D-Load specified shall be that which will produce a 0.01 inch crack, and shall be shown on the plans as $D_{.01}$.

D-Loads shall be specified on project drawings as follows:

36 inch diameter and under - to next highest 250 of calculated value.

39 to 60 inch diameter - to next highest 100 of calculated value.

63 inch diameter and over - to next highest 50 of calculated value.

.*13* The minimum D-Load specified shall be 800-D, except for:

a. Pipe conduits in State Highways where the minimum value is 1350-D.

b. Pipe conduits supporting railroad loads where the minimum value is 2000-D.

.*14* *Design Procedure* - In each case a detailed design shall be made for particular conditions. In all cases consideration shall be given to

* *Special design will be required for reinforced concrete pipe over 96 inches in diameter. See Reference 3.*

the applicable live load and earth loads, as specified herein. Selection of pipe class based on cover, as provided in references, will not be acceptable. The tabulated information may only be used as a check, see Standard Drawing No. 11.

Concrete Pipe Handbook* by American Concrete Pipe Association or any other acceptable publication may also be used in the design of reinforced concrete pipes. Reinforced concrete pipe shall meet the requirements of A.S.T.M. Designation: C76.

.20 *VERTICAL LOADS* 146

.21 *Live Load*

a. Highway Loading

Pipe conduits shall be designed for one HS20-44 truck per lane. The wheel loads shall be distributed through the fill to the top of the pipe as follows:

Transverse (with reference to truck) spread of wheels = 1.2 + 1.6F

Longitudinal (with reference to truck) spread of wheels = 1.5 + 1.5F

Where F = depth of fill over top of conduit in feet.

1. Truck loads on pipe conduits for covers of 10 feet and less are as follows:

TABLE OF VERTICAL LIVE LOADS

Table 441.21

Cover "F" Feet	Wheel Load Kips	L. L. Pressure PSF
1	20.8	2480
2	19.2	970
3	17.6	489
4	16.0	314
5	16.0	234
6	16.0	182
7	16.0	145
8	16.0	119
9	16.0	102
10	16.0	90

These values include the effect of over-lapping wheel loads, and also

*Reference 14

the effect of impact: 30% for F=1 ft., 20% for F=2 ft., 10% for F=3 ft.

2. For covers exceeding 10 feet, the effect of truck loads shall be assumed to be negligible.

b. Railroad Loading

Cooper Loading E72 shall be used for the design of all conduits crossing the Southern Pacific Railroad.

.22 *Earth Load*

a. General

Pipe shall generally be designed for the applicable condition of trench, negative projection or positive projection, as
147 specified in Reference 14.

b. Design Value

The trench width B_d used in the design shall be indicated on the plans as the maximum allowable width of trench. See Standard Drawing No. 11 for maximum allowable trench width.

Where pipe is laid in heavy clay-type soils, higher unit soil weights and a smaller value of sliding friction greatly increase soil loads. Saturation from flooded backfill or ground water further increases loads. Therefore, the design unit soil weight shall be increased where soil analysis and judgement so indicate.

Pipe laid in sand having low cohesive values, particularly dune or beach sand, shall be designed for the Positive Projection Condition or Trench Condition, whichever gives the greater D-Load value.

c. Jacking Condition

The design unit weight of earth for jacked-in-place pipe 96 inches in diameter or under shall be 110 pcf, unless soil investigation at the site discloses material of a greater weight.

1. Where the depth of cover is 15 feet or less, it is considered that the prism of soil above the pipe may be caused to settle downward by traffic vibrations,

climatic variations, etc. to such an extent that the load on the pipe will be essentially equal to that for the Trench Condition, except that the width factor, B_d, is assumed to be the outside diameter of the pipe.

2. Where the depth of cover exceeds 15 feet, the effect of the live load is negligible and the supporting effect of the cohesion of the overburden soil as well as the soil friction may be considered. For this condition the following modification to the formula for Trench Condition is used.*

$$W = C_d . w . B_d^2 - 2C_d . B_d . c$$

Where: C_d = Load Coefficient for trench conduit**

c = Cohesion of overburden soil

RECOMMENDED VALUES OF
COHESION (c) FOR VARIOUS SOILS

Table 441.22

Material	Cohesion Lb. per Sq. Ft.
Clay, very soft	40
Clay, medium	250
Clay, hard	1,000
Sand, loose dry	0
Sand, silty	100
Sand, dense	300
Top Soil, saturated	100

.23 *Other External Loads* - Vertical loads due to existing or proposed structures, such as buildings, abutments, etc., shall be considered in the design.

.24 *Critical Loading Condition* - Pipe designs based on the maximum amount of earth fill plus live load are not always the critical loading condition; the minimum amount of fill plus live load may be the control.

.30 LOAD FACTOR

.31 *Trench Condition and Negative Projection Condition* - Use load factors corresponding

*Reference 17
**Reference 14

to desired bedding condition per Standard Drawing II. The ordinary condition is Type II bedding with consolidated fill to 90% relative density around pipe: Load Factor = 1.9.

.32 *Embankment or Positive Projection Condition*-Load factors shall be determined using the following equation:

Spangler's Formula: $L_f = \frac{1.431}{N - xq}$

Where: L_f = Load Factor

N = .707, Type II bedding, consolidated soil at 90% relative density around pipe.

= .505, where concrete cradle is used.

149 x = A factor which is a function of the area of the vertical projection of the pipe in which the active lateral pressure of the fill material acts.

Projection Ratio, p	Value of x
0	0
0.3	0.217
0.5	0.423
0.7	0.549
0.9	0.655
1.0	0/638

q = The ratio of the total lateral pressure to the total vertical load.

$$= \frac{pK}{C_c} \left(\frac{F}{B_c} + \frac{p}{2} \right)$$

Where: K = The ratio of active lateral pressure to vertical pressure in Rankine's Formula. May ordinarily be taken as 1/3.

B_c = Outside diameter of pipe.

C_c = Load Coefficient*

p = The projection ratio

* *Reference 14 & 17*

.33 *Jacking Condition* - Assume Type II bedding with load factor = 1.9.

.40 *STEEL CLEARANCES*

Ordinarily, it is not necessary to call out steel clearances on D-Load pipe. However, where velocities exceed 20 fps, the concrete cover on the inside face of the pipe must be increased 1/2 inch. If the pipe is subject to the action of sea water or harmful ground water, an additional 1/2 inch of cover on the inside or outside face is required. Pipes subject to harmful industrial wastes may require additional cover. These increases are accumulative. The amount of additional cover needed, and the locations of the pipes affected shall be noted in the Special Provisions Section of the detailed specifications, and on the plans. Type of cement used may also be specified. Harmful waste may require cement type other than Type II cement.

.50 *PIPE TO BE JACKED* 150

The design of pipe to be jacked shall be based on super-imposed loads and not upon loads which may be placed upon the pipe as a result of jacking operations. Any increase in pipe strength required in order to withstand jacking loads shall be the responsibility of the contractor.

In general, the jacking of pipe conduits should not be specified where the cover is less than 6' - 0".

.70 *RUBBER GASKET JOINT PIPE*

Rubber gasket joint pipe should be used when:

1. The pipe conduit is under substantial pressure head.

2. Pipe conduits, which outlet to pump stations, are placed in sandy soil and there is a possibility of sand infiltrating into the pipe through the joints.

3. There is a possibility of the pipe conduit deflecting due to settlement, as in the case of a future freeway fill being placed over the pipe.

It is requested that the District be consulted prior to the start of detailed design.

450. TRAPEZOIDAL OPEN CHANNELS

451. GENERAL

The use of trapezoidal channels shall be discussed with the District before detailed designs are started. Since trapezoidal channels require considerably more right of way, extensive maintenance, and cannot be readily covered, the use of trapezoidal channels in Flood Control projects is not favored.

452. REINFORCED CONCRETE TRAPEZOIDAL CHANNELS

.10 METHOD OF DESIGN

All reinforced concrete trapezoidal channels shall be lined with cast-in-place concrete and shall consist of an invert slab, side slope lining and a beam section at the top of the side slopes. Air blown mortar is permitted only for warped transition walls. A minimum acceptable channel section is shown on Standard Drawing No. 12.

.20 DESIGN LOADS

Horizontal and vertical loads used in the design of trapezoidal open channels shall be in accordance with the following criteria:

.21 Horizontal Loads - Channel walls shall be designed to sustain the entire lateral pressure in shear and 50% of the resultant moment at the base of the side slopes. The lateral pressure shall be computed on the vertical projection of the side slope walls. The lateral pressure shall include an equivalent fluid pressure of not less than 40 psf, live load and loads due to sloping surcharge. Except when located adjacent to railroad tracks, the live load shall consist of a minimum of 2 feet of surcharge distributed uniformly on the grade adjacent to the side slope walls. Surcharge due to railroad shall be determined using E72 loading applied adjacent to the walls. Surcharge due to sloping backfill may be computed from Figure 423.11(a).

.22 Vertical Loads - Soil and uplift pressures on the invert slab shall be computed considering it as a slab with uniform load applied to it. In designing the invert slab, consideration

shall be given to the weight of the entire structure, however, in computing the uplift forces the weight of the invert slab alone shall be used as a resisting force. See Section 470, "Subdrain Systems".

.30 *STRUCTURAL SECTION*

See Standard Drawing No. 12 for typical section.

.31 *Thickness of Members* - Side slope wall and invert slab shall have a minimum thickness of 6 inches, measured normal to the face of the concrete. For velocity in excess of 25 fps, the thickness of the members shall be increased to 7 inches.

.32 *Reinforcing* - Reinforcing steel in side slope walls and in the invert shall consist of a minimum of #4 bars at 12 inch centers. However, additional reinforcing shall be provided as necessary by the design. A minimum lap of 20 and 30 bar diameters shall be provided in all splices, in longitudinal and transverse reinforcing steel respectively. However, the length of the lap shall not be less than 12 inches.

.33 *Steel Clearance* - Steel clearance shall be shown on project drawings from the edge of the bars to the face of the concrete. Clearance on the earth side shall be a minimum of 3 inches, and not less than 2 inches on the inside face.

.34 *Transverse Slope of Invert Slab* - The drop in the invert slab from the toe of the side slope walls to the center of the channel shall be based on the following criteria:

b = 0' - 10'	Flat
b =11' - 20'	Drop = 2"
b =21' or greater	Drop = 3"

.40 *JOINTS*

.41 *Longitudinal Joints*- Longitudinal keyed construction joints shall be provided at the junction of the side slope walls and the invert slab. The keyed joints shall be 1½ inches deep for the entire thickness of the side slope walls. Transverse steel shall be continuous through the construction joints.

.42 *Transverse Joints*

a. Contraction Joints - Transverse contraction joints shall be spaced at 20 foot intervals in the side slope walls and the invert. Contraction joint shall be 3/8 inch wide for 1/3 of the depth of the member. Longitudinal reinforcing shall extend through the transverse contraction joints. The spacing of transverse contraction joints may be reduced to eliminate proximity to junction structures. Minimum spacing shall be 10 feet.

b. Construction Joints - Transverse construction joints shall be in the same plane in the wall and invert slabs. Longitudinal steel shall be discontinued at the transverse construction joint.

.50 *SUBDRAINAGE*

Reinforced concrete trapezoidal channels are inherently weak against uplift pressures, and require careful investigation of ground water conditions and the need for subdrains. See Section 470, "Subdrain Systems", for discussion of types of subdrains.

453. RIP RAP SLOPE PROTECTION FOR TRAPEZOIDAL CHANNELS

.10 *GENERAL*

Various methods of providing rock rip rap protection on the side slopes of trapezoidal channels are in use. However, the methods acceptable by the District for use as temporary slope protection are (1) dumped rock rip rap, (2) grouted rip rap and (3) sacked concrete rip rap. The term rip rap as used herein is defined as "a layer, facing or protective mound of stones randomly placed to prevent erosion, scour, or sloughing of a structure or embankment; also the stone so used"*. The latter of the two protective methods described above shall generally be used for temporary protection at inlets and outlets of permanently improved conveyance structures. Dumped rip rap slope protection may be used as ultimate improvement for fairly wide major channels on a relatively flat grade. District approval shall be obtained prior to use of rock rip rap trapezoidal

* *Reference 15*

channels for ultimate channels. The invert of rock rip rapped trapezoidal channels shall be designed in accordance with Section 314.10, "Permissible Velocities, Unlined Channels". Typical rock rip rap sections are shown on Standard Drawing Number 13.

.20 *DUMPED ROCK RIP RAP*

.21 *General* - Dumped rock rip rap is graded stone dumped on a prepared slope in such a manner that segregation will not take place. Dumped rip rap shall generally be placed on a filter blanket to form a well graded mass with a minimum of voids.

.22 *Design* - The resistance of dumped stone to displacement by moving water depends upon:

(1) Weight, size, shape, and composition of the individual stones

(2) The gradation of the stone

(3) The depth of water over the stone blanket

(4) The steepness and stability of the protected slope

(5) The stability and effectiveness of the filter blanket on which the stone is placed

(6) The velocity of the flowing water against the stone

(7) The protection of toe and terminals of the stone blanket

The toe and terminals of the bank protection are particularly vulnerable to attack by the current. Flow in curved reaches presents a more severe form of attack than water flowing in a straight reach and shall require heavier protection. As a general rule, the slopes of dumped rock rip rap shall not exceed 2 horizontal to 1 vertical, except in temporary inlet and outlet structures where slope of 1½ horizontal to 1 vertical may be used.

.23 *Size of Stone* - The size of stone needed to protect a side slope from erosion by a current moving parallel to the embankment shall be determined by the use of Figures 453.23(a) and 453.23(b). Size (k) is the diameter, in feet, of a spherical stone that would have the same weight as the 50 percent size of stone. The size of stone shall be found by a trial-and-error procedure which consists of first estimating a stone size.

The mean velocity (V_m) of the stream during the design flood must then be converted to velocity against the stone by use of Figure 453.23(a). The ratio ($\frac{k}{d}$) of the equivalent spherical diameter of the 50 percent stone size to the depth of flow during the design flood shall be computed by using 0.4 of the total depth when the depth of flow exceeds about 10 feet. The reason for this is that use of the total depth would result in a stone size which would be adequate at the total depth, but which might be too light to provide protection near the water surface.

155 With the velocity against the stone (V_s) enter Figure 453.23(b) and read the stone size for the embankment slope. The stone size from Figure 453.23(b) is the 50 percent (median) size, by weight, of a well-graded mass of stone with a unit weight of 165 pounds per cubic foot. If the stone size from Figure 453.23(b) agrees with the assumed stone size, this is the correct size. If not, the procedure is repeated until the assumed size is in reasonable agreement with the size from Figure 453.23(b).

When the unit weight of the stone is other than 165 pounds per cubic foot, the size from Figure 453.23(b) should be corrected.

$$k_w = \frac{102.5\ k}{2 - 62.5}$$

where

k = stone size from Figure 453.23(b)

k_w = stone size for stone of w pounds per cubic feet

The size of stone required to resist displacement from direct impingement of the current as might occur with a sharp change in stream alignment is greater than the value obtained from Figure 453.23(b), a factor of 2 shall be applied to the velocity V_s before entering Figure 453.23(b).

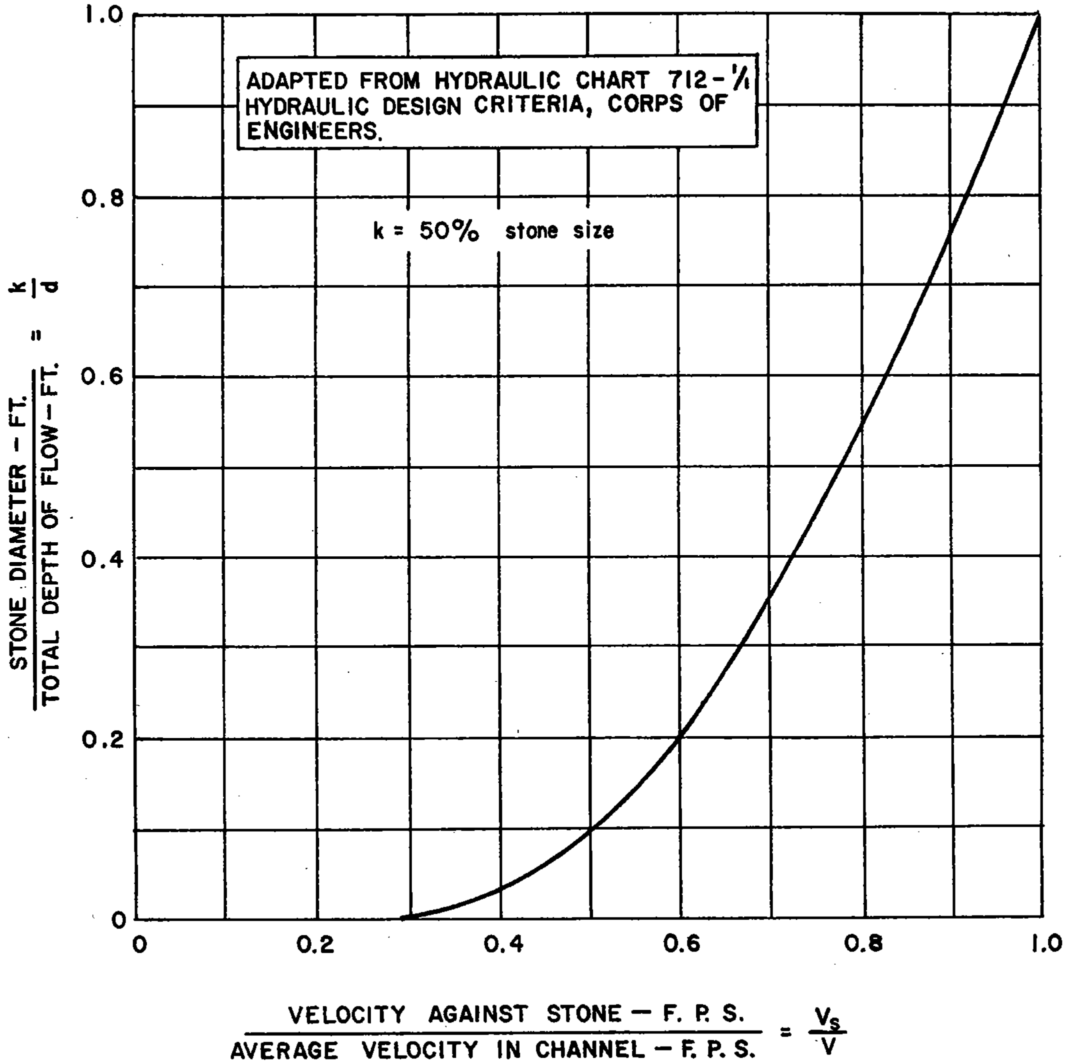

FIGURE 453.23(a) - VELOCITY AGAINST STONE ON CHANNEL BOTTOM *

.24 *Extent of Rock Rip Rap* - The upper vertical limit of the protective cover should extend above design high water. The allowance for freeboard shall be determined as outlined in Section 324.20.

Where the stream channel is composed of sand or silt, bank protection should extend a minimum vertical distance of 5 feet below the stream bed on a continuous slope with the embankment, Standard Drawing 13(a). On the outside of curves or sharp bends, scour is particularly severe, and the toe of the bank protection shall be placed deeper than in straight reaches. Where a toe trench cannot be dug, the rip rap

* *Reference 15*

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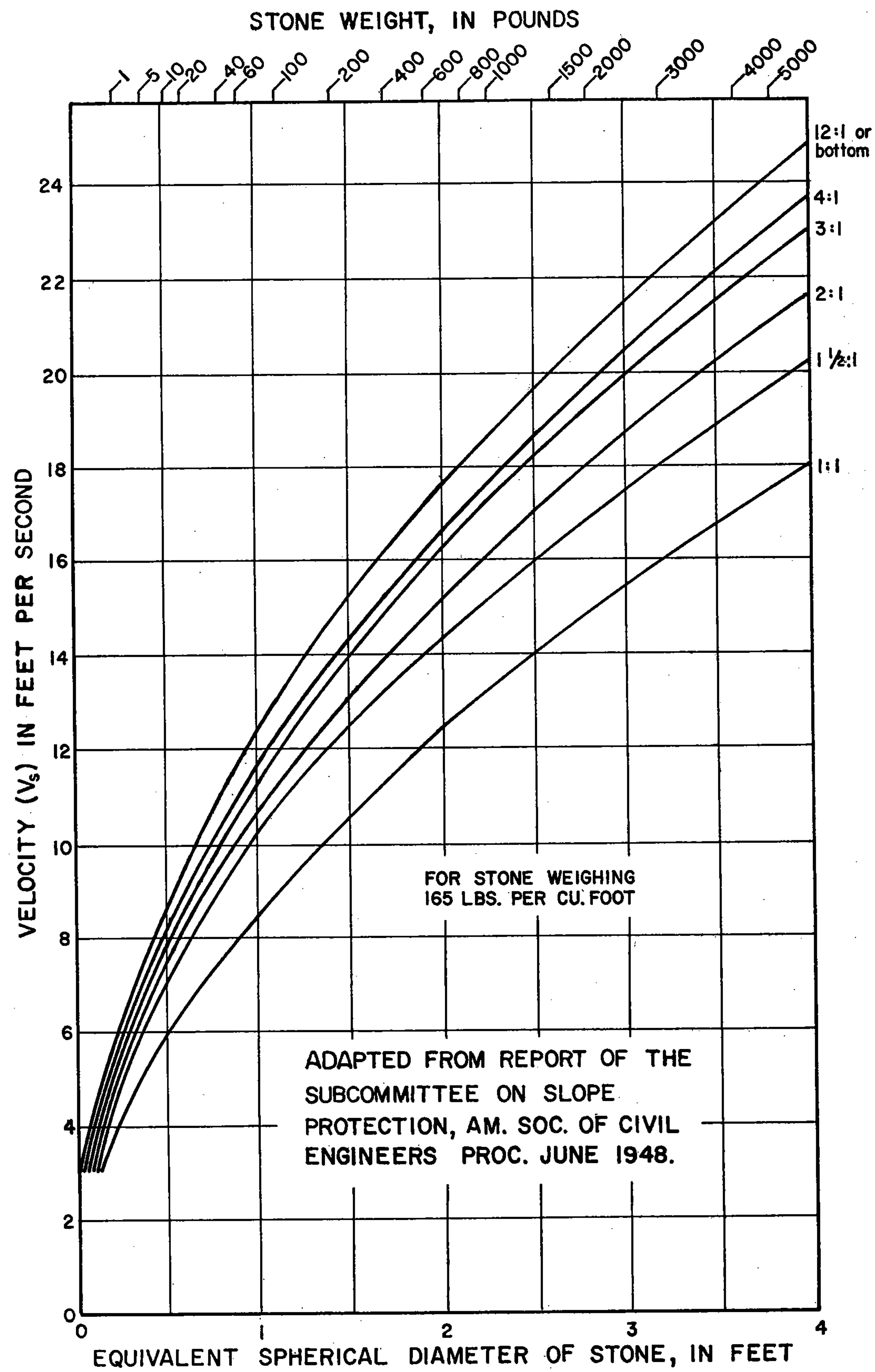

Reference: Use of Riprap for Bank Protection, U. S. Department of Transportation, Bureau of Public Roads. (Hydraulic Engineering Circular No. 11, June '67)	Ventura County Flood Control District DESIGN MANUAL SIZE OF STONE THAT WILL RESIST DISPLACEMENT FOR VARIOUS VELOCITIES AND SIDE SLOPES	Figure 453.23(b)

blanket should terminate in a stone toe at the level of the stream bed (Standard Drawing 13(b)). The toe provides material which will fall into a scour hole and thus extend the blanket. The stone blanket should be keyed into a berm when a toe or toe trench is not provided. The purpose of the toe protection is to prevent undermining, not to support the blanket. Unless the protection has sufficient stability to support itself on the embankment slope, the protection cannot be considered adequate.

The bank protection should extend both upstream and downstream from the point of reverse curvature on the outside of a curved channel. On a straight channel, bank protection should begin and end at a stable feature in the bank 158
if practicable. Such features might be outcroppings of erosion resistant materials, trees, vegetation, or other evidence of stability. When a stable feature does not exist, cutoffs should be provided. If the protective cover is long, intermediate cutoffs might be required to reduce the hazard of complete failure of the stone blanket.

.25 *Thickness and Gradation of Rock Rip Rap* - The thickness of the stone blanket should be at least equal to the maximum size stone. Stone used for dumped rock rip rap shall be hard, durable, angular in shape; resistant to weathering; free from overburden, spoil, shale and organic material; and shall meet the gradation requirements for the class specified. Neither breadth nor thickness of a single stone shall be less than one-third its length. Rounded stone or boulders shall not be acceptable. The data in the Table 453.23 may be used as a guide in specifying the gradation.

Table 453.23

Size of Stone	Percent of Total Weight Smaller than the Given Size
3k	100
2k	80
1k	50
0.1k	not to exceed 10

Each load of rip rap shall be reasonably well graded from the smallest to the maximum size specified. Stones smaller than the specified 10 percent size and spalls shall not be permitted in an amount exceeding 10 percent by weight of each load. See Standard Specifications for detailed data.

.26 *Design of Filter Blanket* - A filter blanket shall usually be placed beneath the rip rap cover to prevent the water from removing bank material through voids in the rip rap. Removal of bank material leaves cavities behind the rip rap cover and failure of the cover might result, particularly if the rip rap cover is rigid and cannot slump to continue contact with the supporting soil. Whether a filter blanket is needed will depend upon the gradation of the bank material and the openings or voids in the rip rap cover. For dumped rip rap, a filter ratio of 5 or less between layers will
159 usually result in a stable condition. The filter ratio is defined as the ratio of the 15 percent particle size (D_{15}) of the coarser layer to the 85 percent particle size (D_{85}) of the finer layer. An additional requirement for stability is that the ratio of the 15 percent particle size of the finer material should exceed 5 but be less than 40. This requirement can be stated thus:

$$\frac{D_{15}\ \text{(of rip rap)}}{D_{85}\ \text{(of bank)}} < 5 < \frac{D_{15}\ \text{(of rip rap)}}{D_{85}\ \text{(of bank)}} < 40$$

If a single layer of filter material will not satisfy the filter requirements, one or more additional layers of filter material must be used. The filter requirement applies between the bank material and the filter blanket, between successive layers of filter blanket material if more than one layer is used, and between the filter blanket and the stone cover. In addition to the filter requirements, the grain size curves for the various layers should be approximately parallel to minimize the infiltration of the fine material into the coarser material. Not more than 5 percent of the filter material should pass the No. 200 sieve.

The thickness of the filter blanket ranges from 6 inches to 15 inches for a single layer blanket. Where the gradation curves of adjacent layers are approximately parallel, thickness of the blanket layers should approach the minimum. Thickness of individual layers should be increased above the minimum proportionately as the gradation curve of the material comprising the layer departs from a parallel pattern. See Reference 15 for example of filter design for dumped rock rip rap.

.30 *GROUTED ROCK RIP RAP*

.31 *General* - Grouted rock rip rap is rip rap with the interstices filled with portland cement mortar. Grouted rip rap shall not be used for channel lining except when stone of suitable size is not available. Grouted rip rap may be used as temporary protection at inlets and outlets to conveyance structures. The need for grouted rip rap shall be determined by the particular conditions. Grouted rip rap shall also be used for all rock lined spillways and energy dissipators regardless of the size of rock, and shall extend along the side slopes and invert.

.32 *Design* - Grouted rock rip rap is rigid and has little strength, accordingly the embankment protected must provide adequate support and the edges of the rip rap cover must be protected from undermining at the toe and the terminals. Weep holes shall be provided in the blanket to provide rapid relief of any hydrostatic pressure behind the blanket, wherever the length of the grouted rip rap exceeds 20 feet. Filter blanket shall be provided for as required in dumped rip rap.

Stones for grouted rock rip shall, in general, meet the requirements for dumped rip rap. However, the size of gradation shall be determined for each particular condition; depending upon the stone available. Grout shall be placed on prepared and thoroughly moistened stones and shall penetrate approximately 80 percent of the thickness of the blanket. The stone shall be brushed until one-half to one-fourth of the surface stone is exposed. See Standard Specifications.

The slope of grouted rock rip rap slope protection shall not, in general, exceed

1½ horizontal to 1 vertical, except in temporary inlet and outlet structures where a slope of 1 horizontal to 1 vertical may be used.

.40 *SACKED CONCRETE RIP RAP*

.41 *General* - Sacked concrete rip rap generally consists of two-thirds cubic foot of Class C concrete in a burlap sack. Sacked rip rap provides good protection, regardless of the requirements of the site. This type of protection shall be used only for temporary short transitions, since the high costs
16 1 make it impractical for larger reaches.

.42 *Design* - Sacked rip rap has little flexibility and low tensile strength, and requires firm support from the protected bank. Adequate protection of terminals and toe is essential. The toe shall extend a minimum of three feet below the stream bed. Slopes of sacked rip rap shall generally be no flatter than 1½ horizontal to 1 vertical, and may be placed vertical, as long as the slope protection does not act as a retaining wall. This type of slope protection shall generally be provided with a filter blanket. Typical section and detail of sacked concrete slope protection is shown in Reference 15.

460. DEBRIS DAMS AND BASINS

461. BASIN DESIGN

.10 *EXCAVATION OF BASIN*

The excavation of basin side slopes shall be guided by the nature of the ground. The cut slopes shall be no steeper than recommended by the soil engineer and supported by his report. Consideration shall be given to safety requirements as may be specified by the State Division of Industrial Safety and the Grading Ordinance.

.20 *SECURITY FENCING*

Adequate fencing enclosing the limits of the debris basin shall be provided to discourage unauthorized persons from entering the area.
163 Said fencing shall conform to District Standards.

.30 *RIGHT OF WAY*

For right of way and access requirements, see Section 132.56.

462. EARTH DAM DESIGN

.10 *PREPARATION OF FOUNDATION*

.11 Preparatory to construction of the earth dam, the ground shall be stripped of all vegetation and other organic material. In addition, any trash, debris, soft compressible material or other objectionable material unsuitable for support of the dam, whether disclosed by the soil investigation or discovered during stripping, shall be excavated as directed by the soil engineer and approved by the District's inspector.

.20 *FACING SLOPES*

.21 In general, the District has found that upstream and downstream slopes of 3:1 of debris dams are usually stable. However, steeper slopes may be permitted provided it can be demonstrated that such steeper slopes are safe and adequate and are in accordance with accepted design principles for small dams.

.22 The upstream slope of the dam shall be treated to control erosion, as specified under Section 124, paragraph .86, subparagraph p.

.23 The downstream slope of the dam shall be protected from erosion as specified in Section 124., paragraph .86, subparagraph q.

.30 *CREST OF DAM*

.31 The crest of the dam shall be 20 feet wide as measured parallel to the center line of the spillway and shall have a minimum slope of 2% towards the spillway, from the spillway walls to the abutment, unless otherwise authorized by the District.

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.32 The crest of the dam shall be graded with a "V" depression of 6 inches in the center, and shall be provided with adequate cover material and drainage to prevent erosion.

.40 *ABUTMENTS*

.41 The horizontal length of the path of percolation between embankment and abutments and foundation shall be of such length as to be consistent with limitations for percolation and piping based upon existing local soil conditions and type of embankment material to be used. As a general rule, a minimum path of percolation ratio of 8:1 is satisfactory. (8 represents the level length of path along the contact and 1 represents the corresponding head differential between the elevation of upstream end of path and the maximum elevation of the reservoir surface. This condition should be satisfied for any horizontal plane through the embankment above the contact of bottom of the basin and upstream slope of embankment.)

.42 The re-entrant contact of two planes of fill, or planes of compacted fill and natural ground, shall be protected by means of paved shallow drainage gutters.

.50 *TRASH BARRIER*

.51 Adequate trash barrier shall be provided upstream of spillways in order to prevent debris of such size as could originate in the given watershed and result in clogging the spillway and/or the conduit downstream from the spillway. Particular attention in this matter is required when the downstream section is a closed conduit or a bridge crossing. The type and the spacing of the trash barrier should depend on the type of the potential debris.

.52 The barrier shall be designed to withstand the pressure created by flow and overflow of water considering the barrier 100% plugged and acting as a sharp crested submerged weir. The freeboard between crest
165 of dam and reservoir level upstream of the trash barrier shall be at least equal to that used to determine the height of spillway wall at spillway crest.

463. SPILLWAYS

.10 *LOADING CONDITIONS AND STRUCTURAL SECTIONS*

.11 Spillway channel shall be designed in accordance with the requirements of Sections 423 and 424.

.12 *Construction Joints*

1. Transverse construction joints shall be spaced at intervals of not more than 50 feet nor less than 10 feet. Shear keys shall not be used for transverse construction joints and steel reinforcement shall be continuous through the construction joints and lapped 20 bar diameters. Transverse joints in walls and slabs shall be in the same plane.

2. Concrete anchors shall be constructed monolithically with the transverse floor joints. The anchors shall be placed within the limits of the spillway that lies on the downstream slope.

.13 *Subdrains* - The subdrain system for the spillway structure shall consist of 6-inch perforated pipes laid in trenches filled with drain material and shall be designed to discharge through the spillway walls above the theoretical maximum water surface in the spillway. See Section 470, "Subdrain Systems".

464. OUTLET WORKS

Consists of a reinforced concrete tower or a tower of reinforced concrete pipe encased in reinforced concrete, and reinforced concrete outlet conduit.

.10 *OUTLET TOWER OR RISER*

.11 The tower shall be a rectangular reinforced concrete structure with a minimum 6 inch wall thickness and perforated with a series of rectangular openings tapered to widen towards the inner surface of the tower.

.12 The tower shall be of sufficient height to project at least one foot above the theoretical debris slope.

.13 The tower shall be located at the lowest point of the debris basin grading and shall be offset from the line of flow between the inlet to the basin and the spillway.

.14 The tower shall have safety collars set a maximum of nine feet apart vertically and shall be accessible for maintenance by means of a manhole.

.20 *OUTLET CONDUIT*

.21 The reinforced concrete pipe shall be not less than 36 inches in diameter encased in reinforced concrete sufficiently reinforced to prevent cracks and provided with cut-off collars to eliminate piping along the pipe encasement.

.22 Rectangular reinforced concrete box conduits may be used as conduits through the dam when the dam is extremely high or the discharge is great.

470. SUBDRAIN SYSTEMS

471. GENERAL

Subdrainage is an important feature in the design of reinforced concrete rectangular sections and lined trapezoidal channels. Effective subdrainage increases the bearing capacities of subgrades, decreases lateral and upward external pressures, and thus allows the use of lighter and more economic structures.

The nature and extent of the subdrain system is dependent upon the type of channel structure and upon judgement and experience as to how much water will have to be discharged in order to relieve unbearable hydrostatic pressures. If ground water levels are above proposed invert grades, it will usually be desirable to provide for more extensive subdrainage than would be necessary in the case of "perched water" or local infiltrations of surface water.

A thorough investigation shall be made to establish the maximum level of ground water that can be expected.

Generally, each project will require the exercise of specific judgement and experience as to subdrainage requirements. It is requested that the District be consulted before detailed design is begun. Prints detailing the various types of subdrain systems are available from the District upon request.

.10 *RIGID FRAME "U" SECTIONS*

"U" Sections are designed and constructed to act as rigid frames.

Any such section, not provided with subdrainage, should at least have adequate weight and strength to withstand hydrostatic forces consistent with the assumed maximum level of external ground water. For this case, the structure should be designed for the full floatation force. Often times, sufficient weight can be obtained by an extension of the wall heels. This is probably the safest method which can be used. In case it proves to be uneconomical, then it may be used in combination with subdrains. With a subdrain system, uplift pressures may be reduced to the extent considered as warranted by the type and expected effectiveness of the subdrainage system. The assumed ground water level shall not be higher than two feet above the bottom of the floor slab for channels without subdrainage, or at the top of the outlets for channels with a subdrain system.

The minimum subdrain system for "U" sections shall consist of perforated asbestos cement pipe line on each wall heel laid in drain material. Where justified by conditions of high ground water or poor drainage, blankets of sand and gravel may be used for base slab subgrade. The use of weepholes is not allowed.

.20 "L" WALL SECTIONS

For special conditions, open channel sections consisting of two "L" shaped cantilever retaining walls with a central concrete invert slab may be used. The invert slab has little weight and must be well protected from uplift pressures. Generally, "Heel Drains" and "Manhole Subdrain Systems", discharged at intervals into the channel, are used when uplift conditions are not severe. Sometimes the heel and floor slab drains are interconnected, and sometimes sand and gravel blankets may be desirable, depending upon the severity of the uplift conditions. Vertical cutoff walls shall be spaced along the channel reach to localize damage to the invert slab.

.30 BOX CONDUITS

In general, where ground water is encountered no subdrain system is required; however, the effect of external pressure on the conduit shall be investigated. In cases where ground water is excessively high or where foundation conditions are unstable, it may be desirable to drain the ground water into the conduit or otherwise provide for relief. Weepholes shall not be used in box conduits.

.40 TRAPEZOIDAL SECTIONS

The invert slab and bank linings of trapezoidal sections are incapable of resisting much hydrostatic head. Consequently, the subdrain system must be so chosen as to assure that the upward pressure will be less than the weight of the invert slab.

For permanent structures, longitudinal "Heel Drains", longitudinal and transverse floor slab drains should be so placed, and possibly interconnected so as to reduce the hydrostatic heads to acceptable limits. The use of filter blankets, or sand and gravel blankets is a desirable method of equalizing pressure and usually results in minimizing the number of pipe drains required and results in a safer structure.

472. TYPES OF SUBDRAINS

.10 HEEL DRAINS

Heel drains are longitudinal perforated pipe lines, laid in drain material, on the wall heels of rectangular sections, or near the outer ends of the invert base in the case of trapezoidal sections. The drains should be at the lowest level consistent with discharging requirements, since their purpose is to protect invert slabs and other linings not designed to resist much uplift. The four-inch or six-inch subdrain pipe shall be asbestos cement pipe.

Generally, the drains are discharged by elbows directly into the channel at specified intervals. In other cases, the flow in the heel drain may be diverted into lateral drains in the invert subgrade, or a longitudinal invert drain. The heel drains should be continuous except that a gap of about three feet should be provided, unless otherwise directed, at about 200 feet intervals.

Drain material shall consist of gravel or crushed rock and shall be reasonably well graded within the following limits, unless the gradation of native or backfill material indicates otherwise.*

Sieve Size	Percent by Weight Passing
1-1/2 inch	100
3/4 inch	65 - 95
3/8 inch	20 - 55
No. 4	0 - 5

The upstream end of each drain unit shall be connected to the channel and sealed with a removable cap or flap gate. This opening will be used to flush out the drain system during maintenance.

* *The 85 percent grain size of drain material shall be twice the maximum size of perforations. See Reference 5.*

.20 *MANHOLE SUBDRAIN SYSTEMS*

Manhole subdrain systems are longitudinal pipe, lateral pipe, or a combination of the two laid in gravel filled trenches or pervious blankets in the channel floor subgrade and connected to manholes outletting into the channel through the walls. Details of manhole subdrain systems may be obtained from the District. Where these details are applicable, they shall be included with the project drawings. Detailed information on the design of the manhole subdrain systems is presented in the publication entitled "Report on Manhole Subdrainage System", U. S. Army Engineering District, Los Angeles, July, 1957.

.30 *SAND AND GRAVEL BLANKETS*

Sand and gravel blankets should be used for either rectangular or trapezoidal sections, where subsoil testing indicates that the excavated subgrades will be wet and soft, or that subdrainage requirements will be extensive for a considerable period of time. In addition to "drying up" the subgrade and improving its bearing capacity, the blanket is considered as effective in filtering out the colloids and transferring subgrade flows to the main collector system.

The blanket material, when used as backfill for a rectangular section, or as subgrade for a bank lining, should not be extended to ground surface. It is preferable that the upper two or three feet of soil be less pervious in order to minimize the infiltration of surface water.

The sand and gravel blanket material is composed of a well blended mixture of sand, No. 2 aggregate and No. 3 aggregate in approximately equal proportions by volume. The blanket should be subjected to moderate rolling.

The need for sand and gravel blankets shall be determined by the Soil Engineer.

APPENDIX A

MISCELLANEOUS DATA, PREPARATION OF PLANS AND SPECIFICATIONS

GENERAL NOTES

1. Elevations shown are in feet above the U.S.C. & G.S. mean sea level datum of 1929.

2. Stations shown on drawings are along center line of structure.

3. Stations and invert elevations of pipe inlets shown on the profiles are at the inside face of the structure, unless otherwise shown.

4. Utility facilities are shown as believed to exist at time of survey. Facilities may have been omitted, misplaced and/or relocated. Contractors shall protect all utilities per Section 5 of the Standard Specifications, whether shown on the plans or not.

5. Unless otherwise noted, existing utilities in the right of way shall be relocated by the respective owners, but the contractor shall be responsible for arranging and scheduling the relocation operations to conform to his construction schedule.

6. Soil tests borings for this project were made / / . Subsurface soil investigation results are furnished for information only in accordance with Section 2-7 of Standard Specifications, and no warranty is made therefore.

7. E.G.L. & H.G.L. are shown for future reference by the District only.

8. Numbers in circles indicate items under which payment will be made.

9. Trees designated by the Symbol * will be removed by the Contractor.

APPENDIX B

MISCELLANEOUS DATA, HYDRAULIC DESIGN

1. Simplified Approach

The general equation 319.10 may be rewritten, for flow in open channels and pipes flowing partly full when side inlet is submerged, in the following manner:

$$\Sigma P = \Sigma M$$

or

$$P_1 + P_w + P_i - P_2 = M_2 - M_1 - M_3 \cos\theta + P_f$$

Simplifying and substituting

$$\Delta y \left(\frac{A_1 + A_2}{2}\right) = \frac{Q_2^2}{A_2 g} - \frac{Q_1^2}{A_1 g} - \frac{Q_3^2}{A_3 g}\cos\theta +$$

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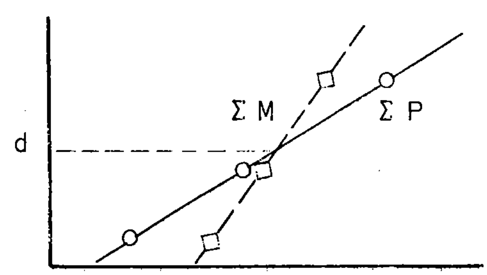
$$L \left(\frac{S_1 + S_2}{2}\right) \left(\frac{A_1 + A_2}{2}\right)$$

The unknown value of depth may be determined by plotting Σ P and Σ M as an ordinate versus depth as the abscissa. The point of intersection of the two lines is the unknown depth. See example plot below.



Σ P & Σ M

2. Control Points*

Control points for junction analysis in open channel flow, ignoring friction, are as follows:

a. Subcritical flow

$$d_2 \doteq d_{2n}$$

* *See "Course Notes - Street and Highway Drainage", Volume 2, The Institute of Transportation and Traffic Engineering, University of California, 1965, for an example of pressure-momentum analysis.*

b. Supercritical flow

1. When $M_{2c} > M_{1n} + M_3 \cos \theta + P_1 + P_w + P_i - P_2$, a hydraulic jump will form upstream of the junction and $d_2 = d_{2c}$.

2. When $M_{2c} < M_{1n} + M_3 \cos \theta + P_1 + P_w + P_i - P_2$, $d_1 = d_{1n}$.

In all cases, computations should be made to determine the backwater or drawdown water surface profile.

Project :

Ventura County Flood Control District

WATER SURFACE COMPUTATION

Calculated Date

Checked Date

Sta.	S_o	F.L. Elev.	d	W.S. Elev.	Sect.	A	Q	V	h_v	E.G.L.	$(\frac{1}{K'})^2$	$(\frac{Qn}{b^{8/3}})^2$	S_f	Ave. S_f	L	h_f	Other h	h_T	E.G.L.	F

Remarks:

Hydraulic W.F. # 1

Project:

Ventura County Flood Control District

FREEBOARD COMPUTATION

Calculated Date

Checked Date

Sta.	F. L. Elev. (1)	Depth (2)	W.S. Elev. (1)+(2) (3)	Section	Velocity	Froude Number	Radius Of Curvature	H_1 (4)	H_2 (5)	H_3 (6)	H_4 (7)	Total (4)+(5)+(6)+(7) (8)	Wall Height Comp. (2)+(8)	Wall Height Used

For Description Of H_1, H_2, H_3, H_4 See Sec. 324 In The Design Manual

Project:				Ventura County Flood Control District BRIDGE PIER LOSSES COMPUTATION						Calculated by Date Checked by Date			
D	$A_1 = A_3$	$P_1 = P_3$	A_p^*	P_p	$A_1 - A_p^*$	$P_1 - P_p$ (1)	$\frac{Q^2}{g(A_1 - A_p^*)}$ (2)	$\frac{Q^2}{g A_1}$	$\frac{Q^2(A_1 - A_p^*)}{g A_1^2}$ (3)	$\frac{Q^2}{g A_3}$ (4)	I (1) + (3)	II (1) + (2)	III (1) + (4)

P_1 = Hydrostatic pressure in unobstructed channel.

P_p = Hydrostatic pressure of bridge piers.

$P_1 - P_p$ = Hydrostatic pressure in obstructed channel.

$$P_1 - P_p + \frac{Q^2(A_1 - A_p^*)}{g A_1^2} = P_1 - P_p + \frac{Q^2}{g(A_1 - A_p^*)} = P_3 - P_p + \frac{Q^2}{g A_3}$$

* Use $\frac{2}{3} A_p$ for round nose piers

$\frac{Q^2}{g(A_1 - A_p)}$ = Kinetic momentum in obstructed channel

$\frac{Q^2}{g A_1}$ = Kinetic momentum in unobstructed channel

$\frac{A_p^* Q^2}{g A_1^2}$ = Kinetic momentum lost

Hydraulic W.F. #3

APPENDIX C

MISCELLANEOUS DATA, STRUCTURAL DESIGN

STRUCTURAL NOTES

The following notes, as applicable, shall appear on the project drawings in the form presented below together with such others as may be needed on a particular project.

GENERAL: (All types of structures)

1. Clear distances for reinforcing steel are from the face of concrete to nearest edge of the bar.

2. Transverse construction joints shall not be placed within 30 inches of manhole or junction structure openings.

3. Transverse construction joints in walls and slabs shall be in the same plane. No staggering of joints will be permitted.

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4. The transverse reinforcing steel shall terminate $1\frac{1}{2}$ inches from the concrete surfaces unless otherwise shown on the structural details.

5. No splices in transverse steel reinforcement will be permitted other than as shown on the drawing without approval of the Engineer.

6. Longitudinal steel shall be lapped 20 bar diameters at splices. Transverse steel shall be lapped 30 bar diameters at splices, unless shown otherwise on the drawings. Splices shall be staggered.

7. Concrete dimensions shall be measured horizontally or vertically on the profile, and parallel to or at right angles (or radially) to centerline of conduit on the plan, unless otherwise shown on the drawings.

ADDITIONAL NOTES FOR BOX SECTIONS:

1. Longitudinal steel shall be continuous and extend through all construction joints.

2. Unless otherwise shown on the details, in curved sections transverse bars shall be placed radially. Straight transverse bars in top and bottom slabs shall be spaced as shown on the typical sections; spacing shall be at the centerline of construction for single-barrel boxes, and at the centerline of the barrel on the outside of the curve for multi-barrel boxes. Straight bars and L-bars in walls shall be spaced as shown on the typical sections, with the spacing measured between the vertical legs of bars.

3. At the beginning and ending of all pours, a complete curtain of reinforcement shall be placed three inches from the transverse construction joint.

4. The vertical wall steel in interior walls and in the interior face of exterior walls may be spliced at the construction joint at the base of the wall. The splice shall be 20 bar diameters in length.

ADDITIONAL NOTES FOR OPEN CHANNEL SECTIONS:

1. Transverse wall joints shall be placed at end of each pour, but spacing thereof shall not exceed 50 feet or be less than 10 feet, measured along the centerline of construction, unless shown otherwise on the drawings. Transverse construction joints in the bottom slab shall be located at the spacing shown on the drawing and at the end of pours.

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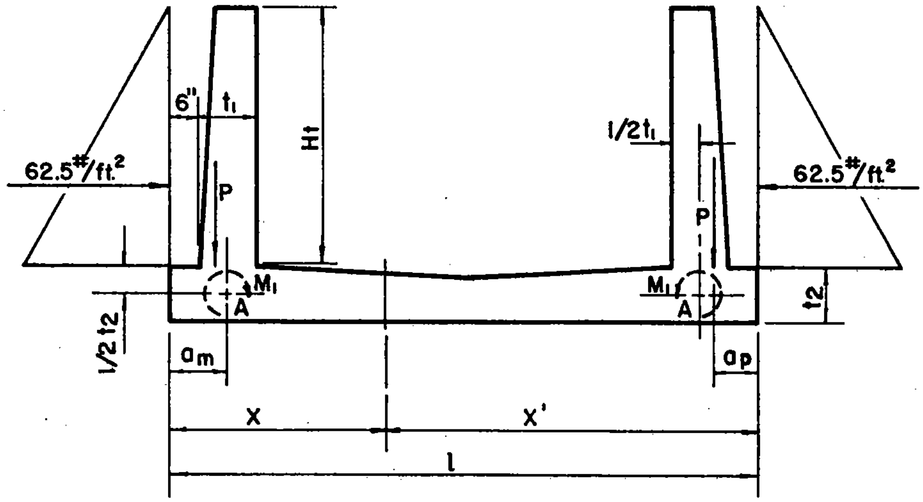
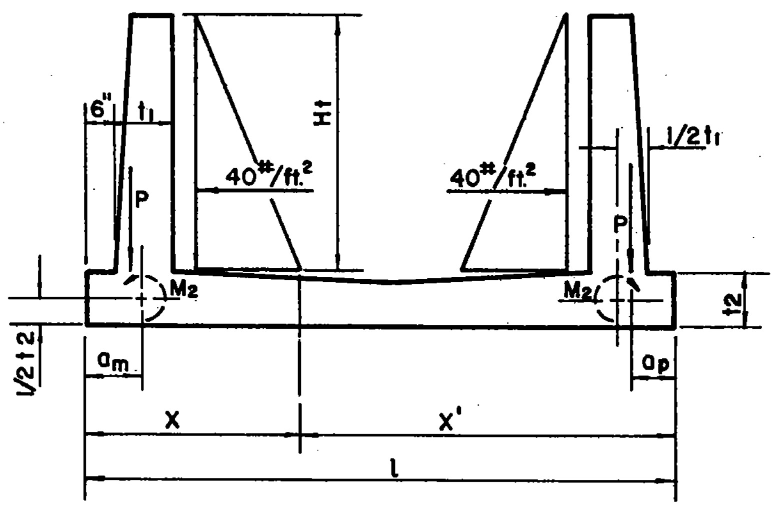
2. Transverse construction joints, as detailed for open channel sections, shall be placed at the junction of Rectangular Open Channel sections with Closed Conduit sections.

3. In curved sections, the maximum spacing of bars shall not exceed that shown for the typical sections. Steel shall be placed radially from the maximum spacing.

4. At the beginning and ending of all pours, a complete curtain of reinforcement shall be placed three inches from the transverse construction joints.



CASE I
CHANNEL EMPTY



CASE II
CHANNEL FULL

P = Resultant load due to weight of wall and earth load (110 lb./ft.³) on heel.
M_1= Moment at "A" due to external horizontal forces acting on wall.
M_2= Moment at "A" due to equivalent differential hydrostatic pressure.

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Reference: Structural Design Manual Los Angeles County Flood Control District, 1964	Ventura County Flood Control District DESIGN MANUAL DESIGN OF FLOOR SLABS IN RECTANGULAR CHANNELS	Figure: C-1

EQUATIONS FOR MOMENTS

MOMENT FOR CASE I, $M_I = M_P + M_{M_1}$

MOMENT FOR CASE II, $M_2 = M_P + M_{M_2}$

$$M_P = \frac{(P_0)_P}{4\lambda}(C_{\lambda x} + C_{\lambda x'}) + \frac{(M_0)_P}{2}(D_{\lambda x} + D_{\lambda x'}) + \frac{P}{4\lambda}\left[C_{\lambda(x-a_P)} + C_{\lambda(x'-a_P)}\right]$$

$$M_{M_1} = \frac{(P_0)_{M_1}}{4\lambda}(C_{\lambda x} + C_{\lambda x'}) + \frac{(M_0)_{M_1}}{2}(D_{\lambda x} + D_{\lambda x'}) + \frac{M_1}{2}\left[D_{\lambda(x-a_M)} + D_{\lambda(x'-a_M)}\right]$$

$$M_{M_2} = \frac{(P_0)_{M_2}}{4\lambda}(C_{\lambda x} + C_{\lambda x'}) + \frac{(M_0)_{M_2}}{2}(D_{\lambda x} + D_{\lambda x'}) - \frac{M_2}{2}\left[D_{\lambda(x-a_M)} + D_{\lambda(x'-a_M)}\right]$$

EQUATIONS FOR SOIL PRESSURES

SOIL PRESSURE FOR CASE I, $p_I = p_P + p_{M_1} + p_S$

SOIL PRESSURE FOR CASE II, $p_{II} = p_P + p_{M_2} + p_S + p_W$

p_S = PRESSURE DUE TO WEIGHT OF SLAB

p_W = PRESSURE DUE TO WEIGHT OF WATER

FOR $0 \leq x \leq a$

$$p_P = \frac{(P_0)_P\lambda}{2}(A_{\lambda x} + A_{\lambda x'}) + (M_0)_P\lambda^2(B_{\lambda x} + B_{\lambda x'}) + \frac{P\lambda}{2}\left[A_{\lambda(a_P-x)} + A_{\lambda(x'-a_P)}\right]$$

$$p_{M_1} = \frac{(P_0)_{M_1}\lambda}{2}(A_{\lambda x} + A_{\lambda x'}) + (M_0)_{M_1}\lambda^2(B_{\lambda x} + B_{\lambda x'}) - M_1\lambda^2\left[B_{\lambda(a_M-x)} - B_{\lambda(x'-a_M)}\right]$$

$$p_{M_2} = \frac{(P_0)_{M_2}\lambda}{2}(A_{\lambda x} + A_{\lambda x'}) + (M_0)_{M_2}\lambda^2(B_{\lambda x} + B_{\lambda x'}) + M_2\lambda^2\left[B_{\lambda(a_M-x)} - B_{\lambda(x'-a_M)}\right]$$

FOR $a \leq x \leq (l-a)$

$$p_P = \frac{(P_0)_P\lambda}{2}(A_{\lambda x} + A_{\lambda x'}) + (M_0)_P\lambda^2(B_{\lambda x} + B_{\lambda x'}) + \frac{P\lambda}{2}\left[A_{\lambda(x-a_P)} + A_{\lambda(x'-a_P)}\right]$$

$$p_{M_1} = \frac{(P_0)_{M_1}\lambda}{2}(A_{\lambda x} + A_{\lambda x'}) + (M_0)_{M_1}\lambda^2(B_{\lambda x} + B_{\lambda x'}) + M_1\lambda^2\left[B_{\lambda(x-a_M)} + B_{\lambda(x'-a_M)}\right]$$

$$p_{M_2} = \frac{(P_0)_{M_2}\lambda}{2}(A_{\lambda x} + A_{\lambda x'}) + (M_0)_{M_2}\lambda^2(B_{\lambda x} + B_{\lambda x'}) - M_2\lambda^2\left[B_{\lambda(x-a_M)} + B_{\lambda(x'-a_M)}\right]$$

WHERE:

$$P_0 = 4E_1\left[Q_A\left(1+D_{\lambda l}\right)+\lambda M_A\left(1-A_{\lambda l}\right)\right]$$

$$M_0 = \frac{-2E_1}{\lambda}\left[Q_A\left(1+C_{\lambda l}\right)+2\lambda M_A\left(1+D_{\lambda l}\right)\right]$$

AND:

$$E_1 = \frac{1}{2}\ \frac{e^{\lambda l}}{\sinh \lambda l + \sin \lambda l}$$

FOR P

$$Q_A = \frac{P}{2}\left[D_{\lambda a_p}+D_{\lambda(l-a_p)}\right]$$

$$M_A = \frac{P}{4\lambda}\left[C_{\lambda a_p}+C_{\lambda(l-a_p)}\right]$$

FOR M_1

$$Q_A = -\frac{M_1\lambda}{2}\left[A_{\lambda a_M}-A_{\lambda(l-a_M)}\right]$$

$$M_A = -\frac{M_1}{2}\left[D_{\lambda a_M}-D_{\lambda(l-a_M)}\right]$$

FOR M_2

$$Q_A = \frac{M_2\lambda}{2}\left[A_{\lambda a_M}-A_{\lambda(l-a_M)}\right]$$

$$M_A = \frac{M_2}{2}\left[D_{\lambda a_M}-D_{\lambda(l-a_M)}\right]$$

"CHARACTERISTIC" λ

$$\lambda = \sqrt[4]{\frac{K}{4EI}}$$

WHERE:

λ = CHARACTERISTIC OF SYSTEM, L^{-1}
K = bk_0, F/L^2
b = WIDTH OF BEAM, USUALLY TAKEN AS UNITY, L.
K_0 = MODULUS OF THE FOUNDATION F/L^3, USE 165 #/IN.^{3}
E = MODULUS OF ELASTICITY OF BEAM, F/L^2
I = MOMENT OF INERTIA OF BEAM, L^4

Reference: Structural Design Manual Los Angeles County Flood Control District, 1964	Ventura County Flood Control District DESIGN MANUAL FINITE BEAM EQUATIONS	Figure: C-2(a)

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FUNCTIONS A, B, C, & D

$$A_{\lambda U} = e^{-\lambda U}(\cos \lambda U + \sin \lambda U)$$

$$B_{\lambda U} = e^{-\lambda U}\sin \lambda U$$

$$C_{\lambda U} = e^{-\lambda U}(\cos \lambda U - \sin \lambda U)$$

$$D_{\lambda U} = e^{-\lambda U}\cos \lambda U$$

NOTE:

CURVES SHOWN AS SOLID LINES ON FIGURES 423.21 (a) THROUGH (h) HAVE BEEN CALCULATED USING FINITE BEAM EQUATIONS.

REFERENCES:

"BEAMS ON ELASTIC FOUNDATIONS" BY M. HETENYI.
EQUATIONS DERIVED BY T.J. KOYAMATSU.

Reference:	Ventura County Flood Control District DESIGN MANUAL	Figure:
Structural Design Manual Los Angeles County Flood Control District, 1964	FINITE BEAM EQUATIONS	C-2(b)

EQUATIONS FOR MOMENTS

$$M_P = \frac{P}{4\lambda}\left[\alpha C_{\lambda x} - 2\beta D_{\lambda x} + C_{\lambda(x-a_P)}\right]$$

$$M_{M_1} = -\frac{M_1}{2}\left[\Omega C_{\lambda x} - \delta D_{\lambda x} - D_{\lambda(x-a_M)}\right]$$

$$M_{M_2} = \frac{M_2}{2}\left[\Omega C_{\lambda x} - \delta D_{\lambda x} - D_{\lambda(x-a_M)}\right]$$

EQUATIONS FOR SOIL PRESSURES

<u>FOR $0 \leq x \leq a$</u>

$$P_P = \frac{P\lambda}{2}\left[\alpha A_{\lambda x} - 2\beta B_{\lambda x} + A_{\lambda(a_P-x)}\right]$$

$$P_{M_1} = M_1\lambda^2\left[-\Omega A_{\lambda x} + \delta B_{\lambda x} - B_{\lambda(a_M-x)}\right]$$

$$P_{M_2} = M_2\lambda^2\left[\Omega A_{\lambda x} - \delta B_{\lambda x} + B_{\lambda(a_M-x)}\right]$$

<u>FOR $a \leq x \leq (\ell - a)$</u>

$$P_P = \frac{P\lambda}{2}\left[\alpha A_{\lambda x} - \beta B_{\lambda x} + A_{\lambda(x-a_P)}\right]$$

$$P_{M_1} = M_1\lambda^2\left[-\Omega A_{\lambda x} + \delta B_{\lambda x} + B_{\lambda(x-a_M)}\right]$$

$$P_{M_2} = M_2\left[\Omega A_{\lambda x} - \delta B_{\lambda x} - B_{\lambda(x-a_M)}\right]$$

Reference: Structural Design Manual Los Angeles County Flood Control District, 1964	Ventura County Flood Control District DESIGN MANUAL	Figure:
	SEMI-INFINITE BEAM EQUATIONS	C-3

WHERE:

$$\beta = C_{\lambda a_P} + D_{\lambda a_P}$$

$$\alpha = C_{\lambda a_P} + 2D_{\lambda a_P}$$

$$\Omega = D_{\lambda a_M} + A_{\lambda a_M}$$

$$\delta = A_{\lambda a_M} + 2D_{\lambda a_M}$$

NOTE:

CURVES SHOWN AS DASHED LINES ON FIGURES 423.21 (a) THROUGH (h) HAVE BEEN CALCULATED USING THE SIMI-INFINITE BEAM EQUATIONS.

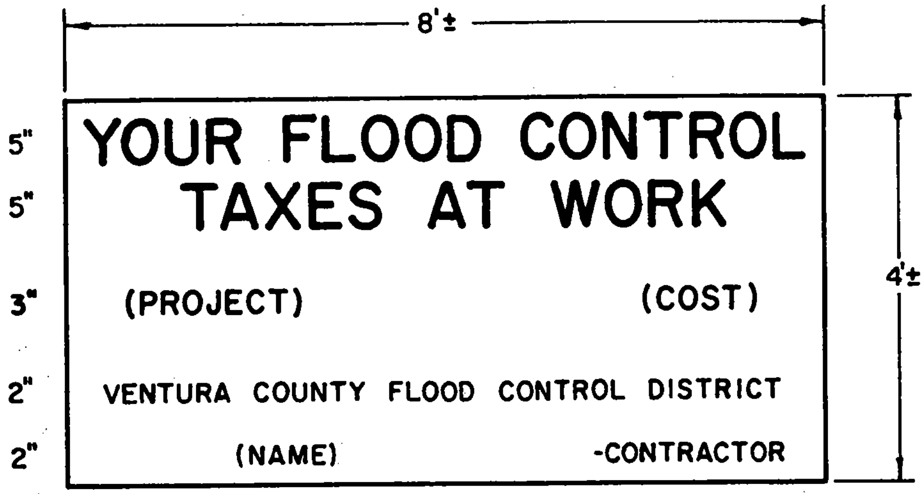
REFERENCES:

"BEAMS ON ELASTIC FOUNDATIONS" BY M. HETENYI.

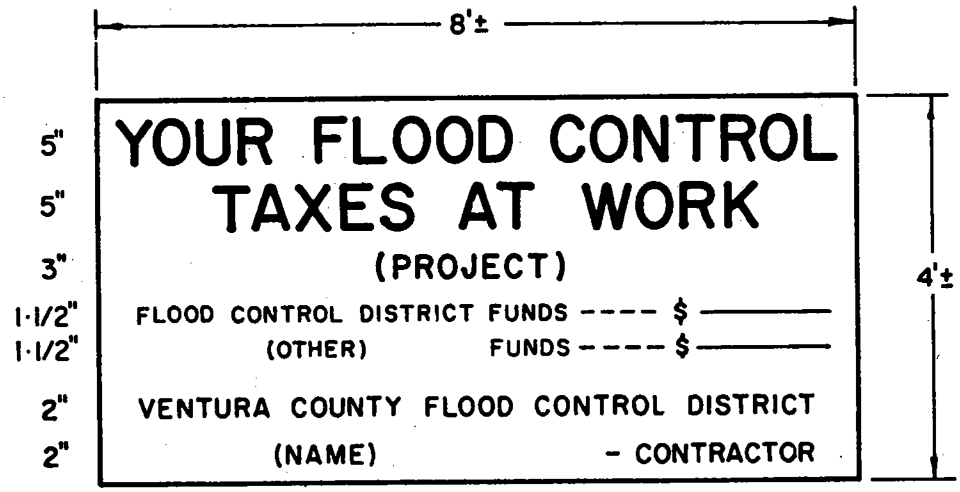
EQUATIONS DERIVED BY B. GLIDDEN.

Reference: Structural Design Manual Los Angeles County Flood Control District, 1964	Ventura County Flood Control District DESIGN MANUAL	Figure:
	SEMI-INFINITE BEAM EQUATIONS	C-3(a)

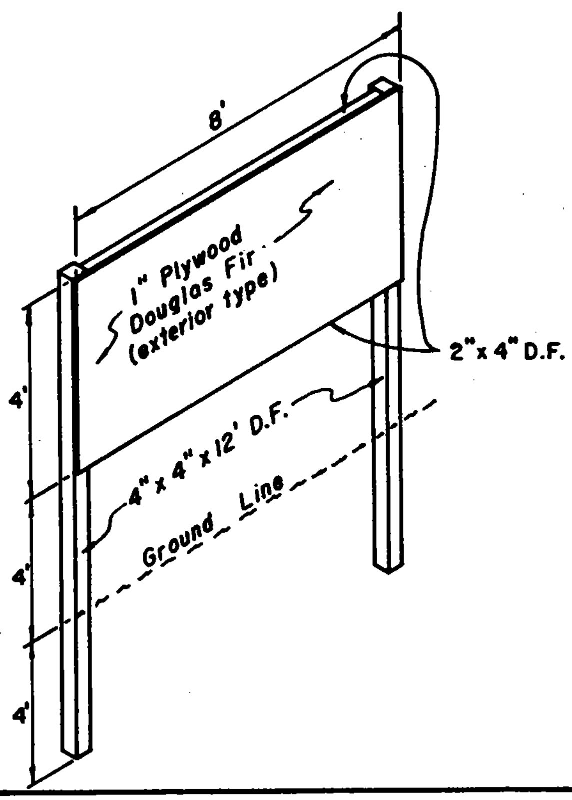
APPENDIX D
DESIGN STANDARDS



TYPE I



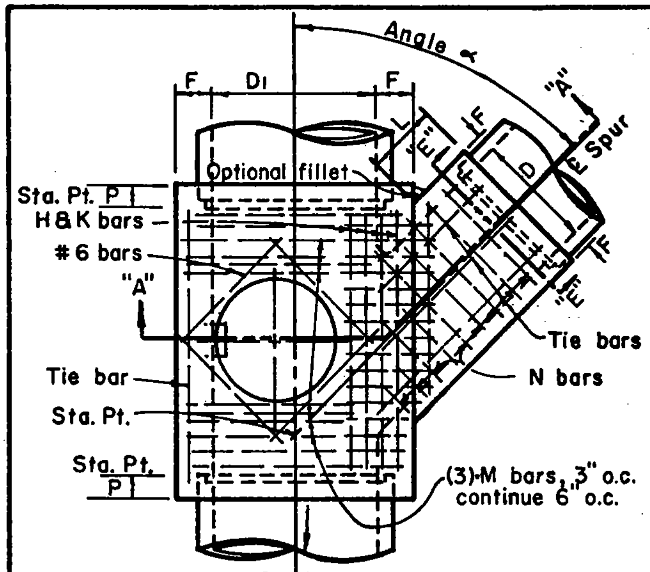
TYPE II



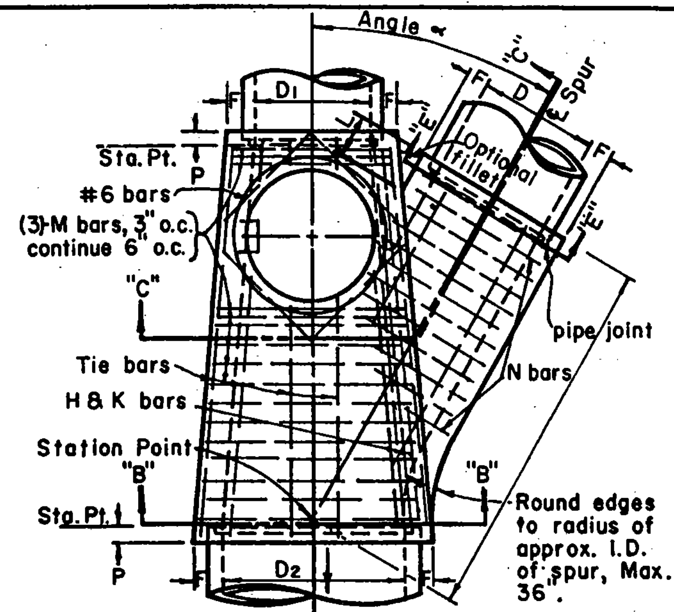
Notes:
U.S. Standard capital and lower case "C" letters. Stroke width 0.16" per inch of letter height.
Flood Control District Funds, Other Funds and information on the name of project to be furnished by the District and painted on the sign by the Contractor.

Ventura County Flood Control District DESIGN STANDARDS
CONSTRUCTION IDENTIFICATION SIGNS
Approved *A. P. Stoker* Date 5-14-68

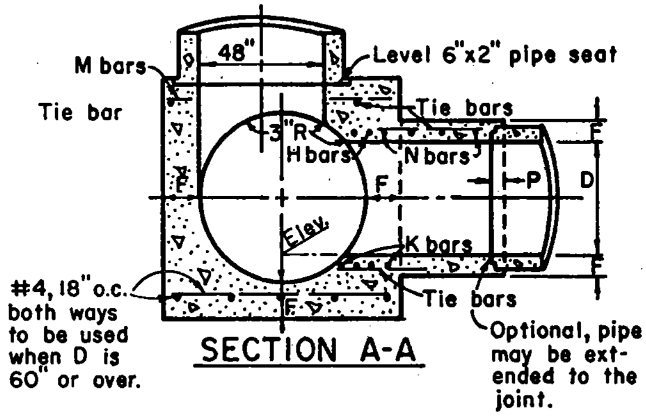
STANDARD DRAWING NO. 1



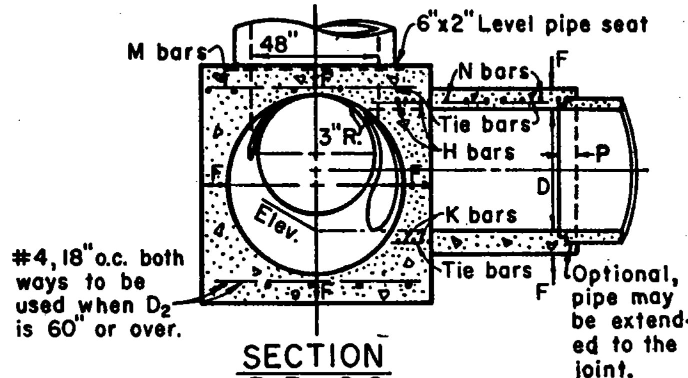
PLAN
TYPE II



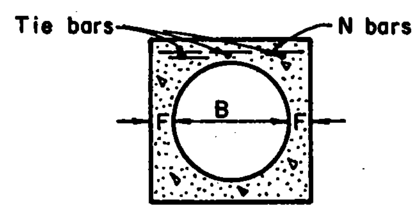
PLAN
TYPE I



SECTION A-A



SECTION
B-B, C-C



SECTION E-E

NOTES:

1. JUNCTION STRUCTURE shall be poured in one continuous operation, except that the contractor shall have the option of placing, at the springing line, a construction joint with longitudinal keyway.
2. FLOOR of junction structure shall be steel trowelled to springing line.
3. REINFORCING STEEL to be 2" clear from face of concrete, unless otherwise specified.
4. If LATERALS enter on both sides, access shaft shall be located on side receiving the smaller lateral.
5. EXTENSION of centerline of inlet pipe shall intersect inside face of concrete at springing line, unless otherwise specified.
6. TIE BARS shall be #4 bars, 18" o.c., min.
7. OPTIONAL CONSTRUCTION, pipe may be extended through Type II junction structure.
8. ALL CONSTRUCTION is subject to conditions of the standard specifications.
9. SEE STD. DRWG. NO. 5 for manhole shaft details.
10. DIMENSIONS & BAR SIZES for TYPE I junction structure, shall be governed by D_2.
11. STEPS shall be constructed per STD. DRWG. NO. 5 or approved equal.

D, D_2, B and Angle ∝ shall be specified on construction plans.

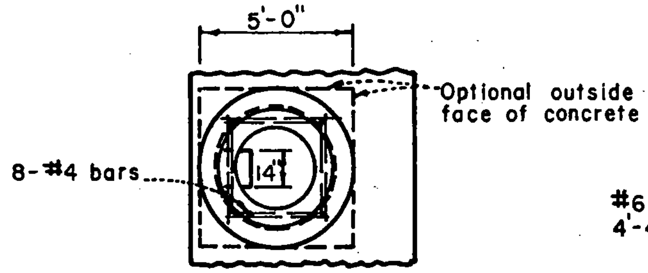
TABLE
Dimensions & Bar Sizes

D, D1 or D2	F	H or K bars	M or N bars	P	L
12"-21" 24"-33" 36"-39"	5" 6" 7"	#5, 3" o.c.	#4, 6" o.c.	5"	12"
42"-48" 51"-57" 60"-66" 69"-84"	8" 9" 10" 11"	#6, 3" o.c.	#5, 6" o.c.		
90"-96" 102"-144"	14" 18"	#7, 3" o.c.	#6, 6" o.c.	8"	18"

Ventura County Flood Control District
DESIGN STANDARDS

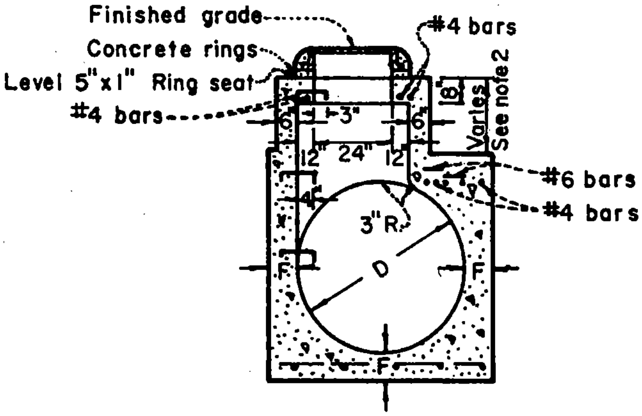
TYPE I & II
PIPE JUNCTIONS

Approved A. P. Stokes Date 5-14-68



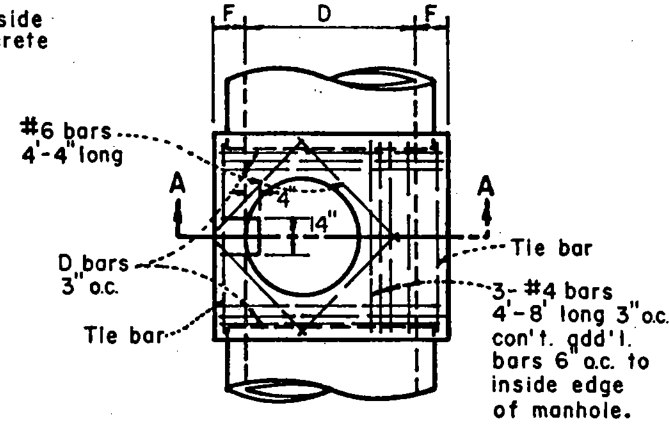
PLAN

(Rings and cover not shown)



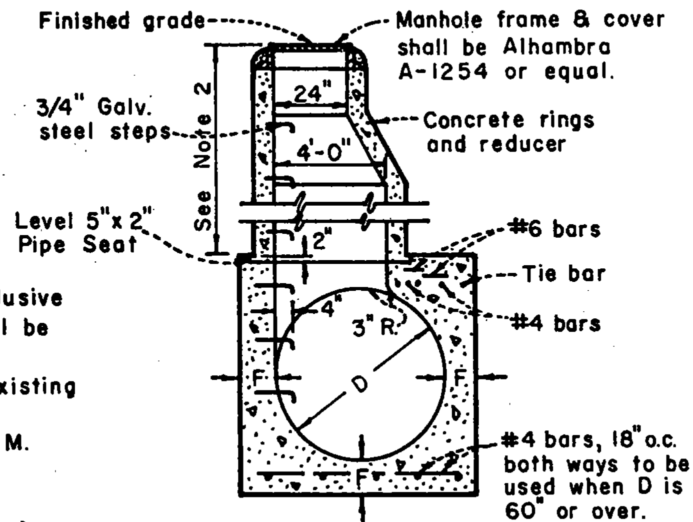
DETAIL M

(See Note 2)



PLAN

(Shaft not shown)



SECTION A-A

NOTES:

1. D BARS shall be #5 for D=48" to 84" inclusive and #6 for D=90" or over. Tie bars shall be #3 bars.
2. DETAIL M: When depth of manhole from existing grade to top of box is less than 3'-0" construct monolithic shaft as per DETAIL M. Shaft for any depth of manhole may be constructed as per DETAIL M.
3. REINFORCING STEEL to be 2" clear from face of concrete unless otherwise specified.
4. RINGS, REDUCER AND PIPE for access shaft shall be seated in mortar and neatly pointed or wiped inside the shaft.
5. CRADLE of manhole shall be poured in one continuous operation, except that a construction joint with a longitudinal keyway may be placed at the springing line.

TABLE OF VALUES FOR "F"

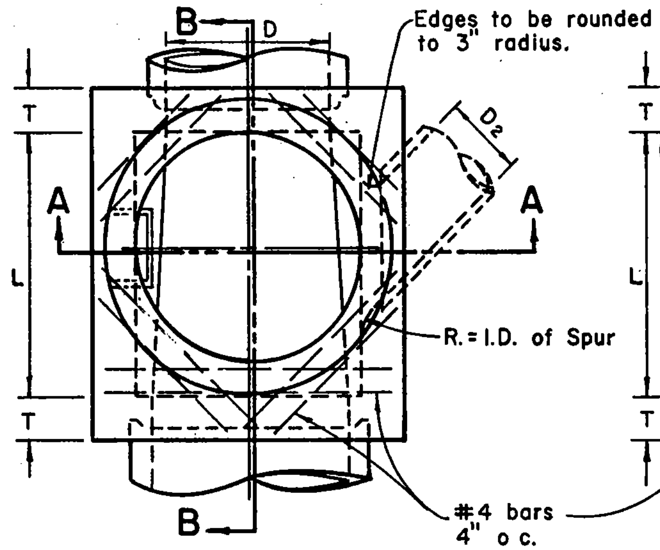
D	F
48"	8"
51" & 54"	9"
57", 60", 63", 66"	10"
69" & 72"	11"
78", 84", 90", 96"	14"
102", 108", 114"	16"
120", 126", 132", 138", 144"	18"

Ventura County Flood Control District

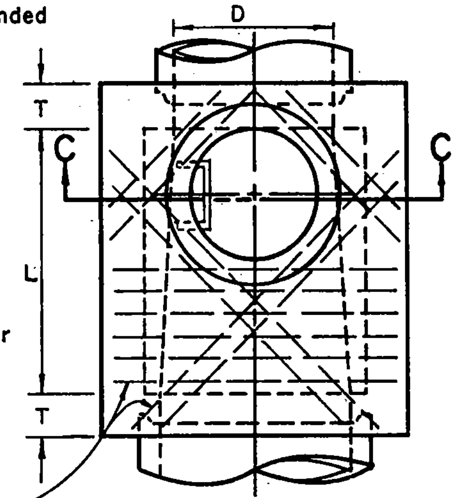
DESIGN STANDARDS

TYPE I MANHOLE

Approved A. P. Stokes Date 5.14.68

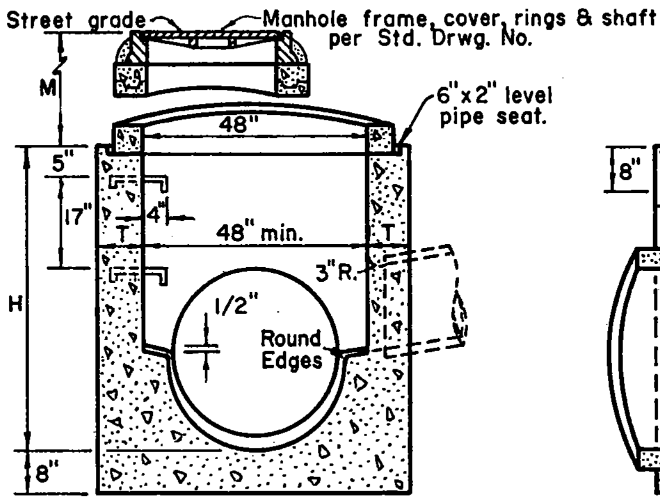


PLAN
(Shaft not shown)

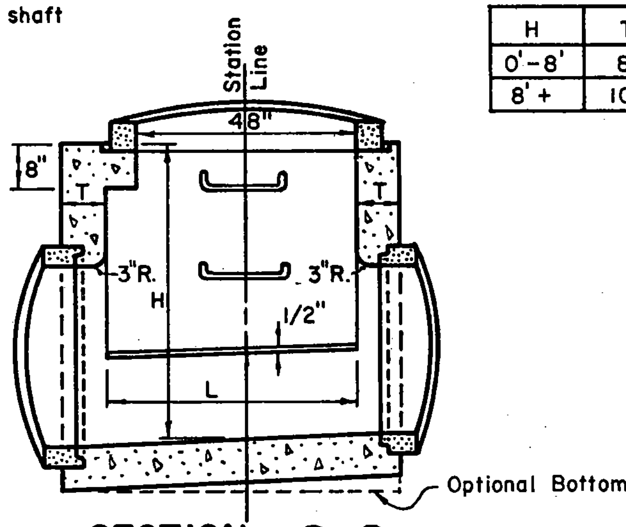


DETAIL N PLAN
(Shaft not shown)
See Note 3

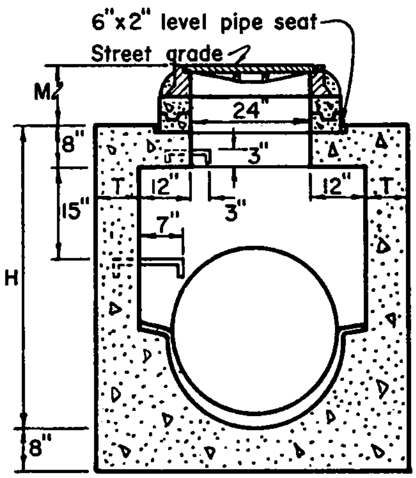
H	T
0'-8'	8"
8' +	10"



SECTION A–A



SECTION B–B



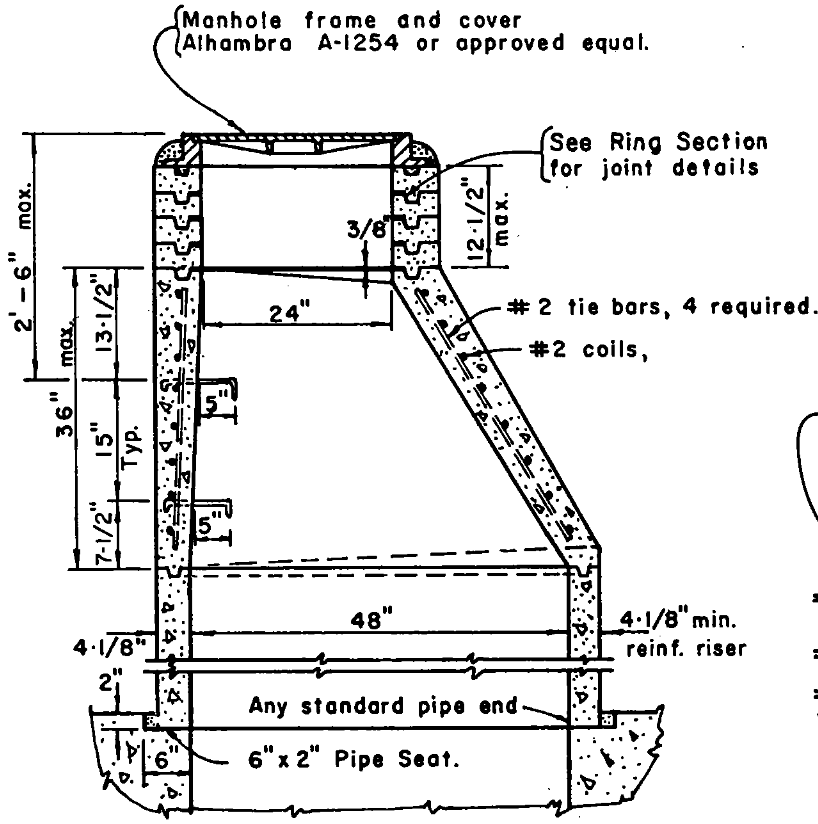
SECTION C – C

NOTES:

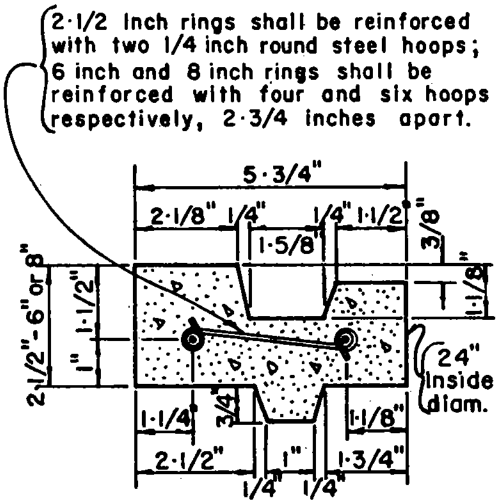
1. HEIGHT H (in Sec. A-A, B-B and C-C) shall be not less than 4'-0" but may be increased provided that the value of M is not less than the minimum specified, and the reducer is used. For H (in Sec. C-C) see note 4.
2. LENGTH L shall be 4 feet unless otherwise shown on plan. L may be increased or location of manhole shifted to meet pipe ends.
3. MANHOLE SHAFT shall be constructed per Sec. C-C & Detail N when depth M, from finished grade to top of box, is less than 3'-0".
4. DEPTH M may be reduced to an absolute minimum of 6" when larger values of M would reduce H (in Sec. C-C) to 3'-6" or less.
5. STEPS shall be constructed per Std. Dwg. No. 5 or approved equivalent.
6. CRADLE of manhole shall be poured in one continuous operation except that a construction joint with a longitudinal keyway may be placed at the springing line.

Ventura County Flood Control District DESIGN STANDARDS	
TYPE II MANHOLE	
Approved A. P. Stoker	Date 5-14-68

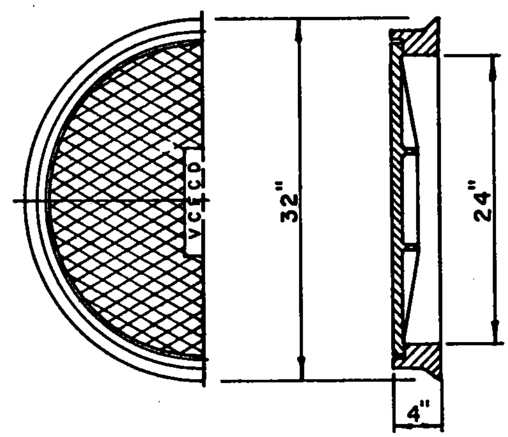
STANDARD DRAWING NO. 4



VERTICAL SECTION
OF REINFORCED CONCRETE
ECCENTRIC MANHOLE SHAFT



CROSS SECTION
OF REINFORCED
CONCRETE RING



MANHOLE FRAME
AND COVER

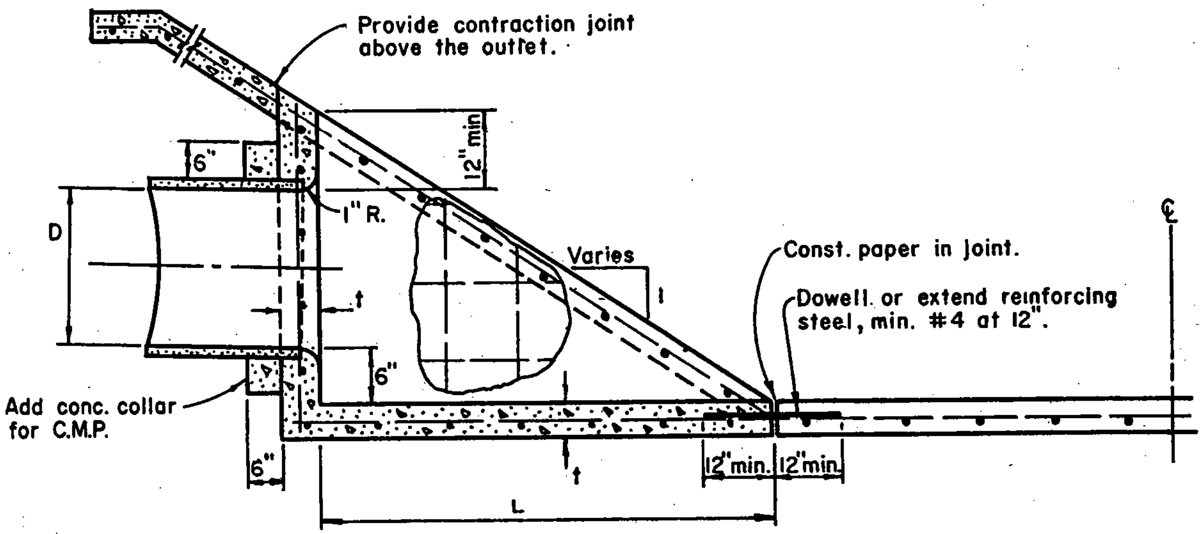
NOTES:

1. ALL JOINTS shall be filled with mortar and neatly pointed or wiped on inside of shaft.

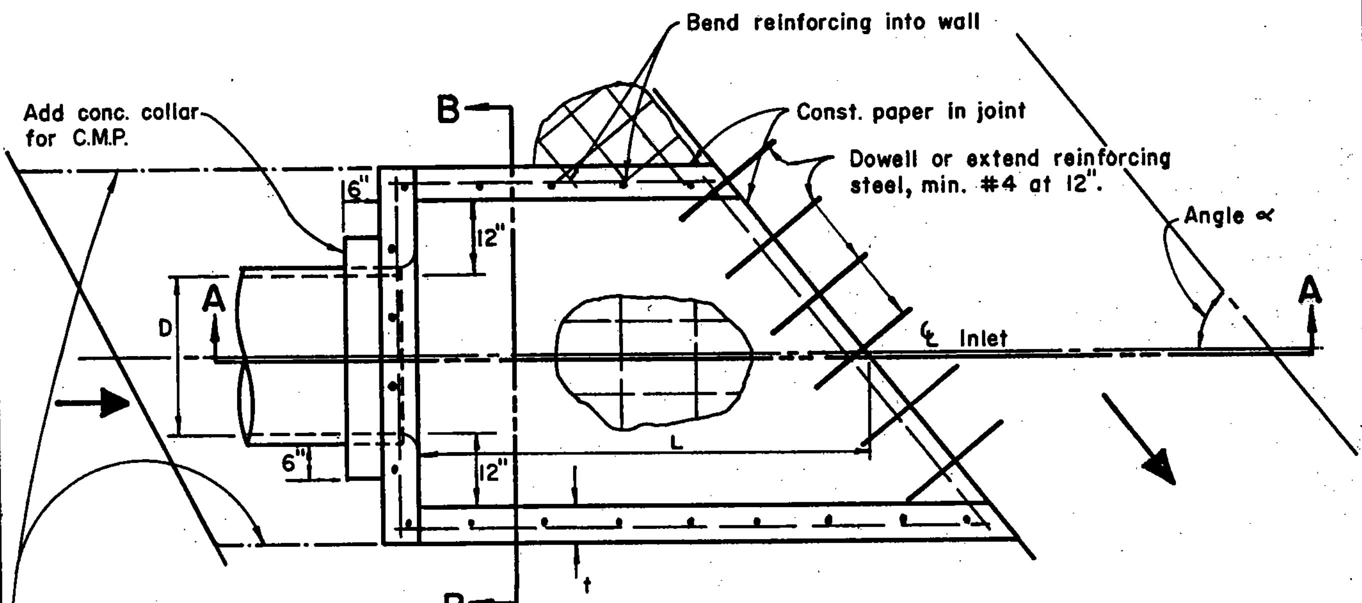
2. COLLAR OF MORTAR around cover frame shall be omitted in paved streets.

3. STEPS shall be 3/4" dia. galvanized steel imbeded 5" in wall.

Ventura County Flood Control District DESIGN STANDARDS
MANHOLE SHAFT AND COVER DETAIL
Approved *A. P. Stokes* Date *5-14-68*



SECTION A-A

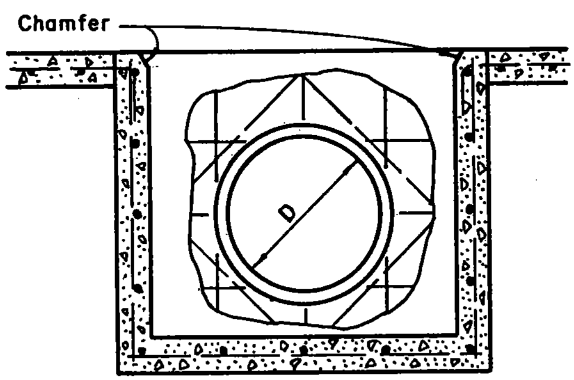


PLAN

NOTES:

1. ANGLE OF CONFLUENCE (∝) of side inlets shall not be greater than 30° for the following cases:
   a. Lateral flow exceeds 10% of the main line flow.
   b. Lateral flow velocities are 20 qfs or greater.
   c. Hydraulic analysis of the junction indicates excessive losses in the main channel.

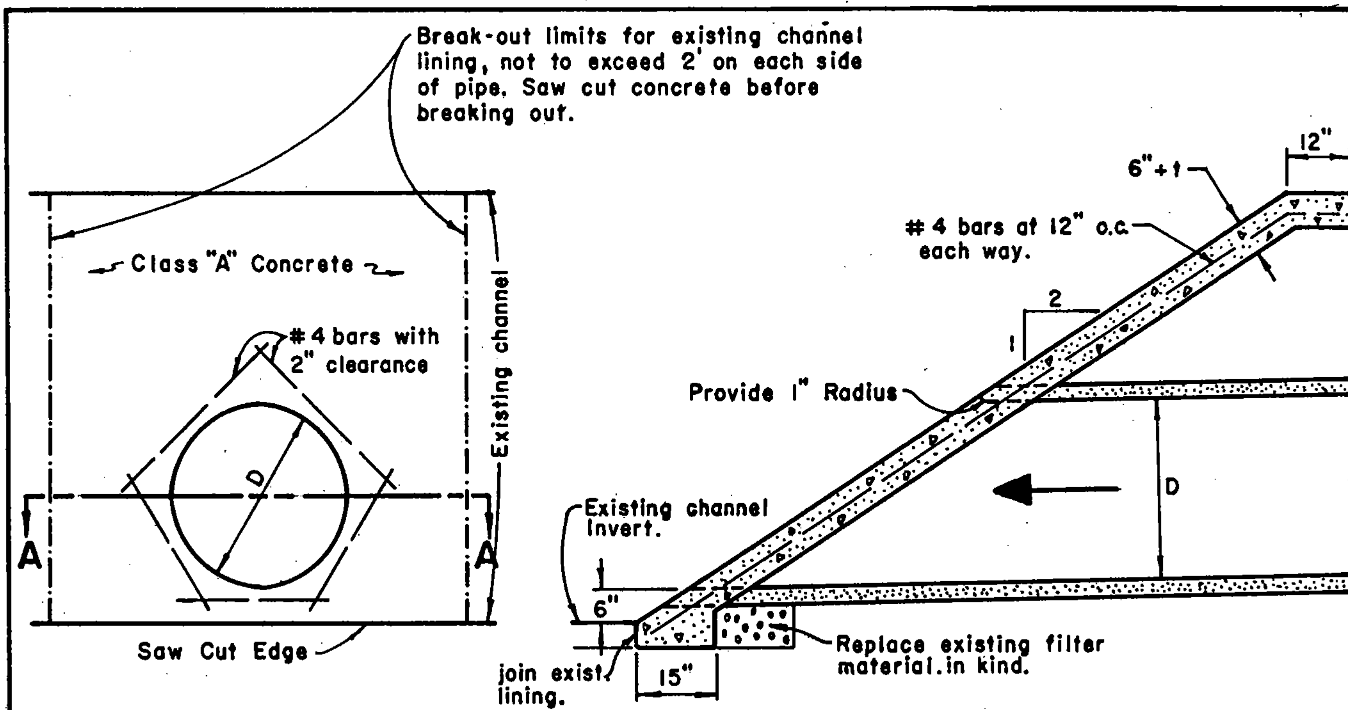
   A confluence angle of 45° may be used if none of the above conditions exist.
2. WALL THICKNESS of the inlet structure (t) and steel reinforcing requirement shall be determined by design analysis. Minimum t=6" and minimum allowable steel, #4 bars at 12".
3. For channels with GRADED EARTH INVERT, provide 1 foot thick grouted rock rip-rap apron extending a minimum distance of 5' upstream and 5' downstream of inlet structure and L feet into channel.



SECTION B-B

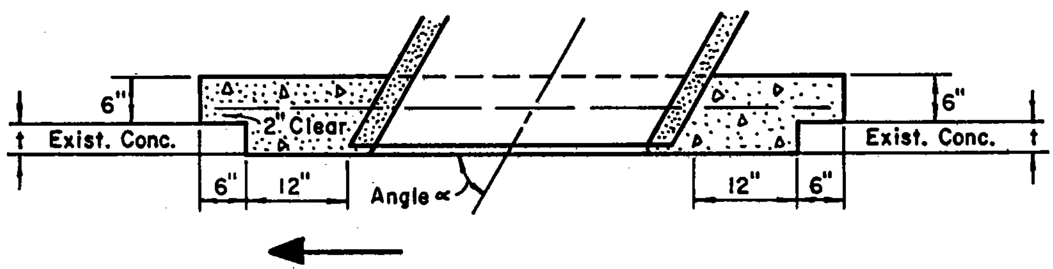
L, D and Angle shall be specified on construction plans.

Ventura County Flood Control District DESIGN STANDARDS
JUNCTION TO R.C. TRAPEZOIDAL CHANNEL TYPE I
Approved A P Stokes Date 5-14-68



ELEVATION

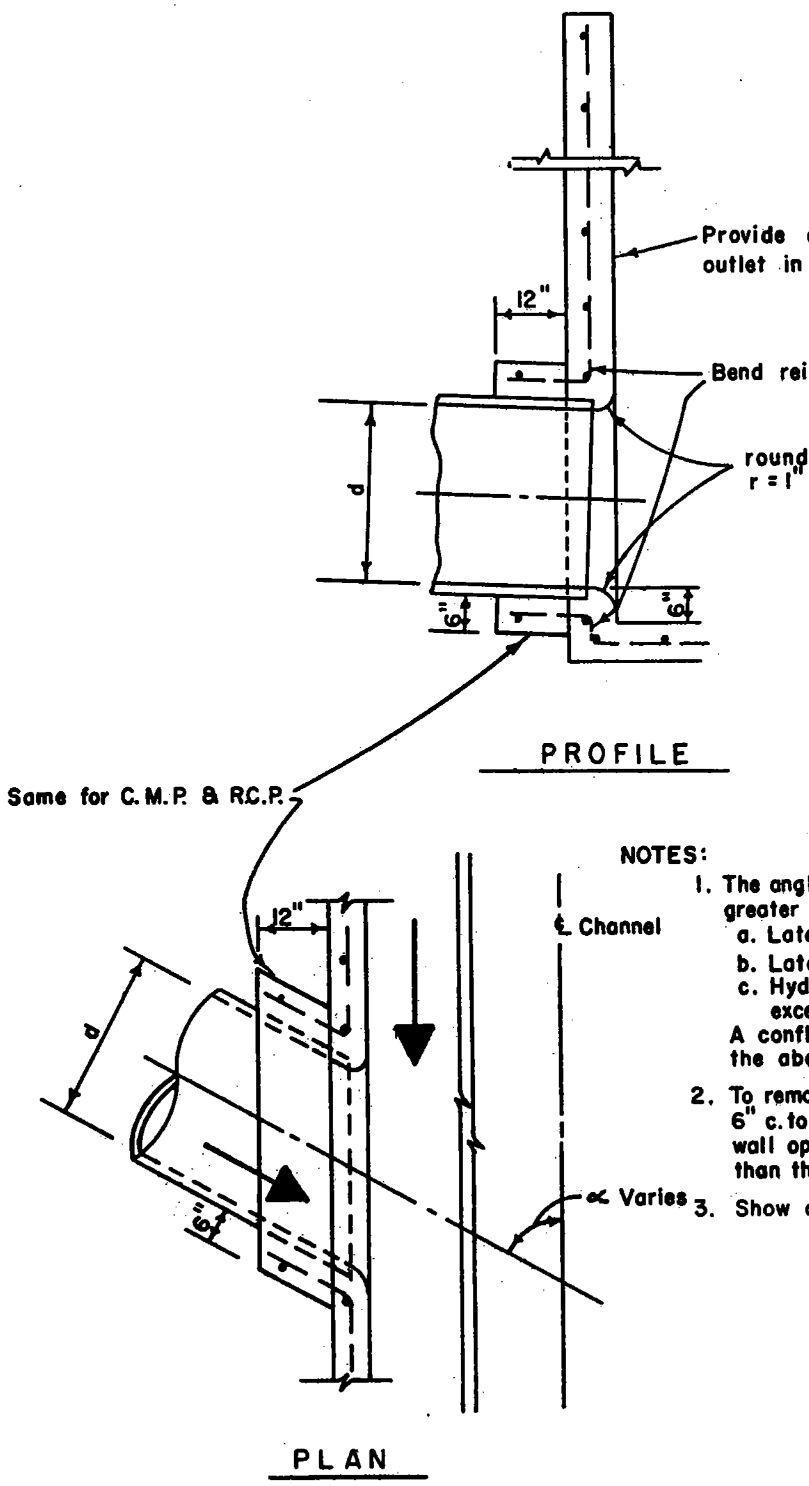
PROFILE



SECTION A-A

D & Angle ∝ shall be specified on construction plans.

Ventura County Flood Control District DESIGN STANDARDS
JUNCTION TO R.C. TRAPEZOIDAL CHANNEL TYPE II
Approved A. P. Stokes Date 5-14-68

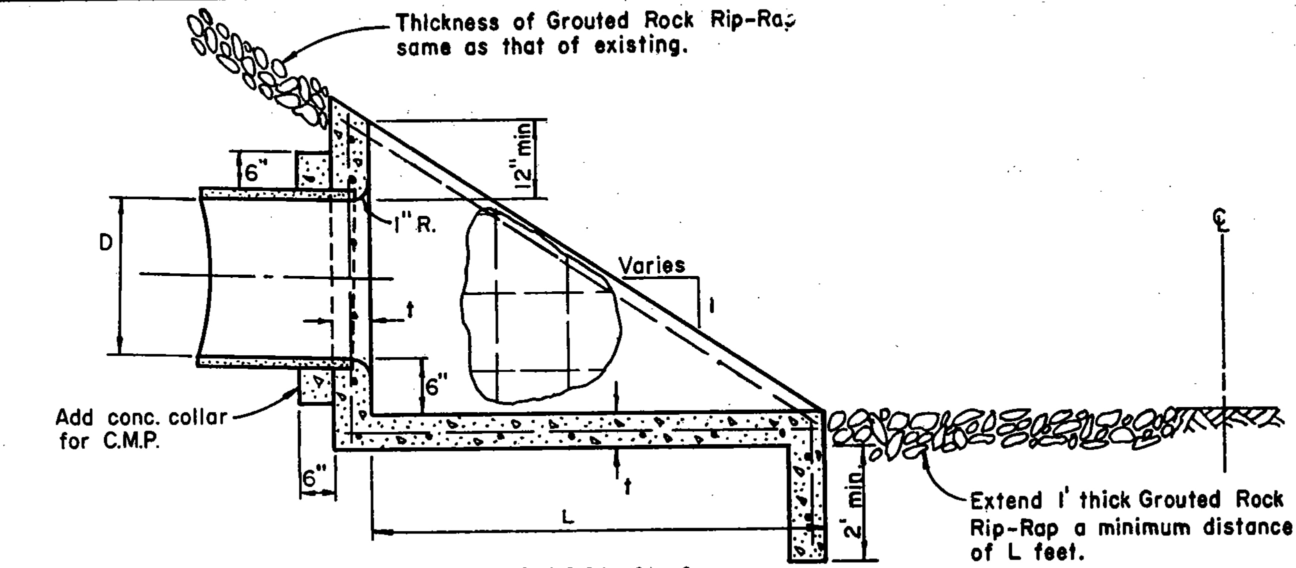


NOTES:

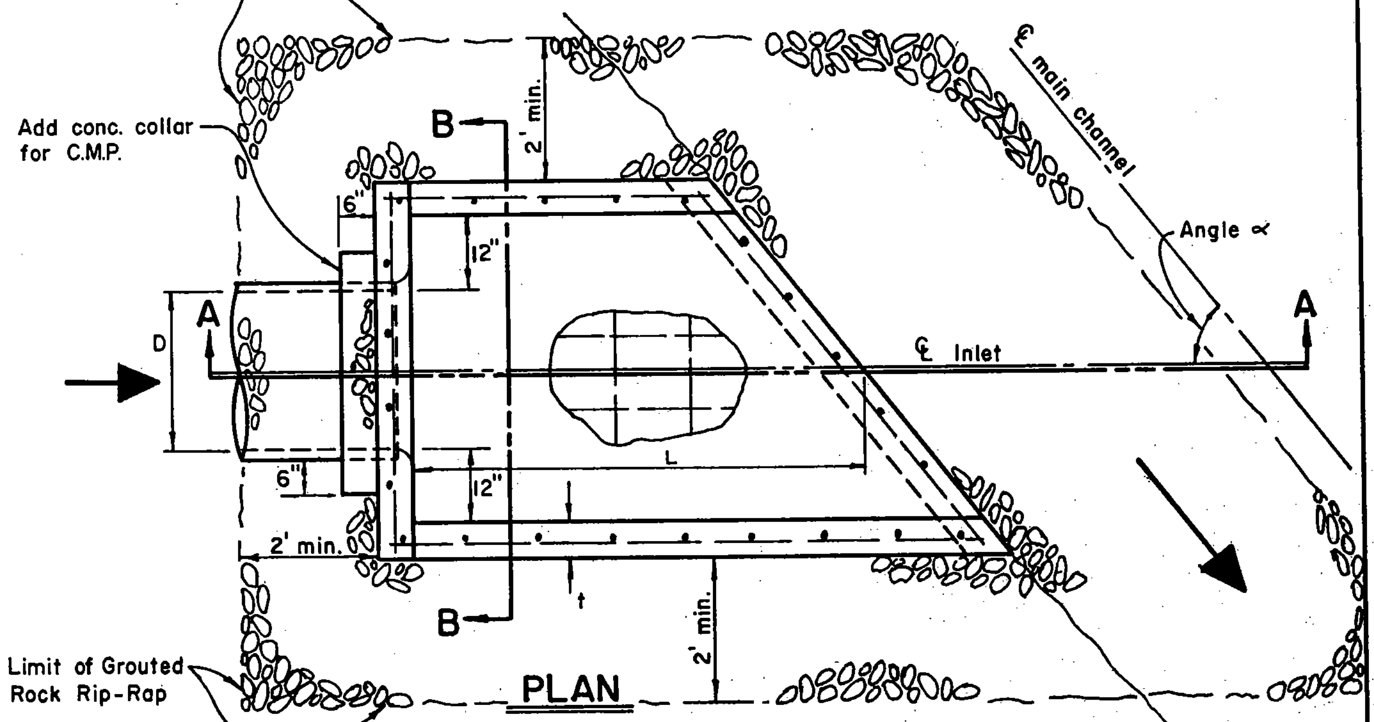
1. The angle of confluence of side inlets shall not be greater than 30° for the following cases:
   a. Lateral flow exceeds 10% of the main line flow.
   b. Lateral flow velocities are 20 fps or less.
   c. Hydraulic analysis of the junction indicates excessive losses in the main channel.

   A confluence angle of 45° may be used if none of the above conditions exist.
2. To remove existing lining, a series of holes spaced 6" c. to c. shall be drilled through wall at limits of wall opening. Opening to be a maximum 2' greater than the outside diameter of pipe.
3. Show direction of flow.

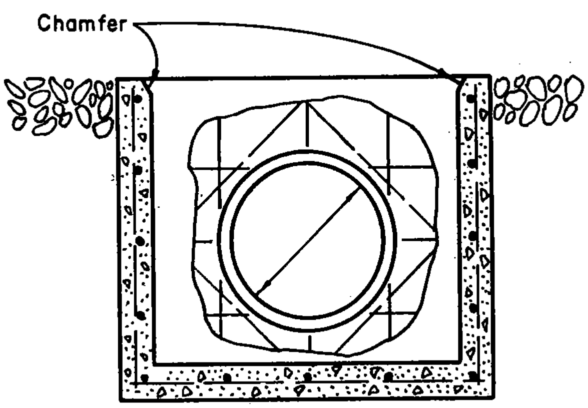
Ventura County Flood Control District DESIGN STANDARDS
JUNCTION TO R.C. RECTANGULAR CHANNELS
Approved *A. P. Stoker* Date 5-14-68



SECTION A-A



PLAN



SECTION B-B

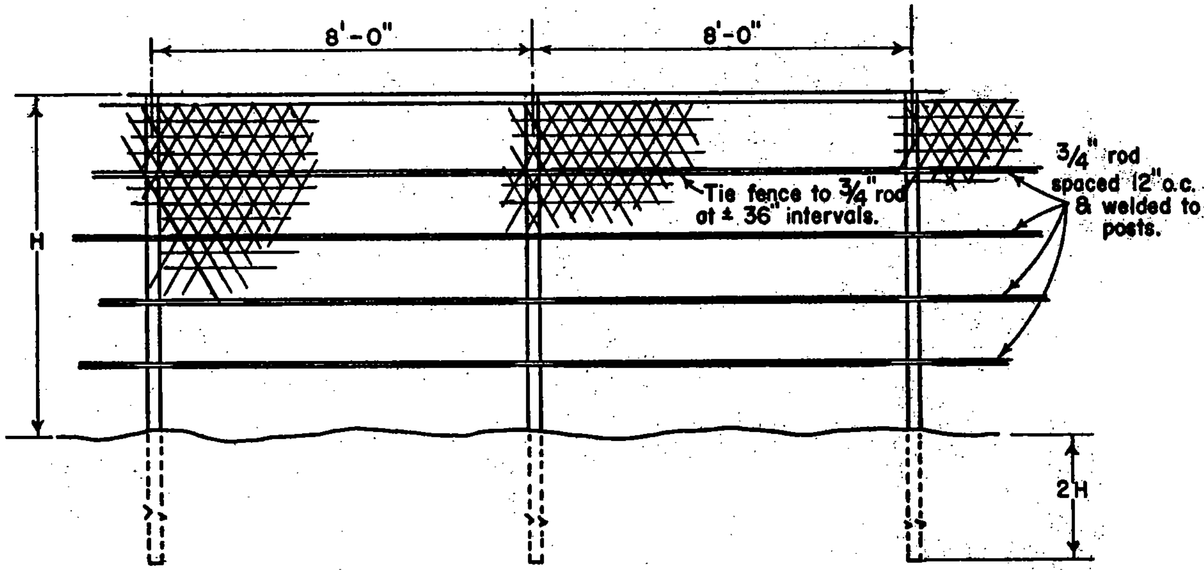
L, D and Angle ∝ shall be specified on construction plans.

Notes:

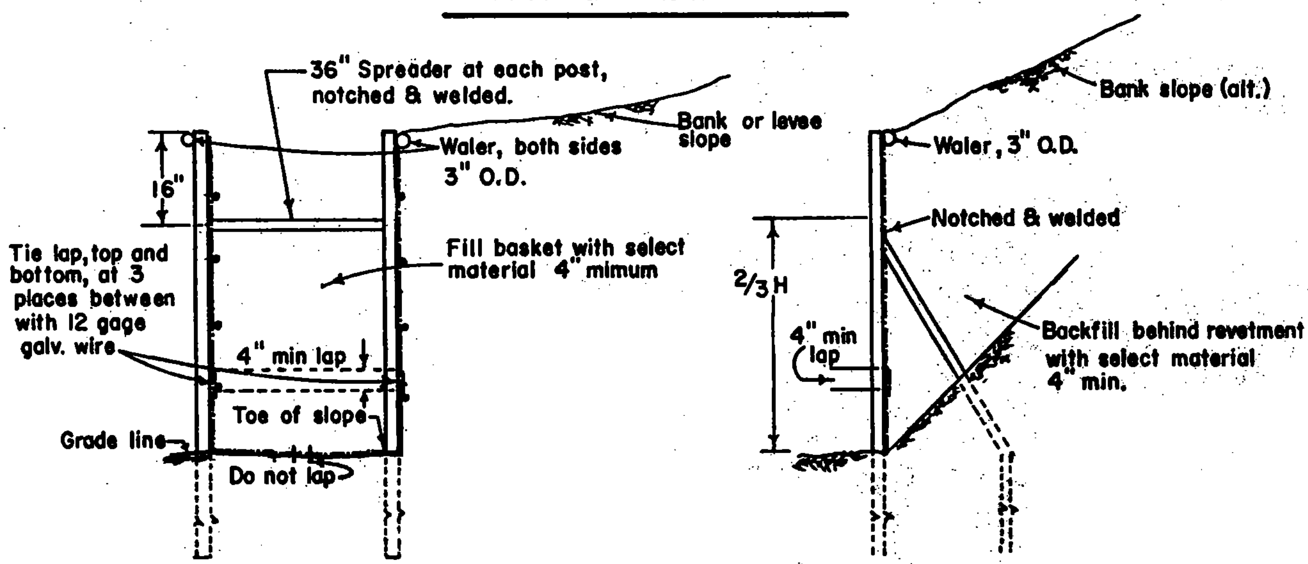
1. ANGLE OF CONFLUENCE (∝) of side inlets shall not be greater than 30° for the following cases:
   - a. Lateral flow exceeds 10% of the main line flow.
   - b. Lateral flow velocities are 20 qfs or greater.
   - c. Hydraulic analysis of the junction indicates excessive losses in the main channel.

   A confluence angle of 45° may be used if none of the above conditions exist.
2. WALL THICKNESS of the inlet structure (t) and steel reinforcing requirement shall be determined by design analysis. Minimum t=6" and minimum allowable steel, #4 bars at 12".

Ventura County Flood Control District DESIGN STANDARDS
JUNCTION TO ROCK RIP-RAP TRAPEZOIDAL CHANNEL
Approved A. P. Stokes Date 5.14.68



TYPICAL ELEVATION



DOUBLE PIPE & WIRE

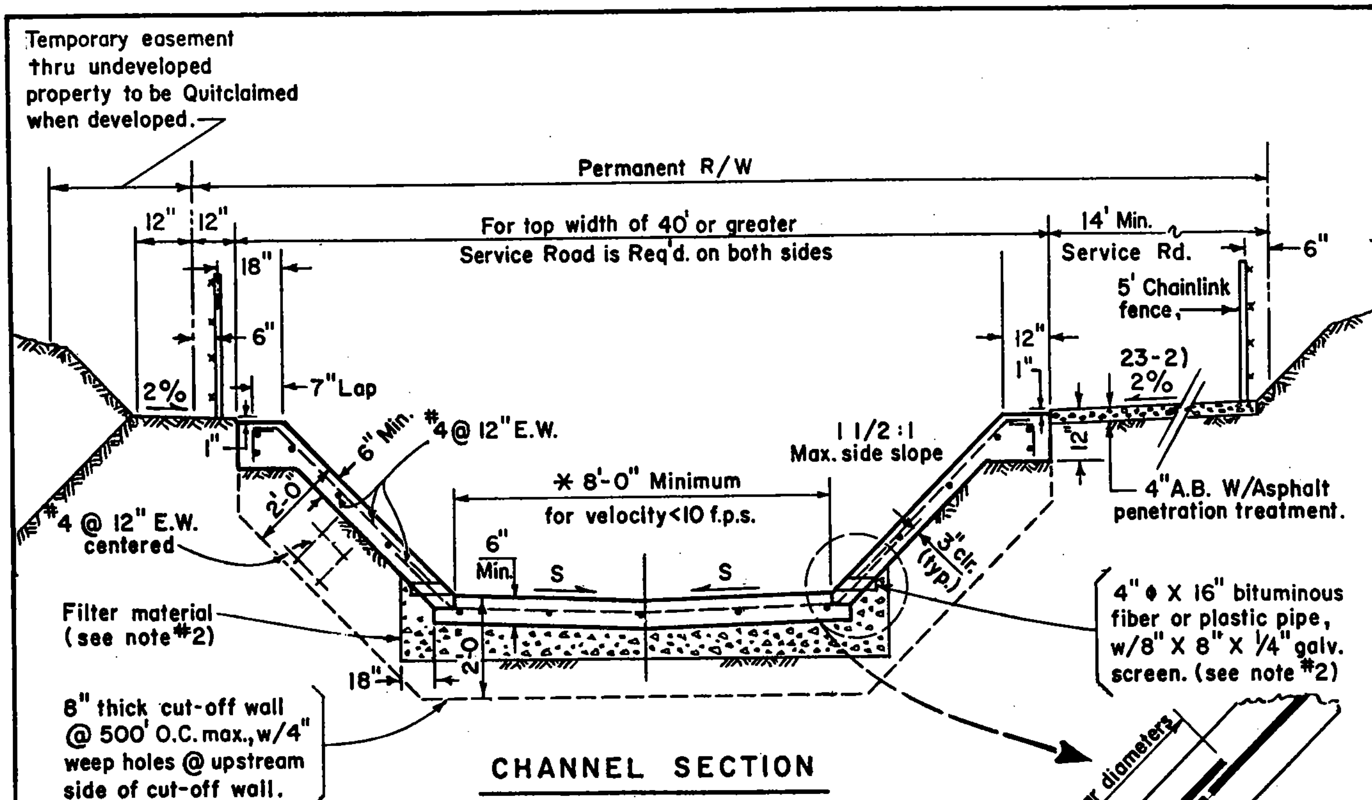
SINGLE PIPE & WIRE

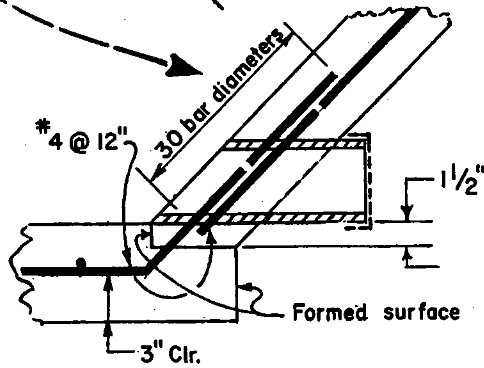
TYPICAL SECTIONS

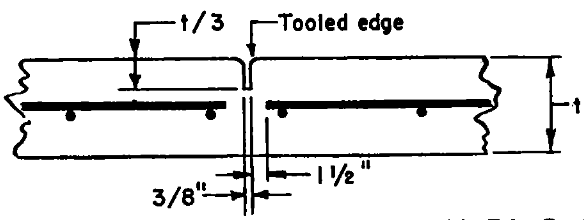
NOTES:

1. HEIGHT H is shown on the construction plans.
2. LENGTH of posts shall be 3H.
3. POSTS, braces, and spreaders shall be 3" O.D. oilfield upset tubing or equivalent.
4. WIDTHS of woven wire fencing varies depending on height H.

Ventura County Flood Control District DESIGN STANDARDS
PIPE & WIRE REVETMENT
Approved A. P. Stoker Date 5-14-68







Bot. width	S.
0 - 10'	"
11' - 20'	2"
21' - __	3"

TRANSVERSE CONTRACTION JOINTS @ 20' O.C.

NOTES:

1. In undeveloped areas and/or where significant sheet flow is intercepted by the channel, a system of parallel ditches and side drain inlets approved by the Flood Control District shall be constructed to control surface flow.

2. Filter material design and weep hole spacing requirements to be determined by soils test of native material.

3. An adequate longitudinal pipe subdrain system of approved design shall be provided where required by high groundwater conditions.

4. Reinforced concrete structural section shown is minimum allowable. The connection between side walls and bottom slab shall be designed for shear and 50% of the moment based on a vertical projected area and equivalent fluid pressure of not less than 40 pounds per cubic foot.

5. Subgrade for lining shall be firm undisturbed natural ground or fill compacted to 90% relative compaction for full depth of fill in accordance with U.B.C. 70-1.

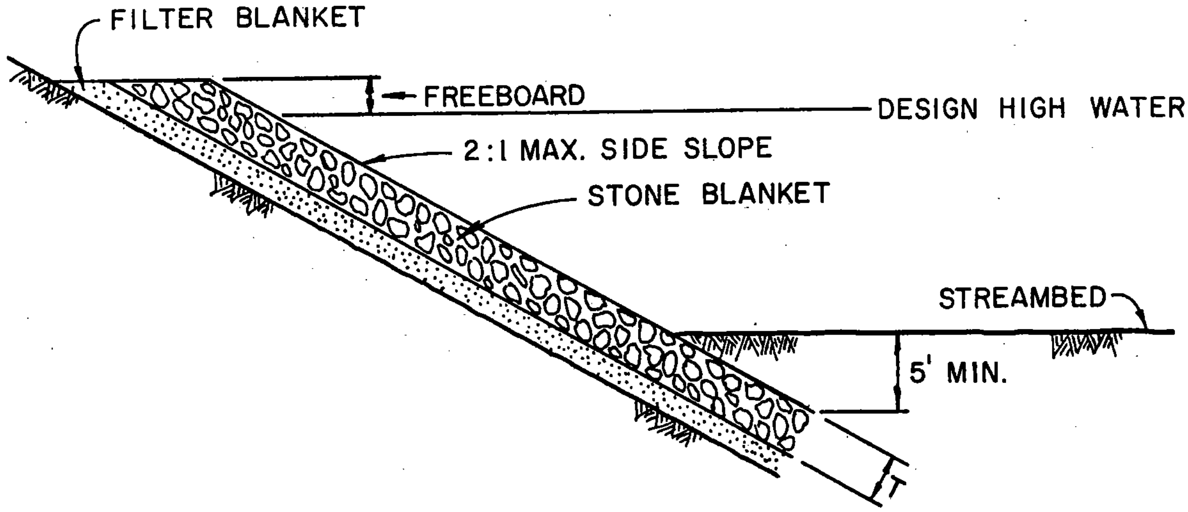
6. See Section 450 of the Design Manual for detailed discussion of the design of trapezoidal R.C. Channels.

7. The use of trapezoidal design in lieu of rectangular must be approved in each case by the District for channel under the jurisdiction of the District.

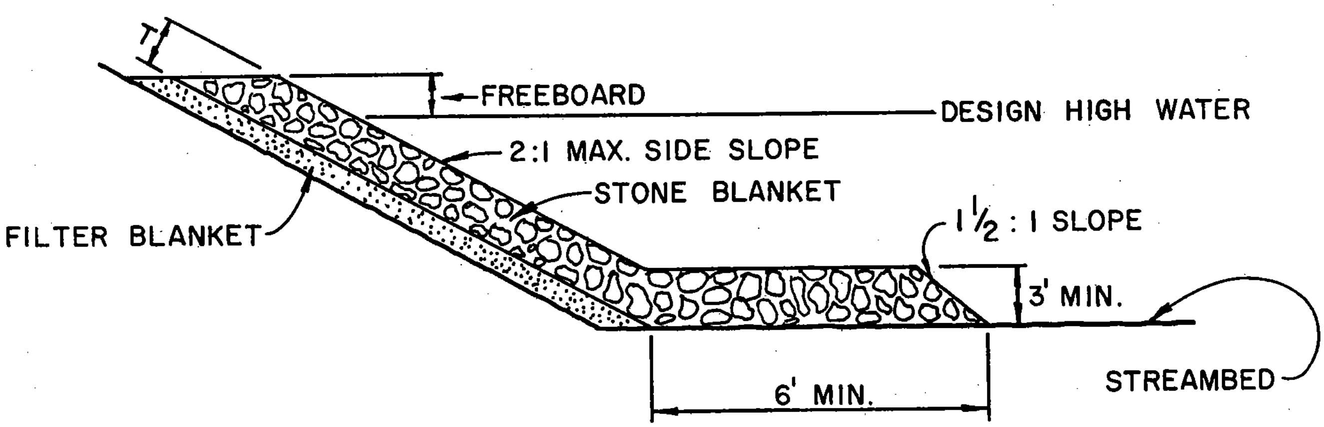
Ventura County Flood Control District
DESIGN STANDARDS

R.C. TRAPEZOIDAL CHANNEL SECTION
MINIMUM DESIGN STANDARDS

Approved A. P. Stoker Date 5.14.68



(a) STONE BLANKET AND TOE TRENCH DETAIL



(b) STONE BLANKET AND TOE DETAIL

NOTES:

1. For discussion on thickness of slope protection, filter blanket and rock gradation see Section 453 of the Design Manual.

Ventura County Flood Control District DESIGN STANDARDS
ROCK RIP-RAP SLOPE PROTECTION FOR TRAPEZOIDAL CHANNELS
Approved A P Stoker Date 5.14.68

STANDARD DRAWING NO. 13

REFERENCES

1. Hydrology and Hydraulic Design Manual - Los Angeles County Flood Control District, 1964.

2. The Institute of Transportation and Traffic Engineering, University of California, Street and Highway Drainage, Course Notes, Volume 2, 1965.

3. Structural Design Manual - Los Angeles County Flood Control District, 1964.

4. Open Channel Hydraulics by Ven Te Chow, 1959.

5. Design of Small Dams, U. S. Department of the Interior, Bureau of Reclamation, First Edition, 1960.

6. Civil Engineering Handbook, Fourth Edition, 1959.

7. Engineering Hydraulics by Rouse, Second Printing, 1958.

8. Handbook of Hydraulics by H. W. King and E. F. Brater.

9. Reclamation Manual, U. S. Department of the Interior, Bureau of Reclamation, 1950.

10. Soil Mechanics in Engineering Practice by Karl Terzaghi and Ralph B. Peck, John Wiley & Sons, 1948.

11. Transactions, American Society of Civil Engineers, Paper No. 2776, Volume 120, 1955.

12. Design Charts for Open-Channel Flow, U. S. Department of Commerce, Bureau of Public Roads, 1961.

13. Engineering Design Standards, Far West States, U. S. Department of Agriculture, Soil Conservation Service, September 1, 1958.

14. Concrete Pipe Handbook, American Concrete Pipe Association, 1955.

15. Use of Riprap for Bank Protection, Hydraulic Engineering Circular No. 11, June, 1967, U. S. Department of Transportation, Federal Highway Administration, Bureau of Public Roads.

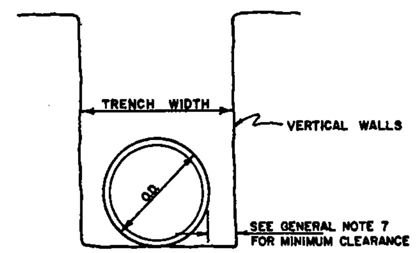
16. Specifications for Highway Bridges, American Association of State Highway Officials, 1965.

17. Foundation Engineering, edited by G. A. Leonards, McGraw-Hill Book Company, Inc., 1962.

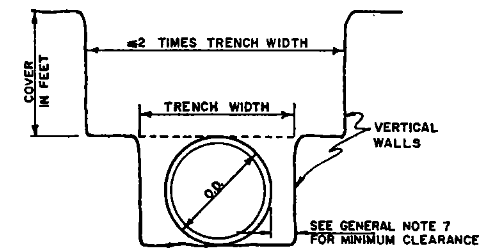
18. Practical Design of Solid-Barrel, Reinforced Concrete Skew Structures, by Bernard L. Weiner, Paper No. 2474, Transactions, American Society of Civil Engineers, Volume 116, 1951.

TRENCH WIDTH

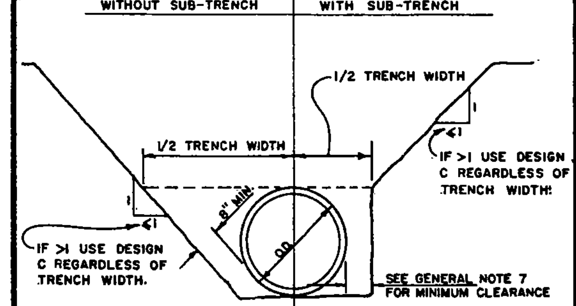
VERTICAL WALL TRENCH



VERTICAL WALL TRENCH WITH SUB-TRENCH



SLOPING WALL TRENCH



MAXIMUM ALLOWABLE TRENCH WIDTH - FEET			
I.D.	DESIGN A	DESIGN B	DESIGN C
18"	3½	5½	
24"	4¼	6¼	
30"	5	7	
36"	5¾	7¾	
42"	6½	8½	
48"	7¼	9¼	
54"	8	10	
60"	8½	10½	NO LIMIT
66"	9¼	11¼	
72"	10	12	
78"	10½	12½	
84"	11	13	
90"	11¾	13¾	
96"	12¼	14¼	
102"	13	15	
108"	13½	15½	

TRENCH NOTES: 1. State construction safety orders require shoring when slopes are steeper than 3/4 : 1 unless otherwise approved by the State.
2. Shape of trench is at the contractor's option providing maximum trench width and slope are not exceeded, unless limited by right of way or adjacent structure or specifically required by the plans or special provisions.

LOADING

THREE TYPES OF LOADING ARE PROVIDED FOR IN THE PIPE SELECTION TABLE, AS FOLLOWS:

TYPE 1 – Earth backfill only with occasional vehicle. Use outside of road rights of way only.

TYPE 2 – Earth backfill with or without A.C. pavement surfacing with superimposed H-20 live load. Usual loading within road rights of way.

TYPE 3 – Earth backfill with 9" thick class "B" P.C.C. pavement with superimposed H-20 live load. P.C.C. pavement must extend 1 1/2 times the O.D. of pipe each side the ℄ of pipe. This type of slab may be used as a corrective measure for construction deviations where applicable.

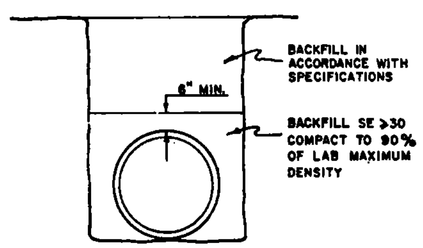
COVER

COVER IS MEASURED FROM THE OUTSIDE TOP OF PIPE TO THE FINISHED SURFACE AT THE ℄ OF PIPE. FINISHED SURFACE IS TOP OF PAVEMENT WHEN INSTALLED. MINIMUM COVER ALLOWED IS 1.0ft.

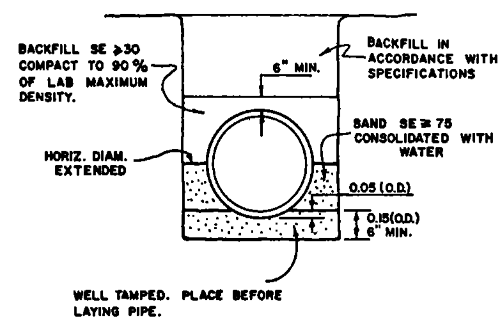
range of cover	cover to be used in selection table
>1.0 to <1.9	1.0
>1.9 to <2.5	2.0
>2.5 to <3.5	3.0
>3.5 to <4.5	4.0
>4.5 to <5.5	5.0
>5.5 to <6.5	6.0
>6.5 to <8.5	8.0
>8.5 to <10.5	10.0
>10.5 to <15.5	15.0
>15.5 to <20.5	20.0
>20.5 to <25.5	25.0
>25.5 to <30.5	30.0

BACKFILL, BEDDING & LOAD FACTOR

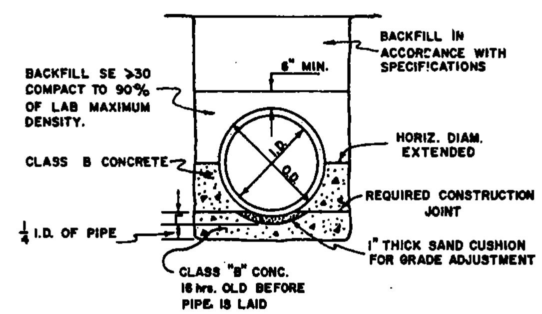
TYPE 1 INSTALLATION
LOAD FACTOR = 1.1



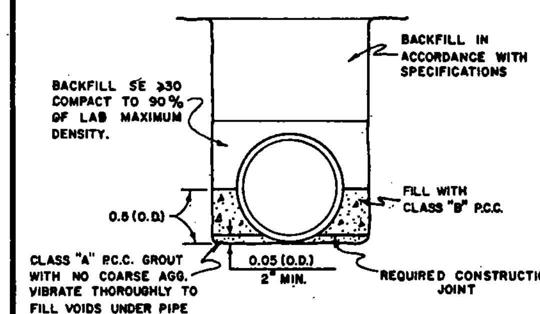
TYPE 2 INSTALLATION
LOAD FACTOR = 1.9



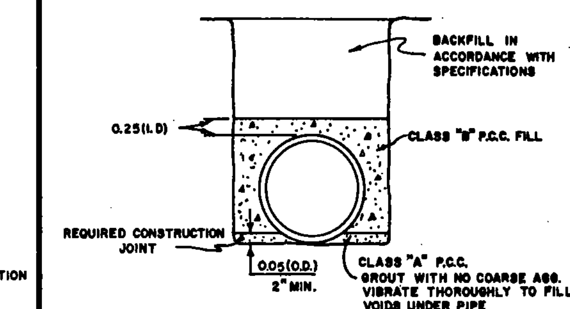
TYPE 3 INSTALLATION
LOAD FACTOR = 3.0



TYPE 4 INSTALLATION
LOAD FACTOR = 1.9



TYPE 5 INSTALLATION
LOAD FACTOR = 3.0



BEDDING NOTES: 1. For trench widths Design A & B, required imported bedding and fill material (soil, aggregate and concrete) shall extend full width of trench.
2. For trench widths Design C, required imported bedding and fill material (soil, aggregate and concrete) shall extend to a width equal to maximum allowable trench width for Design B.
3. Types 4 and 5 are intended primarily as remedial beddings to be used when construction deviates from design in such a manner that increased load factor will compensate for such deviation.

ASTM C-76 REINFORCED CONCRETE PIPE SELECTION TABLE

PIPE I.D. (INCHES)																			
COVER-FEET	1	1	1	1	1	1	1	2	2	2	2	2	2	3	3	3	3	3	3
LOADING TYPE	1	2	2	2	3	3	3	1	2	2	2	3	3	1	2	2	2	3	3
TRENCH WIDTH DESIGN	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY
LOAD FACTOR	ANY	1.1	1.9	3.0	1.1	1.9	3.0	ANY	1.1	1.9	3.0	1.1	1.9,3.0	ANY	1.1	1.9	3.0	1.1	1.9,3.0
18	I	NA	V	III	II	I	I	I	V	III	II	II	I	I	IV	III	I	III	I
24		NA	IV	III	II				V		I	II				II		III	
30		V	IV	II	II				IV			II				II		II	
36		V	III	II	II					III		I				II			
42		V	III	I	I					II						I			
48		IV	III							II									
54			II							II					IV			II	
60			II						IV	I					III			I	
66		IV	I						III										
72		III																	
78															III				
84															II				
90									III										
96		III							II										
102		II							II										
108	I	II	I	I	I	I	I	I	II	I	I	I	I	I	II	I	I	I	I

PIPE I.D. (INCHES)																					
COVER-FEET	4	4	4	4	4	5	5	5	5	5	6	6	6	6	6	8	8	8	8	8	8
LOADING TYPE	1	1	2	2	2	1	1	2	2	2	1	1	2	2	2	1	1	1	2	2	2
TRENCH WIDTH DESIGN	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY
LOAD FACTOR	1.1	1.9,3.0	1.1	1.9	3.0	1.1	1.9,3.0	1.1	1.9	3.0	1.1	1.9,3.0	1.1	1.9	3.0	1.1	1.9	3.0	1.1	1.9	3.0
18	II	I	IV	II	I	III	I	IV	II	I	IV	I	IV	II	I	IV	III	I	V	III	I
24	II			II		III					IV								V		
30	I			II		III					III								V		
36			IV	I		II											III		IV		
42			III						II								II				
48									I												
54								IV												III	
60								III						II						II	
66														I							
72																					
78																					
84											III		IV				II				
90			III			II					II		III				I				
96			II			I		III													
102			II			I		II													
108	I	I	II	I	I	I	I	II	I	I	II	I	III	I	I	IV	I	I	IV	II	I

PIPE I.D. (INCHES)															
COVER-FEET	10	10	10	10	10	10	15	15	15	15	15	15	20	20	20
LOADING TYPE	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY
TRENCH WIDTH DESIGN	A	A	A	B,C	B,C	B,C	A	A	A	B,C	B,C	B,C	A	A	A
LOAD FACTOR	1.1	1.9	3.0	1.1	1.9	3.0	1.1	1.9	3.0	1.1	1.9	3.0	1.1	1.9	3.0
18	V	III	I	V	IV	II	V	IV	II	NA	V	IV	V	IV	III
24	V												V		
30	IV												NA		
36					IV										
42					III							IV			
48						II						III			
54						I					V				
60											IV				
66				V											
72				IV											
78															
84															
90										NA					
96										V					
102		III								V					
108	IV	II	I	IV	III	I	V	IV	II	V	IV	III	NA	IV	III

PIPE I.D. (INCHES)																				
COVER-FEET	20	20	20	20	20	20	25	25	25	25	25	25	25	30	30	30	30	30	30	30
LOADING TYPE	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY	ANY
TRENCH WIDTH DESIGN	B	B	B	C	C	C	ANY	A	A	B	B	C	C	ANY	A	A	B	B	C	C
LOAD FACTOR	1.1	1.9	3.0	1.1	1.9	3.0	1.1	1.9	3.0	1.9	3.0	1.9	3.0	1.1	1.9	3.0	1.9	3.0	1.9	3.0
18	NA	NA	V	NA	NA	V	NA	IV	III	NA	V	NA	V	NA	V	III	NA	V	NA	NA
24		NA	V			V										III				
30		V	IV			IV										IV				
36								IV			V									
42					NA			V			IV									NA
48					V				III											V
54									IV	NA										
60										V										
66																				
72																		V		
78																		IV		
84																				
90																				
96																				
102			IV																	
108	NA	V	III	NA	V	IV	NA	V	IV	V	IV	NA	V	NA	V	IV	NA	IV	NA	V

GENERAL NOTES: 1. The combination of cover, loading, trench width and load factor determines the class of pipe required.
2. Unless specifically restricted by the plans or special conditions, substitutions may be made in accordance with this table providing right of way limits are not encroached upon and providing adjacent structures are not endangered.
3. A special design prepared by a civil engineer and subject to the approval of the Director of Public Works shall be used for any case not specifically cover by this standard.
4. N.A. = Not Applicable. This combination of cover, loading, trench width and load factor requires specially designed pipe with D-Load greater than Class V.
5. Pipe of the same strength is available in one to three wall thicknesses. Any one of these thicknesses may be used unless one is specifically required by the plans or specifications due to limited clearance.
6. All pipe shall be installed in accordance with Ventura County Standard Specifications on public contract jobs, or Ventura County Land Development Specifications on subdivision or permit jobs.
7. Minimum clearance between pipe and trench: 6" for diameter ≤60", 10" for diameters >60" and <96", and 12" for diameters >96".
8. Same as Ventura County P. W. S. D. 34-1

Ventura County Flood Control District
DESIGN STANDARDS

REINFORCED CONCRETE PIPE
SELECTION TABLE

Approved [signature] Date 5.15.68