UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Washington, D. C. 20250

March 19, 1965

ENGINEERING MEMORANDUM-27 (Rev.)

Re: Earth Dams

This memorandum contains the limiting criteria for proportioning earth dams and associated spillways. Engineering Memorandums SCS-27 dated March 14, 1958; SCS-31 dated April 2, 1959; SCS-40 dated August 20, 1959; SCS-42 dated February 20, 1961; and SCS-43 dated January 17, 1961, are canceled.

This memorandum applies to all structures except class (a) structures as defined below for which the product of storage times the height of the dam is less than 3000. The storage is defined as the original capacity of the reservoir in acre-feet at the elevation of the crest of the emergency spillway. The height of the dam is the difference in elevation in feet between the emergency spillway crest and the lowest point in the original cross section on the centerline of the dam.

Each of the following stated criteria indicates whether the limit is a maximum or minimum limit and is not to be construed as being satisfactory design criteria at all sites. Experience, state laws and regulations, investigations, or analysis may dictate more conservative criteria.

Permission for deviation from the following criteria must be obtained from the Director of the Engineering Division. Requests for such action will contain the recommendations of the Head of the Engineering and Watershed Planning Unit before they are submitted to the Director.

Attached as a part of this memorandum are:

Section A - Definitions
Section B - Structure Classification
Section C - Hydrologic Criteria
Section D - Sediment Storage
Section E - Principal Spillways
Section F - Emergency Spillways
Section G - Earth Embankments
Section H - Utilities Under Embankments

Attachments

[signature] Williams

STC
DIR
CA
EWP

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Washington, D. C. 20250

March 19, 1965

ENGINEERING MEMORANDUM-27 (Rev.)

Re: Earth Dams

This memorandum contains the limiting criteria for proportioning earth dams and associated spillways. Engineering Memorandums SCS-27 dated March 14, 1958; SCS-31 dated April 2, 1959; SCS-40 dated August 20, 1959; SCS-42 dated February 20, 1961; and SCS-43 dated January 17, 1961, are canceled.

This memorandum applies to all structures except class (a) structures as defined below for which the product of storage times the height of the dam is less than 3000. The storage is defined as the original capacity of the reservoir in acre-feet at the elevation of the crest of the emergency spillway. The height of the dam is the difference in elevation in feet between the emergency spillway crest and the lowest point in the original cross section on the centerline of the dam.

Each of the following stated criteria indicates whether the limit is a maximum or minimum limit and is not to be construed as being satisfactory design criteria at all sites. Experience, state laws and regulations, investigations, or analysis may dictate more conservative criteria.

Permission for deviation from the following criteria must be obtained from the Director of the Engineering Division. Requests for such action will contain the recommendations of the Head of the Engineering and Watershed Planning Unit before they are submitted to the Director.

Attached as a part of this memorandum are:

Section A - Definitions
Section B - Structure Classification
Section C - Hydrologic Criteria
Section D - Sediment Storage
Section E - Principal Spillways
Section F - Emergency Spillways
Section G - Earth Embankments
Section H - Utilities Under Embankments

Attachments

[signature]

STC
DIR
CA
EWP
WD

SECTION A - DEFINITIONS

A spillway is an open or closed channel, or both, used to convey excess water from a reservoir. It may contain gates, either manually or automatically controlled, to regulate the discharge of excess water.

The principal spillway is the ungated spillway designed to convey the water from the retarding pool at release rates established for the structure.

The emergency spillway of a dam is the spillway designed to convey water in excess of that impounded for flood control or other beneficial purposes.

The retarding pool is the reservoir space allotted to the temporary impoundment of floodwater. Its upper limit is the elevation of the crest of the emergency spillway.

Retarding storage is the volume in the retarding pool.

The sediment pool is the reservoir space allotted to the accumulation of submerged sediment during the life of the structure.

Sediment storage is the volume allocated to total sediment accumulation.

The sediment pool elevation is the elevation of the surface of the anticipated sediment accumulation at the dam.

An earth spillway is an unvegetated open channel spillway in earth materials.

A vegetated spillway is a vegetated open channel spillway in earth materials.

A ramp spillway is a vegetated spillway constructed on the downstream face of an earth dam.

A rock spillway is an open channel spillway in rock materials.

The control section in an open channel spillway is that section where accelerated flow passes through critical depth.

The inlet channel of an emergency spillway is the channel upstream from the control section.

The exit channel of an emergency spillway is that portion of the channel downstream from the control section which conducts the flow safely to a point where it may be released without jeopardizing the integrity of the structure.

The emergency spillway hydrograph is that hydrograph used to establish the minimum design dimensions of the emergency spillway.

The freeboard hydrograph is the hydrograph used to establish the minimum elevation of the top of the dam.

Joint extensibility is the length of a pipe joint measured from the center of the gasket to the point of flare of the bell ring or collar when the joint is engaged.

Joint gap is the longitudinal dimension between the end face of the spigot end of a pipe joint and the corresponding face of the bell end of the connecting pipe. It does not include the beveled portions designed for sealing compounds.

The rotation capacity of a pipe joint is the maximum angular deflection possible for the joint without binding or loss of watertightness.

SECTION B - STRUCTURE CLASSIFICATION

In determining structure classification, a number of factors must be considered. Consideration must be given to the damage that might occur to existing and future developments downstream resulting from a sudden breach of the earth embankment and to the structures themselves. The effect of failure on public confidence is an important factor. State and local regulations and the responsibility of the involved public agencies must be recognized. The stability of the spillway materials, the physical characteristics of the site and the valley downstream, and the relationship of the site to industrial and residential areas all have a bearing on the amount of potential damage in the event of a failure.

Structure classification is determined by the above conditions. It is not determined by the criteria selected for design.

I. CLASSES OF STRUCTURES

The following broad classes of structures are established to permit the association of criteria with the damage that might result from a sudden major breach of the earth dam embankment.

Class (a) -- Structures located in rural or agricultural areas where failure may damage farm buildings, agricultural land, or township and country roads.

Class (b) -- Structures located in predominantly rural or agricultural areas where failure may damage isolated homes, main highways or minor railroads or cause interruption of use or service of relatively important public utilities.

Class (c) -- Structures located where failure may cause loss of life, serious damage to homes, industrial and commercial buildings, important public utilities, main highways, or railroads.

II. STRUCTURES IN SERIES

When structures are spaced so that the failure of an upper structure could endanger the safety of a lower structure, the possibility of a multiple failure must be considered in assigning the structure classification of the upstream structure. Additional safety can be provided in either structure by (1) increasing the retarding storage and/or (2) increasing the emergency spillway capacity.

III. STORAGE OF WATER FOR IMPORTANT PURPOSES

The addition of other functional requirements, such as the storage of water for some beneficial use, adds to the economic value of the structure and could create additional damages should the structure fail. For these reasons, each multiple purpose structure should be carefully evaluated and precautions taken to insure safe structures which will perform their multiple function for at least the economic life of the project. The criteria for planning and design of structures involving industrial and municipal water will be equivalent to hazard class (b) or (c) depending on site conditions. When the multipurpose involves agricultural water or recreation, the minimum criteria will approach that for hazard class (b).

SECTION C -HYDROLOGIC CRITERIA

SECTION C - HYDROLOGIC CRITERIA

I. RUNOFF

Procedures for hydrologic design as contained in the National Engineering Handbook, Section 4 "Hydrology" will be followed.

Specific references for runoff determination are found in Chapter 10. All runoff volumes for design purposes will be based on Antecedent Moisture Condition II or greater. Chapter 21 contains hydrologic procedures for determining principal spillway capacities, retarding storage, and emergency spillway and freeboard hydrographs.

Table C-I gives the minimum hydrologic criteria for structure classes and conditions by reference to specific sheets of Engineering Standard Drawing Numbers ES-1020 (Conterminuous United States), ES-1021 (Hawaii), ES-1022 (Alaska), ES-1023 (Puerto Rico), and ES-1024 (Virgin Islands). The maximum precipitation adjustment for drainage areas between 10 and 100 square miles in size is given on Standard Drawing No. ES-1003, revised 9/10/63. No adjustment is made when the drainage area is 10 square miles or less in size. When the drainage area is greater than 100 square miles in size, the adjustment will be determined for the project by the Engineering Division. Standard Drawing No. ES-1003 also presents the six hour design storm distribution adopted by the Service and a standard relationship for determining the proportional increase in rainfall for durations to 36 hours when the six hour value is known.

A. Structures in Series

For the design of a lower structure in a series, if the total drainage area above a lower structure exceeds 10 square miles, it is necessary to apply two storms for development of both the emergency spillway and the freeboard hydrographs.

The first set of design storms selected for the development of the emergency spillway and freeboard hydrographs are for the uncontrolled drainage area above a lower structure. The dimensions of the emergency spillway for a lower structure under this condition will be determined by reservoir routings of hydrographs developed for each storm.

The second set of design storms will be selected for the entire drainage area above the lower structure. Each design storm rainfall is determined by using this area in the areal adjustment of rainfall amounts (ES-1003). These design storm durations are determined by using the time of concentration of this area assuming no upper structures are in place. The design storm hydrographs will be routed through the emergency spillways of the upstream structures and the

TABLE C-I

MINIMUM HYDROLOGIC CRITERIA FOR STRUCTURE CLASSES AND TYPES

Class of Structure	Purpose of Structure	Existing or Planned Upstream Structure	6 Hour Precipitation Data for Emergency Spillway Hydrograph	6 Hour Precipitation Data for Freeboard Hydrograph
			Sheet No.**	Sheet No.**
(a)	Single or Multiple*	None	1	2
	Single or Multiple	Any	2 but not less than criteria used for upper structures	3 but not less than criteria used for upper structures
(b)	Single or Multiple	None or Any	2 but not less than criteria used for upper structures	3 but not less than criteria used for upper structures
(c)	Single or Multiple	None or Any	4	5

* Structures involving industrial or municipal water will use criteria equivalent to that for class (b) or (c) depending on site conditions.

Criteria approaching that for class (b) will be used when (1) the storage involves water for agricultural use or recreation or (2) the cost of the structure exceeds $75,000.

** Values given on Engineering Standard Sheets as follows:

Conterminous 48 States - ES-1020, 5 sheets
Hawaii - ES-1021, 5 sheets
Alaska - ES-1022, 5 sheets
Puerto Rico - ES-1023, 5 sheets
Virgin Islands - ES-1024, 5 sheets

outflow routed to the lower structure and combined with the hydrograph for the uncontrolled area. The dimensions of the emergency spillway for a lower structure under this condition also will be determined by reservoir routings of the hydrographs developed for each storm.

The design storm imposing the most severe flow condition at the lower structure will be used.

II. PRINCIPAL SPILLWAY

The retarding storage and associated principal spillway discharge will be such that the emergency spillway will not operate more frequently than indicated in table F-I, Section F, Emergency Spillways. The inflow hydrograph or the minimum runoff volume for developing the balance between principal spillway capacity and retarding storage will be determined by procedures in Chapter 21, Section 4, National Engineering Handbook (formerly Technical Release No. 10, March 30, 1959). In areas where streamflow records can be regionalized and transposed to ungaged watersheds (based on the volume-duration-probability analyses of the Central Technical Unit), the Engineering Division will authorize the use of these data for developing the principal spillway capacity and retarding storage. When other streamflow data are used, sufficient documentation must be prepared to show how these values were determined.

In the determination of the retarding storage and the principal spillway capacity, it is assumed that the initial reservoir stage is at the crest of the principal spillway except as provided below.

A. Irrigation Storage Dams

Single purpose class (a) irrigation storage dams with gated outlets and earth or vegetated spillways, which are located on ephemeral streams and in areas where the average annual precipitation is less than 25 inches, may be considered to have discharged 70 percent of the storage, exclusive of sediment storage, in determining the frequency of operation of the emergency spillway as outlined above. When the estimated life of the structure is less than 50 years, the frequency of operation of the emergency spillway may be taken as equal to one-half the life of the structure. This reduced frequency and initial stage for routing will not be applicable to the determination of the emergency spillway capacity.

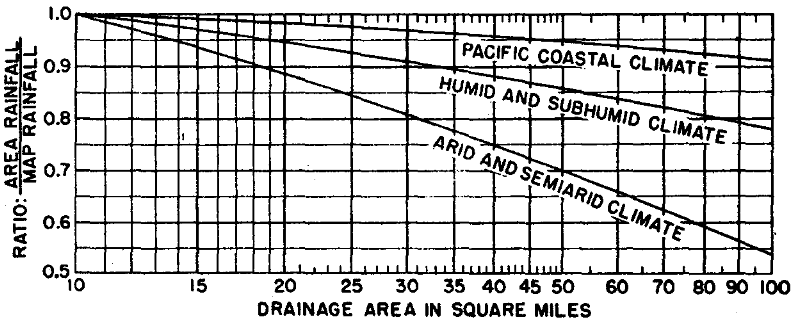
III. EMERGENCY SPILLWAY

The emergency spillway hydrograph will be routed through the reservoir starting with a water surface at the elevation of the sediment pool or at the water surface elevation after 10 days of drawdown, whichever is higher. The 10-day drawdown will be computed from the maximum water surface elevation which would be attained during the passage of the minimum principal spillway design runoff for that class of structure.

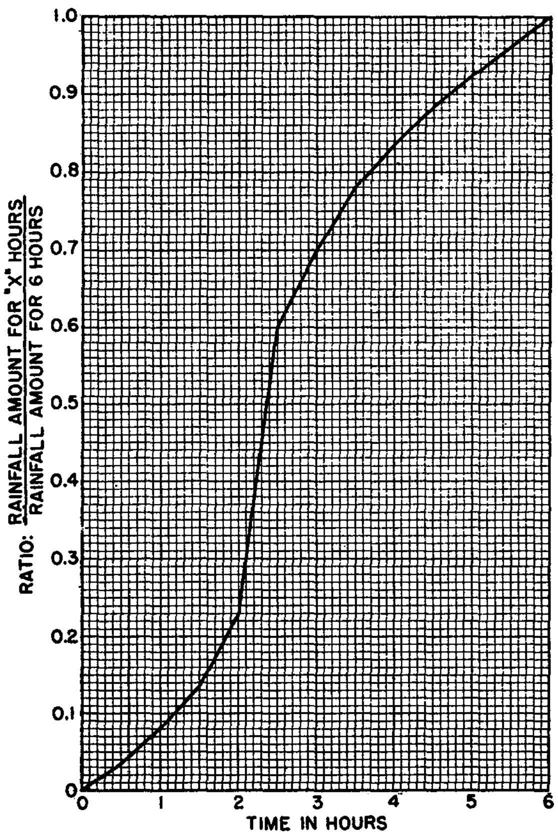
IV. FREEBOARD

The freeboard hydrograph for class (a) and (b) structures will be routed through the reservoir starting at the same water surface elevation as for the emergency spillway hydrograph. The routing of the freeboard hydrograph for class (c) structures may be started at the crest of the principal spillway.

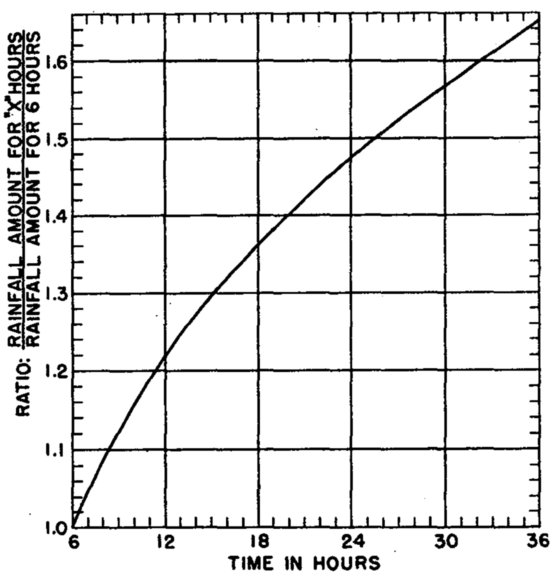
HYDROLOGY: CRITERIA FOR DESIGN STORMS USED IN DEVELOPING EMERGENCY SPILLWAY DESIGN AND FREEBOARD HYDROGRAPHS



(a) RAINFALL RATIOS FOR DRAINAGE AREAS OF 10 TO 100 SQUARE MILES

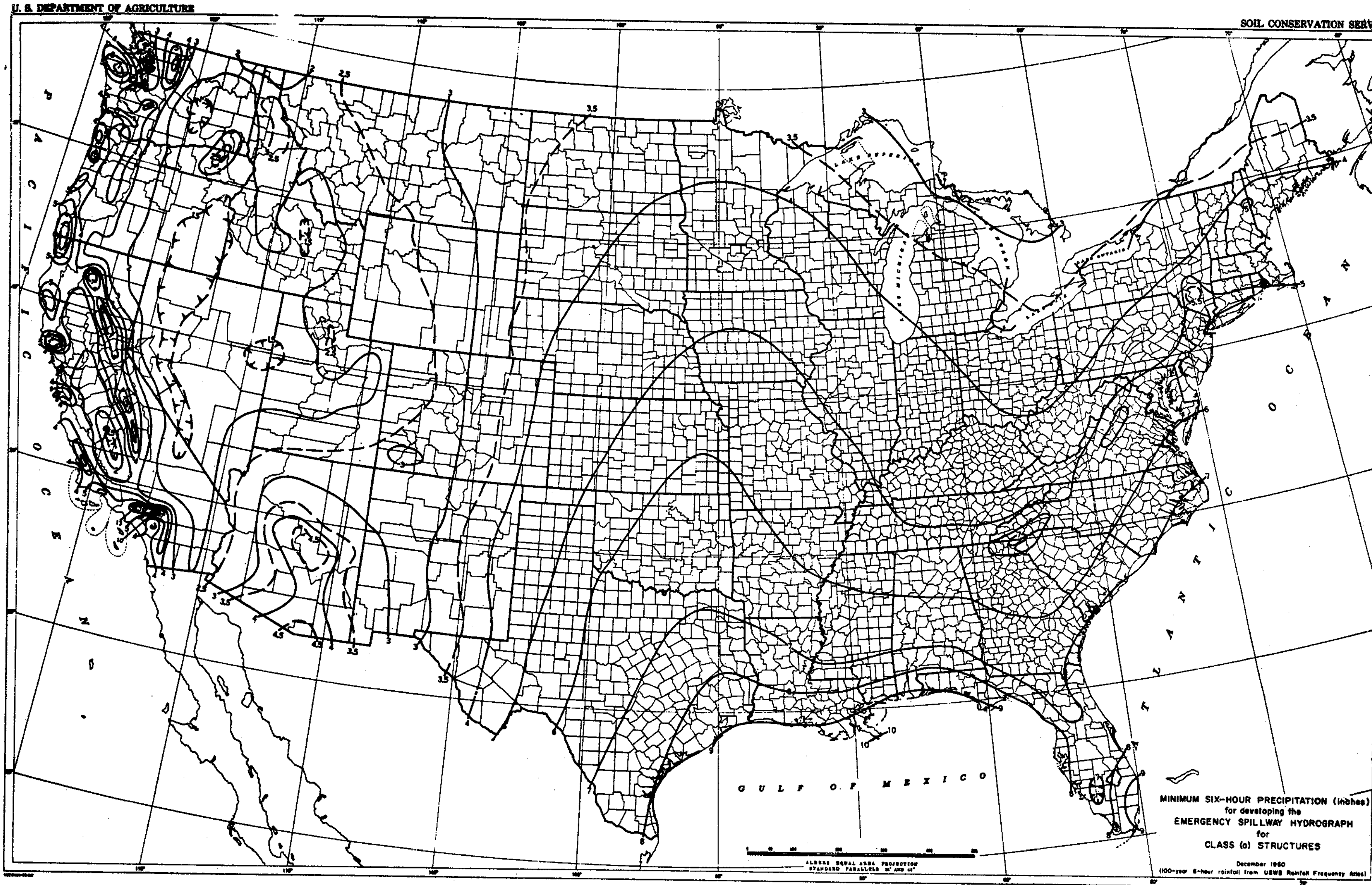


(b) SIX HOUR DESIGN STORM DISTRIBUTION



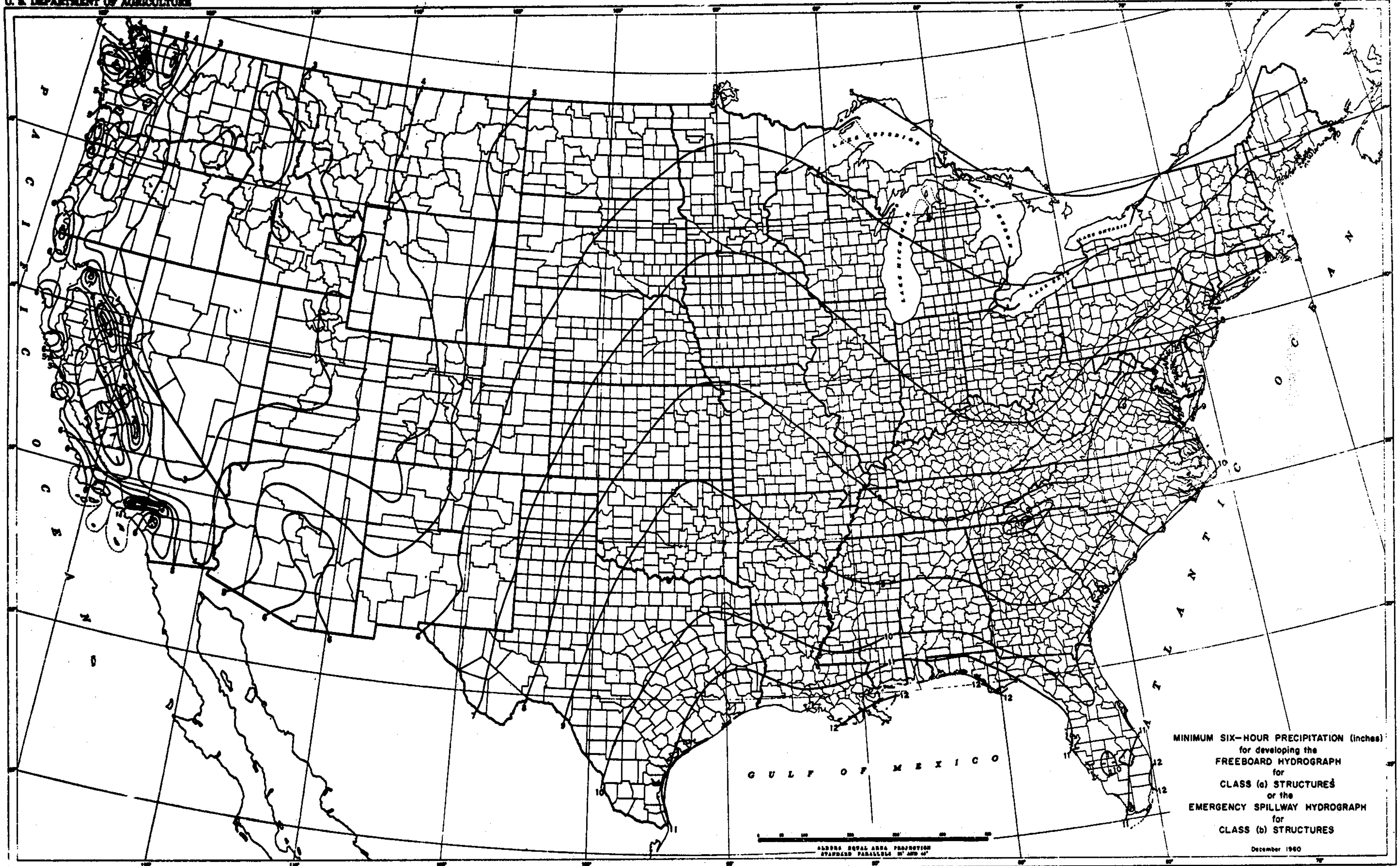
(c) RELATIVE INCREASE IN RAINFALL AMOUNT FOR STORM DURATIONS OVER SIX HOURS

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING DIVISION - CENTRAL TECHNICAL UNIT	STANDARD DWG. NO. ES- 1003 SHEET 1 OF 1 DATE 7-2-56 REVISED 9-10-63


U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
P A C I F I C O C E A N
A T L A N T I C O C E A N
G U L F O F M E X I C O
MINIMUM SIX-HOUR PRECIPITATION (inches)
for developing the
EMERGENCY SPILLWAY HYDROGRAPH
for
CLASS (a) STRUCTURES
December 1960
(100-year 6-hour rainfall from USWB Rainfall Frequency Atlas)
ALBERS EQUAL AREA PROJECTION
STANDARD PARALLELS 29° AND 45°

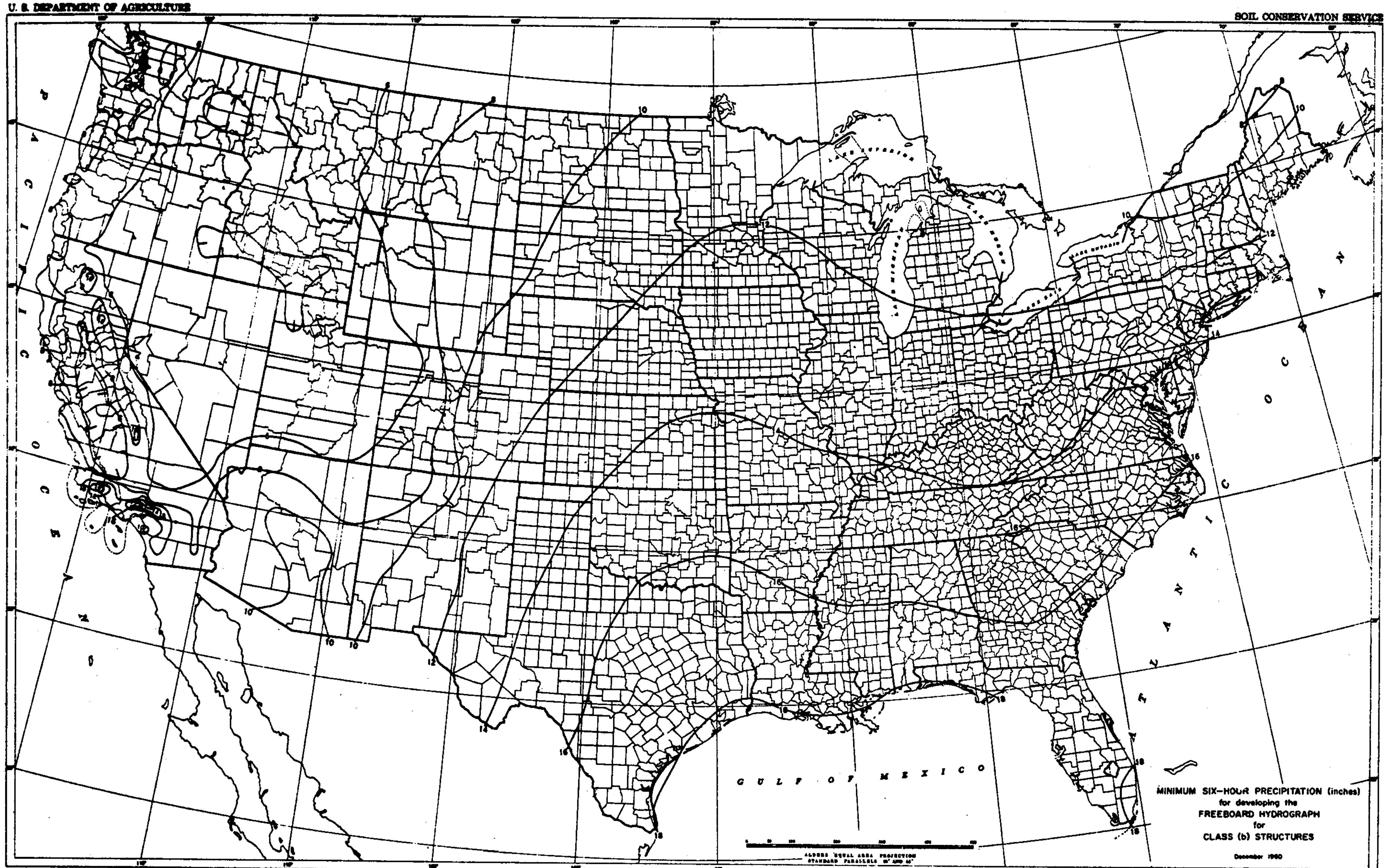
U. S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE



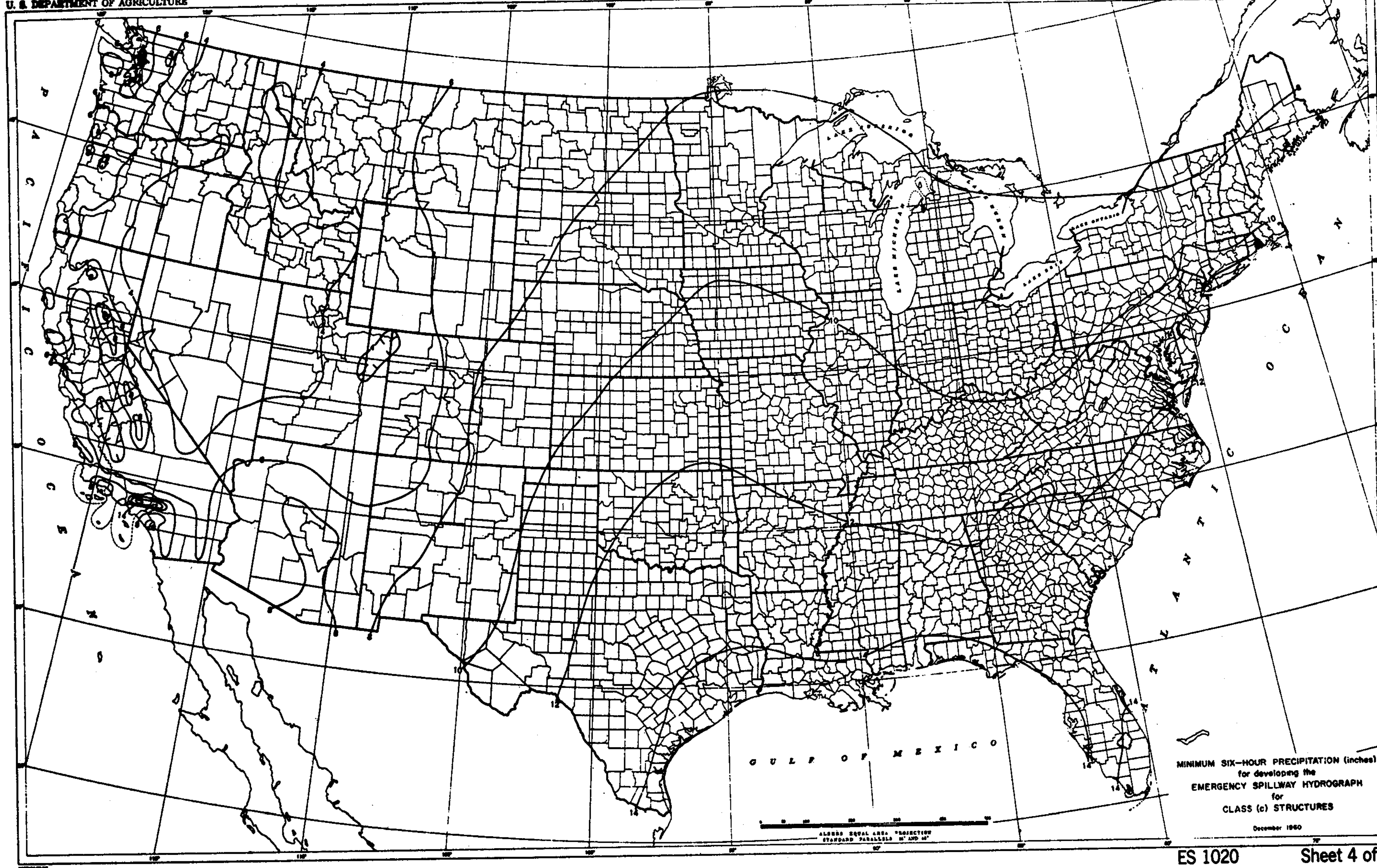
U. S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE



U. S. DEPARTMENT OF AGRICULTURE

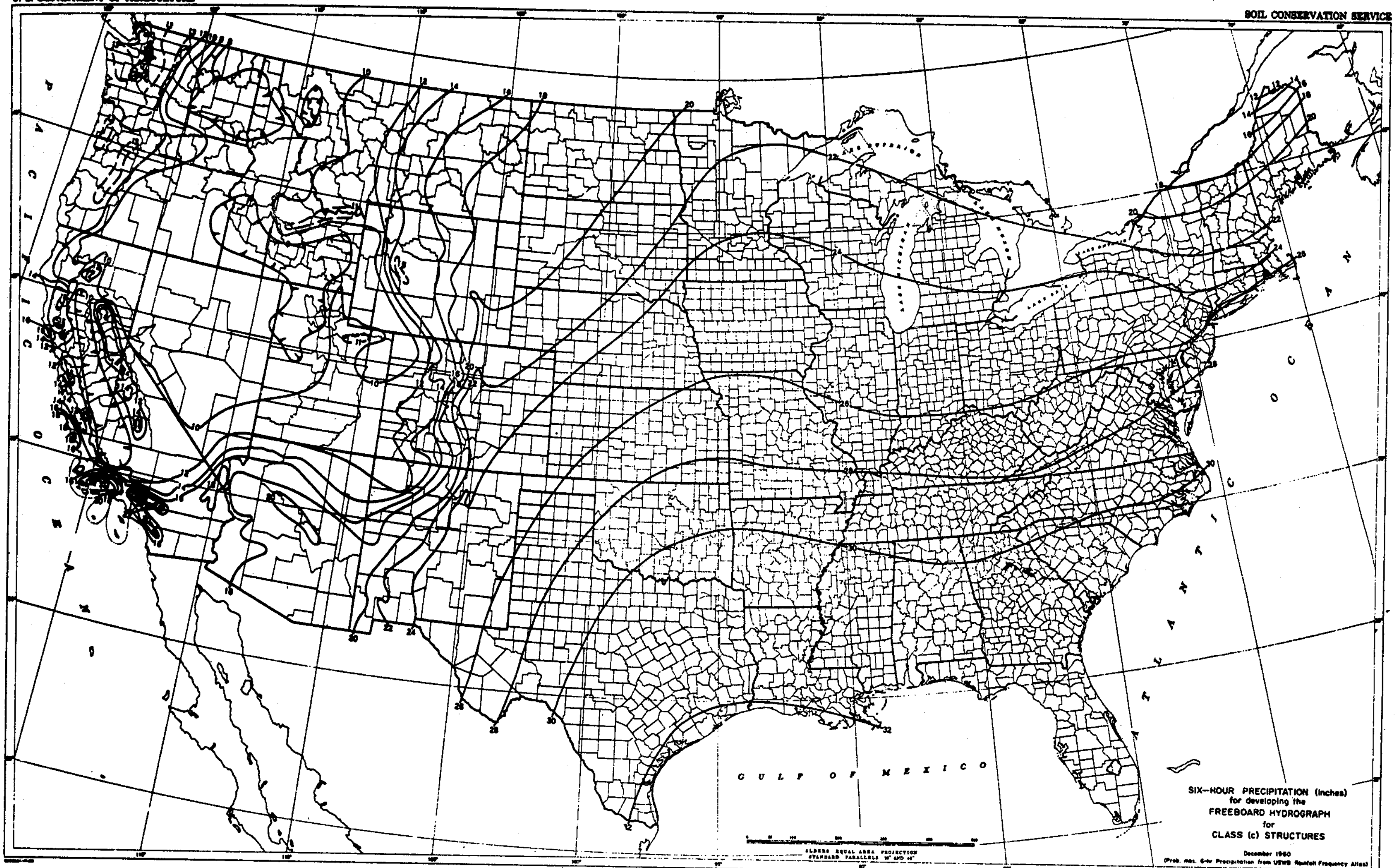
SOIL CONSERVATION SERVICE



ES 1020 Sheet 4 of 5

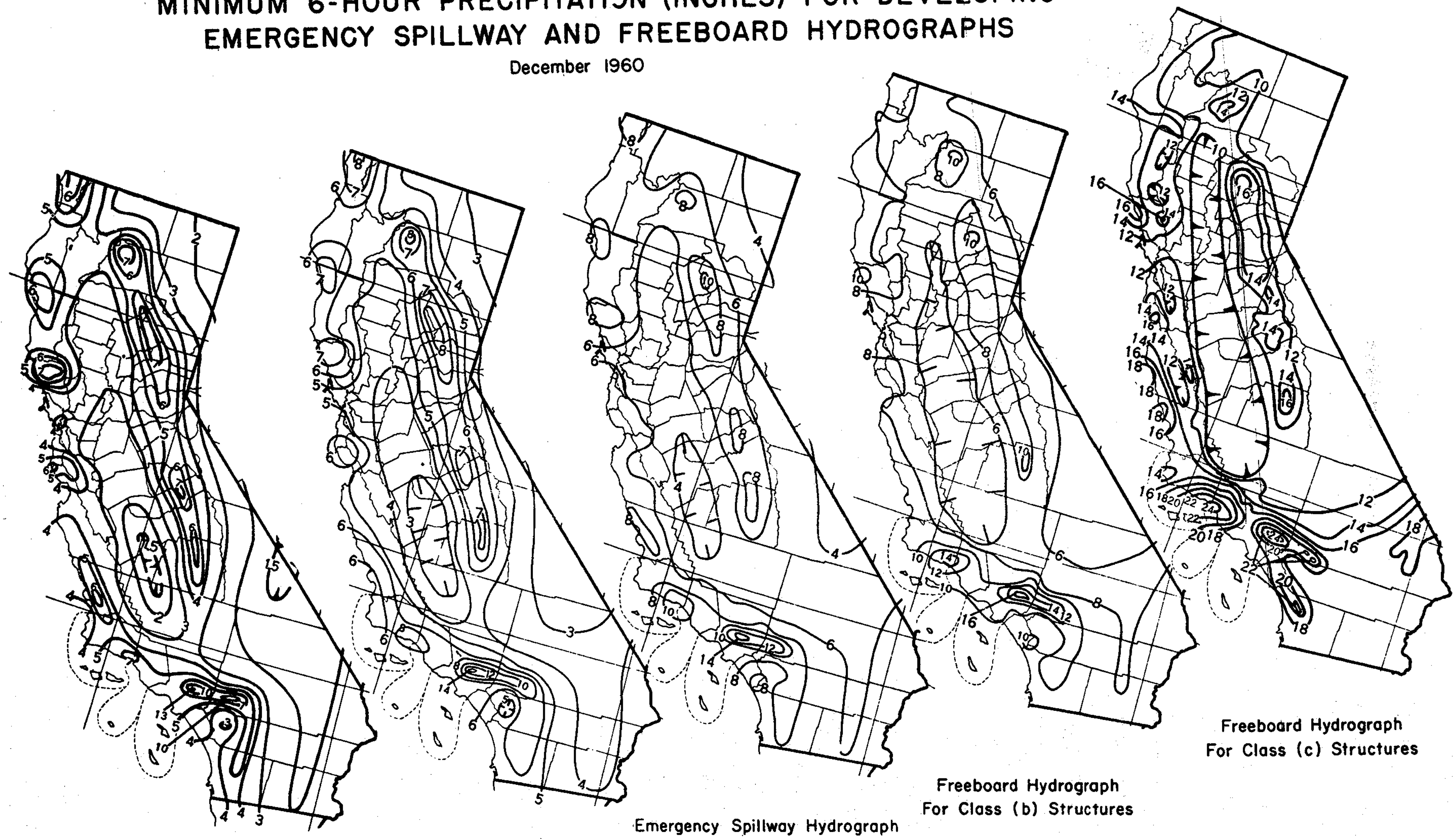
U. S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE



MINIMUM 6-HOUR PRECIPITATION (INCHES) FOR DEVELOPING EMERGENCY SPILLWAY AND FREEBOARD HYDROGRAPHS

December 1960



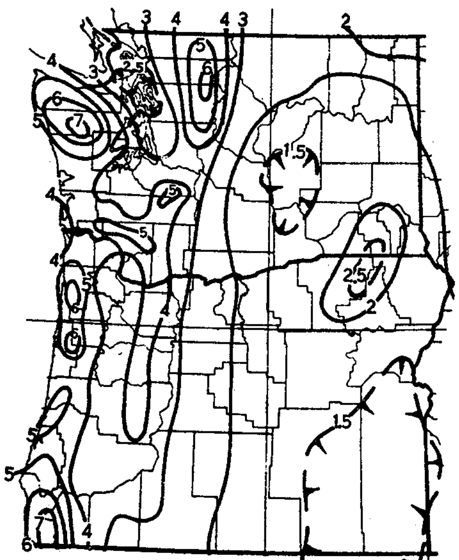
Emergency Spillway Hydrograph
For Class (a) Structures

Freeboard Hydrograph
For Class (a) Structures
and
Emergency Spillway Hydrograph
For Class (b) Structures

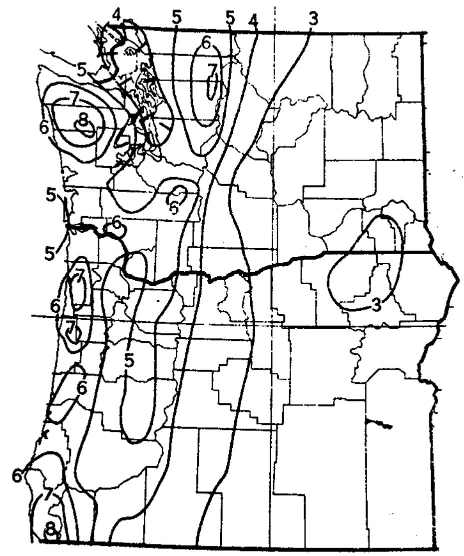
Emergency Spillway Hydrograph
For Class (c) Structures

Freeboard Hydrograph
For Class (b) Structures

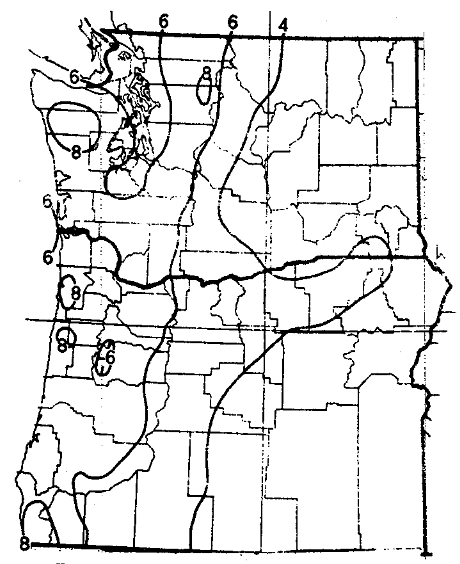
Freeboard Hydrograph
For Class (c) Structures



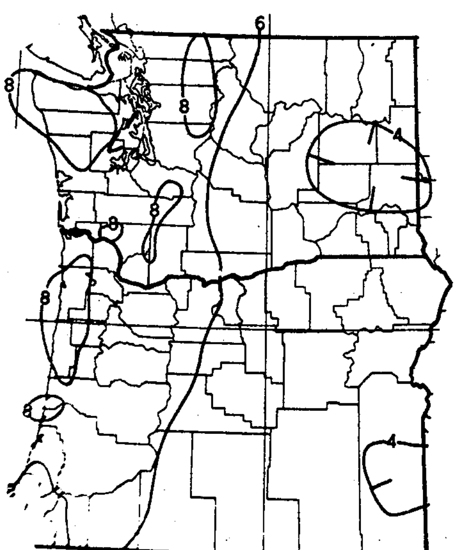
Emergency Spillway Hydrograph
For Class (a) Structures



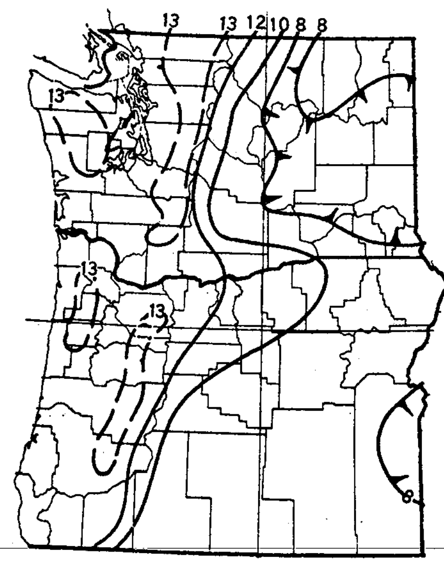
Freeboard Hydrograph For
Class (a) Structures and
Emergency Spillway Hydrograph
For Class (b) Structures



Emergency Spillway Hydrograph
For Class (c) Structures



Freeboard Hydrograph
For Class (b) Structures

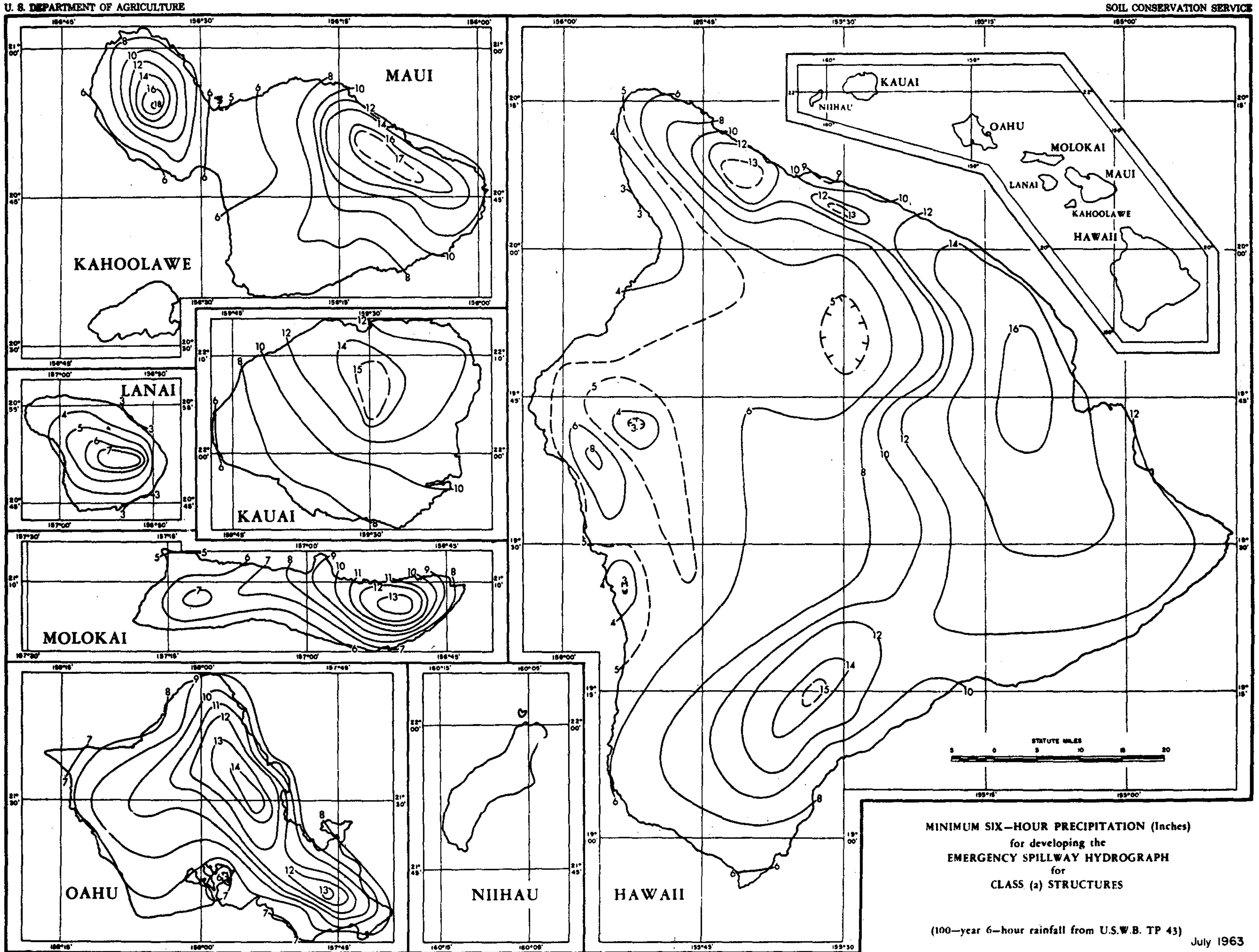


Freeboard Hydrograph
For Class (c) Structures

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

MINIMUM 6-HOUR PRECIPITATION (INCHES) FOR DEVELOPING EMERGENCY SPILLWAY AND FREEBOARD HYDROGRAPHS

December 1960



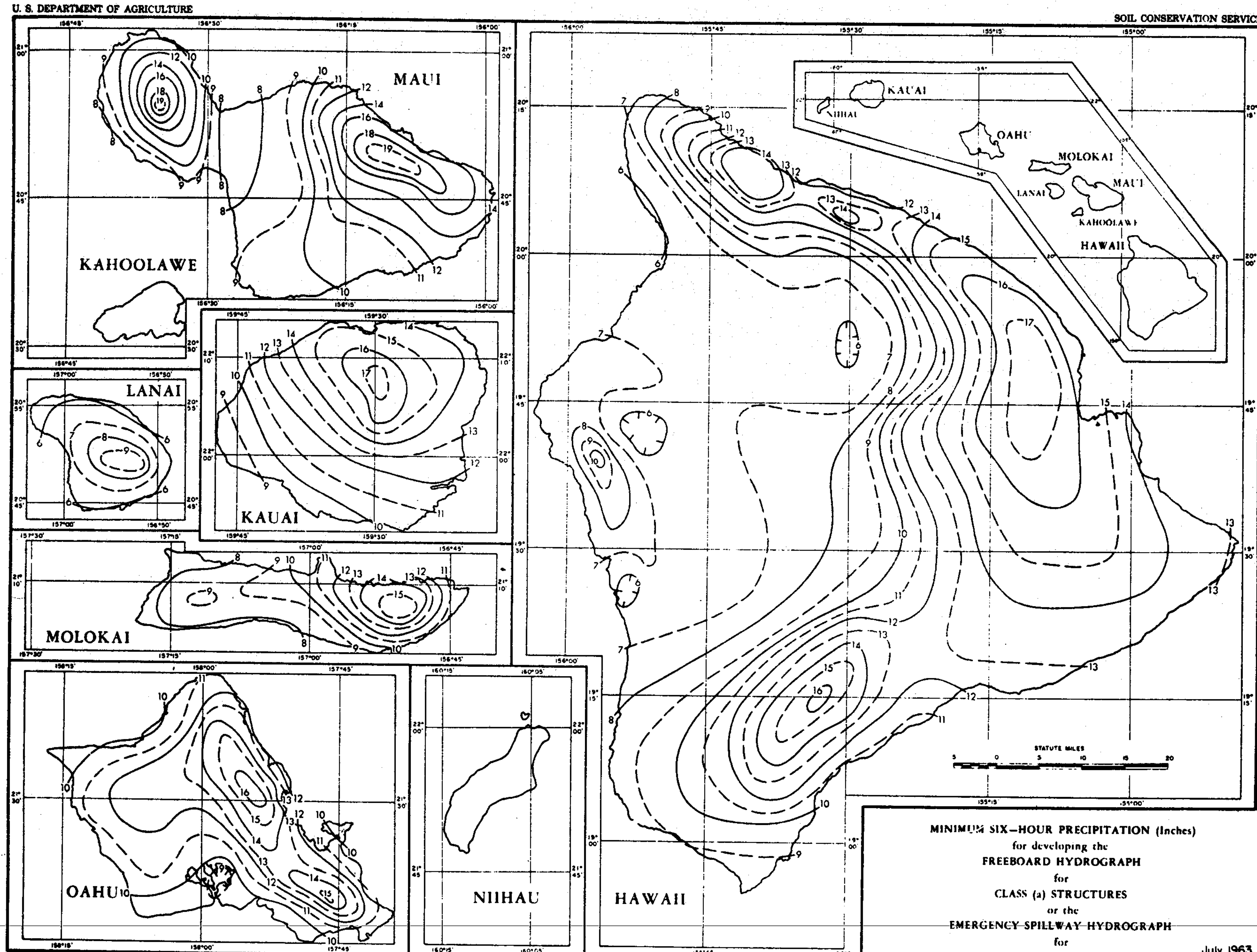
MINIMUM SIX—HOUR PRECIPITATION (Inches)
for developing the
EMERGENCY SPILLWAY HYDROGRAPH
for
CLASS (a) STRUCTURES

(100—year 6—hour rainfall from U.S.W.B. TP 43)

July 1963

U. S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

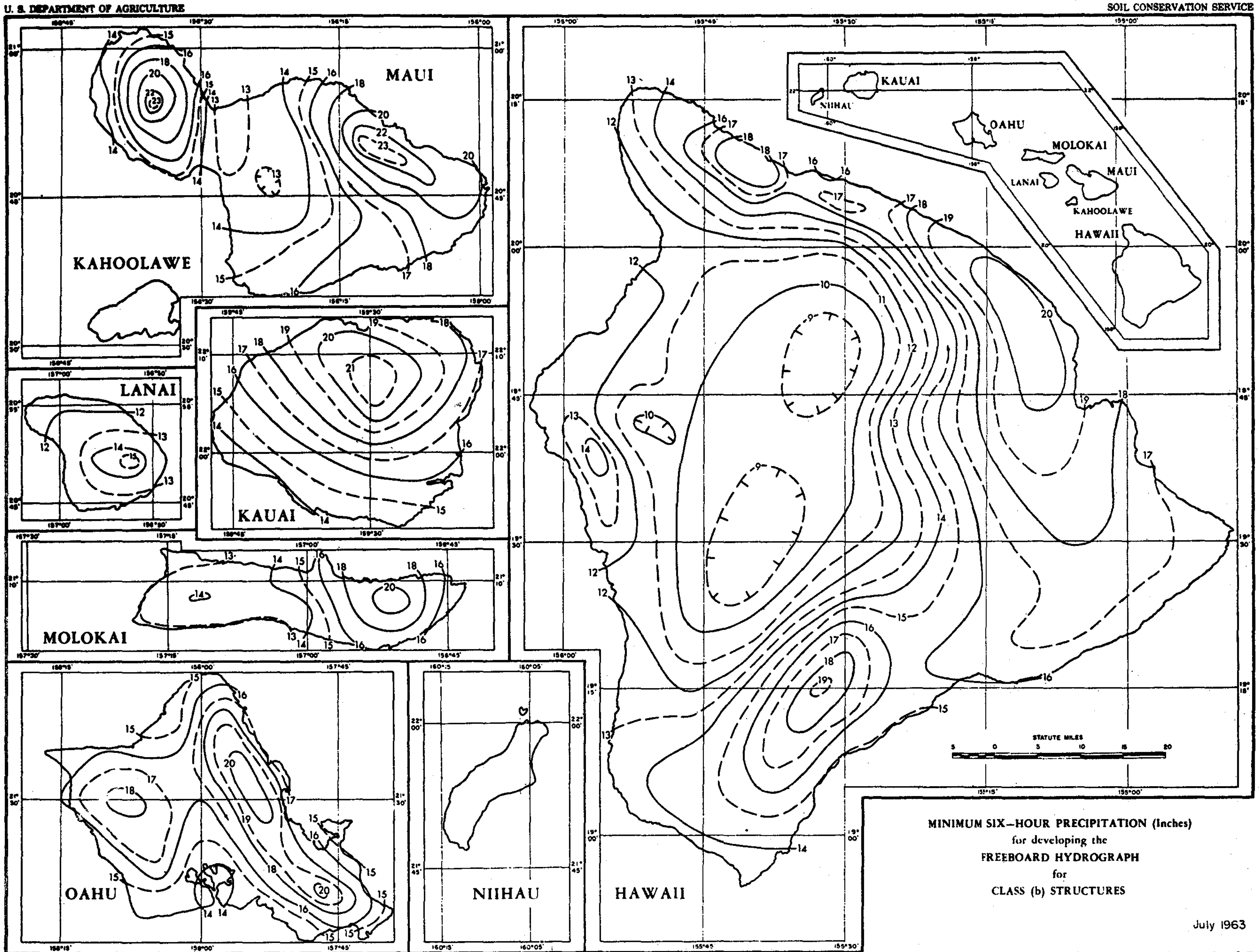


MINIMUM SIX–HOUR PRECIPITATION (Inches)
for developing the
FREEBOARD HYDROGRAPH
for
CLASS (a) STRUCTURES
or the
EMERGENCY SPILLWAY HYDROGRAPH
for
CLASS (b) STRUCTURES

July 1963

U. S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE



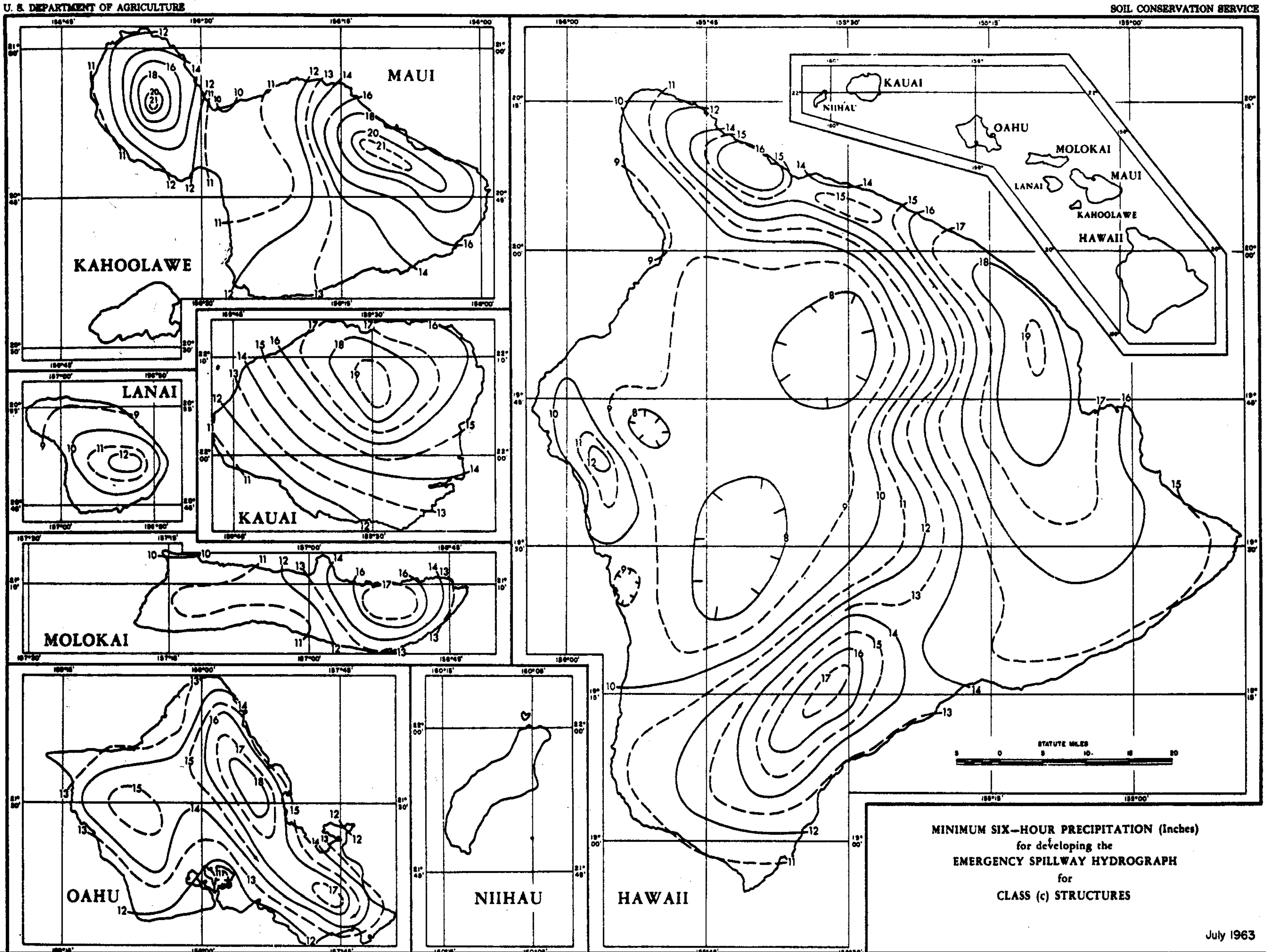
MINIMUM SIX-HOUR PRECIPITATION (Inches)
for developing the
FREEBOARD HYDROGRAPH
for
CLASS (b) STRUCTURES

July 1963

C-15

U. S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

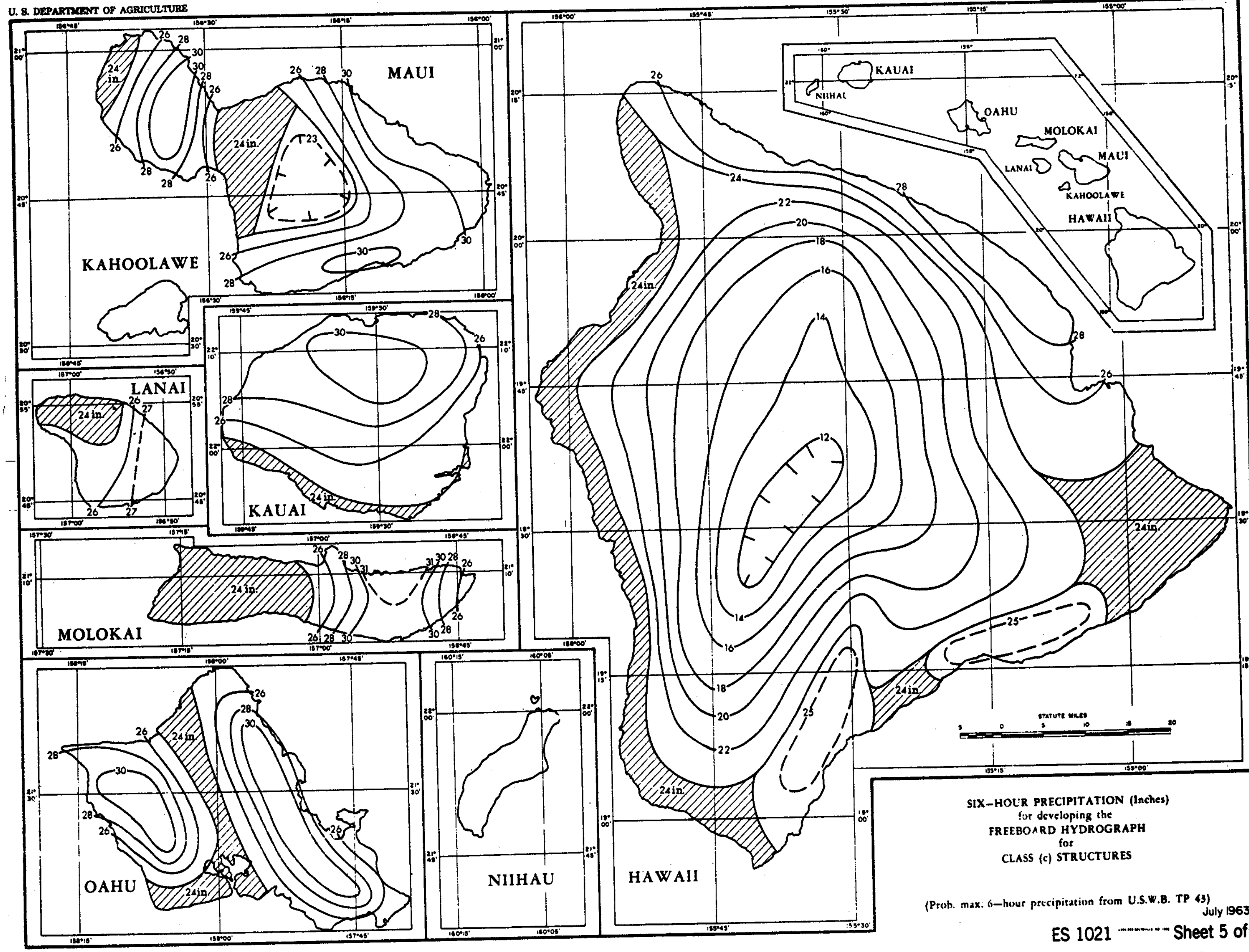


MINIMUM SIX–HOUR PRECIPITATION (Inches)
for developing the
EMERGENCY SPILLWAY HYDROGRAPH
for
CLASS (c) STRUCTURES

July 1963

U. S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

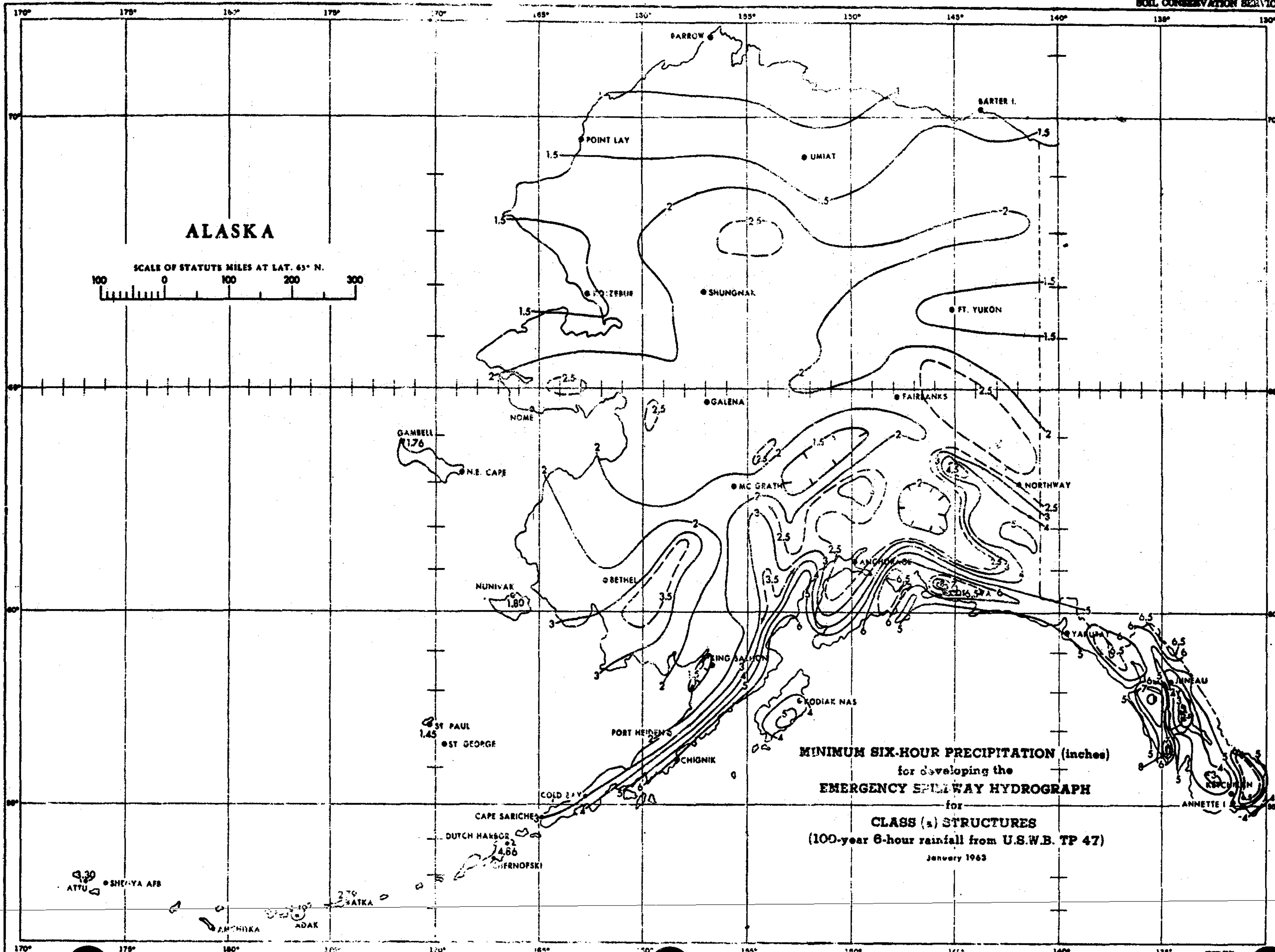


SIX-HOUR PRECIPITATION (Inches)
for developing the
FREEBOARD HYDROGRAPH
for
CLASS (c) STRUCTURES

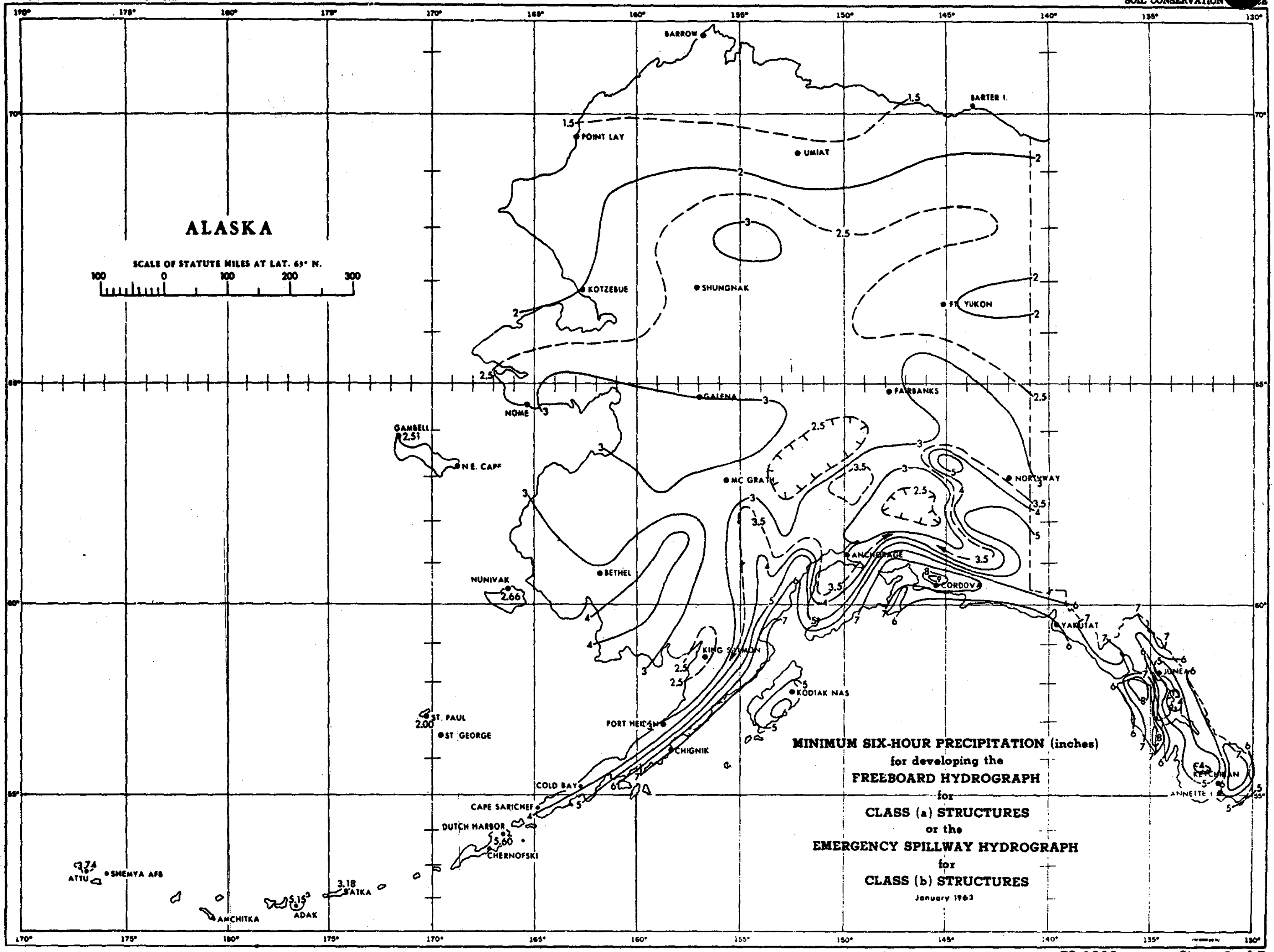
(Prob. max. 6—hour precipitation from U.S.W.B. TP 43)

July 1963

ES 1021 Sheet 5 of 5



MINIMUM SIX-HOUR PRECIPITATION (inches)
for developing the
EMERGENCY SPILLWAY HYDROGRAPH
for
CLASS (a) STRUCTURES
(100-year 6-hour rainfall from U.S.W.B. TP 47)
January 1963

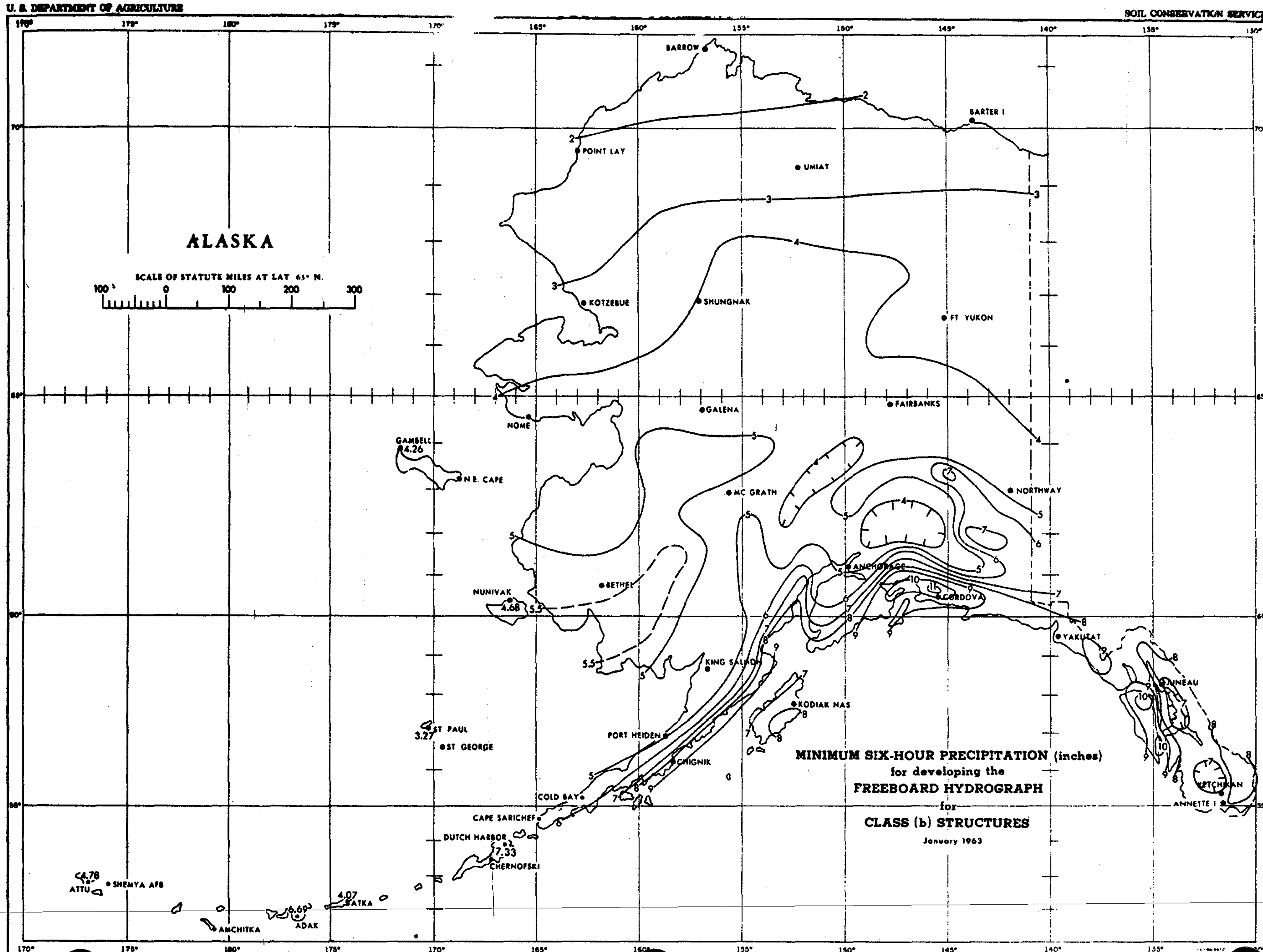


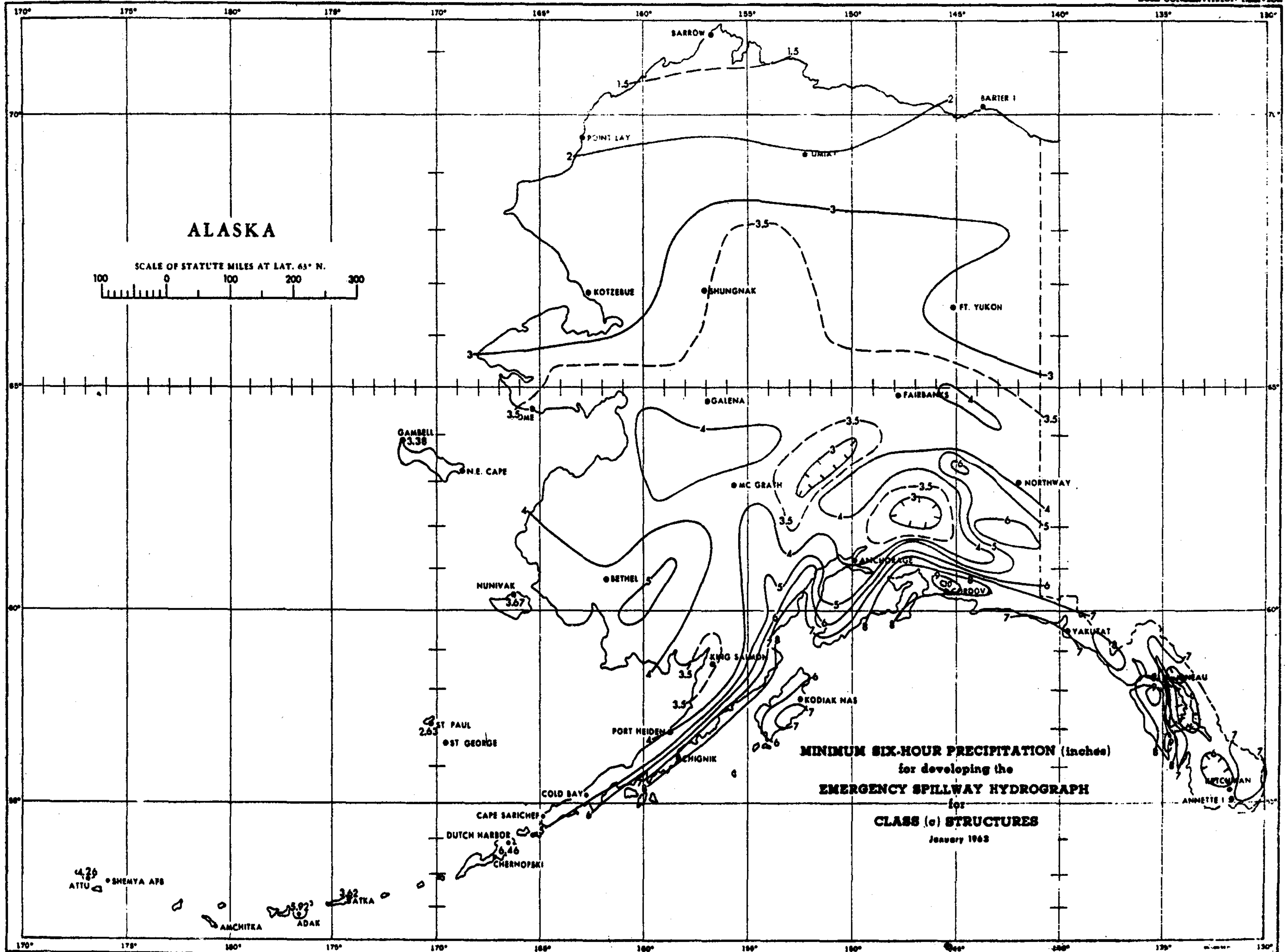
MINIMUM SIX-HOUR PRECIPITATION (inches)
for developing the
FREEBOARD HYDROGRAPH
for
CLASS (a) STRUCTURES
or the
EMERGENCY SPILLWAY HYDROGRAPH
for
CLASS (b) STRUCTURES
January 1963

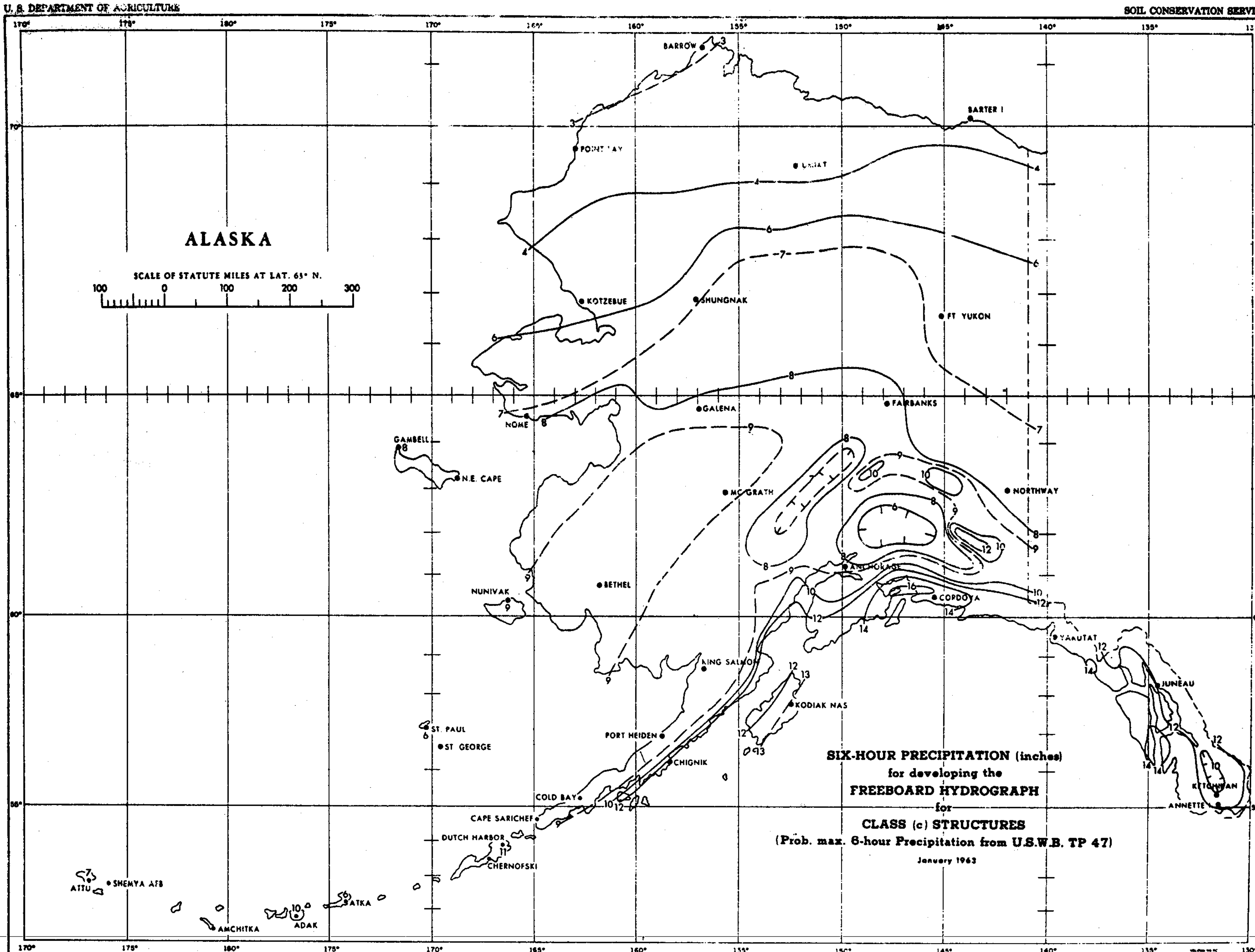
C-19

U. S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

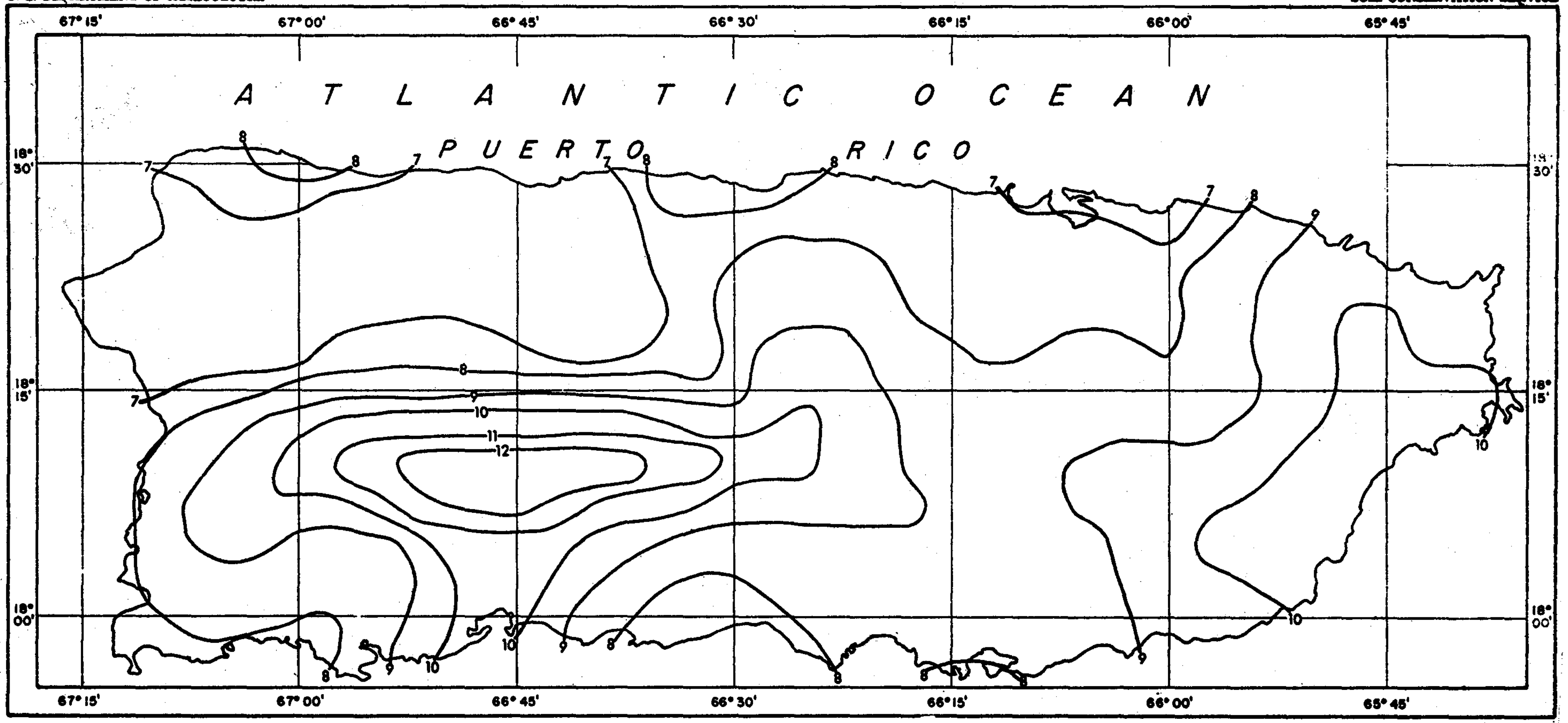



ALASKA
SCALE OF STATUTE MILES AT LAT. 63° N.
100 0 100 200 300
BARROW
BARTER I
POINT LAY
UMIAT
KOTZEBUE
SHUNGNAK
FT. YUKON
GALENA
FAIRBANKS
GAMBELL
N.E. CAPE
MC GRATH
NORTHWAY
BETHEL
NUNIVAK
ANCHORAGE
YAKUTAT
KING SALMON
KODIAK NAS
ST PAUL
ST GEORGE
PORT HEIDEN
CHIGNIK
COLD BAY
CAPE SARICHEF
DUTCH HARBOR
CHERNOFSKI
SHEMYA AFB
ATTU
AMCHITKA
ADAK
ATKA
ANNETTE I
MINIMUM SIX-HOUR PRECIPITATION (inches)
for developing the
EMERGENCY SPILLWAY HYDROGRAPH
for
CLASS (c) STRUCTURES
January 1963

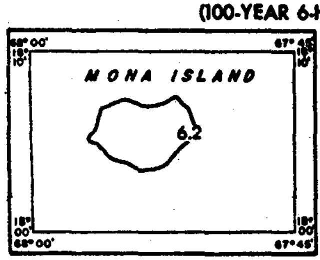


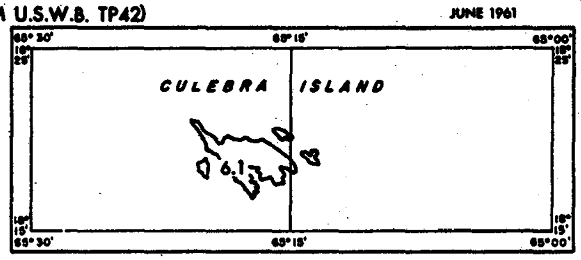
SIX-HOUR PRECIPITATION (inches)
for developing the
FREEBOARD HYDROGRAPH
for
CLASS (c) STRUCTURES
(Prob. max. 6-hour Precipitation from U.S.W.B. TP 47)

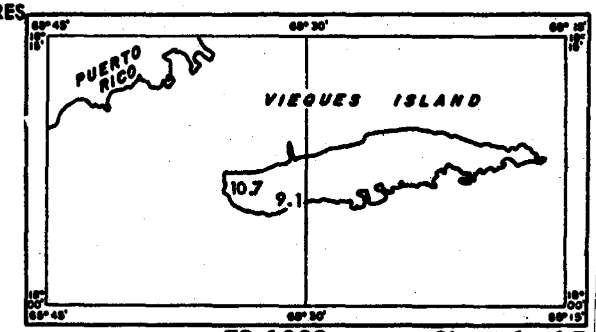
January 1963



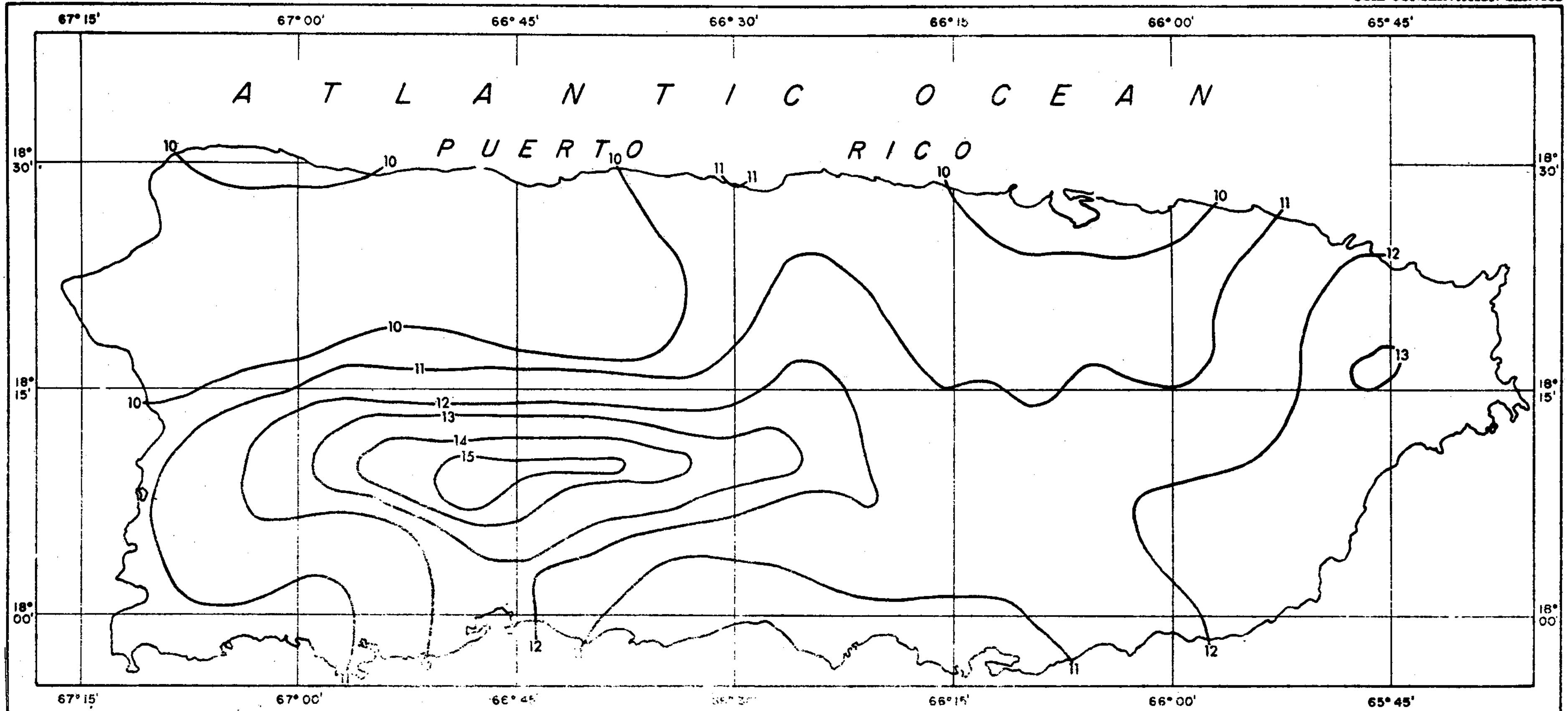
MINIMUM SIX-HOUR PRECIPITATION (INCHES) FOR DEVELOPING THE EMERGENCY SPILLWAY HYDROGRAPH FOR CLASS (a) STRUCTURES
(100-YEAR 6-HOUR RAINFALL FROM U.S.W.B. TP42) JUNE 1961



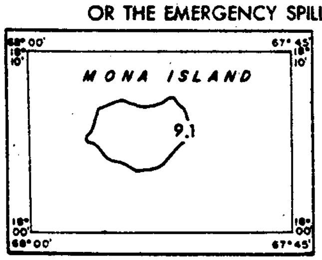


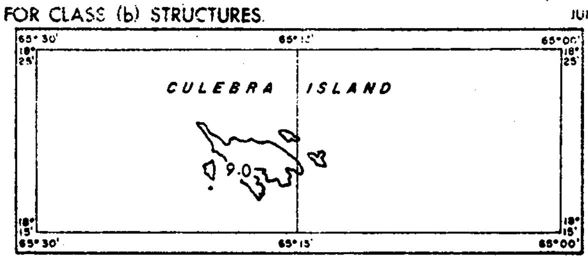


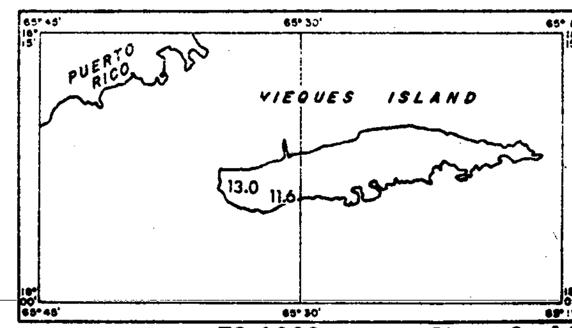
U. S. DEPARTMENT OF AGRICULTURE — SOIL CONSERVATION SERVICE



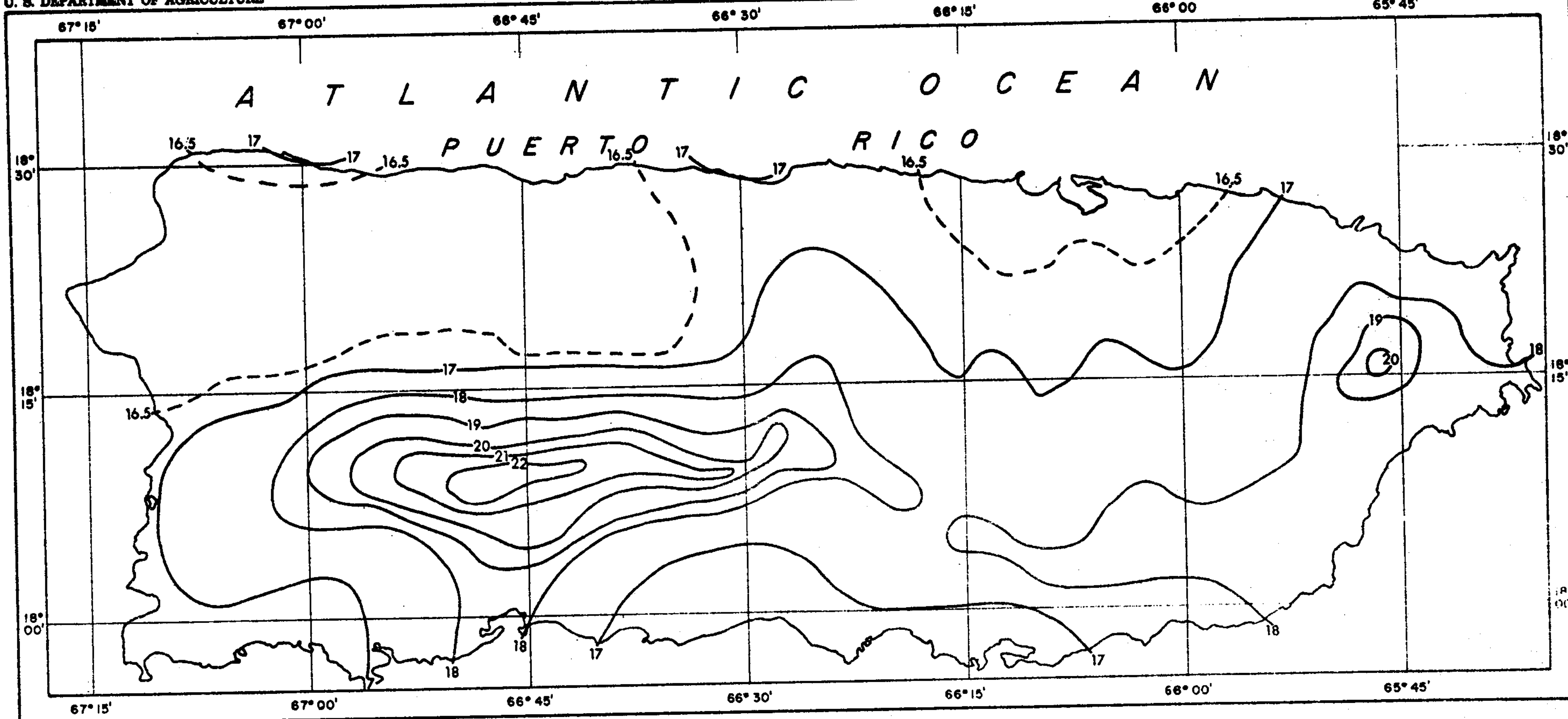
MINIMUM SIX-HOUR PRECIPITATION (INCHES) FOR DEVELOPING THE FREEBOARD HYDROGRAPH FOR CLASS (a) STRUCTURES OR THE EMERGENCY SPILLWAY HYDROGRAPH FOR CLASS (b) STRUCTURES.





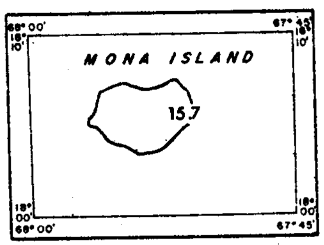


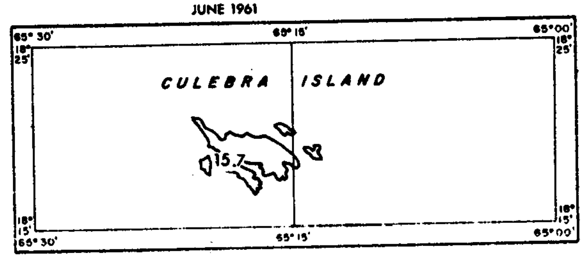
STATUTE MILES

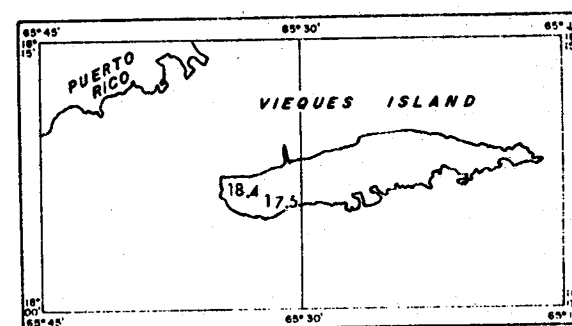


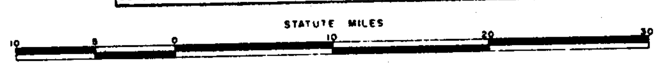
MINIMUM SIX-HOUR PRECIPITATION (INCHES) FOR DEVELOPING THE FREEBOARD HYDROGRAPH FOR CLASS (b) STRUCTURES

JUNE 1961



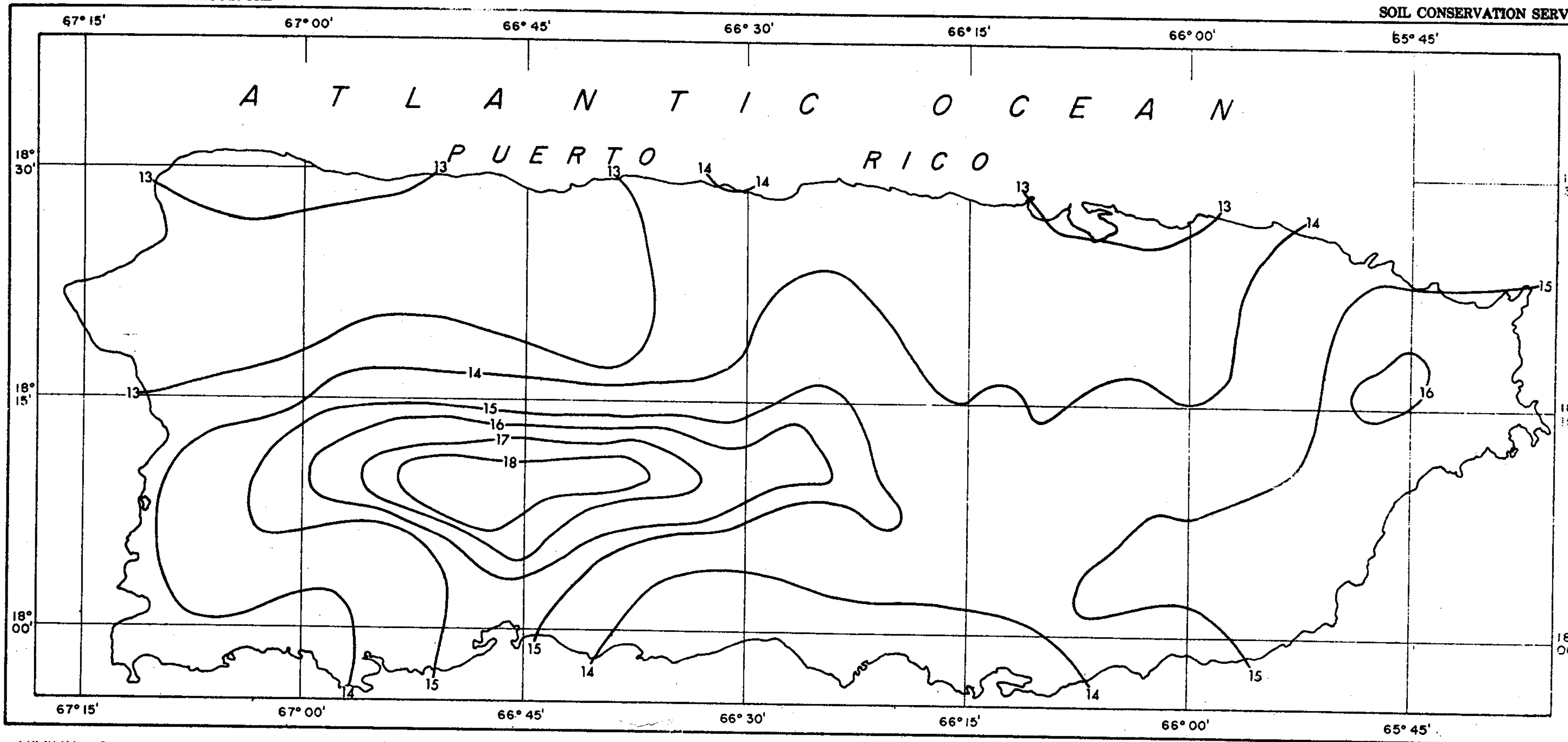






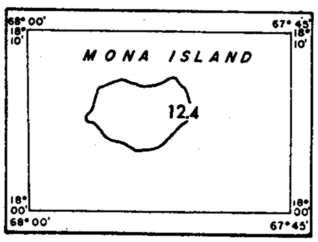
U. S. DEPARTMENT OF AGRICULTURE

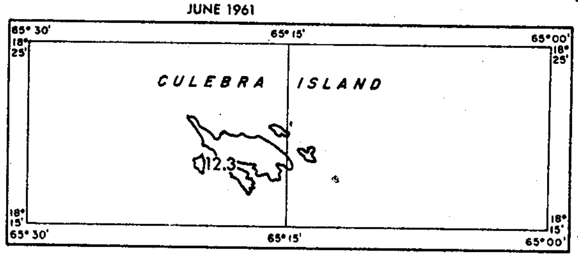
SOIL CONSERVATION SERVICE



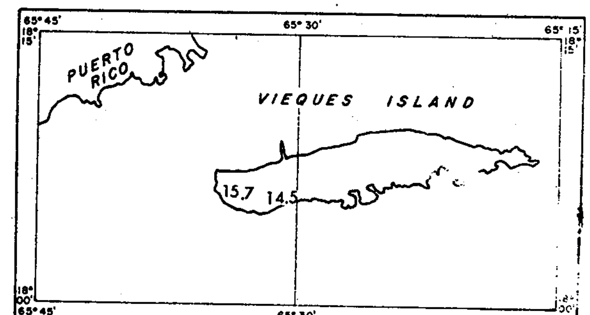
MINIMUM SIX-HOUR PRECIPITATION (INCHES) FOR DEVELOPING THE EMERGENCY SPILLWAY HYDROGRAPH FOR CLASS (c) STRUCTURES

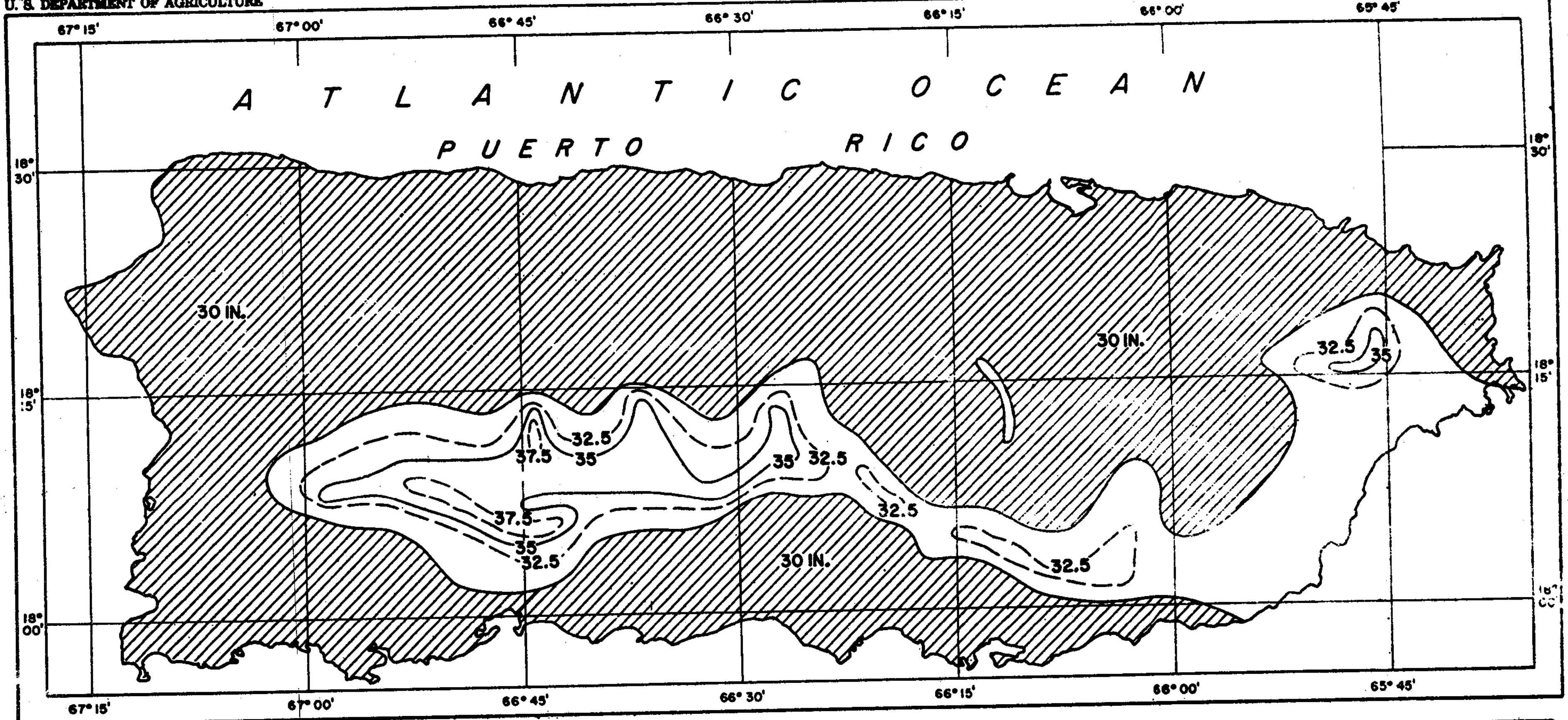
JUNE 1961



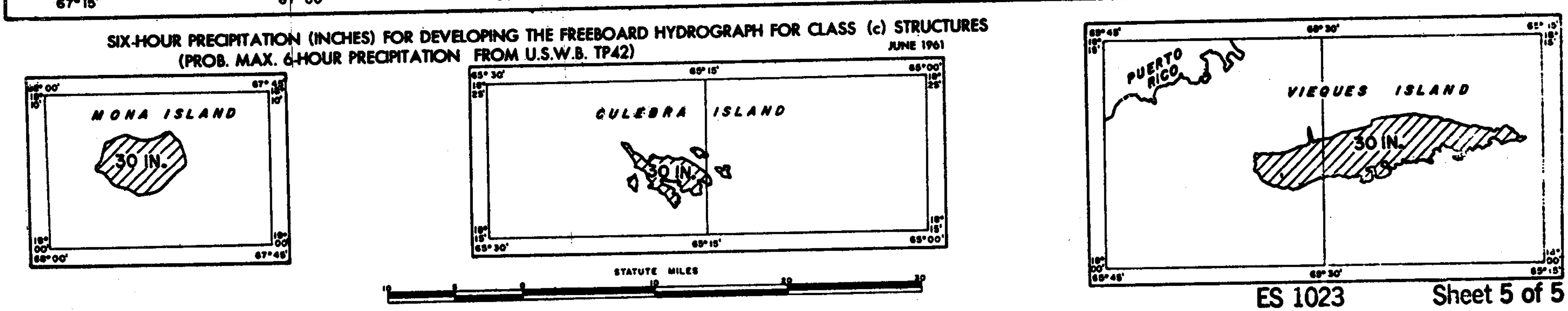


STATUTE MILES

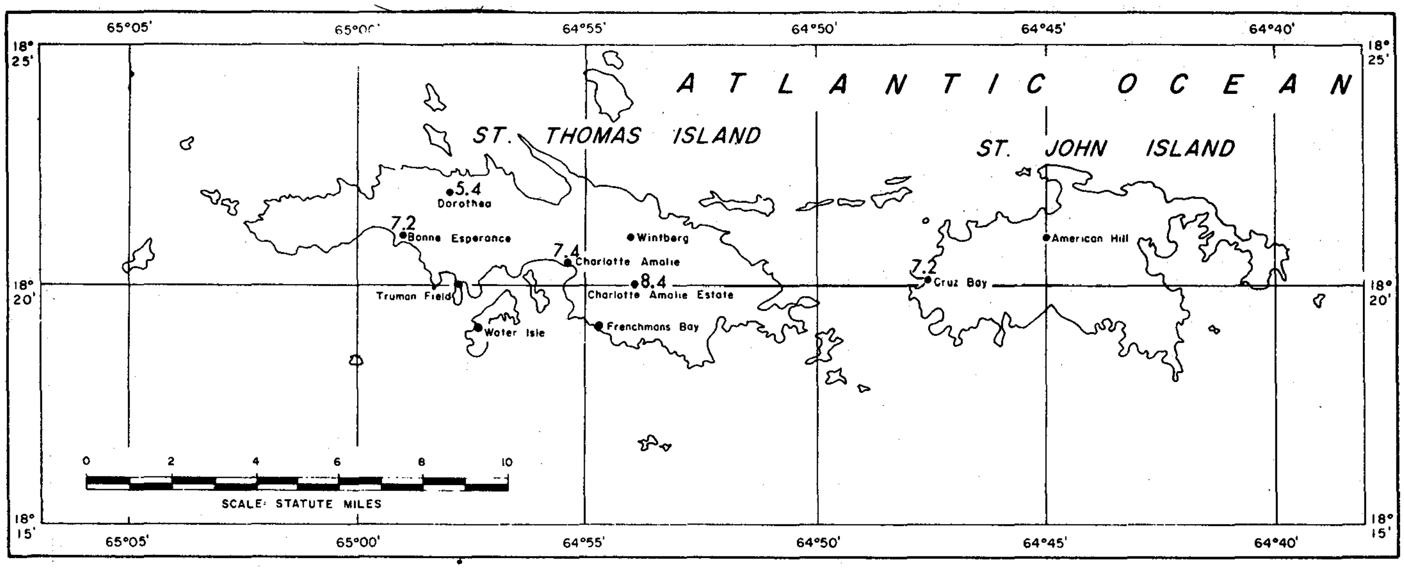




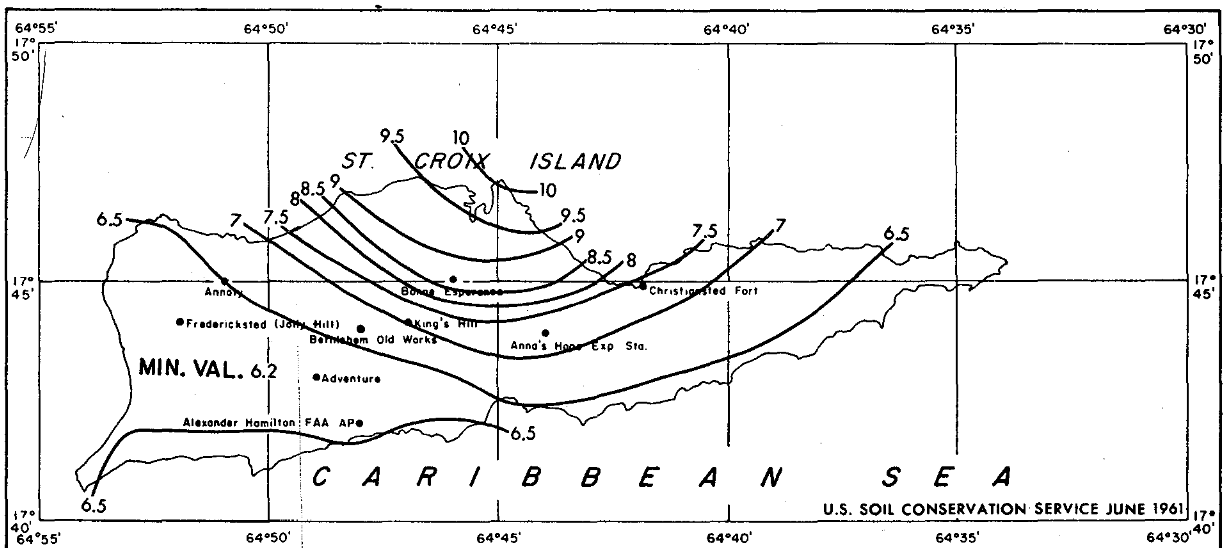
SIX-HOUR PRECIPITATION (INCHES) FOR DEVELOPING THE FREEBOARD HYDROGRAPH FOR CLASS (c) STRUCTURES
(PROB. MAX. 6-HOUR PRECIPITATION FROM U.S.W.B. TP42)
JUNE 1961

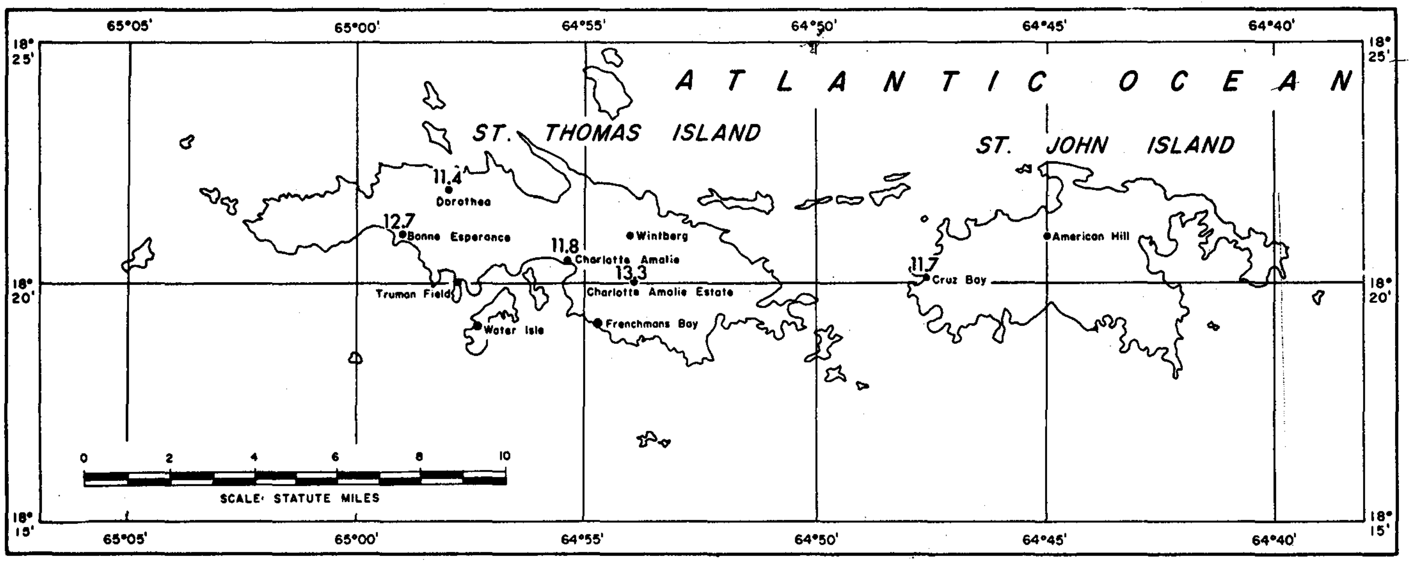


ES 1023 Sheet 5 of 5

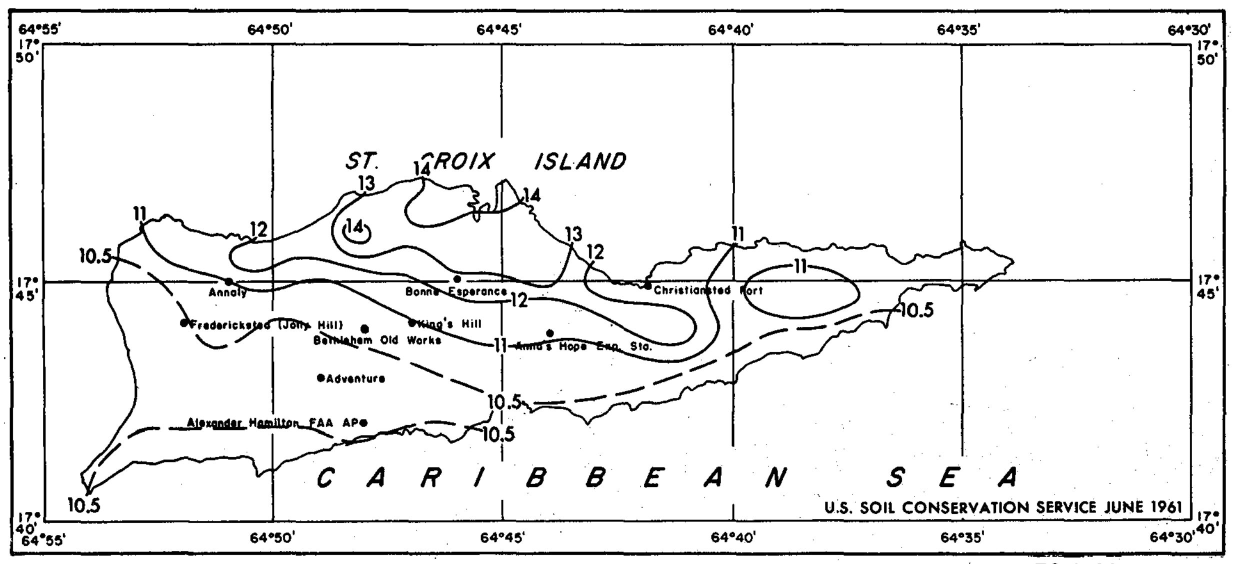


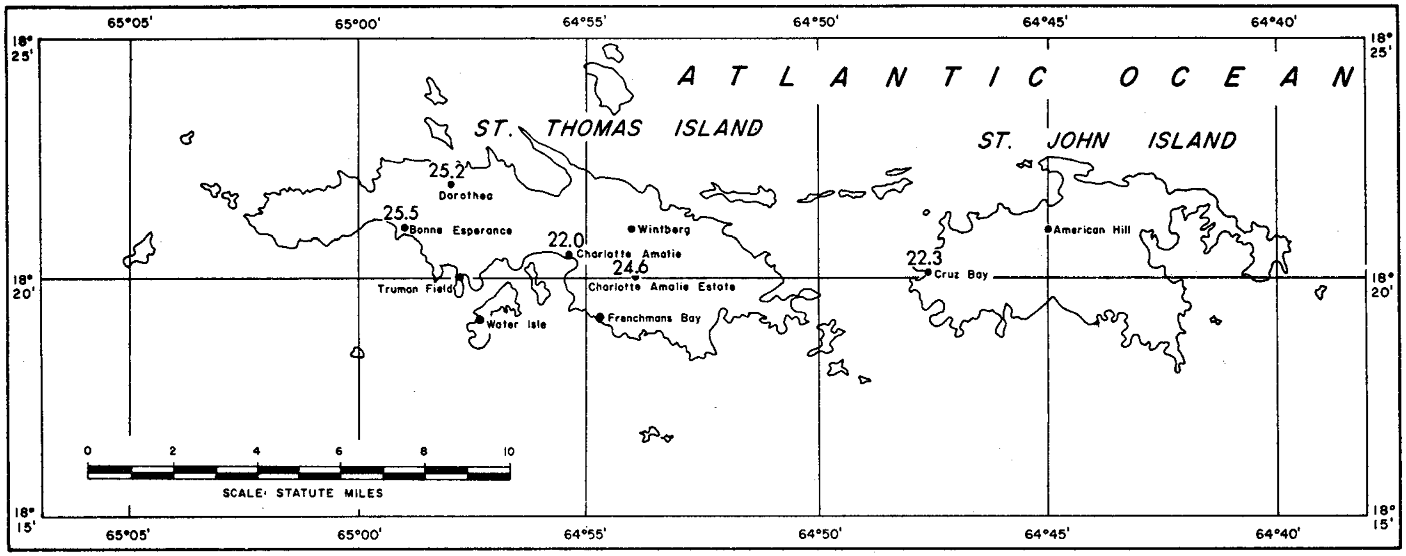
MINIMUM SIX-HOUR PRECIPITATION (inches) for developing the EMERGENCY SPILLWAY HYDROGRAPH for CLASS (a) STRUCTURES (100-year 6-hour rainfall from U.S.W.B. TP42)



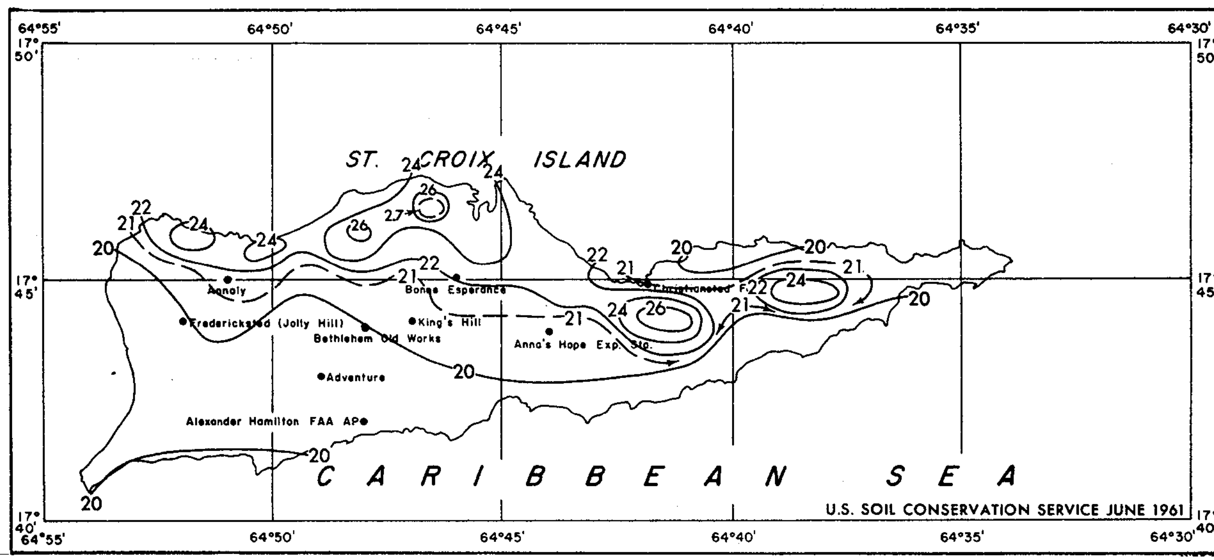


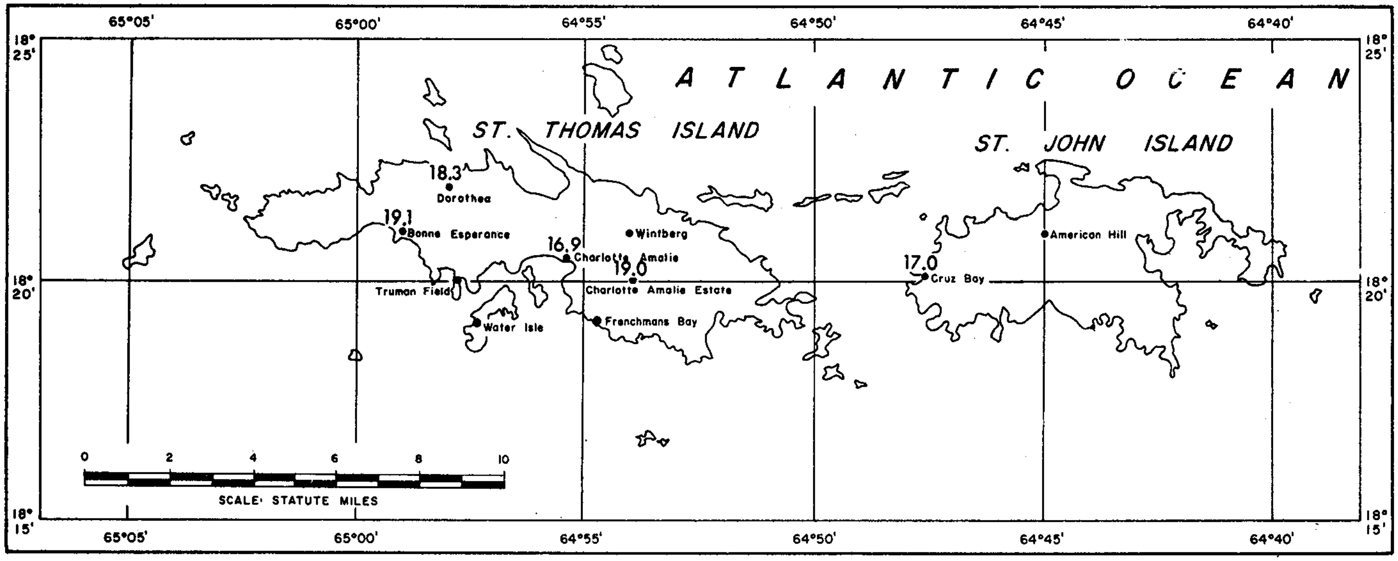
MINIMUM SIX-HOUR PRECIPITATION (inches) for developing the FREEBOARD HYDROGRAPH for CLASS (a) STRUCTURES or the EMERGENCY SPILLWAY HYDROGRAPH for CLASS (b) STRUCTURES



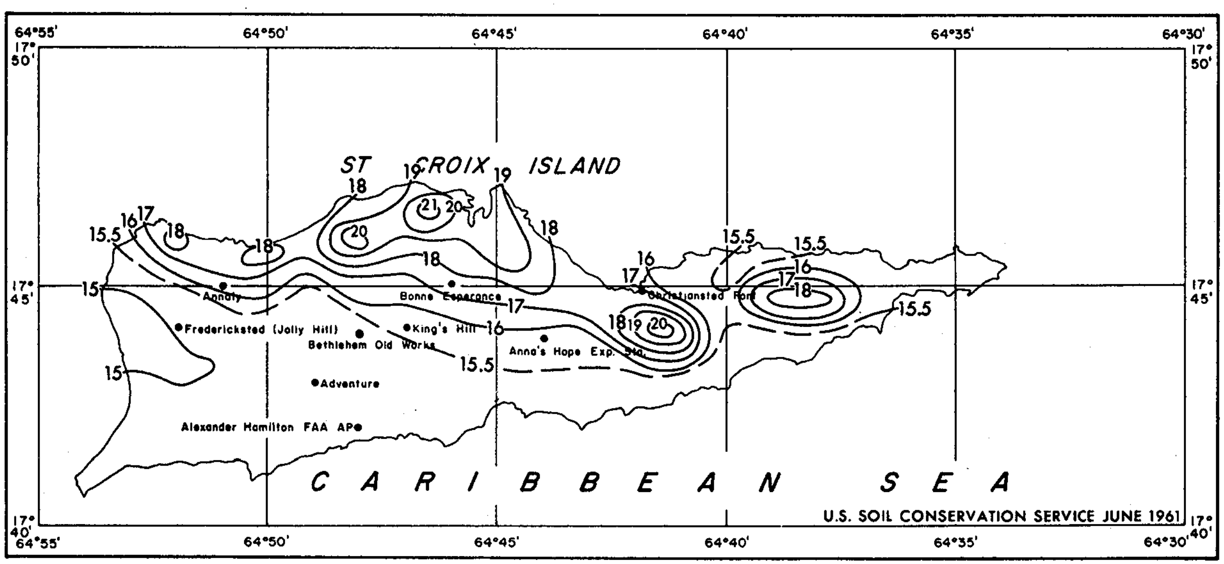


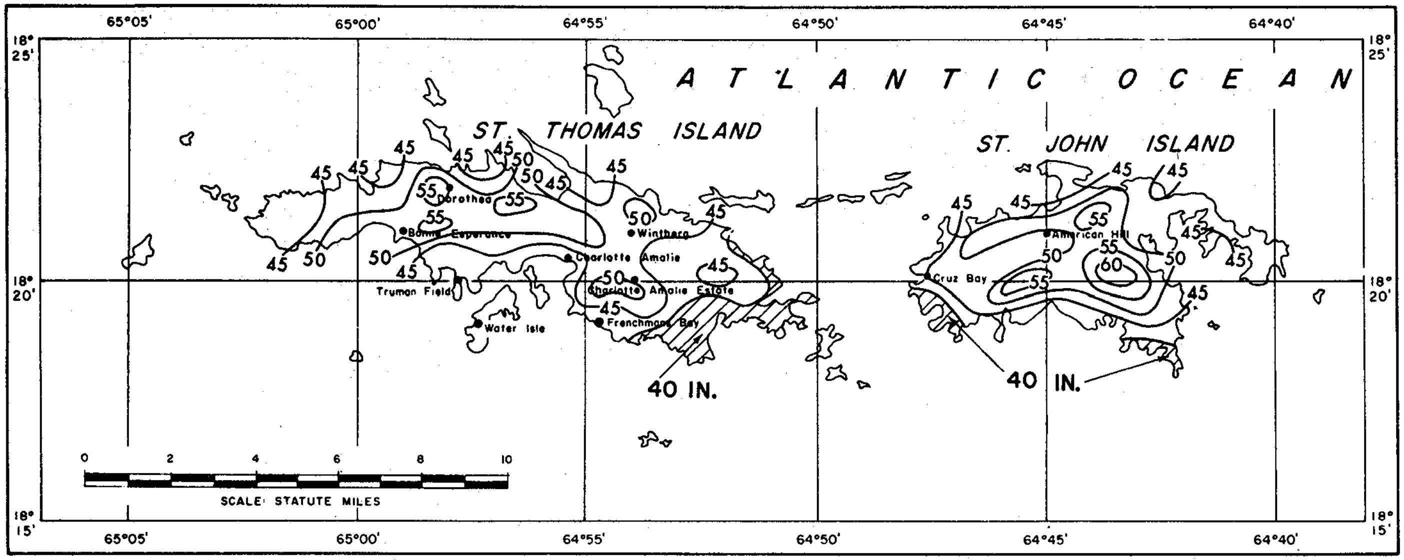
MINIMUM SIX-HOUR PRECIPITATION (inches) for developing the FREEBOARD HYDROGRAPH for CLASS (b) STRUCTURES





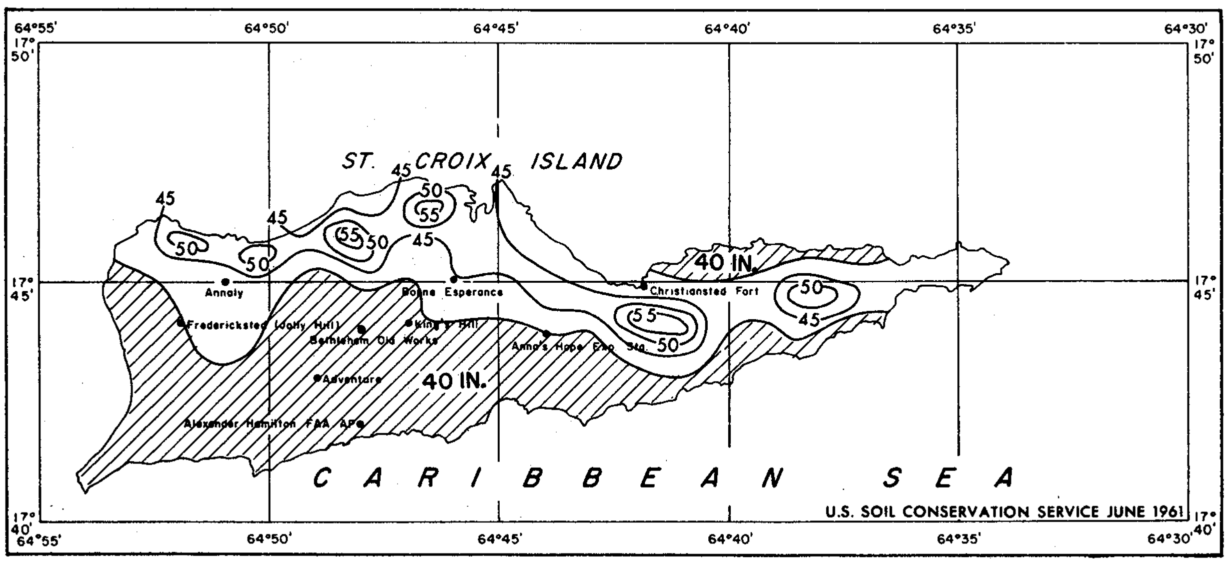
MINIMUM SIX-HOUR PRECIPITATION (inches) for developing the
EMERGENCY SPILLWAY HYDROGRAPH for CLASS (c) STRUCTURES





SIX-HOUR PRECIPITATION (inches) for developing the FREEBOARD HYDROGRAPH for CLASS (c) STRUCTURES

(Prob. max. 6-hour Precipitation from U.S.W.B. TP42)



SECTION D - SEDIMENT STORAGE

Where the primary purpose is floodwater retardation or water storage or combinations thereof, reservoirs are normally designed on the basis of a 50 to 100 year useful life. In order to assure full effectiveness, capacity in addition to that required for project purposes, must be provided in the reservoir to offset depletion due to sediment accumulation for a period equal to its design life.

The computation of sediment yield for the design life of the structure will be based on the prevailing sediment yield adjusted for the expected amount and effectiveness of land treatment and other measures to be applied in the watershed.

The allowance of capacity for sediment accumulation will in no case exceed the amount required as determined by the procedure outlined in Engineering Memorandum-16 and Technical Release 12. Where this amount exceeds two inches of sediment yield in 50 years for the watershed, a careful examination should be made of the land use and treatment and of proposed structural measures to determine whether more economical methods of reducing sediment yield, or trapping sediment, are feasible and applicable in the watershed.

SECTION E - PRINCIPAL SPILLWAYS

SECTION E - PRINCIPAL SPILLWAYS

All component parts of the principal spillway except attached gates and trash racks will be of equal durability. The structural design codes and criteria and detailing of such spillways will conform to the recommendations of the National Engineering Handbook, Section 6, "Structural Design."

I. CAPACITY OF PRINCIPAL SPILLWAYS

The required capacity of the principal spillway depends on (1) the benefits that accrue to the reduction of the discharge rate, (2) damages that may result from prolonged storage in the retarding pool, (3) damages that may result from prolonged outflow, (4) the possibility of occurrence of significant runoff from two or more consecutive storm events within the time required to empty the retarding pool, and (5) limitations in water rights or other legal requirements.

The retarding pool should be emptied in 10 days or less. The use of a longer period must be justified by an appraisal of the considerations listed above.

The discharge through gated outlets will not be considered in determining the emptying time of the retarding pool unless a specific reservoir operation plan has been approved and included in the work plan.

II. ELEVATION OF PRINCIPAL SPILLWAYS

The crest of a single stage principal spillway for single purpose retarding dams will be placed at the elevation of the 50 year sediment pool except where a higher elevation is justified in accordance with paragraph 3107.1 of the Watershed Protection Handbook. For a two stage principal spillway for single purpose retarding dams, the crest of the lower inlet will be set at the same elevation as for a single stage structure. When a period greater than 50 years has been used for evaluation, it is recognized that structural changes may be necessary to make the structure function effectively during the latter part of its life.

For dry dams, the riser will be designed to permit design discharge at the 50 year sediment pool elevation with provisions for discharging water at lower elevations to satisfy the functional requirements of the structure.

When water is stored for beneficial use, the elevation of the lowest ungated inlet of the principal spillway will be determined by the volume, area, or depth of water required for the planned purpose or purposes in addition to the anticipated sediment storage during the design life.

III. DESIGN OF PRINCIPAL SPILLWAYS

A. Layout

The barrel of drop inlets should be straight in alignment when viewed in plan. Any required changes in alignment will be accomplished by angle changes at joints which do not exceed 5 degrees or by special elbows having a radius equal to or greater than the diameter or width of the conduit. Thrust blocks of adequate strength will be provided where special pipe elbows are used. They will be designed to distribute the thrust, due to change in direction, for the maximum possible discharge.

Drop inlet barrels will be installed with sufficient camber to insure free drainage to the outlet of all parts of the barrel at the time of construction and under the maximum anticipated foundation consolidation.

B. Conduits

All conduits under an earth embankment must support the external loads imposed with an adequate factor of safety. They must withstand the internal hydraulic pressures without leakage under full external load and settlement. They must convey water at the design velocity without damage to the interior surface of the conduit.

Principal spillway conduits under earth dams may be designed to support fill heights greater than the original constructed height where there is a reasonable possibility that it may become desirable to raise the embankment height at a later date to incorporate additional storage for some approved beneficial use.

1. Rigid Pipe

Rigid drop inlet barrels will be designed as positive projecting conduits in accordance with the principles and procedures given in Technical Release No. 5, "The Structural Design of Underground Conduits."

For Reinforced Concrete Water Pipe - Steel Cylinder Type, Prestressed, meeting specification AWWA C-301-58, the 3-edge bearing strength at the first 0.001 inch crack will be used in the design analysis with a factor of safety of at least one.

For Reinforced Concrete Water Pipe - Steel Cylinder Type - Not Prestressed meeting specification AWWA C-300-57, for Reinforced Concrete Water Pipe - Noncylinder Type - Not Prestressed meeting specification AWWA C-302-57, and other types of reinforced concrete pipe, the

3-edge bearing strength at the first 0.01 inch crack will be used in the design analysis with a factor of safety of at least 1.33.

Elliptical or other systems of reinforcement requiring special orientation of pipe sections are not permitted in pipe drop inlet barrels.

Reinforced concrete pipe, with or without cradles, will be designed to support at least 12 feet of earth fill above the pipe at all points along the conduit.

Reasonable additional safety should be incorporated in the design to compensate for probable nonuniform foundation conditions.

a. <u>Minimum Inside Diameters on Yielding Foundations</u>

Class (a) dams: The minimum diameter of the principal spillway barrel will be 30 inches, except:

(1) Where a joint extension safety margin of 1.5 inches is used, in which case the minimum diameter will be 24 inches.

(2) Where the drop inlet is designed hydraulically in such a way that the flow in the barrel under all possible conditions of discharge and foundation consolidation is positively known to be open channel flow with the water surface in the conduit subject to atmospheric pressure only, in which case the minimum diameter will be 24 inches.

(3) Where corrugated metal pipe is used for the principal spillway in accordance with conditions presented in Section III-b-2 below.

Class (b) dams: The minimum diameter of the principal spillway barrel will be 30 inches, except where a joint extension safety margin of 1.5 inches is used, in which case the minimum diameter will be 24 inches.

Class (c) dams: The minimum diameter of the principal spillway barrel will be 30 inches.

b. <u>Minimum Inside Diameters on Rock Foundations</u>

Classes (a), (b), and (c) dams: The minimum diameter of the barrel of reinforced concrete pressure pipe drop inlets will be 24 inches. The barrel and cradle or bedding will rest directly on firm bedrock of sufficient thickness so that foundation consolidation under the barrel will be essentially nothing. Under these conditions the cradle under the pipe need not be articulated.

2. Corrugated Metal Pipe

Principal spillways of corrugated metal pipe may be used for class (a) dams under the following conditions, all of which must be met:

a. The minimum diameter of the barrel will be 18 inches.

b. The pipe will be close riveted, asbestos bonded, asphalt coated, paved invert, and have watertight connecting bands. The minimum gage of the pipe will be that gage specified as safe for a height of fill over the pipe of 35 feet.

c. The height of fill over the pipe will be less than 25 feet.

C. Joints

Conduit joints will be designed and constructed to remain watertight under maximum anticipated hydrostatic head and maximum probable conditions of joint opening as computed from Standard Drawing ES-146 and related procedures of Technical Release No. 18, including the effects of joint rotation and a margin of safety where required.

The required joint extensibility is equal to the unit horizontal strain in the earth adjacent to the barrel, multiplied by the length (in inches) of the section of barrel between joints, plus the extension (in inches) due to calculated joint rotation, plus a margin of safety if required. A margin of safety of 0.5 inch is recommended. The required joint extensibility, plus the maximum permissible joint gap equals the required joint length.

The calculation of the required joint extensibility for any particular dam and spillway depends, among other things, on the evaluation of the maximum potential foundation consolidation under the spillway barrel. For classes (b) and (c) dams, the consolidation will be estimated from adequate foundation borings and samples, soil mechanics laboratory tests, and engineering analysis.

For those class (a) dams where undisturbed foundation samples are not taken for other purposes, approximate procedures based on soil classification and experience will be used for estimating foundation consolidation. When AWWA C-302-57 or other types of reinforced concrete pipe are used, they will have rubber to steel joints.

Only joints incorporating a round rubber gasket set in a positive groove which will prevent its displacement from either internal or external pressure under the maximum designed joint extensibility will be used on precast concrete pipe drop inlet barrels.

Articulation of the barrel (freedom for required rotation) will be provided at each joint in the barrel and at the junction of the barrel and the inlet (riser). Concrete bedding for pipe drop inlets need not be articulated; cradles will be articulated when on yielding foundations.

The contractor will be required to submit for approval details of the pipe joint proposed for use. The details will not be approved unless they comply fully with the plans and specifications.

D. Anti-seep Collars

All conduits through earth embankments, foundations, and abutments will be provided with anti-seep collars.

The minimum number of anti-seep collars will be determined by the size of collars and the length of that portion of the conduit which lies in the saturated zone of earth embankment.

The following criteria will be used to determine the size and number of anti-seep collars.

Let V = the vertical projection and minimum horizontal projection of the anti-seep collar in feet

L = length in feet of that portion of the barrel of a drop inlet or culvert lying within the zone of saturation, measured from the downstream side of the riser to the toe drain, or point where phreatic line intercepts the conduit

n = number of anti-seep collars

The length of the line of seepage is defined as the distance along the line of contact between the earth embankment and the barrel and the anti-seep collars from the upstream end of the barrel to the point of intersection of the barrel and the phreatic line. The ratio of the length of the line of seepage ($L + 2nV$) to L will not be less than 1.15.

Anti-seep collars should be equally spaced, except where necessary to avoid pipe joints, along that portion of the barrel within the saturated zone at distances of not more than 25 feet.

In the absence of positive evidence to the contrary (for purposes of computing anti-seep collar requirements) the location of the phreatic line in the earth dam embankment will be estimated on the assumption that the foundation of the embankment is impervious or that it is fully saturated.

E. Cantilever Outlets

The invert of cantilever outlets of pipe drop inlets or culverts at its lower end will be at least one foot above the tailwater elevation of the downstream channel at maximum discharge.

Cantilever outlets will be supported on bents or piers and will extend a minimum of 8 feet beyond the bents or piers. The bents will be located downstream from the intersection of the downstream slope of the earth dam embankment with the grade line of the channel below the dam. They will extend below the lowest elevation anticipated in the scour hole.

In determining the depth of the stilling basin, full consideration must be given to the total energy to be dissipated. The stilling basin will be excavated when soil conditions at the downstream end of the cantilever outlet indicate that a stilling basin will not be readily formed without extensive erosion of channel banks or the embankment.

Adequate safeguards must be taken to insure that the seepage forces into the stilling basin will not result in a piping failure.

F. Trash Racks

Trash racks will be designed and built to provide positive protection against clogging of the spillway at any point. The average velocity of flow through a clean trash rack will not exceed 2 feet per second with the water elevation in the reservoir 5 feet above the top of the trash rack or at the crest of the emergency spillway, whichever is lower. Velocity will be computed on the basis of the net area of opening through the rack.

For dry dams, a trash rack may be used in lieu of a ported concrete riser. The principal spillway trash rack will extend sufficiently above the anticipated sediment elevation at the inlet to provide full design flow through the spillway with velocities through the net area of the trash rack above the sediment elevation not in excess of 2 feet per second when the water surface in the reservoir is 5 feet above the top of the trash rack.

G. Anti-vortex Device

All closed conduit principal spillways designed for pressure flow will have an adequate anti-vortex device.

SECTION F- EMERGENCY SPILLWAYS

SECTION F - EMERGENCY SPILLWAYS

Emergency spillways are provided to convey large flows safely past an earth embankment. They are usually open channels excavated in earth or rock or constructed of compacted embankment or reinforced concrete.

An emergency spillway must be provided for each structure, unless the principal spillway is large enough to pass the routed freeboard hydrograph discharge and the trash that comes to it. A conduit type principal spillway having a barrel with a cross-sectional area of 20 square feet or more, an inlet which will not clog, and an elbow designed to facilitate the passage of trash is the minimum size and design that may be utilized without an emergency spillway. If a principal spillway of this type and size is not provided, danger from clogging requires the use of an emergency spillway regardless of the volume of storage provided.

I. SPILLWAY REQUIREMENTS

A. Capacity of Emergency Spillways

Emergency spillways will be proportioned so they will pass the emergency spillway hydrograph at the safe velocity determined for the site. They will have sufficient capacity to pass the freeboard hydrograph with the water surface in the reservoir at or below the elevation of the settled height of the dam. When the principal spillway is of the size and design that requires the use of an emergency spillway, the capacity of the emergency spillway will not be less than that determined from Figure F-I. The minimum depth for an emergency spillway will be two feet.

State law may also establish minimum capacity or depth greater than those given above.

B. Elevation of the Crest of the Emergency Spillway

The minimum crest elevation of the emergency spillway depends on the frequency of operation selected for the specific site. The minimum retarding storage volume and the associated principal spillway discharge will be such that the emergency spillway discharge will not occur during the routing of the runoff from any duration storm of the selected frequency.

C. Hydraulic Design

The relationship between the water surface elevation in the reservoir and the discharge through the emergency spillway will be evaluated by computing the head losses in the inlet channel upstream of the control section or, if a control section is not used, by computing the water surface profile through the full length of the spillway.

Manning's formula will be used to evaluate friction losses and determine velocities. Policy on the selection of "n" values is given in the discussion of the various types of emergency spillways.

II. VEGETATED AND EARTH EMERGENCY SPILLWAYS

Vegetated and earth emergency spillways are open channels and usually consist of an inlet channel, a control section, and an exit channel (see Section A - Definitions). Subcritical flow exists in the inlet channel and the flow is normally supercritical in the exit channel.

Vegetated emergency spillways are usually trapezoidal in the cross section and are protected from damaging erosion by a grass cover. They are adapted to sites where a vigorous grass growth can be sustained by normal maintenance without irrigation.

Earth spillways are used in those areas where vegetative growth cannot be maintained. They are similar to vegetated spillways but are designed for lower permissible velocities and less frequent use. Normally they will require more maintenance after a flow occurs.

Earth and vegetated emergency spillways are designed on the basis that some erosion or scour may be permissible if its occurrence is infrequent, if maintenance facilities are provided, and if damage from a severe storm, as represented by the freeboard inflow hydrograph, will not endanger the structure.

Technical Release No. 2 outlines procedures for the design of vegetated or earth emergency spillways. A Manning's "n" of 0.04 will be used for determining the velocity and capacity in vegetated spillways. Permissible velocities in earth spillways will be based on a "n" value of 0.02 but the capacity of earth spillways will be based on an appraisal of the roughness condition at the site.

A. Layout

Emergency spillways should be located away from the damsite whenever possible. Topographic saddles generally make good sites.

The layout and profile of vegetated or earth spillways should provide a maximum bulk of material to provide safety against breaching of the spillway during the passage of the freeboard hydrograph. This can be accomplished by the proper selection of the location and layout of the spillway. A long, non-deepened inlet section

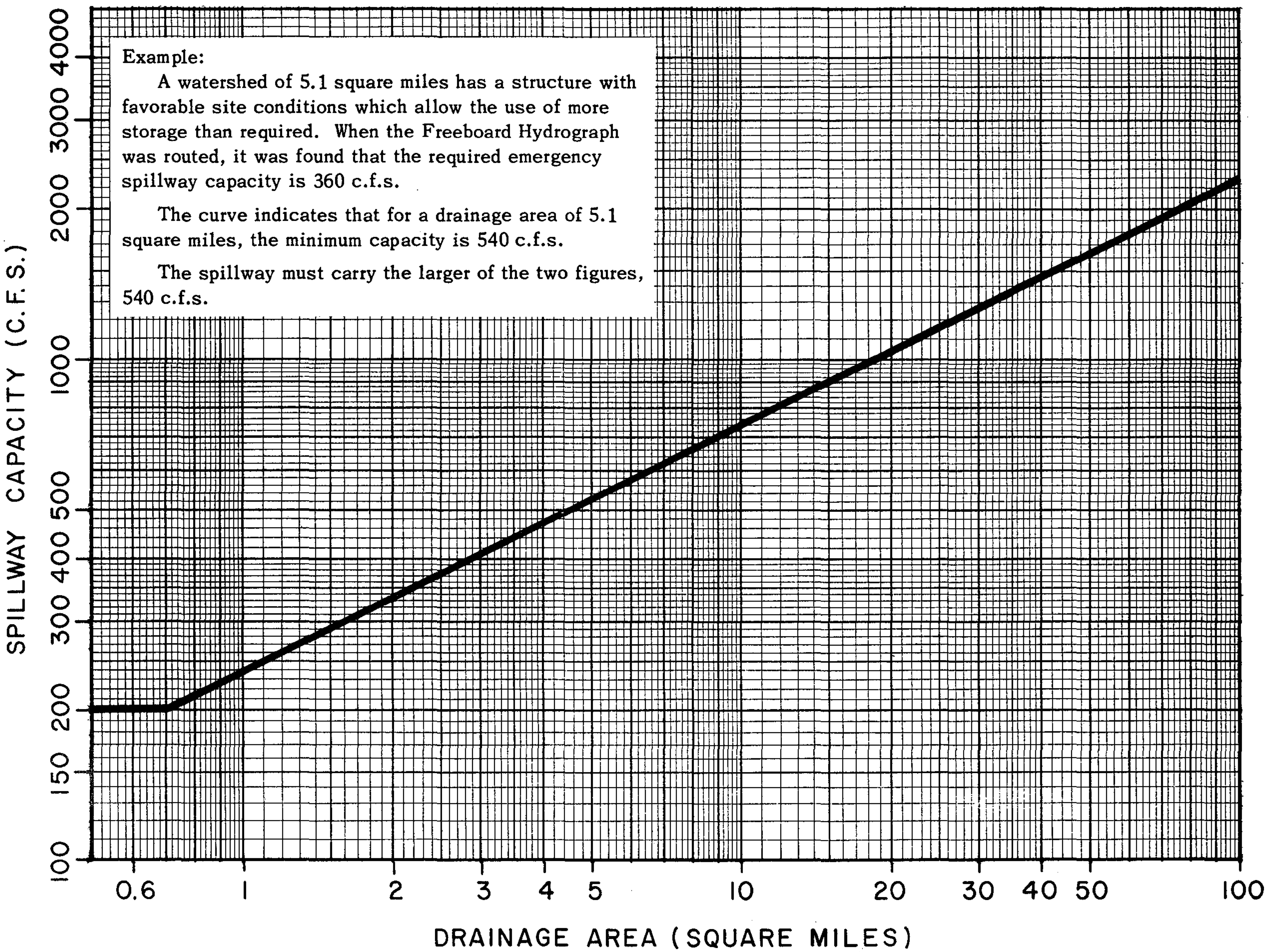


Figure F-I, Minimum emergency spillway capacity — c.f.s.

will provide more bulk but has the disadvantage of requiring a higher stage in the reservoir for any given discharge. The exit channel should be as long as reasonably practical with just sufficient slope to meet hydraulic design requirements. The characteristics and layering of the materials on which the spillway is built must be considered in estimating the volume required to prevent breaching.

The inlet channel will be level for a minimum distance of 30 feet upstream from the control section. This level part of the inlet channel will be the same width as the exit channel, and its centerline will be straight and coincident with the centerline of the exit channel. A curved centerline is permissible in the inlet channel upstream from the level section, but it must be tangent to the centerline of the level section.

The centerline of the exit channel will be straight and perpendicular to the control section for a distance equal to at least one-half of the maximum base width of the dam. Curvature may be introduced below this point if it is certain that the flowing water will not impinge on the dam should the channel fail at the curve.

When a control section is utilized, the grade of the exit channel should be sufficient to insure supercritical flow for all discharges equal to or greater than 25 percent of the maximum discharge through the emergency spillway during the passage of the emergency spillway hydrograph. However, the slope in the exit channel need not exceed 4 percent ($s = 0.04$ ft/ft) to meet this requirement.

The spillway discharge may be conducted by an exit channel to a point some distance above the stable grade of the natural stream channel. When this is done, the discharge is allowed to spread naturally over the existing topography and find its way to the channel downstream. This layout involves no consideration of velocities beyond the exit channel and during spillway discharge there may be considerable erosion on those reaches not designed on a permissible velocity basis.

Another approach is to construct a channel from the end of the exit channel to stable grade below. In this case, the lower constructed channel may be designed with higher velocities than are permissible in the exit channel proper. This assumes that erosion in the lower, well defined, improved channel may be less damaging than that occurring where the discharge is permitted to meander over the natural relief in reaching stable grade.

In both layouts, erosion will occur wherever the permissible velocities are exceeded and maintenance will be required to protect the integrity of the spillway.

1. <u>Special Precautions for Class (c) Structures</u>

Special consideration must be given to the layout of spillways on high hazard structures to assure that the spillway will not breach under the most extreme conditions of flow. The length of the exit channel should be increased to the maximum extent possible so that the area most subject to erosion is at a considerable distance from the dam. Within the limitations of the site, the profile of the spillway will be such that a maximum bulk of material is provided.

It is preferable that the flow be confined without the use of levees, but when they are necessary they will be high enough so that they will not be overtopped during the passage of the freeboard hydrograph. Levees will be constructed of erosion resistant materials and will be compacted to the degree necessary to develop this resistance. They will have a top width not less than 12 feet and, if not protected with riprap, have side slopes not steeper than 3 horizontal to 1 vertical. When constructed on foundations subject to piping or undermining, they will be keyed into the foundation with a compacted core having a width not less than the top width of the levee and sufficient depth to reach sound material, or at least equal to the height of the levee.

Where the bulk or quality of the material in the spillway may be questionable, it may be desirable to provide a crest control structure at the control section. The purpose of this structure is to stabilize the crest of the emergency spillway for at least the period equal to the passage of the freeboard hydrograph. It is subject to eventual failure if the exit channel is not properly maintained.

Consideration should also be given to the reduction of the duration of flow through the emergency spillway by raising the elevation of the crest of the emergency spillway, thereby increasing the volume of storage in the retarding pool. An alternate or complementary procedure is to increase the capacity of the principal spillway by means of a two stage inlet of sufficient size to have an appreciable effect on the outflow hydrograph of the reservoir.

B. <u>Frequency of Use of Earth and Vegetated Emergency Spillways</u>

Table F-I gives the permissible frequency of use of earth and vegetated emergency spillways. For earth spillways, it refers to

TABLE F-I

ALLOWABLE FREQUENCY OF USE OF EMERGENCY SPILLWAYS

Class of Structure	Purpose of Structure	Existing or Planned Upstream Structure	Emergency Spillway Maximum Frequency of Use		
			Earth	Vegetated	
					Ramp
			Once in	Once in	Once in
(a)	Single* Purpose Irrigation	None	½ Structure Life	½ Structure Life	Do not use
	Single or Multiple**	None	50 year	25 year	100 year
		Any#	100 year	50 year	Do not use
(b)	Single or Multiple	None	100 year	50 year	Do not use
		Any#	100 year	50 yr but not less than the frequency of use of the upstream emergency spillway	
(c)	Single or Multiple	None or Any	100 year	100 year	Do not use

* Applies only to structures on ephemeral streams in areas where the annual rainfall is less than 25 inches.

** Structures involving industrial or municipal water will use criteria equivalent to that for class (b) or (c) depending on site conditions. Criteria approaching that for class (b) will be used when (1) the storage involves water for agricultural use or recreation, or (2) the cost of the structure exceeds $75,000.

\# Applicable when the upstream structure is located so that its failure could endanger the lower structure.

sites where peak flow of short duration may be expected, and where erosion resistant soils and moderate slopes exist. When vegetated spillways are used, the sites must have these same characteristics, and in addition, conditions must be such that vigorous vegetation can be maintained without irrigation.

When conditions are less favorable, spillways must be designed for less frequent use by (1) raising the elevation of their crest, (2) providing a second stage of greater capacity to the principal spillway, or (3) increasing the capacity of the principal spillway.

The maintenance required for the emergency spillway will be increased as the flow frequency and duration increases. Good design requires balancing the spillway maintenance cost against the increased cost of modifying the other elements of the dam to reduce the flow frequency.

C. Permissible Velocity in Vegetated or Earth Emergency Spillways

The maximum velocity limitations given below for vegetated or earth emergency spillways apply to the exit channel. They must not be exceeded from the control section to a point where (1) the distance from the control section is at least equal to one-half the maximum base width of the embankment and (2) a channel failure might cause the flow to impinge on the toe of the dam. The velocity limitations are based on the capacity required by routing the emergency spillway hydrograph and the assumption that uniform flow conditions exist in the exit channel. When the spillway is of the minimum capacity as determined by Figure F-I, the velocity limitation will only apply to the lesser flow that would be developed by routing the emergency spillway hydrograph.

1. Vegetated Emergency Spillways

When the anticipated average use of a vegetated emergency spillway is more frequent than once in 50 years, the maximum permissible velocity will be in accordance with the values given in SCS Technical Publication 61, "Handboook of Channel Design for Soil and Water Conservation." The values may be increased 10 percent when the anticipated average use is not more frequent than once in 50 years or 25 percent when the anticipated average use is not more than once in 100 years.

Table F-II summarizes the recommendations of SCS Technical Publication 61. The values given for bermuda grass will be the upper limit for all grasses. Values for other grasses or grass mixtures will be determined by comparison with the other values shown, with due consideration given to the growth characteristics and density attained in the local area by the species under consideration.

TABLE F-II

PERMISSIBLE VELOCITIES FOR VEGETATED EARTH SPILLWAYS

	Permissible velocity* feet per second			
	Erosion resistant soils		Easily erodible soils	
	Slope of exit channel Percent		Slope of exit channel Percent	
	0 to 5	5 thru 10	0 to 5	5 thru 10
Bermuda grass	8	7	6	5
Buffalo grass Kentucky bluegrass Smooth brome Blue grama	7	6	5	4
Grass mixture	5	4	4	3
Lespedeza sericea Weeping lovegrass Yellow bluestem Kudzu Alfalfa Crabgrass	3.5	Do not use	2.5	Do not use

* Increase values 10 percent when the anticipated average use of the spillway is not more frequent than once in 50 years or 25 percent when the anticipated average use is not more frequent than once in 100 years.

Where bona fide studies or investigations have been made to determine the permissible velocity for a species, soil, and site, these values may be used in lieu of those shown in Table F-II.

a. Ramp Spillways

Ramp spillways may be used only when a reasonable alternate solution is not practicable. This type of spillway is not generally accepted by the engineering profession and requires a very conservative design. It may be used only on class (a) dams in humid areas where the soils and rainfall are such that a vigorous growth of grass can be maintained without irrigation.

Slope of the exit channel of a ramp spillway will be uniform and will not exceed 10 percent (0.10 ft/ft). It will be located to discharge for its full width onto an approximately level flood plain and with the anticipated or constructed scour hole below the principal spillway not nearer than 50 feet from the outside toe of the exterior confining levee.

The permissible velocities in the exit channel of a ramp spillway will not be exceeded for a period longer than one hour when the freeboard hydrograph is routed through the structure.

Easily eroded soils and soils subject to excessive shrink or swell will not be used within 3 feet of the wetter perimeter of the ramp spillway.

2. Earth Emergency Spillways

The permissible velocity in earth spillways will be chosen after due consideration of the soils involved, the frequency of use of the spillway and other pertinent factors. Table F-III is taken from Fortier and Scobey's study, "Permissible Canal Velocities After Aging," and may be helpful in determining this velocity. The values given for noncohesive soils are quite applicable and should not be exceeded unless bona fide studies have demonstrated that higher velocities are permissible. The table is not strictly applicable for cohesive soils since it applies to canal beds that are seasoned (perhaps permitting higher velocities) and subject to continuous flow and under conditions where erosion damage cannot be tolerated (requiring lower velocities).

On easily erodible soils, consideration should be given to the use of mechanical control on the spillway crest to maintain the elevation and position of the control section.

TABLE F-III

PERMISSIBLE CANAL VELOCITIES AFTER AGING*

Original material excavated	Feet/second
Fine sand, non-colloidal	1.50**
Sandy loam, non-colloidal	1.75
Silt loam, non-colloidal	2.00
Alluvial silts, non-colloidal	2.00
Ordinary firm loam	2.50
Volcanic ash	2.50
Fine gravel	2.50
Stiff clay, very colloidal	3.75
Graded, loam to cobbles, non-colloidal	3.75
Alluvial silts, colloidal	3.75
Graded, silt to cobbles, colloidal	4.00
Coarse gravel, non-colloidal	4.00
Cobbles and shingles	5.00
Shales and hardpans	6.00

* Recommended in 1926 by Special Committee on Irrigation Research, American Society of Civil Engineers.

** Values shown apply to clear water, no detritus.

III. ROCK EMERGENCY SPILLWAYS

Some of the principles used for the layout of earth emergency spillways are applicable to rock emergency spillways. Allowable average frequency of use and permissible velocities must be ascertained for the specific site based on a knowledge of the hardness, condition, durability, and structure of the rock formation. An individual appraisal is necessary to determine the proper roughness coefficient, "n."

IV. STRUCTURAL EMERGENCY SPILLWAYS

Chutes or drops, when used for emergency spillways, will be designed in accordance with the principles set forth in National Engineering Handbook Section 5 "Hydraulics," Section 11 "Drop Spillways," and Section 14 "Chutes."

SECTION G - EARTH EMBANKMENTS

I. HEIGHT

The earth embankment will be high enough to prevent overtopping with the most severe of the following conditions: (1) the passage of the freeboard hydrograph or (2) the passage of the emergency spillway hydrograph, plus the necessary freeboard required by the site for frost conditions or wave action.

II. TOP WIDTH

The top width of earth embankments will not be less than the value given by the following equation, except for single purpose retarding dams:

$$W = \frac{H + 35}{5}$$

where H = maximum height of embankment in feet

W = minimum top width of embankment in feet

Fpr single purpose retarding dams, the top width may be in accordance with the following table:

Height of Embankment in feet	Top Width in feet
15 or less	10
15 to 25	12
Over 25	14

III. WAVE EROSION PROTECTION

One of the following alternate methods may be used on retarding dams where the crest of the principal spillway falls in close proximity to the base of the dam:

a. A berm having a minimum width of 8 feet will be constructed on the upstream face of the embankment at not more than 1 foot below the crest of the principal spillway. This berm will be level in a longitudinal direction and may be flat or have not greater than a 10 percent slope away from the embankment. Appropriate water tolerant vegetation will be planted on this berm.

b. Rock riprap or other wave protection will be used to protect the upstream face of the embankment.

On water storage dams or multiple purpose dams involving water storage, the earth embankment will be riprapped or other wave protection provided over the full range in stage between the lowest drawdown elevation and at least a few feet above the full normal pond elevation.

SECTION H - UTILITIES UNDER EMBANKMENTS

Existing pipelines, cables, and conduits of a wide variety of sizes, materials, and functions are frequently encountered at dam sites. These conduits usually are located at shallow depth in the flood plain. They constitute a hazard to the safety of the dam and must be (1) relocated away from the site or (2) reconstructed or modified to provide the durability, strength, and flexibility equal in all respects to the principal spillway designed for the site in accord with Service criteria and procedure.

Every reasonable effort should be made to have such conduits, cables, and pipelines removed from the site. Most utilities and industries will want their facility removed from the site for easy maintenance. Only as a last resort and under the limitations imposed will conduits be permitted to remain under an earth dam embankment.

Conduits permitted to remain under any part of the embankment below the crest of the emergency spillway must be (1) provided with anti-seep collars when the location of the pipe creates a piping potential, (2) properly articulated on all yielding foundations, (3) encased in concrete or otherwise treated to insure durability and strength equal to that of the principal spillway, and (4) made absolutely watertight against leaking either into or out of the pipe.

Enclosure of the conduit, cable, or pipeline within another conduit which meets the requirements of this section and which is positively sealed at the upstream end to prevent seepage into the enclosing conduit is acceptable. Such an enclosing conduit will extend the full distance through which the conduit being enclosed is beneath the embankment.