

DEC

Division of Water

**Guidelines
for
Design of Dams**

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New York State Department of Environmental Conservation

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GUIDELINES FOR
DESIGN OF DAMS

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GUIDELINES FOR DESIGN OF DAMS

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PREFACE TO THE JANUARY 1988 EDITION

The January 1988 revision involves:

<u>Page</u>	<u>Item</u>
2	Introduction
4	Corrected definition for the Service Spillway Design Flood (SSDF)
6	Construction Inspection
11	Insertion of Section 6A, Flashboard Policy
14	Filter and drainage diaphragm replacing antiseep collars for pipe conduits
19	Vegetation Control
22	Insertion of Loading Condition 3A
25	Cofferdams
28	The addition of references 3, 4, 5 and 6

PREFACE TO THE JANUARY 1989 EDITION

The January 1989 revision involves:

<u>Page</u>	<u>Item</u>
7	Hydrology Investigations
7	Existing Dams - Service Spillway Design Flood Criteria

1.0 INTRODUCTION

1.1 General

The Department of Environmental Conservation receives many requests for detailed information about designs for dams requiring a permit under Article 15, Section 0503 of the Environmental Conservation law. This brochure has been developed by the department for the general guidance of design engineers.

These guidelines represent professional judgment of the Dam Safety Section's staff engineers. The guidelines convey sound engineering practices in an average situation. Where unusual conditions exist and the guidelines are not applicable, it is the duty of the design engineer to notify the department which will then consider deviation from the guidelines.

Since these are only general guidelines for small dam construction in an average situation, compliance will not necessarily result in approval of the application. The determination by the department of the acceptability of the design and adequacy of the plans and specifications will be made on a case-by-case basis. The primary responsibility of proper dam design shall continue to be that of the applicant.

In the administration of this law, the department is concerned with the protection of both the health, safety and welfare of the people and the conservation and protection of the natural resources of the State. (See Reference 1 and 2).

Water stored behind a dam represents potential energy which can create a hazard to life and property located downstream of the dam. At all times the risks associated with the storage of water must be minimized. This document deals with the engineering guidelines for the proper design of a dam. In order for a dam to safely fulfill its intended function, the dam must also be constructed, operated and maintained properly.

Supervision of construction or reconstruction of the dam by a licensed professional engineer is required to insure that the dam will be built according to the approved plans. See Article 15-0503, Item 5 of the New York State, Environmental Conservation Law (Reference 1).

For the proper operation and maintenance of a dam, see "An Owners Guidance Manual for the Inspection and Maintenance of Dams in New York State" (Reference 6).

1.2 Application

A permit is required if the dam:

- is at least 10 feet high or
- stores 1 million gallons (3.07 acre feet) or
- has a drainage area of 1 square mile.

Waste surface impoundments which are large enough to meet the above mentioned criteria shall not require an Article 15 dam permit. Hazardous waste surface impoundments will continue to be regulated by the Bureau of Hazardous Waste Technology, Division of Hazardous Substances

Regulation of the Department of Environmental Conservation, under 6NYCRR-Part 373, Hazardous Waste Management Regulation. Surface impoundments which are part of an approved waste water treatment process will be regulated within a SPDES permit issued by the Division of Water.

1.3 Application Forms

Applications, including the Supplement D-1 (hydrological, hydraulic and soils information), can be obtained from and should be submitted to the Regional Permit Administrator. The addresses of the Regional Permit Administrators are shown on page 31. Detailed information on application procedures is contained in the Uniform Procedures Regulations, Part 621.

Information on all pertinent items should be given. Construction plans and specifications should be prepared in sufficient detail to enable review engineers to determine if the proposed design and construction is in compliance with department guidelines. Thorough engineering review will be given each application. The time for this review and any additional time if revisions are necessary should be a consideration in each application.

2.0 DEFINITIONS

Appurtenant works are structures or materials built and maintained in connection with dams. These can be spillways, low-level outlet works and conduits.

Auxiliary spillway is a secondary spillway designed to operate only during large floods.

Cofferdam is a temporary structure enclosing all or part of the construction area so that construction can proceed in the dry.

Conduit is an enclosed channel used to convey flows through or under a dam.

Dam is any artificial barrier and its appurtenant works constructed for the purpose of holding water or any other fluid.

Department is the Department of Environmental Conservation (DEC).

Detention/Retention Basin is any structure that functions as a dam.

Earth Dam is made by compacting excavated earth obtained from a borrow area.

Energy Dissipator is a structure constructed in a waterway which reduces the energy of fast-flowing water.

Flood Routing is the computation which is used to evaluate the interrelated effects of the inflow hydrograph, reservoir storage and spillway discharge from the reservoir.

Freeboard is the vertical distance between the design high water level and the top of the dam.

Gravity Dam is constructed of concrete and/or masonry and/or laid-up stone that relies upon its weight for stability.

Height is the vertical dimension from the downstream toe of the dam at its lowest point to the top of the dam.

Low-Level Outlet is an opening at a low level used to drain or lower the water.

Major Size Dam is at least 25 feet high and holds at least 15 acre feet of water or is at least 6 feet high and holds at least 50 acre feet of water.

Maximum Impoundment Capacity is the volume of water held when the water surface is at the top of the dam.

Probable Maximum Flood (PMF) is the flood that can be expected from the severest combination of critical meteorologic and hydrologic conditions possible for the particular region. It is the flow resulting from the PMP.

Probable Maximum Precipitation (PMP) is the maximum amount of precipitation that can be expected over a drainage basin.

Seepage Collar is built around the outside of a pipe or conduit under an embankment dam to lengthen the seepage path along the outer surface of the conduit.

Service Spillway is the principal or first-used spillway during flood flows.

Service Spillway Design Flood(SSDF) is the flow discharged through the service spillway.

Spillway is a structure which discharges flows.

Spillway Design Flood(SDF) is the largest flow that a given project is designed to pass safely.

Toe of Dam is the junction of the downstream face of a dam and the natural ground surface, also referred to as downstream toe. For an earth dam the junction of the upstream face with the ground surface is called the upstream toe.

3.0 HAZARD CLASSIFICATION

3.1 General

The height of the dam, its maximum impoundment capacity, the physical characteristics of the dam site and the location of downstream facilities should be assessed to determine the appropriate hazard classification. Applications should include the design engineer's description of downstream conditions and his judgment of potential downstream hazards presented in the form of a letter designation and a written description.

3.2 Letter Designation

Class "A": dam failure will damage nothing more than isolated farm buildings, undeveloped lands or township or country roads.

Class "B": dam failure can damage homes, main highways, minor railroads, or interrupt use or service of relatively important public utilities.

Class "C": dam failure can cause loss of life, serious damage to homes, industrial or commercial buildings, important public utilities, main highways, and railroads.

3.3 Written Description

The written description is an elaboration of the letter designation. It includes descriptions of the effect upon human life, residences, buildings, roads and highways, utilities and other facilities if the dam should fail.

4.0 DESIGN AND CONSTRUCTION DOCUMENTS

4.1 Engineer Qualifications

The design, preparation of construction plans, estimates and specifications and supervision of the construction, reconstruction or repair of all structures must be done under the direction of a professional engineer licensed to practice in New York State. (See References 1 and 7).

4.2 Design Report

A design report, submitted with the application, should include an evaluation of the foundation conditions, the hydrologic and hydraulic design and a structural stability analysis of the dam. The report should include calculations and be sufficiently detailed to accurately define the final design and proposed work as represented on the construction plans. Any deviations from the guidelines should be fully explained.

4.3 Construction Plans

Construction plans should be sufficiently detailed for department evaluation of the safety aspects of the dam. The cover sheet should include a vicinity map showing the location of the dam. The size of the plans should be not less than 18 x 24 inches and no more than 30 x 48 inches. As-built plans of the project are required upon completion of construction.

4.4 Construction Inspection

The dam's performance will largely be controlled by the care and thoroughness exercised during its construction. Undisclosed subsurface conditions may be encountered which may materially affect the design of the dam. To ensure a safe design, the designer must be able to confirm design assumptions and revise the dam design if unanticipated conditions are encountered. Construction inspection is required in order to ensure that the construction work complies with the plans and specifications and meets standards of good workmanship. Therefore, construction inspection of a dam is required by a licensed professional engineer to monitor and evaluate conditions as they are disclosed and to observe material placement and workmanship as construction progresses.

The engineer involved in the construction of the dam work will be required to submit a periodic construction report to the Department covering the critical inspection activities for the dam's construction/reconstruction. Prior to permit issuance the applicant shall submit, for review and approval, a proposed schedule of construction inspection activities to be performed by the applicant's engineer. Upon permit issuance, the approved schedule shall be part of the required work.

4.5 Specifications

Materials specifications will be required for items incorporated in the dam project. Materials specifications including format found acceptable are those issued by the following agencies and organizations.

State: New York State Department of Transportation

Federal: COE - Corps of Engineers
SCS - Soil Conservation Service

Industry: ASTM - American Society for Testing and Materials
ACI - American Concrete Institute
AWWA - American Water Works Association
CSI - Construction Specifications Institute

5.0 HYDROLOGIC CRITERIA

5.1 Hydrologic Design Criteria

A table of hydrologic design criteria giving the spillway design flood, the service spillway design flood and minimum freeboards for various hazard classifications can be found in Table 1.

5.2 Design Flood

The National Weather Service has published data for estimating hypothetical storms ranging from the frequency-based storm to the Probable Maximum Precipitation event. For the frequency-based storms Technical Paper TP-40 (Ref 17) and TP-49 (Ref 18) will be used to determine rainfall. For the Probable Maximum Precipitation event, Hydrometeorological Report HMR-51 (Ref 16) will be used.

When using the above mentioned TP's and HMR's, the minimum storm duration will be six hours. For large drainage areas in which the time of concentration exceeds six hours, the precipitation amounts must be increased by the applicable duration adjustment.

The Soil Conservation Service (SCS) has developed Technical Release 55 (TR-55) "Urban Hydrology for Small Watersheds". TR-55 presents simplified procedures for estimating runoff and peak discharge and is an acceptable procedure for designing spillways for small watersheds. In developing TR-55 the SCS uses a storm period of 24 hours for the synthetic rainfall distribution.

Although the "rational method" ($Q=CIA$) is used for estimating design flows for storm drains and road culverts, it normally is not an acceptable method for determining peak discharge for the design of a dam spillway. The rational method should not be used for watershed areas larger than 200 acres because of its inaccuracy above that range. The greatest weakness of the "rational method" for predicting peak discharges lies in the difficulty of estimating the duration of storms that will produce peak flow. The greatest probability for error, both as to magnitude and understanding relates to the term "intensity" or "rate of rainfall". Although the units are inches per hour, the term does not mean the total inches of rain falling in a period of one hour. "Intensity" should be related to the time of concentration. "Intensities" would be higher for storms of short duration and would be lower for storms of longer duration.

Table I indicates that the appropriate Spillway Design Flood will be a percentage of the 100 year flood or the PMF. Therefore, in order to correctly determine the peak flow, the rainfall values used will be for the 100 year flood or the PMF and the appropriate peak discharge will be computed. After the peak discharge has been found, this value will then be multiplied by the appropriate percentages. For example a small dam in the Class "B" hazard category will have the discharge based on the

rainfall from a 100 year flood and this discharge will then be multiplied by 2.25 to obtain the peak discharge. The percentages should be applied to the discharge values in the final step of the calculations. It is incorrect to apply the percentages to the rainfall values.

5.3 Existing Dams - Design Flood

Existing dams that are being rehabilitated should have adequate spillway capacity to pass the following floods without overtopping:

<u>Hazard Classification</u>	<u>Spillway Design Flood (SDF)</u>
A	100 year
B	150% of 100 year
C	50% of PMF

The Service Spillway Design Flood (SSDF) for existing dams is the same as shown for the new dams on Table 1.

TABLE 1 - NEW DAMS

HYDROLOGIC DESIGN CRITERIA TABLE

HAZARD CLASSIFICATION	SIZE DAM	SPILLWAY DESIGN FLOOD (SDF)	SERVICE SPILLWAY DESIGN FLOOD (SSDF)	MINIMUM FREEBOARD (FT.)
"A"	*SMALL	100 year	5 year	1
"A"	*LARGE	150% of 100 yr.	10 year	2
"B"	SMALL	225% of 100 yr.	25 year	1
"B"	LARGE	40% of PMF	50 year	2
"C"	SMALL	50% of PMF	25 year	1
"C"	LARGE	PMF	100 year	2

*SMALL

Height of dam less than 40 feet. Storage at normal water surface less than 1000 acre feet.

*LARGE

Height at dam equal to or greater than 40 feet. Storage at normal water surface equal to or greater than 1000 acre feet.

NOTE:

Size classification will be determined by either storage or height, whichever gives the larger size category.

6.0 HYDRAULICS OF SPILLWAYS

6.1 Spillways

Spillways protect the dam from overtopping. Consideration must be given to dams and reservoirs upstream of the dam in question when designing the spillway. A dam should be provided with either a single spillway or a service spillway-auxiliary spillway combination.

6.2 Single Spillway

For a single spillway, the structure should have the capacity and the durability to handle sustained flows as well as extreme floods and be non-erodible and of a permanent-type construction. Free overall spillways, ogee spillways, drop inlet or morning glory spillways, and chute spillways are common types. An earth or grass-lined spillway is not durable under sustained flow and should not be used as a single spillway.

6.3 Criteria for a single spillway are as follows:

- 6.3.1 Sufficient spillway capacity should be provided to safely pass the spillway design flood with flood routing through the reservoir. (See Table 1 for spillway design flood).
 - 6.3.2 Assuming no inflow, the spillway should have sufficient discharge capacity to evacuate 75% of the storage between the maximum design high water and the spillway crest within 48 hours.
 - 6.3.3 The spillway will have an energy dissipater at its terminus.
 - 6.3.4 A drop inlet or morning glory spillway, as a single spillway, is only acceptable on a Hazard Class "A" structure with a drainage area of less than 50 acres. In this case, sufficient storage capacity should be provided between the spillway crest and top of dam to contain 150% of the entire spillway design flood runoff volume.
- 6.4 Service Spillway - Auxiliary Spillway Combination:
In the case of the service spillway - auxiliary spillway combination, the service spillway discharges normal flows and the more frequent floods, while the auxiliary spillway functions only during extreme floods.

Service spillways must be durable under conditions of sustained flows; whereas auxiliary spillways do not. Service spillways should have sufficient capacity to pass frequent floods and thus reduce the frequency of use of the auxiliary spillway. The service spillway usually does not have sufficient capacity to pass the entire spillway design flood. Drop inlet or morning glory spillways are common types of service spillways. This type of structure will consist of a vertical inlet riser connected to a service spillway conduit with an energy

dissipator at the outlet. An auxiliary spillway is capable of handling high but short duration flows. It may be an excavated grass-lined channel if the designer is able to limit velocities to the non-erodible range for grass. It cannot carry prolonged flows because of eventual deterioration of the grass linings. For spillways which will be required to discharge flows at a high velocity, a more permanent type of material such as concrete will be required. An auxiliary spillway may be located adjacent to a dam abutment or anywhere around the rim of the reservoir. It should be located sufficiently apart from the dam to prevent erosion of any embankment materials. A spillway over the dam is not acceptable. It may either discharge back into the natural watercourse below the dam, or so long as a flood hazard is not created, into a watercourse within an adjacent drainage basin.

- 6.5 Criteria for an auxiliary spillway-service spillway combination are as follows:
 - 6.5.1 Sufficient service spillway capacity should be provided to safely pass the service spillway design flood with flood routing through the reservoir. (See Table 1 for service spillway design flood).
 - 6.5.2 The service spillway normally should be provided with an energy dissipater at its outlet end.
 - 6.5.3 The auxiliary spillway crest must be placed at or above the service spillway design high water, and not less than 1 foot above the service spillway crest.
 - 6.5.4 The auxiliary spillway-service spillway combination must provide sufficient discharge capacity to safely pass the spillway design flood with flood routing through the reservoir (See Table 1 for spillway design flood).
 - 6.5.5 Assuming no inflow, the auxiliary spillway-service spillway combination should have sufficient capacity to evacuate the storage between the maximum design high water and the auxiliary spillway crest within 12 hours.
 - 6.5.6 Assuming no inflow, the service spillway should have sufficient capacity to evacuate 75% of the storage between the auxiliary spillway crest and the service spillway crest within 7 days.
 - 6.5.7 Auxiliary spillways shall not be placed on fill.
 - 6.5.8 Velocities in auxiliary spillways should not exceed the maximum permissible velocities (non-erodible velocities) of the spillway materials.

6.5.9 If an auxiliary spillway is located near an embankment, it should be located so as not to endanger the stability of the embankment. The following criteria will help guard against damage to the embankment:

a. Discharge leaving the exit channel should be directed away from the embankment and should be returned to a natural watercourse far enough downstream as to have no erosive effect on the embankment toe.

b. The spillway exit channel, from the spillway crest to a section beyond the downstream toe of dam, should be uniform in cross-section, contain no bends, and be longitudinally perpendicular to the spillway crest. Curvature may be introduced below the toe of dam if it is certain that the flowing water will not impinge on the toe of dam.

6.0 A FLASHBOARD POLICY

Background

Flashboards are used to raise the water surface of an impoundment. However, the installation of flashboards along the crest of a spillway may permanently reduce the size of the spillway opening. Our records indicate that in some instances the reduction of spillway capacity with the installation of flashboards has resulted in overtopping and subsequent dam failure. Two examples are the Tillson Lake Dam (#1942420) in Ulster County and the Lake Algonquin Dam (#171-2700) in Hamilton County.

In 1939 flashboards were placed across the spillway of the 40 foot high Tillson Lake Dam in such a manner as to greatly reduce the spillway opening. Storm flow caused dam overtopping which eroded the earth slope in front of the 100 foot wide, 30 foot high concrete core wall. Failure of the core wall resulted in a tremendous amount of erosion to farm land, loss of farm machinery, chickens, several local bridges and basement flooding. The dam was rebuilt and failed in 1955 because flashboards were again in place and did not fail during storm flow.

In 1949 the Lake Algonquin Dam failed because flashboards were not removed for the winter. A January storm caused overtopping and subsequent dam failure at the right abutment. The dam failure resulted in the loss of a home, several farm buildings and a road.

When wood flashboards are installed properly they will be

supported by steel pins. These steel pins will be designed to fail when the depth of flow over the top of the flashboards reaches a certain level. Critical to the design of the flashboard system are the diameter of the steel pin, the ultimate strength of the steel and the spacing of the pins. In very few cases is the Consulting Engineer or Contractor who designed the flashboards able to provide sufficient quality control to ascertain that the as-built condition is similar to the design proposal.

Many field maintenance personnel do not understand the need for flashboards to fail when the depth of flow over the flashboards reaches a certain level. Therefore, there is a tendency to insert the flashboards in such a manner so that they will never fail, thus permanently reducing spillway capacity and increasing the possibility of dam failure by overtopping. This is what nearly happened at the Gore Mountain Dam at North Creek. During the period of 1977-1980 DEC operations personnel installed wide flange beams to support the wood flashboards. The approved design for the flashboard supports were one inch diameter steel pins. However, operations personnel decided they would have less maintenance problems if they permanently secured the wood flashboards between the six inch wide flange beams. Under this support the flashboards would never fail.

Around February 15, 1981 a sudden thaw and rain caused the water level at Gore Mountain Dam to rise within eight inches of the top of dam. This level was about two feet, four inches over the top of the flashboards. The extra sturdy wide flange beam support system precluded any chance of flashboard failure. Fortunately this abnormally high level was reported to the DEC by a local resident while he was snowmobiling. During the fall of 1981, DEC revised the flashboard support system so that the flashboards were properly supported by one inch diameter steel pins and the steel pins would fail in bending when the depth of flow over the top of the flashboards reached one foot.

For the foregoing reasons the Dam Safety Section has developed the following policy regarding the installation of flashboards on dams.

New Dams

Flashboards shall not be installed on any new dams. The dam owner or hydroelectric developer shall determine the normal pool elevation for the proposed impoundment and provide a permanently fixed spillway crest at the selected elevation. If pool elevation fluctuations are desired, they should be achieved by means of adequately sized gates, drains, siphons or other acceptable methods.

Existing Dams

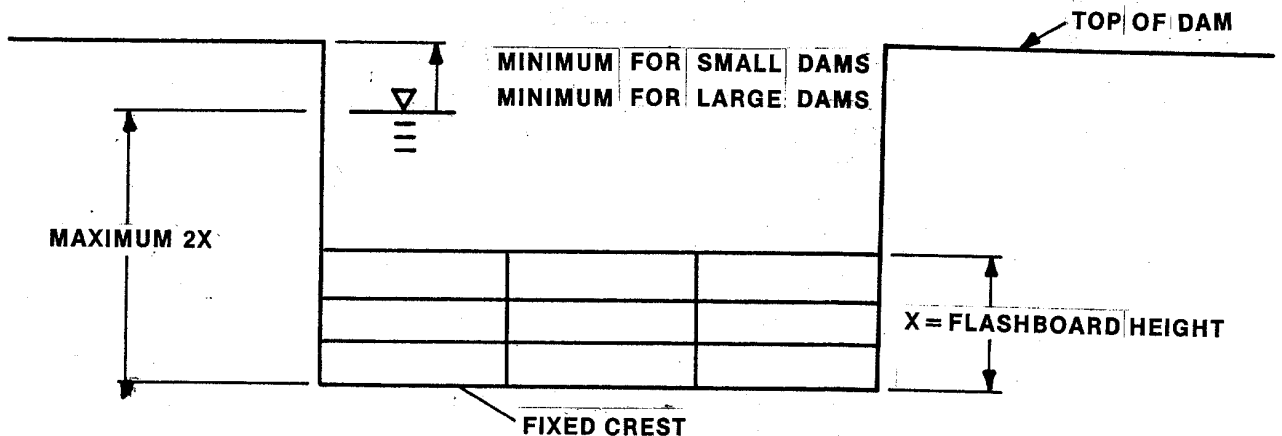
A permanently fixed spillway crest is the preferred method of establishing normal pool elevation.

The installation or continued use of flashboards on existing dams will be considered on a case by case basis. Flashboards on existing dams will only be acceptable if the dam is able to satisfy the hydraulic and structural stability criteria contained in the Guidelines for Design of Dams. If the flashboards are designed to fail in order to satisfy either criterion, detailed failure calculations must be submitted for Department review and approval. The maximum pool elevation the flashboards are designed to fail at shall be the lower of:

1. Two times the height of the flashboards measured from the bottom of the flashboards, or
2. Two times the freeboard specified in Table 1 of these Guidelines, for a dam of the pertinent size and hazard classification, measured downward from the top of dam.

The maximum pool elevation that would be reached under Spillway Design Flood conditions, without the flashboards failing, shall also be determined.

Flashboards shall be installed, operated and maintained as intended in their design and in accordance with the terms and/or conditions of any permits or approvals. The approved flashboard configuration (pin spacing, pin size, board height, board size, etc.) shall not be modified without prior Department approval.



7.0 OUTLET WORKS AND CONDUITS

7.1 Outlet Works

A low-level outlet conduit or drain is required for emptying or lowering the water in case of emergency; for inspection and maintenance of the dam, reservoir, and appurtenances; and for releasing waters to meet downstream water requirements. The outlet conduit may be an independent pipe or it may be connected to the service spillway conduit. The low level drain is required to have sufficient capacity to discharge 90% of the storage below the lowest spillway crest within 14 days, assuming no inflow into the reservoir.

7.2 Control

Outlet conduits shall have an upstream control device (gate or valve) capable of controlling the discharge for all ranges of flow.

7.3 Conduits

Only two types of conduits are permitted on Hazard Class "B" and "C" structures; precast reinforced concrete pipe and cast-in-place reinforced concrete.

On Hazard Class "A" structures, welded steel pipe or corrugated metal pipe may be used providing the depth of fill over the pipe does not exceed 15 feet and the pipe diameter does not exceed 24 inches.

All outlet conduits shall be designed for internal pressure equal to the full reservoir head and for the superimposed embankment loads, acting separately.

The minimum size diameter conduit used as the barrel of a drop inlet service spillway shall be 12 inches.

The joints of all pipe conduits shall be made watertight.

Any pipe or conduit passing through an embankment shall have features constructed into the embankment whereby seepage occurring along the pipe or conduit is collected and safely conveyed to the downstream toe of the embankment. This can be accomplished by using a properly designed and constructed filter and drainage diaphragm. The filter and drainage diaphragm will be required unless it can be shown that antiseep collars will adequately serve the purpose.

Antiseep collars will not be permitted for dams with a height in excess of 20 feet. If antiseep collars are used in lieu of a

drainage diaphragm, they shall have a watertight connection to the pipe. Collar material shall be compatible with pipe materials. The antiseep collars shall increase the seepage path along the pipe by at least 15%.

A means of dissipating energy shall be provided at the outlet end of all conduits 12 inches or more in diameter. If a plunge pool is used, the conduit should be cantilevered 8 feet over a concrete, steel or treated timber support located near or at the downstream toe of the embankment. The plunge pool should be riprap-lined if a conduit 18 inches or more in diameter is used. The foregoing may apply to smaller pipes if the embankment's downstream slope is steep and the soil erodible.

8.0 GEOTECHNICAL INVESTIGATION

8.1 Foundations

8.1.1 Subsurface explorations (drill holes, test pits and/or auger holes) should be located along the centerline of the dam, at the proposed service and auxiliary spillway locations, and in other critical areas. The depth of the subsurface explorations should be sufficient to locate and determine the extent and properties of all soil and rock strata that could affect the performance of the dam, the reservoir and appurtenant structures. Referring to information such as geologic bulletins, soil survey maps, groundwater resources bulletins, etc., may aid the designer in determining the scope of the exploration program needed and interpreting the results of the program. For even the smallest low hazard dams, at least three explorations should be made along the centerline of the dam, one in the deepest part of the depression across which the dam will be built and one on each side. At least one exploration should be made at the proposed auxiliary spillway location. For small low-hazard dams, to be built on a foundation known from the geology of the area to be essentially incompressible and impervious to a great depth, the minimum depth of explorations should be 5 feet unless bedrock is encountered above this depth. In other cases the minimum depth of explorations should be 10 feet, with one or more borings extending to a depth equal to the proposed height of the dam. If it is proposed to excavate in the reservoir area, the possibility of exposing pervious foundation layers should be investigated by explorations or a review of the geology of the area. If rock is encountered in explorations, acceptable procedures, such as coring, test pits, or geologic information, should be used to verify whether or not it is bedrock.

8.1.2 Sufficient subsurface explorations should be made to verify the suitability of encountered rock for use as a foundation

and/or construction material. Testing of the rock materials shall ascertain its strength, compressibility, and resistance to degradation, and its ability to safely withstand the loads expected to be imposed upon it by the proposed project.

- 8.1.3 Soils encountered in explorations should be described accurately and preferably classified in accordance with the Unified Soil Classification System.
- 8.1.4 For Hazard Class "C" dams, appropriate field and/or laboratory tests should be performed in order to aid in evaluating the strength, compressibility, permeability, and erosion resistance of the foundation soils. Also, appropriate laboratory tests should be performed on samples of the proposed embankment materials in order to ascertain their suitability for use in the dam. Field and/or laboratory tests may be required also for dams of lower hazard classification in the case of critical foundation strength or permeability conditions.
- 8.1.5 Stability of the foundation under all operating conditions should be evaluated.
- 8.1.6 Settlement of the dam and appurtenant works should be evaluated and provisions made in the design to counteract the effects of any anticipated settlements.
- 8.1.7 Whenever feasible, seepage under the dam should be controlled by means of a complete cutoff trench extending through all pervious foundation soils into a relatively impervious soil layer. If the dam is to be built on an impervious foundation, the cutoff or key trench should be excavated to a depth of at least 3 feet into the foundation soils and backfilled with compacted embankment material. Where the final depth of cutoff cannot be established with certainty during design, a note should appear on the plans stating that the final depth of the cutoff trench will be determined by the engineer during the time of construction. Backfilling of the cutoff or key trench should be performed in the dry, unless special construction procedures are used. The bottom width of the trench should be at least 8 feet and should be increased in the case of dams more than 20 feet high. The widths of complete cutoffs may be made considerably less if the cutoff is extended vertically a minimum distance of 4 feet into impervious material. In the case of a cutoff or key trench extending to bedrock, the trench does not have to extend into rock. However, all shattered and disintegrated rock should be removed and surface fissures filled with cement grout. The need for pressure grouting rock foundations should be evaluated and, if necessary, adequately provided for.

8.2 Borrow Sources for Embankment Materials

Sufficient subsurface explorations should be made in borrow areas to verify the suitability and availability of an adequate supply of borrow materials. Logs of explorations should be included for review with the plans and specifications. Exposure of pervious soils and fissured rock below normal water surface of the proposed pond, at borrow areas located in or connected to the reservoir area, should be avoided.

If pervious soils or fissured rock conditions are encountered during borrow operations these exposed areas should be sealed with a sufficient thickness of compacted impervious material. In no case should this seal be less than two feet thick and consideration should be given to utilizing a greater thickness where site conditions and hazard classifications dictate.

Borrow areas should be located with due consideration to the future safety of the dam and should be shown on the plans. In general, no borrow should be taken within a distance measured from the upstream toe of the dam equal to twice the height of the dam or 25 feet, whichever is greater.

9.0 EARTH DAMS

9.1 Geometry

9.1.1 The downstream slope of earth dams without seepage control measures should be no steeper than 1 vertical on 3 horizontal. If seepage control measures are provided, the downstream slope should be no steeper than 1 vertical on 2 horizontal.

9.1.2 The upstream slope of earth dams should be no steeper than 1 vertical on 3 horizontal.

9.1.3 The side slopes of homogenous earth dams may have to be made flatter based on the results of design analyses or if the embankment material consists of fine grained plastic soils such as CL, MH or CH soils as described by the Unified Soil Classification System.

9.1.4 The minimum allowable top width (W) of the embankment shall be the greater dimension of 10 feet or W, as calculated by the following formula:

$W = 0.2H + 7$; where H is the height of the embankment (in feet)

9.1.5 The top of the dam should be sloped to promote drainage and minimize surface infiltrations and should be cambered so that the design freeboard is maintained after post-construction settlement takes place.

9.2 Slope Stability

Where warranted and especially for new Hazard Class "C" dams, the department may require that slope stability analyses be provided for review. The method of analyses and appropriate factors of safety for the applicable loading conditions shall be as indicated by U. S. Army Corps of Engineers publications (latest edition) (Ref. 11).

Earth dams, in general, should have seepage control measures, such as interior drainage trenches, downstream pervious zones, or drainage blankets in order to keep the line of seepage from emerging on the downstream slope, and to control foundation seepage. Hazard Class "A" dams less than 20 feet in height and Hazard Class "B" dams less than 10 feet in height, if constructed on and of erosion-resistant materials, do not require special measures to control seepage.

In zoned embankments, consideration should be given to the relative permeability and gradation of embankment materials. No particle greater in size than six inches in maximum dimension should be allowed to be placed in the impervious zone of the dam.

9.3 Compaction Control and Specifications

Before compaction begins, the embankment material should be spread in lifts or layers having a thickness appropriate to the type of compaction equipment used. The maximum permissible layer thickness should be specified in the plans or specifications.

Specifications should require that the ground surface under the proposed dam be stripped of all vegetation, organic and otherwise objectionable materials. After stripping, the earth foundation should be moistened, if dry, and be compacted before placement of the first layer of embankment material. Inclusion of vegetation, organic material, or frozen soil in the embankment, as well as placing of embankment material on a frozen surface is prohibited and should be so stated in the specifications.

For all dams, compaction shall be accomplished by appropriate equipment designed specifically for compaction. The type of compaction equipment should be specified in the plans or specifications.

The degree of compaction should be specified either as a minimum number of complete coverages of each layer by the compaction equipment or, in the case of higher or more critical dams, based on standard ASTM test methods.

When the degree of compaction is specified as a number of complete coverages or passes, the final number of passes required shall be determined by the engineer during construction.

In order to insure that the embankment material is compacted at an appropriate moisture content, a method of moisture content control should be specified. For Hazard Class "A" dams less than 20 feet high, the moisture content may be controlled visually by a qualified inspector. Hand tamping should be permitted only in bedding pipes passing through the dam. All other compaction adjacent to structures should be accomplished by means of manually directed power tampers.

Backfill around conduits should be placed in layers not thicker than 4 inches before compaction with particle size limited to 3 inches in greatest dimension and compacted to a density equal to that of the adjacent portion of the dam embankment regardless of compaction equipment used.

Care should be exercised in placing and compacting fill adjacent to structures to allow the structures to assume the loads from the fill gradually and uniformly. Fill adjacent to structures shall be increased at approximately the same rate on all sides of the structures.

The engineer in charge of construction is required to provide thorough and continuous testing to insure that the specified density is achieved.

9.4 VEGETATION CONTROL - TREES AND BRUSH

9.4.1 Trees and Brush

Trees and brush are not permitted on earth dams because:

- a. Extensive root systems can provide seepage paths for water.
- b. Trees that blow down or fall over can leave large holes in the embankment surface that will weaken the embankment and can lead to increased erosion.

- c. Brush obscures the surface limiting visual inspection, provides a haven for burrowing animals and retards growth for grass vegetation.

Stumps of cut trees should be removed so grass vegetation can be established and the surface mowed. Stumps should be removed either by pulling or with machines that grind them down. All woody material should be removed to about 6 inches below the ground surface. The cavity should be filled with well compacted soil and grass vegetation established.

9.4.2 Grass Vegetation

Grass vegetation is an effective and inexpensive way to prevent erosion of embankment surfaces. It also enhances the appearance of the dam and provides a surface that can be easily inspected.

10.0 STRUCTURAL STABILITY CRITERIA FOR GRAVITY DAMS

10.1 Application

These guidelines are to be used for the structural stability analysis of concrete and/or masonry sections which form the spillway or non-overflow section of gravity dams.

These guidelines are based on the "Gravity Method of Stress and Stability Analysis" as indicated in Reference 13.

If the gravity dam has keyed or grouted transverse contraction joints, then the "Trial-Load Twist Method of Analysis" (Reference 13) may be used for the stability analysis.

Elastic techniques, such as the finite element method, may be used to investigate areas of maximum stress in the gravity dam or the foundation. However, the finite element method will only be permitted as a supplement to the Gravity Method. The Gravity Method will be required for the investigation of sliding and overturning of the structure.

10.2 Non-Gravity Dams

For non-gravity structures such as arch dams, the designer is required to present calculations based on appropriate elastic techniques as approved by the Dam Safety Section.

10.3 Loads

Loads to be considered in stability analyses are those due to: external water pressure, internal water pressure (pore pressure or uplift) in the dam and foundation, silt pressure, ice pressure, earthquake, weight of the structure.

10.4 Uplift

Hydrostatic uplift pressure from reservoir water and tailwater act on the dam. The distribution of pressure through a section of the dam is assumed to vary linearly from full hydrostatic head at the upstream face of the dam to tailwater pressure at the downstream face or zero if there is no tailwater. Reduction in the uplift pressures might be allowed in the following instances:

10.4.1 When foundation drains are in place. The efficiency of the drains will have to be verified through piezometer readings.

10.4.2 When a detailed flow net analysis has been performed and indicates that a reduction in uplift pressures is appropriate. Any reduction of pressure of more than 20% must be verified by borings and piezometer readings.

10.4.3 When a sufficient number of borings have been progressed and piezometer readings support the fact that actual uplift pressures are less than the theoretical uplift pressures.

10.5 Loading Conditions

Loading Conditions to be analyzed.

Case 1 - Normal loading condition; water surface at normal reservoir level.

Case 2 - Normal loading condition; water surface at normal reservoir level plus an ice load of 5,000 pounds per linear foot, where ice load is applicable. Dams located in more northerly climates, may require a greater ice load.

Case 3 - Design loading condition; water surface at spillway design flood level.

Case 3A- Maximum hydrostatic loading condition; maximum differential head between headwater and tailwater levels as determined by storms smaller in magnitude than the spillway design flood. This loading condition will only be considered when the is submerged under Case 3 loading condition.

Case 4 - Seismic loading condition; water surface at normal reservoir level plus a seismic coefficient applicable to the location.

10.6 Stability Analysis for New Dams

10.6.1 Field Investigation

Subsurface investigations should be conducted for new dams. Borings should be made along the axis of the dam to determine the depth to bedrock as well as the character of the rock and soils under the dam. The number and depth of holes required should be determined by the design engineer based on the complexity of geological conditions. The depth of holes should be at least equal to the height of the dam. Soil samples and rock cores should be collected to permit laboratory testing. The values of cohesion and internal friction of the foundation material should be determined by laboratory testing.

On proposed sites where the foundation bedrock is exposed, the requirements for borings may be waived in some cases. An engineering geologist's professional opinion of the rock quality and the acceptability of the design assumptions will be required in those cases.

10.6.2 Overturning

The resultant force from an overturning analysis should be in the middle third of the base for all loading conditions, except for the seismic analysis (Case 4), where the resultant shall fall within the limits of the base.

10.6.3 Cracking

The resultant force falling outside the middle third of the base and its resulting tension cracks will not be accepted in the design of new dams, except for the seismic loading condition (Case 4).

10.6.4 Sliding

Sliding safety factors may be computed using the Shear-Friction method of analysis when shear values are based on either the results of laboratory testing or an engineering geologist's professional opinion. When the Shear-Friction method is used, the structure should have a minimum safety factor of 2.0 for all loading conditions except for Case 4 (seismic loading) where the minimum acceptable sliding safety factor shall be 1.5.

Designs which are not based on laboratory testing or an engineering geologist's professional opinion must be analyzed using the Friction Factor of Safety. This analysis assumes that the value of shear or cohesion is zero. The minimum safety factor using this method should be 1.5 for all loading conditions except Case 4 where the minimum safety factor shall be 1.25.

10.7 Stability Analysis for Existing Dams

10.7.1 Field Investigations

Subsurface investigations should normally be conducted as part of a detailed structural stability investigation for an existing dam and should provide information regarding the materials of the dam and its foundation. The number and depth of holes required should be determined by the engineer based on the complexity of the composition of the dam and foundation. Samples should be collected and tested to determine the material properties. The program should also measure the uplift pressures at several locations along the base of the dam.

In cases where no subsurface investigations are conducted conservative assumptions regarding material properties and uplift pressures will be required.

10.7.2 Overturning

The resultant force from an overturning analysis should be in the middle third of the base for normal loading conditions (Case 1) and within the middle half of the base for the ice loading condition (Case 2) and the spillway design flood loading condition (Case 3). For the seismic loading condition (Case 4), the resultant force should fall within the limits of the base.

10.7.3 Cracking

If the overturning analysis indicates that the resultant force is outside the middle third, then tension exists at the heel of the dam which may result in the cracking of the concrete. For existing dams cracking will be permitted for all loading conditions except the normal loading condition (Case 1). If the criteria specified above in Overturning for the location of the resultant force are not satisfied, further study and/or remedial work will be required. The Bureau of Reclamation's Cracked Section Method of analysis is acceptable for investigating the stability of the dam for the above mentioned loading conditions. When the Cracked Section Method of analysis is used, the criteria for the minimum sliding factor of safety will have to be satisfied.

10.7.4 Sliding

Sliding safety factors may be computed using the Shear-Friction method of analysis when shear values are based on the results of laboratory testing of samples from subsurface investigations. When the Shear-Friction method is used, the structure should have a minimum safety factor of 2.0 for Case 1 and Case 2; a value of 1.5 for Case 3 and a value of 1.25 for Case 4.

If no subsurface explorations are performed, the sliding safety factors must be computed using the Friction Factor of Safety. The minimum safety factor using this method should be 1.5 for Case 1; a value of 1.25 for Case 2 and Case 3; and a value of 1.0 for Case 4.

11.0 EXISTING DAMS: REHABILITATION AND MODIFICATION

Additional data should be submitted for dam rehabilitations or dam modifications, including a report by a professional engineer describing the performance and maintenance history of the existing dam. In addition, all data regarding construction, such as existing subsurface explorations, construction materials used for the dam, and plans and specifications should be submitted. If this information is not available, the engineer should inspect and evaluate the structure as to its condition, performance, maintenance history and other information regarding foundation soils and existing conditions.

The engineer should also assess the safety and adequacy of the existing structure against those criteria for spillway capacity and structural stability, indicated in the appropriate sections of these guidelines.

Where a new embankment is to be constructed against an existing dam embankment, the existing slope shall be benched as the new fill is spread and compacted in layers as described in the plans and specifications. This benching is done to provide an interlock between the existing and new embankments. Benching shall not be done in the upstream-downstream direction.

All topsoil and sod shall be stripped from the surface of the existing embankment before placing new material within the area of reconstruction.

Remove or seal all existing drainage structures which are not to be operative in the proposed design, in order to prevent a plane of seepage from developing through the dam.

12.0 COFFERDAMS

A cofferdam in most cases is a temporary structure enclosing all or part of the construction area. The purpose of the cofferdam is to provide protection so that construction can proceed in the dry.

12.1 When using a cofferdam the following criteria must be met:

12.1.1 Flood Plain Management

A hydraulic analysis must be performed to determine the backwater effect of the cofferdam. A range of flood discharges up to and including the 100 year return frequency flood shall be evaluated to determine the potential flood damages to lands and improvements upstream of the cofferdam not owned or otherwise controlled by the applicant. The analysis shall focus on determining if the project meets the flood plain management criteria of 6NYCRR-Part 500, if applicable, or regulations adopted by the local jurisdiction for participation in the National Flood Insurance Program.

12.1.2 Dam Safety

The applicant will have to demonstrate that cofferdam failure will not adversely impact lives and property. The evaluation will focus on the potential for flooding, loss of life and damage to properties downstream of the cofferdam not owned or otherwise controlled by the applicant.

If cofferdam failure could adversely impact properties downstream of the cofferdam, not controlled by the applicant, or if the cofferdam failure could adversely impact lives, then more specific information regarding the geotechnical, structural and hydraulic aspects of the cofferdam design will be required. The determination by the department of the acceptability of the cofferdam design will be made on a case-by-case basis.

13.0 MISCELLANEOUS

The earth embankment, earth spillways, and all disturbed earth adjacent to the embankment or other appurtenances should be seeded, except where riprap or other slope protective materials are specified.

Where destructive wave action is expected, the upstream slope of the embankment should be protected with rock riprap or other suitable material for effective erosion control.

A trash rack designed to prevent debris from entering and obstructing flow in the conduit should be provided on the vertical riser for any drop inlet spillway.

An anti-vortex device is required on the vertical riser for any drop inlet spillway with riser diameter greater than 12 inches.

Instrumentation

1. Piezometers - All earth dams 40 feet high or higher shall have at least two piezometers on the downstream slope of the embankment to measure saturation levels and hydrostatic pressures. All concrete dams 40 feet or higher should have at least two piezometers along the crest of the dam.

2. Weirs - on all dams with toe drains, weirs are required at the downstream end of the drain. The weirs measure the amount of seepage water through the embankment. Measurements of the seepage should be documented and correlated with the reservoir surface elevation. See Reference 6, pages 55-56.

14.0 EMERGENCY ACTION PLAN

An emergency action plan (EAP) should be developed by the owner of a high hazard dam (Class "C").

A copy of this EAP is to be provided to the Dam Safety Section of the department during the initial permit review period for new dams and for existing dams, if a copy of the EAP has not been previously submitted. See Reference 6, pages 69-73.

15.0 APPROVAL TO FILL RESERVOIR OF A NEW DAM

Before any water can be impounded by the dam, the dam owner shall adhere to the following:

15.1 For all Hazard Class "C" and [major size] Hazard Class "B" dams.

Within two weeks after completion of dam construction the permittee shall notify the Regional Permit Administrator in writing by certified mail of its completion and shall include a notarized statement from the owner's engineer that the project has been completely constructed under his care and supervision in accordance with plans and specifications as approved by the department. Any changes in the construction of the dam from the approved plans will be reflected in the "As-Built" plans.

The department will inspect the completed dam with the owner's engineer. During the inspection, the owner's engineer will submit "As Built" drawings and other construction records for review, such as foundation data and geological features, properties of embankment and foundation materials, concrete properties and construction history. Upon review of the data and the determination of the adequacy of the structure the "Approval to Fill" letter will be issued, permitting the owner to store water.

15.2 For all Hazard Class "A" and [Below Major Size] Hazard Class "B" dams.

Within two weeks after completion of dam construction the permittee shall notify the Regional Permit Administrator in writing by certified mail of its completion and shall include a notarized statement from the owner's engineer stating that the project has been completely constructed under his care and supervision in accordance with plans and specifications as approved by the department. Any changes in the construction of the dam from the approved plans will be reflected in the "As-Built" plans that will be submitted to the Department.

No water shall be impounded for at least 15 days subsequent to the notification to the Regional Permit Administrator.

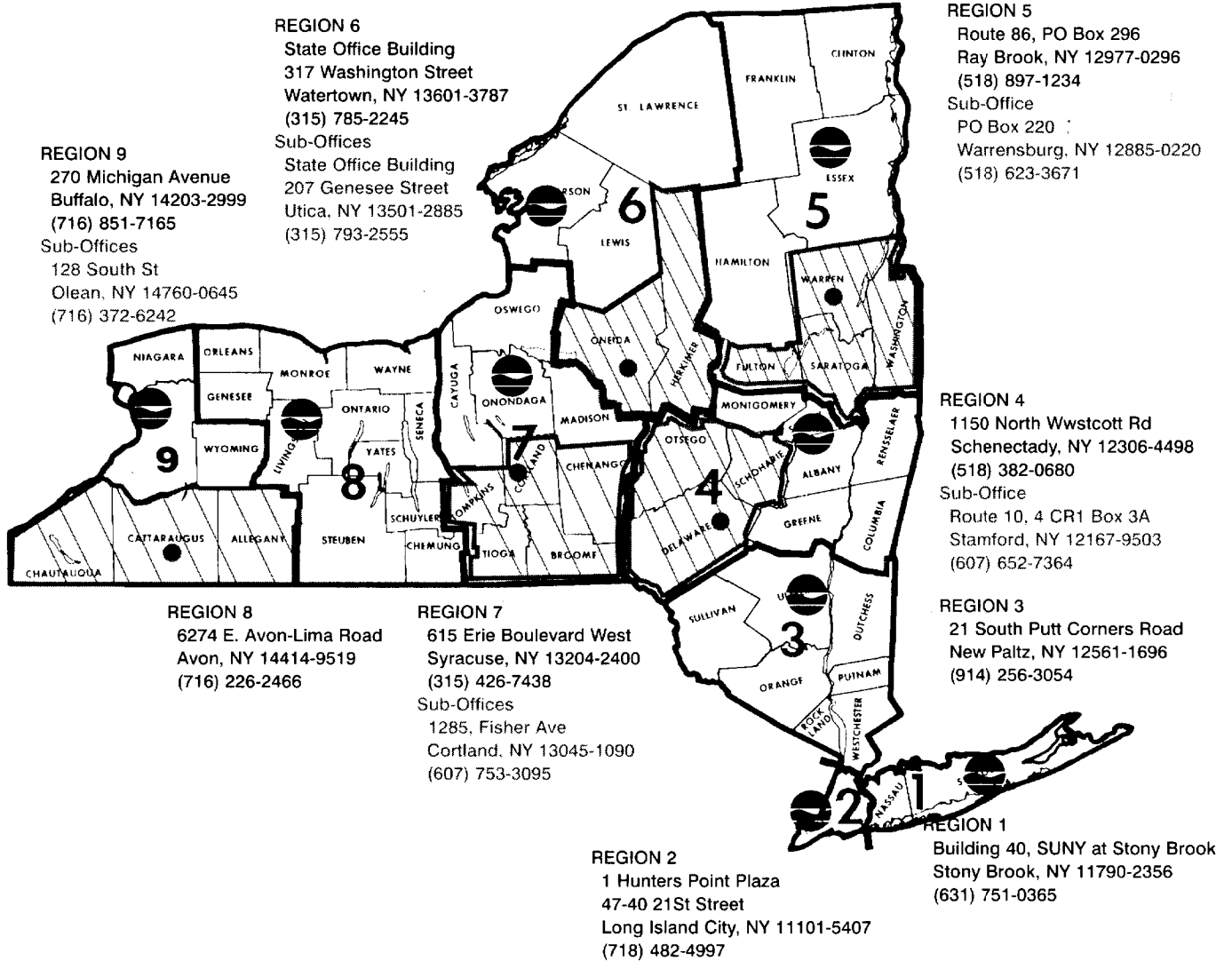
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