3. DIMENSIONS OF CHUTE SPILLWAYS

Introduction

One of the original intents in the organization of the material for the Chute Spillway Section was to furnish information and data concerning chutes in a form which would make them readily usable for the design of systems of flood prevention, gradient control, water storage, and sediment collecting structures. This requires that material, quantities, and capacities of this structural type be given for a preselected range of sizes in order that a minimum cost may be determined with ease and at a nominal cost. Within limits of administrative decisions, this has been accomplished. The chute section is incomplete in this original intent, as well as others, because it was felt that much of the information now assembled should be disseminated to the field as quickly as possible. Without data of this kind for each type of structure available for use, the time and cost required to make the determination of minimum cost for a system of structures would be high.

The method of determining the dimensions of a chute spillway is dependent on one of two broad situations. The first and simpler situation is that in which the chute spillway is not a part of a system of proposed structures. This situation will be discussed in detail and illustrated by examples. The second situation arises when the chute spillway is a part of a system of structures in which the most economical system is being determined. Examples for this situation are to be given in the Engineering Handbook, Section 10, Gradient and Flood Control Systems. An understanding of the first situation is essential to the determination of the dimensions for the most economical system of structures.

Nine factors (listed next page) are used to determine the dimensions of the chute spillways. Most of these factors have values as defined by the relationship of certain parameters.[1] Many of the parameters used in evaluating

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[1]To understand the definition of a parameter, the definition of a function must be understood.

DEFINITION OF A FUNCTION: A function is a quantity whose value depends upon the value of other quantities. The "other quantities" are frequently known as "arguments" and "independent variables of the function."

Example:

$$y = \frac{x^2}{4}$$

Here y is a function of x. When the value of x is fixed, the value of y is known. x is known as the independent variable of the function y.

DEFINITION OF A PARAMETER: When the function and its arguments are functions of a third quantity, the third quantity is known as a parameter.

Example:

$$y = \frac{x^2}{4} \qquad (1)$$

$$y = \alpha^2 \qquad x = 2\,\alpha \qquad (2)$$

Here y is a function of its argument x, and the function y is a function of α. The argument or the independent variable x of the function y is also a function of α. The quantity α is known as a parameter and equations 2 are known as parametric equations of the dependent variable y and of the independent variable x.

a factor are also used in evaluating other factors. For instance, in hydraulic design the height h of the sidewalls above the crest of the inlet is a parameter used in a relationship involving the capacity of the inlet without freeboard. It is also a parameter used in structural design to determine the thickness of the sidewalls. All of the factors, in the most general situation, are interrelated.

The factors are

1. Purpose of chute
2. Spillway storage
3. Design discharge Q_r
4. Vertical drop Z
5. Site location
6. Hydraulic design relationship
7. Structural design relationship
8. Economic relationship
9. Systems of Structures

These nine factors are exhibited separately from other parameters because of the relationships that exist between them. The four factors, spillway storage, design discharge Q_r, vertical drop Z, and site location, are often interrelated. For example, the design discharge Q_r is decreased by increasing the value of Z if the spillway storage is increased significantly.

The hydraulic design relationship and the structural design relationship are written in terms of the factors Q_r and Z and all the other dimensions of the chute. When the factor spillway storage of the chute spillway is significant, it is related to the dimension h of the chute spillway. Thus, in the general case all the factors are interrelated. A more nearly complete discussion of these relationships for the first situation will be given after describing a few of the parameters related to each factor.

I. FIRST SITUATION--Introduction

To prevent a misunderstanding, a fuller explanation is made of the first situation. Chute spillways are often associated with an embankment and other appurtenances to form an integral structure. When a number of integral structures are located within a drainage area and are designed to be interdependent, the totality of such interdependent integral structures is known as a system of structures. Under the first situation will be discussed the methods of determining the dimensions of the chute spillway when the chute is not a part of a system of structures in which the most economical system is being determined. The first situation includes those situations in which the chute spillway is to become a part of an existing system of structures. Since the first situation is not of a system of structures, the ninth factor is eliminated. A general discussion of the first eight listed factors and their interrelationship in the first situation follows.

1. Purposes of chute. The purposes for which chute spillways are usually used by the Soil Conservation Service are

a. Spillways for gradient control structures or as a gradient control structure.

b. Spillways for flood prevention reservoirs (retarding reservoirs). The degree of flood prevention is often used as a parameter.

c. Spillways for water conservation reservoirs (irrigation, livestock, recreational, and wildlife).

d. Spillways for sediment collecting reservoirs.

Reservoirs are often constructed for more than one purpose.

2. Spillway storage. The spillway storage and the purpose of the chute spillway are usually related in the following manner.

a. Chute spillways when used as gradient control structures generally have insignificant spillway storage. The spillway storage is insignificant if the ratio of spillway storage to the total volume of runoff is sufficiently small to cause no significant difference between the peak inflow to the reservoir and peak outflow from the reservoir when the inflow hydrograph is routed through the reservoir.

b. Flood prevention reservoirs are dependent on the availability of significant retarding spillway storage. Spillway storage is always significant when a chute is associated with a retarding reservoir.

c. Water conservation structures and sediment collecting reservoirs having chute spillways usually have significant spillway storage.

When reservoirs are constructed for more than one purpose, the associated chute spillways will usually have significant spillway storage.

3. The design discharge Q_r. (See Engineering Handbook, Section 4, Hydrology.) When the spillway storage is insignificant, the design discharge Q_r is the peak rate of inflow as determined by hydrological principles and the three parameters listed at the top of page 1.3.

If the chute spillway is associated with a significant spillway storage, the discharge Q_r is dependent on the design inflow hydrograph, the spillway storage, and the rate of outflow, i.e., the dimensions h and W of the chute spillway. The dimensions h and W are dimensions which are to be determined. (See Engineering Handbook, Section 5, Hydraulics, Reservoir Routing.)

4. The vertical drop Z from the crest of the inlet to the floor of the outlet. (See Engineering Handbook, Section 3, Sedimentation.) This factor is a dimension of the spillway and its value is dependent, along with other parameters, on the purpose of the chute.

a. When the chute is a gradient control structure, the vertical drop Z is dependent on the vertical gradient control required, including the aggradation or degradation downstream from the chute spillway. Tailwater requirements are a parameter in determining the bottom elevation of the SAF outlet.

b. The factor Z of the inlet is dependent on the parameters which express the degree of flood prevention, the design discharge Q_r, spillway storage, site location, and the dimensions h and W of the inlet of the chute spillways associated with retarding reservoirs.

c. When the chute spillway is associated with water conservation systems, the value of Z will be dependent on water yields and needs.

d. Sediment yield and trap efficiency, along with types of sediment, become important parameters in evaluating Z for chute spillways associated with sediment collecting pools.

5. Site location. (See Engineering Handbook, Section 7, Soil Mechanics, and Section 8, Engineering Geology.) The values of parameters used in the determination of site locations are obtained from an evaluation of the pertinent site data of surface and foundation investigations. The topography of the reservoir area is included in this factor. The location of the site with respect to the rest of the drainage area however is not one of the parameters. Such parameters are included in the factors Q_r, Purpose and Economics. The geographic location of the site is not a parameter in site location; it is a parameter in the design discharge Q_r.

6. Hydraulic design. (See part 2, Hydraulic Design, Chute Spillway Section.) The general relationship of parameters used in the determination of a proper hydraulic proportioning of a chute are given in part 2.

7. Structural design. (See Engineering Handbook, Section 6, Structural Design.) The general relationship of parameters used in the determination of required structural dimensions are given in Section 6. At this time administrative decision has resulted in the abandonment of writing these relationships as they pertain to chutes in the Chute Spillway Section.

8. Economics. The dimensions of the chute spillway are to be taken as those dimensions which will give the minimum combined estimated costs of the spillway and its associated appurtenances consistent with the first seven listed factors. This requires that quantities of materials and unit costs of the materials be known or closely estimated. Combined costs of the structure throughout this section is used to mean the total estimated cost of the integral structure including the estimated cost of all spillways, embankment, excavation, toe drainage, land clearing, right-of-ways, and other estimated costs associated with the structure.

RELATIONSHIP OF hydraulic design, structural design, and economics. Observe that the last three factors are relationships of parameters which are to be satisfied. Examining the relationships involved in the hydraulic design when only Q_r, Z, and s_o are given, the dimensions of the chute spillway cannot be uniquely determined. For purposes of illustration, assume the values of Q_r, Z, and s_o are fixed and are not interrelated. The interdependence of the three factors, hydraulic design, structural design, and economics, is to be examined.

Assume the chute has a straight inlet. Part 2 does not give the dimensions of the chute for a given capacity; it gives the capacity for a given set of dimensions. Any number of sets of dimensions can be found with the same capacity. Arbitrarily choosing a width W for the chute with a straight inlet, all other dimensions of the chute are determined by hydraulic and structural design. For every width, there is a set of dimensions associated with each width. Since any number of widths could arbitrarily be chosen for the chute, there exists any number of sets of dimensions of the chute which satisfy the hydraulic and structural design criteria. For example; if the width W is arbitrarily chosen, the dimensions h, M, N, L_B, J, etc., are determined since the design discharge Q_r, vertical drop Z, and s_o are known. The dimensions W, h, M, N, L_B, J, etc., are a set of dimensions in which each has a value dependent on the value of W. The hydraulic relationship for chutes with a straight inlet has one degree of freedom because by choosing one dimension (the width W) all other dimensions of the chute are fixed.

For a particular set of site conditions, each arbitrary choice of W has an associated volume of concrete in the chute spillway; but there is one particular width which has the least volume of concrete.

Assume the chute has a box inlet instead of a straight inlet. If the inlet of the chute is changed to a box inlet, two degrees of freedom are present in the hydraulic criteria of Part 2. If only Q_r, Z, and s_o are given, the hydraulic relationship does not uniquely determine the dimensions of the chute if W is arbitrarily chosen. By arbitrarily choosing both W and h for the chute with a box inlet, all other dimensions of the chute are determined by hydraulic and structural design relationships. When a set of dimensions is selected which satisfy the hydraulic relationship, all other dimensions can be uniquely determined by the relationships involved in structural design.

Economics dictates which set of dimensions, satisfying the hydraulic and structural design relationships, is to be taken for the dimensions of the chute. It is that set of dimensions which results in the lowest combined cost of the chute spillway and its associated appurtenances.

RELATIONSHIP OF spillway storage, design discharge Q_r, vertical drop Z, and site location. The hydraulic and structural design relationships have as parameters the factors Q_r and Z. Before the dimensions of a chute spillway at a given site location and for a stated purpose can be determined, the relationship between Q_r and Z is required. In some situations the values of Q_r and Z are known before the dimensions of the chute are known; while in other situations the values of these factors are determined simultaneously with the dimensions of the chute. The relationship of Q_r and Z are dependent on the site location since the spillway storage along with certain dimensions of the inlet and the design hydrograph are parameters used to express this relationship.

When the spillway storage is insignificant, the factors Q_r and Z are independent. The manner of determining the values of these factors has been given. In this situation the factors Q_r and Z are known prior to the dimensions of the chute spillway.

When the spillway storage is significant, the four factors, spillway storage, Q_r, Z, and site location, are interrelated. Reservoir routing is required to determine the relationship of Q_r and Z. The data required to determine this relationship by reservoir routing are

(1) volume of storage vs elevation curve which is dependent on the site location

(2) the design inflow hydrograph

(3) the rate of outflow which is dependent on the type and dimensions of spillways. When the chute spillway is the only type of spillway associated with the integral structure, the type and dimensions of the inlet will determine the rate of outflow.

Since the type and the dimensions of the inlet are parameters to be determined, the factors Q_r, Z, hydraulic and structural design, and economics will need to be solved simultaneously to obtain the dimensions of the chute and the values of Q_r and Z.

Straight Inlets. When the only spillway for the integral structure is a chute spillway with a straight inlet, the relationship of Q_r and Z can be ascertained as an independent determination. The relationship can be expressed in terms of the parameter W or in terms of the parameter h. It is desirable to have this relationship in both forms. The relationship of Q_r, Z, and W is obtained by determining the value of Q_r by reservoir routing for various selected values of Z and W. The relationship of Q_r, W, and h is given by the weir formula $Q_{fr} = 3.1\ W\ h^{3/2}$. The relationships of Q_{fr}, Z, W, and h can be represented graphically. The graphical representation has a family of W-lines and a family of h-lines when the values of Z are plotted as ordinates and the values of Q_{fr} as abscissas.

Straight inlet associated with a drop inlet. When the integral structure has other spillways besides the chute spillway with a straight inlet, a graphical relationship of Q_{fr}, Z, W, and h can be determined by recognizing the elevations of the crest and the sizes of the other spillways. This plot is determined in a manner similar to that given in the preceding paragraph.

Box Inlets. When the only spillway of the integral structure is a chute spillway with a box inlet, a graphical relationship of Q_{fr}, Z, h, and (2 B + W) can be determined in a manner similar to that used for a straight inlet. The relationship can be expressed in terms of these parameters for any of the four classifications of box inlets listed on page 2.19 if entrance conditions to the inlet are known. Usually the approach channel to box inlets having significant spillway storage is wide.

OUTLINE OF THE METHODS FOR DETERMINING THE DIMENSIONS OF A CHUTE--Introduction

Because Q_r and Z are independent factors when the spillway storage is insignificant and are interrelated when the spillway storage is significant, the first situation will be divided according to whether the spillway storage is significant or insignificant. For each of these divisions, a discussion will be made of chutes having any known general slope s_o. The situation in which the bottom slope s_o is one of the parameters to be determined is considered in the outline. The discussion pertaining to the bottom slope of the channel is subdivided according to whether the associated appurtenance costs of the chute are significantly or insignificantly dependent on the parameters W and h for a given value of the factor Z. Usually the appurtenance costs will not be significantly dependent on the parameters W and h for a given value of Z if the associated embankment and excavation of the chute are insignificant. Only inlets having no functions other than those listed on page 2.1 and requiring no freeboard are considered in the outline. This limits the types of inlets for consideration in the outline to the straight inlet and the box inlet. Additional comments of other types of inlets having other functions or inlets requiring wave freeboard are made after the outline.

Concrete volumes of chutes with straight inlets and box inlets. A chute with a straight inlet of proper dimensions for a given set of values of Z, Q_r, and s_o will always contain less volume of concrete than a chute with a box inlet for the same given set of values of Z, Q_r, and s_o. Chutes with box inlets are only used to serve other functions or to decrease the cost of appurtenances. The decreased cost of appurtenances is accomplished by an increased cost of the chute.

OUTLINE

I. The associated spillway storage is insignificant. Structures involving chute spillways which have insignificant spillway storage are usually gradient control structures, and it is unlikely that any wave freeboard is required. The design discharge Q_r is not dependent upon any of the other seven factors listed except the amount of damage to the chute spillway by a higher runoff discharge. (See related item b, top of page 1.3.) The factor Z and site location in this situation are independent of the factor Q_r. Some site locations of this situation need to be examined for the possibilities of decreasing combined costs by increasing the value of Z to attain significant spillway storage and reduce the design discharge Q_r.

A. Bottom slope of the spillway is known. The bottom slopes of chutes are usually known only when they are located on a moisture-controlled compacted embankment. The bottom slope of such spillways will usually have the same slope as the embankment. The volume of concrete in a chute spillway decreases as the bottom slope of the chute spillway increases. The maximum bottom slope of a chute is limited by the stability of its foundation, anticipated water-table levels, type of materials in its foundation and the construction difficulties to be encountered on steep slopes.

1. Chute spillways having associated appurtenance costs which are not significantly dependent on the dimensions of the chute will always have straight inlets unless the inlet has additional functions besides those listed on page 2.1 or a large wave freeboard is required. (As already stipulated in the superheading of this outline the values of Z, Q_r, and s_o are fixed here.) When the cost of the embankment and excavation is insignificant, a change in the dimensions of the chute will not materially change the cost of embankment and excavation. If the combined costs less the cost of the concrete in the chute spillway do not change appreciably with the dimensions of the chute, then that set of dimensions which gives the minimum volume of concrete in the chute is the desired set.

In this situation one degree of freedom occurs; i.e., one dimension (the width W) is determined to find all other dimensions of the chute spillway.

2. Chute spillways having associated appurtenance costs which are dependent on the dimensions of the chute. In this situation it will usually be necessary to compare the combined cost of the chute with a straight inlet and box inlet.

Straight Inlets. When the associated embankment of a chute is significant, a saving in embankment cost may be made by increasing the width of the chute having a straight inlet. The value of the dimension h of the straight inlet decreases as the width of the chute increases. Decreasing the value of h is accompanied by an equal lowering of the top elevation of the embankment. Similarly when the excavation associated with the chute is significant, a saving in excavation cost may be obtained by changing the width of the chute.

This situation has one degree of freedom; i.e., one dimension (the width W) is determined to find all other dimensions of the chute spillway. A graphical representation of the relationship of the cost of concrete and the width W is obtained by plotting the cost of concrete in the chute spillway as ordinates and the width W as the abscissas. In a similar manner, on plotting the cost of embankment as ordinates and the widths W as abscissas, the relationship of the cost of embankment and the width W of the chute is obtained. After making similar additional plots of excavation, toe drainage, and other costs associated with the structure, it will be possible to sum the ordinates of each plot for a particular width W to obtain the combined cost of the structure having a chute of width W. A graphical representation of the relationship of combined cost and width of the chute spillway is obtained by repeating this summation for various values of W. This is a plot of combined cost plotted as ordinates and widths as abscissas. The value of the width W which gives the minimum combined cost may be read from this graph and all other dimensions of the chute can be readily found.

Since this situation has one degree of freedom the relationship of combined cost vs width W is given by a single curve. The minimum combined cost of the chute with a straight inlet should be compared to the minimum combined cost of the chute with a box inlet.

Box Inlets. For a given width W the head over the crest of a box inlet may be reduced by increasing the dimension B. Since the value of h for a given width W may be further reduced by using box inlets instead of the straight inlet, the minimum combined cost of a chute with a box inlet needs to be compared with the minimum combined cost of a chute with a straight inlet. Two degrees of freedom exist in this situation. A graphical representation of the cost of a chute with a box inlet and its width W can be made. This graphical relationship has a family of h-lines in a plot of cost of the chute for various widths as ordinates and the corresponding widths W as abscissas. After plotting the lower envelope of the h-lines on this graphical representation, other graphs consisting of cost of embankment, excavation, and other costs vs width of chute can be prepared. Summing the ordinates of these graphs, the minimum combined cost of the integral structure for various widths W may be found.

B. Bottom slope of the spillway is unknown. In this situation the bottom slope of the chute is one of the parameters to be determined. Chute spillways having unknown bottom slopes usually are placed in excavations. The slope which results in a minimum combined cost is to be determined. Of course it is understood such slopes are not to exceed a maximum limit as previously stated.

When the associated excavation is not significantly dependent on the dimensions of the chute, then the bottom slope of the chute is known.

1. Chute spillways having associated appurtenance costs which are dependent on the dimension of the chute. The excavation cost is significant for this situation.

Straight inlets will always be used for this situation if the combined cost less the concrete and excavation costs is not significantly dependent on the value of h. Two degrees of freedom exist in this situation. Two dimensions, namely the width W and the bottom slope s_o, are required to find all other dimensions of the chute spillway. A graphical representation of the relationship of the cost of concrete and width W for a given bottom slope s_o is obtained by plotting the cost of concrete in the chute as ordinates and the width W as abscissas. By plotting these values for various values of s_o, a graphical relationship is obtained consisting of s_o-curves with coordinates of cost of concrete in the chute vs width W. Similar graphs of embankment, excavation, and other costs as ordinates and widths as abscissas can be plotted for various values of s_o. The summation of the ordinates of these graphs for a particular set of W and s_o values will give the combined cost corresponding to that particular set of values of W and s_o. The value of W and s_o which gives the minimum combined cost may be read from this graph and all other dimensions of the chute can be readily found. This result should be compared with the minimum combined cost of chute spillways with a box inlet if the embankment cost is significant to determine the type of inlet. Since this situation has two degrees of freedom the relationship of combined cost vs width W is given by a family of s_o-curves.

Box inlets will usually be used when the associated embankment cost is significant. Three degrees of freedom exist in this situation. The determination of the three dimensions W, h, and s_o are required to find all other dimensions of the chute spillway. A graphical representation of the relationship of the combined cost of chutes as given in the outline heading IA2 (Box Inlets) can be found for various selected bottom slopes. The minimum combined cost for each selected slope can be plotted as ordinates and bottom slopes as abscissas. This type of analysis will give the minimum combined cost and the values of the three parameters, namely W, h, and s_o. Knowing these values permits the evaluation of all other parameters. This determination of minimum combined cost should be compared with the minimum combined cost of chutes with straight inlets. Since this situation has three degrees of freedom the relationship is determined by the two graphs.

a. Combined cost vs width W and a family of h-curves.

b. Minimum combined cost of chutes with box inlets of selected bottom slopes s_o as determined by the first graph vs bottom slope s_o.

II. The associated spillway storage is significant. The design discharge Q_r is dependent on the value of Z at any site location as well as certain dimensions of the inlet when the associated spillway storage is significant. The relationship of Q_r and Z and the method of obtaining this relationship have been discussed on pages 3.5 and 3.6. In some site locations the minimum combined cost of integral structures will decrease as the value of Z is increased from a low value to a higher value until a value of $Z = Z_l$ is reached. As Z is further increased above the value of Z_l, the minimum combined cost will increase. When the required value of Z, in accordance with the purpose of the chute and other factors is less than Z_l, the combined cost of the integral structure can be decreased by increasing the value of Z to Z_l. This situation requires that the value of Z_l be determined. When the required value of Z in accordance to the purpose of the chute and other factors is greater than Z_l, the combined cost of the integral structure is greater than that for a structure having a $Z = Z_l$. This situation requires that the minimum combined cost for the structure be determined when Z has the required value. The remainder of this outline pertains to the determination of the minimum combined cost of the integral structure for a given value of Z. A graphical solution may be made to obtain the value of Z_l. The graphical solution consists of the plot of minimum combined costs for selected values of Q_{fr} as ordinates and the corresponding value of Z as abscissas.

A. Bottom slope of the spillway is known.

1. Chute spillways having associated appurtenance costs which are not dependent on the dimensions of the chute will rarely be encountered. The value of Q_r will for a fixed Z increase as the value of W is increased because the spillway storage is reduced. Since the chute spillway will have a straight inlet in this situation, the chute is being sought which has the least volume of concrete. The value of W associated with the set of dimensions of this chute can be found by a graphical solution. The graphical solution consists of a plot of chute costs for various widths plotted as ordinates and the corresponding width plotted as abscissas. The capacity of the chutes for the various widths would need to reflect the design discharge Q_r corresponding to those widths.

This situation has one degree of freedom; i.e., one dimension (the width W) is determined to find all other dimensions of the chute spillway.

2. Chute spillways having associated appurtenance costs which are dependent on the dimensions of the chute.

Straight inlets. This situation has one degree of freedom. The width W is determined to find all the other dimensions of the chute. Associated with each width is a design discharge Q_r and as the width W is increased, the associated value of Q_r is increased. A graphical representation of the cost of the relationship of the cost of concrete and the width W is obtained by plotting the cost of concrete in the chute spillways as ordinates and the width W as abscissas. In a similar manner, on plotting the cost of the embankment as ordinates and the width W as abscissas, the relationship of the cost of embankment and the width W of the chute is obtained. After making similar additional plots of excavation, toe drainage, and other costs associated with the structure, it will be possible to sum the ordinates of each plot for a particular width to obtain a plot of combined cost of the integral structure vs width of the chute. The value of the width W which gives the minimum combined cost can be read from this graph. The minimum combined cost of the chute with a straight inlet should be compared to the minimum combined cost of the chute with a box inlet.

Box Inlets. For a given width W the head over the crest of a box inlet may be reduced by increasing the dimension B, but the spillway storage is reduced and the required values of Q_r and (2 B + W) according to the relationship of Q_r, Z, h, and (2 B + W) are both increased. Two degrees of freedom exist for this situation. A graphical representation of the relationship of the cost of a chute with a box inlet and the chute width can be made. This graphical relationship has a family of h-lines in a plot of cost of the chute for various widths as ordinates and the corresponding width W. The plot of h-lines will necessarily need to reflect the design discharge Q_r corresponding to the values determined by routing (see page 3.6, Box Inlets). After plotting the envelope of the h-lines on this graphical representation, the combined cost of the integral structure for various widths can be determined in a similar manner as previously illustrated.

B. Bottom slope is unknown. It is impossible to have the bottom slope unknown and the associated appurtenance costs independent of the dimension of the chute. The excavation cost for a chute is considered as a part of the associated appurtenance costs.

1. Chute spillways having associated appurtenance costs which are dependent on the dimensions of the chute.

Straight inlets used in this situation have two degrees of freedom. The two dimensions W and s_o are required to find all other dimensions of the chute spillway. A graphical representation of the relationship of the cost of concrete and width W for a given bottom slope s_o is obtained by plotting the cost of concrete in the chute as ordinates and the width W as abscissas. The change in the value of Q_r for various widths W as obtained by routing the design hydrograph should be reflected in the preparation of this graph. The set of dimensions for the chute with a fixed Z is obtained in a manner similar to that given by the situation under the outline heading IB1, Straight Inlets, page 3.9.

Box Inlets. Three degrees of freedom exist in this situation. The method of determining the set of dimensions is similar to that given in IB1, Box Inlets, page 3.9.

TYPES OF INLETS FOR OTHER FUNCTIONS OR WHEN THE WAVE FREEBOARD IS SUFFICIENTLY LARGE

Type of inlet when the wave freeboard is large. When the wave freeboard is large, the cost of other types of inlets should be investigated. Frequently culvert and box-culvert inlets can be used advantageously instead of a straight or box inlet. The use of culverts and box-culvert inlets permits the use of earth embankment and riprap over their top slab to withhold waves from overtopping the chute.

Type of inlet when other functions are required. Vehicle crossings of spillway will generally require that culvert or box-culvert inlets be used.

When the maximum elevation of the reservoir is limited and the value of Z is sufficiently large to prevent the use of the set of dimensions which corresponds to the minimum combined cost of the integral structure, other types of inlets may be required. In some situations the width of the straight inlet which would normally be used if the limitation were not present will be wider. In other situations the straight inlet would be changed to a box inlet. The decision of whether a straight inlet or a box inlet is to be used is made by comparative costs. The analysis of such situations would be simpler than that given in the outline because one degree of freedom is removed by such a limitation.