CHAPTER DR-09
DAMS & STORAGE

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DR-09.100 FUNDAMENTALS

DR-09.110 General

A dam is an artificial barrier placed across a watercourse or natural drainage area to create an impoundment. This impoundment results in an increased depth of water on the upstream side of the dam. This increase, if significant, should result in storage of the water. The flowrate downstream of the dam is reduced by the dam.

The above relationship is true for dams of small size, such as a grated inlet and a header curb, which pond up water on a parking lot through large Corps of Engineers Multi-Purpose Dams. The distinction is the design criteria used to design the components in the dam.

The principal spillway, the emergency spillway, and the storage volume between the elevation of these spillways are the primary components used in the hydrologic and hydraulic analysis of a dam. This chapter introduces these components of a dam and procedures used to size them. Refer to Division of Water, Engineering Memorandum No. 5 for hydrologic,hydraulic, and physical requirements for large dams.

DR-09.120 Structural Classification

In determining structural classification, consideration must be given to the damage that may occur to existing and future developments downstream resulting from a sudden breach of the earth embankment and to the structure failure. The negative 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 have a bearing on the amount of potential damage.

Structural classification is determined by the above criteria and is not determined by the criteria selected for design.

The classification of the proposed structure shall be determined after considering the characteristics of the valley below the site and probable future development. Establishing a minimum criteria does not preclude provisions for greater safety when deemed necessary.

Considerations other than those mentioned in the following classifications may make it desirable to exceed the established minimum criteria. A statement of the classification shall be shown on the first sheet of the structure drawings.

CLASS (A) - LOW HAZARD

The (A) Classification may be applied for structures located such that failure may cause loss of the structure itself but little or no additional damage to other property. Such structures are usually located in rural or agricultural areas where failure may damage farm buildings (other than residences), agricultural lands, or county roads.

CLASS (B) - MODERATE HAZARD

The (B) Classification may be applied for structures located such that failure may cause significant damage to property and project operations, but loss of human life is not envisioned. Such structures will generally be located in predominantly rural agricultural areas where failure may damage isolated homes, main highways, or major railroads, or cause interruption of use or service of relatively important public utilities.

CLASS (C) - HIGH HAZARD

The (C) Classification must be applied for structures located such that failure may cause loss of life, or serious damage to homes, industrial or commercial buildings, important public utilities, main highways, or major railroads. This classification must be used if failure would cause probable loss of human life.

DR-09.130 Conservation and Sediment Retention Storage

When water is stored for beneficial use, the elevation of the principal spillway will be determined by the volume, area, or depth of water required for the planned purpose or purposes. The control limits for this conservation storage is usually determined by an outside agency.

The anticipated sediment storage for the design life of the structure must be determined so that this volume may be added to the conservation volume below the principal spillway.

The following criteria and general procedures are needed to determine the volume required for sediment accumulation:

1. The sediment yield for present and future conditions after planned land treatment and other measures are applied in the drainage area of the dam;

2. The trap efficiency of the reservoir.

3. The distribution and types of sediment expected to accumulate.

4. The proportion of the sediment that will be continuously submerged vs. that aerated.

5. The densities to which the sediment will become compacted.

If the amount of sediment accumulation calculated exceeds two watershed inches in 50 years for the uncontrolled drainage area of the dam, reevaluate the entire watershed to determine if more economical methods of reducing sediment yield or trapping sediment may be feasible and applicable.

DR-09.140 Retardation Storage

The Retarding Pool (i.e. detention) is a holding pond for stormwater. It is most often used in urban or residentially developed areas to release storm runoff at a rate comparable to or equal to the predeveloped rate.

The design of stormwater detention structures is dependent on several factors: drainage area, design return period, peak inflow rate, volume of runoff, timing of the inflow hydrograph, maximum allowable depth of ponding, maximum allowable outflow rate, and length of time water is allowed to remain in the structure. The above factors are incorporated into the development of the inflow hydrograph, stage-storage relationship, and the stage-discharge relationship for the structure. These items are used in the Storage Indication Method (Modified Puls) of reservoir routing to obtain the outflow rate, water surface elevation, and storage volume at any time as the inflow hydrograph passes through the detention facility.

DR-09.150 Principal Spillway

The required capacity of the principal spillway depends on: (1) 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 possibilities of the occurrences 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.

DR-09.160 Emergency Spillway

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.

A single uncontrolled open channel spillway may be used for most purposes provided it is designed to accommodate all discharges, including the freeboard storm, without damage to the structure. However, a positive means to drain the lake also must be provided.

NOTES AND COMMENTS

DR-09.200 HYDROLOGIC CRITERIA

DR-09.210 General

The evaluation of the adequacy of a dam may require the routing of three hydrographs through the structure: the principal spillway, the emergency spillway, and the freeboard hydrographs.

For small dams of height less than 25 feet, retarding storage less than 50 acre-feet, and drainage area less than one square mile, the hydrologic procedures shown in Chapter Four of this manual may be used to determine the necessary discharges.

For dams where any of the three parameters are exceeded, the procedures that are contained in the USDA - Soil Conservation Service National Engineering Handbook, Section 4, are accepted by the Kentucky Department of Highways, Division of Design. Copies of this publication are available from the US Government printing office.

The specific references for runoff determination are found in Chapter 10 of the SCS handbook and 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. See Exhibit 09.901.

The precipitation values are found in the publication entitled "Rainfall Frequency Values for Kentucky", Division of Water, Kentucky Department for Natural Resources and Environmental Protection in Engineering Memorandum No. 2 (see Exhibit 04.939). In areas where streamflow records can be regionalized and transposed to ungaged watersheds (based on the volume-duration-probability analyses), the use of the this data for developing the principal spillway capacity and retarding storage will be authorized. When other streamflow data are used, sufficient documentation must be prepared to show how these values were determined.

NOTES AND COMMENTS

DR-09.300 FLOOD ROUTING

DR-09.310 General

Once the flood hydrographs are determined by the above methods, these hydrographs are used to determine the effects of the dam on the flood stage and the flow rate. The instantaneous outflow for a point in a watershed is the instantaneous inflow minus the available storage for the stage created by the inflow. Conventional culvert design is based upon the principle that the peak instantaneous inflow for a design storm is allowed to flow through the culvert with the outflow equal to the inflow with no use of the available storage. The culvert is sized so there is an insignificant increase or decrease in the stage at the inlet of the culvert. Detention basin design incorporates the increase in the use of storage at the inlet. The use of available storage is a practical method of alleviating the adverse effects of development in urban areas. For rural areas, the use of storage could allow the use of a smaller culvert than one sized conventionally.

The inflow hydrograph or the minimum runoff volume for developing the balance between principal spillway capacity and retarding storage will be determined by the procedures in the Soil Conservation Service (SCS) Handbook. In 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.

The retarding storage and associated principal spillway discharge will be such that the emergency spillway will not operate more frequently than indicated in Exhibit 09.902. The emergency spillway hydrograph will be routed through the reservoir starting with a water surface at the elevation of the principal spillway inlet. The size of the spillway shall be determined by use of this hydrograph.

The freeboard hydrograph will be routed through the reservoir starting at the crest of the principal spillway. The assumption shall be made that the principal spillway is plugged with debris.

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One of the most useful tools in today's dam design is the program DAMS2 developed by the SCS. The program can route different designs, different storm levels, and compute construction quantities. There are other "Dam" programs that are acceptable to the Department. The designer should contact the Drainage Section for approval to use these programs prior to the design of any dam.

NOTES AND COMMENTS

DR-09.400 DETENTION BASIN DESIGN

DR-09.410 General

Some of the permissible methods to increase the use of the storage for a watershed are as follows:

1. Culvert inlet modification.
2. Basin excavation.
3. Culvert sizing.

The simplest form of detention associated with highways is the use of a baffle wall at the end of the inlet wing wall for a small culvert. An opening is constructed at the bottom of the wall. This opening is a constriction which ponds low inflows and thus reduces the outlet flow. This constriction is effective up to a five year flood. Floods greater than this will overflow the baffle wall. The culvert will control for these floods as designed.

The design procedure entails first a visual inspection of the area, to see if ponding would be effective. If a ponding area is available, the amount of detention is determined by comparing the discharge that will flow through the pipe with a headwater equal to the height of the end of the wings and the discharge that will flow through an assumed opening in the baffle. Then, if the desired detention is not obtained, another opening size should be assumed.

The next level of detention is obtained by excavating a basin at the inlet of a culvert. This alternate is available when there is a limit to the allowable ponding depth and when the existing ponding volume is inadequate.

The design procedure is to determine the positive difference in volume between the triangular hydrographs for the two conditions studied. This volume should be provided at or below the crown of the culvert.

Culvert sizing that uses the available storage to reduce the outflow or the size of culvert required proves to be cost-effective. As much as a fifty percent savings may be obtained.

The design procedure for this option is more complicated when compared to conventional drainage design or when compared to the first two options. The first two options will have a minimal or positive effect upon the area upstream and down stream of the culvert. The culvert sizing option, however, could have a significant effect upon the upstream area, the roadway, and the downstream area. Therefore, the use of runoff hydrographs is recommended to determine the effect of the proposed detention basin on all areas affected. Both a stage-discharge and a stage-storage relationship shall be established for the culvert. The triangular rational formula hydrograph and the Modified Puls method may be used as a manual method to evaluate the inflow/outflow relationship for a small structure. A computer program such as DAMS2 could be used to evaluate the structure.

Establishing the design criteria does not eliminate the need for sound engineering judgement. It only establishes the lowest limit of design considered acceptable.

The responsibility is given to the design engineer to classify the structure and to determine if the design requirements are in excess of the minimum.

NOTES AND COMMENTS

DR-09.500 PHYSICAL REQUIREMENTS

DR-09.510 General

Pipe culverts used as principal spillways will require an Anti-Vortex device if the HW/D for the pipe is greater than 3.0.

Pipe culverts or other structures less than 36 square feet used as principal spillways require the addition of an emergency spillway.

Pipe or box culverts used for emergency spillways will require trash racks.

NOTES AND COMMENTS

DR-09.900 EXHIBITS

NOTES AND COMMENTS

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	Principle Spillway Hydrograph	Emergency Spillway Hydrograph	Freeboard Hydrograph
	Hazard Classification "A"		
Baffle Wall	Q_5	$>Q_5$	N.A.
Excavated Basin	$Q_{25}(\pm)$	N. A.	N. A.
Detention Basin *	Q_{25}	Q_{100}	Q_{100}
All Above, **	$P_{50}(\pm)$	P_{100}	P_{100}+ .12(PMP-P_{100})
	Hazard Classification "B"		
**	"	P_{100}+ .12(PMP-P_{100})	P_{100}+ .40(PMP-P_{100})
	Hazard Classification "C"		
**	"	P_{100}+ .26(PMP-P_{100})	PMP

* D. A. < 1.0 S. M., Ht < 25 Ft., Storage < 50 A-Ft.

** D. A. ≥ 1.0 S. M. OR Ht. ≥ 25 Ft. OR Storage ≥ 50 A-Ft.

Q_{25} - 25 Year Discharge (cfs)

P_{25} - 25 Year - 6 Hour Percipitation (inches)

PMP - 6 Hour Probable Maximum Percipitation (inches)

ALLOWABLE FREQUENCY OF USE OF EMERGENCY SPILLWAYS

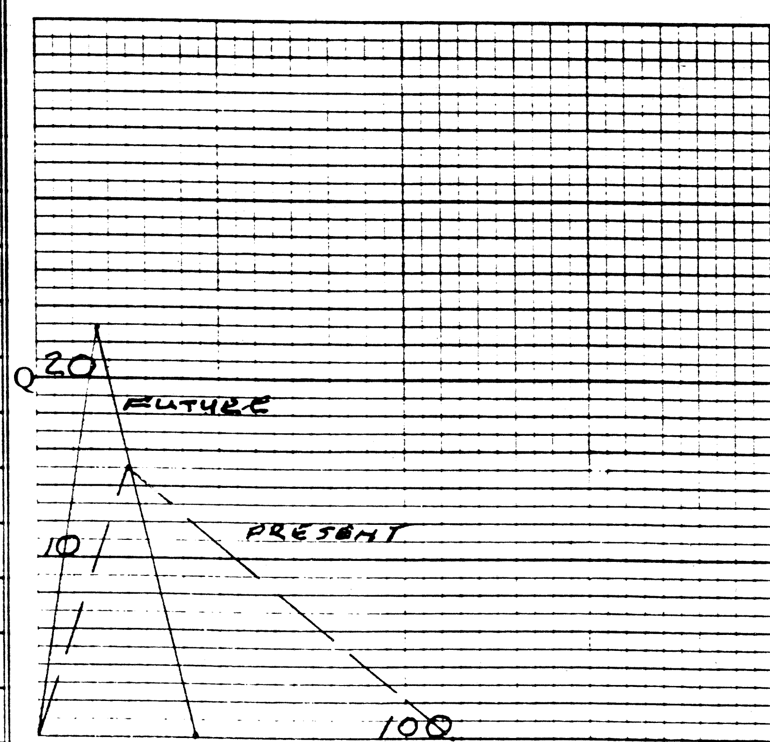
CLASS OF STRUCTURE	EARTH	MATERIAL VEGETATED	ROCK
A	50 YEARS	25 YEARS	10 YEAR
B	100 "	50 "	25 "
C	100 "	100 "	50 "

UNIT HYDROGRAPH COMPUTATIONS : TC 61-UU1 (Rev. 1-93) 1 of 4

County FRANKLIN	Route US 127	Item No. 5-999.9
UPN FSP 37 127 000-012	FPN	Station 61+50
Drainage Area (acres) 7.1 acres	C Present 0.46	C Future 0.75

Formulas	Present	Future
Q 25 = CIA	15	23
Tc = Time of Concentration (min)	18	14
Tr = Unit Duration (min) (≤ Tc)	18	14
Tl = Lag Time (min) 0.7 Tc for C = 0.8	16	10
1.0 Tc for C = 0.2		
Tp = Time to Peak (min) = Tc + (Tr / 2)	25	17
Tb = Time of Base (min) 2.5 Tp for C = 0.8	4.5	2.5
6.0 Tp for C = 0.2	112.5	42.5
T∆ = Routing Interval (min) (≤ Tr)		
RO = Runoff = T∆ min.sec.ft. = 60.5 (A / T∆)		
b = Unit Base = Tb / T∆		
Qp = Peak Runoff (cfs) = RO (2 / b)		

Time	Present Q	Future Q
0	0	0
5	1.5	4.0
10	4.3	10.3
15	8.0	17.0
20	10.5	23.0
25	13.4	17.8
30	14.6	13.0
35	13.8	8.3
40	13.0	4.2
45	12.0	0.0
50	11.2	0.0



Time

UNIT HYDROGRAPH COMPUTATIONS : TC 61-UU2 (Rev. 1-93)

County FRANKLIN Route US 127 Item No. 5-999.9

UPN FSP 37 127 000-012 FPN Station 61+50

TRIAL STORAGE AND PIPE SIZE

Time	RO Future	RO Present	Δ
0	0	0	0
5	4.0	1.5	2.5
10	10.3	4.3	6.0
15	17.0	8.0	9.0
20	23.0	10.5	12.5
25	17.8	13.4	4.4
30	13.0	14.6	0.0

Σ = 34.4

Storage = 34.4 (Σ) x 5 (TΔ) x 60 = 10,320 Ft³

@ Allowable Headwater Elevation 3

Trial Pipe Size (AHW @ Qp for RO Present)
= 24"

UNIT HYDROGRAPH COMPUTATIONS : TC 61-UU3 (Rev. 1-93)

County FRANKLIN | Route US 127 | Item No. 5-999.9

UPN FSP 37 127 000-012 | FPN | Station 61+50

STORAGE OUTFALL

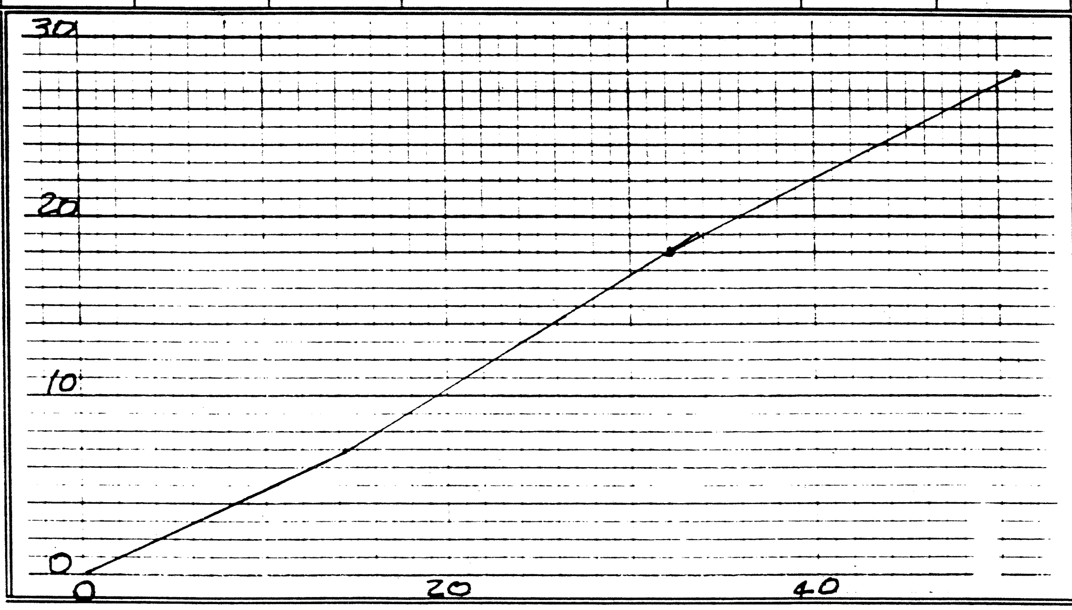
* 5 min.sec.ft. = Vol ft³ / (5 min x 60 sec)

Storage , S = Σ Vol

TRY 24" pipe and 50x60x3 Basin

Water Surface		Q	O / 2	Surface Area	Δ Vol	* Δ Vol	S	S + O/2
Elev.	d	cfs		ft²	ft³	______min.sec.ft		
300	0			3000			0	0
301	1	7	3.5	3456	3228	10.8	10.8	14.3
302	2	18	9	3944	3700	12.3	23.1	32.1
303	3	28	14	4464	4204	14.0	37.1	51.1

O (cfs)



S + (O / 2) cfs

UNIT HYDROGRAPH COMPUTATIONS : TC 61-UU4 (Rev. 1-93)

County FRANKLIN Route US 127 Item No. 5-999.9

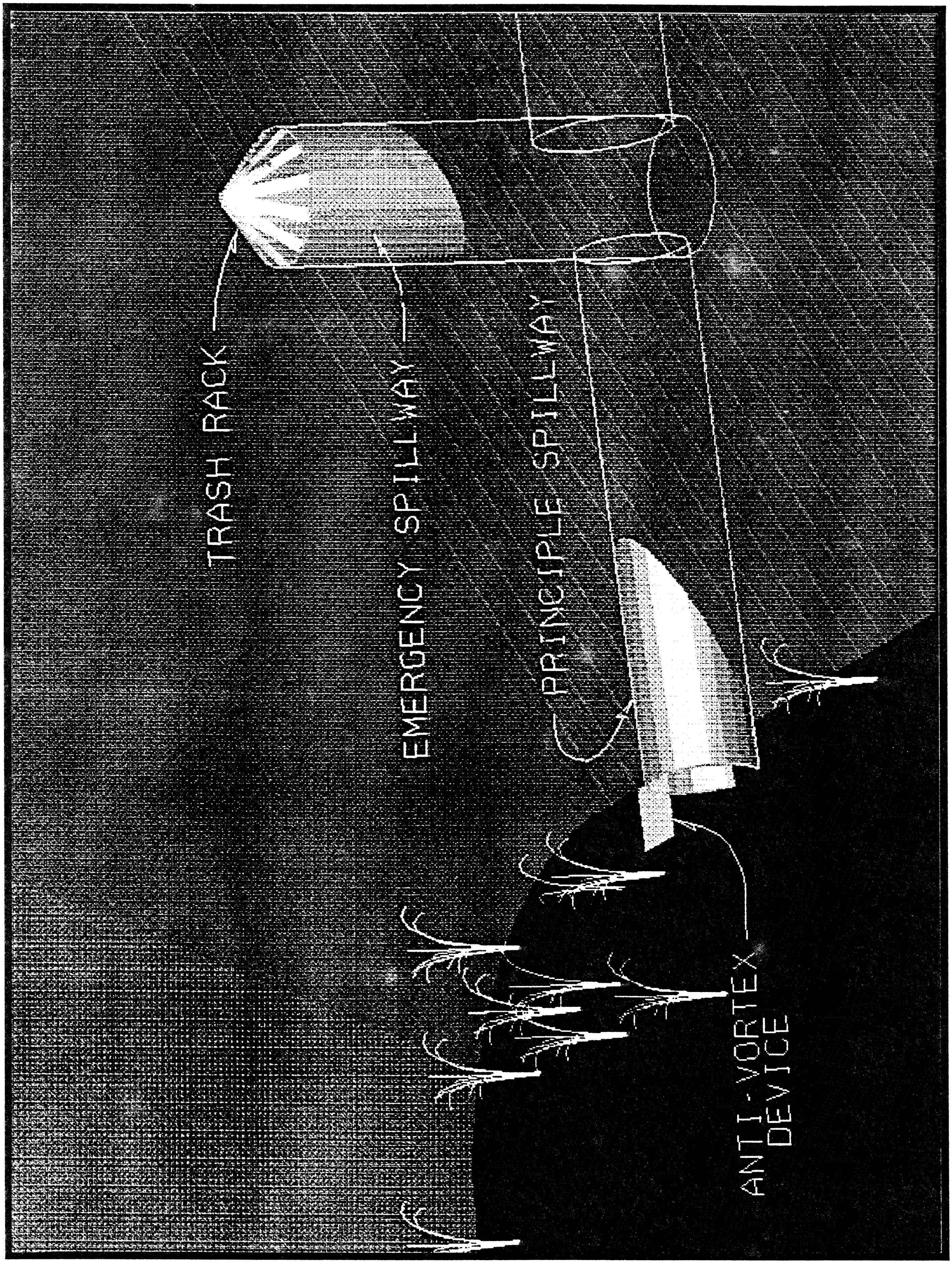
UPN FSP 37 127 000-127 FPN Station 61+50

RETENTION DETERMINATION

Time min	Inflow cfs	Inflow Avg.	$S_1 + (O_1 / 2)$	O_1	$S_2 + (O_2 / 2)$	O_2	Remarks
0	0		0	0	0	0	0
5	4.0	2.0	0	0	2.0	1.2	
10	10.3	7.2	2.0	1.2	8.0	4.0	
15	17.0	13.6	8.0	4.0	17.6	9.0	
20	23.0	20.0	17.6	9.0	28.6	15.7	
25	17.8	20.4	28.6	15.7	33.3	18.7	
30	13.0	15.4	33.3	18.7	30.0	16.6	
35	8.3	10.2	30.0	16.6	23.6	12.5	

((18.7 cfs greater than 15 cfs))

((TRY 18" PIPE))


TRASH RACK
EMERGENCY SPILLWAY
PRINCIPLE SPILLWAY
ANTI-VORTEX
DEVICE