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Stormwater Detention and Discharge from Aquaculture Ponds in Florida¹

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Overview

A wide variety of aquatic plants and animals are grown in Florida. The semitropical climate, abundant supply of fresh water, and extensive coastline make it suitable for both marine and freshwater plants and animals. Due to increased demands for aquaculture products and the diminishing sources of wild fish, Florida aquaculture has expanded rapidly in recent years and continued growth can be expected.

Water is a resource required in all aquacultural production systems. As the industry has grown, so has the demand for water. State regulations require treatment and controlled discharge of water used in aquaculture production, and that which passes through aquaculture facilities as a result of rainfall.

Purpose

This publication provides engineering information on the design, construction, and installation of a relatively inexpensive trickle-flow control device for management of stormwater discharge and water conservation. It also provides information on production pond freeboard requirements and size of detention pond required.

A trickle-flow control device with capacity to manage the flood water resulting from a 25-yr, 24-hr Florida rainstorm is described in this publication. The

device detains the flood water in the production pond and discharges it at a rate that does not exceed the capacity of the on-site detention pond.

Specifications are given for flow control devices which drain one-half of the flood water resulting from the 25-yr, 24-hr rainstorm within 7 days, and the total flood water within 30 days following the rainstorm. The water flow rate necessary to discharge flood waters in this manner is consistent with the flow characteristics of a circular orifice trickle-flow control device.

While the trickle-flow device construction is relatively simple, the computations necessary to design such a device to fit the conditions of a specific farm can be complex. The tables provided in this publication show the relationships between the factors affecting discharge rates and orifice sizes. The user may then select the desired size by comparing their specific conditions with those described in this publication.

Expected Results

Using a trickle-flow control device will accomplish several desirable results:

- Because flood water will be detained in the production pond and only slowly discharged, the capacity of the detention pond will not be exceeded by flood events.

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- Because the flow rate at which water is allowed to pass through the treatment facilities will be reduced, water quality is expected to be better than in a system where flow rates fluctuate widely.
- Because of the controlled low discharge rates, growers will be able to use smaller detention ponds without compromising water treatment.
- With the orifice flow control device, the discharge rate will be greater when the pond water level is higher. Thus, a substantial part of the stormwater storage capacity will be recovered relatively quickly. This will allow capture and controlled release of flood water from multiple storm events that occur over days or weeks.
- The trickle orifice device is inexpensive and easily constructed. However, the pond embankment height must be sufficient to permit 8 to 11 in of temporary flood storage--in addition to that freeboard required to prevent overtopping the earth embankment.
- Because the orifice flow device drains very slowly as the water depth drops to near the normal water level, an extended time will be required to drain the final increments of flood storage. Since less makeup water will need to be added to provide for seepage and evaporation losses, water will be conserved.

Pipe Spillways

The water level in a levee pond is typically controlled with a vertical standpipe spillway (Figure 1): an L-shaped PVC pipe with a horizontal section placed through the earth embankment and a shorter vertical standpipe inside the pond. The purposes of the pipe spillway are to maintain the normal pond water level, and to drain excess rainfall that raises the pond water level above the top of the vertical standpipe. When enough rain raises the pond level above the vertical standpipe, the excess water quickly drains to re-establish the normal water level. The pipe spillway must be large enough and the freeboard must be sufficient to prevent flood water from overtopping the earth embankment during large rainstorms.

This pipe spillway design works well to establish and maintain the normal pond water level and to quickly drain flood waters. However, recent water quality regulations require that water drained from aquaculture ponds be held in a detention structure for at least 24 hours before being discharged off-site. This detention period improves the discharge water quality by allowing time for particulate matter to settle and nutrients to be extracted by aquatic vegetation in the littoral zone of the detention structure. The detention structure is typically a detention pond with an outflow control structure such as a culvert or weir. The detention pond must have

FISH POND PIPE SPILLWAY

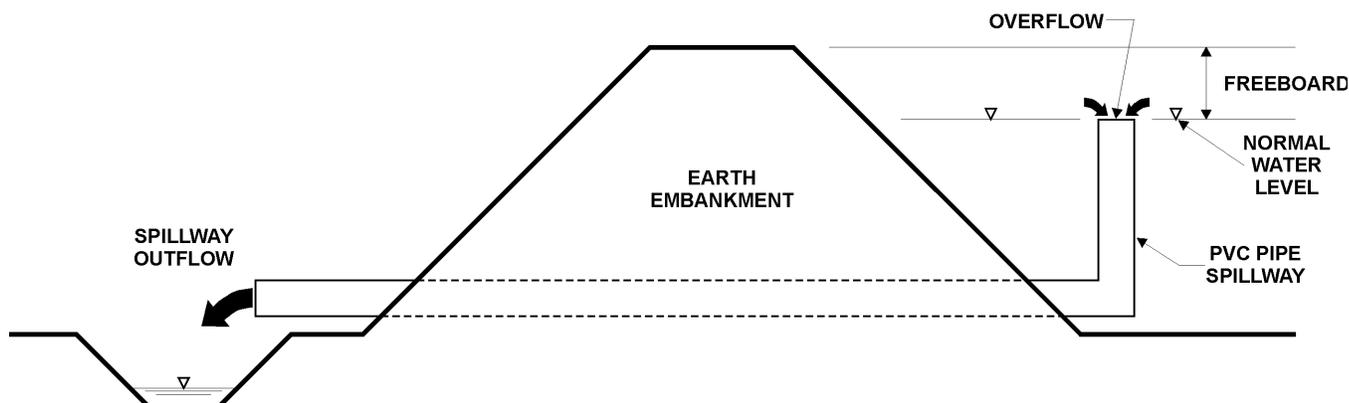


Figure 1. Vertical standpipe spillway typically used to maintain the normal water level in aquaculture ponds.

sufficient capacity so that inflow water remains in the pond at least 24 hours during drainage events.

A problem with using a typical pipe spillway as shown in Figure 1 is that flood water drains quickly, increasing the size of the detention pond required, especially when several production ponds drain into a single detention pond. A second problem is also due to the rapid rate of flood water drainage. This rapid drainage rate reduces the effectiveness of rainfall. Because the pond water level is quickly lowered to the normal water level by drainage, most of the rainfall drains from the production pond. Then, if frequent rains do not occur, water must be pumped from groundwater aquifers or other sources to replace evaporation and seepage losses to maintain the normal pond water level.

An improved design would provide flood storage capacity in the production ponds for large rainfall events, then meter that water out at a rate that does not exceed the detention pond capacity. Further, if the water is metered out in proportion to its depth in the pond, adequate capacity could be provided to discharge

large rains without exceeding the detention pond capacity for water treatment, while smaller rains and the last increment of larger rains would slowly discharge. This slow discharge would increase the effectiveness of rainfall use, reducing the amount of water required to be pumped from groundwater sources by the producer.

Trickle Pipe Spillway Characteristics

The typical vertical pipe spillway can easily be modified by the addition of an orifice flow control device and a vertical extension of the pipe spillway to provide temporary flood storage and trickle outflow from the pond as shown in Figure 2. Here the normal pond level is established by one orifice (or 2 or 3 orifices) in the vertical pipe. Excess water above the bottom of the flow control orifice will drain through the orifice at an accurately controlled trickle-flow rate that depends on the size and number of orifices and the depth of water above the bottom of the orifice.

FISH POND TRICKLE PIPE SPILLWAY

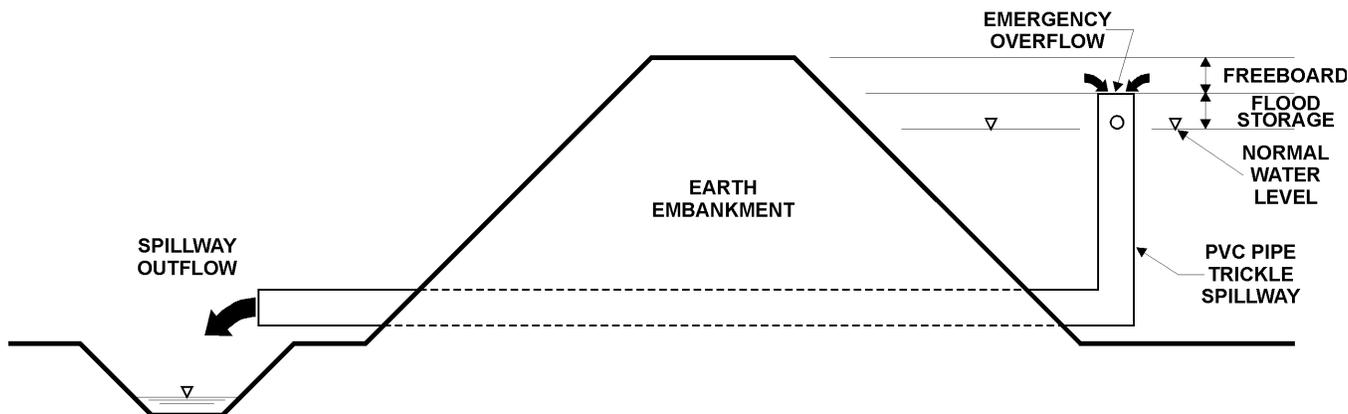


Figure 2. Trickle pipe spillway designed to provide trickle outflow control of flood storage water.

Flood Storage Depth

Flood storage depth is the depth of water that can be stored between the bottom of the trickle orifice and the top of the vertical pipe spillway. For optimal management, this depth is set as the depth of the 25-yr, 24-hr rainfall at the pond location.

In Florida, this depth ranges from 8 inches in the north central part of the state to 11 inches in both the extreme western panhandle (Pensacola) and the southeastern peninsula (Ft. Lauderdale-Miami) as shown in Figure 3. Setting the correct flood storage depth for the pond location allows the entire 25-yr, 24-hr rainstorm depth to be temporarily stored in the pond and slowly metered out into the detention pond.

In practice, some runoff from the surrounding levee tops (roadways) and side slopes occurs during

rainstorms, thus adding to the depth of water collected. However, this amount is relatively small, especially for larger ponds where the surrounding embankment area is only a small fraction of the total pond surface area. Also, drainage begins as soon as the pond water level rises above the trickle orifice, and drainage continues throughout the rainstorm, removing a portion of the flood water before the entire 25-yr, 24-hr depth can be stored in the pond. This early outflow compensates for any additional inflow from runoff for typical levees with 4:1 side slopes and the 14-ft top width assumed in this analysis. Thus, using the 25-yr, 24-hr rainstorm depths from Figure 3 is recommended because it provides a conservative estimate of flood water storage requirements for typical Florida aquaculture production systems.

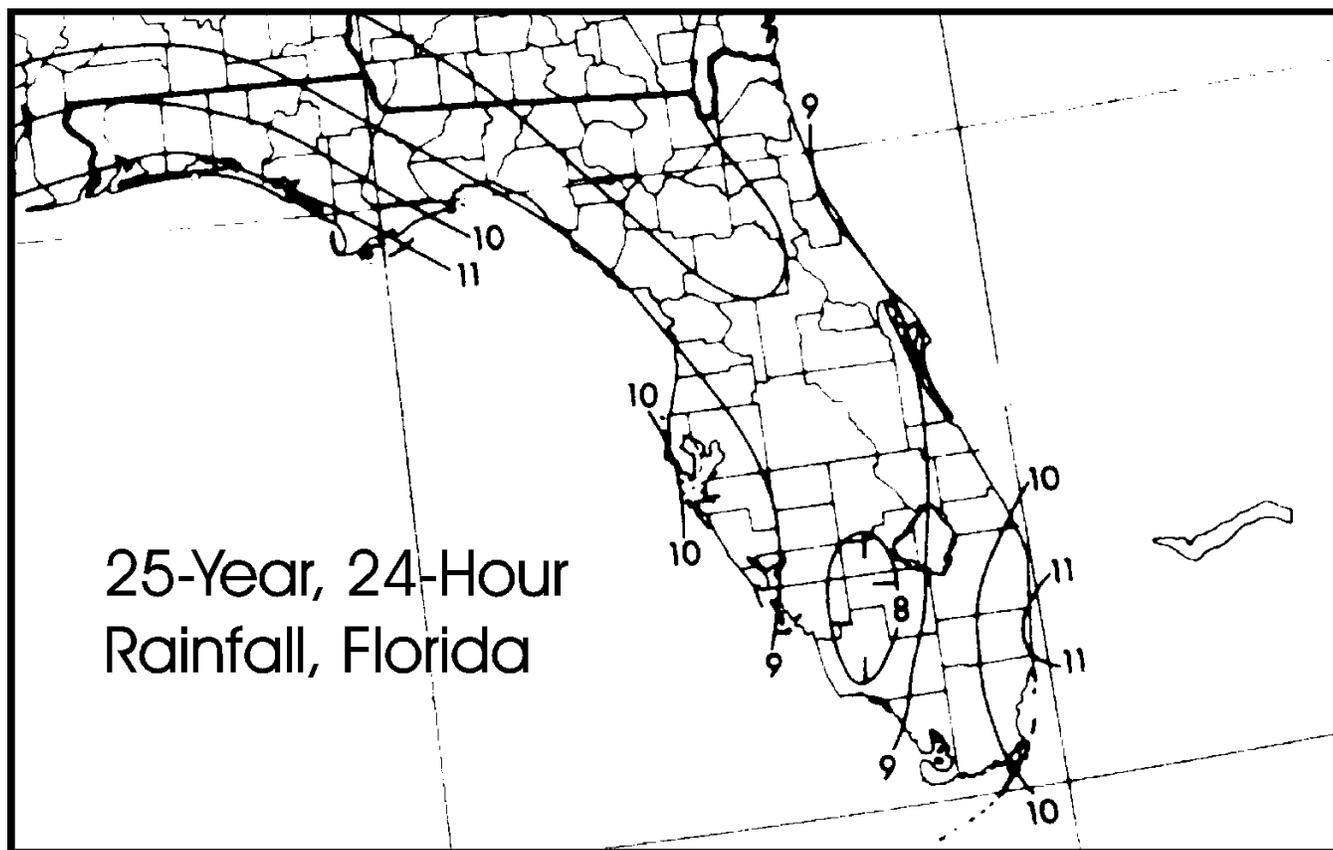


Figure 3. 25-year, 24-hour rainfall depths for Florida (Reference: Hershfield, 1961).

Emergency Overflow

If rainfall does exceed the 25-yr, 24-hr rainfall depth, the excess will raise the pond water level above the top of the vertical pipe spillway where it will flow directly into the open end of the pipe. This emergency overflow capability protects the earth embankments by allowing rapid drainage of flood water from extremely large rainstorms. The drainage rate will depend on the spillway pipe diameter and flow characteristics.

To further protect their embankments, producers may install emergency spillway structures such as chutes or flumes to allow high rates of outflow without overtopping the earth embankments. *Note: Because the pipe spillway is designed for a 25-year return period rainstorm, these emergency overflow structures would be expected to be used no more often than every 25 years--for hurricane precipitation, for example.*

Freeboard

Freeboard is the vertical distance between the maximum water level anticipated in the pond and the top of the settled embankment. If the trickle pipe spillway is used, and the system is designed for the 25-yr, 24-hr rainstorm, the design maximum water level becomes the top of the PVC pipe spillway.

Unobstructed Pond Surface Length(ft)	Freeboard Required (ft)		
	Wave Action	Freeze/Surface Disturbance	Total
up to 400	0.5	0.5	1.0
600	0.61	0.5	1.1
800	0.71	0.5	1.2
1000	0.79	0.5	1.3
1200	0.87	0.5	1.4
1500	0.97	0.5	1.5
2000	1.1	0.5	1.6

Calculated from Wave Height = 0.025(Pond Surface Length)^{1/2}, where pond surface length is the longest unobstructed length (ft) across the pond. Reference: Schwab et al. (1993).

Adequate freeboard must be provided to prevent embankments from being overtopped when the design maximum occurs. Freeboard of at least 1ft must always be provided: 0.5ft for wave action, plus 0.5ft for surface soil that may have been weakened by frost action or otherwise disturbed.

Wave Action

Freeboard will need to be increased for larger ponds because of the greater effect of wave action. Wave height depends on the unobstructed water surface length that the wind can blow across. Table 1 shows freeboard recommendations as a function of water surface length. Although these are the minimum freeboard depths recommended to prevent overtopping the earth embankment when the design 25-yr, 24-hr rainstorm occurs, growers can decrease the likelihood of failure of their structures and production systems by increasing these values. The actual freeboard used should be based on the cost of providing additional embankment height versus the value of fish and other components of the production system being protected.

Trickle Pipe Spillway Design

The trickle pipe spillway is based on a simple design -- an orifice (or 2 or 3 orifices) drilled in the vertical pipe spillway as shown in Figure 4. As examples, Figure 4 shows 2-, 3- and 4-inch diameter orifices constructed in an 8-inch diameter vertical pipe spillway. In each case, the bottom of the orifice is located the distance below the top of the pipe spillway that equals the required flood storage depth.

With this trickle orifice spillway design, outflow rate is controlled by the size and number of orifices used, and the head (or depth) of water above the normal water level. Because a circular orifice is used as the flow control device, the flow rate is well-known as a function of the water depth at any time. Thus, the length of time required to drain all or part of the flood storage depth can be calculated for a given orifice size, number of orifices, and pond size. Orifice sizes and number of orifices required to drain all or part of the flood storage depth can then be calculated as a function of pond size.

TRICKLE PIPE SPILLWAYS WITH ORIFICE FLOW CONTROL

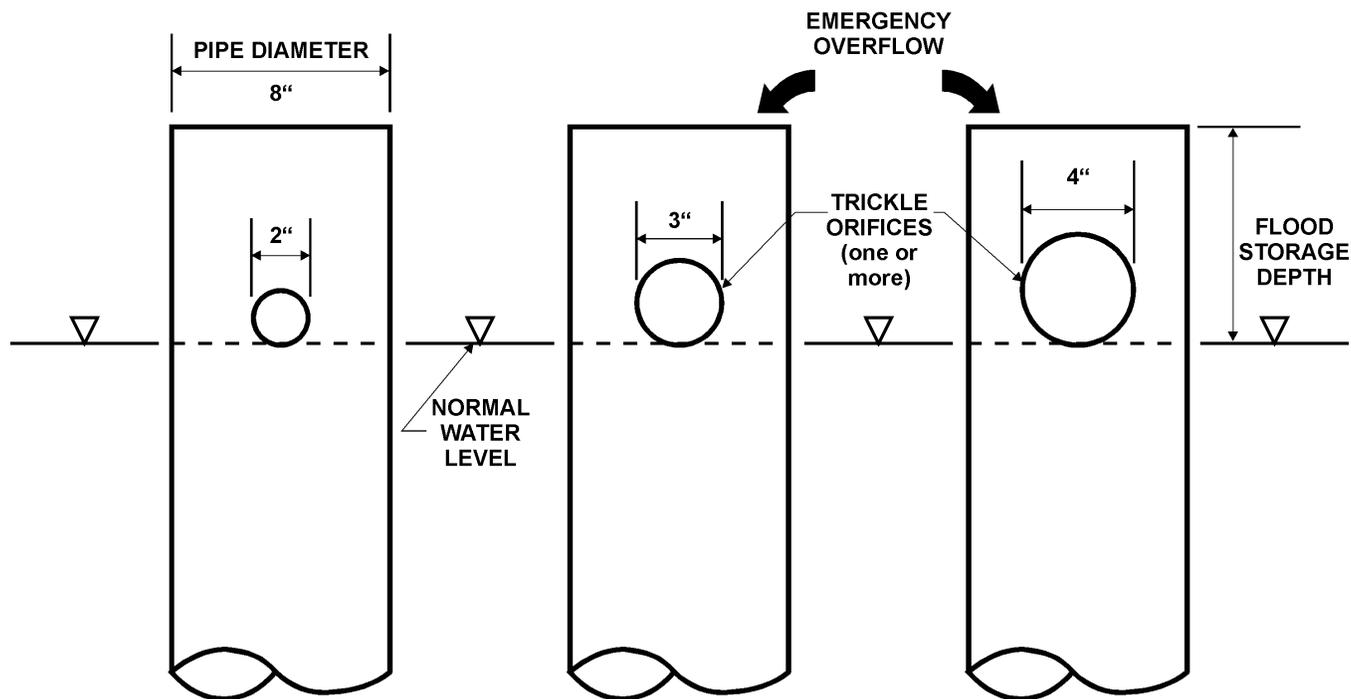


Figure 4. Trickle orifice designs for trickle pipe spillways.

Table 2. Trickle flow control orifice diameters required to drain flood water from 1-acre to 30-acre ponds.

Pond Surface Area (acres)	Orifice Sizes (inches)		
	1 orifice	2 orifices	3 orifices
1	1.19	---	---
2	1.72	1.19	---
3	2.13	1.48	1.19
4	2.48	1.72	1.39
5	2.79	1.93	1.56
6	3.07	2.12	1.72
7	3.33	2.30	1.86
8	3.57	2.47	2.00
10	4.00	2.78	2.24
12	---	3.06	2.47
15	---	3.44	2.78
20	---	4.00	3.23
25	---	---	3.64
30	---	---	4.00

Table 2 shows the trickle orifice sizes required to drain half of the 25-yr, 24-hr flood storage in seven days and all of the flood storage in 30 days for pond sizes up to 30 acres. Orifice sizes range from 1.2 to 4in. Orifices smaller than 1.2in should not be used because of their susceptibility to clogging, while an orifice larger than 4in is not recommended because its size is large as compared to the 25-yr, 24-hr rainfall depth and as compared to the size of the vertical standpipe.

Notice that required orifice sizes depend only on pond size. Required orifice sizes do not depend on the 25-yr, 24-hr rainstorm depth because of an important characteristic of orifice flow--the orifice flow rate is higher when the water depth is greater. And so, the greater depths drain at faster rates, which compensates for the differences in volume to be drained within the 8 to 11-inch flood storage depths required in Florida.

To use Table 2, assume that the pond surface area is one acre. Then, a single 1.2-inch diameter orifice will effectively drain the flood water for all storms up to the 25-yr, 24-hr rainstorm. As another example, assume that the pond size is two acres. Here, a single 1.7-inch or two 1.2-inch diameter orifices can be used. If two orifices are used, both are to be located the same distance from the top, and on opposite sides of the standpipe.

As a third example, assume the pond size is 10 acres. Three choices are available: a 4.0-inch, two 2.8-inch, or three 2.2-inch diameter orifices. Each choice has the same drainage rates over seven and 30-day periods, so the orifice size used depends on grower preference.

Table 3 shows pond sizes that can be drained with orifices ranging from 1 to 4 inches in diameter. For example, flood storage from a 4.1-acre pond would effectively be drained using one 2.5-inch diameter orifice, while pond size could be doubled to 8.2 acres and tripled to 12.3 acres with two and three orifices, respectively.

Table 3. Pond sizes drainable by a given size and number of trickle spillway orifices.

Orifice Size (inches)	Pond Size (acres)		
	1 orifice	2 orifices	3 orifices
1.00	0.7	1.4	2.2
1.25	1.1	2.2	3.3
1.50	1.5	3.1	4.7
1.75	2.1	4.2	6.2
2.00	2.7	5.4	8.3
2.25	3.3	6.7	10.0
2.50	4.1	8.2	12.3
2.75	4.9	9.8	14.7
3.00	5.8	11.6	17.4
3.25	6.7	13.5	20.2
3.50	7.7	15.5	23.3
3.75	8.8	17.7	26.5
4.00	10.0	20.0	30.0

Debris Screens

Pipe spillways work only if they are kept unplugged by debris. Unfortunately--under flood conditions--leaves, sticks, branches, or other debris often end up in ponds. Large debris can drift or float to the pipe outlet, become lodged in the opening and prevent the spillway from working. Even small debris can plug trickle orifices. A debris screen should be installed to prevent the pipe spillway from plugging.

**DEBRIS SCREEN
Side View (Cut-Away)**

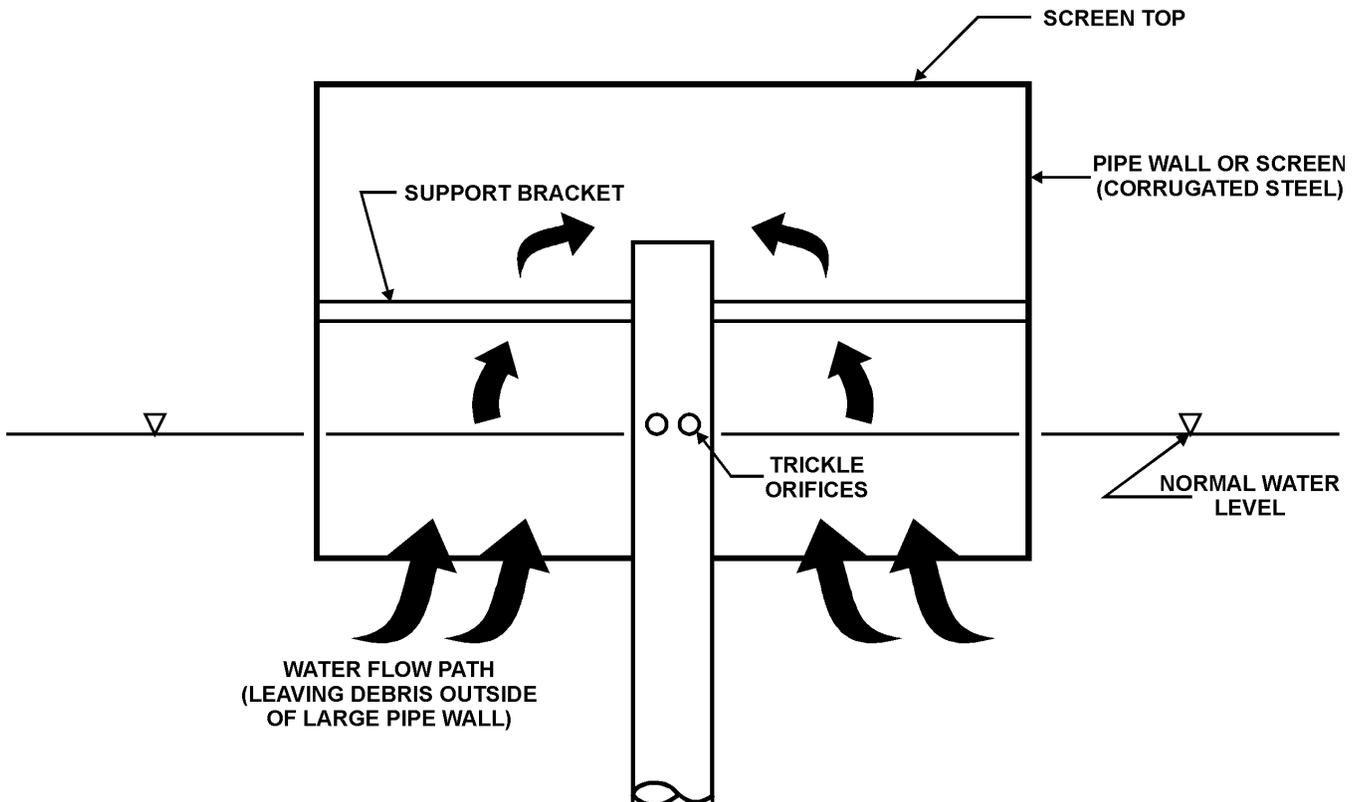


Figure 5. Debris screen designed to prevent floating debris from entering the trickle pipe spillway.

A debris screen is a structure designed to prevent debris from plugging the trickle orifice or pipe outlet. Figure 5 shows one possible design where the vertical pipe spillway is surrounded by a larger diameter section of pipe or screen. Construct a support bracket to bolt the debris screen to the vertical spillway. The supporting pipe or screen must be at least 2ft long-- long enough to extend at least 6in both above the pipe spillway inlet and below the normal water level.

The top of the debris screen is heavy wire mesh that prevents surface debris from falling directly into the spillway pipe and prevents floating debris from entering through the top when the water level is high. Monitoring any buildup of debris is a recommended practice, particularly after storms. Wire mesh allows easy visual inspection; and a hinged door in the screen mesh top allows access for cleaning.

Extending the debris screen below the water surface prevents floating debris from entering during normal spillway operation. With this design, water must enter the pipe spillway from below, following the pathway shown in Figure 5 so floating debris cannot approach the pipe spillway.

A debris screen must be large enough to keep floating debris well away from the pipe spillway. It must be strong enough to withstand collapsing if debris accumulates on it. A short section of corrugated steel pipe with angle steel brackets and a heavy wire mesh screen top can provide a long-lasting, functional structure. *Note: it is not acceptable to simply wrap the vertical standpipe with screen mesh, since this could readily be plugged.* The diameter of the debris screen should be two to four times larger than the vertical pipe spillway diameter to keep floating debris well away from the spillway inlet.

Detention Pond Size

The detention pond size required for a given aquaculture production system is a function of the size of production ponds, desired stormwater drawdown time, design of the production pond drainage system, and, of course, the design 25-year, 24-hour rainfall depth. Sufficient detention pond capacity must be provided to adequately treat discharge water during de-watering of ponds and during stormwater drainage.

Aquaculture ponds are occasionally drained for harvest operations or for other purposes. The detention pond must have sufficient capacity to treat the drainage water during these operations. Pipe systems are typically designed to drain ponds in up to a 10-day period, thus the detention pond capacity must be at least 1/10 of the capacity of the largest pond in the

production system. With this design, it is assumed that only one pond will be drained at a time.

When rainstorms occur, all ponds in the production system drain at once. So, the detention pond must have additional capacity to adequately treat the combined stormwater runoff that will occur from all ponds as the result of the design 25-yr, 24-hr rainstorm. This is the volume of water that will drain in the first day after the pond water level has been raised to the top of the vertical standpipe by rainfall.

Because a 25-yr, 24-hr rainstorm can occur while a pond is being drained, minimum allowable detention pond capacity is the sum of the volume required for one day of de-watering of the largest pond plus total volume required for stormwater drainage from all ponds during the first day after the design storm.

Table 4. Stormwater drainage volume (acre-inches) during the first day following a 25-yr, 24-hr rainstorm of 8 to 11 inches.

Pond Size (acres)	25-yr, 24-hr Rainfall Depth (inches)			
	8	9	10	11
1	0.64	0.72	0.80	0.88
2	1.28	1.44	1.60	1.76
3	1.92	2.16	2.40	2.64
4	2.56	2.88	3.20	3.52
5	3.20	3.60	4.00	4.40
6	3.84	4.32	4.80	5.28
7	4.48	5.04	5.60	6.16
8	5.12	5.76	6.40	7.04
10	6.40	7.20	8.00	8.80
12	7.68	8.64	9.60	10.6
15	9.60	10.8	12.0	13.2
20	12.8	14.4	16.0	17.6
25	16.0	18.0	20.0	22.0
30	19.2	21.6	24.0	26.4

Calculated as 8% of the 25-yr, 24-hr rainstorm depth based on the flow characteristics of the trickle orifice flow control device.

Table 4 presents the volumes of stormwater that would drain from a pond with a trickle orifice control system during the day after the design rainstorm. Rainfall depths from 8 to 11 inches are shown because these represent the range of 25-yr, 24-hr rainstorm depths in Florida. Pond sizes from 1 to 30 acres are shown. Drainage volumes were calculated as 8% of the 25-yr, 24-hr rainstorm depth because this is the peak daily flow of the trickle orifice sizes shown in Table 2

and Table 3. For example, determine the minimum detention pond capacity required if the production system has four 5-ft deep 8-acre ponds (each with a capacity of 40ac-ft) which all use the same detention pond. Assume the ponds are located near Pensacola where the 25-yr, 24-hr rainstorm depth is 11 inches. Then, the detention pond volume required for de-watering any pond in a 10-day period is $(40\text{ac-ft}/10) = 4.0\text{ac-ft}$. In addition, the stormwater volume draining from each 8-acre pond during the first day following an 11-inch rain would be 7.04ac-in (from Table 4). For four ponds, this volume is 28.16ac-in. Dividing by 12 results in 2.35ac-ft. Finally, the total detention pond volume required would be

$$4.0\text{ac-ft} + 2.35\text{ac-ft} = 6.35\text{ac-ft}.$$

A Final Note

If additional land areas drain into a detention pond, it will need proportionally greater capacity. To minimize the detention pond size required, limit the drainage area to the production ponds and levees, and divert flood waters from surrounding land areas around the detention pond.

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