The following example problem is for the design of a sediment basin and only addresses the hydraulic capacity and storage capacity. This design assumes a uniform basin geometry – a trapezoidal volume with a flat rectangular bottom surface. Note that basins can have many design constraints, such as available space, topography and proximity to receiving stream, that influence the final basin shape, location and geometrical configuration. Each design must be compatible with the site layout and must clearly address the design constraints. Detailed grading plans are required to ensure that the basin design can be constructed as intended on the site, given the site topography and space limitations.

This design follows the steps outlined in Chapter 7, Section 7.31. (The initial basin planning step should include consideration of determining the best location and general layout for the basin. The following steps provide a general approach toward developing the basin hydraulic design for storage and spillways.

GIVEN:

Design a sediment basin for an outfall to an *impaired* stream for the following assumptions and conditions:

1. Total drainage area = 10 acres
2. Time of concentration, T_c = 7.4 min (TR-55 analysis)
3. Construction site SCS Curve Number, CN = 91 (TR-55 analysis)
4. Incoming 5-year, 24-hour peak flow, Q_p = 47 cfs (TR-55 generated non-routed inflow to the sediment basin)
5. Incoming 25-year, 24-hour peak flow, Q_p = 47 cfs (TR-55 generated non-routed inflow to the sediment basin)
6. Assume that stormwater runoff enters the basin at the upper forebay end
7. Assume a minimum 4L:1W rectangular pond having 2H:1V interior side slopes where the incremental volume of basin depth is calculated from $V = \frac{(A_t + A_b)d}{2}$ where

   V = Volume of basin (ft^3)
   A_t = Basin top surface area (ft^2)
   A_b = Basin bottom surface (ft^2)
   d = incremental or total depth (ft)
8. Assume a permanent pool depth of 2 ft
9. Wet storage (permanent pool) basis = 67 CY/acre (1,809 ft^3/acre)
10. Total Dry Storage basis (Basin + Forebay) = 67 CY/acre (1,809 ft^3/acre)
11. Forebay storage = 25% x 67 CY/acre = 16.8 CY/acre (452 ft^3/acre)

REQUIRED DESIGN ELEMENTS:

- Wet, dry & forebay storage volumes
- Permanent pool - principal spillway riser crest elevation
- Riser pipe size
- Principal spillway conduit (barrel) pipe size
- Floating skimmer design: overall size selection and orifice diameter
- Emergency Spillway design: trapezoidal X-section, control crest elevation, width and side slopes
- Embankment dam crest elevation
- Bottom of pond elevation

<u>SOLUTION</u>:

<u>Step 1:</u> Set the basin geometry.

- Set the basin length to width ratio at 4L:1W
- Determine the storage volume needed (Total = sum of the wet, dry, and forebay storage volumes below riser crest)

  Total storage volume = (134 CY/ac) x (10 ac) = 1,340 CY = 36,180 ft^3

  Wet storage required at permanent pool = (67 CY/ac) x (10 ac) = 670 CY = 18,090 ft^3

  Total dry storage, including forebay vol. required = (67 CY/ac) x (10 ac) = 670 CY = 18,090 ft^3

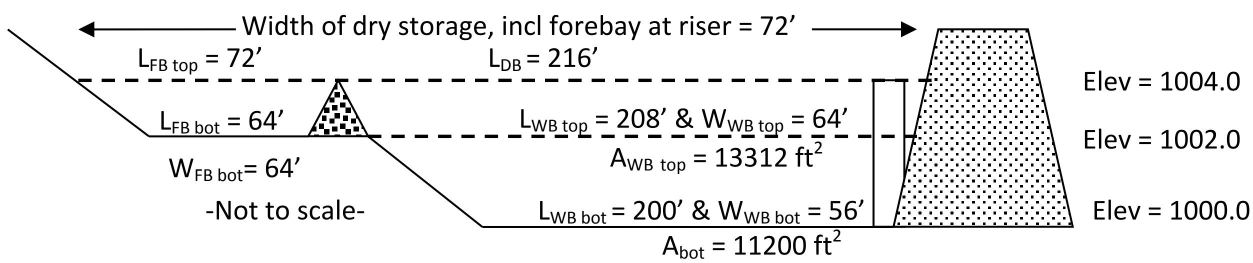
  - Dry storage in forebay= (16.8 CY/ac) x (10 ac) = 68 CY = 4536 ft^3
  - Dry storage in main basin = 18,090 ft^3 - 4536 ft^3 = 13,554 ft^3
- Determine the required minimum surface area at the riser elevation, A_s

  $A_s = 0.01Q_p$ = (0.01) x (47 cfs) = 0.47 ac = 20,473.2 ft^2

  Determine a basin shape that provides the 4L: 1W surface geometry.

  - Try 72 ft x 288 ft
  - A_s = 72ft x 288 ft = 20,736 $ft^2 \geq$ 20,473.2 ft^2 ← Therefore OK

- The required surface area needs to be split between the basin and the forebay. The widths will be the same but the sum of the lengths should be equal to the total length of 288 ft. *(Note: the thickness of the forebay berm, normally around 4 or 5 ft, is not included here in determining wet and dry storage, but would need to be added to the overall basin length and shown in the plans):*



Note: In order to determine the Wet Storage Volume (from bottom to the given permanent pool depth of 2’) an intermediate surface elevation at the permanent pool needs to be calculated. For this example the surface area at the permanent pool is 157’ x 64’.

Step 2: Establish basin elevations.

Determine the riser height that corresponds to the required storage volumes. From the storage volume, determine storage volumes at specific elevations:

$$V = \frac{(A_t + A_b)d}{2}$$

- Assume a trial riser height of 4 ft (elev. 1004.0 ft)
  - Set the elevation of the bottom of pond = 1000.0 ft and Permanent Pool Elev. = 1002.0
  - Pond Dimensions at bottom of pond (elev 1000.0) = 149’ x 56’ = 8344 ft^2 for 2:1 SS
  - Pond Dimensions at permanent pool (elev. 1002.0) = 157’ x 64’ = 10,048 ft^2 for 2:1 SS

- Wet Storage (From bottom to permanent pool) = 24,512 ft^3 ≥ 18,090 ft^3 <u>therefore OK</u>

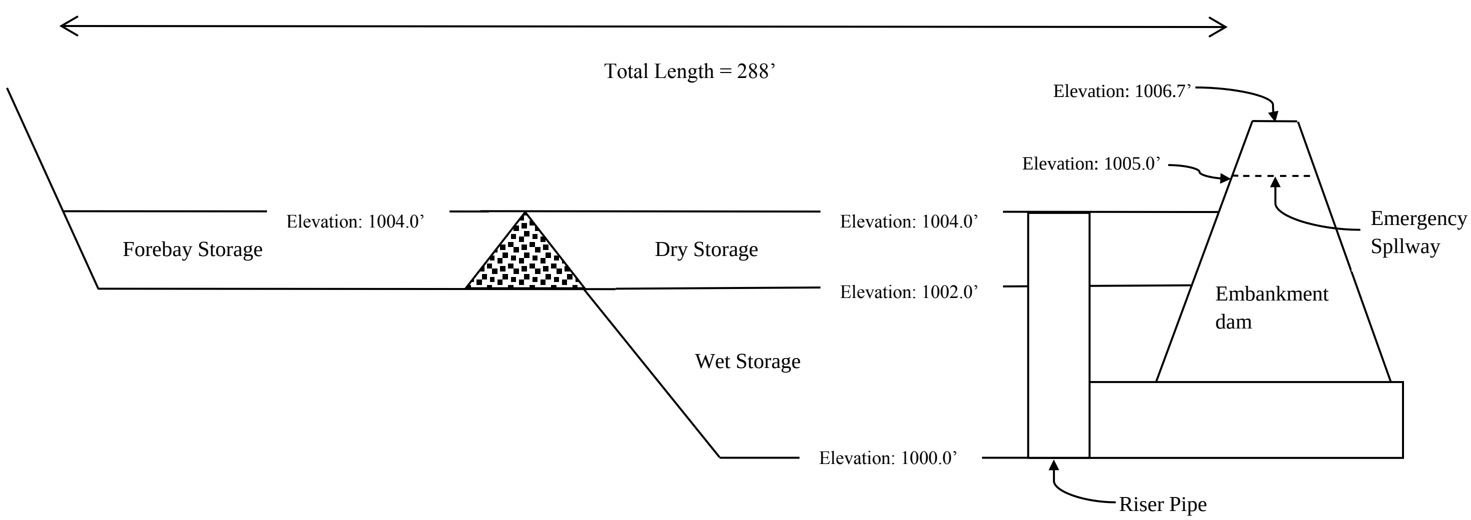
- Forebay Dimensions at bottom (elev. 1002.0) = 64' x 64' = 4096 ft^2 for 2:1 SS
- Forebay dimensions at top (elev. 1004.0) = 72' x 72' = 5184 ft^2 for 2:1 SS
- **Forebay Storage = 9,280 ft^3 ≥ 4,536 ft^3 <u>therefore OK</u>**

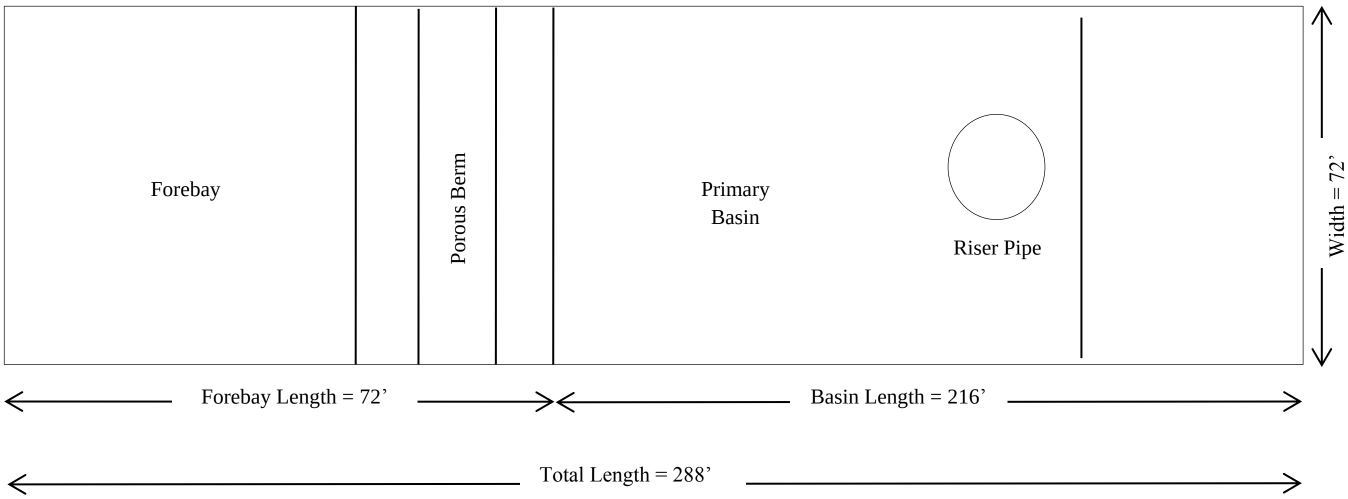
- Main dry pond dimensions at perm pool (elev 1002.0) = 157' x 64' = 10,048 ft^2 for 2:1 SS
- Main dry pond dimensions at top (elev 1004.0) = 216' x 72' = 15,552 ft^2 for 2:1 SS
- **Dry Storage (from Elevation 1002' to elev. 1004') = 28,864 ft^3 ≥ 13,554 ft^3 <u>therefore OK</u>**

- Total Dry Storage, including Forebay = 9,280 ft^3 (24%) + 28,864 ft^3 (76%) = 38,144 ft^3 ≥ 18,090 ft^3 <u>therefore OK</u>

Therefore the trial riser height of 4 ft is acceptable

Set the bottom of basin elevation = 1000.0 ft
Set the permanent pool elevation = 1002.0 ft
Set the riser crest elevation = 1004.0 ft





Step 3: Design spillways

Principal Spillway

(A) Establish principal spillway elevation = 1004.0 ft

- Assume riser diameter = 36" = 3 ft
  Circumference = 113" = 9.42' of weir length
- Assume rectangular sharp crested weir w/ a coefficient of 3.33
  (Note: The riser operates as a sharp-crested weir up to a certain head and then switches to orifice flow.)
- Hydraflow Express gives a depth of 1.31' for 47 cfs. At the minimum freeboard of 1' from top of principal spillway to emergency spillway, the emergency spillway will convey a portion of the 5-year, 24-hour design storm.
- *Conduit Pipe Size (The capacity of the service spillway is usually limited by the outlet pipe.)*
  From Hydraflow Hydrographs an outlet pipe size = 24" = 2' has adequate capacity.

Emergency Spillway (Flow credit is given to the service spillway but not the dewatering device.)

(B) Emergency spillway elevation = 1004.0' (Principal Elevation) + 1' (minimum freeboard) = 1005.0 ft

- 25-year, 24-hour storm event: Q_p = 67 cfs
- Emergency spillway design flow = 67 cfs - 31.37 cfs (flow credited to 3-ft diameter principal spillway at 1-ft head over crest) = 35.63 cfs
- Assume a weir length = 20'
- Hydraflow Express gives a flow control depth of 0.66 ft
- Top of Berm Elevation = 1005.0' (Emergency Spillway Elevation) + 0.66' (depth of 25 yr storm) + 1' (minimum freeboard) = 1006.7 ft
- Emergency Spillway Sideslopes = 4:1

Step 4: Dewatering Device (Skimmer)

Need to dewater the dry storage (38,144 ft^3) in 72 hours

- Choose a 4-inch skimmer which has a capacity of 60,327 cubic feet in 3 days.
- Determine the orifice size for the manufacturer's given orifice head and discharge coefficient. The head will vary depending upon the manufacturer's design depth of submergence for a given orifice diameter. Use the following Skimmer size vs. orifice head table based on the Faircloth® skimmer as an example.

Skimmer Size (inches)	Head (h) on orifice in ft
1.5	0.125
2	0.167
2.5	0.208
3	0.25
4	0.333
5	0.333
6	0.417
8	0.5

*The flow (cfs) through an orifice can be computed as:

$$Q = CAo\sqrt{2gH} = C\,\pi r_o^2\sqrt{2gH}$$

where C is the orifice coefficient (assumed to be 0.59), A_o is the orifice cross-sectional area in ft^2, r_o is the orifice opening radius (ft), g is the acceleration of gravity (32.2 ft/sec^2), and H is the driving head on the orifice center in feet.

Rearranging the previous equation, the desired orifice radius in feet can now be calculated using the following equation:

$$r_o = \sqrt{\frac{Q}{14.87 * \sqrt{H}}}$$

Where flow, Q, is based on draining the total dry volume in 3 days as follows:

$$Q_d = \frac{V}{t_d} = \frac{38{,}144\ ft^3}{3\ days} = 12{,}715\ \frac{ft^3}{day} = 0.147 \text{ cfs}$$

Try a 4-inch skimmer, which has a flow capacity rating for draining up to 60,327 cubic feet in 3 days and has an orifice head, h = 0.333 ft

$$r_o = \sqrt{0.147\frac{ft3}{sec}/(14.87 * \sqrt{0.333\ ft})} = 0.131 \text{ ft} = 1.6 \text{ inches}$$

Therefore, use a 4- inch skimmer with an orifice diameter d_o of 3.2 inches

*Note: Skimmer manuafacturer charts or software may be used as an alternative method for sizing orifice.

In Summary:

EXAMPLE BASIN 1	RISER PIPE DIA. (FT)	BARREL PIPE DIA. (FT)	PERMANENT POOL ELEVATION (FEET, AMSL)	PRINCIPAL SPILLWAY ELEVATION (FEET, AMSL)	EMERGENCY SPILLWAY ELEVATION (FEET, AMSL)
	3	2	1002.0	1004.0	1005.0
	EMERGENCY SPILLWAY WIDTH (FT)	EMERGENCY SPILLWAY SIDESLOPE	TOP OF EMBANKMENT ELEVATION (FEET, AMSL)	BOTTOM OF BASIN ELEVATION (FEET, AMSL)	SKIMMER (ORIFICE) SIZE (INCHES)
	20	4:1	1006.7	1000.0	4 (3.2)

Option: The above parameters can be entered into hydraulic routing software to refine the design. This would likely result in more credit being given to the principal spillway for a portion of the 25-year, 24-hour storm flow and the overall depth and volume of the basin may be able to be reduced. Following the design presented above will result in a conservative design (i.e. storage > 134 CY/acre). A minimum 25% of the dry storage volume will be provided as part of the forebay at the pond inlet. In other words, this volume can be credited to the overall dry storage (such that 75% of the required total dry storage volume is provided in the primary basin).

Note: This sediment basin design example does not include required emergency spillway lining calculations and design nor does it include service spillway outlet structure apron design and calculations. Furthermore, the sediment basin design example does not discuss required service spillway anti-buoyancy pad, anti-vortex & trashrack, dam design analysis, anti-seep collars, details of surface skimmer connection to riser & skimmer base pad, or forebay berm design.