# KS650.1180 Ponds

## (a) General

Ponds are bodies of water created by the construction of an embankment across a watercourse, the excavation of a pit or dugout, or a combination of the two. Typically, ponds are used for livestock water but may have other beneficial uses such as recreation, wildlife habitat, or fire control. Proper planning and layout of the pond can maximize the beneficial uses of the pond and minimize adverse effects to the surrounding ecosystem.

## (b) Planning and Investigation

Proper planning for pond locations is dependent on the type of pond to be installed and the expected beneficial use. Embankment ponds should be placed where the most storage can be obtained with the least amount of earthfill. Embankments placed in a narrow section of a valley with steeper side slopes and where the valley slope permits a large area to be flooded are generally better sites. Excavated ponds are generally better suited for areas with higher evaporation and less annual runoff or areas with flat topography where frequent flows out of the pond will not cause erosion. They are also suited to areas with shallow groundwater if there is an impermeable layer available for the bottom of the excavation. Excavated ponds with a designed embankment are suited for valleys with steeper grades. The bulk of the storage is determined by the excavated quantity, but additional capacity is available by constructing an embankment. These “modified” excavated ponds are considered embankment ponds if the depth of water impounded against the embankment at the auxiliary spillway crest elevation is 3 feet or more.

Constructed ponds may require permits from the U.S. Army Corps of Engineers (USACE) and the Kansas Department of Agriculture Division of Water Resources (DWR). Owners of ponds for livestock water should follow the General Permit (GP)-40 guidance from the USACE. Most embankment ponds will not require a permit to construct from DWR but may require notification. Guidance on permit and notification requirements can be found at the DWR website http://agriculture.ks.gov/divisions-programs/dwr.

A geological investigation of the site will help to determine if the soils are suitable for water storage or if the potential exists to intercept a shallow groundwater source. Ponds located in areas with small depressions, shallow groundwater, or spring flow may require a wetland determination along with the geologic investigation. Ponds may be designed and constructed in wetland areas as long as the lost wetland functions are mitigated as required by the National Environmental Policy Act (NEPA) requirements in General Manual (GM) Title 190, Subpart B, Section 410.26.

The geologic investigation for embankment ponds will be as required for Group B structures as referenced in National Engineering Manual (NEM), Subpart C, Section 531.30, and NEM Section KS531.4. Embankment ponds with a fill height of more than 20 feet should be investigated by a geologist. The investigation for all embankment ponds should include at least 2 borings along the proposed centerline of the dam, 2 borings in the proposed location of the auxiliary spillway, and at least 2 borings in the proposed borrow area. Additional borings may be needed to determine the need for foundation drainage and should be based on the findings in the required borings.

The geologic investigation for excavated ponds will consist of at least 1 boring for each 1000 square feet of surface area to be disturbed during excavation. The borings may be completed by a soil scientist, geologist, or a Natural Resources Conservation Service (NRCS) person with appropriate job approval authority as delegated on Form KS-CPA-1, Kansas Practice Approval Certification, for the pond being designed.

Ponds that rely on surface runoff for water storage must have adequate drainage area to meet the needs for beneficial use plus losses due to evaporation and seepage. Figure 11 in Agriculture Handbook (AH) 590 can be used as a guide to determine required drainage area based on the storage requirements. Figure KS11-1 shows the Kansas portion of the map in Figure 11 of AH 590. Ponds with significant spring flow in the drainage area will require less drainage acres to maintain adequate pool levels. Experience with the local area or local runoff information (if available) should be used in place of the information in Figure KS11-1. Computer models such as Soil-Plant-Air-Water (SPAW), WinPond, or SITES may be useful in documenting adequate drainage area as well.

## (c) Sediment Storage

Ponds relying on surface runoff as the source of water will provide for adequate sediment storage as part of the permanent storage of the pond. Permanent storage is defined as the storage below the elevation of the lowest ungated outlet of the pond. This outlet may be the auxiliary spillway for ponds without a pipe or the inlet elevation of the principal spillway or trickle tube. Sediment storage will be based on the expected sediment yield of the drainage area for the life of the structure. Sediment yield may be determined using the procedure in Bulletin No. 16, Sediment Yield from Small Drainage Areas in Kansas, for drainage areas up to 10 square miles.

This procedure has been simplified for ponds with much smaller drainage areas. A value for the expected sediment yield has been assigned to cropland and rangeland acres for each Major Land Resource Area (MLRA) in Kansas. These values are shown in Table KS11-1 and are based on the information in Figure 8 from Bulletin No. 16, an assumed trap efficiency of the pond, and an average drainage area for the location. Figure KS11-2 has a map showing the MLRA boundaries for the state.

To determine the sediment storage required for the pond location, multiply the appropriate values from Table KS11-1 for cropland and rangeland times the number of acres of each in the drainage area times the number of years for the practice life (typically 20 for ponds). The result is divided by 640 to convert from acres to square miles.

**Table KS11-1** Sediment yield values

| | Annual Sediment Yield acre-foot per square mile per year (ac-ft/sq mi/yr) | |
|---|---|---|
| MLRA | Rangeland | Cropland |
| 72 | 0.07 | 0.20 |
| 73 | 0.11 | 0.40 |
| 74 | 0.28 | 0.96 |
| 75 | 0.29 | 0.67 |
| 76 | 0.30 | 1.15 |
| 77A | 0.06 | 0.10 |
| 77E | 0.11 | 0.25 |
| 78C | 0.17 | 0.54 |
| 79 | 0.07 | 0.24 |
| 80A | 0.29 | 1.14 |
| 84A | 0.25 | 1.00 |
| 106 | 0.50 | 1.71 |
| 107B | 0.90 | 3.60 |
| 112 | 0.34 | 1.16 |
| 116B | 0.30 | 1.00 |

**Example KS11-1** Sediment yield calculation

Given: Diedrick Farms, Inc. Stockwater Pond, Dickinson County, Kansas

Drainage area = 146 acres total, 95 acres of rangeland and 51 acres of cropland.

Practice life of the pond is expected to be 20 years.

From Figure KS11-2, Dickinson County is in MLRA 74. Annual sediment yield is 0.28 ac-ft/sq mi for rangeland and 0.96 ac-ft/sq mi for cropland.

Sediment yield from rangeland is computed as follows:

0.28 ac-ft/sq mi x 95 acres x 20 years ÷ 640 ac/sq mi = 0.83 ac-ft.

Sediment yield from cropland is computed as follows:

0.96 ac-ft/sq mi x 51 acres x 20 years ÷ 640 ac/sq mi = 1.53 ac-ft

Total sediment yield from the drainage area—based on a 20-year life of the pond—is 2.36 ac-ft. The pond design should include that amount of sediment storage in the permanent storage of the pond.

The Pond Spreadsheet contains the sediment yield information in Table KS11-1 and can be used to determine the required sediment storage for a pond.

## (d) Runoff Calculations

Runoff calculations will include the estimated annual runoff, the required detention storm runoff, and the peak discharge from the design storm. All runoff will be determined using the Antecedent Runoff Condition (ARC) II weighted curve number. Use the procedure in Chapter 2 in National Engineering Handbook Part 650 (NEH 650), *Engineering Field Handbook*, and information in Table KS2-1 in NEH 650 to determine the weighted curve number based on soil hydrologic group, land use, and treatment. Runoff computations can be done manually by using Forms KS-ENG-137, Hydrologic Summary Sheet, and KS-ENG-137b, Hydrologic Summary Sheet, or by using the Pond Spreadsheet.

The estimated annual runoff will be determined for the 50%, 80%, and 90% chance runoff using the weighted curve number for the drainage area. The mean annual runoff will also be determined. The procedure in Section KS650.281 in NEH 650 will be used to determine these runoffs. The results can be summarized on either Forms KS-ENG-137 and KS-ENG-137b or documented in the "Storage" tab of the Pond Spreadsheet.

The detention storm runoff will be determined using the procedures in Chapter 2 in NEH 650 and corresponding information in NEH 650, Section KS650.280. The recommended minimum rainfall event to determine the auxiliary spillway crest elevation is the 2-year, 24-hour storm. Additional detention storage may be required if flood control is a purpose of the structure or if the auxiliary spillway is unsuitable for long duration flow events.

Table KS2-6 in NEH 650 provides unit runoff amounts for different frequency storms for each county and various weighted curve numbers. The runoff amount is multiplied by the drainage acres to determine the volume of runoff from the drainage area.

**Example KS11-2** Detention storm runoff

Given: Diedrick Farms, Inc. Stockwater Pond, Dickinson County, Kansas

Drainage area = 146 acres total, 95 acres of rangeland and 51 acres of cropland. Range is in fair condition on Hydrologic Group C soils. Cropland is in a wheat-sorghum rotation on B soils with gradient terraces. Weighted ARC II curve number is 76.

Recommended detention storage is the runoff from a 2-year, 24-hour storm.

Table KS2-6 in NEH 650 shows a runoff of 1.22 inches for the 2-year storm and a curve number of 76. Multiply the runoff by the drainage acres and divide by 12 to get total detention storm runoff in acre-feet:

1.22 inches x 146 acres ÷ 12 inches/foot = 14.84 ac-ft

Form KS-ENG-137b may be used to get the runoff depth for the required detention storm instead of Table KS2-6 in NEH 650.

The design storm peak discharge will be the peak discharge from the minimum design storm frequency shown in Table 5 of Conservation Practice Standard (CPS) 378, Pond. It is usually the 25-year, 24-hour storm but may be different due to the size of the drainage area or other factors. The design storm peak discharge is determined by using the procedures in Chapter 2 in NEH 650 and corresponding information in NEH 650, Section KS650.280 or by using Form KS-ENG-137b.

**Example KS11-3** Design storm peak discharge

Given: Diedrick Farms, Inc. Stockwater Pond, Dickinson County, Kansas

Drainage area = 146 acres total, 95 acres of rangeland and 51 acres of cropland. Range is in fair condition on Hydrologic Group C soils. Cropland is in a wheat-sorghum rotation on B soils with gradient terraces. Weighted ARC II curve number is 76.

Average watershed slope is 4.5%, and the hydraulic flow length is 4000 feet.

Required design storm is the 25-year, 24-hour storm. Rainfall distribution type storm is Type II.

The unit peak discharge ($q_u$) is determined using the rainfall distribution type or zone, the time of concentration ($t_c$), and initial abstraction ($I_a/p$). The time of concentration is determined using equation 2-5 in Chapter 2 in NEH 650. This empirical equation relates $t_c$ to the flow length ($\ell$), curve number (CN), and watershed slope (Y).

Information from Tables KS2-8, KS2-9, and KS2-10 in NEH 650 is used to determine the $t_c$ from hand calculations. The flow length component from Table KS2-8 in NEH 650 is 761, the CN component from Table KS2-9 in NEH 650 is 2.71, and the watershed slope component from Table KS2-10 in NEH 650 is 2,418. The time of concentration is computed as follows:

$$t_c = 761 \times 2.71 \div 2418 = 0.85 \text{ hour}$$

The initial abstraction $I_a$ from Table KS2-11 in NEH 650 is 0.632 for a CN of 76. The 25-year, 24-hour storm rainfall is 5.8 inches for Dickinson County, and the runoff (Q) is 3.21 inches from Table KS2.6 in NEH 650:

$$I_a/p = 0.632 \div 5.8 = 0.11$$

Use Table KS2-12 in NEH 650 to find the unit peak discharge ($q_u$) for $t_c$ = 0.85 and $I_a/p$ = 0.11:

$$q_u = 0.63 \text{ cubic foot second (cfs)/acre/inch}$$

Peak discharge ($q_p$) is then determined by multiplying the unit discharge by the drainage area and the storm runoff (Q):

$$q_p = 0.63 \times 146 \times 3.21 = 295.3 \text{ cfs}$$

Graphical methods in Chapter 2 in NEH 650 may be used to derive many of the values given in the tables. Form KS-ENG-137b is recommended to determine these values and the peak discharge, and it also gives discharges for other frequency storms. Some or all of these calculations are embedded in the Pond Spreadsheet, SITES, and WinPond. These design aids should be used to minimize calculation errors. The procedures and examples are presented here to give the designer a good overview of the many variables involved in pond design.

## KS650.1181 Embankment Ponds

### (a) Hazard Class Determinations

The hazard class of embankment ponds will need to be verified during the planning process and prior to site investigation. The verification will ensure that the proposed location will meet low hazard criteria in CPS 378. The criteria for hazard classes low, medium, and high can be found in NEM KS520.21(e). Low hazard structures are dams located in rural or agriculture areas where the failure of the dam may cause minor damage to one or more of the following:

- A building
- Agricultural land (cropland or range)
- A township or country road that is overtopped by more than 0.5 foot during passage of the breach wave and has an average annual daily traffic (AADT) count of 500 vehicles or less
- Any road or highway that would be overtopped by 0.5 foot or less during passage of the breach wave

In addition, if any part of the dam or auxiliary spillway is used as a public road, the AADT count of the road must be 100 vehicles or less for the dam to be considered low hazard.

Ponds with embankments 25 feet or greater in height or ponds with storage of 50 acre-feet or more at the auxiliary spillway crest elevation are considered inventory dams. Hazard class documentation for inventory size dams must use breach routing procedures as outlined in NEM KS520.23(b). Smaller dams may use simplified procedures including ½ dam height and equivalent area methods, and these procedures will be outlined further. The breach routing procedures are beyond the scope of this document.

For non-inventory size dams, the floodplain for at least 1 mile downstream of the proposed location will be reviewed for potential hazards such as roads, railroads, and homes or other inhabited buildings. A cross section will be considered and/or surveyed at each potential hazard. The elevation of the hazard above the low point in the cross section will be compared to ½ the dam height. If the height of the potential hazard is above ½ the dam height, information should be shown in the Remarks section on Form KS-ENG-12, Hazard Classification Documentation for Ponds, that indicates the ½ dam height analysis.

If the height of the potential hazard is less than ½ of the dam height, a cross section will need to be surveyed at both the dam location and potential hazard location. Plot each cross section either on graph paper or by using computer drafting software. Measure the cross section area below the top of dam elevation at the dam cross section. Measure the cross section below the potential hazard elevation at the hazard cross section. If the cross section area at the potential hazard elevation is greater than the cross section area of the dam, document this on Form KS-ENG-12. Include a comment to indicate the equivalent area method was used to determine that the potential hazard was above the breach wave. If the cross section area at the potential hazard is less than the dam cross section area, breach routing procedures must be used to complete a hazard classification.

The ½ dam height rule and equivalent area method are both very conservative in determining the breach wave elevation. Additional analysis may still result in a low hazard classification, but additional engineering skills and judgment are required to complete the breach routing procedures in accordance with NEM KS520.23. In all cases, a potential inundation area map should be developed for the downstream area within 1 mile of the dam. The map should show the limit of the floodplain that may be inundated during a breach of the dam based on the type of analysis done. If the ½ dam height criteria is used, the area of the floodplain up to that depth should be indicated on the map. If the equivalent area method is used, at least 2 cross sections shall be used to identify the extent of the area that is equivalent to the dam cross section. The predicted breach wave elevations for selected cross sections shall be used to determine the potential inundation area when breach routing procedures are used.

If there are roads as potential hazards, the lowest point in the road cross section will be considered the potential hazard elevation for both the ½ dam height and equivalent area methods. If the road will be overtopped by at least 0.5 foot using these methods, then breach routing procedures will be required to complete the hazard classification.

## (b) Reservoir Storage Determinations

The design of embankment ponds is based on the expected storage at different elevations in the reservoir of the proposed embankment location. This expected storage is also referred to as the stage-storage capacity and can be expressed in tabular form or graphical form as a curve. The stage-storage information is determined from a channel profile and cross sections or a topographic map showing contours at various elevations. The channel profile method may be suitable for embankments less than 10 feet in height with a uniform channel valley. A topographic map should be developed for larger embankments with elevations every 2 or 4 feet—depending on the size of the reservoir. The elevation interval should not exceed 2 feet for dams less than 20 feet in height.

The topographic map shall be developed from field surveys or computer-generated data such as digital elevation models (DEMs), national elevation dataset (NED), or Light Detection and Ranging (LiDAR) information. The maps generated using DEMs or NED data are suitable for planning purposes but lack the required accuracy for design. Maps generated using LiDAR data can be used for design if they have been field-referenced using a handheld or survey grade Global Positioning System (GPS) to verify the proposed centerline location.

Field surveys shall meet the accuracy requirements shown in Table 1-1 in NEH 650, Chapter 1. The type of survey used to develop the topographic map is dependent on the size of the embankment and complexity of the original ground surface. Simple topographic maps may be developed using a handheld GPS along with a laser level and rod. The laser level and rod are used to maintain a constant elevation while the GPS locates points along the contour line. Total stations or survey grade GPS instruments along with electronic data collectors should be used for taller embankments or more complex topographic locations. Maps may be drawn by hand using the centerline profile and cross section method or developed using computer drafting equipment for the other methods.

The contours on the topographic map shall extend upstream to at least 1 contour interval above the expected top of dam elevation. They shall also extend downstream from the proposed centerline enough distance to adequately show the path of flow from the auxiliary spillway to the existing channel. This distance will normally be between 100 and 300 feet downstream—depending on the size of the embankment.

The storage volume will be determined by the average end area method using the surface area at successive contour elevations. The area at each elevation shall be either by the triangulation method or measurement of the surface area using a planimeter or computer drafting software.

The triangulation method is suitable for use with ponds that have an embankment height less than 10 feet and where the valley shape is uniform. Plot the profile of the stream channel from a point where the upstream natural ground elevation is higher than the planned top of dam elevation to a point at least 50 feet downstream of the planned dam location. Show the planned centerline of dam location on the profile. Plot the surveyed centerline of dam profile. Note the lowest elevation on the dam profile and record it to the nearest 0.1 foot. This will be the zero area elevation on the stage-storage table. The next elevation would typically be the next even integer elevation. For example, if the lowest elevation is 78.3, the next elevation used would be 80.0. Determine all areas at successive even elevations to at least 1 contour above the planned top of dam. Areas are determined using the area formula for a triangle or as follows:

A = ½ (L x W)

Where: A = Area
L = Upstream distance
W = Width along the centerline profile for each elevation

The length and width should be measured in feet from the plots and the area will be square feet. An example of the plotted data and measurement for a given elevation are shown in Figure KS11-3. Convert the area to acres by dividing by 43,560. The calculations can be done by hand or by using a simple spreadsheet. The Pond Spreadsheet has this option available in the stage-storage calculations on the "AcreFeet" tab.

**Example KS11-4** Area determination using triangulation method

From Figure KS11-3:
L = 30 feet and W = 12 feet at elevation 80
A = ½ x (30 x 12) = 180 square feet (sq ft)
A = 180 ÷ 43560 = 0.004 acre

L = 85 feet and W = 26 feet at elevation 82
A = ½ x (85 x 26) = 1105 sq ft
A = 1105 ÷ 43560 = 0.025 acre

For other ponds, the area at each elevation will be based on the contour of the natural ground of the reservoir and the proposed centerline of the embankment joined to form a closed contour. This area shall be measured on a printed map using a planimeter or electronically using computer mapping or drafting software. Areas measured by the planimeter must be converted to square feet from square inches. The conversion factor will be the drawing scale squared.

**Example KS11-5** Area determination using a planimeter

Given: Diedrick Farms, Inc. Stockwater Pond, Dickinson County, Kansas

Planimeter area at:
Elevation 80 = 0.072 square inch (sq in)
Elevation 82 = 0.338 sq in

Map scale: 1 inch = 50 feet

Area at elevation 80:
A = 0.072 sq in x (50 x 50) sq ft/sq in
A = 180 sq ft
A = 180 ÷ 43560 = 0.004 acre

Area at elevation 82:
A = 0.338 sq in x (50 x 50) sq ft/sq in
A = 845 sq ft
A = 845 ÷ 43560 = 0.019 acre

Maps developed and measured electronically may give the area in either square feet or acres depending on the software. Convert square feet to acres as needed. The Pond Spreadsheet has both of these options available in the stage-storage calculations on the "AcreFeet" tab.

To determine the storage capacity, a table shall be developed showing the associated area, incremental volume, and total accumulated volume for each contour elevation. The area may be shown in square feet for small structures, but all volumes should be shown as acre-feet. This table should be shown on the construction drawings and include the elevations of the principal spillway, auxiliary spillway, and top of dam for inventory size dams. The areas for these additional elevations may be interpolated or read from a curve plotted from the table information. The table should also include the principal spillway and auxiliary spillway outflows at each elevation for inventory size dams. Figure KS11-4 has an example of a typical storage capacity table for an inventory size dam and the plotted curve from the capacity table data.

## (c) Permanent Storage Requirements

Permanent storage is defined as the storage below the elevation of the lowest ungated outlet of the pond. This outlet may be the auxiliary spillway for ponds without a pipe or the inlet elevation of the principal spillway or trickle tube. Permanent storage includes both the sediment storage calculated in Section KS650.1180(c) and the planned use of the water in storage. The planned or consumptive use may be water for livestock, fire control, recreation, or wildlife benefits.

The permanent storage should typically be between the 80% or 90% chance runoff and the mean annual runoff calculated in Section KS650.1180(d). If the consumptive use is less than the 90% chance runoff, use the 90% chance runoff to determine the permanent storage required.

The percent chance figure is an estimate of how dependable the water supply will be for the planned location. For example, the 80% chance runoff is estimated to be available 80% of the time. The consumptive use should never exceed the 50% chance runoff, and the total permanent storage should not exceed the mean annual runoff for ponds with a drainage area of greater than 20 acres.

If livestock water is the planned use, the water requirements given in CPS 614, Watering Facility, or other references may be used. If the pond is the only water source, the consumptive use should not exceed the 90% chance runoff. For other consumptive uses or a combination of uses, the 80% chance runoff is the recommended maximum amount for this portion of the permanent storage. This maximum may be limited by the mean annual runoff requirement for permanent storage.

**Example KS11-6** Permanent storage calculation

Given: Diedrick Farms, Inc. Stockwater Pond, Dickinson County, Kansas

Drainage area = 146 acres. Practice life of the pond is expected to be 20 years. Weighted CN is 76. Annual precipitation is 31.8 inches.

Sediment storage = 2.36 ac-ft.

Consumptive use is for 120 head of beef cattle between May 1 and October 15.

Use the procedure in NEH 650, Section KS650.281 to determine runoff amounts as follows:

From Figure KS2-2 in NEH 650:
90% chance runoff is 0.60 inch and total volume is 0.60 inch x 146 acres ÷ 12 = 7.30 ac-ft

From Figure KS2-3 in NEH 650:
80% chance runoff is 0.90 inch and total volume is 0.90 inch x 146 acres ÷ 12 = 10.95 ac-ft

From Figure KS2-5 in NEH 650:
Mean annual runoff is 2.50 inches and total volume is 2.50 inches x 146 acres ÷ 12 = 30.42 ac-ft

Consumptive use is 220 head x 15 gallons/day/head x 167 days = 551100 gallons ÷ 326000 gallons/ac-ft = 1.69 ac-ft

Consumptive use of 1.69 ac-ft is less than 90% chance runoff, so use 90% chance runoff for design. Permanent storage for design is 2.36 + 7.30 = 9.66 ac-ft. The principal spillway, trickle tube, or auxiliary spillway should be placed at an elevation to provide at least this amount of storage. Use the stage-storage table to determine the required elevation based on the total storage.

## (d) Detention Storage Design

The detention storage for embankment ponds with an auxiliary spillway should be large enough to prevent frequent flows in the auxiliary spillway due to storm runoff. Frequent flows are defined as occurring annually or more frequently. Flood routing procedures based on pipe flow calculations may be used to reduce the detention storage volume and lower the spillway crest elevation. These procedures are contained in design tools such as the Pond Spreadsheet, SITES, or WinPond. The reduction in the detention storage volume is proportional to the maximum discharge through the principal spillway pipe. Table KS11-2 gives the minimum required pipe flow for different reduced detention storage amounts in the pond. This table is an extension of Table B in Exhibit 11-4 on page 11-55c in Chapter 11 of NEH 650.

**Example KS11-7** Design detention storage

Given: Diedrick Farms, Inc. Stockwater Pond, Dickinson County, Kansas

Drainage area = 146 acres. Recommended detention storage is the runoff from a 2-year, 24-hour storm or 14.84 ac-ft.

Planned principal spillway pipe is 8-inch diameter polyvinyl chloride (PVC) plastic pipe, Standard Dimension Ratio (SDR) 26.

Using the Pond Spreadsheet, the designer can adjust the detention storage on the “Input” tab to determine the minimum detection storage allowed for the chosen pipe size. For this example, the minimum detention storage is 10.59 ac-ft for the planned 8-inch PVC plastic pipe with a maximum pipe flow of 5.27 cfs.

The stage-storage table is used to determine the auxiliary spillway crest elevation. The total storage at the crest should be the sum of the permanent storage and detention storage or at least 20.25 ac-ft:

Permanent Storage + Detention Storage = Required Storage at Auxiliary Spillway Crest
9.66 + 10.59 = 20.25 ac-ft

From the stage-storage table and curve in Figure KS11-4, the approximate elevation for the required storage is 95.6. The Pond Spreadsheet will set the auxiliary spillway crest at the required elevation (95.7) to meet the total storage requirements. The designer may set the auxiliary spillway crest higher than the minimum to increase the flood storage capacity or reduce the flow through the auxiliary spillway during the design storm. Reducing the flow will reduce the required width of the auxiliary spillway. This is discussed more in Section KS650.1181(k).

## (e) Principal Spillway Design

A principal spillway is a pipe conduit through the embankment that is designed to discharge long-duration, continuous, or frequent flows without flow through the auxiliary spillway. A principal spillway should be installed on all dams greater than 15 feet in height or that are located in areas where the annual rainfall exceeds 25 inches.

Ponds that do not meet the height or annual rainfall requirements may be subject to spring flows or other long-duration flows. These ponds should use a trickle tube to protect the vegetated auxiliary spillway from continuous flows. The trickle tube can be metal or plastic pipe and must be at least 6 inches in diameter, but it does not require an anti-vortex device at the inlet. The inlet crest shall be at least 1 foot below the auxiliary spillway crest unless the pond has a drainage area less than 20 acres. The minimum elevation difference for those ponds is 0.5 foot. Trickle tubes cannot be used to reduce the required detention storage or auxiliary spillway capacity due to design discharges of the trickle tube.

Some ponds in low rainfall areas may be designed without a principal spillway or trickle tube. The design documentation should provide a water budget to show that the losses from evaporation and seepage will remove the detention storage in a reasonable time period—typically 2 to 3 weeks. The auxiliary spillway capacity should not be reduced due to detention storage if the time period exceeds 2 weeks.

Additional design information for auxiliary spillways is found in Section KS650.1181(k).

Principal spillways may be metal or plastic pipe conduits. The type of pipe materials used will be dependent on the minimum pipe size required and the amount of fill over the pipe. Use the tables in CPS 378 to determine the acceptable pipe type based on the diameter and actual maximum fill over the pipe. The designer may use the design procedure in Chapter 52 in National Engineering Handbook Part 636 (NEH 636), *Structural Engineering*, to exceed the limitations in the tables if needed for a particular location.

The most common material used is smooth-wall PVC plastic with watertight gasket joints. Other materials include dual-wall PVC or polyethylene (PE) plastic pipes that are corrugated outside and smooth inside with gasket joints. Plastic pipe typically uses a bell and spigot type of connection with an O-ring gasket to be watertight. Solvent-cemented connections for PVC and PE plastic pipes are acceptable when the depth of fill in the embankment is less than 10 feet. Corrugated metal pipe (CMP) is still widely used for larger pipes and with drop inlets. It is important to specify a good watertight connection when using CMP because these pipes do not use a bell and spigot connection but instead use a flanged or butt connection. Additional gasket material or mastic is required along with proper installation to ensure a watertight connection. Both CMPs and corrugated dual-wall PE and PVC plastic pipes have soiltight and watertight connectors. It is important to specify the watertight connections for these types of pipes if they are used in ponds.

The minimum principal spillway pipe diameter allowed is 6 inches if a canopy inlet is used or 8 inches if a drop inlet is used. The minimum pipe diameter is determined by checking the release time of the designed detention storage. At least 95% of this storage must be released within 10 days.

**Example KS11-8** Release time calculation

Given: Diedrick Farms, Inc. Stockwater Pond, Dickinson County, Kansas

Designed detention storage is 10.59 ac-ft.

Maximum principal spillway flow = 5.27 cfs for 8-inch diameter PVC plastic pipe.

The Pond Spreadsheet indicates the release time is 30.4 hours based on the average flow method which estimates the average flow being equal to 0.8 times the maximum flow. WinPond and SITES use actual declining flow rates based on the changing water surface elevation and will give slightly longer release times. The average flow method can be used to estimate the required pipe size by using the entire detention runoff and an estimated pipe flow from Table KS3-1 in NEH 650. The release time is determined by the equation:

Time = Storage ÷ Pipe flow

Where:
- Time = Release time in hours
- Storage = Detention storage in acre-inches
- Pipe flow = Average pipe flow in cfs (maximum flow x 0.8)

Increasing the pipe size will decrease the design detention storage and reduce the amount of earthfill required. The designer must determine if the additional pipe costs can be offset by reduced earthfill costs. In addition, reducing the detention storage will increase the flow in the auxiliary spillway and may require a wider constructed auxiliary spillway to safely pass these increased flows. The WinPond program allows the user to check 3 different pipe sizes or types to quickly look at different principal spillway options; however, only 1 of them may be used to check the auxiliary spillway design. The SITES program will allow the user to look at only 1 principal spillway type but will allow several different auxiliary spillway options. The Pond Spreadsheet uses the information in Table KS11-2 to determine the minimum pipe size required for the storage volume available. The designer can try different storage amounts and determine the most economical pipe size and storage volume.

## (f) Principal Spillway Inlet

Principal spillway inlets can be hooded, canopy, or drop inlets—depending on the elevation difference between the permanent storage elevation and the downstream channel. Elevation differences greater than 15 feet should use a drop inlet unless local conditions or previous experience justifies the use of hooded or canopy inlets. The riser diameter for a drop inlet should be at least 1.25 times larger than the principal spillway pipe or barrel diameter. The minimum riser size should be 12 inches.

A larger diameter riser will provide full pipe flow at lower elevations and also allow easier access to the barrel entrance for maintenance purposes. Drop inlets are typically used with CMP spillways, and the riser connections include a stub pipe welded to the riser for the barrel connection. An additional stub pipe may be added upstream for installation of a drawdown pipe in the pool area. The drawdown pipe must be installed when required by downstream water rights, and the flow can be controlled by a slide gate valve or similar type of installation. The riser base for CMP risers should be either a metal base or a concrete base. Use Form KS-ENG-402, Corrugated Metal Pipe Drop Inlet with Concrete Base, or Form KS-ENG-403, Corrugated Metal Pipe Drop Inlet with Metal Base, to show details for fabricating and installing corrugated metal drop inlets.

Concrete, polypropylene, PE, or PVC risers may also be fabricated for use with plastic principal pipes. Information from the manufacturer should be used for details concerning the size and installation of these risers. The riser base should be concrete or formed as part of the riser. Some installations may require a rubber boot or fitting to maintain a watertight connection from the riser to the barrel if a connecting stub is not included as part of the riser by the manufacturer.

Canopy inlets are typically chosen over hooded inlets as the type of inlet required to meet the anti-vortex requirement for pressure flow pipes. Canopy inlets are easier to fabricate than hooded inlets—especially for plastic pipe. They work well for smooth-wall PVC plastic pipe and CMP but are less desirable for dual-wall PVC or PE plastic pipe. These pipes are corrugated on the outside with a smooth inner wall. Cutting them at an angle to form the canopy will expose the area between the outside corrugation and inside wall. That area may be hollow or filled with plastic supporting material—depending on the pipe diameter. This exposure to water and the elements may decrease the life expectancy of the pipe materials. For those types of pipes, a smooth-wall fitting should be used to fabricate the inlet. Use Figure KS11-5 and the information in Tables KS11-3 and KS11-4 to determine the dimensions for fabrication of the canopy inlet. Those dimensions can be transferred to Form KS-ENG-409, C.M. Canopy Inlet, or Form KS-ENG-410, PVC Canopy Inlet and Anti-Seep Collar for PVC Pipe, as appropriate. The Pond Spreadsheet will provide a detailed drawing with the appropriate dimensions for the type of pipe used. Embankments that require a level or sloping berm for wave protection should use concrete protection for canopy or hooded inlets. These are especially important when using dual-wall corrugated pipe materials as these are subject to floating due to the hollow areas of the corrugations. Use Form KS-ENG-440, Concrete Protection for 15” to 24” Diameter Pipe Inlets, or Form KS-ENG-441, Concrete Protection for 8”, 10”, or 12” Diameter Pipe Inlets, as needed for the concrete protection designs.

A suitable trash guard shall be installed on all drop inlets. A trash guard is recommended for other inlets when the watershed contains woody debris that may clog the conduit. Designs that do not require a trash guard should include a statement in the operation and maintenance plan concerning the removal of accumulated debris from the structure following storm events that cause principal spillway flow. For the design of suitable trash guards, use Form KS-ENG-414, Trash Rack for Corrugated Metal Canopy Inlet, for canopy inlets and Form KS-ENG-411, Trash Rack for 12-inch to 21-inch Corrugated Metal Pipe Riser; Form KS-ENG-412, Trash Rack for 24-inch to 36-inch Corrugated Metal Pipe Riser; or Form KS-ENG-413, Trash Rack for 42-inch to 60-inch Corrugated Metal Pipe Riser, for drop inlets.

## (g) Principal Spillway Outlets

Principal spillway pipes should outlet in or near the existing downstream channel. Pipes that are 18 inches in diameter or larger should have a constructed stilling basin or other energy-dissipating structure at the outlet. Smaller pipes may outlet into the channel or into an area where a small basin can develop without damaging the downstream embankment. Pipes that are 12 inches in diameter and smaller should be placed at least 1 foot above the channel elevation to account for tailwater depths. Larger pipes up to 18 inches in diameter should be placed at least 1.5 feet above the channel elevation unless a tailwater analysis indicates a lower elevation is acceptable. The outlet of the pipe must extend at least 5 feet beyond the embankment toe for 12-inch pipes and smaller. All other pipes must extend at least 8 feet beyond the embankment toe. The pipe must be supported by a constructed pipe support or may be supported by an additional downstream berm. Pipe supports may be constructed of treated timbers, corrugated metal, or pre-cast concrete. Approved Kansas standard engineering drawings are listed in NEH 650, Section KS650.680 for each type of support. If a pipe support is used, it must be placed upstream of the location corresponding to the downstream embankment toe based on the elevation of the outlet channel.

Lined stilling basin outlet structures are recommended for pipes larger than 24 inches in diameter, and they should be designed in accordance with Design Note 6 or a standard design should be used. Unlined excavated basins may be adequate in erosion-resistant soils for 18-inch to 24-inch diameter pipes. The basin should have a minimum bottom width of 10 feet with 3 horizontal to 1 vertical (3:1) side slopes and a minimum bottom length of 20 feet. The elevation of the excavated bottom should be at least 4 feet below the outlet channel for an 18-inch pipe and 6 feet below the channel for a 24-inch pipe. The upstream slope should be the same as the downstream slope of the dam, and the downstream slope should not be steeper than 2½:1. See Figure KS11-6 for an example section of the basin with recommended slopes and dimensions. The upstream slope of the basin may be lined with riprap or other materials to provide additional erosion protection. A pipe support must be used when an excavated basin is constructed.

## (h) Seepage Control Along Pipes

Seepage control for principal spillway pipes or other pipe conduits through the embankment shall be installed as required by CPS 378. Seepage control shall be accomplished by installation of a filter diaphragm or anti-seep collars. A filter diaphragm is recommended for all installations requiring seepage control but should be used for all principal spillway pipes 18 inches and larger. The filter should be designed using the recommendations in Chapter 45 in National Engineering Handbook Part 628 (NEH 628), *Dams*. It shall be at least 2 feet thick and extend vertically upward and horizontally from the outside of the pipe at least 3 times the outside diameter. It shall extend vertically downward 18 inches or 2 times the outside pipe diameter—whichever is greater. See Figure KS11-8 for a section view. The filter should be located at the downstream toe of the cutoff trench if the cutoff trench is along the centerline of the embankment. If the cutoff trench is installed upstream of the embankment centerline, install the filter with the upstream edge at the embankment centerline. See Figure KS11-9 for recommended locations of the filter diaphragm. The filter diaphragm shall have an outlet consisting of drain filter material under the pipe extending from the diaphragm to the excavated basin or downstream toe. Use Form KS-ENG-409a, PVC Canopy Inlet–Drain Diaphragm, for the drain outlet design. As an alternative, a 4-inch slotted drain pipe may be placed in the filter below the principal spillway pipe and be connected to a solid pipe that outlets into the excavated basin or at the downstream toe. The solid outlet pipe may parallel the principal spillway pipe and be offset a distance of 5 to 10 feet to allow for easier placement of the drain outlet. Protect the drain outlet as needed from damage by animals or equipment since it will outlet near the ground surface at the embankment toe. A CMP with an animal guard encasing the PVC plastic pipe will provide suitable protection.

Anti-seep collars may be used on smaller pipes based on the experience of the designer. They shall be compatible with the principal spillway pipe and have a watertight connection to the pipe using clamps or other methods. Typically, the collar and the principal spillway pipe will be made of the same materials but may be of different materials. If the pipe does not have a corrugated surface, the collar may be of nearly any type of material such as butyl rubber, PVC, or other watertight material that can be shaped to the circumference of the pipe. CMPs may use metal collars that are welded to the flanged coupling used to connect the pipes. Corrugated plastic or metal pipes may also use a butyl rubber or similar flexible material that can be tightly clamped to the pipe to provide a watertight connection.

The number of collars (N) required is based on the size of the collars and the saturated distance (L) of the embankment. The goal is to increase the flow path of water traveling along the pipe by at least 15%. L is the horizontal distance in feet from the inlet of the pipe to the location of downstream toe based on the elevation of the outlet channel as shown in Figure KS11-9. The number of collars and the collar spacing are determined by the following equations:

$$N = \frac{L}{7 \text{ x } (V - D)}$$

Anti-seep collar spacing = 4 x (V – D)

Where: V = Vertical dimension of the collar
D = Pipe diameter
Both V and D must be in feet.

The first collar should be placed 12 to 15 feet downstream of the inlet and the remaining collars spaced uniformly downstream. The most downstream collar location should not be more than 0.6b downstream of centerline ("b" is the horizontal distance of the downstream slope of the embankment as shown in Figure KS11-9). The location of the first collar and the collar spacing can be adjusted as needed to meet this condition.

**Example KS11-9** Anti-seep collar size and location

Given: Diedrick Farms, Inc. Stockwater Pond, Dickinson County, Kansas

Constructed embankment slopes:
3:1 upstream and 2½:1 downstream

Top width: 12 feet

Constructed top dam elevation: 100.0

Inlet elevation: 93.0

Downstream toe elevation: 78.0

The distance b is determined by multiplying the downstream slope ratio times the elevation difference between the top of dam and downstream toe. The saturated distance L is the sum of the upstream slope ratio times the elevation difference between the top of dam and pipe inlet elevation, the top width, and b.

b = 2.5 x (100 - 78) = 55.0
L = 3 x (100 - 93) + 12 + 55.0 = 88.0 feet

Determine the number of anti-seep collars required using the saturated distance, vertical dimension of the collar, and pipe diameter.

Assume a collar size of 4 feet x 4 feet and a pipe diameter of 8 inches (0.667 foot).

$$\mathrm{N} = \frac{88}{7 \text{ x } (4 - 0.667)} = 3.77$$

Use 4 collars

Locate the most upstream collar 15 feet downstream of the inlet. This location is also equal to 12 feet upstream of centerline. Space the remaining collars at 13 feet—based on the following spacing equation:

Anti-seep spacing = 4 x (4 - 0.667) = 13.3 feet

Use 13 feet for ease of drawing and staking the locations. Collar locations will be 12 feet upstream and 1 foot, 14 feet, and 27 feet downstream of centerline. Downstream limit is 0.6b or 33 feet downstream.

As a check, the spacing should be at least 10 feet but not greater than 25 feet. These calculations are included in the Pond Spreadsheet on the "Canopy or Drop Inlet" tab. In general, it is recommended to use the largest anti-seep collar available to reduce the amount of work required to install the collars. The use of anti-seep collars increases the complexity of the principal spillway installation—especially hand-compacted backfill around the pipe. Reducing the number of collars should provide for a more uniform and better installation of the hand-compacted materials around the principal spillway.

Anti-seep collars for CMPs are sometimes welded to the flange coupling. The upstream location and spacing will need to be adjusted to match the pipe joint locations for these designs.

## (i) Drawdown Pipes

Pipes set at a suitable elevation to drain the pool or provide downstream flow shall be installed as needed or as required by state laws and regulations. Dams subject to approval by DWR will normally require a drawdown pipe. In most cases when a drawdown pipe is required, a drop inlet should be used and a 4-inch minimum diameter pipe installed from the riser on a level grade into the pool area. The elevation of the drawdown will be dependent on the riser height but should be set as low as possible to provide the most management options available. Typically, the drawdown will be placed 1 foot higher than the riser base to allow for installation of a water control valve and ease of future maintenance on the valve. The valve may be installed in the riser or in a separate valve well just upstream of the riser.

A separate 4-inch pipe through the embankment may be installed if a drawdown pipe is required and a canopy inlet is desired. The water control valve can be placed in a valve box or well at or near the downstream toe of the embankment. The drawdown pipe should outlet into the natural drain or excavated basin. The drawdown pipe should be installed at least 20 feet from the principal spillway if anti-seep collars are used on the principal spillway for seepage control. The drawdown pipe will also require anti-seep collars using the same design criteria as for the principal spillway. If a filter diaphragm is installed around the principal spillway, the location of the drawdown may be closer to the principal spillway pipe to use the filter diaphragm for seepage control of the drawdown pipe as well. The location of the diaphragm may need to be moved downstream to take advantage of this alternative. The separate drawdown pipe may be used as a water supply line downstream if desired by the landowner. Additional valves and fittings will be required for this option. The inlet of the drawdown pipe should have a suitable trash guard, but no anti-vortex device is required. A perforated pipe inlet similar to a water supply line inlet may be used instead of a trash guard.

## (j) Water Supply Lines

Water supply from the pond, especially water for livestock, is the largest benefit and the main reason for installing most ponds. A water supply line should be installed through the embankment to provide water downstream to a watering facility when livestock water is a resource concern. A water supply line may also be installed to mitigate wetland functions downstream of the structure or to supply water for irrigation or fire suppression. The size of pipe installed will be based on the use requirements. In most cases, a 1½-inch or 2-inch diameter pipe is adequate for livestock water supply or for the mitigation of wetland functions. A 6-inch or larger pipe will normally be required for irrigation supply or fire suppression, and the pipe size should be based on water requirements. Use the tables in CPS 378 to determine the acceptable pipe type based on the diameter and actual maximum fill over the pipe. The designer may use the design procedure in Chapter 52 in NEH 636 to exceed the limitations in the tables if needed for a particular location.

The livestock water supply line should have a suitable strainer at the inlet to prevent clogging and a control valve near the downstream toe of the embankment. Seepage along installed pipes should be controlled by the use of anti-seep collars or a filter diaphragm. The design and location of the anti-seep collars or filter diaphragm shall be as outlined in the Section KS650.1181(h). If a filter diaphragm is used for the principal spillway, the water supply pipeline shall use the same filter diaphragm to the extent possible.

The strainer inlet will consist of a perforated section of pipe that extends at least 6 feet into the pool area of the pond. The perforated area must be large enough to provide pressure flow in the pipe; and for pipe sizes 2 inches or smaller, the minimum area of perforations must be at least 14 square inches. This can be accomplished by drilling 4 rows of ⅜-inch holes on at least 90% of the 6 feet of pipe that extends into the pool. The maximum spacing between the holes along the pipe should be 2 inches. The inlet can be installed in the pool as shown in Figure KS11-10, but the recommended method would be to install it vertically and protect it by placing it in a preformed perforated riser (Hickenbottom or similar) filled with 1½-inch size gravel. The bottom portion of the riser should be buried at least 18 inches deep to provide stability to the exposed portion, and the entire riser should be filled with gravel. This will allow adequate flow—even if the pool fills with sediment in the future.

The control valve can be a ball valve for use with PVC plastic pipe or a brass gate valve for use with metal pipe. Each type of valve can be used with other types of pipes if the proper fittings are used. It is easier to determine visually if the ball valve is in the open or closed position, but it may tend to be stuck in one position if not operated very frequently. A gate valve will normally operate very easily no matter how often it is operated, but the open or closed position cannot be determined by visual observation. The valve and pipeline downstream of the embankment must be placed below frost line or a minimum of 3 feet. An 8-inch pipe can be used as the valve well as shown in Figure KS11-11. In some cases, the water supply pipe may connect directly to a buried watering facility with a shutoff valve as part of watering facility. A control valve is still recommended in the water supply line just upstream of the watering facility.

If the watering facility is placed more than 50 feet away from the downstream toe of the embankment, the pipeline that extends beyond the downstream control valve should be designed according to CPS 516, Pipeline. In lieu of site-specific flow and pipe size calculations, the pipeline shall have a minimum size as follows—based on the grade line of the pipe:

- 1¼-inch diameter for line grades of 1 percent or greater
- 1½-inch diameter for line grades of 0.5 to 1 percent
- 2-inch diameter for line grades from 0.2 to 0.5 percent

Suitable locations for watering facilities may not be available using gravity delivery systems. Water supply lines may still be installed to provide water to a wet well or cistern with a float valve to control flows. A submersible pump can be placed in the wet well, and water can then be piped to suitable watering facility locations. The pumps can be powered by an electric motor or internal combustion engine. If the installation is in a remote area, a solar-powered pump is a recommended installation. Recent advances in photovoltaic arrays and electronics have increased the dependability of these types of systems. These systems are able to provide adequate volumes of water for livestock needs at total dynamic head of greater than 100 feet. Follow CPS 533, Pumping Plant, to design pumps and power supplies for alternate delivery systems.

Larger lines for irrigation supply or fire suppression will be installed in the same manner as the livestock water supply line. They should be designed by an engineer or other professional as required for the particular installation.

## (k) Auxiliary Spillway Design

Auxiliary spillways (formerly called emergency spillways) are constructed to protect the embankment during large runoff events that could overtop the dam. Water flowing over a steep embankment could cause major erosion of the embankment and possibly erode the dam away—resulting in failure of the structure. Auxiliary spillways are designed to prevent this by providing a controlled flow area around the embankment with a safe outlet downstream of the embankment. The size of the auxiliary spillway is based on the runoff from the design storm, the detention storage in the pond, and the slope of the exit channel from the crest elevation down to the floodplain. The design storm is determined by the drainage area and embankment height, but it is normally the 25-year, 24-hour storm. Refer to Table 5 in CPS 378 to determine the required design storm frequency and duration.

The peak discharge from the design storm is determined as shown in Section KS1180(d). The minimum auxiliary spillway capacity will be the peak discharge from the design storm less any reduction due to principal spillway flows or detention storage. The reduction due to flow in the principal spillway is allowed if the principal pipe size is 10 inches or larger. The Pond Spreadsheet will always reduce the peak discharge if the pipe size is 10 inches or larger. The WinPond program allows the user to specify if the peak discharge should be reduced by the pipe flow and should only be used if the pipe size is greater than 10 inches. The SITES model will not use the pipe flow to reduce auxiliary spillway flow for pipes smaller than 10 inches.

The auxiliary spillway design is a combination of both stability and capacity. The spillway and exit channel must be stable against erosion during passage of the design discharge when the vegetation is short due to mowing or grazing. This is normally referred to as a D retardance condition and the design conditions are the exit channel slope and maximum allowable (permissible) velocity. These conditions are used to find the allowable unit discharge (cfs/ft of width) to determine the minimum bottom width of the spillway. The spillway must also have adequate capacity when the vegetation is at its maximum growth, usually a B or C retardance condition. The unit discharge and crest length are used with these retardance conditions to determine the maximum flow depth in the spillway.

Tables 1, 2, and 3-A through 3-E in Exhibit 11-2 in NEH 650, Chapter 11, are used for auxiliary spillway design in the Pond Spreadsheet. Retardance condition A may be used for capacity and retardance condition E for stability, but these are not common in Kansas.

**Example KS11-10** Auxiliary spillway design

Given: Diedrick Farms, Inc. Stockwater Pond, Dickinson County, Kansas

From Example KS11-3: the design peak discharge is 295.3 cfs

Principal spillway pipe: 8-inch diameter

Auxiliary spillway exit channel slope: 4%

Exit channel soils are erosion-resistant

Existing vegetation is a sod-forming mix

Proposed level crest length: 50 feet

There is no reduction due to principal spillway flow since the pipe is less than 10 inches in diameter. Check the exit channel for permissible velocity using D retardance.

The permissible velocity for the given soils, slope, and vegetation is 5 feet/second from Table 1 in Exhibit 11-2 in NEH 650, Chapter 11.

Find the allowable unit discharge for the D retardance condition. The unit discharge per foot of width (q) is 3 cfs/foot for a velocity of 5 feet/second and slope of 4% from Table 3-D in Exhibit 11-2 in NEH 650, Chapter 11.

Minimum width of auxiliary spillway is 295.3 ÷ 3 = 98.4 feet (use 100 feet wide).

Find the maximum depth of flow in the spillway for the B retardance condition. From Table 3-B in Exhibit 11-2 in NEH 650, Chapter 11, maximum depth of flow in spillway is 1.7 feet for a q of 3 cfs/foot and a crest length of 50 feet.

If the auxiliary spillway width of 100 feet is acceptable, design the top of dam to be at least 1 foot higher than the maximum water elevation from the design storm (or 2.7 feet higher) than the auxiliary spillway crest. If site conditions limit the width of the spillway due to rock or other conditions, the discharge may be reduced due to detention storage.

The reduction due to detention storage is always allowed, and each design model will provide a slightly different result due to the different procedures used. The SITES model and WinPond each use a graphical analysis of the inflow hydrograph, outflow hydrograph, and stage-storage information to provide the maximum water surface elevation based on the bottom width and exit channel slope of the auxiliary spillway. The Pond Spreadsheet allows the user to provide an optional design capacity based on the detention storage (Vs) and total runoff (Vr) for the design storm. The optional design capacity (Qo) is determined by multiplying the required discharge or inflow (Qi) by the factor given in Table KS11-5 and a safety factor. Table KS11-5 is the same as Table A in Exhibit 11-4 in NEH 650, Chapter 11, and this method of reducing the required discharge capacity due to detention is used in WinTR55.

The volume of detention storage (Vs) at the auxiliary spillway crest elevation is 0.97 inch from the "Input" tab in the Pond Spreadsheet.

The volume of runoff (Vr) from the 25-year, 24-hour storm is 3.21 inches from the "Storage" tab in the Pond Spreadsheet.

Vs/Vr = 0.97 ÷ 3.21 = 0.30

From Table KS11-5 with Vs/Vr of 0.30, the Qo/Qi factor is 0.47. Multiply this factor times the required discharge and a safety factor (SF) to determine the optional spillway design capacity. A minimum safety factor of 1.1 should be used due to the wide variation of allowable slopes in the tables. The safety factor should not exceed 1.3.

Qo = 0.47 x 295.3 x 1.1 SF = 152.7 cfs

Use the optional design capacity to determine the minimum width of the auxiliary spillway as follows:

152.7 cfs ÷ 3 cfs/foot = 50.9 feet (use 52 as the design width)

This is the method used by the Pond Spreadsheet on the auxiliary spillway tab. These results are conservative, and the SITES model and WinPond will give different results with more specific auxiliary spillway exit channel velocities based on various spillway widths.

Adequate vegetation on the floor and slopes is a key component in the design of the auxiliary spillway. Fencing for livestock exclusion may be required to establish and maintain vigorous growth of desirable vegetation in the spillway. Removal of woody vegetation in the spillway and the outlet area will reduce potential erosion problems during spillway flow events.

## (l) Embankment Design

The embankment of a dam should be designed to be resistant to erosion from runoff and wave attack. The minimum top width and side slope criteria are given in CPS 378 and are repeated here for convenience.

**Minimum top width for dams**

| Total Height of Embankment (feet) | Top Width (feet) |
|---|---|
| Less than 20 | 10 |
| 20 - 24.9 | 12 |
| 25 - 34.9 | 14 |
| 35 or more | 15 |

The upstream slope shall not be steeper than 3:1, and the downstream slope shall not be steeper than 2½:1. Embankments that are not as steep will have less maintenance due to better vegetation and less erosion due to runoff events or damage from livestock. The initial additional costs for flatter slopes on embankments less than 15 feet in height will be minimal and should result in lower maintenance costs. Typical slopes for smaller embankments may be 3:1 or 4:1 on both the upstream and downstream slopes. Embankments greater than 25 feet in height that are constructed of high plastic clay materials (CH) shall not be steeper than 3:1 or shall have a stability berm as part of the embankment cross section. The elevation of the stability berm shall be designed to limit the maximum elevation difference along the 2½:1 slope to 20 feet or less. The stability berm should be at least 10 feet wide to allow for construction and maintenance equipment to operate on the berm.

Embankments shall be constructed of either fine-grained soils (CL or CH) or coarse-grained soils (SC or GC) with adequate clay materials to provide an impermeable embankment. Soils used for embankments shall have adequate moisture to facilitate compactive efforts during construction. Fine-grained soils shall have enough moisture to be plastic, and this is normally within 1 or 2 percent of optimum. This can be measured in the field by rolling a ½-inch or smaller thread between the hands or being able to ribbon out the soil between the thumb and forefinger to a length of at least 1 inch. Coarse-grained soils should have enough moisture so that a ball of soil can be formed in the hand.

The foundation for embankments shall have all vegetation removed prior to placing embankment fill. Any soil containing large amounts of organic material should also be removed prior to placing embankment fill. The moisture in the foundation should meet the same requirements as the embankment. In addition, a cutoff trench should be excavated along or upstream of the centerline of the embankment to remove shallow sand lenses or other pervious materials as determined by the geologic investigation. The cutoff trench should extend into a relatively impervious clay layer or bedrock if possible. A minimum depth of 4 feet is recommended to intercept potential seepage through the uncompacted, near-surface, soil strata. The cutoff trench should extend up the abutments to at least the elevation of the principal spillway or trickle tube. The bottom width of the trench should be large enough to allow construction equipment to operate in the trench during excavation and backfill operations. A minimum width of 10 feet is acceptable if compaction is done with a tamping or sheepsfoot roller. A greater width of at least 14 feet may be required if compaction is completed with rubber-tired equipment so there is adequate space to compact the entire width of the trench bottom. Trench side slopes should be 1:1 unless the depth exceeds the trench bottom width, then slopes should be 1½:1 or flatter. The material used for backfill in the trench should meet the moisture requirements of the embankment and be the most impervious materials available as fill.

The embankment will need to be constructed to a greater elevation than the minimum design elevation to account for settlement in the foundation and embankment fill. The minimum design elevation is also referred to as the settled top of dam elevation. The difference between the constructed and settled elevation should be at least 5% of the height of dam unless detailed soil mechanics analysis or experience indicates a lesser amount is adequate. The settlement amount can be calculated at each staked location or significant change in fill height. This will result in a constructed top of dam that is not uniform across the centerline profile. When this method is used, the side slopes of the embankment are calculated based on the settled top of dam elevation. The constructed slopes will be steeper and not be uniform along the centerline of the dam. Checkout of the embankment is slightly more difficult in that the constructed slopes are not uniform and change with the amount of fill in the embankment.

Another method is to calculate the maximum settlement required at the deepest section and maintain that top of dam elevation across the entire profile except for the last 50 feet on each end. The side slopes of the embankment are usually based on the constructed top of dam elevation and are uniform along the profile except for the ends of the dam. The payment quantity using this method results in more volume than the other method, but typically the unit cost is lower for the owner since the contractor is actually getting paid for all of the material being placed.

In both cases, the settled top of dam is also the designed top of dam elevation and must be at least 1 foot above the maximum water surface elevation during the design storm. The maximum water surface elevation is the auxiliary spillway crest elevation plus the depth of flow in the auxiliary spillway during the design storm. The elevation difference between the design top of dam and the maximum water surface is referred to as freeboard. In addition, the designed top of dam must be at least 2 feet higher than the auxiliary spillway crest elevation for dams with more than 20 acres of drainage area or more than 20 feet in effective height. Effective height is the difference between the elevation of the auxiliary spillway crest and the lowest point on natural ground along centerline of the embankment. See Example KS11-10 for setting the top of dam elevation based on maximum flow depth in the auxiliary spillway.

The upstream slope of the embankment may require additional protection due to wave action. The type and amount of protection is normally a function of the size of the pool at normal water levels and the orientation of the dam to the prevailing wind direction. Prevailing wind directions in Kansas are south, southeast, north, and northwest. The fetch length of the pool is defined as the maximum straight line distance of open water to any point on the face of the dam. Dams that face a prevailing wind direction with more than 500 feet of fetch will require additional erosion protection for wave action. A procedure has been developed to determine the type of wave erosion protection needed based on several contributing factors. Figure KS11-12 shows the state divided into 3 zones. These zones represent general areas with high, moderate, and low wind velocity and duration. It also roughly divides the state into zones of rainfall, elevation, and climatic severity—all of which affect the degree of required vegetative protection.

(1) Fetch–Assigned value is the fetch length (maximum straight line distance from any point on the reservoir water surface to any point on the face of the dam) in feet divided by 100. Example:

$$\text{Fetch} = \frac{2000}{100} \text{ feet} \quad \text{Value} = 20$$

(2) Exposure (direction from which waves strike the dam)

| | |
|---|---|
| N, S, NW, or SW | 50 |
| W, NE, and SE | 40 |
| E | 30 |

(3) Soil plasticity index (PI) in upstream face of dam where wave erosion will normally occur

| | |
|---|---|
| 0 - 6 | 50 |
| 6 - 10 | 30 |
| 10 - 15 | 10 |
| > 15 | 0 |

(4) Constant water surface (relative to normal pool elevation)

| | |
|---|---|
| Minor fluctuation | 0 |
| Intermediate | 25 |
| Extreme fluctuation to a lower elevation | 50 |

(5) Vegetative effectiveness (ability of vegetation to grow vigorously)

| | |
|---|---|
| Low | 20 |
| Moderate | 10 |
| High | 5 |

(6) Trees and overlooking high ground (topography and trees around reservoir area)

| | |
|---|---|
| Flat slopes, no trees | 10 |
| Moderate slopes, no trees | 8 |
| Steep slopes, no trees | 6 |
| Flat slopes with > 75% trees | 4 |
| Moderate slopes with > 75% trees | 2 |
| Steep slopes with > 75% trees | 0 |

(7) Other–Values 20 to 0 depending upon recreational usage, dispersion, soil deficiency, and other adverse factors

The wave erosion treatment needed should be based on the sum of the influencing factor values and the allowable limits as follows:

| Zone | Vegetative Slope Protection | Armored Slope Protection |
|---|---|---|
| Eastern | Less than 130 | More than 130 |
| Central | Less than 120 | More than 120 |
| Western | Less than 110 | More than 110 |

Vegetative slope protection will apply to the "Vegetative Treatment of Upstream Berms" portion under "Earth Dams" in Section 8 (Specific Treatment for Critical Areas) of Kansas Construction Specifications 342, Critical Area Planting. Figure KS11-13 will be used as a guide to select an upstream cross section for vegetative treatment.

Armored slope protection will apply to the use of quality rock riprap, sand-gravel slope protection, or other armored slope protection. The selection of rock riprap, sand gravel beaching slope, or other armoring alternatives will usually be based upon the best economical design. The design of this slope protection will be in accordance with procedures approved by the state conservation engineer.

**Example KS11-11** Wave erosion protection design

Given: Diedrick Farms, Inc. Stockwater Pond, Dickinson County, Kansas

Fetch length = 800 feet

Reservoir lies in a northerly direction above the dam.

Soil in embankment is a clay (CL) material with PI about 12. Water surface is expected to lower about 1 foot during the summer in periods of near-normal rainfall.

Vegetation will be relatively sparse.

Reservoir area is in a moderately deep, wide valley with no trees–topography will have little effect on wind velocity.

No power boats or other wave-generating recreational equipment is expected.

Find the type of wave protection needed using the following:

| Factor | Value |
|---|---|
| Fetch = 800 feet | 8 |
| Direction of exposure = N | 50 |
| Soil PI = 12 | 10 |
| Water surface fluctuation is minor | 0 |
| Vegetative effectiveness is low | 20 |
| Trees and overlooking high ground | 8 |
| Other | 0 |
| Total | 96 |

From Figure KS11-12, the dam is in the eastern zone where a summation of values less than 130 indicates vegetative measures will provide adequate slope protection. Since fetch is 800 feet, a 10-foot or wider berm at normal pool elevation should be considered (see Figure KS11-13) with vegetative plantings as suggested in CPS 342 and Construction Specifications 342. The berm may be level or graded slightly toward the pool to reduce ponded areas. The slope of the berm should be 10:1 or flatter.

## KS650.1182 Excavated Ponds

### (a) All Ponds

Excavated ponds are constructed in areas with higher evaporation, less annual runoff, or with flat topography that is unsuitable for embankment ponds. They may also be constructed in an area with groundwater near the surface if there is an impermeable layer available for the bottom of the excavation. A geologic investigation should be completed to determine if groundwater exists and the suitability of the soils for water storage. Ponds constructed in wet areas with a high water table should also have a wetland determination completed as part of the planning process.

The side slopes of excavated ponds shall be stable and not subject to sloughing when saturated. Side slopes shall be 3:1 or flatter to allow excavation by equipment such as a dozer or scraper. If the pond is to be constructed using an excavator due to wet conditions, the side slopes can be 2:1—but no steeper—to minimize the amount of excavation. For all ponds, if livestock will have access to the pond, at least one slope—typically an end slope—must be 4:1 or flatter. It is recommended that the access slope be protected using the criteria in CPS 561, Heavy Use Area Protection. This will reduce potential erosion of the slope and sedimentation of the pond. This slope can also serve as the inlet protection where surface water enters the pond (if needed).

The minimum required depth of excavated ponds is 5 feet, and the recommended depth is 8 to 10 feet. The minimum required bottom area at 5 feet of depth is 500 square feet for ponds where surface runoff is the primary source of water. If the pond depth is greater, the bottom area may be decreased to reduce the total required excavation as long as the area at 5 feet of depth is at least 500 square feet. Typically these types of ponds will have a total excavated volume between 2500 and 3000 cubic yards. Where groundwater is the primary source of water, the minimum area at 5 feet of depth is reduced to 200 square feet. The typical volume of these types of ponds is 1500 to 2000 cubic yards. Tables KS11-7 and KS11-8 have information on excavated volumes for various bottom areas and side slopes. The beneficial use, sediment storage, and surface evaporation should be considered when determining the planned excavated volume of the pond.

Material excavated from the pond shall be placed where it does not endanger the side slopes of the pond due to the additional weight of the spoil material and where it will not be washed back into the pond by rainfall. In some cases, the material will be hauled to another location to be used as fill material. If not, the recommended disposal method is to uniformly spread the material to a height less than 3 feet to create a small berm around the pond. The top shall be graded so that runoff water is directed away from the pond. The berm can be placed on all sides of the pond except where natural runoff enters the pond. The berm should be graded to allow it to be seeded with a grass drill or similar equipment. This method is best suited for excavated ponds constructed with dozers and scrapers.

Ponds constructed with an excavator due to wet conditions will normally have the spoil material placed in piles at least 12 feet away from the edge of the pond slope. These spoil piles should be reasonably shaped and smoothed to blend visually with the landscape and be able to be seeded by hand methods.

Water supply lines may be installed to downstream watering facilities or to wet wells with submersible pumps installed. Use the guidance in Section KS650.1181(j) to design the water supply line. Seepage control for these lines is not required unless the conduit is larger than 8 inches in diameter. A control valve may not be required if the supply line is to a wet well.

## (b) Excavated Ponds with Embankments

The material from excavated ponds may also be used to construct low embankments. Low embankments are defined as having less than 8 feet of earthfill above the channel bank or less than 10 feet of earthfill above the lowest point along the centerline of the embankment. Excavated ponds with a designed low embankment are suited for valleys with steeper grades. The bulk of the storage is determined by the excavated quantity, but additional capacity is available by constructing an embankment. These “modified” excavated ponds are considered embankment ponds if the depth of water impounded against the embankment at the auxiliary spillway crest elevation is 3 feet or more. The design must include a trickle tube or principal spillway.

Use the guidance in Sections KS650.1181(e), (f), and (g) to determine the required size and material to be used for the conduit along with the inlet and outlet requirements. Seepage control must be provided if the conduit has a smooth exterior and a diameter larger than 8 inches or if the conduit has a corrugated exterior and a diameter larger than 12 inches. Use the guidance in Section KS650.1181(h) to design the required seepage control.

An auxiliary spillway must be designed for these modified ponds that will meet the capacity requirements of Table 5 in CPS 378. Use the guidance in Section KS651.1181(k) to determine the required width of the auxiliary spillway. The reduction in required capacity of the spillway due to detention may be used if a topographic map and stage-storage table are developed. If the map and table are not developed, then the spillway must have the capacity to safely pass the peak flow from the design storm in Table 5 in CPS 378.

The embankment shall have a minimum top width of 10 feet, and the side slopes shall be 3:1 or flatter. No cutoff trench is required for the embankment, but the foundation should be stripped of all vegetation and unsuitable materials. The minimum elevation of the designed top of dam shall be 1 foot above the water surface in the reservoir with the auxiliary spillway flowing at design depth. The minimum elevation difference between the crest of the auxiliary spillway and the designed top of dam shall be 2 feet if the drainage area is greater than 20 acres. The constructed top of dam elevation shall be at least 0.5 foot higher than the designed top of dam elevation to account for any settlement. Typically, the design dimensions of the embankment are adjusted based on the volume of excavation in the pond.

**Table KS11-2** Pipe outflow table

This table can be used to determine the minimum pipe outflow requirements for ponds and other detention storage structures based on the total runoff and total detention storage. The pipe outflow unit is cfs/drainage-acre so the table value must be multiplied by the drainage area acres to determine required pipe flow in cfs. Numbers to the left of the line are for interpolation only.

Vs, Storage in Watershed Inches

| Vr, Runoff in Watershed Inches | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.2 | 0.05 | 0 | | | | | | | | | | | | | |
| 0.3 | 0.13 | 0.02 | 0 | | | | | | | | | | | | |
| 0.4 | 0.2 | 0.04 | 0.01 | 0 | | | | | | | | | | | |
| 0.5 | 0.24 | 0.07 | 0.02 | 0.01 | 0 | | | | | | | | | | |
| 0.6 | 0.34 | 0.13 | 0.04 | 0.02 | 0.01 | 0 | | | | | | | | | |
| 0.7 | 0.45 | 0.17 | 0.08 | 0.03 | 0.02 | 0.01 | 0 | | | | | | | | |
| 0.8 | 0.55 | 0.23 | 0.12 | 0.06 | 0.03 | 0.02 | 0.01 | 0 | | | | | | | |
| 0.9 | 0.7 | 0.3 | 0.15 | 0.08 | 0.04 | 0.03 | 0.02 | 0.01 | 0 | | | | | | |
| 1.0 | 0.89 | 0.39 | 0.19 | 0.1 | 0.06 | 0.045 | 0.03 | 0.02 | 0.01 | 0 | | | | | |
| 1.1 | | 0.49 | 0.26 | 0.15 | 0.09 | 0.065 | 0.04 | 0.03 | 0.02 | 0.01 | 0 | | | | |
| 1.2 | | 0.62 | 0.33 | 0.2 | 0.12 | 0.08 | 0.05 | 0.04 | 0.03 | 0.02 | 0.005 | 0 | | | |
| 1.3 | | | 0.45 | 0.26 | 0.17 | 0.11 | 0.07 | 0.055 | 0.04 | 0.03 | 0.02 | 0.005 | 0 | | |
| 1.4 | | | 0.57 | 0.31 | 0.21 | 0.14 | 0.09 | 0.07 | 0.05 | 0.04 | 0.03 | 0.02 | 0.01 | 0 | |
| 1.5 | | | | 0.44 | 0.27 | 0.19 | 0.13 | 0.09 | 0.065 | 0.05 | 0.04 | 0.03 | 0.02 | 0.01 | 0 |
| 1.6 | | | | 0.57 | 0.33 | 0.23 | 0.16 | 0.11 | 0.08 | 0.06 | 0.05 | 0.04 | 0.03 | 0.02 | 0.01 |
| 1.7 | | | | | 0.46 | 0.30 | 0.21 | 0.15 | 0.12 | 0.08 | 0.06 | 0.05 | 0.04 | 0.03 | 0.02 |
| 1.8 | | | | | 0.59 | 0.37 | 0.25 | 0.19 | 0.13 | 0.09 | 0.08 | 0.06 | 0.05 | 0.04 | 0.03 |
| 1.9 | | | | | | 0.51 | 0.34 | 0.23 | 0.17 | 0.07 | 0.10 | 0.08 | 0.06 | 0.05 | 0.04 |
| 2.0 | | | | | | 0.64 | 0.42 | 0.27 | 0.21 | 0.14 | 0.12 | 0.09 | 0.08 | 0.06 | 0.05 |
| 2.1 | | | | | | | 0.54 | 0.36 | 0.27 | 0.19 | 0.15 | 0.11 | 0.10 | 0.07 | 0.05 |
| 2.2 | | | | | | | 0.62 | 0.45 | 0.32 | 0.23 | 0.18 | 0.13 | 0.11 | 0.08 | 0.07 |
| 2.3 | | | | | | | | 0.55 | 0.41 | 0.29 | 0.23 | 0.16 | 0.13 | 0.10 | 0.09 |
| 2.4 | | | | | | | | 0.65 | 0.49 | 0.34 | 0.27 | 0.20 | 0.16 | 0.12 | 0.1 |
| 2.5 | | | | | | | | | | 0.42 | 0.34 | 0.24 | 0.20 | 0.15 | 0.13 |
| 2.6 | | | | | | | | | | 0.49 | 0.39 | 0.28 | 0.23 | 0.17 | 0.14 |
| 2.7 | | | | | | | | | | | 0.47 | 0.35 | 0.28 | 0.21 | 0.18 |
| 2.8 | | | | | | | | | | | 0.69 | 0.41 | 0.33 | 0.25 | 0.21 |
| 2.9 | | | | | | | | | | | | 0.48 | 0.39 | 0.30 | 0.25 |
| 3.0 | | | | | | | | | | | | 0.55 | 0.44 | 0.34 | 0.28 |
| 3.1 | | | | | | | | | | | | | | 0.42 | 0.35 |
| 3.2 | | | | | | | | | | | | | | 0.49 | 0.40 |
| 3.3 | | | | | | | | | | | | | | 0.58 | 0.48 |
| 3.4 | | | | | | | | | | | | | | | 0.55 |

**Table KS11-2 (continued)** Pipe outflow table

Vs, Storage in Watershed Inches (columns); Vr, Runoff in Watershed Inches (rows)

| Vr \ Vs | 1.6 | 1.7 | 1.8 | 1.9 | 2 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.6 | 0 | | | | | | | | | | | | | | |
| 1.7 | 0.01 | 0 | | | | | | | | | | | | | |
| 1.8 | 0.02 | 0.01 | 0 | | | | | | | | | | | | |
| 1.9 | 0.03 | 0.02 | 0.01 | 0 | | | | | | | | | | | |
| 2.0 | 0.04 | 0.03 | 0.02 | 0.01 | 0 | | | | | | | | | | |
| 2.1 | 0.05 | 0.04 | 0.03 | 0.02 | 0.01 | 0 | | | | | | | | | |
| 2.2 | 0.05 | 0.05 | 0.04 | 0.03 | 0.02 | 0.01 | 0 | | | | | | | | |
| 2.3 | 0.07 | 0.05 | 0.05 | 0.04 | 0.03 | 0.02 | 0.01 | 0 | | | | | | | |
| 2.4 | 0.08 | 0.07 | 0.05 | 0.05 | 0.04 | 0.03 | 0.02 | 0.01 | 0 | | | | | | |
| 2.5 | 0.10 | 0.09 | 0.07 | 0.05 | 0.05 | 0.04 | 0.03 | 0.02 | 0.01 | 0 | | | | | |
| 2.6 | 0.11 | 0.01 | 0.08 | 0.07 | 0.05 | 0.05 | 0.04 | 0.03 | 0.02 | 0.01 | 0 | | | | |
| 2.7 | 0.14 | 0.12 | 0.10 | 0.08 | 0.07 | 0.05 | 0.05 | 0.04 | 0.03 | 0.02 | 0.01 | 0 | | | |
| 2.8 | 0.16 | 0.14 | 0.11 | 0.01 | 0.08 | 0.07 | 0.05 | 0.05 | 0.04 | 0.03 | 0.02 | 0.01 | 0 | | |
| 2.9 | 0.20 | 0.17 | 0.13 | 0.12 | 0.10 | 0.08 | 0.07 | 0.05 | 0.05 | 0.04 | 0.03 | 0.02 | 0.01 | 0 | |
| 3.0 | 0.22 | 0.19 | 0.15 | 0.13 | 0.11 | 0.10 | 0.08 | 0.07 | 0.05 | 0.05 | 0.04 | 0.03 | 0.02 | 0.01 | 0 |
| 3.1 | 0.27 | 0.23 | 0.18 | 0.13 | 0.13 | 0.11 | 0.09 | 0.08 | 0.07 | 0.05 | 0.05 | 0.04 | 0.03 | 0.02 | 0.01 |
| 3.2 | 0.31 | 0.26 | 0.20 | 0.17 | 0.14 | 0.12 | 0.10 | 0.09 | 0.08 | 0.07 | 0.05 | 0.05 | 0.04 | 0.03 | 0.02 |
| 3.3 | 0.38 | 0.31 | 0.24 | 0.21 | 0.17 | 0.15 | 0.12 | 0.11 | 0.09 | 0.08 | 0.07 | 0.05 | 0.05 | 0.04 | 0.03 |
| 3.4 | 0.44 | 0.36 | 0.28 | 0.24 | 0.19 | 0.17 | 0.14 | 0.12 | 0.10 | 0.09 | 0.08 | 0.07 | 0.05 | 0.05 | 0.04 |
| 3.5 | | 0.42 | 0.34 | 0.29 | 0.23 | 0.20 | 0.17 | 0.15 | 0.12 | 0.11 | 0.09 | 0.08 | 0.07 | 0.05 | 0.05 |
| 3.6 | | 0.48 | 0.39 | 0.33 | 0.26 | 0.23 | 0.19 | 0.17 | 0.14 | 0.12 | 0.10 | 0.09 | 0.08 | 0.07 | 0.05 |

**Table KS11-3** Canopy inlet dimensions for corrugated pipe

| Pipe Dia (in) | Pipe Grade % | W (in) | L (in) | A degrees | h (ft) |
|---|---|---|---|---|---|
| 6 | 0-5 | 1 1/8 | 3 1/4 | 56 | 0.7 |
| | 5.1-15 | 1 1/4 | 4 7/8 | 45 | 0.8 |
| | 15.1-25 | 1 5/8 | 6 5/8 | 33 | 0.8 |
| 8 | 0-5 | 1 1/2 | 4 3/8 | 56 | 1 |
| | 5.1-15 | 1 5/8 | 6 3/8 | 45 | 1 |
| | 15.1-25 | 2 1/8 | 8 3/4 | 33 | 1.1 |
| 10 | 0-5 | 1 7/8 | 5 3/8 | 56 | 1.2 |
| | 5.1-15 | 2 | 8 | 45 | 1.3 |
| | 15.1-25 | 2 5/8 | 11 | 33 | 1.4 |
| 12 | 0-5 | 2 1/4 | 6 1/2 | 56 | 1.4 |
| | 5.1-15 | 2 3/8 | 9 5/8 | 45 | 1.5 |
| | 15.1-25 | 3 1/4 | 13 1/4 | 33 | 1.6 |
| 15 | 0-5 | 2 7/8 | 8 1/8 | 56 | 1.8 |
| | 5.1-15 | 3 | 12 | 45 | 1.9 |
| | 15.1-25 | 4 | 16 1/2 | 33 | 2.0 |
| 18 | 0-5 | 3 3/8 | 9 3/4 | 56 | 2.1 |
| | 5.1-15 | 3 5/8 | 14 3/8 | 45 | 2.3 |
| | 15.1-25 | 4 7/8 | 19 3/4 | 33 | 2.4 |
| 21 | 0-5 | 4 | 11 3/8 | 56 | 2.5 |
| | 5.1-15 | 4 1/4 | 16 3/4 | 45 | 2.6 |
| | 15.1-25 | 5 3/4 | 23 | 33 | 2.8 |
| 24 | 0-5 | 4 1/2 | 13 | 56 | 2.8 |
| | 5.1-15 | 4 3/4 | 19 1/4 | 45 | 3.0 |
| | 15.1-25 | 6 1/2 | 26 3/8 | 33 | 3.2 |

**Table KS11-4** Canopy inlet dimensions for smooth pipe

| Pipe Dia (in) | Pipe Grade % | W (in) | L (in) | A degrees | h (ft) |
|---|---|---|---|---|---|
| 6 | 0-5 | 1 1/8 | 3 1/4 | 56 | 0.7 |
| | 5.1-15 | 1 1/4 | 4 7/8 | 45 | 0.8 |
| | 15.1-25 | 1 5/8 | 6 5/8 | 33 | 0.8 |
| 8 | 0-5 | 1 1/2 | 4 3/8 | 56 | 0.9 |
| | 5.1-15 | 1 5/8 | 6 3/8 | 45 | 1.0 |
| | 15.1-25 | 2 1/8 | 8 3/4 | 33 | 1.1 |
| 10 | 0-5 | 1 7/8 | 5 3/8 | 56 | 1.1 |
| | 5.1-15 | 2 | 8 | 45 | 1.3 |
| | 15.1-25 | 2 5/8 | 11 | 33 | 1.4 |
| 12 | 0-5 | 2 1/4 | 6 1/2 | 56 | 1.3 |
| | 5.1-15 | 2 3/8 | 9 5/8 | 45 | 1.5 |
| | 15.1-25 | 3 1/4 | 13 1/4 | 33 | 1.6 |
| 14 | 0-5 | 2 5/8 | 8 1/8 | 56 | 1.5 |
| | 5.1-15 | 2 3/4 | 11 1/4 | 45 | 1.8 |
| | 15.1-25 | 3 3/4 | 15 3/8 | 33 | 1.9 |
| 16 | 0-5 | 3 | 8 5/8 | 56 | 1.7 |
| | 5.1-15 | 3 1/4 | 12 3/4 | 45 | 2.0 |
| | 15.1-25 | 4 3/8 | 17 5/8 | 33 | 2.1 |
| 18 | 0-5 | 3 3/8 | 9 3/4 | 56 | 2.0 |
| | 5.1-15 | 3 5/8 | 14 3/8 | 45 | 2.3 |
| | 15.1-25 | 4 7/8 | 19 3/4 | 33 | 2.4 |
| 20 | 0-5 | 3 3/4 | 10 7/8 | 56 | 2.2 |
| | 5.1-15 | 4 | 16 | 45 | 2.5 |
| | 15.1-25 | 5 3/8 | 22 | 33 | 2.7 |

**Table KS11-5** Qo/Qi factors for auxiliary spillway discharge

This table can be used to determine the Qo/Qi factor based on Vs/Vr.

| Vs/Vr | 0.00 | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.07 |
|---|---|---|---|---|---|---|---|---|
| **0.0** | 1.00 | 0.99 | 0.98 | 0.96 | 0.95 | 0.94 | 0.92 | 0.91 |
| **0.1** | 0.87 | 0.85 | 0.84 | 0.82 | 0.81 | 0.79 | 0.78 | 0.76 |
| **0.2** | 0.70 | 0.67 | 0.64 | 0.61 | 0.58 | 0.56 | 0.54 | 0.52 |
| **0.3** | 0.47 | 0.45 | 0.44 | 0.42 | 0.41 | 0.40 | 0.39 | 0.38 |
| **0.4** | 0.35 | 0.32 | 0.30 | 0.28 | 0.26 | 0.24 | 0.23 | 0.21 |
| **0.5** | 0.18 | 0.17 | 0.16 | 0.15 | 0.14 | 0.13 | 0.12 | 0.12 |
| **0.6** | 0.10 | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.07 | 0.07 |
| **0.7** | 0.06 | 0.06 | 0.06 | 0.06 | 0.05 | 0.05 | 0.05 | 0.05 |
| **0.8** | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 |

**Table KS11-6** Water supply flow rates

This table can be used to size the water supply line from a pond to a watering facility based on the length and feet of head over the inlet. Flow rates are in gallons per minute.

| | Pipe Length - feet | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 75 | | | 100 | | | 150 | | | 200 | | |
| H | Pipe Diameter (inches) | | | Pipe Diameter (inches) | | | Pipe Diameter (inches) | | | Pipe Diameter (inches) | | |
| (feet) | 1 1/4 | 1 1/2 | 2 | 1 1/4 | 1 1/2 | 2 | 1 1/4 | 1 1/2 | 2 | 1 1/4 | 1 1/2 | 2 |
| 2 | 7.9 | 12.7 | 27.7 | 6.9 | 11.1 | 24.4 | 5.7 | 9.2 | 20.2 | 4.9 | 8.0 | 17.7 |
| 4 | 11.2 | 18.0 | 39.2 | 9.8 | 15.8 | 34.5 | 8.0 | 13.0 | 28.6 | 7.0 | 11.3 | 25.0 |
| 6 | 13.7 | 22.1 | 48.0 | 12.0 | 19.3 | 42.2 | 9.8 | 15.9 | 35.0 | 8.6 | 13.9 | 30.6 |
| 8 | 15.8 | 25.5 | 55.4 | 13.8 | 22.3 | 48.7 | 11.4 | 18.4 | 40.4 | 9.9 | 16.0 | 35.3 |
| 10 | 17.7 | 28.5 | 61.9 | 15.4 | 24.9 | 54.5 | 12.7 | 20.6 | 45.2 | 11.1 | 17.9 | 39.5 |
| 15 | 21.6 | 34.9 | 75.8 | 18.9 | 30.5 | 66.7 | 15.6 | 25.2 | 55.4 | 13.5 | 21.9 | 48.3 |
| 20 | 25.0 | 40.3 | 87.6 | 21.8 | 35.2 | 77.0 | 18.0 | 29.1 | 63.9 | 15.6 | 25.3 | 55.8 |
| 25 | 27.9 | 45.0 | 97.9 | 24.4 | 39.4 | 86.1 | 20.1 | 32.5 | 71.5 | 17.5 | 28.3 | 62.4 |

**Table KS11-7** Excavated pond volumes (3:1 slopes)

This table can be used to plan the sizes of excavated ponds to fit different locations.

Excavated Pond Volumes (cu yds) 3 :1 slopes

| Bottom Dimensions (ft) | | Depth (ft) | | | | | |
|---|---|---|---|---|---|---|---|
| Width | Length | 5 | 6 | 7 | 8 | 9 | 10 |
| 10 | 30 | 222 | 323 | 448 | 601 | 784 | 1000 |
| 10 | 40 | 269 | 385 | 528 | 702 | 907 | 1148 |
| 10 | 60 | 361 | 509 | 689 | 903 | 1154 | 1444 |
| 10 | 80 | 454 | 634 | 850 | 1105 | 1401 | 1741 |
| 10 | 100 | 546 | 758 | 1011 | 1306 | 1647 | 2037 |
| 10 | 120 | 639 | 883 | 1171 | 1508 | 1894 | 2333 |
| 20 | 20 | 241 | 345 | 474 | 631 | 817 | 1037 |
| 20 | 40 | 370 | 514 | 687 | 891 | 1131 | 1407 |
| 20 | 60 | 500 | 683 | 899 | 1152 | 1444 | 1778 |
| 20 | 80 | 630 | 852 | 1112 | 1413 | 1757 | 2148 |
| 20 | 100 | 759 | 1020 | 1324 | 1673 | 2071 | 2519 |
| 30 | 30 | 389 | 536 | 712 | 921 | 1164 | 1444 |
| 30 | 40 | 472 | 643 | 845 | 1081 | 1354 | 1667 |
| 30 | 60 | 639 | 856 | 1109 | 1401 | 1734 | 2111 |
| 30 | 80 | 806 | 1069 | 1374 | 1721 | 2114 | 2556 |
| 30 | 100 | 972 | 1283 | 1638 | 2041 | 2494 | 3000 |
| 40 | 40 | 574 | 772 | 1003 | 1271 | 1577 | 1926 |
| 40 | 60 | 778 | 1029 | 1319 | 1650 | 2024 | 2444 |
| 40 | 80 | 981 | 1287 | 1635 | 2029 | 2471 | 2963 |
| 40 | 100 | 1185 | 1545 | 1952 | 2408 | 2917 | 3481 |
| 40 | 120 | 1389 | 1803 | 2268 | 2788 | 3364 | 4000 |
| 50 | 50 | 796 | 1052 | 1345 | 1679 | 2057 | 2481 |
| 50 | 60 | 917 | 1203 | 1529 | 1899 | 2314 | 2778 |
| 50 | 80 | 1157 | 1505 | 1897 | 2337 | 2827 | 3370 |
| 50 | 100 | 1398 | 1807 | 2265 | 2776 | 3341 | 3963 |
| 50 | 120 | 1639 | 2109 | 2634 | 3214 | 3854 | 4556 |
| 60 | 60 | 1056 | 1376 | 1739 | 2148 | 2604 | 3111 |
| 60 | 80 | 1333 | 1723 | 2159 | 2645 | 3184 | 3778 |
| 60 | 100 | 1611 | 2069 | 2579 | 3143 | 3764 | 4444 |
| 60 | 120 | 1889 | 2416 | 2999 | 3641 | 4344 | 5111 |
| 60 | 140 | 2167 | 2763 | 3419 | 4139 | 4924 | 5778 |

**Table KS11-8** Excavated pond volumes (4:1 slopes)

This table can be used to plan the sizes of excavated ponds to fit different locations.

Excavated Pond Volumes (cu yds) 4 :1 slopes

| Bottom Dimensions (ft) | | Depth (ft) | | | | | |
|---|---|---|---|---|---|---|---|
| Width | Length | 5 | 6 | 7 | 8 | 9 | 10 |
| 10 | 30 | 302 | 451 | 639 | 873 | 1156 | 1494 |
| 10 | 40 | 358 | 526 | 738 | 997 | 1309 | 1679 |
| 10 | 60 | 469 | 677 | 935 | 1246 | 1616 | 2049 |
| 10 | 80 | 580 | 828 | 1132 | 1495 | 1923 | 2420 |
| 10 | 100 | 691 | 980 | 1329 | 1744 | 2229 | 2790 |
| 10 | 120 | 802 | 1131 | 1526 | 1993 | 2536 | 3160 |
| 20 | 20 | 321 | 473 | 665 | 902 | 1189 | 1531 |
| 20 | 40 | 469 | 668 | 914 | 1210 | 1563 | 1975 |
| 20 | 60 | 617 | 864 | 1163 | 1519 | 1936 | 2420 |
| 20 | 80 | 765 | 1060 | 1412 | 1827 | 2309 | 2864 |
| 20 | 100 | 914 | 1255 | 1661 | 2135 | 2683 | 3309 |
| 30 | 30 | 488 | 691 | 940 | 1240 | 1596 | 2012 |
| 30 | 40 | 580 | 811 | 1090 | 1424 | 1816 | 2272 |
| 30 | 60 | 765 | 1051 | 1391 | 1791 | 2256 | 2790 |
| 30 | 80 | 951 | 1291 | 1692 | 2159 | 2696 | 3309 |
| 30 | 100 | 1136 | 1531 | 1992 | 2526 | 3136 | 3827 |
| 40 | 40 | 691 | 953 | 1267 | 1637 | 2069 | 2568 |
| 40 | 60 | 914 | 1237 | 1619 | 2064 | 2576 | 3160 |
| 40 | 80 | 1136 | 1522 | 1972 | 2490 | 3083 | 3753 |
| 40 | 100 | 1358 | 1806 | 2324 | 2917 | 3589 | 4346 |
| 40 | 120 | 1580 | 2091 | 2677 | 3344 | 4096 | 4938 |
| 50 | 50 | 932 | 1260 | 1645 | 2093 | 2609 | 3198 |
| 50 | 60 | 1062 | 1424 | 1847 | 2336 | 2896 | 3531 |
| 50 | 80 | 1321 | 1753 | 2252 | 2822 | 3469 | 4198 |
| 50 | 100 | 1580 | 2082 | 2656 | 3308 | 4043 | 4864 |
| 50 | 120 | 1840 | 2411 | 3061 | 3794 | 4616 | 5531 |
| 60 | 60 | 1210 | 1611 | 2075 | 2609 | 3216 | 3901 |
| 60 | 80 | 1506 | 1984 | 2532 | 3154 | 3856 | 4642 |
| 60 | 100 | 1802 | 2357 | 2988 | 3699 | 4496 | 5383 |
| 60 | 120 | 2099 | 2731 | 3444 | 4245 | 5136 | 6123 |
| 60 | 140 | 2395 | 3104 | 3901 | 4790 | 5776 | 6864 |

**Figure KS11-1** Map to estimate drainage area

This map can be used as a guide to estimate the approximate size of a drainage area (in acres) required for each acre-foot of storage in an embankment or excavated pond.

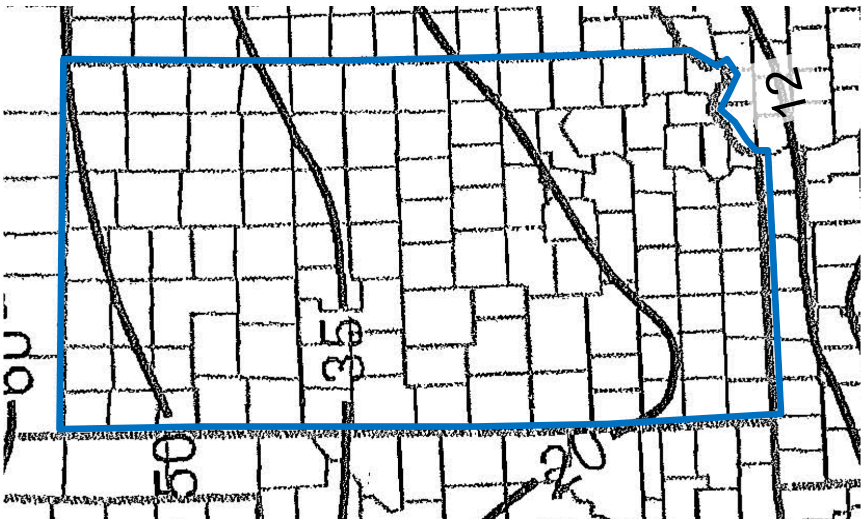



**Figure KS11-2** MLRA map

This map can be used to determine the MLRA for a project. When a site is near the border of two MLRAs, a determination can be made more precisely using the MLRA shapefile in ArcMap.

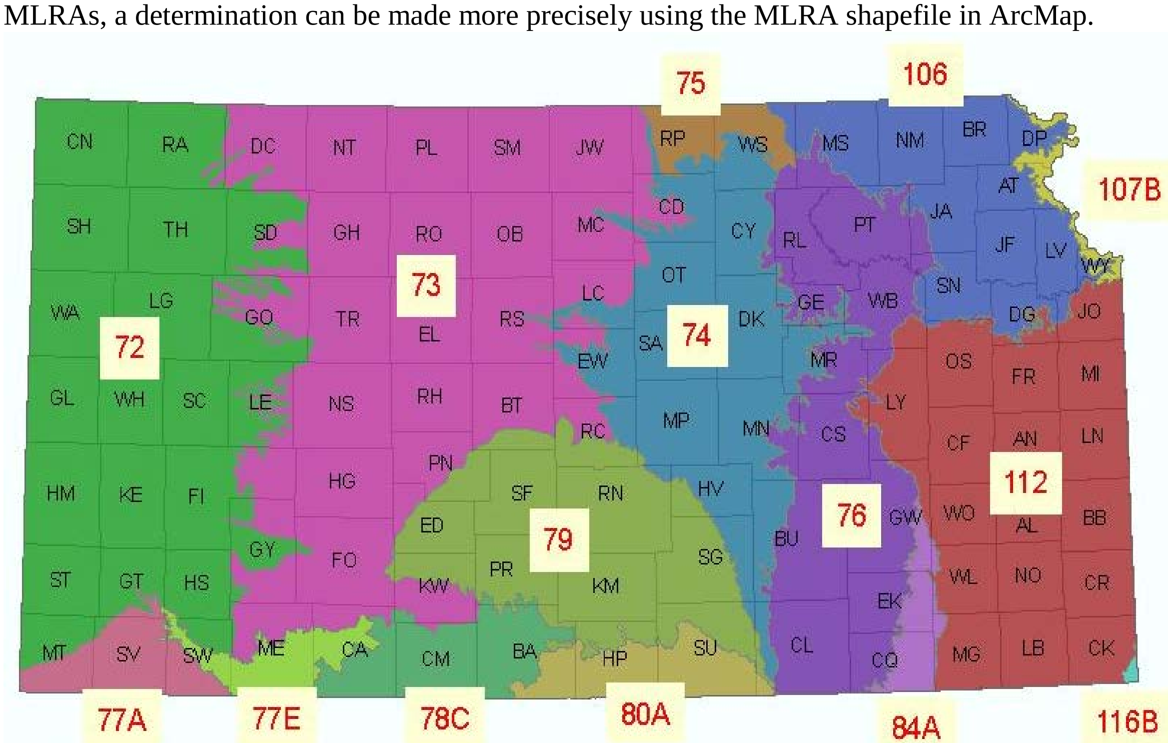
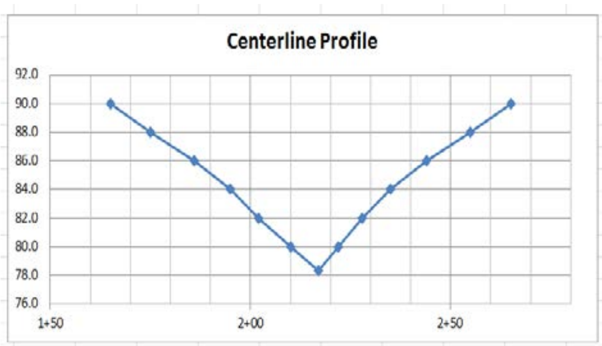


**Figure KS11-3** Example of centerline profile (section) and channel profile for a small dam using channel profile and section to determine stage-storage information



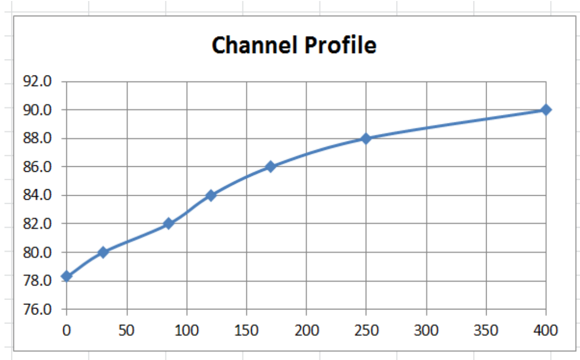




**Figure KS11-4** Example of stage-storage table with outflows and data plotted as a curve

| | Eleva-tion | Area (acres) | Storage (ac-ft) | Total Storage (ac-ft) | Outflow (cfs) |
|---|---|---|---|---|---|
| | 78.3 | 0.0 | 0.0 | 0.0 | |
| | 80.0 | 0.04 | 0.03 | 0.03 | |
| | 82.0 | 0.21 | 0.25 | 0.28 | |
| | 84.0 | .049 | 0.70 | 0.98 | |
| | 86.0 | 0.76 | 1.25 | 2.23 | |
| | 88.0 | 1.18 | 1.94 | 4.17 | |
| | 90.0 | 1.64 | 2.82 | 6.99 | |
| | 92.0 | 2.04 | 3.68 | 10.67 | |
| Principal Spillway | 93.0 | 2.38 | 2.21 | 12.88 | 0.0 |
| | 94.0 | 2.71 | 2.55 | 15.43 | 2.6 |
| | 96.0 | 3.28 | 5.99 | 21.42 | 9.2 |
| Crest Auxiliary Spillway | 97.0 | 3.63 | 3.46 | 24.87 | 9.8 |
| | 98.0 | 3.98 | 3.81 | 28.68 | 420 |
| Top of Dam | 100.0 | 4.67 | 8.65 | 37.33 | 560 |
| | 102.0 | 5.48 | 10.15 | 47.48 | |

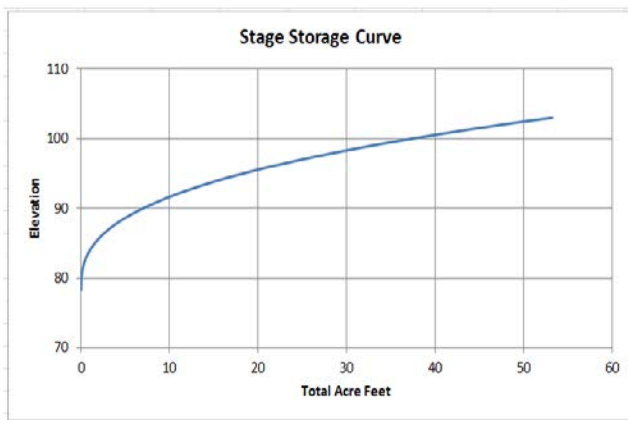


**Figure KS11-5** Example of canopy inlet details

Use with information in Tables KS11-3 and KS11-4 to determine the required dimensions for design—based on the type of pipe and the pipe diameter.

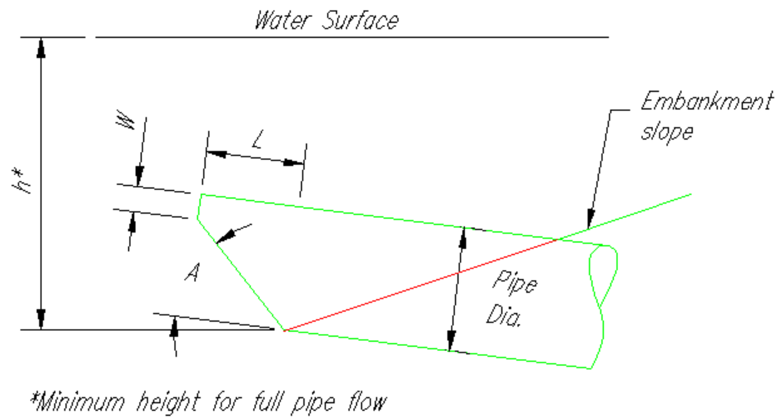



**Figure KS11-6** Dimensions for an unlined stilling basin

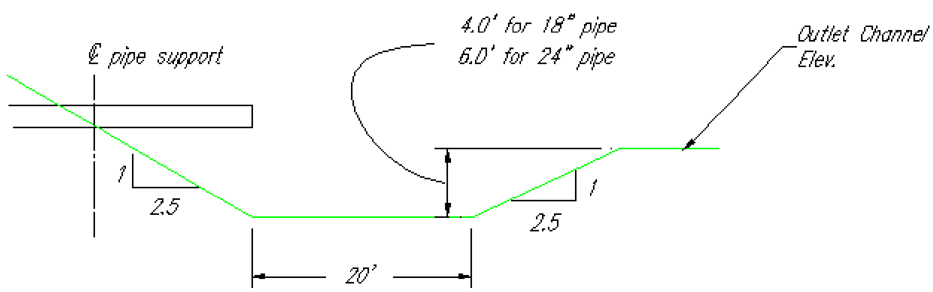



**Figure KS11-7** Minimum dimensions for a filter diaphragm section

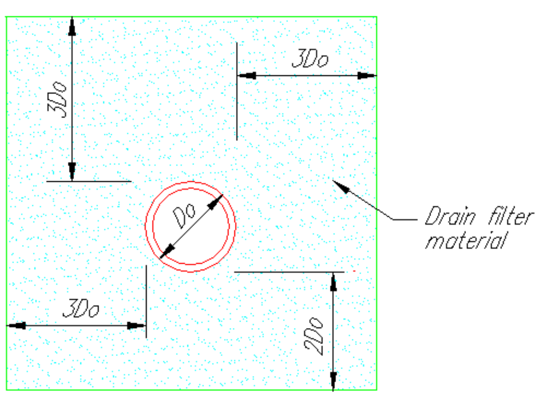
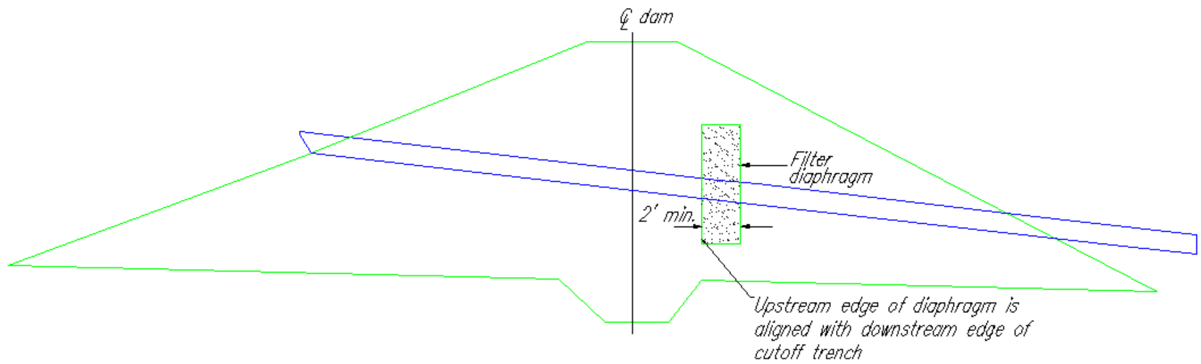
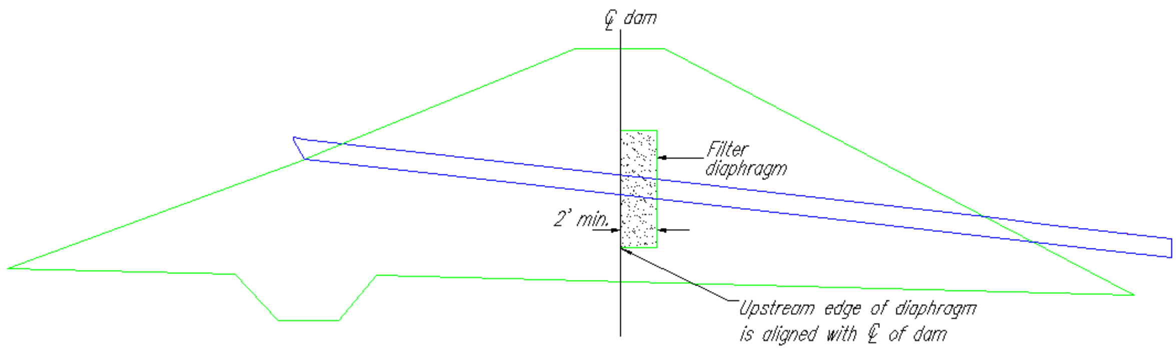


**Figure KS11-8** Dimensions and locations of filter diaphragms based on cutoff trench location




Location of Filter Diaphragm with
Cutoff Trench at ℄ of Dam




Location of Filter Diaphragm with
Cutoff Trench Upstream of ℄ of Dam

**Figure KS11-9** Dimensions to determine required anti-seep collars and location

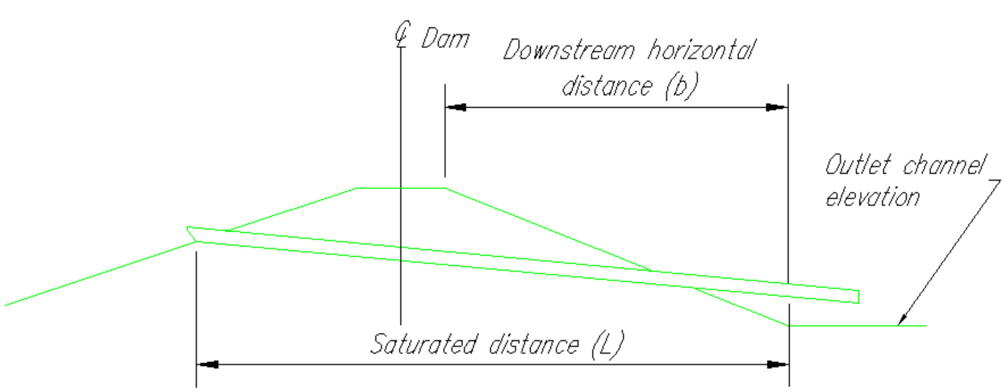


**Figure KS11-10** Options for the strainer inlets of water supply lines

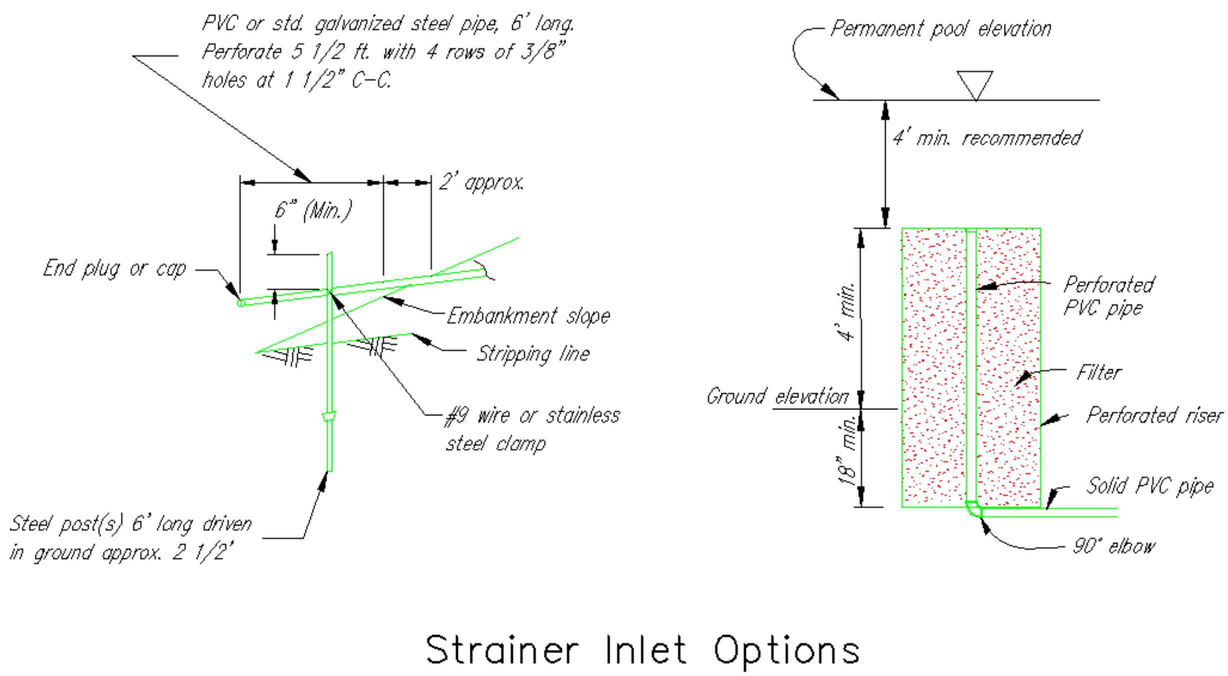



**Figure KS11-11** Detail of typical valve box for water supply line for livestock water

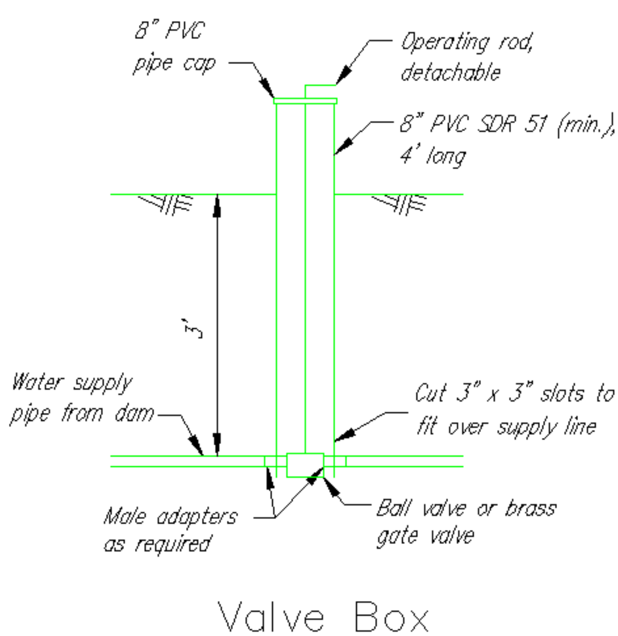


**Figure KS11-12** Slope protection zones—high, moderate, and low wind velocity and duration in Kansas

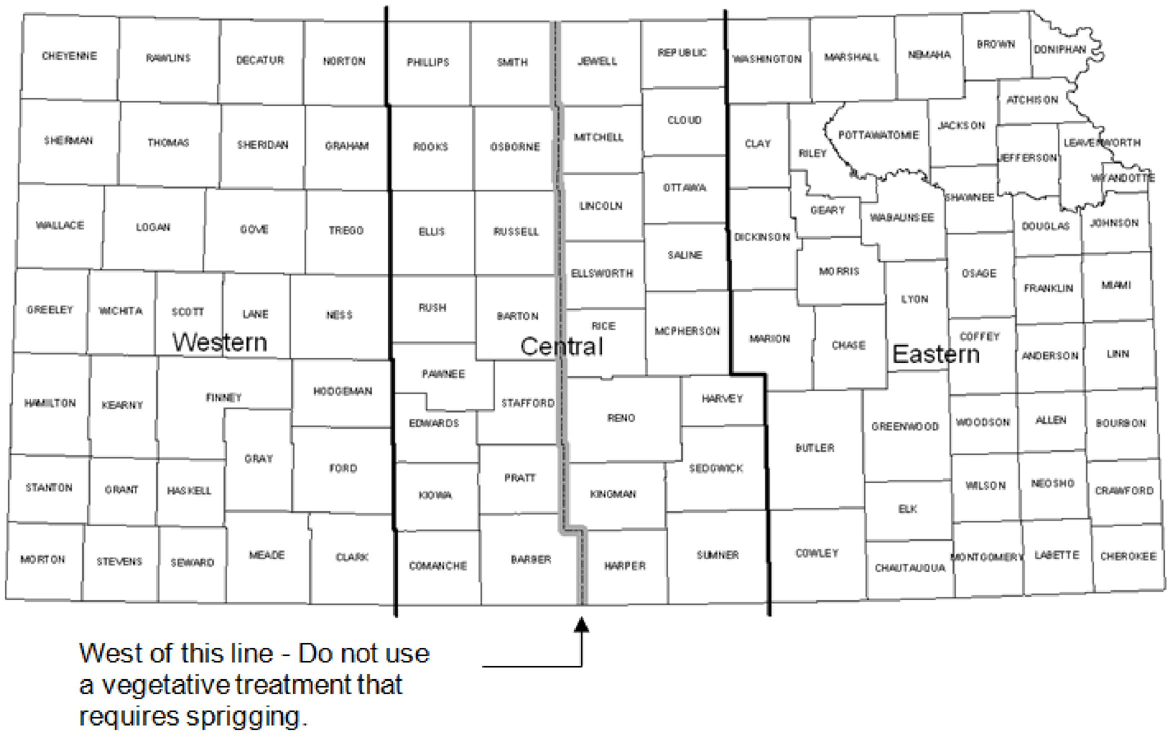


**Figure KS11-13** Recommended cross sections for vegetative slope protection

Use as a guide to select an upstream cross section for vegetative treatment.