**NATURAL RESOURCES CONSERVATION SERVICE**

**CONSERVATION PRACTICE STANDARD**

# GRADE STABILIZATION STRUCTURE

**(No.)**

**CODE 410**

## DEFINITION

A structure used to control the grade and head cutting in natural or artificial channels.

## PURPOSE

To stabilize the grade and control erosion in natural or artificial channels, to prevent the formation or advance of gullies, and to enhance environmental quality and reduce pollution hazards.

## CONDITIONS WHERE PRACTICE APPLIES

This standard applies to all types of grade stabilization structures, including a combination of earth embankments and mechanical spillways and full-flow or detention-type structures. This standard also applies to channel side-inlet structures installed to lower the water from a field elevation, a surface drain, or a waterway to a deeper outlet channel.

This standard does not apply to structures designed to control the rate of flow or to regulate the water level in channels (587), or to structures designed to stabilize the bed or bottom of a continuous flow (non-intermittent) stream channel (584).

This standard applies in areas where the concentration and flow velocity of water require structures to stabilize the grade in channels or to control gully erosion. Special attention shall be given to maintaining or improving habitat for fish and wildlife where applicable.

For embankment dam structures, this standard applies where:

- Failure of the dam will not result in loss of life; damage to homes, commercial or industrial buildings, main highways, or railroads; or in interruption of the use or service of public utilities (Low hazard).
- The product of the storage times the effective height of the dam is less than 3,000. Storage is the volume, in acre-feet, in the pool area below the elevation of the crest of the auxiliary spillway. The effective height of the dam is the elevation difference, in feet, between the auxiliary spillway crest and the lowest point in the original ground cross section taken along the centerline of the dam. If there is no auxiliary spillway, the top of the dam is the upper limit.
- The effective height of the dam is 35 feet or less.

## CRITERIA

### General Criteria Applicable to All Purposes

Design the structure for stability after installation. Set the crest of the inlet at an elevation that stabilizes upstream head cutting. Ensure that runoff from the total design storm can be safely passed through either a combination of a principal spillway and an auxiliary spillway, or a principal spillway.

Grade stabilization structures designed to impound permanent water must meet or exceed the requirements for 378 – Pond.

All federal, State and local requirements must be addressed in the design.

**Utilities and permits.** The landowner and/or contractor shall be responsible for locating all buried utilities in the project area, including drainage tile and other structural measures.

The landowner shall obtain all necessary permissions from regulatory agencies, including the Illinois Department of Agriculture, US Army Corps of Engineers, US Environmental Protection Agency, Illinois Environmental Protection Agency and Illinois Department of Natural Resources – Office of Water Resources, or document that no permits are required.

**Protection.** The exposed surfaces of the embankment, earth spillway, non-cropped borrow/spoil areas, and other areas disturbed during construction must be seeded or sodded as necessary to prevent erosion, according to the criteria in conservation practice standard 342, Critical Area Planting. If climatic conditions or site features preclude the use of vegetation, non-vegetative coverings such as gravel or other mulches may be used.

**Geological Investigations**. Ensure that the soil material proposed for use as fill and for foundation is suitable for the purpose, using soil borings, review of existing data or other suitable means. Characterize materials within the embankment foundation, auxiliary spillway and borrow areas.

**Foundation cutoff.** Provide a cutoff of relatively impervious material under the dam as necessary to reduce seepage through the foundation. For most Illinois soils, grade stabilization structures which do not impound permanent water and with a total height of embankment less than 4 feet will not require foundation cutoff. Locate the cutoff at or upstream from the centerline of the dam. The bottom width of the cutoff trench should be adequate to accommodate the equipment used for excavation, backfill, and compaction operations, and the side slopes of the cutoff trench should not be steeper than one horizontal to one vertical.

**Foundation/Embankment Seepage Control.** Provide seepage control in all embankments over 25 feet high. For embankments less than 25 feet high, seepage control is to be included if (1) pervious layers are not intercepted by the cutoff, (2) seepage could create swamping downstream, (3) such control is needed to ensure a stable embankment, or (4) special problems require drainage for a stable dam. Seepage may be controlled by (1) foundation, abutment, or embankment drains; (2) reservoir blanketing; or (3) a combination of these measures.

**Earth embankment.** The grade stabilization structure must include an embankment or berm to direct flow to the entrance of the principal spillway.

The minimum top width for the embankment is shown in Table 1. If the embankment top is to be used as a public road, the minimum width must be 16 ft for one-way traffic and 26 ft for two-way traffic. Use guardrails or other safety measures where necessary, and ensure that the safety measures meet the requirements of the responsible road authority.

**Table 1. Minimum top width for embankments**

| Total height of embankment* | Top width |
|---|---|
| *feet* | *feet* |
| Less than 4 | 4 |
| 4 – 9.9 | 6 |
| 10 – 14.9 | 8 |
| 15 – 19.9 | 10 |
| 20 – 24.9 | 12 |
| 25 – 34.9 | 14 |
| 35 or more | 15 |

*Top of dam to downstream toe of embankment

**Side slopes.** The upstream and downstream side slopes of the settled embankment must each be no steeper than two horizontal to one vertical. For all embankments with effective height greater than 4 feet, the sum of the upstream and downstream side slope of the settled embankment must be at least 5 horizontal to one vertical. All slopes must be designed to be stable, even if flatter side slopes are required. Downstream or upstream berms can be used to help achieve stable embankment sections.

**Settlement.** Increase the design fill height of the dam by the amount needed to ensure that after eventual settlement, the height of the dam equals or exceeds the design height. This increase must be at least 5 percent of the height of the dam, except where detailed soil testing and laboratory analyses or experience in the area show that a lesser amount is adequate. Use a settlement allowance of at least 10% when fill material is pushed up and compacted by a bulldozer.

**Freeboard.** For structures that include an auxiliary spillway, set the elevation of the top of the settled embankment at least 1 foot above the water surface in the auxiliary spillway flowing at design depth. The minimum difference in elevation between the crest of the auxiliary spillway and the settled top of the dam is 2 feet for all dams having more than a 20-acre drainage area or more than 20 feet in effective height.

For structures where the principal spillway carries the entire design storm without an auxiliary spillway, provide an alternate route for storm flows in excess of the design event without overtopping the dam. This can be done by setting the top of the settled embankment at least 1 foot above the natural ground surface at one or both ends of the embankment. If site topography is too steep, design an opening in natural ground at one end of the embankment at least 10 feet wide and 1 foot lower than the top of the embankment, similar to an auxiliary spillway but without a designed exit slope.

**Auxiliary spillways.** Auxiliary spillways convey large flood flows safely past earth embankments and have historically been referred to as “Emergency Spillways”.

An auxiliary spillway must be provided for each grade stabilization structure, unless the principal spillway is large enough to pass the peak discharge from the routed design hydrograph and the trash that comes to it while meeting the freeboard requirements.

When design discharge of the principal spillway is considered in calculating peak outflow through the auxiliary spillway, the crest elevation of the inlet must be such that the principal spillway design storm discharge will be generated in the principal spillway before there is discharge through the auxiliary spillway.

The minimum capacity of a natural or constructed auxiliary spillway must be adequate to carry the portion of the total design storm for the structure which is not carried by the principal spillway. For structure designs that utilize flood routing, begin routing either with the water surface at the elevation of the crest of the principal spillway or at the water surface after 10 days’ drawdown, whichever is higher. The 10-day drawdown should be computed from the crest of the auxiliary spillway or from the elevation that would be attained if the entire design storm were impounded, whichever is lower. The auxiliary spillway must provide for passing the design flow at a safe velocity to a point downstream where the dam will not be endangered.

Constructed auxiliary spillways are open channels that usually consist of an inlet channel, a control section, and an exit channel. The constructed channel must be trapezoidal, and located in undisturbed or compacted earth or in-situ rock. The side slopes of the auxiliary spillway must be stable for the material in which the spillway is to be constructed. For dams having an effective height exceeding 20 feet, the auxiliary spillway must have a bottom width of not less than 10 feet.

Upstream from the control section, the inlet channel should be level for the distance needed to protect and maintain the crest elevation of the spillway. The inlet channel may be curved to fit existing topography. The grade of the exit channel of a constructed auxiliary spillway must fall within the range established by discharge requirements and permissible velocities.

Spillway dikes or shaped exit channels should be used as needed to ensure that spillway flows remain in the spillway and do not damage the earth embankment. The constructed spillway dike should have a side slope of 2:1 or flatter, a minimum top width of 4 feet and a minimum height of 2 feet above the outlet channel grade.

If a chute or drop structure is used as an auxiliary spillway, design the spillway according to the criteria applicable to open flow structures, except that the design flow will match the requirements for the auxiliary spillway instead of the principal spillway.

## Criteria Applicable to Open Flow Structures

**Full flow open structure.** Design drop, chute, and box inlet drop spillways according to the principles set forth in the National Engineering Handbook (NEH) Part 650, Engineering Field Handbook, and other applicable NRCS publications and reports. The minimum capacity must be that required to pass the peak flow expected from a design storm of the frequency and duration shown in Table 2, less any reduction because of detention storage. If site conditions exceed those shown in table 2, the minimum design 24-hour storm frequency is 25 years for the principal spillway and 100 years for the total capacity. Structures must not create unstable conditions upstream or downstream. Provisions must be made to ensure reentry into the outlet channel of bypassed storm flows.

Toe wall drop structures can be used if the vertical drop is 4 ft or less, flows are intermittent, downstream grades are stable, and tail water depth at design flow is equal to or greater than one-third of the height of the overfall.

Higher overfall structures with semicircular configuration similar to the toe wall drop structure are classified as open weir drop structures rather than toe wall structures because they are designed to handle the entire vertical drop. This structure type may be used where significant structural reinforcement such as double wing walls or waler supports are provided in the design to compensate for the additional structural loading.

Lined chute spillway structures can be used if the flows are intermittent, downstream grades are stable, and tail water depth at design flow is equal to or greater than the entrance flow depth for the structure. Flow velocity in the chute must not exceed stability limitations for the material used to line the chute. Maximum design velocities for selected types of chutes are as follows:

- The velocity in a concrete block chute must not exceed 20 ft/sec for the principal spillway storm flow and 25 ft/sec for the total design storm flow.
- The velocity in a rock chute must remain below the velocity that would displace the rock during the total design storm. Allowable velocities for selected riprap gradations are listed in an Illinois Supplement to the Engineering Field Handbook, Chapter 6.
- The velocity in a chute lined with a manufactured product must meet allowable criteria as specified by the manufacturer.

**Drop box inlet to culvert.** The ratio of the capacity of a drop box inlet to road culvert must be as required by the responsible road authority or as specified in Table 3 (less any reduction because of detention storage), whichever is greater. The drop box capacity (attached to a new or existing culvert) must equal or exceed the culvert capacity at design flow.

Ensure that the dimensions of the drop box inlet to a road culvert are sufficient to prevent submergence of the existing culvert headwall at minimum design capacity, unless the headwall is raised and designed to act as an anti-vortex device. If the culvert wing walls are flared out from the headwall so as to cause restriction of weir flow into the box, remove the flared wing walls to the elevation of the inlet or increase the box dimensions to compensate for the restriction.

**Island-type structure.** For an open flow structure located where the capacity of the downstream channel is less than the requirements in the criteria for full flow open structures, the design capacity of the mechanical spillway must be at least equal to the capacity of the downstream channel or the 2-year, 24-hour runoff event, whichever is greater.

Design the minimum auxiliary spillway capacity equal to that required to pass the peak flow expected from the total capacity design storm shown in Table 2. During this design event, the flow depth through the principal and auxiliary spillway must not overtop the headwall extensions of a mechanical spillway or the lined side slopes at the chute entrance. Make provision for stable reentry of bypassed flow into the outlet channel as necessary.

## Criteria Applicable to Side Inlet Drainage Structures

A side inlet drainage structure is defined as a spillway used to lower surface water from field elevations or lateral channels into deeper open channels in specific landscape areas which have been artificially drained to lower the water table for crop production. The spillway may be an open flow type or a closed conduit. Eligible areas must include all of the following attributes:

- the land is extensively tile drained
- contributing drainage area to the side inlet drainage structure has a very flat land slope (average 1.5% or less.)

- the drainage ditch into which the structure leads has very little grade (approximately 0.2% or less.)
- there is a need for grade stabilization where a side channel enters a main channel.

The minimum capacity of the side inlet drainage structure must be that required to pass the peak flow expected from a design storm of the frequency and duration shown in Table 4, less any reduction because of detention storage. If site condition values exceed those shown in Table 4, the 2-year frequency storm must be used for minimum capacity of the principal spillway, and the 50-year frequency storm must be used for minimum design of total capacity.

**Table 2. Design criteria for establishing minimum capacity of full flow open structures**

| | | Minimum Design Frequency (24-Hour Duration Storm) | |
|---|---|---|---|
| Maximum Drainage Area, acres | Vertical Drop, ft | Principal Spillway Capacity, year | Total Capacity, year |
| 450 | ≤5 | 5 | 10 |
| 900 | ≤10 | 10 | 25 |

**Table 3. Design Capacity For Box Inlets to Culverts**

| Culvert Capacity[1] | Minimum Box Inlet Design Capacity |
|---|---|
| $\leq Q_{50}$ | 1.25 Culvert Capacity |
| $>Q_{50}$ but $\leq 1.5\ Q_{50}$ | 1.25 $Q_{50}$ or culvert capacity, whichever is greater |
| $>1.5Q_{50}$ | Culvert Capacity, not to exceed $1.5Q_{50}$ |

[1]Note: Culvert capacity is capacity calculated using head measured at the lowest point in the top of the road. $Q_{50}$ is the flow experienced in a 50-year, 24-hour duration storm event.

**Table 4. Design criteria for establishing minimum capacity of side-inlet drainage structures**

| | | | Minimum Design Frequency (24-Hour Duration Storm) | |
|---|---|---|---|---|
| Maximum Drainage Area, acres | Vertical Drop, ft | Receiving Channel Depth[2], ft | Principal Spillway Capacity, year | Total Capacity, year |
| 450 | ≤5 | ≤ 10 | 2 | 5 |
| 450 | >5-10 | ≤ 20 | 2 | 10 |
| 900 | ≤5 | ≤ 20 | 2 | 25 |

[2] Maximum in-channel flow depth of the receiving channel in the general vicinity of the structure

## Criteria Applicable to Closed Conduit Structures

**Principal spillway.** The minimum capacity for the closed conduit must be adequate to discharge the runoff from the storm frequency in Table 5 or 6, as applicable, prior to auxiliary spillway flow.

For dams with a drainage area of 20 acres or less, the auxiliary spillway crest elevation must be at least 0.5 feet higher than the principal spillway crest elevation. For dams with a drainage area over 20 acres, this difference must be at least 1.0 feet.

Pipe conduits designed for pressure flow must be provided with adequate anti-vortex devices. The inlets and outlets must be designed to function satisfactorily for the full range of flow and hydraulic head anticipated.

The capacity of the pipe conduit must be adequate to discharge long-duration, continuous, or frequent flows without flow through the auxiliary spillways. The diameter of the principal spillway pipe must be at least 4 inches. Pipe conduits used solely as a supply pipe through the embankment for watering troughs and other appurtenances must be at least 1-1/4 inches in diameter.

For closed conduit grade stabilization structures with a settled total fill height (top of dam to downstream toe of embankment) of less than 15 ft and a drainage area of less than 20 acres, the designer may use the criteria of Conservation Practice Standard 638, Water and Sediment Control Basin. Design the grade control structure to control the peak flow from the 10-year frequency, 24-hour duration storm without overtopping. If the combination of storage and mechanical spillway discharge will handle the design storm, an auxiliary spillway is not required.

**Conduit Material.** The pipe conduit must be designed and installed to withstand all external and internal loads without yielding, buckling, or cracking. Design flexible pipe for a maximum deflection of 5 percent, using the methods outlined in NRCS National Engineering Handbook (NEH) Part 636, Chapter 52, Structural Design of Flexible Conduits. Tables of allowable fill heights for different materials are available as Illinois supplements to the Engineering Field Handbook, Chapter 17. Dual wall plastic pipe (corrugated plastic with smooth interior) is approved for use in fill only where the structure has no permanent pool.

Design the pipe conduit to be water tight by means of couplings, gaskets, caulking, waterstops, or welding. Joints must remain watertight under all internal and external loading, including pipe elongation due to foundation settlement. Connections of flexible pipe to rigid pipe or other structures must accommodate differential movements and stress concentrations. Include a concrete cradle or bedding if needed to provide improved support for the pipe to reduce or limit structural loading on pipe to allowable levels.

Cantilever outlet sections, if used, must be designed to withstand the cantilever load. Provide pipe supports when needed. Other suitable devices such as a Saint Anthony Falls stilling basin or an impact basin may be used to provide a safe outlet.

In areas that have traditionally experienced pipe corrosion, or in embankments with saturated soil resistivity less than 4000 ohms-cm or soil pH less than 5, provide protective coating for steel pipe and couplings. Protective coatings must be compatible with the pipe type, and may be asphalt, polymer over galvanizing, aluminized coating, coal tar enamel, or an alternative product approved by the State Conservation Engineer. Plastic pipe that will be exposed to direct sunlight must be ultraviolet-resistant and protected with a coating or shielding, or provisions provided for replacement as necessary.

**Table 5. Spillway Capacity Requirements – Non Permit Dams**

| | | | Minimum Design Frequency (24-Hour Duration Storm) | |
|---|---|---|---|---|
| Drainage Area, acres | Effective Dam Height[3], ft | Storage[3], ac-ft | Principal Spillway, year | Auxiliary Spillway, year |
| 0-20 | 0-20 | <50 | 5 | 10 |
| 0-20 | 21-35 | <50 | 10 | 25 |
| >20 | 0-35 | <50 | 10 | 25 |
| All Others | 0-35 | ≥50 | 25 | 50 |

[3]As defined under "Conditions Where Practice Applies"

**Table 6. Spillway Capacity Requirements – Permit Dams[6]**

| | | | Minimum Design Frequency (24-Hour Duration Storm) | |
|---|---|---|---|---|
| Drainage Area, acres | Dam Height[4], ft | Impounding Capacity[5], ac-ft | Principal Spillway, year | Auxiliary Spillway, year |
| All | All | All | 25 | 100 |

[4] Dam height is the elevation difference measured from the natural ground at the downstream toe to the top of the embankment.

[5] Impounding capacity is the volume in the pond below the top of the embankment.

[6] Permit dam requirements are listed in Illinois Administrative Code (Reference 1)

**Cathodic protection.** Cathodic protection is to be provided for coated welded steel and galvanized corrugated metal pipe where soil and resistivity studies indicate that the pipe needs a protective coating, and where the need and importance of the structure warrant additional protection and longevity. If cathodic protection is not provided for in the original design and installation, electrical continuity in the form of joint-bridging straps should be considered on pipes that have protective coatings. Cathodic protection should be added later if monitoring indicates the need.

**Seepage control.** Seepage control along a pipe conduit spillway must be provided if any of the following conditions exist:

- The effective height of dam is greater than 15 feet.
- The conduit is of smooth pipe larger than 8 inches in diameter.
- The conduit is of corrugated pipe larger than 12 inches in diameter.

Seepage along pipes extending through the embankment should be controlled by use of a drainage diaphragm, unless it is determined that anti-seep collars will adequately serve the purpose.

Anti-seep collars will be considered adequate for embankments with a relatively impermeable zone up to permanent pool elevation and for all dry dams.

**Drainage diaphragm.** The drainage diaphragm is to function both as a filter for adjacent base soils and a drain for intercepted seepage. The drainage diaphragm should consist of sand meeting the requirements of ASTM C-33, for fine aggregate. If unusual soil conditions exist such that this material may not meet the required filter or capacity requirements, make a special design analysis.

Design the drainage diaphragm at least 2 feet thick. Extend the diaphragm vertically upward and horizontally at least three times the outside pipe diameter, and vertically downward at least 18 inches beneath the conduit invert. Locate the drainage diaphragm immediately downstream of the cutoff trench, but downstream of the centerline of the dam if the cutoff is upstream of the centerline.

Outlet the drainage diaphragm at the embankment downstream toe using a drain backfill envelope continuously along the pipe to where it exits the embankment. Protect drain fill from surface erosion.

**Anti-seep collars.** When anti-seep collars are used in lieu of a drainage diaphragm, ensure a watertight connection to the pipe. Maximum spacing should be approximately 14 times the minimum projection of the collar measured perpendicular to the pipe, but not more than 25 feet. The minimum anti-seep collar spacing is 10 feet. Collar material must be compatible with pipe materials.

Seepage path along the pipe is defined as the shortest length of pipe within the earthfill. The anti-seep collar(s) must increase by at least 15 percent the seepage path along the pipe.

**Trash guard.** To prevent clogging of the conduit, an appropriate trash guard should be installed at the inlet or riser unless the watershed does not contain trash or debris that could clog the conduit.

**Other outlets.** For structures with a permanent pool, provide a pipe with a suitable valve to drain the pool area if needed for proper management or if required by State law. The principal spillway conduit may be used as a pond drain if it is located where it can perform this function.

**Sediment storage.** Sediment storage capacity must be adequate to handle the sediment delivery over the expected life of the structure, unless a provision is made for periodic cleanout.

## CONSIDERATIONS

Earth embankment structures which impound water are potentially hazardous and precautions must be taken to prevent serious injury or loss of life. Protective guardrails, warning signs, fences, or lifesaving equipment should be added as needed.

If the area is used for livestock, the structure, earthfill, vegetated spillways, and other areas should be fenced as necessary to protect the structure. Near urban areas, fencing may be necessary to control access and exclude traffic that may damage the structure or to prevent serious injury or death to trespassers.

**Water Quantity.** Consider effects upon components of the water budget, especially:

- Effects on volumes and rates of runoff, evaporation, deep percolation and ground water recharge.
- Effects of the structure on soil water and resulting changes in plant growth and transpiration.

**Water Quality.** Consider the effects on water quality, especially:

- Ability of structure to trap sediment and sediment-attached substances carried by runoff.
- Effect of structure on the susceptibility of downstream stream banks and streambeds to erosion.
- Effects of the proposed structure on the movement of dissolved substances to ground water.
- Effects on visual quality of downstream water resources.

**Landscape resources.** In highly visible public areas and those associated with recreation, give careful consideration to landscape resources. Landforms, structural materials, water elements, and plant materials should visually and functionally complement their surroundings. Excavated material and cut slopes should be shaped to blend with the natural topography. Shorelines can be shaped and islands created to add visual interest and valuable wildlife habitat. Exposed concrete surfaces may be formed to add texture or finished to reduce reflection and to alter color contrast. Site selection can be used to reduce adverse impacts or create desirable focal points.

## PLANS AND SPECIFICATIONS

Plans and specifications for installing grade stabilization structures must be in keeping with this standard and describe the requirements for applying the practice to achieve its intended purpose. As a minimum, include the following items in the plans and specifications:

1. A plan view of the layout of the grade stabilization structure and appurtenant features.
2. Typical profiles and cross sections of the principal spillway, embankment, and appurtenant features as needed.
3. Structural drawings adequate to completely describe the design details.
4. Requirements for vegetative establishment.
5. Construction and material specifications.

**OPERATION AND MAINTENANCE**

Prepare an operation and maintenance plan for the operator of the grade stabilization structure. As a minimum, address the following items in the operation and maintenance plan:

1. Periodic inspections of all structures, earthen embankments, spillways, safety components, and other significant appurtenances.
2. Eradication or removal of rodents and burrowing animals from the dam.
3. Prompt repair or replacement of damaged components.
4. Prompt removal of sediment when it reaches pre-determined storage elevations.
5. Periodic removal of trees and brush.
6. Maintenance of vegetative protection.

**REFERENCES**

Illinois Administrative Code, Title 17: Conservation, Chapter I: Department of Natural Resources, Subchapter h: Water Resources, Part 3702: Construction and Maintenance of Dams.

USDA-NRCS, National Engineering Handbook, Part 650, Engineering Field Handbook, Chapters 6 and 11.USDA-NRCS, National Engineering Handbook, Section 5, Hydraulics.

USDA-NRCS, National Engineering Handbook, Section 11, Drop Spillways.

USDA-NRCS, National Engineering Handbook, Section 14, Chute Spillways.

USDA-NRCS, National Engineering Handbook, Part 636, Chapter 52, Structural Design of Flexible Conduits.