United States Department of Agriculture

Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

GRADE STABILIZATION STRUCTURE

CODE 410

(no)

DEFINITION

A structure used to control the grade in natural or constructed channels.

PURPOSE

This practice is used to accomplish one or more of the following purposes:

- Reduce erosion
- Improve water quality

CONDITIONS WHERE PRACTICE APPLIES

This practice applies where channels require a structure to stabilize the grade or to control gully erosion.

The product of the storage times the effective height of the structure is less than 3,000, the effective height of the structure is 35 feet or less, and the structure is low hazard potential.

Failure of the structure will not result in loss of life; in damage to homes, commercial or industrial buildings, main highways, or railroads; or in interruption of the use or service of public utilities.

CRITERIA

General Criteria Applicable to All Purposes

Plan, design, and construct this practice to comply with all Federal, State, *Tribal*, and local regulations. *The owner is responsible for obtaining all permits.*

A site assessment shall be conducted, documented, and incorporated into the design. The assessment shall be performed to determine physical site characteristics that will influence the placement, construction, maintenance, and environmental integrity of the proposed structure. The assessment shall include input from the owner/operator. The site assessment shall include:

1. *Locations and elevations of buildings, roads, lanes, soil test pits, property lines, setbacks, easements, springs, wells, floodplains, surface drains, drain tile, utilities, overhead lines, cultural resources, wetlands, and potential contamination sources.*
2. *Test pit logs, soil test results, and a soil survey photo, if available. Test pits or test holes shall include:*
   a. *The number and distribution needed to characterize the subsurface. Key areas to be investigated include the foundation, auxiliary spillway area, and borrow area.*
   b. *The elevation of bedrock and bedrock type, if encountered, such as sandstone, limestone, dolomite, or granite.*
   c. *Saturation indicators, if encountered, such as seepage from sand and gravel lenses, lens*

thickness, and elevation. Ground water maps and well construction logs may be included when available and applicable.

3. *Locations and elevations of sinkholes and other karst features within 500 feet of any impoundment.*
4. *Locations and elevations, soil volumes, soil samples, and reclamation plans of any borrow areas.*
5. *Identification of potential impacts from failure of the embankments, liners, or structures. Document hazard potential classification.*
6. *An estimate or measurement of the base flow rate when present.*
7. *Identification of navigability, water quality and wetland issues by permitting authorities.*

The structure owner must have ownership or legal control of the structure site and impoundment including the right to flood all land in the impoundment up to the 1% flood event. Legal control is usually obtained through permanent easements recorded on the deed of the affected property.

The structure cannot be constructed within 400 feet of an existing or proposed community well. Additionally it cannot be constructed within a horizontal separation distance of 25 feet of an existing or proposed private well, pond, or spring. This distance is measured from the edge of the pond formed during the 1% flood event, unless the well is properly decommissioned in accordance with Wisconsin Administrative Code Chapter NR 812 and Wisconsin NRCS Conservation Practice Standard (WI NRCS CPS) Well Decommissioning (Code 351).

Set the crest of the inlet at an elevation that will stabilize the channel and prevent upstream head cutting.

Design earthen embankments and auxiliary spillways to handle the total capacity flow indicated in Tables 1 or 2 without overtopping any embankment. The foundation preparation, compaction, top width, and side slopes must ensure a stable earthen embankment for anticipated flow conditions.

Provide a minimum sediment storage capacity equal to the expected life of the structure, or provide for periodic cleanout.

Provide measures necessary to prevent serious injury or loss of life such as protective guardrails, warning signs, fences, or lifesaving equipment.

Seed or sod the exposed surfaces of earthen embankments, earth spillways, borrow areas, and other areas disturbed during construction in accordance with WI NRCS CPS Critical Area Planting (Code 342). If climatic conditions preclude the use of seed or sod, use WI NRCS CPS Mulching (Code 484) to install inorganic cover material such as gravel.

Table 1. Design Criteria for Establishing Minimum Capacity of Full-flow Open Structures

Maximum drainage area	*Overfall height* [1]	Frequency of minimum design, 24-hour duration storm*(MSE- 3 or 4 distribution) frequency*	
		Principal spillway capacity	Total capacity [2]
acres	feet	year	year
450	0–5	5	10
900	0–10	10	25
All Others	*All Others*	*25*	*100*
1 For rock chutes, this is measured from the inlet apron to the design elevation of the outlet channel.			

Maximum drainage area	*Overfall height* 1	Frequency of minimum design, 24-hour duration storm*(MSE- 3 or 4 distribution) frequency*	
		Principal spillway capacity	Total capacity 2
acres	feet	year	year
2 For an island type structure, auxiliary spillway flow must be bypassed at a nonerosive velocity for reentry into the downstream channel.			

Table 2. Design Criteria for Establishing Minimum Capacity of Side-inlet, Open-weir, or Pipe-drop Drainage Structure

Maximum drainage area	*Overfall height*	Frequency of minimum design, 24-hour duration storm		
		Receiving channel depth	Principal Spillway Capacity	Total capacity
acres	feet	feet	year	year
450	0–5	0–10	*(Cypress Creek equation):*[1]	5
450	5–10	10–20	(Cypress Creek equation):[1]	10
900	0–10	0–20	(Cypress Creek equation):[1]	25
All Others			(Cypress Creek equation):[1]	*50*

1 (Cypress Creek equation) - Curves for determining runoff for drainage design have been prepared in most of the humid areas of the United States. They are based on the climate, soils, topography, and agriculture of the particular area. See NRCS EFH, Chapter 14.

$Q = C * M^{(0.83)}$

Q = flow in ft³/s for which the drain is to be designed

C = the appropriate drainage curves Use C=37

M = area in mi² of watershed

Embankment dams

Low-hazard dams that have a product of storage times the effective height of the dam of 3,000 ac-ft^2 or more, those more than 35 feet in effective height, and all significant and high-hazard dams must meet or exceed the criteria specified in NRCS Engineering Technical Release (Title 210), 60, “Earth Dams and Reservoirs.”

Low-hazard dams that have a product of storage times the effective height of the dam of less than 3,000 ac-ft^2 and an effective height of 35 feet or less must meet or exceed the requirements specified in WI NRCS CPS Pond (Code 378).

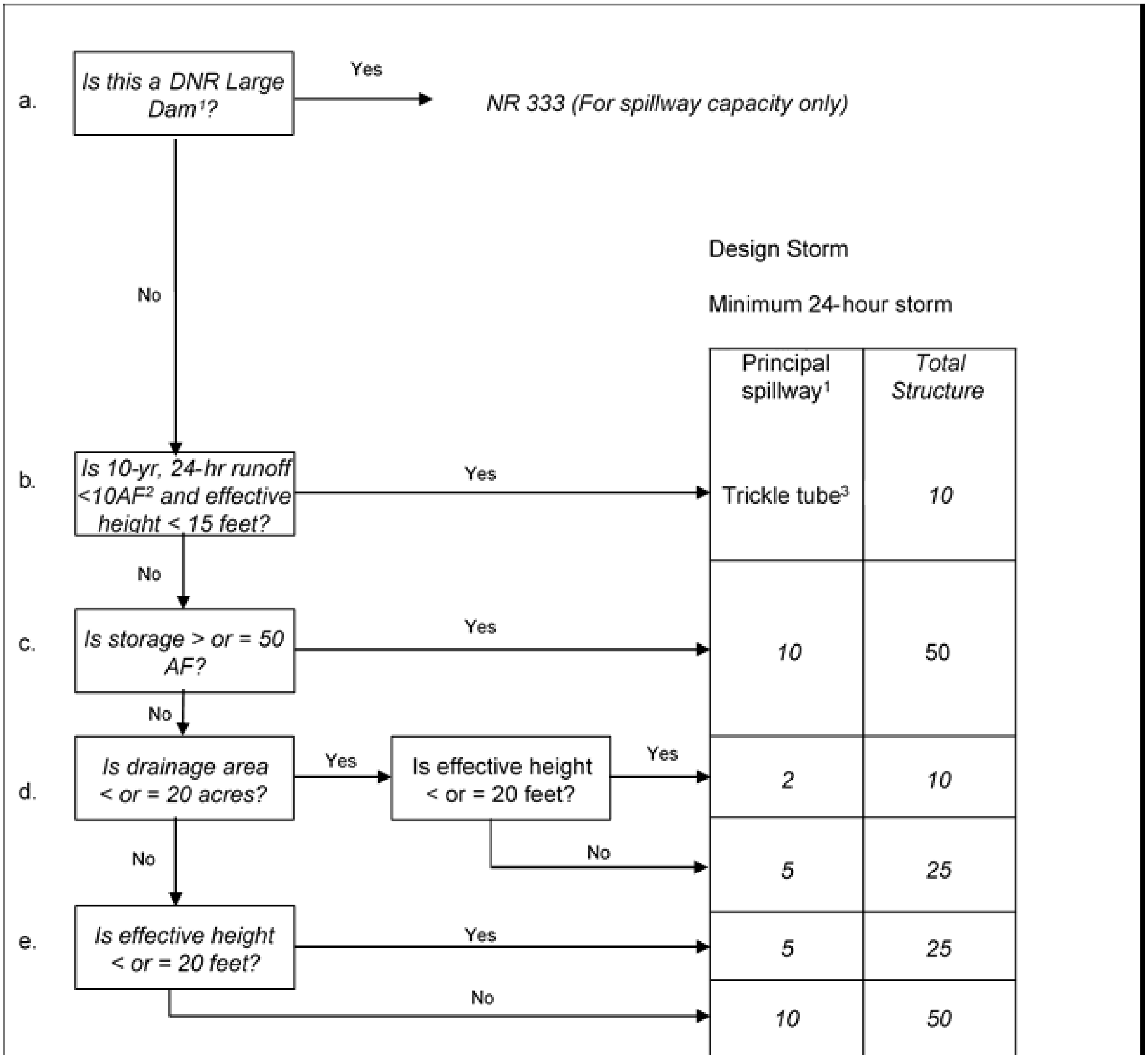
Pond-sized dams

If mechanical spillways are required, the minimum capacity of the principal spillway must convey the peak flow expected from a 24-hour duration design storm of the frequency shown in Table 3, less any reduction from detention storage.

Small pond-sized dams
For dams with an effective height of less than 15 feet and 10-year frequency, 24-hour storm runoff volume less than 10 acre-feet, the designer may use the requirements of WI NRCS CPS Water and Sediment Control Basin (Code 638). 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. *(Table 3, box b)*

Full-flow open structures
Design drop, chute, and box inlet drop spillways to the guidance in the NRCS National Engineering Handbook (Title 210), Part 650, “Engineering Field Handbook” and other applicable NRCS publications and reports. Provide a minimum capacity to pass the peak flow expected from a design storm of the frequency and duration shown in Table 1, less any reduction from detention storage. Structures must not create unstable conditions upstream or downstream. Install provisions for reentry of bypassed storm flows. The ratio of the capacity of drop boxes to road culverts must meet the requirements of the responsible road authority or as specified in Table 1 or 2, as applicable, less any reduction from 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.

Table 3 - Minimum Spillway Capacity for Dams



[1] Consideration should be given to increasing principal spillway design storm frequency to reduce the frequency of the auxiliary spillway's use.
[2] AF = acre-feet
[3] Trickle tube or other type of principal spillway required. If another type of principal spillway is used, it shall meet the separation distances required for a trickle tube. If a trickle tube is used, it shall be a 4-inch diameter minimum conduit, or the size required to pass 2 times the base flow. Trickle tube material shall meet the requirements of NRCS FOTG Standard 620, Underground Outlet

Toewall Drop Structures

Toewall drop structures can only be used if the vertical overfall height is 4 feet or less, flows are intermittent, downstream grades are stable, and tailwater depth at design flow is equal to or greater than *one-third of the overfall height. Toewall drop structures shall be designed according to the principles set forth in NRCS NEH Part 650, EFH, Chapter 6.*

1. *Drainage systems. Drainage systems shall be provided for headwalls and sidewalls of structures having an overfall height of 4 feet or more. Drainage components may consist of collection pipes, "weep" holes, or drain fill material.*
2. *Riprap for drop spillways and toewall drop structures. Riprap shall be placed at least 3 feet upstream and 5 feet downstream from structures with the following dimensions.*
   a. *Drop spillways or toewall drop structures with weir depths 2.5 feet or greater.*
   b. *Drop spillways with an overfall height of 4 feet or greater.*
   c. *Toewall drop structures with overfall heights of 3 feet or greater.*
   If tailwater depth is less than three-fourths of the overfall height, the length of riprap needs to be evaluated. For additional guidance, see NRCS NEH Section 11, Drop Spillways.
3. *Embankment for drop spillways and toewall drop structures. The embankment shall extend at least 1 foot above the headwall extension and have a top width of 6 feet or more. The combined upstream and downstream side slopes shall not be less than 5 horizontal to 1 vertical, and neither slope shall be steeper and 2 horizontal to 1 vertical.*
4. *Headwall elevation for drop spillways and toewall drop structures. The minimum headwall elevation shall be set by adding 0.25 feet to the design flow depth over the weir.*

Gabion Structures

Structures made of rock-filled gabions can be used for vertical overfall heights of 8 feet or less. When available, manufacturer's instructions shall be used in the design for this type of structure. Otherwise, use guidelines for proportioning drop spillways, shown in NRCS NEH Section 11, Standard Drawing ES-67. The following items apply to gabion design:

1. *Aprons or stilling basins shall be installed downstream from the weir to prevent undercutting.*
2. *Structures must be keyed into both banks to prevent flanking during high water.*
3. *Foundations must provide sufficient strength to adequately support the structure.*
4. *The structural components must be tied or stacked so they will act as a unit to prevent overturning or displacement by the action of ice and water.*
5. *Suitable drain fill material or geotextile shall be placed adjacent to the baskets to prevent piping of foundation soil material into the rock-filled gabions.*

Rock Chutes

The cross section of the completed chute shall be trapezoidal. Side slopes shall be 2 horizontal to 1 vertical or flatter.

Chutes shall be designed by using the D50 rock size for a roughness value, allowable velocity, rock gradation and thickness of the rock layer. A minimum factor of safety (FS) of 1.2 shall be used to size the rock. The rock gradation shall be as shown in Table 4.

NRCS NEH Part 650, EFH Chapter 6; American Society of Agricultural Engineers (ASAE) Paper No. 972062, "Design of Rock Chutes"; ASAE Paper No. 982136 "Rock Chutes on Slopes Between 2% and 40%"; or ASAE Paper No. 002008, "An EXCEL Program to Design Rock Chutes for Grade Stabilization" shall be used for the design.

The following criteria apply to all rock chutes:

1. *The rock-lined section must be straight.*
2. *The maximum chute slope shall be 3 horizontal to 1 vertical.*
3. *The minimum depth for the chute shall be the design flow depth needed to pass the design flow through a trapezoidal-shaped, broad-crested weir at the inlet or the depth of the hydraulic jump at the outlet, plus 0.5 feet.*
4. *Inlet apron length shall be a minimum of 10 feet and be flat (0% grade).*
5. *Outlet apron length shall be 15 x D50 (feet) x FS and recessed a minimum of 1 foot below the outlet channel bottom and be flat (0% grade).*
6. *The minimum rock thickness shall be 2 times the D50* rock size.*
7. *A geotextile must be placed beneath the rock. If a sand-gravel bedding is used, the bedding thickness shall be a minimum of 2 inches and placed beneath the geotextile.*
8. *Flow in the upstream channel shall be sub-critical. The upstream channel shall be at least as wide as the chute inlet apron for a minimum of 50 feet upstream of the chute inlet apron.*
9. *The bottom width and side slopes of downstream channels in line with the chute shall be the same as the bottom width and side slopes at the downstream end of the outlet apron. A transition section in the downstream channel at least 50 feet long must be provided for other channel dimensions or configurations. The slope of the downstream channel shall be stable at the design flow for a minimum distance of 100 feet and provide sufficient tailwater on the rock chute.*
10. *Outlets other than in-line channels shall be stable and provide sufficient tailwater at the design flow.*

Table 4 – Rock Gradation

Percent Passing	*Size [1] (in)*
100	*1.5 x D50* — 2.0 x D50**
85	*1.3 x D50* — 1.8 x D50**
50	*1.0 x D50* — 1.5 x D50**
10	*0.8 x D50* — 1.3 x D50**
1 Round up to nearest inch.	

Sod Chutes

Sod chutes shall be designed according to the procedures shown in NRCS NEH Part 650, EFH Chapters 6 and 7. The maximum design velocity shall not exceed 6 feet/second. Sod strips shall extend a minimum of 2 feet on the side slope (measured on the sloping plane) or provide 0.3 feet freeboard above the flow depth, whichever is greater.

Sod chutes which outlet into permanent tailwater or other conditions which will not support continuous vegetation shall be protected from erosion by drop structures, rock riprap or other suitable methods.Turf reinforcement can be used to increase the maximum design velocity. Maximum velocity shall be based on manufacturer's recommendations but not to exceed 10 feet/second for erosion-resistant soils and 8 *feet/second for easily eroded soils as defined in NRCS NEH Part 650, EFH Chapter 7. Installation of the turf reinforcement shall be based on manufacturer's recommendations.*

Island-type structures
Design the minimum capacity equal to the capacity of the downstream channel. Design the minimum auxiliary spillway capacity equal to that required to pass the peak flow expected from a 24-hour duration storm of the frequency shown in Table 1 for total capacity without overtopping the headwall extensions of the mechanical spillway. Make provision for safe reentry of bypassed flow as necessary.

Side-inlet, open weir, or pipe-drop drainage structures
Table 2 provides the design criteria for minimum capacity of open-weir or pipe structures used to lower surface water from field elevations or lateral channels into deeper open channels. Design the minimum principal spillway capacity equal to the design drainage curve runoff for all conditions. If site condition values exceed those shown in Table 2, use the 50-year frequency, 24-hour duration storm for minimum design of total capacity.

CONSIDERATIONS

Provide sufficient discharge to minimize crop-damaging water detention.

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 complement their surroundings visually and functionally. Consider using a diverse mix of native vegetation that is adapted to the site to provide enhanced ecological, habitat, and pollinator benefits. Shape excavated material and cut slopes to blend with the natural topography. Shape shorelines and create islands to add visual interest and wildlife habitat. Form and finish exposed concrete surfaces to add texture, reduce reflection, and to alter color contrast. Select sites to reduce adverse impacts or create desirable focal points.

Consider the effect of the grade control structure on aquatic habitat. For channels supporting fish, consider the effect of the structure on fish passage.

In natural channels, consider the effect of the grade control structure on fluvial geomorphic conditions.

Provide fences to protect structures, earth embankments, and vegetated spillways from livestock. Near urban areas, provide fencing as appropriate to control access and exclude traffic.

PLANS AND SPECIFICATIONS

Prepare plans and specifications for installing grade stabilization structures that describe the requirements for applying the practice according to this standard. As a minimum, include—

- A plan view of the layout of the grade stabilization structure and appurtenant features.
- Typical profiles and cross sections of the grade stabilization structure and appurtenant features as needed.
- Structural drawings, as needed.
- Seeding requirements, as needed.
- Safety features.
- Site-specific construction requirements.

OPERATION AND MAINTENANCE

Prepare an operation and maintenance plan for the operator. As a minimum, include—

- Periodic inspections of all structures, earthen embankments, spillways, and other significant appurtenances.
- Prompt repair or replacement of damaged components.

- Prompt removal of sediment when it reaches predetermined storage elevations.
- Periodic removal of trees, brush, and invasive species.
- Periodic inspection of safety components and immediate repair if necessary.

Require maintenance of vegetative protection and immediate seeding of bare areas as needed.

REFERENCES

USDA NRCS. 2019. Engineering Technical Release (Title 210), 60, Earth Dams and Reservoirs. Washington, D.C. https://directives.sc.egov.usda.gov

USDA NRCS. 2008. National Engineering Handbook (Title 210), Part 628, Dams. Washington, D.C. https://directives.sc.egov.usda.gov

USDA NRCS. 2012. National Engineering Handbook (Title 210), Part 650, Engineering Field Handbook. Washington, D.C. https://directives.sc.egov.usda.gov

American Society of Agricultural Engineers (ASAE), Paper no. 972062, “Design of Rock Chutes.”

American Society of Agricultural Engineers (ASAE), Paper no. 982136, “Rock Chutes on Slopes Between 2% and 40%.”

American Society of Agricultural Engineers (ASAE) Paper No. 002008, “An EXCEL Program to Design Rock Chutes for Grade Stabilization”.

Definitions

1% flood event – A flood determined to be representative of large floods, which in any given year has a 1% chance of occurring or being exceeded. The 1% flood is based on a statistical analysis of lake level or streamflow records available for the watershed or an analysis of rainfall and runoff characteristics in the watershed, or both. This is commonly referred to as the 100 year event or regional flood.

Auxiliary spillway – The auxiliary spillway is the spillway designed to convey excess water through, over, or around a dam. This has been commonly referred to as an “emergency spillway”.

Bedrock – The solid or consolidated rock formation typically underlying loose surficial material such as soil, alluvium, or glacial drift. Bedrock includes but is not limited to limestone, dolomite, sandstone, shale, and igneous and metamorphic rock.

D50 – The D50 rock size is the rock diameter of which 50% of the material by weight is smaller.

D50 – D50* is the specified D50 which equals the designed D50 x factor of safety.*

DNR Large Dam (Table 3) – Any dam with a structural height of more than 6 feet and impounds 50 acre-feet or more of water at the design elevation or has a structural height of 25 feet or more and impounds more than 15 acre-feet of water at the design elevation. Structures meeting this definition must be designed in accordance with the standards of Wisconsin Administrative Code NR 333.

Effective height – The effective height of the dam is the difference in elevation, in feet, between the lowest open channel auxiliary spillway crest and the lowest point in the original cross section taken on the centerline of the dam prior to stripping. If there is no open channel auxiliary spillway, the design elevation for the top of the dam is the upper limit.

Freeboard – Freeboard is the additional depth or elevation required above computed design requirements.

Full-flow open structures – Full-flow open structures are those which must pass the design storm through the principal and auxiliary spillways without creating storage above the design flow's normal depth.

High hazard potential – Dams assigned the high hazard potential classification are those where failure or mis-operation will probably cause loss of human life.

Island-type structure – The island-type structure uses a drop spillway in the channel with auxiliary earth spillways for carrying excess flows around the structure. To prevent washing around the structure, dikes extending each way from the structure must be provided.

Karst – Refers to areas of land underlain by carbonate bedrock (limestone or dolomite). Typical land features in karst areas include sinkholes, disappearing streams, closed depressions, blind valleys, caves, and springs.

Low hazard potential – Dams assigned the low hazard potential classification are those where failure or mis-operation results in no probable loss of human life and low economic and/or environmental losses. Losses are primarily limited to the owner's property.

Overfall height – Vertical drop from the weir crest to the downstream outlet invert.

Principal spillway (Table 3) – The principal spillway is the lowest ungated spillway designed to convey water from the reservoir (pond) at predetermined release rates.

Sediment storage – Sediment storage is the reservoir capacity allocated to total sediment accumulation (submerged and aerated) during the life of the dam.

Side-inlet drainage structures – A structure designed to convey surface water from fields or open areas into drainage ditches.

Significant hazard potential – Dams assigned the significant hazard potential classification are those dams where failure or mis-operation results in no probable loss of human life but can cause economic loss, environmental damage, disruption of lifeline facilities, or can impact other concerns. Significant hazard potential classification dams are often located in predominantly rural or agricultural areas but could be located in areas with population and significant infrastructure.

Sinkholes – Closed, usually circular, depressions that form in karst areas. Sinkholes are formed by the downward migration of unconsolidated deposits into solutionally enlarged openings in the top of bedrock.

Spillway – A spillway is an open or closed channel, conduit, or drop structure used to convey water from a reservoir. It may contain gates, either manually or automatically controlled, to regulate the discharge of water.

Storage – Storage is the capacity of the reservoir in acre-feet below the elevation of the crest of the lowest auxiliary spillway or the elevation of the top of the dam if there is no open channel auxiliary spillway. (From NHCP-378)

Structural height (DNR Large Dam) – The difference in the elevation between the design elevation and the lowest elevation of the natural stream or lake bed at the downstream toe of the embankment.

Trickle tube (Table 3) – A trickle tube is a minimum 4 inch diameter conduit intended to draw down the pool to a level below the auxiliary spillway. The trickle tube discharge is not credited in the design.

Vegetated spillway- A vegetated spillway is a vegetated open channel spillway in earth materials.