NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD
ARIZONA

GRADE STABILIZATION STRUCTURE

(No.)

CODE 410

DEFINITION

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

SCOPE

This standard applies to all types of grade stabilization structures *methods and materials*, including a combination of earth embankments and mechanical *or principal* 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. It does not apply to structures designed to control the rate of flow or to regulate the water level in channels, *per conservation practice* 587, *Structure for Water Control*.

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 practice 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.

This standard applies to erosion control structures constructed of any combination of predominantly natural materials such as rock, soil, brush, timber, posts, or woven wire. Structures may include drop inlets, hood and canopy inlets, chutes, and drop spillways or toewalls.

DESIGN CRITERIA

Conservation practices shall be designed on an individual basis to meet site conditions and functional requirements. They shall be part of an approved and overall engineering plan for irrigation, drainage, wildlife, recreation, channel improvement, or similar purposes.

Design and implementation of subsidiary components and/or structures shall meet all applicable Natural Resource Conservation Service (NRCS) conservation practice standards. The criteria for the design of any components not specifically addressed in NRCS practice standards or specifications shall be consistent with sound engineering principles and/or manufacturer recommendations.

The structure must be designed for stability after installation. The crest of the inlet must be set at an elevation that stabilizes upstream head cutting. *Structures must not create unstable conditions upstream or downstream. Provisions must be made to ensure safe reentry of bypassed flows.*

Laws and Regulations*. This practice must be planned, designed and constructed to meet all federal, state, Tribal and local laws, rules, and regulations. Laws and regulations of particular concern include those involving water rights, land use, pollution control, property easements, wetlands, preservation of cultural resources, and endangered species.*

The owner is responsible for securing necessary permits and water rights, complying with all laws and regulations, and meeting legal requirements applicable to the installation, operation, and maintenance of this practice and associated structures.

Cultural Resources and Wildlife Habitat. *Impact to cultural resources, wetlands and Federal and state protected species shall be evaluated and avoided or minimized to the extent practicable during planning, design and implementation of this conservation practice in accordance with established National policy, General Manual (GM) Title 420-Part 401; Title 450-Part 401, Title 190-Parts 410.22 and 410.26, National Planning Procedures Handbook (NPPH) Florida Supplements to Parts 600.1 and 600.6, National Cultural Resources Procedures Handbook (NCRPH), National Food Security Act Manual (NFSAM), and the National Environmental Compliance Handbook (NECH).*

Embankment dams. Class (a) *(low hazard)* dams that have a product of storage times the effective height of the dam of 3,000 or more, those more than 35 ft in effective height, and all class (b) *(significant hazard)* and class (c) *(high hazard)* dams shall meet or exceed the requirements specified in Technical Release No. 60 (TR-60), *Earth Dams and Reservoirs*.

Class (a) dams that have a product of storage times the effective height of the dam of less than 3,000 and an effective height of 35 ft or less shall meet or exceed the requirements specified for conservation practice standard for ponds (378), *except as described in this standard*.

The effective height of the dam is the difference in elevation, in feet, between the *auxiliary* (*(formerly referred to as* emergency) spillway crest and the lowest point in the cross section along the centerline of the dam. If there is no *auxiliary* (emergency) spillway, the top of the dam is the upper limit.

Earth Embankments*. Design earth embankments to meet the requirements of Arizona NRCS conservation practice standard 378, Pond.*

Earth embankment and auxiliary spillways of structures for which criteria are not provided in Arizona NRCS conservation practice standard 378, Pond or in NRCS Technical Release (TR) No. 60, must be stable for all anticipated conditions. If earth spillways are used, design them to handle the required total capacity without overtopping the embankment. The foundation preparation, compaction, top width, and side slopes must ensure a stable embankment or anticipated flow conditions. Discharge from the structure shall be sufficient that no crop damage results from flow detention.

The combined side slopes of the settled embankment shall be not less than 5 horizontal to 1 vertical (5:1), and neither slope shall be steeper than 2 horizontal to 1 vertical (2:1). Design all slopes to be stable. Where embankments are to be mowed; 3 horizontal to 1 vertical (3:1) or flatter slopes are recommended.

Compaction of the embankment fill material shall be in accordance with the specified design requirements for compaction and moisture content. Maximum thickness of earth fill layers will be 9 inches. If for any reason the designer is of the opinion that more stringent compaction requirements are necessary, percent of standard proctor and moisture limits may be specified. The design height of the embankment shall be increased by the amount needed to ensure that after settlement has taken place, the constructed height of embankment will equal or exceed the design height. This settlement shall not be less than 3 percent for rubber tired pans and scrapers and 5 percent for track type equipment such as bulldozers, except where detailed soil testing and laboratory analysis shows a lesser amount is adequate or field observations indicate a greater amount is needed to obtain the needed level of compaction.

Pond size dams. If mechanical *or principal* spillways are required, the minimum capacity of the principal spillway shall be that required to

pass the peak flow expected from a 24-hour duration design storm of the frequency shown in table 1, less any reduction because of detention storage.

Table 1 – Design criteria for establishing minimum capacity of the principal spillway for dams with storage capacity of less than 50 acre-feet

Maximum drainage area for indicated rainfall [1]			Effective height of dam	Frequency of minimum design, 24-hour duration storm
0 – 3 inches	3 – 5 inches	5 + inches		
----------acres----------			ft	yr
200	100	50	35 or less	2
400	200	100	20 or less	2
400	200	100	20 – 35	5
600	400	200	20 or less	5

[1] In a 5-year frequency, 24-hour duration storm

If the effective height of the dam is less than 20 ft and the *auxiliary* (emergency) spillway has a stable grade throughout its length with no overfalls and has good vegetation along its reentry into the downstream channel, the principal spillway capacity may be reduced but can be no less than 80 percent of the 2-year frequency, 24-hour duration storm.

If criteria values exceed those shown in table 1 or the storage capacity is more than 50 acre-ft, the 10-year frequency, 24-hour duration storm must be used as the minimum design storm.

Grade stabilization structures with a settled fill height of less than 15 ft and 10-year frequency, 24-hour storm runoff less than 10 acre-ft, shall be designed to control the 10-year frequency storm without overtopping. The *principal* (mechanical) spillway, regardless of size, may be considered in design and an *auxiliary* (emergency) spillway is not required if the combination of storage and mechanical spillway discharge will handle the design storm. The embankment can be designed to meet the requirements for water and sediment control basins (638) rather than the requirements for ponds (378).

Erosion Control Dams*. Embankments shall be limited to a vertical height of 15 feet from the upstream toe to the crest of the emergency spillway and must not have more than l0-acre-feet storage at the emergency spillway level unless approved by the State Conservation Engineer. All erosion control dams must have un-gated outlet works such that the structure cannot store more than 2 acre-feet of runoff longer than 36 hours.*

All erosion control dams will have a principal spillway, except where the emergency spillway is non-erosive and the volume of runoff from the principle spillway design storm, (table 1, NHCP 410-5), and sediment can be stored below the crest of the emergency spillway. Principle spillway capacity requirements shall not be reduced for specific site conditions, except as described for structures designed as Water and Sediment Control Basins (638). The principal spillway shall be sized to pass the required amount of storm runoff without flow through the emergency spillway. The crest of the principal spillway shall be set to stabilize the upstream watercourse and drain storm runoff.

Emergency spillways may be natural or constructed. Earth spillways shall be considered non-erosive if the outlet grade has no overfalls, is stable under design flows, and extends downstream to the outlet channel beyond the toe of the embankment. Vegetated emergency spillways shall be used only where appropriate plants can be established within a reasonable time after construction to ensure safety of the structure. Emergency spillways shall be designed using the procedures in Chapter 11 of the Engineering Field Manual. The minimum width of an excavated emergency spillway shall be 8 feet. The type of vegetation, fertilizer, and mulch shall be selected from the critical area planting standard, (342).

Full-flow open structures. *Full-flow open structures are those which must pass the design storm through the principal and auxiliary spillways without flooding the surrounding area. They may consist of formless concrete chutes, gabion chutes drop spillway structures,*

aluminum toewalls, etc. installed in locations where tail water does not affect the discharge capacity for the principal spillway design storm.

Concrete, rock, masonry blocks, steel, plastic and wood are acceptable materials for construction of structures under this standard. The materials shall be durable and appropriate for the intended purpose of the structure.

Straight drop *spillways, drop boxes,* chute *spillways,* and box inlet drop spillways shall be designed according to the principles set forth in the Engineering Field Manual for Conservation Practices, the National Engineering Handbook *Section 11, Drop Spillways and Section 14, Chute Spillways, Arizona* conservation practice standard 587, Structure for Water Control, and other applicable *NR*CS publications and reports. *Minimum capacity for concrete, metal, wood and fiber glass or plastic structures shall be that required to pass the peak flow expected from a design storm of the frequency and duration shown in Table 2.* The minimum capacity shall 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 insure reentry of bypassed storm flows.

Toe wall drop structures can be used if the vertical drop is 4 f*ee*t 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.

The ratio of the capacity of drop boxes to road culverts shall be as required by the responsible road authority or as specified in table 2 or 3, as applicable, 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.

Table 2 – Design criteria for establishing minimum capacity of full-flow open structures

Maximum drainage area for indicated rainfall [1]			Vertical drop	Frequency of minimum design, 24-hour duration storm	
0 – 3 inches	3 -5 inches	5 + inches		Principal spillway capacity	Total capacity
----------acres----------			ft	yr	yr
1,200	450	250	5 or less	5	10
2,200	900	500	10 or less	10	25
All Other				*25*	*100*

[1] In a 5-year frequency, 24-hour duration storm

Table 3 – Design criteria for establishing minimum capacity of side-inlet, open weir, or pipe-drop drainage structures

Maximum drainage area for indicated rainfall [1]			Vertical drop	Frequency of minimum design, 24-hour duration storm	
0 – 3 inches	3 -5 inches	5 + inches		Receiving channel depth	Total capacity
----------acres----------			ft	yr	yr
1,200	450	250	0 – 5	0 – 10	---
1,200	450	250	5 – 10	10 – 20	10
2,200	900	500	0 – 10	0 – 20	25
All other					*50*

[1] In a 5-year frequency, 24-hour duration storm

Structures with flashboard risers shall be designed to handle the design discharge with the water surface below the crest of auxiliary spillway with all the flashboards in place.

Refer to NEH, Part 639, ASAE Paper 972062, "Design of Rock Chutes" for typical rock chute design information.

Rock drop structures and combination log crest and rock apron type flow through structures may be used in series to effectively control head cuts. The effective drop in any structure should not exceed 2 feet and shall not exceed 4 feet.

Geotextile fabric material or a sand/gravel bedding/filter shall be placed between earth and rock/log surfaces unless the existing soil materials meet the requirements for a filter.

Combination rock and brush structures may be used subject to the following limitations: (a) drainage area less than 200 acres (b) channel slope less than 6 percent (c) height from crest of structure to low point in channel along structure is 4 feet or less. The minimum apron length shall be at least 2 times the height of the drop through the structure. The crest width of rock and brush structures shall be at least equal to the height. Structures in series shall be spaced so the design drop of a structure is elevation from weir to weir of next downstream structure. Structures shall be keyed a minimum of 2 feet into the channel banks and a minimum of 1 foot into the channel bottom.

Drop boxes to road culverts shall be as required by the responsible road authority or as specified in Table 2 (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.

Structures used in surface drainage systems to lower water from constructed ditches or laterals into deeper open channels may have the principal spillway capacity based on the design drainage curve in lieu of the frequency shown in Table 2. The total capacity need not be greater than a 50-year frequency for structures in the "all other" category.

The structure design shall include freeboard in the amount suggested in the NRCS references or 0.25 foot. Freeboard is the additional height of the headwall extension or sidewall above the head of the design storm flowing over the crest of the inlet.

When earth spillways are used, the principal spillway plus the earth spillway must be designed to handle the total capacity indicated in Table 2. The flow depth in the earth spillway shall not exceed 1 foot, and a minimum freeboard of 1 foot shall be provided between the maximum water surface and the top of the embankment.

Embankment shall extend a minimum of 1 foot over the top of the headwall extension or sidewall and have side slopes no steeper than 3:1 and a minimum top width of 6 feet. Excavations must be stable for all anticipated conditions. Side slopes shall be no steeper than 2:1.

Island-type structures. *Island-type structures are a special case of full-flow structure. For island-type structures, out of bank flooding can be tolerated. Consist of full-flow open structures installed in locations where downstream tailwater conditions limit the structure capacity prior to the passage of the principal spillway storm shown in Table 2. Downstream channel discharge shall be computed using Manning's formula. The minimum anticipated "n" value and the maximum anticipated hydraulic gradient slope shall be used to estimate downstream channel capacity. NRCS approved water surface profile computer programs may be used to evaluate downstream capacities.*

If the mechanical spillway is designed as an island-type structure, its minimum capacity shall equal the capacity of the downstream channel. For channels with very small drainage areas *(less than 40 acres)*, the mechanical spillway should carry at least the 2-year, 24-hour storm or the design drainage curve runoff. The minimum emergency *(auxiliary)* spillway capacity shall be that required to pass the peak flow expected from a design storm of the frequency and duration shown in table 2 for total capacity without overtopping the headwall extensions of the mechanical spillway, *the top of the embankment or side dikes. Side dikes shall extend downstream to a point where re-entry flows will not affect the principal spillway system.* Provision must be made for safe reentry of bypassed flow as necessary.

Detention structures*. Detention type structures are designed to reduce runoff rates in addition to providing grade control. Reduced runoff rates*

result when: the drop structure has sufficient reservoir storage or reservoir surface area to reduce runoff outflow rates (flood routing) or un-gated orifices on a riser release water at rates less than inflow. Un-gated orifices are located at vertical intervals beginning at the riser foundation, release water at rates less than inflow with the balance of inflow going to storage. As runoff waters enter the reservoir or detention basin, out flow begins immediately, but at a lower rate. Outflow rate increases as the head (depth) in the basin increases and additional openings are used. Full principle spillway capacity is reached when orifice flows plus weir flow over the top of the riser are operating at the design water surface. Minimum emergency spillway capacity shall be that shown in Table 3.

Side-inlet drainage structures. 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 are shown in table 3. The minimum principal spillway capacity shall *be* equal *to or greater than* the design drainage curve runoff for all conditions. If site condition values exceed those shown in table 3, the 50-year frequency storm shall be used for minimum design of total capacity *less any reduction creditable to principal spillway discharge and detention storage. Provisions must be made to prevent damage from overtopping the structure and to divert excess flows away from the structure. On structures with drainage areas of 3 acres or less, overtopping of the structure is permitted only if damage will be minor and island type construction will interfere with normal farming operations.*

Design side-inlet structures with flashboard risers to handle the design discharge with the water surface below the crest of the auxiliary spillway with all the flashboards in place.

Earth embankment side slopes may be as steep as 1.5 horizontal to 1 vertical (1.5:1) on pipe island-type or side-inlet drainage structures where the effective height is less than 10 feet and the vertical drop is less than 10 feet from natural ground to channel bottom or normal downstream water level.

A pipe drop used as a side inlet drainage structure is generally a simple structure consisting of a straight, relatively short section of pipe out-letting into a drainage ditch or channel with a headwall or other provision at the inlet to direct flow into the pipe. It is adapted for low head discharge of small quantities of water and fill heights which are normally less than 4 feet above natural ground. The distance measured from the bottom of outlet end of pipe to bottom of outlet ditch or channel should not exceed 2 feet.

When a pipe drop is used to control a headcut or overfall at the end of a lateral drainage ditch, it shall be designed to discharge the design capacity of the lateral ditch plus 25 percent.

Landscape resources. In highly visible public areas and those associated with recreation, careful considerations should be given 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 *and protected as necessary to prevent erosion*. 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.

Seepage Control. *Include seepage control if (1) seepage will create unstable conditions downstream, (2) it is needed to ensure a stable embankment or (3) special circumstances require drainage for a stable structure. Seepage may be controlled by foundation, abutment or embankment drains.*

Drainage Diaphragm. *A drainage or filter diaphragm shall be provided for all pipes or conduits installed through an earthen embankment. The drainage or filter diaphragm*

shall function both as a filter for adjacent base soils and a drain for seepage that it intercepts. The drainage diaphragm shall consist of sand meeting the requirements of ASTM C33, for fine aggregate. If unusual soil conditions exist such that this material may not meet the required filter or capacity requirements, a special design analysis (designed according to National Engineering Handbook, Part 628 Dams, Chapter 45, Filter Diaphragms) shall be made.

The drainage diaphragm shall be a minimum of 2 feet thick and extend vertically upward and horizontally at least three times the outside pipe diameter, and vertically downward at least 18 inches beneath the conduit invert. The drainage diaphragm shall be located immediately downstream of the cutoff trench, but downstream of the centerline of the dam if the cutoff is upstream of the centerline.

The drainage diaphragm shall be outletted at the embankment downstream toe using a drain backfill envelope continuously along the pipe to where it exits the embankment. Drain fill shall be protected from surface erosion.

***Trash Guards**. Where needed to prevent clogging of the conduit, install an approved type of trash rack on the riser of drop inlets. Openings for trash racks shall be no larger than one-half of the barrel conduit diameter, but in no case less than 6 inches. The total cross sectional area of the trash rack openings shall be equal to or greater than the area of the box or riser protected.*

***Anti-vortex Device**. Drop inlet pipe spillways shall be installed with an anti-vortex device where needed to prevent the formation of vortices. Design anti-vortex devices in accordance with ARS publication NC-33, Hydraulics of Closed Conduit Spillways, Part XIV.*

***Materials**. Structures installed under this standard shall be constructed of durable material with a life expectancy equal to the planned life of the structure. Pipe conduits used in grade stabilization structures shall meet the requirements as stated in Arizona NRCS conservation practice standard 378, Pond and applicable Arizona construction and material specifications.*

General criteria. *All components, such as* earth embankments and *auxiliary* (emergency) spillways of structures for which criteria are not provided under the standard for ponds (378) or in TR-60 must be stable for all anticipated conditions. If earth spillways are used, they must be designed to handle the total capacity flow indicated in tables 2 or 3 without overtopping the dam. The foundation preparation, compaction, top width, and side slopes must ensure a stable dam for anticipated flow conditions. Discharge from the structure shall be sufficient that no crop damage results from flow detention.

If peak discharge is reduced due to detention storage, Job Class V or larger dams and inventory size dams shall be flood routed by using SITES, Water Resource Site Computer Analysis Computer Program or other approved method. Stream hydraulics (calculation of velocities assuming uniform or gradually varied flow conditions) is the preferred method for calculating time of concentration (T_c). If T_c is calculated from a published formula, the associated average velocity shall be checked for reasonableness.

A stability analysis of downstream channel shall be made. The structure shall be designed and installed so that anticipated downstream channel degradation will not affect the proper function of the structure.

Sediment Storage. Necessary sediment storage capacity must equal the expected life of the structure, unless a provision is made for periodic cleanout. *Sediment storage will be provided whenever detention storage is used to size the principal spillway conduit. Sediment storage will be based upon the estimated life of the structure and will be allocated to a sediment pool or partially to the detention pool. The state-storage curve used for routing will reflect the*

anticipated accumulation of sediment above the inlet crest.

Safety. The earth embankment pond structures are potentially hazardous and precautions must be taken to prevent serious injury or loss of life. Protective guardrails, warning signs, fences, or lifesaving equipment shall be added as needed.

Excavations over 4 feet shall comply with local, state and federal (OSHA) requirements.

If the area is used for livestock, the structures, 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.

Protection. The exposed surfaces of the embankment, earth spillway, borrow area, and other areas disturbed during construction shall be seeded or sodded as necessary to prevent erosion. *All areas shall be vegetated in accordance with Arizona NRCS conservation practice standard 342, Critical Area Planting*. If climatic conditions preclude the use of vegetation, non-vegetative coverings such as gravel or other mulches may be used.

Vegetation. The exposed surfaces of the embankment, earth spillway, outlet channel, borrow area, spoil, and other areas disturbed during construction shall be seeded. Seedbed preparation, seeding, fertilizing, and mulching shall comply with Conservation Practice Standard 342, Critical Area Planting.

Rock and Brush Structures (410A) on drainage areas less than 200 acres. *The structure must be designed for stability after installation and shall be designed in accordance with:*

- *Available typical designs*
- *Engineering Field Manual, Chapter 10, "Gully Treatment"*
- *Forest Service Research Paper RM-169, Revised 1979 (Structures designed under these criteria shall be approved by the Area Engineer.).*
- *No hydrology or hydraulic computations are usually necessary.*
- *Structures shall have a weir thickness at the crest equal to or exceeding the height of the structure. The height of the structure is measured from the lowest point in the drainage way to the lowest point of the weir crest (notch).*
- *The maximum height of any structure, as defined above, shall not exceed 4 feet.*
- *The side slopes of these structures shall not be steeper than the requirements set forth in Table 1.*
- *The weir shall be designed to direct flows away from the gully banks, with the weir notch width being approximately equal to the current width of the gully bottom. The structure shall be designed to safely pass a minimum flow depth of 1 foot through the weir, without overtopping the structure.*

Allowable Side slopes (H to V)

Rock Type	*Upstream*	*Downstream*
Rectangular Slab Rock or Flagstone, Hand Placed	*½*	*1 ½ to 1*
Angular Rock	*1 to 1*	*1 ½ to 1*
Round Rock	*1 to 1*	*2 to 1*

Rock and Bush Structure (410A) for drainage Areas between 200 and 1,200 acres. *The structure shall be designed in accordance with:*

- *Available typical designs*
- *Engineering Field Manual, Chapter 10, "Gully Treatment"*
- *Forest Service Research Paper RM-169, Revised 1979, (Structures designed under these criteria shall be approved by the Area Engineer.).*
- *Adequate hydrology and hydraulic computations shall be made to assure the stability of the structure for the proposed depth of flow over the weir, rock shape and size, and for the proposed side slopes of the structure.*
- *Available design tables shall be used to size the necessary rock size – side slope combinations.*

Rock Drops. *Rock drops shall apply to channels with grades less than five percent and width less*

than 50 feet, or with grades less than eight percent and width less than 25 feet. Flows shall not exceed 3 ft. over the drop for a 50-year frequency storm. These structures are limited to a maximum drop (F_T) of 4 feet measured from weir to downstream toe; except structures in series, the structures are limited to a drop (F_T) of 4 feet measured from weir to weir.

Loose rock drops shall be designed according to the principles set forth in National Engineering Handbook, Section 5, Hydraulics, and Figure 2 attached.

Filter blankets will be provided by placement of Geotextile fabric on all interfaces of earth and rock riprap.

The rock size shall be determined by using the empirical relationship shown by the curve in Figure 2. D_{75} (percent passing) size rock placed in a row along the downstream crest provides greater stability. Rock should be fairly well graded with no more than 10 percent smaller than 3 inches in size. The total thickness of the rock riprap in the completed structure shall be D_{100} (T). All rock shall be angular or sub-angular. Sub-rounded and rounded rock is not permitted.

For structures in series the drop will be measured weir to weir, (F_T). The upstream slope of the structure shall be no steeper than 2:1. The top width shall be three feet or greater. The downstream slope shall be no steeper then 6:1 for drops to 3 feet. For drops over 3 feet the downstream slope shall be no steeper than 8:1. The length of the apron (A) of the drop shall be a minimum of $2F_T$. The larger rocks shall be placed in the weir section of the drop. The downstream slope

***Rock riprap drop structures**. Rock riprap drop structures can be used in water courses having grades less than five percent and width less than 50 feet, or with grades less than eight percent and width less than 25 feet. Depth of flow over the weir shall not exceed 2 feet for a 50 year frequency storm.*

Maximum drop (F_T) for Grade Control structures is limited to 4 feet measured from weir to downstream toe. For structures in series, the maximum drop (F_T) of 4 feet shall be measured from weir to weir.

Hydraulics of loose rock riprap drops shall be designed according to the principles set forth in National Engineering Handbook, Part 634 Hydraulic Engineering and the National Engineering Field Handbook for Conservation Practices, Chapter 6, Structures. Minimum freeboard shall be 0.5 feet above the water surface at the upstream end of the spillway section flowing at design capacity.

***Grouted rock riprap**. Use of properly designed and installed grouted rock riprap, especially in the spillway crest, chute and apron sections, is a consideration. Typically rock volume and size is lower. At least 50% of the D_{50} rock dimension shall extend above the in place concrete grout.*

Minimum rock size for grouted rock riprap shall be 6 to 9 inches. Larger voids improve concrete placement, however additional mortar is required. Maximum aggregate size for concrete mortar is one half inch. Using a probe type concrete vibrator is strongly recommended. Touching rocks expedites concrete mortar placement.

***Bedding, Filter, or Geotextile Material**. Where used, bedding material shall consist of well graded, clean, sand and gravel, which is not subject to decomposition in air or water and is free from roots and other foreign materials. Bedding materials that also serve as a filter shall be designed according to standard NRCS procedures. Bedding and filter thickness and gradation limits shall be as shown on the drawings or specified on the Construction Requirements Worksheet.*

Geotextile material shall be installed between all rock and earth surfaces, except where bedding or filter sand and gravel is used. However, geotextile may be specified between earth and bedding sand and gravel when filter properties are desirable. The type of geotextile

fabric required shall be stated in the Construction Requirements Worksheet.

A keyway at least 2 feet deep and 4 feet wide shall be installed beneath rock riprap drop structures, except where located on bedrock material. The keyway shall be located approximately perpendicular to the channel centerline, and extend the full width of the structure

D_{75} (percent passing) size rock placed in a row along the downstream sill provides greater hydraulic stability. Thickness of rock riprap in the completed structure shall be D100 (T). All rock shall be well graded, hard, durable, angular or sub-angular rock. Sub-rounded and rounded rock is not permitted.

The upstream slopes shall be no steeper than 2 horizontal to 1 vertical (2:1). Minimum top width of any component shall be 2 feet. Downstream side slopes shall be 3:1. Rock riprap shall extend a vertical distance up the sides of the channel or chute a minimum of 2 feet. Minimum vertical dimension for the apron (stilling basin) is 3 feet.

Investigations, Surveys and Design Criteria
Documentation requirements will be as outlined below, in additional to the documentation requirements of the practice components used in the system.

Conduct a preliminary site assessment or investigation to determine the location(s) of the structures, complexity of the site and may include:

1. *Review of soil borings or geological site investigation, depending on existing site conditions or scope and complexity, to determine site feasibility. Documentation shall include the following, at a minimum:*
   a. *Ground surface elevation of each hole or site and depth to ground water and/or seasonal high water table;*
   b. *Description (silty sand, lean clay, etc.) and classification (SM, CL, etc.)*
   c. *Soil physical and chemical properties and limitations.*
   d. *Determination of foundation materials and borrow source or disposal area.*
2. *Verify appropriate state or local laws for permitting and approval requirements and notify landowner of his/her responsibilities.*
3. *Verification or certification of used materials (if any).*

To adequately plan and layout this practice, a detailed topographic survey is required, that adequately details:

1. *Site topography, as needed to show the physical features of the site, including existing features/practices, field elevations, location of any utilities or markers, etc.*
2. *Centerline profiles and cross sections to establish the centerline or location of the structure; the centerline of auxiliary spillway, from below the inlet section to the base grade of the outlet channel on grade stabilization structures; the centerline of the principal spillway far enough downstream to determine tailwater conditions; upstream and downstream profiles; cross sections at maximum fill section, and cross section of auxiliary spillway.*
3. *A permanent benchmark(s) shall be set and described. Preferably, the elevations and coordinates should be based on a local (assumed) or coordinate system (State or grid) and clearly stated on the plan. Datum may be in the form of Northing and Easting coordinates, or Longitude and Latitude.*

Where applicable, USGS 7.5-minute topographic Quadrangles may be used, provided design analysis verifies minimum criteria are meet at all locations.

The design of a practice is the application of Field Office Technical Guide practice standards, and using experience and judgment in the development of a solution to the problem or the objective. All computations and decisions made during the design of a practice are to be checked by another qualified individual and appropriate notations made. Design computations, calculations or analysis shall meet the following criteria:

1. *Compute the capacity requirements, discharge, frequency, etc. per TR-55, EFM2 or other approved method.*
2. *Design grade and profile, including the ditch or channel bottom and water surface elevations.*
3. *Hydraulic analysis and determinations (capacity of ditch, channel or structure)*
4. *Structural analysis, if applicable*
5. *Construction material estimates (material volume computations), includes estimates of earthwork, pipe, concrete, rock, vegetative components, geotextile and erosion control fabrics, or other appurtenances.*
6. *Subsidiary and applicable components shall be designed in accordance with applicable conservation practice standards (i.e., structures shall meet the requirements of Conservation Practice 587, Structure for Water Control, etc.).*

Installation and Basis of Acceptance. *For construction that does not meet State, OSHA, or Tribal criteria or requirements where deficient construction materials were used, NRCS may consider a waiver request for approval of construction after it has received a signed and sealed construction and/or material exemption from a licensed engineer. Required exemption shall be for installation of materials that do not meet minimum quality criteria as found in applicable Standards, Specifications, ASTM's, AWWA standards, etc.*

Contractors performing work under this practice shall abide by all Federal, State or Tribal laws or criteria, and must be licensed by the state board of technical registers where the work is being implemented.

PLANNING CONSIDERATIONS FOR WATER QUANTITY AND QUALITY

Where conditions preclude or make it difficult to establish vegetative cover, consider using non-vegetative coverings such as rock, geoweb, gabions, interlocking blocks or other type of protection.

Grade stabilization structures with detention storage may affect the volume and rates of runoff, evaporation, deep percolation and ground water recharge.

Grade stabilization structures may trap sediment and sediment attached substances carried by runoff. Consideration should be given to the amount of sediment that will be deposited and allowances made for removal.

In highly visible public areas and those associated with recreation, careful considerations should be given 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.

Consider the susceptibility of downstream stream banks and streambeds to erosion in selecting the type of outlet and in determining the final grade of the outlet channel.

When selecting the design storm frequency at a particular site, consider the potential hazards from damage or failure of the structure during larger runoff events. Select design storm frequency considering construction costs, Operation and Maintenance and replacement costs and potential damages.

Special consideration should be given to maintaining or improving habitat for fish and wildlife where applicable.

Water Quantity

1. Effects on *the water budget, especially* volumes and rates of runoff, *infiltration,* evaporation, *transpiration,* deep percolation and ground water recharge.

2. Effects of the structure on soil water and resulting changes in plant growth and transpiration.
3. *Potential for changes in plant growth and transpiration because of changes in the volume of soil water.*
4. *Effects on downstream flows or aquifers that impact other water uses or users.*
5. *Effects on the volume of downstream flow that could have undesirable environmental, social, or economic impacts.*

***Water* Quality**

1. Ability of structure to trap sediment and sediment-attached substances carried by runoff.
2. Effect of structure on the susceptibility of downstream stream banks and stream beds to erosion.
3. Effects of the proposed structure on the movement of dissolved substances to ground water.
4. Effects on visual quality of downstream water resources.
5. *Effects on wetlands or water-related wildlife habitats.*
6. *Effects on cultural resources.*

Design alternatives presented to the client should address economics, ecological concerns and acceptable level of risk for design criteria as it relates to hazards to life or property.

PLANS AND SPECIFICATIONS

Use Arizona standard drawings to the extent possible. These may be supplemented by additional drawings or specification notes on the drawings to provide full installation instructions.

Construction plans shall include all components needed for the safe operation of the proposed improvements such as railing, fencing, or warning signs as appropriate. The plans shall address operations near existing utilities, trench excavations and any other items related to construction of the structure that may pose a safety risk to those involved.

Development of plans and specifications for installing grade stabilization structures *will be guided by the National Engineering Handbook, Part 650, the Engineering Field Handbook, Chapter 5, and shall be in accordance with the National Engineering Manual, Parts 541 and 542, and* shall be in keeping with this standard, *prepared for each specific site* and shall *adequately* describe the requirements for applying *or installing* the practice to achieve its intended purpose. *As a minimum, the plans and specifications shall include:*

- *Project location map, including section, township and range, North arrow, cooperator/owner acknowledgement and certification signature blocks, engineering job class (cover sheet);*
- *References that the owner/cooperator are responsible for all permits, rights-of-way, easements and the contact, coordination and location determination of any existing utilities or clearances (buried utility disclaimer);*
- *If applicable, a map showing the location of the practice(s) or system in reference to a known or established benchmark or reference point with the location, description and elevation clearly shown. Topographical features and/or controls shall be shown, showing tie in with existing or other planned practices;*
- *Field surveys and notes, soil investigations or geologic soil boring locations and soil classifications, earthwork or material estimates/quantities (if applicable);*
- *System overview and layout (i.e., alignment, stationing, topographical features, and reference to existing or proposed features or grade stabilization structure; special requirements for foundation preparation and treatment; details of seepage control; location of the principal and auxiliary spillway; requirements for diverting water, dewatering the site, and/or soil disposal, borrow source, vegetative requirements, construction/installation criteria, State and Federal [OSHA] safety requirements, etc.), including size and types, necessary appurtenances and/or structures;*
- *Profile typical cross section of the excavations, embankments, spillways, and/or cutoff trench along proposed centerline with*

stationing, side slopes, dimensions (bottom width, embankment height) and elevations; details for pipe conduits, including invert elevations, size, type of material, seepage control, pipe cradle, and joints; foundation or subgrade preparation and requirements; and earthfill compaction methods;

- *Sufficient sectional, dimension or detail views of all system components and appurtenances (i.e., details for pipe conduit size and material, drainage or filter diaphragm, pipe cradle, special joints) as required, for proper system functionality, including concrete reinforcement details or steel schedules, as appropriate.*
- *Sufficient section or detail views of all system components and appurtenances, as required, for proper system functionality.*
- *Specifications for the construction of metal, wooden, or rock grade stabilization structures shall describe installation requirements on the drawings in sufficient detail to achieve the intended purpose.*
- *Use Arizona Construction and Material Specifications for each item of work and material, as applicable and available. Additional specifications may need to be written to provide full material and installation instructions. Fill in blanks and add or delete items from the specifications to make them fit the job as needed.*

All designs completed by non-NRCS personal shall meet minimum State licensing board requirements and NRCS requirements and criteria as outlined in the General Manual, the National Engineering Manual (including Arizona Supplements), and the National Engineering Handbook.

ONCE ALL PARTIES HAVE ACCEPTED AND SIGNED THE PLANS AND SPECIFICATIONS, NO CHANGES SHALL BE MADE TO THE DRAWINGS OR SPECIFICATIONS WITHOUT PRIOR APPROVAL OF NRCS.

OPERATION AND MAINTENANCE

An operation and maintenance (O&M) plan specific to the site and facilities installed shall be prepared, and reviewed, for use by the landowner, cooperator or operator responsible for operation and maintenance and shall be commensurate with the size and complexity of the project. The plan shall document needed actions, including reference to periodic inspections and the prompt repair or replacement of damaged components, and should provide specific instructions for operating and maintaining facilities to ensure they function properly and adequately throughout their expected life.

The plan shall include provisions to address the following, as a minimum:

- *Inspect the grade stabilization structure periodically to ensure that the structure functions as planned.*
- *Inspect vegetation on all earthfills. Mow when vegetative growth becomes excessive. Repair and/or fertilize damaged vegetation in accordance with NRCS conservation practice standard Critical Area Planting, Code 342.*
- *Inspect structures for deterioration and capacity. Remove any blockage of trash and debris that could affect flows through the structure. Repair or replace materials that have deteriorated, including rock used for outlet protection.*
- *Inspect for safety of people or animals using the area near the structure.*
- *Periodically remove sediment if storage is less than the expected accumulation during the design life.*
- *O&M plans shall include checking for clogging and/or pipe damage.*
- *Periodic cleaning and re-grading of collection facilities (ditches, pipes, structures) to maintain proper flow lines and functionality and maintain design border/furrow spacing as designed.*
- *Periodic checks and removal of debris, foreign material obstructions, or blockage as necessary from trash racks, ditch/pipe inlets, outlets and structures to assure proper operation.*
- *Periodic removal and planned placement of sediment from traps and/or storage facilities to maintain design capacity and efficiency.*
- *Inspection or testing of all pipeline and pumping plant components and appurtenances,*

as applicable, including the prompt repair of all leaks or worn parts in delivery facilities.

- *Routine maintenance of all screens, filters, valves, timers, mechanical and/or electrical components (pumps, agitators, pipe, valves, etc.) in accordance with manufacturer's recommendations.*
- *Eradicate or otherwise remove all rodents or burrowing animals that have or may potentially damage any part of the delivery or application facilities. Immediately repair any damage caused by their activity.*
- *Immediately repair any damage resulting from vandalism, vehicles, or livestock.*
- *Install and maintain fences to prevent livestock access where excessive trampling of banks or ditch may occur, and do not allow livestock near equipment during operation.*
- *Maintain vigorous growth of vegetative coverings, this may include re-seeding, fertilization, and application or herbicides. Periodic mowing may also be needed to control excessive growth.*

REFERENCES

- *National Engineering Handbook - Part 650, Engineering Field Handbook, Chapter 1 – Engineering Surveys; Chapter 2 – Hydrology; Chapter 3 – Hydraulics; Chapter 4 – Elementary Soils Engineering; Chapter 5 – Preparation of Engineering Plans; Chapter 6 – Structures; Chapter 11 – Ponds and Reservoirs; Chapter 13 – Wetland Restoration; and Chapter 17 – Construction & Construction Materials*
- *National Engineering Handbook, Part 531 Geology 531.31, USDA, Natural Resources Conservation Service*
- *USDA-NRCS, TR-62 – Engineering Layout, Notes, Staking and Calculations; TR-56, Wave Protection For Earth Dam Embankment; TR-69, Riprap For Slope Protection Against Wave Action; TR-77, Design & Installation of Flexible Conduits; TR-60*
- *National Environmental Compliance Handbook*
- *General Manual, Title 420-Part 401, Title 450-Part 401, Title 190-Parts 410.22 and 410.26*
- *National Planning Procedures Handbook*
- *USDA NRCS, Engineering Design Standards – Far West States*
- *National Cultural Resources Handbook*
- *USDA-NRCS, National Engineering Manual (NEM), 2nd Edition*
- *USDA-NRCS, National Engineering Handbook (NEH), Part 652 – Engineering Guide; Part 624 – Drainage Water Table Control; Part 628 – Dams, Chapter 45, Filter Diaphrams; Part 630 – Hydrologic Engineering; Part 634 – Hydraulic Engineering; Part 636 – Structural Engineering; Part 639 – Erosion Control Engineering*
- *NRCS Field Office Technical Guide (eFOTG), Section IV, Conservation Practice Standard 430 – Irrigation Pipeline; 533 – Pumping Plant; 342 – Critical Area Planting; 378 – Pond;*
- *NRCS Construction Specification 32, Structure Concrete*

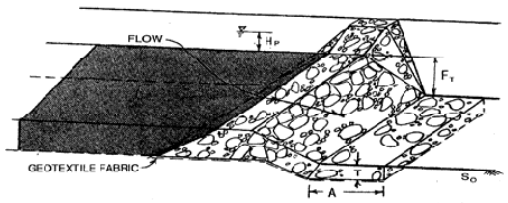

FIGURE - 1 LOOSE ROCK DROP

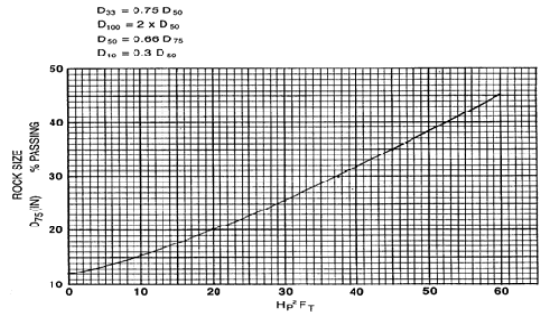

FIGURE - 2 DETERMINATION OF ROCK SIZE