August 14, 2014

KANSAS ENGINEERING TECHNICAL NOTE NO. KS-6 (Revision 2)

SUBJECT: ENG–Rock Check Dam Planning, Design, and Construction

Purpose. To provide guidance on the planning, design, and construction of rock check dams using Conservation Practice Standard (CPS) 587, Structure for Water Control

Effective Date. Upon receipt

Background

This guidance was developed with the assistance of Richard Weber, Hydraulics Engineer, Central National Technology Support Center (CNTSC), and Jon Fripp, Civil Engineer, National Design, Construction, and Soil Mechanics Center (NDCSMC). It is anticipated that national guidance will be developed in the future.

What Are Rock Check Dams?

A rock check dam is a type of water control structure that is used to restore a small eroding gully.

Typical Site Conditions

Rock check dams are needed to restore small eroding gullies back to a non-erosive state in some upper watershed areas in Kansas. These watercourses are found on low stream order reaches and thus do not have the drainage area required to establish a stream and floodplain system. The typical site includes a headcut, but stabilization of the single headcut will not restore stable conditions on a long, linear reach of watercourse. On many (if not most of these reaches), shallow groundwater or shallow subsurface flow is adequate to maintain a vegetative plant community indicative of wet conditions. Many of these reaches contain wetlands, which fit within the Slope Hydrogeomorphic (HGM) wetland class. In this region, wetland sites are typically dominated by Prairie Cordgrass with less wet sites dominated by Switchgrass. Whether the sites meet the criteria for wetlands or not, the formation of a gully removes shallow groundwater and discharges sediment downstream. The loss of headwater water storage reduces downstream base flow, and the sediment discharge impairs water quality and reduces reservoir storage. The loss of stored water also reduces forage as the switchgrass and cordgrass community transitions to an upland range site. Wetland conditions that exist along these reaches are lost as the groundwater level is drawn down to the grade of the incised channel.

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The landscape position where this practice applies can be described by the following attributes:

- Low stream orders (as defined by the Strahler Stream Order System)—These are typically waterways that are third order or smaller. Stream order for this purpose is defined in Wetlands Technical Note 210-2, Understanding Fluvial Systems: Wetlands, Streams, and Floodplains.
- Soil map units mapped above those with a "floodplain" term in the geomorphic description—In most areas, these sites are on reaches above the floodplain soil map units.
- Landscapes that fit within the Slope HGM wetland class—It should be noted that this is a landscape definition and does not require that Food Security Act (FSA) wetlands exist within it. However, wetlands found on this landscape are of the Slope class.

Watercourses (exclusive of tributary streams) that are on mapped floodplain soils can be assumed to be in the Riverine HGM landscape class. These watercourses should be treated with stream restoration techniques using the guidance found in National Engineering Handbook Part 654 (NEH 654), *Stream Restoration Design*. While rock check dams may be an appropriate technique, their use on this landscape is beyond the scope of this technical note.

Ecological Sites

The Slope HGM class landscape and the Riverine HGM class landscape may also be considered as ecological sites and could be good candidates for the development of an Ecological Site Description (ESD). These sites are distinct from each other based on soils, vegetative plant community, hydrology, and landscape position. The appropriate practices for treatment also vary along the site boundaries, and the ESD can serve as a good template for planning alternatives.

Kansas Conservation Practice Standard

There are two conservation practice standards (CPS) that may be considered for the treatment of this problem. CPS 410, Grade Stabilization Structure, is appropriate for the control of a headcut. However, a single structure meeting CPS 410 criteria constructed for headcut control will not treat the reach nor will it restore the hydrologic conditions in these headwater landscapes. The national version of CPS 410 does make allowances for the use of structures meeting "Island Structure" criteria. Island Structures are designed to pass peak discharge over the structure without an auxiliary spillway. However, this requires that structures be built in series with each individual structure having a capacity that provides tailwater up to the channel bank downstream. In practice, this would require the construction of an earthen berm to provide adequate hydraulic head for this capacity. Such a series of structures would not restore the headwater landscape to its original hydrologic conditions and would require extensive maintenance. Their high cost would preclude their use in all but the most serious conditions. A relaxed interpretation of "Island Structure" to allow a minimum head drop to a downstream water surface less than bankfull would reduce the size and cost of CPS 410 structures. However, a strict interpretation of the standard is not in keeping with the treatment of a gully reach and the hydrologic functions of the landscape.

An alternative is CPS 587. This standard includes the following:

Conditions Where Practice Applies:

- Control the water table level . . .
- Modify water flow to provide habitat for fish, wildlife, and other aquatic animals . . .
- Create, restore, or enhance wetland hydrology

Purpose:

- The practice may be applied as a management component or a water management system to control the stage, discharge, distribution, delivery, or direction of water flow.

On these sites, the restoration of shallow surface and subsurface flow conditions is needed to restore the original plant community, and the original plant community will work in tandem with rock check dams to decrease or eliminate the gully erosion. These needs appear to be in keeping with the purpose and conditions of CPS 587.

Conservation Planning

The use of Geographic Information Systems (GIS) can assist with planning on these landscapes. All applicable sites will be found along reaches within the first through third stream orders and will be above the floodplain soil map units. CPS 587 includes this landscape definition in "Criteria."

Planning and Design Guidance

Project Reach Boundaries

In most cases, the degraded site will have a gully headcut at its upper longitudinal boundary. The first structure in series must be capable of stabilizing this headcut. The crest of the first structure should be set at the grade at the top of the headcut. The next structures in series downstream will provide adequate tailwater protection if they are spaced such that the crest of one is at or above the elevation of the toe of the next upstream structure. The lower downstream boundary is more problematic. Ideally, the channel reach below the last structure is stable or even aggrading. If this is the case, the crest of the last structure should be set within a foot of the downstream channel grade. This will minimize the potential water surface profile drop at the transition. In cases where the channel grade becomes flatter downstream, the channel bottom will converge with the crest-to-crest profile, and the last structure(s) crest will converge with the channel grade. If the downstream channel is not stable or the water surface profile drop is too great, the structure should be considered to be a grade stabilization structure and meets the criteria for CPS 410.

Individual Structure Site Considerations

In most cases, out-of-bank flows induced by the structures will enter discrete macrotopographic features adjacent to the channel (such as oxbows and scour channels) and re-enter the channel downstream via the same features. These features should be considered when siting individual structures. Structures should be placed upstream of areas where water will be directed away from the channel and downstream of areas where water will re-enter the channel.

Use of the Channel Evolution Model

When assessing a channel reach for layout, the Channel Evolution Model is a useful tool (see the Upland Check Dam Structure Concept Detail and Design Guidance section). The Channel Evolution Model is described in detail in Section 654.0305(c) in NEH 654 as well as Wetlands Technical Note 210-2. Stable reaches correspond to Stage 1 channels. Many headwater reaches will not have a defined channel when they are at Stage 1 conditions. The channel directly below a headcut is considered to be in Stage 2. Stage 2 reaches are actively incising, and the first structure should be placed in this reach—either at the headcut or at a downstream point where the crest can be set at the elevation of the headcut. The next structures in series will be in stream reaches in Stage 2 or 3. The intent of the structure installation is to cause deposition and move these reaches to a restored Stage 4 and eventually Stage 5. The difference will be with the profile raised to what it was under a Stage 1. In this manner, the frequency of out-of-bank flow (as well as bank storage) is partially restored.

Structure Hydraulics

The structure top should always incorporate a low flow control section, even when the goal is to restore to a "slough" geometry with no defined channel. This maintains a channel thalweg though the project reach and keeps long-term low flows away from the channel banks. If the upstream stable reach has "slough" geometry, the control section may be the low point in a v-shaped crest. In cases where the stable geometry is a defined Stage 1 channel, a trapezoidal section matching the Stage 1 cross-section should be provided (see Crest Section Options 1 and 2 on Figure 2).

Structure Stability

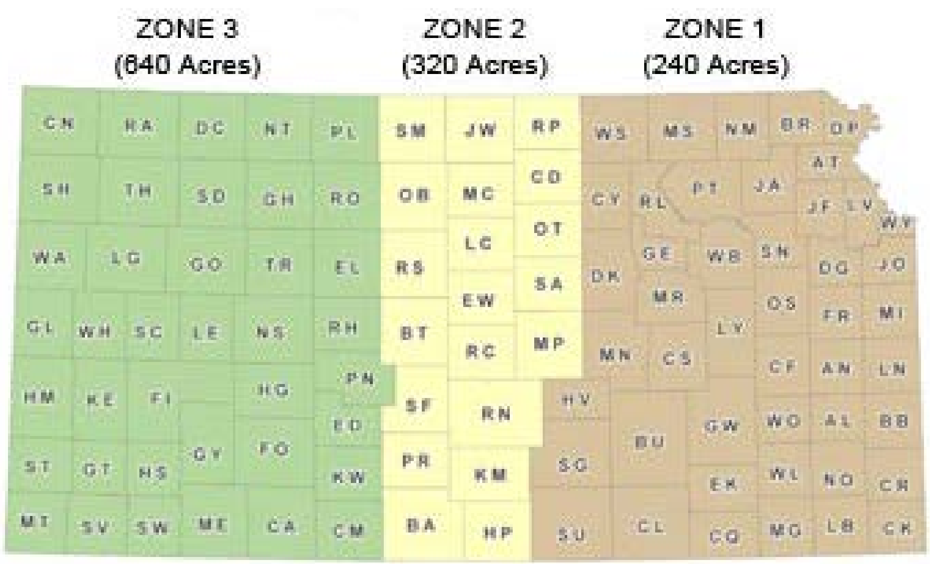
Structures with a maximum height of 3 feet and with a 5 vertical to 1 horizontal (5:1) downstream ramp slope will be stable up to 2 feet of flow depth with riprap having a D_{50} size of 6 inches. This 2-foot maximum depth can be taken as the depth from the crest to the top of bank with the assumption that water spreads laterally across the adjacent landscape with little increase in depth. Also, the backwater effects from downstream structures at higher-than-bankfull flows are under sub-critical flow conditions with reduced tractive stress.

Structure excavation can be placed in the channel between structures with sod salvaged for placement over exposed rock at the top of the bank keys (see Figure 2). The optimum spoil placement location is immediately upstream of the structure face. The rock should be keyed into the channel bed a minimum of 1 foot and into the banks a minimum of 3 feet. If shallow bedrock precludes a 1-foot bottom key, the spoil upstream of the structure face should be placed to a 1-foot depth and compacted by wheel packing with a rubber-tired machine. This material should extend a distance of 10 feet minimum upstream.

Recommended Site Limitations

1. Install on watercourses with a drainage area not exceeding the areas shown in Figure 1 for the 3 zones across Kansas.
2. Install on channels less than 4 feet deep.
3. Install in channels meeting Shumm Channel Evolution Model (CEM) Stages 2 and 3 and in accordance with the Layout Details section below.
4. Install in slope landscapes as described in HGM classification.

Figure 1—Maximum drainage area



Hydrology

Given the channel size, structure height, and drainage area limitations described above and in Figure 2, there are no specific hydrologic criteria. The intent of the practice is to create continuous backwater conditions between structures with out-of-bank flows controlled by downstream tailwater. Flows higher than bankfull will create hydraulic conditions less critical than the first bankfull discharge flow.

Permits

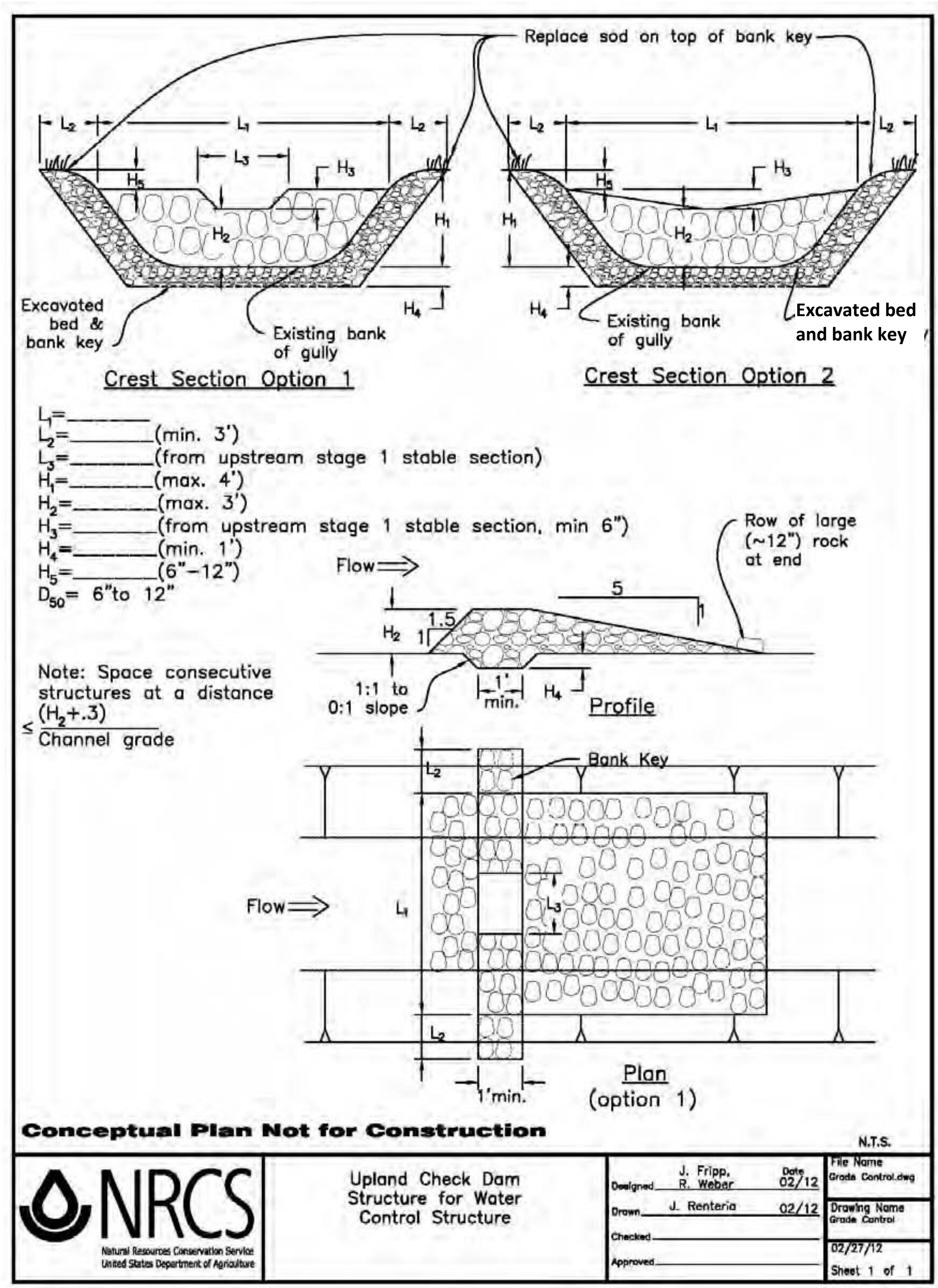
For guidance on permit requirements, see Kansas Engineering Technical Note No. KS-5, Temporary Permits Required for Streambank Activity.

Design and Layout

See the Upland Check Dam Structure Concept Detail and Design Guidance section for a preliminary design and layout job sheet.

Upland Check Dam Structure Concept Detail and Design Guidance

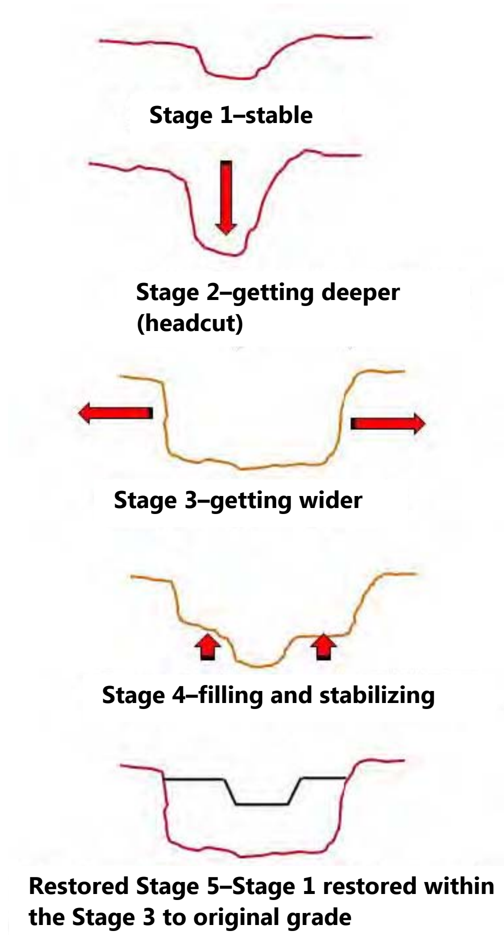
Figure 2–Design and layout details for an upland check dam structure for water control structure



<u>Layout Details</u>

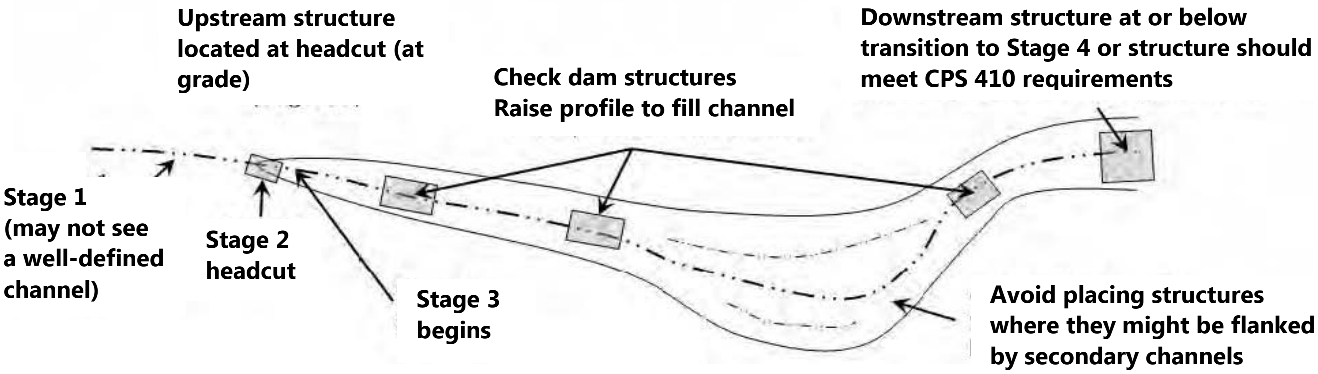
1. Install the first upstream structure with the control section crest at the elevation of the upstream headcut (if one exists). This should be in a Shumm CEM Stage 1 or 2 reach (see Figure 3).

Figure 3–CEM stages



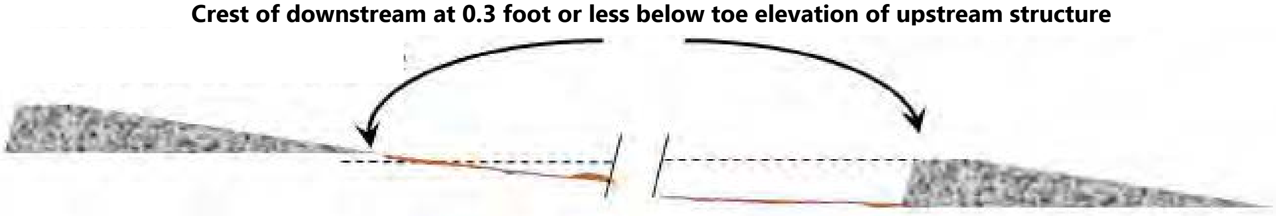
2. The structures are placed in Stage 3 or 4 channels where there is a minimal risk of being undermined by advancing headcuts.
3. Install the last downstream structure at or below the transition to a stable channel reach as defined as a CEM Stage 4 or 5 channel reach. If the downstream receiving reach is not CEM Stage 4 or 5, the last structure must meet the criteria in CPS 410.
4. Structure height of the last downstream structure shall be 2 feet or less from channel bottom to crest.
5. Install structures upstream of points where flow is directed away from the channel by natural features.
6. Install structures downstream of points where flow is directed into the channel by natural features. The location of the individual structures should be chosen to minimize the possibility of the watercourse flanking the structures though adjacent channels and gullies (see Figure 4).

Figure 4–Layout details



7. Maximum structure spacing shall be (H2 + 0.3) / channel grade. This will space the structures at essentially a terrace grade (see Figure 5).

Figure 5–Structure spacing



8. Install structures at natural high points in channel (riffles/shallow areas) to the extent practicable.

Structure Geometry Details

1. On sites where the stable upstream reach does not have a defined channel, use Crest Section Option 2 on Figure 2.
2. On sites where the stable upstream reach has a defined channel, use Crest Section Option 1 on Figure 2 with H3 and L3 matching the channel width and depth within the H3 limits established on the details.
3. Where the minimum 1-foot bottom key is precluded by bedrock, install compacted spoil to a minimum depth of 1 foot and a minimum distance of 10 feet upstream. Compact with rubber-tired equipment.
4. Orient structures at right angles with watercourse thalweg.

Construction Details

1. Minimize disturbance to site vegetation.
2. Salvage sod and place on channel banks downstream and on top surface of bank key rock.
3. Place spoil immediately upstream of structures.
4. Riprap shall be sound, durable rock with a minimum D_{50} of 6 inches and a maximum D_{50} of 12 inches.
5. Clearing and Grubbing shall be limited to that necessary to install structures and establish uniform flow conditions immediately upstream.

Contact

Technical assistance is available from NRCS at your local USDA Service Center (listed in the telephone book under United States Government). More information is also available on the Kansas Web site at www.ks.nrcs.usda.gov.

(signed)

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