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1101 INTRODUCTION

This MANUAL defines hydraulic structures as structures that control storm runoff during a condition of rapid directional change or rapid acceleration or deceleration of velocity. These structures include drop structures, check structures, rundowns and energy dissipators for pipe outfalls, and raw water ditch crossings. Culverts, bridges, weirs, and channel bends also cause rapid changes in velocity, but these are discussed in other sections of this MANUAL.

Because each hydraulic structure is site specific, the criteria in this section are somewhat generalized. The design of channel drops, checks, and rundowns within the Denver and Boulder metropolitan areas has evolved considerably over the last few decades due to performance evaluations and maintenance concerns. It is reasonable to assume that the design of these structures will continue to be refined over time. This section relies heavily on design guidance in the USDCM (UDFCD, 2016) so that Boulder County can benefit from the ongoing performance evaluations of recently constructed channel drops, checks, and rundowns.

This section will also include discussion on aspects of design that are often neglected, but play an important role in the overall function and lifespan of a structure. These include safety, access, and environmental considerations. Coordinating with the County Engineer is strongly encouraged when planning and designing hydraulic structures.

1102 SLOPING DROP STRUCTURES

The design, specifications, and criteria for all sloping drop structures within Boulder County shall be in accordance with the most recent version of the USDCM. All sloping drops shall be grouted sloping boulder (GSB) drops unless a Design Exception is granted for the use of sculpted concrete where specific aesthetic concerns may justify its use. Construction quality control and oversight is a key component to the successful installation of any drop structure. Care should be taken during construction to ensure that the drop is constructed in strict accordance with the design plans and specifications. Minor modifications to the design of GSB drops may be incorporated to allow for fish passage and to minimize impacts to macroinvertebrates, especially on perennial streams, with the approval of the County Engineer, which is discussed more at the end of this section.

1103 VERTICAL DROP STRUCTURES

Vertical drop structures are generally discouraged because they can cause dangerous hydraulic conditions and require extensive maintenance. Vertical drop structures should not be used on a channel where fish passage is a concern or where the design flow exceeds 500 cfs or a unit discharge of 35 cfs per foot (cfs/ft). These structures may be acceptable in locations where the drop footprint needs to be minimized and where there is a very low chance of access by minors. If a vertical drop structure is

allowed, the net drop structure height should be limited to 2 feet. A stilling basin 1 foot deep should be constructed immediately downstream of the crest. The design procedure for a vertical drop structure can be found in *Open Channel Hydraulics* (Chow, 1959) for a straight drop spillway. This procedure is also provided for reference in the USDCM.

1104 LOW FLOW DROP STRUCTURES AND CHECK STRUCTURES

Low flow drop structures and check structures may be used when a channel has not yet experienced significant erosion and degradation, but is anticipated to degrade in the future. The criteria and design guidance in the USDCM may be used for low flow drop structures and check structures on major drainageways.

Where roadside ditches require check structures to maintain their stability, a lesser degree of protection is needed, as the forces associated with flows in roadside ditches are considerably less than those in a major drainageway. Figure 1100-1 is a schematic of a roadside ditch check that may be used in the county. Roadside ditch checks can be used to flatten proposed ditch slopes or where erosion is already apparent in a retrofit scenario.

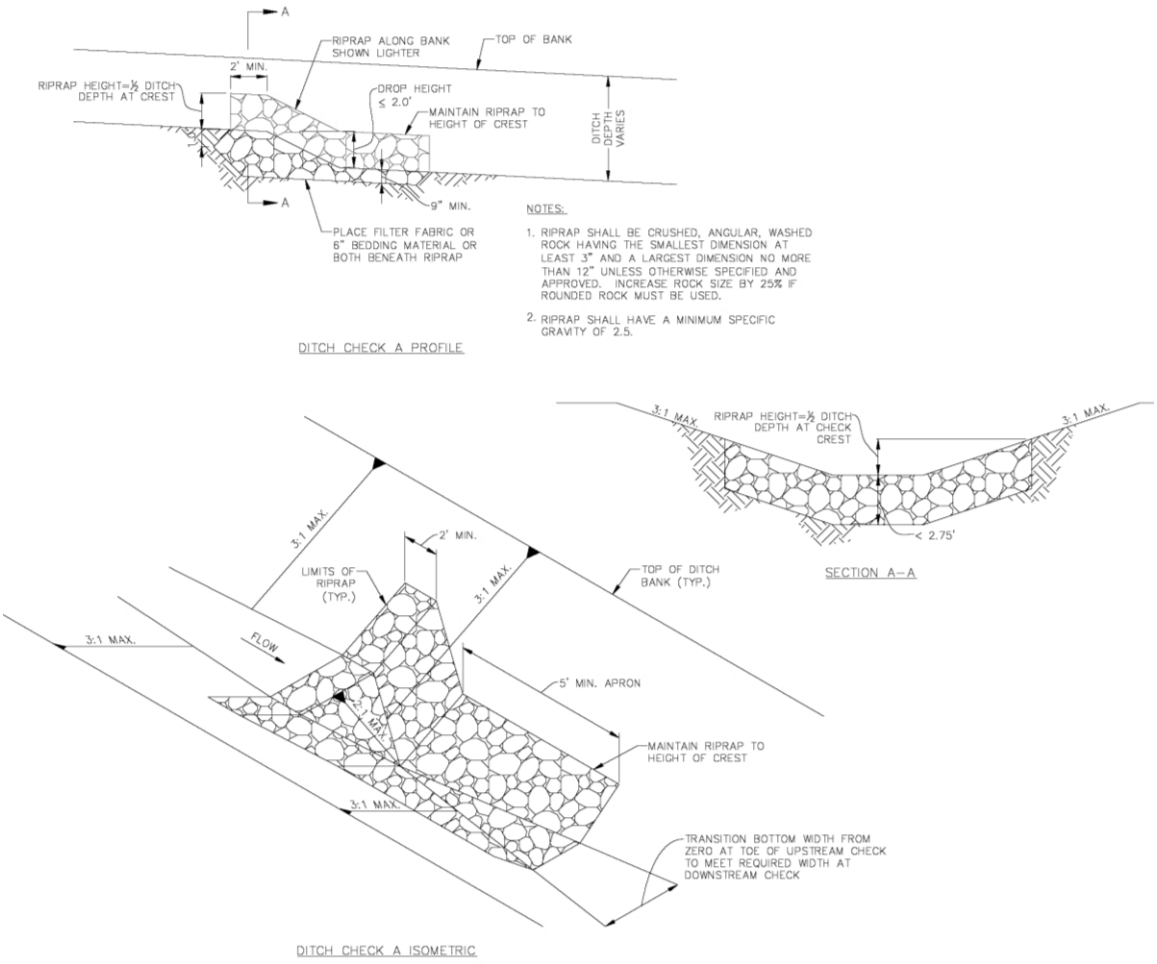

Figure 1100-1. Schematic Roadside Ditch Check Structure.

1105 CULVERT RUNDOWNS

When a culvert or storm drain discharges above a channel invert, a riprap rundown has historically been constructed to convey the water from the pipe outlet to the channel invert. Culvert rundown installations have a very high rate of failure and are not permitted in Boulder County without a Design Exception. If the culvert or storm drain cannot be designed to discharge within 1 foot of the channel invert, a pipe should be used to convey flows to just above the channel invert. Appropriate energy dissipation in the form of a riprap apron, low tailwater basin, or Type VI stilling basin should be used at the pipe outlet to prevent erosion at the pipe outlet.

1106 ENERGY DISSIPATORS

Energy dissipators are required at channel drops when the unit discharge exceeds 35 cfs/ft and at the outlet of culverts or storm sewers when the velocity exceeds 16 fps. The USBR Type III and USBR Type IX energy dissipators are approved for use in Boulder County for spillways and channels, and the USBR Type VI is approved for pipe outlets. Comprehensive design guidance for each of these structures can be found in the *Hydraulic Design of Stilling Basins and Energy Dissipators* (USBR, 1987) and is included in HEC-14 (Thompson and Kilgore, 2006). Figure 1100-2 is a photograph of a Type VI impact basin in Colorado.

Figure 1100-2. Example of a USBR Type VI Impact Stilling Basin (CDOT, 2004).

1107 RAW WATER DITCH CROSSINGS

A structure shall be constructed at all raw water ditch crossings to separate peak storm runoff from irrigation and other raw water delivery flows unless otherwise permitted. Three types of structures are recognized to achieve this requirement.

1. Type 1 structures result in complete separation of storm flows and raw water flows. This type of control is often used for smaller ditches or where intermingling of storm and raw water flows would cause water quality concerns. Type I structures are typically an irrigation flume crossing of a gulch or a pipe to convey storm flows under the ditch.
2. Type 2 structures discharge storm flows into the raw water ditch and then release excess flows into the drainageway downstream via a formal control structure. This type of control is often used where the ditch has water rights on the stream in question, in which case not all storm flows may need to be returned to the drainageway. This type of control could also be used where the ditch does not have water rights on the stream in question, in which case all storm flows would have to be returned to the drainageway. In this latter case, the type of structure required may be very difficult to design and operate to meet all regulatory requirements. The requirements for this type of structure may be less expensive than complete flow separation, especially for larger drainageways.
3. Type 3 structures discharge runoff into the raw water ditch without returning the runoff peak back to the drainageway. This type of structure requires a thorough analysis of the ditch capacity and the storm runoff peaks and volumes and may require a detention pond to reduce the runoff to what the ditch is capable of conveying.

A typical ditch crossing does not exist because each raw water ditch crossing a drainageway will have its own unique design and requirements. When a raw water ditch crossing structure is required, the applicant shall meet with the County Engineer and the ditch owner(s) to develop specific design requirements for the structure, and shall obtain written approval of the design from the raw water ditch owner(s).

1108 ACCESS, SAFETY, AND ENVIRONMENTAL IMPACT

Drop structures are constructed to dissipate the erosive forces of water at specific locations to limit those forces in the rest of the channel. The focus is traditionally on the hydraulic design of the structure, but other considerations play an important role in how the structure will interact with other aspects of its surroundings besides simply the physical force of the water.

Maintenance access must be provided to each drop structure constructed in Boulder County. Routine inspection and maintenance will ensure the structure is performing as it should and could catch any structure failures early enough to prevent more expensive rehabilitation. The county should be consulted early in the design process to identify maintenance access requirements.

Channels may be used by kayakers, paddle boarders, or swimmers or are enjoyed by hikers or campers who may venture to the water's edge. Drop structures should be designed in a way that is consistent with the requirements for recreational user safety. Drop structures in boatable channels should incorporate a boat chute, bypass, or full river passage to allow passage for boats.

Fish passage through drop structures and consideration of macroinvertebrate habitat is critical in certain channels. Colorado Parks and Wildlife, the US Fish and Wildlife Service, or other local agency can establish the need to provide fish passage and specific site requirements. Regulatory requirements and project objectives generally should be established early, but additional requirements may arise during the 404 permitting process. Features that improve habitat and offer fish passage can include creating currents that encourage passage, avoiding sediment deposition, avoiding shallow zones, and providing resting areas. Features should be designed to accommodate behaviors and capabilities of target species. When fish passage or habitat is an important design element or a permit requirement, specialists in fish passage should be included on the design team.

Where both fish and boat passage is desired, inclusion of integral fish passage features into boatable drop structures is feasible. This usually results in a roughened channel type of fish passage such as a rock ramp or riffle-pool fishway. Roughened channel fish passages can be readily included into boatable drop structures, but the specific criteria depend on the target species and other related factors.

1109 REFERENCES

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