Introduction to Hydraulic Structures

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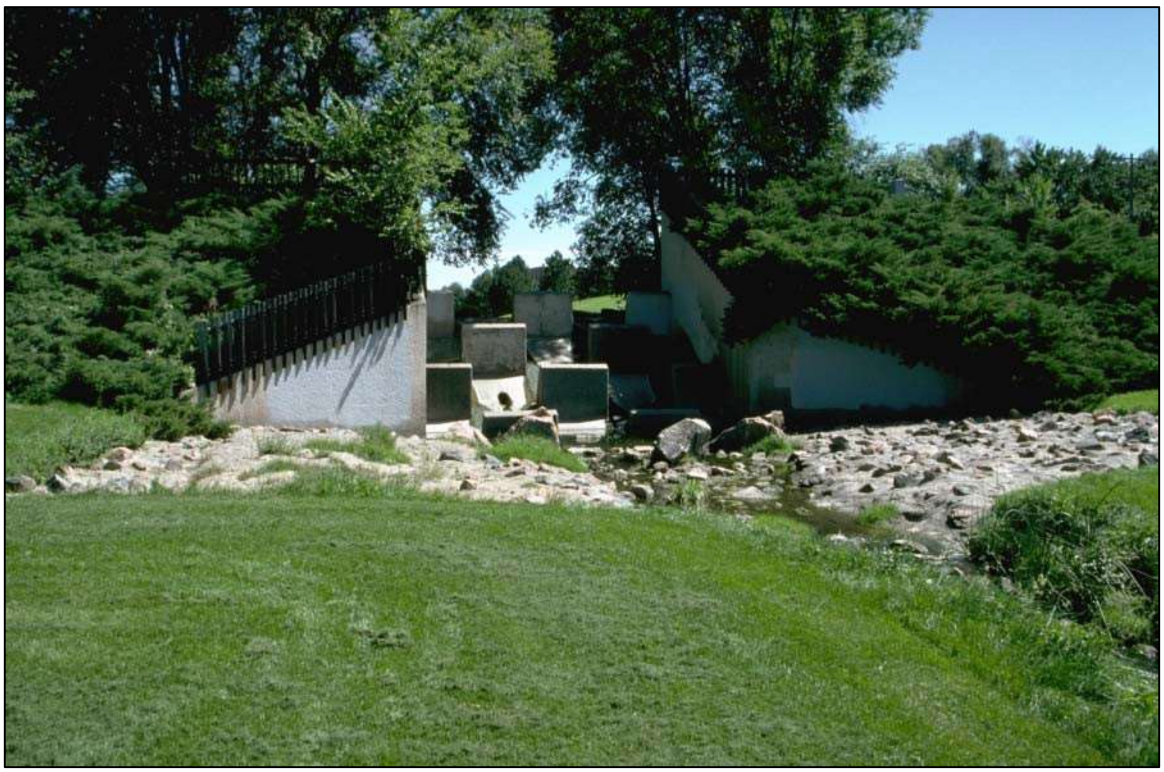
1.0 USE OF STRUCTURES IN DRAINAGE

1.1 Introduction

Hydraulic structures are used to guide and control water flow velocities, directions and depths, the elevation and slope of the streambed, the general configuration of the waterway, and its stability and maintenance characteristics.

Careful and thorough hydraulic engineering is justified for hydraulic structures. Consideration of environmental, ecological, and public safety objectives should be integrated with hydraulic engineering design. The proper application of hydraulic structures can reduce initial and future maintenance costs by managing the character of the flow to fit the environmental and project needs.



Photograph HS-1—Denver's Harvard Gulch Flood Control Project introduced the baffle chute drop structure to urban flood control in 1966. Vegetation and time have made the structure part of the city's urban poetry.

Hydraulic structures include transitions, constrictions, channel drops, low-flow checks, energy dissipators, bridges, bends, and confluences. Their shape, size, and other features vary widely for different projects, depending upon the discharge and the function to be accomplished. Hydraulic design procedures must govern the final design of all structures. These may include model testing for larger structures when the proposed design requires a configuration that differs significantly from known documented guidelines or when questions arise over the character of the structure being considered.

This chapter deals with structures for drainage and flood control channels, in contrast to dam spillways or specialized conveyance systems. Specific guidance is given on drop structures for channels that match the District's guidelines for grass-lined and riprap-lined channels as given in the MAJOR DRAINAGE chapter of this *Manual*. In addition, guidance is provided for the design of energy dissipaters at conduit outlets. Sections on bridges, transitions, and constrictions primarily refer to other sources for more extensive design information.

Photograph HS-2—The Clear Creek I-25 vertical concrete drop structure was a "drowning machine" until it was retrofitted by CDOT with a 10:1 downstream face. (Photograph taken before retrofit.)

1.2 Channels Used for Boating

There are streams in the District in which rafting, canoeing, kayaking, and other water-based recreational activities occur. Design and construction of hydraulic structures in these waterways require a standard of care consistent with common sense safety concerns for the public that uses them. The ultimate responsibility for individual safety still resides with the boating public and their prudent use of urban waterways.

It is reasonable to retain a whitewater boating specialist to assist in the design criteria for a hydraulic structure on a boatable stream. In particular, reverse rollers are to be avoided (USACE 1985).

1.3 Channel Grade Control Structures

Grade control structures, such as check structures and drop structures, provide for energy dissipation and thereby result in a mild slope in the upstream channel reaches. The geometry at the crest of these structures can effectively control the upstream channel stability and, to an extent, its ultimate configuration.

A drop structure traverses the entire waterway, including the portion that carries the major flood. A check structure is similar, but is constructed to stabilize the low-flow channel (i.e., one carrying the minor or lesser flood) in artificial or natural drainageways. It crosses only the low-flow portion of the waterway or floodplain. During a major flood, portions of the flow will circumvent the check. Overall channel stability is maintained because degradation of the low-flow channel is prevented. Typically, the 2-year flows are contained in the protected zone so that the low-flow channel does not degrade downward, potentially undermining the entire waterway.

1.4 Wetland Channel Grade Control

Wetland channels, whether low-flow channels or from bank to bank, require modest slopes not exceeding about 0.3%. Grade control structures are often required for stability. Due to the environmental nature of the wetlands, the grade control structures are planned and designed to be compatible with a wetland environment. Wetland channels do not need a trickle channel, but where used, the trickle channel should not lower the wetland water table more than 12 inches.

1.5 Conduit Outlet Structures

Design criteria given in this chapter are for structures specifically designed to dissipate flow energy at conduit outlets to the open waterway. These types of structures are typically located at storm sewer outlets. Design criteria for culverts and storm sewers that discharge in-line with the receiving channel are described in the MAJOR DRAINAGE chapter of this *Manual*.

1.6 Bridges

Bridges have the advantage of being able to cross the waterway without disturbing the flow. However, for practical, economic, and structural reasons, abutment encroachments and piers are often located within the waterway. Consequently, the bridge structure can cause adverse hydraulic effects and scour potential that must be evaluated and addressed as part of each design project.

1.7 Transitions and Constrictions

Channel transitions are typically used to alter the cross-sectional geometry, to allow the waterway to fit within a more confined right-of-way, or to purposely accelerate the flow to be carried by a specialized high velocity conveyance. Constrictions can appreciably restrict and reduce the conveyance in a manner that is either detrimental or beneficial. For example, a bridge, box culvert, or constriction may increase the upstream flooding by encroaching too far into the floodplain conveyance, whereas in another situation a hydraulic control structure can be employed to purposely induce an upstream spill into an off-stream storage facility.

1.8 Bends and Confluences

General considerations for lined channels and conduits are discussed in the MAJOR DRAINAGE chapter of this *Manual*. Additional emphasis is added herein for certain situations. Channels and conduits that produce supercritical flow may require special structural or design considerations. This discussion is limited since these types of structures are generally associated with hydraulic performance exceeding the recommended criteria for grass-lined channels. Extensive study, specialized modeling and/or analysis may be required for these situations.

On the other hand, confluences are commonly encountered in design. Relative flow rates can vary disproportionately with time so that high flows from either upstream channel can discharge into the downstream channel when it is at high or low level. Depending on the geometry of the confluence, either condition can have important consequences, such as supercritical flow and hydraulic jump conditions, and result in the need for structures

1.9 Rundowns

A rundown is used to convey storm runoff from high on the bank of an open channel to the low-flow channel of the drainageway or into a detention facility. The purpose is to control erosion and head cutting from concentrated flow. Without such rundowns, the concentrated flow will create erosion.

1.10 Energy Dissipation

The energy of moving water is known as kinetic energy, while the stored energy due to elevation is potential energy. A properly sloped open channel will use up the potential energy in a uniform manner through channel roughness without the flow being accelerated. A grade control structure (i.e., drop and check) converts potential energy to kinetic energy under controlled conditions. Selection of the optimum spacing and vertical drop is the work of the hydraulic engineer. Many hydraulic structures deal with managing kinetic energy—to dissipate it in a reasonable manner, to conserve it at structures such as transitions and bridges, or occasionally to convert kinetic to potential energy using a hydraulic jump. Thus, managing energy involves understanding and managing the total energy grade line of flowing water.

1.11 Maintenance

Urban drainage facilities should not be built if they cannot be properly maintained on a long-term basis. This means that suitable access must be provided, a maintenance plan must be developed and funded, and the drainage facilities must be maintained in accordance with public works standards.

1.12 Structure Safety and Aesthetics