All bridges shall be investigated for drainage requirements. The FHWA publication, *Design of Bridge Deck Drainage*, Hydraulic Engineering Circular No. 21 (HEC-21) (Publication No. FHWA-SA-92-010, May 1993), shall be used for the design of Bridge Drainage Systems. The hydraulic design frequency shall be 5 years rather than the frequencies specified in HEC-21. The maximum spread width shall not encroach into through driving lanes.

When deck drainage is necessary, designers shall decide how it will be incorporated in a bridge early in the design process, ideally, when the girder spacing is determined. Designers need to be aware that deck drains will have an impact on other structural components that will carry throughout the design of the bridge.

A *complete* Bridge Drainage System (BDS) consists of a Bridge Deck Drainage System (BDDS) and a Bridge End Drainage System (BEDS). The BDDS includes all drains located on the bridge deck and the means used to convey the water collected by them. The BEDS intercepts drainage immediately upslope and downslope of the bridge and shall daylight between 150 mm and 300 mm (6" and 1') above the toe of the fill or the rip-rap at that location.

Designers shall perform a structural analysis on all bridge components modified to accommodate deck drains. The amount of reinforcing steel may need to be increased or structural components thickened in the vicinity of the deck drains depending on the outcome of the structural analysis. Designers may need to adjust the girder spacing and deck overhang length, notch the girder flange, or adjust drain locations due to the proximity of bridge rail posts to incorporate deck drains in a bridge. Flanges may be notched (with transitions) near abutments where the bending moment is low without adverse impact since the flange beyond the web does not contribute to the shear strength of the girder. Flanges may also be notched near piers on simple span girders made continuous since the negative moment reinforcing steel in the deck is in tension. Precast, prestressed girders can have voids formed in the top flange by the fabricator or if the bridge is retrofitted, a portion of the flange removed (the prestress force should redistribute in the deck).

The station and offset for each deck drain shall be specified on the plans. All deck, curb, and bridge rail reinforcing steel impacted by the presence of deck drains shall be detailed on the plans.

Drainage from structures shall not drip onto bearings, pier caps, abutment caps, nor onto roadways, railroad templates, pedestrian walkways, bicycle paths, slope paving, or unprotected fill slopes. For free fall drains, the horizontal distance necessary to keep wind-driven drainage away from piers or other features is 3 m (10'). Pipes from deck drains shall extend at least 75 mm (3") below the bottom of the adjacent girder.

When a BDS is specified, a reasonable and acceptable hydraulic path for the discharge shall be detailed on the plans, beginning at the outfall. Drainage may be allowed to discharge directly into waterways (depending on the site) provided the ADT does not exceed 30,000 per the CDOT National Pollutant Discharge Elimination System (NPDES) Task Force (August 1992). At present, this is not a regulation. When the ADT exceeds 30,000, drainage should be directed to a storm water quality management facility, including but not

limited to, a grass lined swale, grass buffer strip, or a detention pond. The preferred discharge area is not in the area occupied by the ordinary high water.

Pipes attached to deck drains should be capable of removal in the field by mechanical means. The welding of steel pipe to gray iron castings is strongly discouraged since it cannot be readily disassembled. The weld can be made with a nickel electrode, but the connection is weak. This connection should be considered and used only as a last resort.

Schedule 40 pipe shall be used for the BDDS and may be either galvanized steel or polyvinyl chloride (PVC). The PVC pipe should be painted to match the color of the adjacent bridge component such that the color doesn't contrast (the PVC should be lightly abraded to make the appropriate primer adhere). Pipes which convey drainage shall be a minimum of 203 mm (8") in diameter. Bends in pipe shall not exceed 45 degrees and shall have a 610 mm (2'-0") minimum radius. Clean outs shall be located at all bends.

The discharge end of the BDDS shall be between 150 mm and 300 mm (6" and 1') above the finished grade elevation (final ground line) at piers. Erosion protection is required since the exit velocity of the discharge is high. The erosion protection may include rip-rap with filter cloth beneath, a concrete splash block, or a concrete lined channel. See the Culvert Outlet Paving Detail shown on CDOT Standard Plan M-601-12.

Deck drain grates shall be designed for the highway wheel loading and bicycle safety, when appropriate. Deck drains available from the Neenah Foundry Company are designed for the M 18 (H 20) wheel loading. Designers may specify that deck drains be installed 15 mm (1/2") lower than the surrounding deck to reduce the snag potential of the grate from snow plow blades.

Galvanizing gray iron castings is not desirable or necessary. While the structural steel components of drains must be galvanized, the use of steel for deck drains is discouraged since gray iron offers superior corrosion resistance over galvanized steel. The use of reinforcing steel or weathering structural steel for deck drain components is prohibited.

The use of curb cuts for deck drains is discouraged due to their poor hydraulic performance and maintenance history. HEC-21 discusses a drain such as this in the last paragraph of Section 5.1. That paragraph concludes with the following sentence: "Perhaps the best comment on their usage is that they may be better than nothing." There are design concerns with curb cuts since the curb is an integral part of the bridge rail. AASHTO Article 2.7.1.1.3 states, "Traffic railings should provide a smooth continuous face of rail…" This requirement precludes any break in the curb necessary for a curb cut. If curb cuts are specified, the water captured shall be carried to a point at least 75 mm (3") below the bottom of the exterior girder before being released.

DECK DRAINS

Structures should be drained as necessary and water shall be kept away from bearing devices. If possible, drains should not be positioned above riprap. When drains must be placed over riprap, special filter fabric shall be placed under the riprap. This filter fabric shall be highly permeable and non-biodegradable.

Curb cuts shall not be used when they would allow water to drain across adjacent walkways.

Drainage from structures shall not drip onto girder flanges, bearings, pier caps, or abutment caps, nor onto roadways, railroad templates, or pedestrian/bikeways.

Pipe drains, scuppers, and grated inlet drains shall extend below bottom of deck to assure that drainage is kept off steel girder flanges.

Curb drains shall be as shown in Figure 9-2 of the CDOT Bridge Detailing Manual and shall provide a continuous curb for wheel impact.

Pipe drains shall have a minimum diameter of 6 inches and a maximum diameter of 8 inches. Pipe drains shall have internal grates 2 inches below the surface or be covered by a grate designed for HS 20 wheel loading. Inlet grates shall be removable for cleaning. Project specific details shall be included.

GENERAL

The following is taken directly from the Staff Bridge Engineer's *5/22/90 Policy Letter Number 5*.

The Hydraulics unit is now designing all structures for an appropriate design frequency, then checking the channel structure for stability and scour effects for a 500 year event. This information will be plotted on the Hydraulics sheet for all major structures by the Hydraulics unit.

We will show the elevation of the maximum combined scour depth on the General Layout. If individual substructures have significantly different depths, they should all be shown separately.

The structures shall continue to be designed per AASHTO as presently done, but considering potential scour effects on your structure type. When the final scour calculations are received, a stability check of the structure will be performed and, if necessary, a redesign of the substructure units or foundations may be required.

Spread footings should be located such that the top of footings are below the total anticipated scour level and the bottom of the footings at least 6 feet below the streambed.

Each substructure unit shall be treated independently; i.e., the footing depths need not all necessarily be below the thalweg for the 500 year event.

In the event that the 500 year flow would over-top the structure, the designer should determine the appropriate AASHTO loads and groupings to apply during the stability analysis.

FOOTING SUPPORTED BY PILES OR CAISSONS

The following is from the Staff Bridge Engineer's 5/22/90 Technical Memorandum Number 6.

There is no benefit to be gained in the reduction of local scour by placing the top of footings supported by piles or caissons at an elevation other than flush with the streambed. This is especially the case in those instances where neither contraction scour nor general degradation are expected to be significant. As a general rule the disturbance of the streambed below this level is discouraged.

In those cases where contraction scour or general degradation is predicted in the hydraulic analysis the designer may consider locating the top of the footing at the elevation of the projected level of scour. Should contraction scour be predicted to exceed about 10% of the design depth of flow, the contracted opening should be re-evaluated. General degradation may be more difficult to control or even be aware of because of the potential lack of historical knowledge to predict at all stream locations.

The preceding two paragraphs should not be interpreted to apply to spread footings, in which case AASHTO minimums and other criteria shall apply except when otherwise controlled by hydraulic scour predictions.