debris or heavy bed loads. Hydraulic designs that size bridge or large culvert openings shall meet the following hydraulic criteria:

I. Bridges and large culverts shall be designed to have sufficient hydraulic capacity to convey the required design storm frequency channel flows without damage to the structure and to approach embankments.

II. Design of all structure openings shall be analysed for the peak design storm frequency flow of 100 years design return period maintaining 1 m clear between high water and bridge deck for freeways, expressways, and arterials and 50 years design return period for collector and local roads.

III. Backwater Effects: bridges have an effect on the flow of the watercourse over which they are located. This is because part of the bridge structure is usually located within the channel of the river or stream, and causes an obstruction of water flow. Bridges which cross a river in more than one span have piers located in the watercourse, which force water to flow around them. The abutments of bridges also generally protrude into the watercourse, causing obstacles at either side of the channel. Even if under normal flow conditions no part of the bridge is obstructing flow, in flood conditions, where the water level is significantly raised, parts of the bridge superstructure may cause an obstruction to flow.

IV. As water flowing in the channel approaches a bridge structure that restricts its flow area, the flow is forced to contract, in order to pass through the bridge, before expanding once again to the full channel width. As the constricted flow passes through the obstruction of the bridge, it accelerates, causing a depression in level of water surface. As the flow expands once more to the full channel width, so the water level recovers, to its downstream boundary condition level. The successive contraction and expansion results in a local head loss, which is compensated by an increase in water level upstream of the bridge. This phenomenon is known as afflux, or the backwater effect. Water levels upstream are raised by Δy with respect to downstream levels, (refer to Figure 2-1), where Δy is equal to the head loss caused by the contraction and expansion of flow at the bridge.

V. Design flows shall be determined in accordance to the procedures in Chapter 3. Hydraulic conditions for the design and overtopping flows shall be determined using an open channel-type modelling program, Modelling of backwater flow effects with HEC-RAS HEC-RAS can be used to model the effects of a bridge crossing a watercourse, and to examine backwater effects[)]. In particular, modelling shall be done for both the existing channel and the proposed crossing conditions and differences compared.

VI. Bridge crossings of sea channels, inlets, and bays with tidal flows shall be analysed using an engineering approach suitable for the given site and shall consider flow due to normal tidal exchange, storm surge, and wave attack.

VII. Design of the bridge flow openings shall be such that the proposed water surface is not increased more than 0.3m at a distance of 50 m upstream of the bridge — above the existing water surface in the channel during the peak design storm frequency flow.

VIII. Low chords of the structure shall provide at least a 1-m clearance above the peak design storm frequency water surface or, in areas with tidal influence, of 1-m above the mean high tide level.

IX. Economical approach for crossings of wide wadi floodplains will usually require a bridge structure over the main flow channel. This bridge opening is sized for the maximum flow occurring within the wadi channel banks, but does not overtop the channel banks.