Practical Hydraulic Modeling Considerations

The recommended process for determination of hydrotechnical design parameters (Flow depth (Y), Mean Velocity (V), Flow(Q)) for stream crossing sites is described in the published Hydrotechnical Design Guidelines. This process requires the use of hydraulic calculations to determine these parameters and computer based tools can assist in this process. For example, the "Channel Capacity Calculator" tool can be applied to "typical" channel parameters to determine V and Q for specified values of Y in the natural channel. Additional hydraulic calculations use design values of Y, V, and Q to assess performance of stream crossing options at a site (culvert sizes, bridge fill locations). These calculations estimate the impact of the constriction of flow due to the proposed structure, accounting for the impacts of flow expansion and contraction, and higher velocities through the constricted opening. For culverts, a tool such as HydroCulv should be employed to handle the range of complex flow profiles that may occur. For bridges, a simple tool like "Flow Constrict" will perform the necessary calculations.

More detailed and complex hydraulic modeling tools than these are available. These include unsteady flow models, 2D hydraulics models, and 1D gradually varied flow models such as HEC-RAS. In general, the benefits from using these models in analysis and design of stream crossings are minimal and do not justify the expense and time to use them. These models can be very complex to operate, require a lot of data that is not readily available, are still based on assumed boundary conditions, and have many internal parameters that have limited physical meaning. The results can also be very difficult to analyse or locate errors, and seldom provide results that are necessary to the making of engineering decisions.

"Flow Constrict" and "Channel Capacity Calculator" require a description of the channel geometry that is representative of what is "typical" for the channel. Most channels can be reasonably described by a trapezoidal shape with Bedwidth (B), Topwidth (T), and bank height (h). For smaller channels, the best source of typical channel parameters is site inspection by the designer, paying attention to what is natural and what may have been influenced by past construction work. Other sources of channel information include surveys, past descriptions, and photos on file. For larger channels, additional sources of channel descriptions include airphotos, bridge drawings, WSC gauging records, flood risk mapping studies, and other engineering studies. In the future, detailed DEM data may become a useful tool in determination of typical channel parameters.

Floodplains can have a down-slope component to flow conveyance. However, at design water levels, down-slope floodplain conveyance is usually a small percentage of the overall flow. This is due to factors such as the shallow depths, high relative roughness, low velocities, lack of continuous down-slope flow path, and blockage to flow path (trees, buildings, roads, natural topography etc.).

Some of the velocities in the floodplain are due to equalization of water levels and lateral interaction with the main channel flow. In general, it is recommended that the floodplain component not be considered in hydraulic modeling. It should be noted, however, that as water levels rise above the top of bank in the main channel, the mean velocity will continue to rise in addition to the increased flow area, and the design discharge can still be considerably higher than flow at top of bank stage.

The channel slope (S) is also an important factor in hydraulic calculations. In many cases, this value is difficult to determine from site surveys, as the overall drop along the surveyed section is often similar in scale to the variations within the surveyed reach. For most sites, a reasonable estimate of channel slope can be obtained from the profiles derived from DEM data and included in the HIS tool (or derived from the DEM data for channels not yet profiled). These profiles also provide context for the crossing site within the channel, and assist in identifying channel reaches with similar hydraulic properties. For sites near breaks in slope additional guidance on slope selection may be required from site observations and hydraulic calculations.

The other major factor to open channel flow hydraulic calculations is a roughness parameter. Traditionally, the Manning equation and associated roughness parameter has been used for hydraulic calculations, with the roughness parameter selected from publications or calculated from observations. However, a recent study of WSC gauging measurement data in Alberta has shown that for larger channels a variable roughness parameter is not required if the form of the hydraulic equation is changed slightly (see "Evaluation of Open Channel Flow Equations" document). It is recommended that the equation presented in this document be used for channels with B > 10m. This equation is not applicable to smaller channels due to the increased irregularity and influence of the channel banks. The "Hydrotechnical Design Guidelines" provide guidance on selection of Manning roughness coefficient for these channels based on B and S. At in-bank stages, such as used in fish passage calculations, higher roughness coefficients should be used to account for the higher relative roughness. The "Channel Capacity Calculator" and "Flow Constrict" tools can handle both a Manning roughness coefficient and the AT equation. HydroCulv requires a roughness coefficient for the culvert type being analyzed, which can usually be obtained from publications.

Hydraulic calculations of constricted openings will also require coefficients to assess energy losses at sections of rapidly varied flow. These coefficients are usually applied to the velocity head at the constricted section (culvert inlet) or the difference in velocity head between the two sections (bridges, culvert outlet). HEC-RAS documentation suggests a contraction and expansion coefficient of 0.3 and 0.5 respectively for bridges. A coefficient of 1.0 is often used for culvert outlets, but is likely high for structures that match the channel well, especially at lower flows. Coefficients for culvert inlets range from 0.2 for smooth transitions, to 0.5 for beveled inlets and 0.9 for projected ends (no bevel).

Comparison of hydraulic analysis results to known observations should always be performed to verify the parameters being used. For many small sites, known observations may include estimates of channel velocity and observed headloss at structures during runoff events. For sites near WSC gauges, gauging measurements and rating curves (included with the “PeakFlow” tool) can be used to confirm the hydraulic analysis parameters. Caution should be used with rating curves that extend beyond the highest gauged measurement, as these are extrapolations, not measurements.

Most hydraulic calculation tools deliver a high level of precision, but the accuracy is dependant on the input parameters, which all have some degree of uncertainty. Natural channels have mobile boundaries and can undergo both natural and man-made changes. Historic highwater marks can be misinterpreted and blockage and scour can affect hydraulic performance under high runoff conditions. Due to these uncertainties, it is advisable to do a sensitivity analysis covering a likely range of hydraulic parameters, and assessing the impact on structure performance. Although presentation of one set of parameters is more convenient for reporting, the reported precision should be commensurate with the believed accuracy.