Chapter 5
Diversions

5-1. Overview

This chapter presents special requirements for formulating and evaluating flood damage reduction by means of diversion measures. Diversions reduce damage by reducing discharge directly. Table 5-1 is a checklist that summarizes critical requirements for diversions.

5-2. Applicability

A diversion is well-suited for damage reduction in the following cases:

a. Damageable property is water from the system concentrated for bypass measures or spread over a large geographic area with relatively minor local inflows for diversions removing water from the system.

b. A high degree of protection, with little residual damage, is desired.

c. A variety of property, including infrastructure, structures, contents, and agricultural property, is to be protected.

d. Sufficient real estate is available for location of the diversion channel or tunnel at reasonable cost.

e. The value of damageable property protected will justify economically the cost of the diversion.

Table 5-1
Checklist for Diversion

Hydrologic Engineering Study Components	✓	Issues
Layout		Delineate environmentally sensitive aquatic and riparian habitat
		Identify damage centers, delineate developed areas, define land uses for site selection
		Determine right-of-way restriction
		Identify infrastructive/utility crossing conflicts
Economics		Determine with-project modifications to downstream frequency function for existing and future conditions
		Quantify uncertainty in frequency function
		Formulate and evaluate range of outlet configurations for various capacities using risk-based analysis procedures
Performance		Determine expected annual exceedance probability
		Determine expected lifetime exceedance probability
		Describe operation for range of events and analyze sensitivity of critical assumptions
		Describe consequences of capacity exceedances
		Determine event performance
		Formulate OMRR&R plan and prepare O&M manual to include surveillance and flood fighting
Design		Formulate/evaluate preliminary control structure configurations
		Conduct diversion channel sedimentation analysis
		Evaluate all downstream hydrologic and hydraulic impacts
		Formulate preliminary operation plans
Environmental and Social		Evaluate aquatic and riparian habitat impact and identify enhancement opportunities

5-3. Diversion Operation Overview

Figure 5-1 is a sketch of a diversion. This diversion includes a by-pass channel and a control structure that is a broad-crested side-overflow weir. Alternatively, this control structure might be a conduit through an embankment or a gated, operator-controlled weir, and a pipe or other conduit might be used instead of the open diversion channel. For the design illustrated, when the discharge rate in the main channel reaches a predetermined threshold, the stage at the overflow is sufficient to permit water to flow into the diversion channel. This, in turn, reduces discharge in the main channel, thus eliminating or reducing damage to the downstream property. Downstream of the protected area, the bypass and the main channel may join. A plan view of this is shown in Figure 5-2.

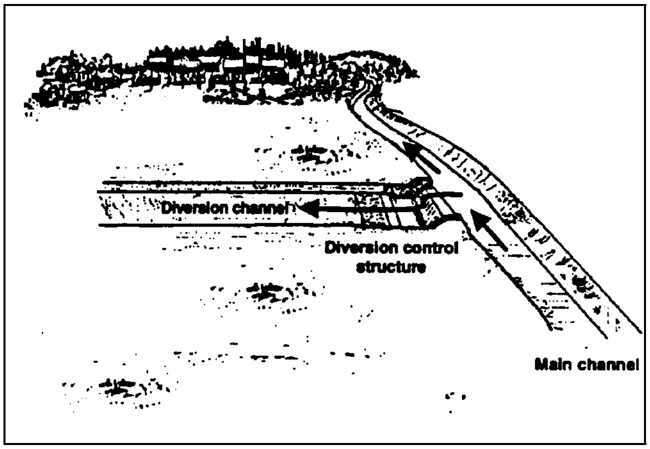

Figure 5-1. Major components of diversion

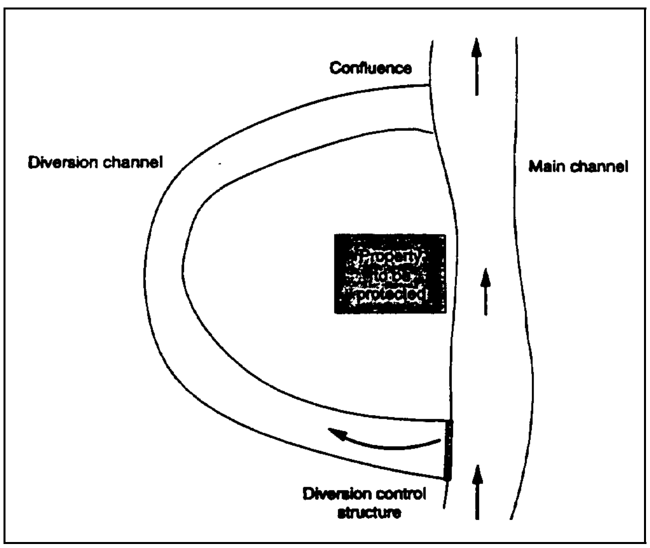

Figure 5-2. Plan view of diversion with downstream confluence

5-4. Discharge-Reduction Assessment

a. As a diversion alters discharge for individual flood events, it will eventually alter the discharge-frequency function. Figure 5-3 shows typical modifications due to a diversion. The solid line represents the without-project discharge frequency function at a location downstream of the diversion control structure. Q_1 represents a target flow at that point; as with a reservoir, this may be the channel capacity downstream, the flow corresponding to the maximum stage before damage is incurred, or any other target selected for a particular alternative. If the main-channel discharge is less than the target, no water need be diverted. When the main-channel discharge exceeds the target, the excess is diverted, limiting main-channel discharge to the target. Consequently, the with-project frequency function, which is shown as a dashed line, is equal to the without-project frequency function for events with exceedance probabilities greater than P_1 and discharges less than Q_1. The with-project function has flows equal to Q_1 when the main channel discharge exceeds this target. However, regardless of the design, some extreme event of probability P_2 will cause the bypass channel to reach its capacity. Then the diversion will no longer be capable of limiting main-channel flow to Q_1. Of course, the diversion may reduce main-channel discharge somewhat. However, as the magnitude of the events increases (and the probability decreases), the with-project main-channel discharge will approach the without-project discharge. Finally, for an event in which the without-project peak discharge equals Q_3, the diversion will have negligible impact, and the without-project and with-project frequency functions will be identical.

b. As with a reservoir, the impact of a diversion on the discharge-frequency function can be evaluated via period-of-record analysis or simulation of selected events. With the period-of-record analysis, the historical discharge time series is analyzed to estimate channel flow when the proposed diversion operates. The resulting modified main-channel discharge time series is analyzed with statistical procedures to define the frequency function. Otherwise, operation of the diversion with selected historical or hypothetical runoff hydrographs is simulated, and the resulting discharge peaks are assigned probabilities equal to the probabilities of the peaks without the diversion.

c. The behavior of a diversion can be modeled with the routing models described in EM 1110-2-1417. At the control structure, a hydraulic model estimates the distribution of discharge into the diversion channel and discharge

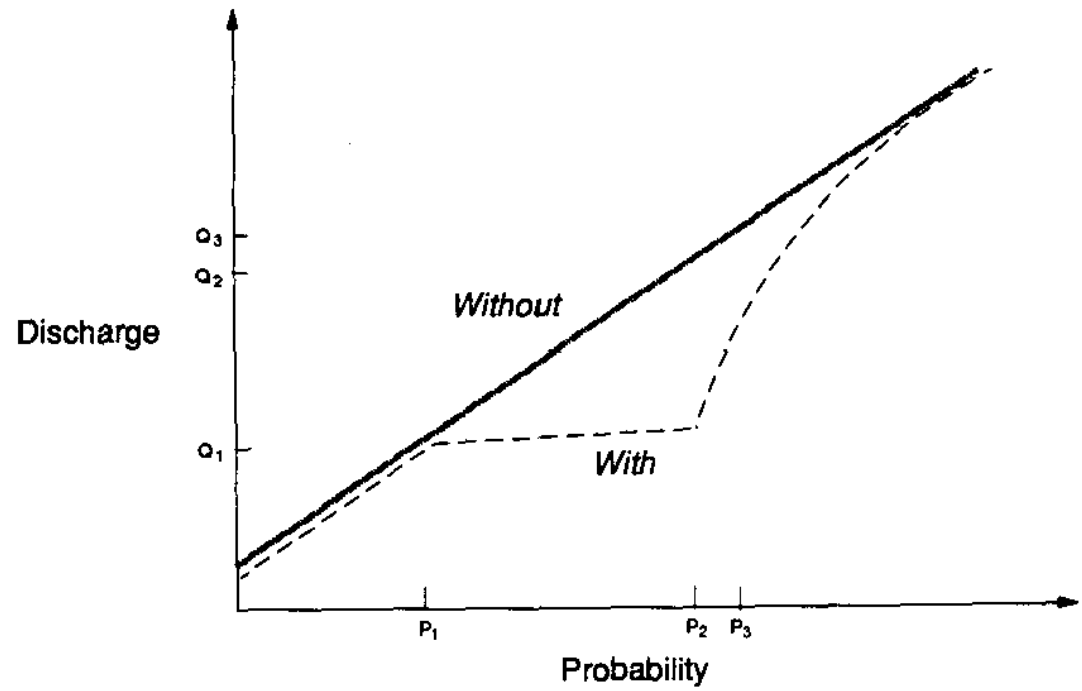

Figure 5-3. Discharge-frequency function modifications due to diversion

in the main channel. This model may be as simple as a diversion-channel flow versus main-channel flow rating curve derived with a one-dimensional gradually varied steady flow (GVSF) model or as complex as the two-dimensional models described in EM 1110-2-1416. Passage of flow in the diversion channel and in the main channel is modeled with a routing model, or, for more detailed analysis of the behavior, with a one-dimensional or gradually varied unsteady flow (GVUSF) model, or even a multi-dimensional flow model. EM 1110-2-1416 provides guidance in model selection.

5-5. Technical Considerations

a. The following potential problems must be considered to ensure proper performance of a diversion: channel stability, deposition, and safety during operation.

(1) Channel stability. A plan that includes a diversion must take care to ensure channel stability in both the diversion and main channels. Stability problems and solutions are described in EM 1110-2-1416 and EM 1110-2-1601, and are summarized in Chapter 4 of this manual.

(2) Deposition. EM 1110-2-4000 points out that "... deposition is a common problem at diversions." Consequently, a sedimentation analysis which estimates the magnitude of this problem and includes the plan remedial actions must be performed. This may include adjustments to the design to minimize deposition, or it might be limited to guaranteeing sufficient funds for continuous OMRR&R.

(3) Safety during operation. A diversion such as that shown in Figures 5-1 and 5-2 is an attractive nuisance. When the main-channel reaches the design level, and water is discharged into the bypass, the public will be attracted. Care must be taken to provide for public safety.

b. Further, under normal circumstances, a diversion channel is dry, so it is subject to unwise temporary or permanent use. If main-channel flows rise quickly, the diversion may begin to function with little advance notice, and the bypass channel will fill. Precautions should be taken to minimize damage within the channel or risk to life if the bypass channel is accessible to the public.