

USDA Forest Service road management decisions are based on Transportation Analysis Process (TAP) (USDA Forest Service 1999) results. Transportation Analysis (previously known as Road Analysis) is an integrated ecological, social, and economic approach to transportation planning, covering both existing and future road and trail systems. Ideally, the TAP should be conducted along with watershed Hydrologic Condition Assessment (Watershed Analysis). The two analyses together create a long-term, large-scale view of both watershed conditions and the transportation system. These extensive results enable road system planning that takes into consideration the context of current watershed conditions and predicted future trends, as well as the location and objectives of individual crossings.

2.1 Evaluate the Whole Road

Large-scale road or trail management objectives should be formulated before locating a new crossing or deciding to fix or replace an existing one. Formulating such objectives requires analyzing the entire road or trail location and asking the following questions:

- Is the road needed?
- Is the road being used?
- What future development is likely to occur, and where?
- How is traffic type likely to change?
- How is traffic volume likely to change?
- Are there alternative access routes with less risk to other resources?
- Is the road located and designed to fit the topography, minimizing resource and maintenance problems?
- Are there recurrent road surface drainage, slope stability, stream stability, or water quality problems?
- What road relocation possibilities exist?
- Are there opportunities to decrease the number of stream crossings?

Many roads were originally constructed where access was easy or traditional, such as through meadows or in riparian corridors with multiple stream crossings. Costs to soil, water, and other resources were not necessarily considered. With new timber harvest technologies, changing management emphasis, and a more developed road network, the road itself may no longer be needed and decommissioning may be a reasonable management choice. Alternatively, a different location may better fit the landscape.

Low-Water Crossings

Certainly in some places, topography, private land, or archeological sites can limit relocation possibilities. Nevertheless, road relocation often solves both resource and long-term maintenance problems. Road relocation, therefore, merits serious consideration even when upfront costs are larger than simple replacement. A truly inclusive value analysis that considers both resource and road-related benefits and costs might lead to a decision to relocate the road away from the stream, minimizing their interactions.

2.2 Evaluate the Crossing Site in its Watershed Context

In addition to the large-scale road or road system evaluation, the site should be evaluated in its watershed context. The entire watershed is linked via its drainage network and upstream and downstream changes can seriously affect a site. Although this is not an exhaustive list, the following questions will help identify essential ecological processes that should be factored into decisions about crossing location and design. (Refer to the site survey and assessment recommendations in section 4.2.)

1. Is the crossing on or just downstream from unstable landforms (e.g., alluvial fans, landslides)? Is it located in a depositional area?

Landslides and earthflows can intermittently produce large amounts of sediment that may cause downstream culvert structures to plug and fail. Alluvial fans and other depositional areas are located where valley gradient flattens or where a confined stream enters a wider valley. Crossing structures in these locations are subject to plugging. In addition, when deposition happens rapidly, such as during a large flood, the channel may shift to another location, leaving the structure isolated.

2. Is the channel stable at the watershed scale? Is there a headcut working upstream that could affect the site in the future? What changes from planned watershed development could affect channel stability upstream or downstream of the site and therefore the site itself?

A stream is a dynamic continuum. Changes in watershed and channel conditions occurring upstream or downstream can affect any point on the stream. For example, streams continuously adjust in response to floods, changes in sediment loads, or changes in riparian conditions that control bank stability. **Channel incision** initiated by, for example, gravel mining or channel straightening can migrate upstream, affecting the entire system's bank and bed stability. An existing or planned dam in the river

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system will change the channel sediment load and can affect streambed elevations. See Rosgen (1996) for information about how and why natural stream channels change over time. Castro (2003) has good information about channel incision mechanisms and effects.

3. *What types of flows are expected from the watershed? Are **base flows** steady, or is the watershed “flashy” with brief, high peak flows? Are most flows clear water or do high flows carry a lot of sediment and debris?*

4. *What hydrologic changes are likely to occur due to any planned watershed development? How might the current streamflow regime (i.e., flow quantity, timing, and duration) change over the structure lifetime?*

Changes in land cover, such as road and housing development, fires, or timber harvests, can change the proportion of precipitation that runs off quickly in floods. Because the road network connects directly to the stream system through ditches and crossings, runoff is delivered to the stream system more quickly, increasing peak discharge and stream power. The increase in the erosive capabilities of the stream can lead to the undermining and outflanking of a structure. If major development is foreseen, consider selecting structures with larger capacities, and upgrading or rearmoring existing structures.

The same changes that increase peak flows may also decrease baseflows, because a greater proportion of precipitation runs off rather than infiltrating into the soil mantle for storage and slow release later in the season. If such decreases are foreseen, consider changing the crossing structure design to ensure low-flow passage for aquatic organisms.

5. *What aquatic biota are present? What are their passage needs?*

Is it necessary to design for passage of aquatic organisms or a specific target species/lifestage? [See the sidebar in section 4.3.] Is a barrier needed to exclude an exotic species from progressing upstream?

6. *What are the constraints on crossing location, (e.g., nearby archeological sites, private land, location of threatened, endangered, or sensitive (TES) plants, special use permits)?*

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7. How is the current crossing affecting the stream? Is it causing sediment deposition (**aggradation**) upstream and/or incision (**degradation**) downstream? Is it causing bank erosion?

8. Is there an active flood plain, or is the channel entrenched (see box Entrenchment Ratio)?

Wide active flood plains that are frequently inundated often have high ecological value as groundwater reservoirs and as specialized habitats for wildlife. In addition to economical and other objectives, crossing objectives at sites like this might include minimizing the degree to which the road and crossing obstruct flows on the flood plain.

Slightly entrenched streams (see box) in broad flood plains are often highly sinuous and, because the outer banks on bends erode, channel location may shift across the flood plain. If this shifting is rapid enough to affect the structure, it will need to be considered in crossing design.

Entrenchment Ratio

Rosgen (1996) defined the entrenchment ratio as flow width when the stream is at “floodprone elevation” (i.e., when the water surface elevation is twice the maximum bankfull depth) divided by bankfull width (fig. 2.1).

Where a channel is incised deeply enough that high flows do not overflow the valley floor, the channel is entrenched (fig. 2.1A). Another type of entrenched channel is one where steep valley walls border the channel. In these channels, when the water surface elevation rises to twice maximum bankfull depth, flow width is no more than 40-percent wider than bankfull.

A slightly entrenched channel is only slightly incised below the valley floor, and when flows exceed bankfull (fig. 2.1D), flow widens out over the flood plain. When flow depth in a slightly entrenched channel reaches two times maximum bankfull depth, flow width exceeds 2.2 times bankfull width. Moderately entrenched channels are intermediate between entrenched and slightly entrenched.

Exactly quantifying the entrenchment ratio is not important for our purposes. We use the degree of entrenchment to describe vertical containment of the channel, which is an important factor in low-water crossing feasibility because it affects:

- How steep the road approaches will need to be.
- How sharp the vertical curve will be.

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- How well the stream can be protected from sediment produced from the road surface and ditches.

The main limitations for low-water structures in entrenched channels are difficulties designing a mild vertical curve and stabilizing and draining a steep approach road (table 3-3). Potential limitations for low-water crossings in slightly entrenched channels are that flow obstructions in the main channel may cause aggradation and bank erosion. The stream may even shift location in some cases.

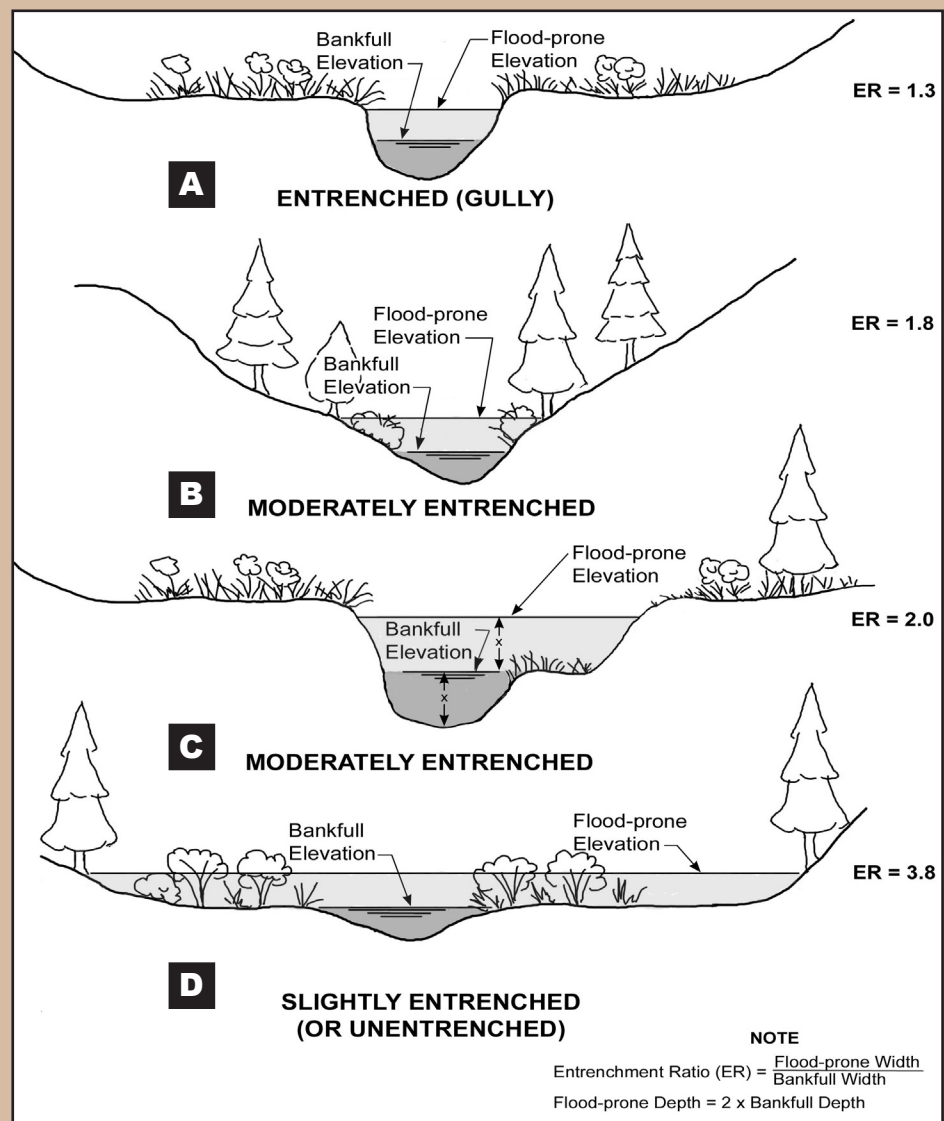


Figure 2.1—Channels with different entrenchment ratios.

Low-Water Crossings

9. Is the channel stable (local scale)?

Both lateral and vertical channel stability should be assessed. If the channel is located on an alluvial fan or where a steep tributary meets the valley edge, sediment deposition is likely during floods, and the channel may be—or become—either laterally or vertically unstable, or both. In arid areas, riparian vegetation may not stabilize streambanks and the channel may shift location dramatically during floods. A relatively cheap and easily reconstructed at-grade structure could be desirable there.

A useful method for evaluating channel stability near road-stream crossings is “Rapid Assessment of Channel Stability in the Vicinity of Road Crossings” by Johnson et al. (1999). The method can help identify specific stability risks the design should cover.

Naturally, stable sites are ideal locations for all types of crossings. At less ideal locations, low-water crossings are sometimes a better choice than ordinary culverts or bridges (see table 3.3.). Nonetheless, when given a choice, always select the best possible crossing site for long-term stability rather than living with a poor site that may continue to require maintenance regardless of the structure type. Given local channel and valley characteristics, consider which location is the best one. From the stream perspective, the “best” location would be:

- Where the crossing least interferes with the movement of water, sediment, debris, and aquatic organisms along both channel and flood plain.
- Where rock and/or dense, deeply rooted bank vegetation make the bed and banks resistant to any flow acceleration the structure may cause.