CHAPTER 4

ACTIVE CHANNEL DESIGN OPTION

LIST OF FIGURES

4 ACTIVE CHANNEL DESIGN OPTION

4.1 Design Method Applicability

As defined by NMFS in their Guidelines for Salmonoid Passage at Stream Crossings document, an active channel is “a waterway of perceptive extent that periodically or continuously contains moving water. It has definite bed and banks which serve to confine the water and includes stream channels, secondary channels, and braided channels. It is often determined by the ordinary high water mark which means that line on the shore established by the fluctuations of water and indicated by physical characteristics such as clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or the appropriate means that consider the characteristics of the surrounding areas.” See Figure 3-2 from Chapter 3 for a graphical identification of active channel.

An active channel design employs a culvert placed at a level grade, sized sufficiently large enough to encourage the natural movement of bedload and the formation of a stable bed inside the culvert. The active channel design method originally was developed with the intent of providing a simplified stream simulation design for private landowners with short crossings under driveways and similar sites. For those limited projects satisfying specific criteria regarding channel slope and culvert length, the active channel design method can greatly reduce the engineering effort necessary to develop a culvert design approved by State and Federal fisheries agencies. The tradeoff for the reduced engineering effort is that it provides a road crossing culvert that is commonly larger than would be required under more rigorous hydraulic design approaches. On a long-term basis, the larger culvert size is likely to enhance the effectiveness of passing storm flow, debris and fish.

The active channel design option will be allowed only if the following conditions apply:

- The natural slope of the stream is 3% or less.
- The culvert length is less than l00 feet.
- The design will be applied to a new culvert installation or to replacement of an existing culvert.

Sites having a natural streambed slope greater than 3%, or sites that require a culvert length greater than 100 feet, must have culvert designs based on the streambed simulation design option or the hydraulic design option. The active channel design option is not appropriate for the design of culvert retrofits.

4.2 Active Channel Design Process Overview

4.2.1 Required Data

Information and field data required to complete a culvert design using the active channel design option includes:

1. Hydrologic determinations of the 10-year and 100-year peak flood discharges. If a hydrologic analysis has not yet been completed, it will be necessary to have a) a topographic map that can be used to identify the boundary, area and slopes of the drainage basin upstream of the culvert location, and b) a description of the ground cover of the drainage basin.
2. Field data indicating the active channel width of the stream in the vicinity of the culvert. Documentation of this data may be facilitated (or may have been previously prepared for

planning purposes) using the active channel portion (page 7) of the form for Caltrans Fish Passage Data Collection - Second Pass Survey Information. Additional information describing the identification and measurement of the active channel width can be found in Section IX of the California Salmonid Stream Habitat Restoration Manual (CDFG 2003).

3. Field data indicating the slope of the natural channel in the vicinity of the culvert site. (The natural channel in the vicinity of the project is commonly called the “reference reach”.) Documentation of longitudinal survey data may be facilitated (or may have been previously prepared for planning purposes) using pages 4 and 5 of the form for Caltrans Fish Passage Data Collection - Second Pass Survey Information. Background information describing key features of a longitudinal survey can be found in Section IX of the California Salmonid Stream Habitat Restoration Manual (CDFG 2003). In cases where there are significant changes in steam channel slope in the vicinity of the culvert, or for culvert replacement projects where the channel has been affected by the existing culvert, it may be necessary to obtain a detailed longitudinal survey to predict the natural channel slope and elevation at the culvert site by interpolating from unaffected conditions upstream and downstream.
4. The proposed roadway alignment and stream alignment in the vicinity of the culvert. (See Topic 823 of the Highway Design Manual for guidelines relating to culvert alignment and Section 3.1 of this manual for additional measures that can enhance fish passage effectiveness of culverts.)
5. The proposed roadway cross section, taken at the midpoint of the culvert.
6. Corrosion zone location, pH, and resistivity of the site.
7. Any other unique features that can affect design, such as low-lying structures that could be affected by excessive headwater or other considerations discussed in Section 2.2.

4.2.2 Engineering Analysis and Reporting

The collected data will be used to perform an engineering analysis and complete the active channel culvert design. Summary information from the analysis and design will be recorded in a report that shall include the following:

1. Data as described in Section 4.2.1.
2. Culvert design calculations as described in Section 4.3.
3. Roadway stationing of the culvert location.
4. Culvert length and size.
5. Culvert material.
6. Culvert profile, plus additional profile of the stream channel if required by Section 4.4.
7. Roadway cross-section and roadway profile, demonstrating the maximum height of fill over the culvert.
8. Calculations for flood capacity check.
9. Calculations for structural design check.
10. Description of culvert end treatment and any additional culvert appurtenances.

4.3 Culvert Design

The active channel method for culvert design uses a simplified approach to determine the size of the culvert, based generally on the dimensions of the stream in the vicinity of the road crossing. Although this reduces much of the hydraulic engineering effort required for the design, it is nonetheless necessary to conduct hydrologic, hydraulic and structural analyses to complete the design effort.

This chapter includes references to the following manuals:

- The Federal Highway Administration's "Hydraulic Design Series No. 5 - Hydraulic Design of Highway Culverts" (HDS 5).
- The Caltrans "Highway Design Manual".

The designer should refer to these manuals for greater detail regarding the theories supporting the methods and materials presented in this section.

The general procedure to follow when using the active channel design option includes the following steps:

1. Determine the minimum culvert size (Section 4.3.1).
2. Determine the invert elevations and associated embedment elevations at the channel inlet and outlet (Section 4.3.2).
3. Calculate the culvert design flows and complete an interactive flood capacity check (Section 4.3.3).
4. Design the culvert appurtenances, such as the end treatments (Section 4.3.4).
5. Conduct a structural design check (Section 4.3.5).
6. Determine channel profile design requirements (Section 4.4).

4.3.1 Culvert Size and Shape

The active channel design option is based on the average active channel width in the vicinity of the culvert, as reported in the compiled data. The preliminary minimum culvert diameter is calculated by multiplying the average active channel width by 1.5. It is anticipated that all culverts designed by the active channel method will comply with Topic 828 of the Caltrans HDM, requiring that a culvert diameter be greater than 450 mm for roadway cross culverts and greater than 300 mm for other culverts.

Any culvert shape can be used with the active channel design option. (See Section 3.2 for a discussion of common culvert shapes and the terminology used for their dimensions.) At this stage of the design, a preferred culvert shape should be selected. If the selected culvert shape is not circular, establish preliminary values for the culvert span and rise based on the minimum culvert diameter previously calculated, taking into account the standard dimensions of culvert products commonly used in the project area.

4.3.2 Culvert Invert

The active channel design option provides for the culvert to be installed at a zero slope with the culvert invert placed below the natural streambed elevation, allowing the natural movement of bedload to form a stable bed inside the culvert. Criteria established by CDFG (Appendix B) and

NOAA Fisheries (Appendix C) require the invert at the culvert outlet to be embedded no less than 20 percent of the culvert diameter or rise. Additionally, the invert at the culvert inlet must be embedded no more than 40 percent of the culvert diameter or rise. Figure 4.1 illustrates the criteria requirements for an active channel design.

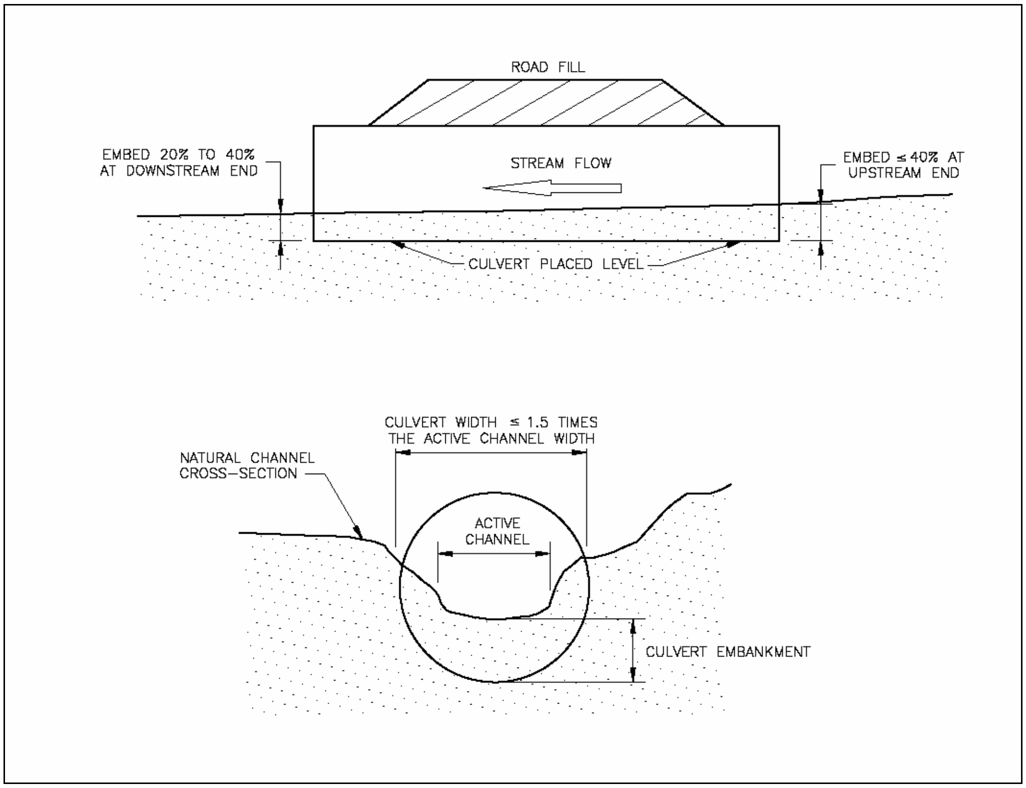

Figure 4-1. Active channel criteria diagram

The first step in designing the culvert invert elevation is to determine the natural streambed elevations at both the outlet and inlet of the proposed culvert. The highest elevation at which the invert can be placed is calculated by subtracting 20 percent of the culvert height from the streambed elevation at the outlet. The lowest allowed elevation for the invert is calculated by subtracting 40 percent of the culvert height from the streambed elevation at the inlet. If these calculations result in a "lowest" elevation that is greater than the "highest" allowed elevation, then it will be necessary to select a culvert with a larger diameter or rise, and reiterate the design process until the embedment criteria are met.

If the project involves replacement of an existing culvert that is either perched or undersized, it is probable that the culvert will have affected the local channel slope, width and elevation. In these cases, it will be necessary to obtain a detailed longitudinal survey that extends to unaffected areas upstream and downstream of the culvert site, in order to predict the natural channel slope and elevation at the culvert site by interpolation.

4.3.3 Flood Flow Capacity Check

At this stage of the active channel design, the preliminary size, shape and embedment characteristics of the culvert are analyzed to estimate water surface elevations that occur during discharges associated with a 10-year peak flood and 100-year peak flood. Current passage criteria of CDFG (2003) and NOAA-SWR (2001) state the upstream water surface elevation shall not exceed the top of the culvert inlet for the 10-year peak flood. In addition, for the 100-year peak flood, the upstream water surface elevation shall not be greater than 50 percent of the culvert height or diameter above the top (ceiling)of the culvert inlet.

Hydrologic analyses to determine flood flows are often completed during the planning stages of design. If project planning documents do not identify the flood flow discharges for the 10-year and 100-year peak flood events, the designer should refer to Section 3.4 for a more detailed discussion of hydrologic methods that can be used to derive these values.

The open area of an embedded circular or elliptical pipe can be estimated from basic geometric properties of the radius (or pipe rise), corner radius (where applicable), and depth of embedment. The open area of the pipe is then used in the determination of the water surface elevation under the peak flood discharge conditions. If either of the flood capacity criteria noted above are not satisfied with the selected pipe size, then the design process should be repeated with a larger pipe size until the flood capacity criteria are met. Section 3.5 provides equations and nomographs that facilitate the hydraulic analysis of the pipe flow capacity.

4.3.4 Culvert Appurtenances

The design of culvert end treatments may vary depending on site specific issues such as retention of roadway embankment, hydraulic efficiency, and debris control. In general, fisheries agencies encourage end treatments that provide a smooth hydraulic transition between the upstream channel and the culvert inlet, as a means to facilitate the passage of flood borne debris. Section 3.6 provides a more detailed discussion of end treatment options that should be considered during the design of an active channel culvert.

Interior illumination should not be required for an active channel design, since active channel culverts are limited to a maximum length of 100 feet; current passage criteria of CDFG (2003) and NOAA-SWR (2001) require interior illumination only when the culvert length is greater than 150 feet.

4.3.5 Structural Design Check

All culvert stream crossings, including those developed with the active channel design option, must be analyzed to ensure the installation can withstand the 100-year peak flood flow without structural damage to the crossing. The analysis must consider debris loading that is likely to be encountered during flooding. Section 3.9 provides a more detailed discussion of accepted methods for completing the check.