Illinois Department of Transportation

Memorandum

To:	Studies and Plans Squads		PPM 50-10
From:	James M. Sullivan	Revised by:	Tim Brandenburg
Subject:	Culvert Lengths and Design		
Date:	December 23, 1999	Revision Date:	May 6, 2004

PLAN PREPARATION MEMORANDUM 50-10

BACKGROUND

The purpose of this policy is to outline the correct procedures for determining culvert lengths, end treatments, safety treatments, and other details of culvert design. This memo supersedes, incorporates, and/or replaces the following memos. All of these earlier versions should be discarded: 76-78.P (September 29, 1976), 84-144.P (August 27, 1984), 87-19.P (Rev.) (April 20, 1990), 86-177.P (September 25, 1986).

PROCEDURE

Culvert Material

Refer to Chapter 40-3.07 of the BDE Manual for allowable culvert materials, based on location, traffic, and other factors. However, all across road culverts and across road culvert extensions on State maintained highways shall be Class A. Existing culvert extensions of other materials may remain if they are in good condition, require no further extension, and are beyond the shoulder line of the proposed work.

Culvert Length

The end of the culvert is located at the point where the top of the culvert end section or headwall intercepts the embankment side slope. The embankment slope adjacent to the end section is steepened to match the slope of the end section wingwalls. This procedure is necessary to ensure that the culvert end section and the steeper slopes around the end section do not encroach into the road ditch cross section.

These procedures vary slightly, depending on the specific type of end section used. The procedures may be divided into four cases: precast concrete flared end sections, metal end sections, cast-in-place concrete end sections, and precast box culvert end sections. These cases are detailed for right angle culverts, in the attachments to this memo.

The details for the cases are shown for across road culverts, but the information can be used for entrance and sideroad culverts. Rural, 3R project normally require 2' shoulders for field and private entrances, 3' shoulders for commercial entrances and 4:1 sideslopes for all entrances. Rural expressways allow only field or private entrances, using 2' shoulders and 6:1 sideslopes. Section 38 of the BDE Manual gives further recommendations for acceptable sideslopes. Mailbox turnouts adjacent to entrances pose problems on many projects. An acceptable sideslope must be maintained adjacent tot eh turnout, many times requiring the culvert to extend well beyond the entrance to the end of the turnout.

Pay lengths of precast culverts shall be from end to end of precast segments.

Culvert End Treatments – General

Unless they are adapted for the specific skew angle(s), precast end sections and metal end sections are not allowed on culvert with skews greater than 15 degrees. End sections with slopes steeper than 2:1 should not be used.

Precast end sections with the wingwalls parallel to the barrel walls will not be allowed without the approval of the Project Engineer, or Bridge and Hydraulics Engineers.

Culvert End Treatments – Precast Box Culverts

Cast-in-place end treatments for precast box culverts will be used. Refer to Figure 2.3.4-3 and 2.3.4-4 of the Culvert Manual for a feasible design using a collared end section with an apron floor. Another option, for a single barrel precast culvert, is to construct the last 1.8 m (6 feet) of the barrel as cast-in-place and employing horizontal cantilever wingwalls designed according to the Culvert Manual. The cast-in-place portion of the barrel shall be collared onto the last precast section. The designer shall check soil support requirements against soil borings at the site, and limitations on height, length, and fill height for the various types of cast-in-place wingwalls.

Cast-in-place end treatments for precast culverts shall be designed in detail with complete and accurate drawings, bills of materials, and specifications for bidding. District General Note 540-A shall be included in the plans for these end treatments. Payment for these end sections shall be per BOX CULVERT END SECTIONS of the culvert number specified.

Safety Treatments at Culverts

This section deals with culvert treatments on 3R jobs. For new construction or reconstruction refer to Chapter 38 of the Bureau of Design and Environment Manual.

Ideally, all culvert end treatments would match into traversable roadside slopes and would not present hazards to vehicles. However, the ends of culverts do usually pose some potential hazard and should be analyzed. The first consideration must be to eliminate or reduce the hazard. One way to reduce the hazard is to move the end of the culvert outside the clear zone. Considerations for this option are given later in this section.

Dropoffs 36 Inches or Less:

For culverts with 36 inch or less dropoff, the 3R guidelines do not require any treatment, other than assuring that they end beyond the shoulder line. The designer should remain aware of any special hazards posed even by small culverts. At times it may be attractive to extend small culverts if their outlets create sharp ditches across the clear zone, if they have drop inlets, or other features which would be particularly hazardous.

Dropoffs 36 to 54 Inches:

For culverts with dropoffs between 36 inches and 54 inches, the 3R guidelines indicate that flared precast end sections with gratings should be installed when the culverts end beyond the shoulder but still within the clear zone. Obviously, this is only feasible for concrete pipe culverts. For other culverts, such as box culverts, consideration should be given to custom grating for the end section, installation of guardrail, or analysis to justify the “do nothing” option.

For either the precast flared end sections, or for custom designed grating systems on box culverts, the designer must consider the possibility of drift from fields and woods plugging the grating and causing water over the road or other problems. Please consult your Project Engineer when you identify areas that may be susceptible to plugging.

When gratings are used, spacing for the pipes of up to 30” should be considered. See Chapter 50 of the BDE Manual. This treatment allows for the culvert to match into the prevailing slopes while keeping the sideslope traversable.

If grating is not feasible and the culvert dropoff must occur within the clear zone, the designer should make an analysis of guardrail vs. “do nothing”. Although FIGURE 3 in the 3R guidelines refers to culverts greater than 1400 mm (54 inches), this chart may be used for smaller culverts by entering the size of the culvert as 54 inches. Although the actual culvert may be smaller, the resulting answer will be conservative and may be use.d Another possible tool for guiding this decision is the Cost-Effectiveness Analysis outlined in the Roadside Design Guide.

Dropoffs Greater than 54 Inches:

The designer may use FIGURE 3 and/or the Cost-Effectiveness Analysis, both mentioned above, to help decide guardrail warrants for culverts over 54 inches. Gratings may be feasible for these larger culverts but require special attention to span length of the pipes, and consideration of drift from large upstream drainage areas. Also, at the tips of the wingwalls, the remaining dropoff may still remain a significant hazard.

Culverts with dropoffs of 10 feet or more are not allowed to remain within the clear zone without guardrail shielding.

Guardrail – General Considerations:

If guardrail is necessary, the designer should optimize the taper rate, and use a flared end section, if possible, to minimize the length of need and exposure of the guardrail.

Guardrail is a continuous maintenance problem for mowing, snow removal, and repair. Also, it is a significant roadside hazard, and a much larger target than the culvert itself. The embankment widening at the terminal sections may present unusual design problems for ditch alignment or even create right of way needs. As a general rule, guardrail is preferable to extending the culvert to the clear zone for larger height culverts/dropoffs.

Extension to Clear Zone – General Considerations:

Culvert extensions to the clear zone require careful design of the slopes to assure that the foreslope transitions do not create a “ramp” effect. These transitions should be at a minimum taper rate of 7.5 longitudinal to 1 lateral, and should not present a concave surface with respect to the approaching traffic. Also, extension of a hazard to a point at or just beyond the clear zone only reduces the likelihood that the hazard will be involved in a serious crash. The hazard remains as severe as ever to the vehicle and occupants who have the misfortune to confront it. As a general rule, extending a culvert beyond the clear zone is preferable for smaller dropoffs requiring action.

Culvert Inspection/Scoping

The preparation of studies and plans includes the field inspection of all drainage structures, investigation of high water reports, hydraulic review, and design of box culverts. The Squad Leader should inspect all single barrel or pipe culverts on each project as soon as possible to determine if the culverts should remain and whether they are suitable to extend if necessary. Where significant culvert work is needed, it should be diagrammed for inclusion in the study or project report, and reflected in the cost estimate.

Should the Squad Leader need help to determine a particular or unusual culvert condition, the District Bridge and Hydraulics Engineer will help as necessary. Should the Squad Leader become aware of a multiple box culvert that has not been addressed by the Bridge and Hydraulics Section in the Bridge Condition Report for the section, he/she should notify the Bridge and Hydraulics Engineer at once. If there is a survey for the project, the survey crew will *note (if requested by the Squad Leader)*, the culvert condition in the survey; however, it is the Squad Leader's responsibility to confirm the survey crew's findings.

Foundations for Precast Box Culverts

When precast concrete box culverts or cast-in-place box culverts with the option to use precast box culverts are called for on the plans, oil borings are required. Please note the Standard Specifications allow the precast option unless the plans clearly state cast-in-place is the only option allowed. A request to the Geotechnical Engineer in Project Implementation for the borings and to check the soil condition at the location of culvert must be made by the designer. The request for soil borings should be in the form of a memo to the Geotechnical Engineer. The memo shall include a location map giving the site, stationing of the culvert, the proposed culvert's size and length, and the timeframe needed for the boring information. The borings must be made and included in the plans prior to submittal for letting.

The District Geotechnical Engineer will analyze the soil borings and give the designer any specific foundation requirements. Depending on soil conditions, and this analysis by the Geotechnical Engineer, something other than the 6 inch thickness of porous granular material under the culvert, and/or wingwalls may be required. If undercut is required with backfill of RR-1, use District special Provision "PRECAST CONCRETE BOX CULVERTS", along with job-specific details and specifications for the undercutting work. If no undercut is required, use the Central Office specifications for this work.

Porous Granular Backfill

Porous Granular Backfill should be considered when poor soil conditions dictate, or when it is critical to place the backfill very quickly. Placement of pipe culverts and precast box culverts across existing roadways constructed under traffic will usually require Porous Granular backfill. For roadway construction on new alignments closed to traffic during construction, or for locations constructed using staged traffic control with signals, time constraints will not usually require the Porous Granular Backfill. When Porous Granular Backfill is used, the plans must clearly show the pay limits. If Porous Granular Backfill is required for a culvert, use District Special Provision "POROUS GRANULAR BACKFILL".

Structural Design

Effective January 4, 1988, the Bureau of Bridges and Structures has no longer been reviewing final plans for simple span box culverts prepared by us or consultants where the design is within the scope of the Culvert Manual.

Effective April 10, 1990, the Bureau of Bridges and Structures has allowed the District to design all multiple cell precast box culverts.

The latest guidance from the Bureau of Bridges and Structures regarding simple span & multiple cell box culverts is included in Sections 2.2 & 2.3 of the Culvert Manual, respectively. Comments from a memorandum dated June 18, 1999, from Ralph E. Anderson, titled "Multiple Cell Precast Box Culverts" shown below. The District has considered the "General Guidelines" Items 1 through 4 and will follow them as noted below:

1. *"Use precast end sections whenever possible, subject to hydraulic acceptability."* Precast end sections with the wingwalls parallel to the box culvert sidewalls should not be used without special consideration and approval of the Project Engineer or the Bridge and Hydraulics Engineer.

2. *"Use cast-in-place wingwalls with apron when precast ends are not feasible."* Cast-in-place end treatments for precast culverts will be used as previously discussed. (See "Culvert End Treatments – Precast Box Culverts."). The designer must carefully check any proposed cast-in-place wingwall type against the criteria in the Culvert Manual. Factors including fill height, wing length, and wing height will control which types are feasible.

3. *"Avoid using a cast-in-place end barrel with cast-in-place wingwalls as much as possible."* Cast-in-place end barrels with cast-in-place wingwalls may be considered. The designer should consider all potential negative impacts of this design. The cost may well be higher, and the shorter placement length for the precast sections may compromise the safety or feasibility of stage construction.

4. *"For skewed culverts, lengthen the culvert as required (even if additional right-of-way is needed) to allow the use of precast end sections whenever possible."* Lengthening the culvert does not improve the fit of precast end sections for skewed culverts. For skewed culverts, the end sections, whether cast-in-place or precast, shall be designed according to the sections above with full consideration and comparison of alternates based on cost, right of way impacts, and safety.

Traffic Control

There are two main types of traffic control for construction of across culverts, road closure at the construction site, and stage construction. They have subtypes as follows:

Staging

Daytime Operations Only – Suitable for small culverts with shallow covert.
24-Hour Flaggers – May be feasible for operations up to 72 hours.
Traffic Signals – Feasible for most jobs. Does not apply for multi-lanes.

Road Closure

Runaround Detour – Consider for major structures when economical.
Marked Route Detour – Consider when time of closure is short and traffic light to moderate.
Median Crossover Detour – Consider for major structures on multilane roads when economical.

The selection of the type of traffic control must consider the factors mentioned in Chapter 13 of the BDE Manual. In addition, for culvert construction, a few additional items must be considered:

Depth of cover – The deeper the cover over a culvert, the more difficult and expensive stage construction will be. Temporary sheet piling becomes necessary when exposed vertical surfaces are necessary at nor near the stage construction line. Also, deeper excavations affect the time required for construction. Deep excavations are not feasible for Daytime Operations Only. When the total time from start to finish would exceed 72 hours, the option of 24-Hour Flaggers should be avoided. Deep excavations also pose more risk to traffic, and usually require Temporary Concrete Barriers to protect traffic.

Skew of crossing – The Designer must lay out the culvert joints along the stage construction line in evaluating stage construction of precast box culverts. As the skew, width, or diameter of precast culvert, and number of barrels increase, the skewed joint area becomes wider and stage construction becomes less feasible.

Temporary Sheet Piling – If Temporary Sheet Piling is required for Stage Construction, then traffic signals and Temporary Concrete Barrier should be used. Design of Temporary Sheet Piling is addressed in All Bridge Design Memorandum (ABD) 03.01, dated January 6, 2003.

Time Required for Construction – Some culverts, especially precast, can be built very quickly with the road closed. The designer should consider all factors including type of culvert (precast vs. cast-in-place), time duration of construction, and cost of adverse travel. Usually only the barrel portion will have to be in place to reopen the road, with the end treatments being built after traffic restored.

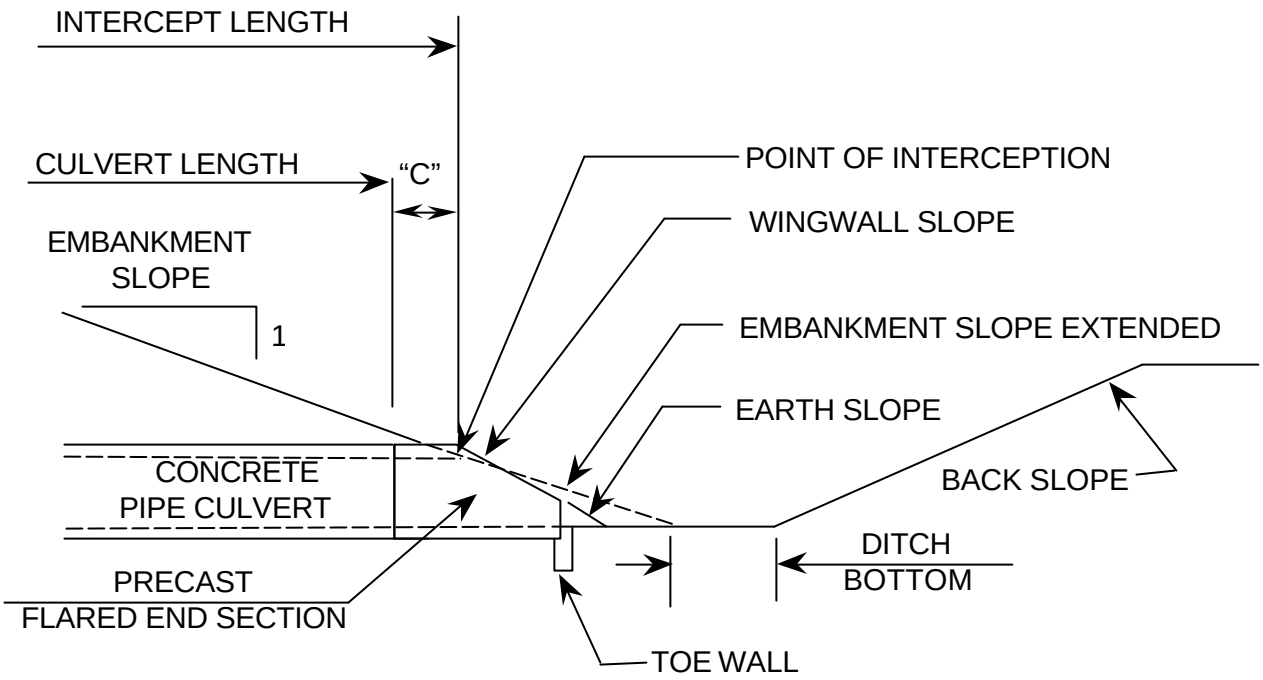
Attach.:

Culvert Length Sketches; Cases I thru IV

CASE I

Pipe culverts with precast reinforced concrete flared end sections.

The Length to the interception of the embankment with the top, inside of the pipe is calculated. The value of "C" for the end section, from the appropriate highway standard, is deducted from the interception length. This resulting length is then used to determine culvert length.

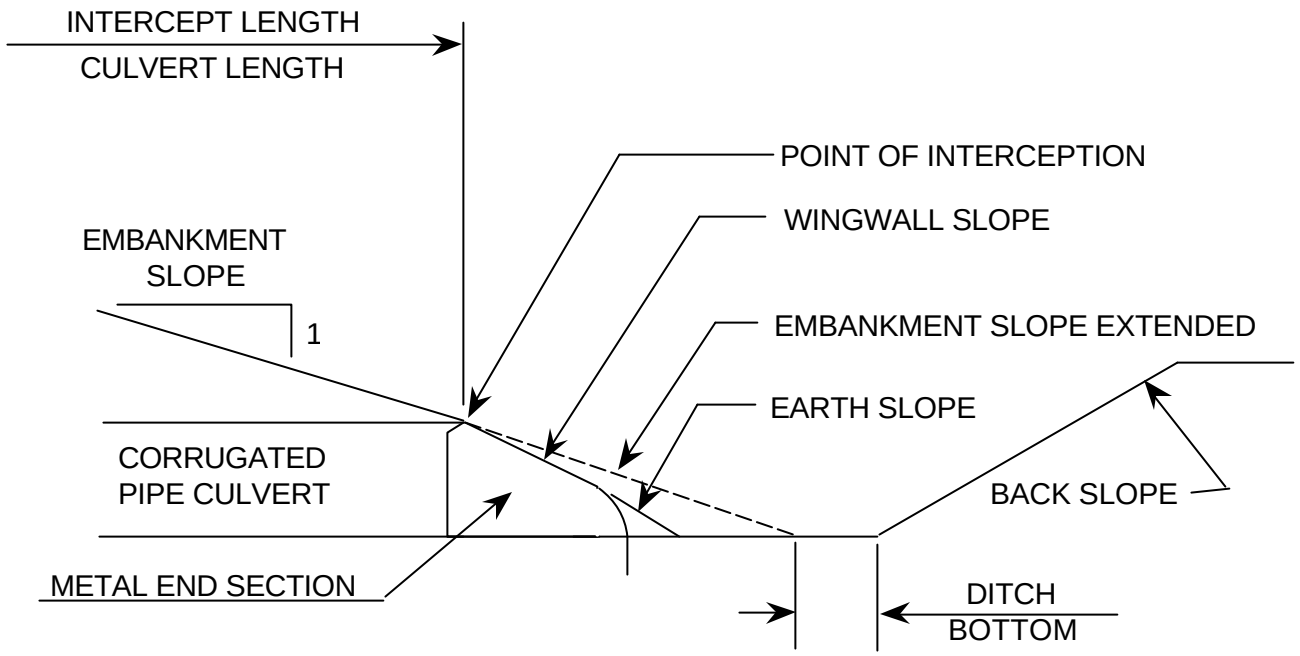


ELEVATION

CASE II

Pipe culverts with metal end sections.

The length of the interception on the embankment slope with the top of the pipe culvert is used to determine culvert length.

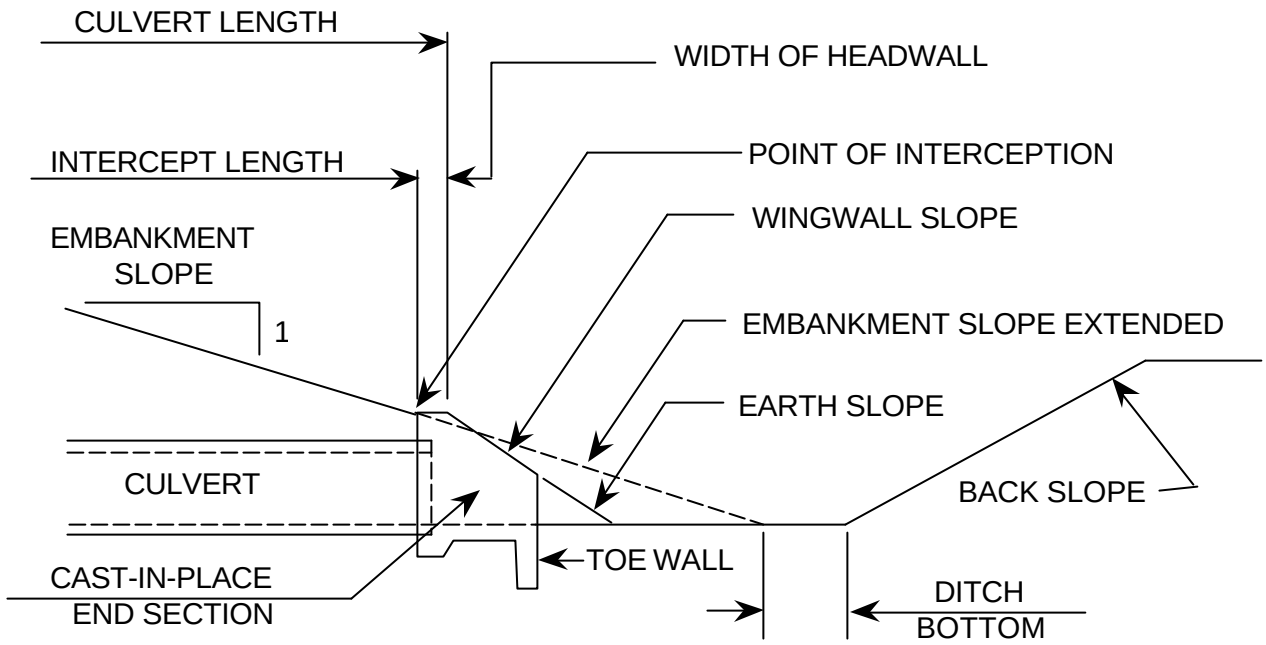


ELEVATION

CASE III

Culverts with cast-in-place end sections.

The length to the interception of the embankment slope with the top, back of the headwalls is calculated. The width of the embankment is added to the interception length.
This resulting length is then used to determine the culvert length.



ELEVATION

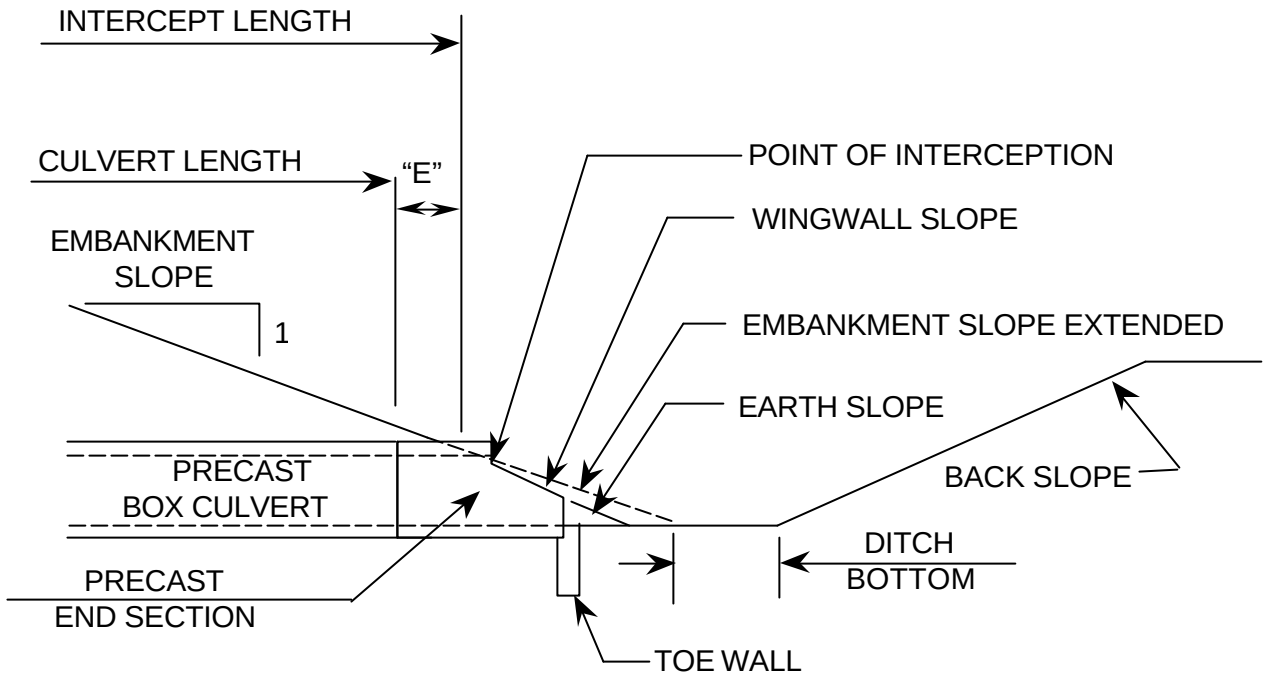
CASE IV

Precast box culverts with precast box culvert end sections (parallel wingwalls).

Precast box culvert end sections are not desirable unless they include flared wingwalls that will prevent encroachment of the earth slopes into the culvert opening.

Precast end sections without flared wingwalls should definitely NOT be used if the span is less than twice the rise.

The length of the interception of the embankment slope with the top, inside of the box culvert is calculated. The value "E" from the precast end section detail is deducted from the interception length. This resulting length is then used to determine culvert length.



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