American Railway Engineering and Maintenance-of-Way Association
Ballot

1. **Committee and Subcommittee: 1**

2. **Ballot Number:** D4-8-17

3. **Assignment:**

4. **Ballot Item:** update of Section 4.12

5. **Rationale:**

SECTION 4.12 HYDRAULICS OF CULVERTS AND STORM DRAINAGE SYSTEMS

NOTE TO AREMA HEADQUARTERS:
THIS SECTION REPLACES AREMA SECTION 4.12.1

4.12.1 INTRODUCTION (2023)

It is recommended that an experienced professional conduct a study to determine the appropriate system for railroad facilities and field check the system to provide the most optimum design for protection of railroad operations, infrastructure and surrounding property.

Designers of culverts and storm sewer systems should have a basic understanding of hydrology and hydraulic principles. Detailed coverage of these subjects is available in *HDS-2, Hydrology, HDS-4, Introduction to Highway Hydraulics, Design and Construction of Urban Stormwater Management Systems* and other hydrologic and hydraulic texts.

DESIGN OF CULVERT SYSTEMS

A culvert is a hydraulically short conduit which conveys stream flow through a roadway embankment or past some other type of flow obstruction as defined in Hydraulic Design Series 5 (HDS-5)

a) Research by the National Bureau of Standards (NBS), supported by the Federal Highway Administration (FHWA), formerly the Bureau of Public Roads (BPR), began in the 1950s and resulted in a series of seven reports, which provided a comprehensive analysis of culvert hydraulics under various flow conditions. This data was used by the BPR staff to develop culvert design aids (nomographs). These are the basis of the culvert design procedures in *Hydraulic Engineering Circular (HEC) No. 5, 13 and HDS-5*. Computational algorithms are also incorporated into many of the common computer programs in use today for culvert hydraulics such as HY-8 and HEC River Analysis System (Hec-RAS). A complete theoretical analysis of culvert hydraulics is time-consuming and difficult and flow conditions may vary over time for a given culvert. Use of the design aids and computer programs is acceptable and encouraged; however, developing good engineering judgement when applying them is critical to the safety and operations of railroads.

b) Designers are referred to the Federal Highway Administration's *Hydraulic Design Series 5* (HDS-5) for a comprehensive treatment of culvert hydraulic design. The latest edition of this drainage manual may be downloaded free of charge at the FHWA's website:
https://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=7&id=13

ITEMS TO KEEP IN MIND WHEN DESIGNING CULVERTS INCLUDES BUT IS NOT LIMITED TO:

- The operating railroad's most current **hydrologic and hydraulic design criteria** for the specific line segment should be applied where the system is located. If the operating railroad does not have criteria, State Departments of Transportations (DOTs), Local jurisdictions or other agencies may have appropriate design guidance. *TABLE 1-4-1A SUGGESTED DISCHARGES* is also provided for guidance. For estimating discharges refer to AREMA Section 3.2 for guidance.
- FEMA requirements, such as FEMA flood zone designation or designated Floodway. These factors may affect decisions regarding designing the system.
- Available design headwater for the culvert to operate. The railroad may have specific restrictions on the allowable headwater elevation. Additionally, there may be upstream property that might restrict the design headwater elevation for the culvert.
- Additional environmental considerations may be necessary depending on the culvert or storm drainage system location, site conditions, and requirements by various local and federal agencies. Such considerations may include but not be limited to aquatic organism passage (AOP), end treatments, stream bed / invert design, wildlife crossing, sustainability / resilience, and aesthetic requirements. Environmental considerations may affect structure sizing and require additional features beyond structure hydraulics.
- Permitting by the Federal, State, or local authorities.
- Past performance of the previous culvert if one existed. Local railroad personnel may have institutional knowledge of problems associated with the existing culvert such as slow orders, debris load (obstructions),

ice flow, flooding, embankment washouts, or scour on the upstream or downstream end of the culvert.

- Stream planform surrounding the railroad and evidence of vertical or lateral instability or lateral migration. The culvert should be located to accommodate the stream planform for its service life as much as practical.

CULVERT HYDRAULIC DESIGN PROCESS

- Decisions made at the inception of a design are critically important. Design discharge estimates, roughness coefficients, inlet, and outlet configurations, tailwater conditions, and other factors may affect system hydraulic performance and should be carefully considered.

- Conducting a risk analysis is a means of assessing the economic behavior of different design alternatives. HDS-5 lists a process to produce the *least total expected cost* (LTEC) design alternative. A flowchart for this design process is shown below:

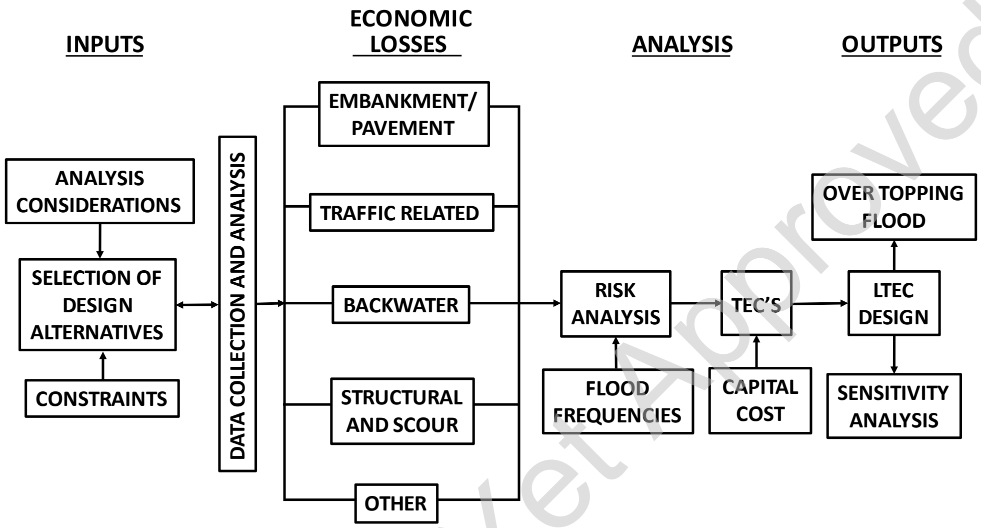

Figure 1-4-1A—LTEC Design Process

See HDS-5 Section IV– E-4 for a complete discussion of Risk analysis and the LTEC Design Process.

- An alternate process listed in HDS-5 involves analyzing a culvert for various types of flow control and then selecting design for the flow control which produces the **minimum performance** (maximum headwater conditions). Designing for minimum performance ignores transient conditions which might result in periods of better performance. Advantages of designing for minimum performance include simplified design and assurance that adequate performance is met under the least favorable hydraulic conditions. This also follows a basic design philosophy of many railroad industry professionals: **IF THE SYSTEM FAILS, MAKE SURE IT FAILS IN THE SAFEST WAY POSSIBLE.**

The basic design procedure consists of:

1. Collecting field data
2. Compiling facts about the railroad facility
3. Making a reasonable estimate of flood flow to the various drainage system components
4. Designing an economical drainage system to handle the flow with minimum damage to the right of way or adjacent property.

DESIGN OF STORM SEWER SYSTEMS

A storm drainage system receives surface water into system openings (inlets) and conveys the water through conduits (segments of pipe or ditches or a combination of both pipes and ditches) to an outfall. These types of systems may exist in rail yards and run longitudinally or transverse between tracks. They may also exist along roadways parking areas or other railroad facilities.

Designers are referred to the Federal Highway Administration's *Hydraulic Engineering Circular No. 22 (HEC-22), - Urban Drainage Manual* for a comprehensive treatment of storm drainage design. The latest edition of this manual may be downloaded free of charge from FHWA's website:
https://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=22&id=140

A LIST OF ITEMS TO KEEP IN MIND WHEN DESIGNING A STORM SEWER SYSTEM MAY INCLUDE BUT ARE NOT LIMITED TO:

- The operating railroad's most current **hydrologic and hydraulic design criteria** for the specific line segment should be applied where the system is located. If the operating railroad does not have criteria, State Departments of Transportations (DOTs), Local jurisdictions or other agencies may have appropriate design guidance. *TABLE 1-4-14A SUGGESTED DISCHARGES* is also provided for guidance. For estimating discharges refer to AREMA Section 3.2 for guidance.
- FEMA requirements, such as FEMA flood zone designation or designated Floodway. These factors may affect decisions regarding designing the system.
- Decisions regarding tailwater conditions, design discharge estimates, roughness coefficients, inlet and outlet configurations and other items that affect system performance should be carefully considered.
- HEC-22 also has guidance for determining design discharges, which is the first step in determining the appropriate size for inlets, pipes and ditches and other conveyance systems for a given site.
- HEC-22 provides a comprehensive and practical guide for the design of storm drainage systems that collect, convey and discharge stormwater flowing within and along the right-of-way.
- Past performance of the previous system if one existed. Local railroad personnel may have institutional knowledge of problems associated with the existing systems such as slow orders, debris load, flooding, washouts, or scour.
- Stream planform surrounding the railroad and evidence of vertical or lateral instability should be considered in system designs. The system should be located to accommodate the stream planform for its service life as much as practical.
- Ecological considerations if applicable for the project site.
- Permitting issues such as Federal, State and Local authorities.
- Consider having an overflow channel or way to convey flood flow safely for less frequent storm events in excess of the drainage system's maximum capacity.

The basic design procedure consists of:

1. Collecting field data
2. Compiling facts about the railroad facility
3. Making a reasonable estimate of flood flow to the various drainage system components.
4. Designing an economical drainage system to handle the flow with minimum damage to the right of way or adjacent property.

TABLE 1-4-14A

TYPE OF RAILROAD FACILITY	SUGGESTED DESIGN DISCHARGE	COMMENTS
CULVERT DESIGN DISCHARGES		
MAIN LINE TRACKS		
PRIMARY MAIN LINE AND SIDINGS	50 YEAR / 100 YEAR	50 YEAR DESIGN DISCHARGE TO HAVE FREE SURFACE AT THE CULVERT ENTRANCE - 100 YEAR DISCHARGE TO NOT COME IN CONTACT WITH THE TRACK SUB-BALLAST AT THE LOWEST POINT OF THE CROSSING
SECONDARY MAIN LINE AND SIDINGS	25 YEAR / 50 YEAR	25 YEAR DESIGN DISCHARGE TO HAVE FREE SURFACE AT THE CULVERT ENTRANCE - 50 YEAR DISCHARGE TO NOT COME IN CONTACT WITH THE TRACK SUB-BALLAST AT THE LOWEST POINT OF THE CROSSING
YARD TRACKS		
LEAD TRACK	25 YEAR / 50 YEAR	25 YEAR DESIGN DISCHARGE TO HAVE FREE SURFACE AT THE CULVERT ENTRANCE - 50 YEAR DISCHARGE TO NOT COME IN CONTACT WITH THE TRACK SUB-BALLAST AT THE LOWEST POINT OF THE CROSSING
YARD TRACKS	10 YEAR / 25 YEAR	10 YEAR DESIGN DISCHARGE TO HAVE FREE SURFACE AT THE CULVERT ENTRANCE - 25 YEAR DISCHARGE TO NOT COME IN CONTACT WITH THE TRACK SUB-BALLAST AT THE LOWEST POINT OF THE CROSSING
STORM SEWER DESIGN DISCHARGES		
MAIN LINE TRACKS		
PRIMARY MAIN LINE AND SIDINGS	25 YEAR / 100 YEAR	25 YEAR DESIGN DISCHARGE TO HAVE FREE SURFACE IN ALL PIPE SECTIONS - 100 YEAR DISCHARGE TO BE CONVEYED SAFELY IN DESIGNED OVERFLOW CHANNELS
SECONDARY MAIN LINE AND SIDINGS	10 YEAR / 100 YEAR	10 YEAR DESIGN DISCHARGE TO HAVE FREE SURFACE IN ALL PIPE SECTIONS - 100 YEAR DISCHARGE TO BE CONVEYED SAFELY IN DESIGNED OVERFLOW CHANNELS
YARD & INDUSTRY TRACKS		
LEAD TRACK	25 YEAR / 100 YEAR	25 YEAR DESIGN DISCHARGE TO HAVE FREE SURFACE IN ALL PIPE SECTIONS - 100 YEAR DISCHARGE TO BE CONVEYED SAFELY IN DESIGNED OVERFLOW CHANNELS
YARD TRACKS	10 YEAR / 100 YEAR	10 YEAR DESIGN DISCHARGE TO HAVE FREE SURFACE IN ALL PIPE SECTIONS - 100 YEAR DISCHARGE TO BE CONVEYED SAFELY IN DESIGNED OVERFLOW CHANNELS