HEC 26 Aquatic Organism Passage Design Manual Evolution & Application

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Presentation Outline

- HEC 26 Purpose & History
- HEC 26 Contents
- 13–Step Design Procedure Summary
  - Focus on Steps 6-9
- Case History Comparisons
- Design Method Limitations
- Conclusions

HEC 26 Purpose

- Culvert Design for Aquatic Organism Passage (AOP) (HEC 26)
- Provide a quantitative stream simulation design procedure
- Incorporate geomorphic-based design

- HEC – Hydraulic Engineering Circular

HEC 26 Development History

- FHWA Published October 2010
- Technical Advisory Committee (7)
  - US Forest Service (3)
  - National Marine Fisheries Service
  - California Department of Fish and Game
  - Maryland State Highway Administration
  - Maine Department of Transportation
- FHWA Review Panel (10)
  - Ecologist, Biologist, Environmental Specialists (4)

HEC 26 Contents

- 2. Barrier Mechanisms
- 3. AOP Culvert Assessment & Inventory
- 4. Fish Biology
- 5. Passage Hydrology
- 6. Stream Geomorphology
- 7. Design Procedure
- 8. Construction
- 9. Post Construction

HEC 26 Design Method Goals

- Culvert designs providing successful aquatic organism passage via stream simulation approach
- Culvert designs satisfying peak hydraulic standards/criteria for protecting traveling public
- Objective procedure yielding reproducible results
- Universal applicability, use anywhere
- Efficient procedure, easy to apply
- Defensible results for justifying expenditures
- Interdisciplinary acceptance

HEC 26 Approach

- *Premise:* Stream bed materials experience same forces as aquatic organisms. If bed behavior in a culvert is similar to the channel during passage flows, organisms that pass stream can pass culvert.

- *Objective:* Create sediment mobility conditions within the culvert that *simulate* those in the natural channel in both structure and function for the range of passage flows.

Required Variables

- Peak design flow (Q25, Q50, Q100)
- High passage design flow
- Low passage design flow
- Bed material gradation (D16, D84, D95)
- Bed material permissible shear stress

Applied Tests

- Does culvert satisfy peak flow requirements?
- Is bed material in culvert stable for:
  - high passage design flows?
  - peak design flows?
- Is velocity in culvert for high passage design flows consistent with upstream and downstream channels?

Applied Tests (cont.)

- Is depth in culvert for low passage design flows consistent with upstream and downstream channels?

Tools Required / Available

- Culvert hydraulics
  - HEC-RAS
  - HY-8/Normal depth computations
- Channel hydraulics
  - HEC-RAS
  - Normal depth computations
- HEC 26 spreadsheet (iterative computations, gradation plotting, and data management)

Design Procedure Summary

- Step 1: Determine Discharges Q_L, Q_H, Q_P
- Step 2: Define Project Reach and Determine Channel Characteristics
  - Bed material
- Step 3 and 4: Evaluate Channel Stability
- Step 5: Identify initial trial culvert
  - Determine embedment depth

Step 6. Is Culvert Bed Stable at Q_H?

- Compute *permissible* shear stress
  - Modified Shields equation (function of D_{84} and D_{50})
  - Bathurst critical unit discharge equation
  - USDA equation for cohesive materials
- Compute maximum *applied* shear stress at:
  - Inlet, outlet of culvert and normal depth
  - Upstream and downstream cross-sections

$$\tau = \gamma y S_e$$

Step 6 (cont.) Is Culvert Bed Stable at Q_H?

- Accuracy of applied shear computations
  - Accurate depth and energy slope
  - Accurate Manning's roughness

- Manning's roughness
  - *Compute* Manning's 'n' for bed D_{84} (Iterative Procedure)
    - HEC 26 Spreadsheet
  - Select Manning's n for culvert walls
  - *Compute* composite Manning's n for culvert

Step 7. Check Channel Bed Mobility at Q_H

- If maximum shear stress in <u>any</u> channel XS is less than permissible, culvert shear must be equal or less than permissible.
  - If not, redesign culvert
- If maximum shear stresses in <u>all</u> channel XS are greater than permissible, bed is considered mobile (common for sand beds).
  - Culvert shear must be within channel range. If exceeds range, redesign culvert

Step 8. Check Culvert Bed Stability at Q_P

- Few sites will exhibit natural bed stability at Q_P due high shear of contracted flow
- Compute applied shear for Q_P and compare to permissible shear for natural bed material
  - Repeat iterative procedure for Manning's 'n'
- If bed not stable, design a stable sublayer.

Step 9.
Design Stable Bed for Q_P

- *Provide well-graded, oversized sublayer to resist shear at Qp, provide grade control and a rough surface to aid replenishment of native materials.*

- Minimum Thickness Criteria for sublayer
  - Identify maximum oversize gradation that will fit thickness criteria for culvert

Step 9 (cont.). Design Stable Bed for Qp

- Repeat permissible shear computations for sublayer
- Compute applied shear for Qp and compare to permissible shear for oversize sublayer
  - Repeat iterative procedure for Manning’s ‘n’
- If oversize layer not stable, redesign culvert.

Procedure Summary (cont.)

- Step 10 Check: Compare Culvert and Channel Velocities for Q_H
  - If culvert $\leq$ channel, Ok. If not, redesign.
- Step 11 Check: Compare Culvert and Channel Depths for Q_L
  - If culvert $\geq$ channel, Ok. If not, go to Step 12.
- Step 12: Design a low-flow channel.

Step 13. Review Design (HEC Example)

- Original 36” CMP
- 8.5 ft CMP
- 2.6 ft Embedment
  - 1.0’ Natural layer
  - 1.6’ Oversize layer
- Constructability
- Service life
- Other shapes or materials?

Case History Comparisons

	North Thompson Creek, Colorado	Tributary to Bear Creek, Alaska	Sickle Creek, Michigan
AOP barrier/ Existing	3-ft CMP	5-ft CMP	Twin 3-ft CMPs
As-built	12'x ? squash pipe	9.75'x 6.6' pipe arch	16'x 6' concrete arch bridge
HEC-26 procedure	8.5' CMP	12' CMP	10' CMP
Difference in span	-3.5 ft	+2.25 ft	-6 ft
Bankfull Width Estimate (ft)	8 - 17	7 - 11	not available

Design Method Limitations

- Tools rely on 1-D energy & momentum equations that may not be appropriate for natural channels or channels inside culverts
- Estimating friction and energy losses correctly
- Estimating bed material gradation correctly
- Not appropriate for degrading or aggrading streams

Design Method Limitations (cont.)

- Optimizing culvert size results in small embedment depth
- Embedment depth may not allow much natural channel profile lowering

Design Method Limitations (cont.)

- Requirement for stable bed at peak design flow will often dictate an oversized layer below the natural layer
- When natural layer scours, oversized layer may become exposed and restrict AOP passage

Conclusions

- HEC 26 stream simulation procedure results in larger openings than “hydraulic” design procedures
- WFLHD not allowed by the resource agencies to use approach
- Manual used by some DOT’s, but not widely, why?
- Additional work needed to check/update procedure
- Monitoring needed to determine ultimate success of any AOP culvert design

Questions?

- Did design method meet goals?