



Hydraulics of Buried Invert Culverts With Natural Stream Bottoms

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NCHRP Project 15-24 Hydraulic Loss Coefficients For Culverts

- **Utah Water Research Lab Capabilities**
- **Project Objectives**



Utah Water Research Laboratory

- 102,000 sf Facility
- 50,000 sf Hydraulics Section
- Gravity flow rates up to 200 cfs
- Large flume (8'x6'x600')
- High velocity flume (4'x2'x80')
- 300,000 pound weight tank
- Rainfall simulator/erosion bed (20'x20')
- Simulated rainfall up to 31 in/hr
- 11,000 sf Environmental Quality Lab
- Extensive computer facilities
- Faculty, staff and student offices





72-inch venturi flow meter calibration





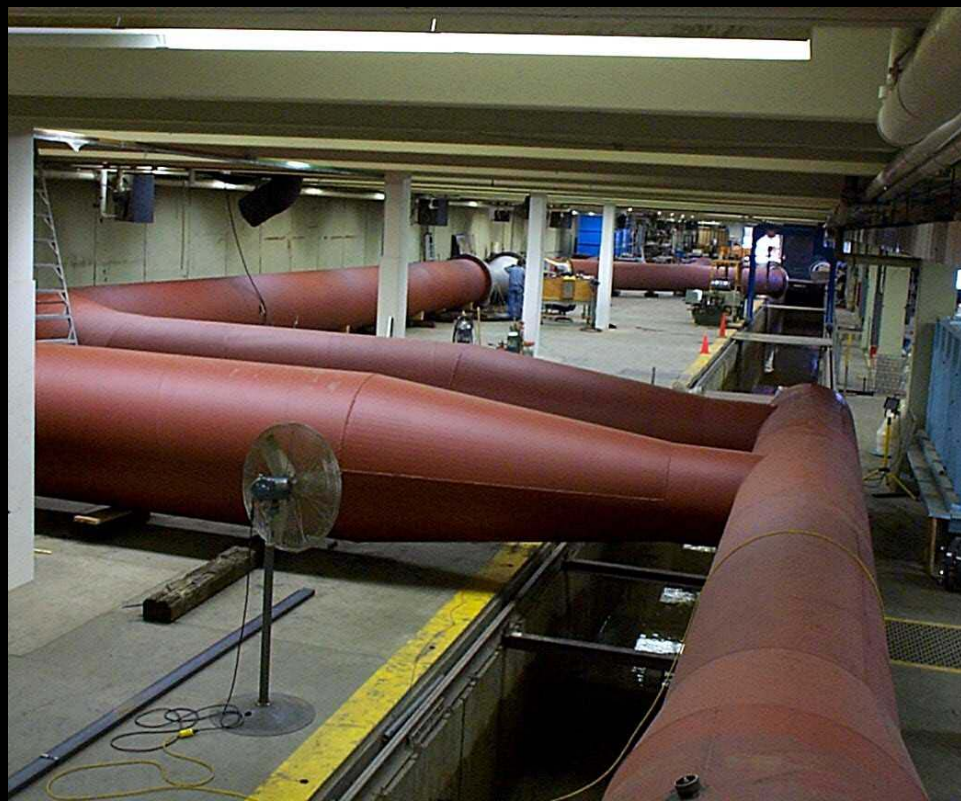
Southern Nevada Water Authority

180 Inch venturi flow meter serving Las Vegas





10-, 20-, & 60-inch models of 180-inch field piping/flow meter





Erosion Control

8' High Velocity Flume

Durability and failure point for erosion control blankets.





Erosion Control

Rainfall Simulator





Scale River Models

(Guadalupe River, CA)





Dam Modernization & Rehabilitation

Lake Turner,
Wesley Seale, and
Wirtz , Texas





Pipe/Culvert Testing





Stability of retaining wall blocks under high velocity (31 cfs) and shear stress.





Discharge velocity = 31 fps





Hyper Calc

HyperCalc Version 2.0

Number Format: Fixed Min. Sig. 5
Number Style: English Min. Decimal 3

Standard Conversion: Transportation Transportation Tables Drainage Misc.

Contexts:

- Length
- Area
- Volume
- Mass
- Force
- Velocity
- Acceleration
- Energy
- Power
- Pressure/Stress
- Dynamic Viscosity
- Kinematic Viscosity
- Flow

Conversion Options

Metric <> Metric Metric <> English English <> English

Metric	English
cubic mm (mm ³)	cubic inch
cubic cm (cm ³)	cubic feet
milliliter (mL)	cubic yard
cubic m (m ³)	acre-ft
liter (L)	teaspoon
	tablespoon
	fluid oz.
	cup
	pint
	quart

1 | 00000 67.628
liter (L) tablespoon

Common Civil Structural Electrical

Keep 'tear-offs' on top



HY8 Energy

Design of Energy Dissipators -

File View Options Help

Scour Internal External

Input

Title: Project 1 Slope: 0.01

Flow: 150 ft³/s Manning's n: 0.02

Span: 5 ft Number of slots: 2

Rise: 5 ft

Use 4 or 5 rows of elements.
 Check for high leading element

Output

Element Dimensions		Hydraulics		Splash shield for channel	
Height	1.471 ft	Yc	3.035 ft	Splash shield height	5.265 ft
Min Spacing	12.504 ft	Yn	3.216 ft	Edge height	0.164 ft
Max Spacing	14.711 ft	Y2	NA ft	Splash guard length	7.355 ft
Leading height	NA ft	Vc	9.885 ft/s	Splash shield for culvert	
Leading Spacing	NA ft	Vn	9.328 ft/s	Splash shield height	5.265 ft
Slot width	0.736 ft	Fr1	NA	Edge height	0.000 ft
Element width	1.176 ft				

Tumbling Flow: Circular Tumbling Flow: Rectangular Interior Roughness: Circular Interior Roughness: Rectangular



HY8 Inp Generator

C:_Prjctlm\FHWA_IMP\NewInp\DirINP\NewFile.inp, English Units

File View Actions Tools Help

Road and Channel **Culverts**

Culvert Inlet and Edge

Conventional | Side Tapered | Slope Tapered

Approx Fall Avail: 1.000 ft Span: 3.000 ft Rise: 3.000 ft

Inlet edge and wall
Thin edge projecting

Depressed inlet

Inlet Invert Station	100.000	ft
Inlet Invert Elev.	1224.000	ft
Outlet Invert Station	250.000	ft
Outlet Invert Elev.	1223.000	ft
Invert Length	150.003	ft
Invert Slope	0.0067	ft
Improved Inlet Throat Station	0.000	ft
Improved Inlet Throat Elev.	0.000	ft
Improved Inlet Crest Station	100.000	ft
Improved Inlet Crest Elev.	1224.000	ft
L1	0.000	ft
L2	0.000	ft
L3	0.000	ft
L4	0.000	ft

Culvert #1



HDS-5 Chart Calculator

Hydraulic Design Charts (Nomographs) Keep Applet On Top

Charts 1-9 | Charts 10-19 | Charts 20-29 | Charts 30-39 | Charts 40-49 | Charts 50+

Headwater Depth for Concrete Pipe Culverts with Inlet Control

Square Edge with Headwall
 Groove End with Headwall
 Groove End Projecting

Critical Depth (ft)

Critical Velocity (ft/s)

Q = Discharge (cfs)

Culvert Barrel Slope (ft/ft)

Culvert diameter (ft)

Headwater (ft)

Units English Metric

Chart 1 | Chart 2 | Chart 3 | Chart 4 | Charts 5 - 7 | Chart 8 | Chart 9



Prototype Hydraulic Model

Free Surface Flow

File Options

Close All ↑ Open All ↓

Define Section Shape

Pipe Arch

Pipe Arch

Rise: ft Rb: ft

Rt: ft B: ft

Span: ft

Rc: ft

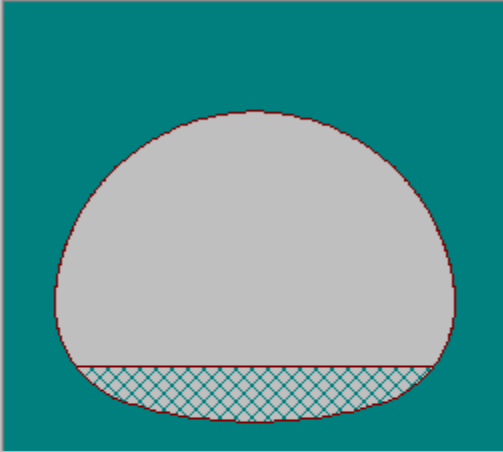
Sediment Details

Sediment Depth: ft

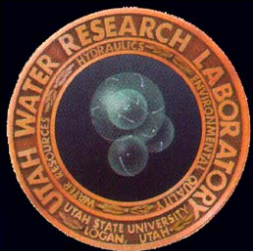
Section Slope and Flow

ft

ft³/sec



Open Channel Properties



Prototype Hydraulic Model

Free Surface Flow [Close] [Maximize] [Exit]

File Options

Close All [Up] Open All [Down]

Results

Normal Flow Results Output [Down]

Critical Flow Results Output [Up]

Y_c : 2.8634 ft V_c : 10.137 ft/sec
 A_c : 19.729 ft² T_c : 6.1819 ft
 P_c : 12.522 ft Y_{bar} : 1.4432 ft
 R_c : 1.5756 ft
Composit n: 0.01929

Maximum Flow Results Output [Down]

Q_{max} : 468.05 ft³/sec P: 17.251 ft
 Y_{max} : 4.3573 ft R: 1.5596 ft
A: 26.905 ft² T: 2.6253 ft
 Y_{bar} : 2.3763 ft
Composit n: 0.01967

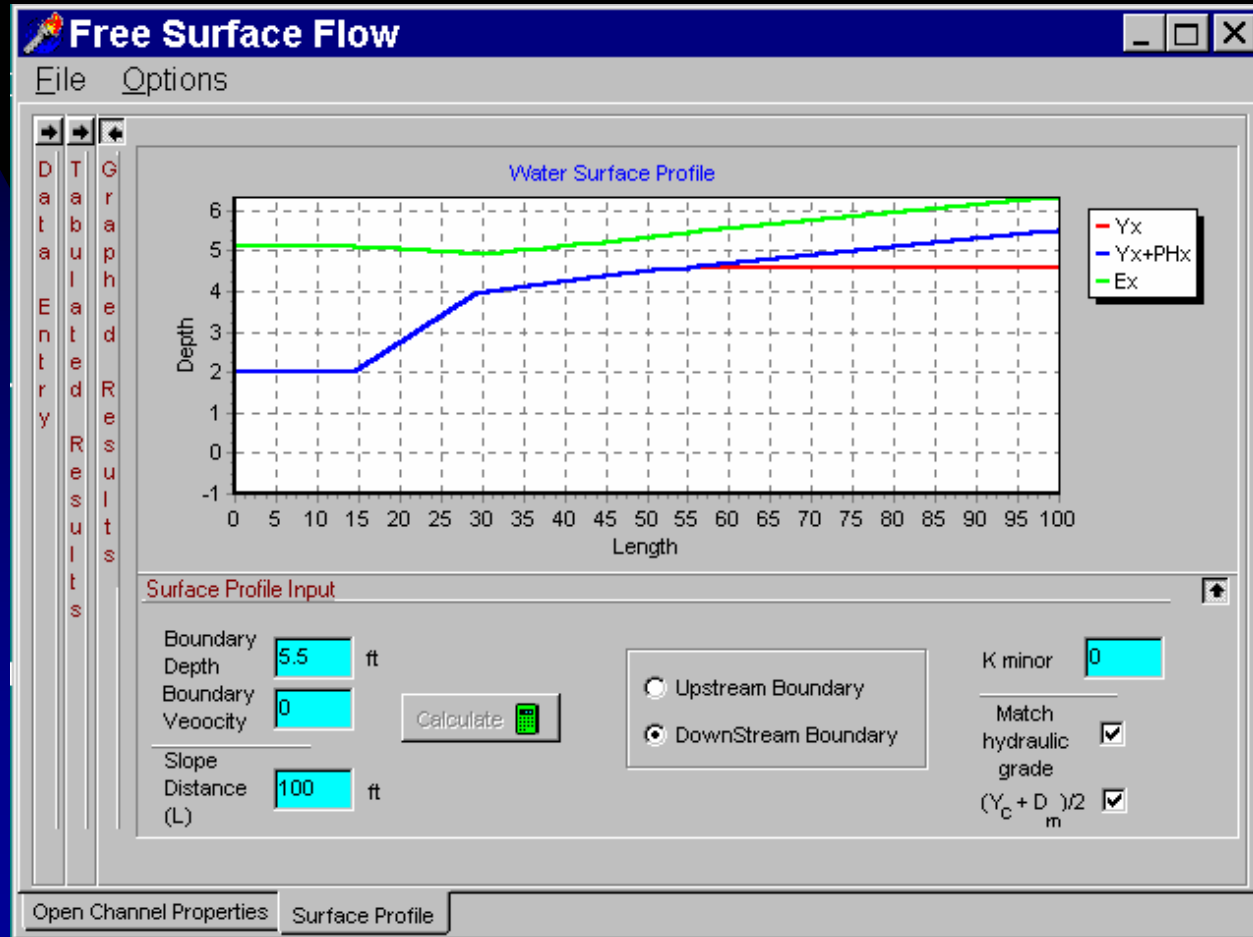
Calculate [Calculator Icon] Clear All [Eraser Icon]

Open Channel Properties Surface Profile

A diagram showing a semi-circular channel cross-section. The channel is filled with water, represented by a light blue color. The bottom of the channel is a semi-circular arc with a cross-hatched pattern, indicating the channel bed. The water surface is a horizontal line above the arc.



Prototype Hydraulic Model





Culvert loss coefficients, what's the big deal?





NCHRP Project 15-24 Project Objectives

1. *Refine and/or develop loss coefficients for conventional and nontraditional installations in environmentally sensitive applications. Specifically, this includes:*
 - *Determine inlet control design curves and entrance and exit loss coefficients for outlet control for various culvert shapes and end treatments. The order of priority for modeling/testing culvert shapes is **circular, rectangular/square, arch, and elliptical.***



NCHRP Project 15-24

Project Objectives

(continued)

- *Each culvert shape tested will be evaluated for both **submerged** and **unsubmerged** conditions for the following:*
 - ◆ *a. **buried and/or bottomless culverts***
 - ◆ *b. **multiple circular culverts***
 - ◆ *c. **rehabilitated circular culverts***



NCHRP Project 15-24 Project Objectives (continued)

- 2. Develop hydraulic roughness coefficients for bottomless (i.e., open footings) or buried invert culverts. Coefficients shall be developed for both full and partially full conditions and shall include various streambed materials for both concrete and metal culverts.*



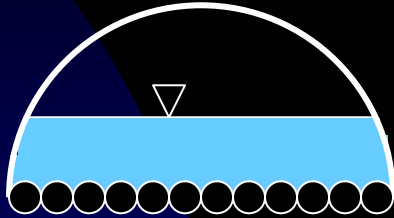
Phase I

- Literature Review
 - a) Identify deficiencies in loss coefficient data base for culvert/end treatment designs for environmentally sensitive culvert installations.
 - b) Review published methods for determining flow resistance coefficients for composite channels (i.e., side wall material differs from bed material).
 - c) Review published data for multi-barrel culvert installations
- Finalize work plan based on results of literature review

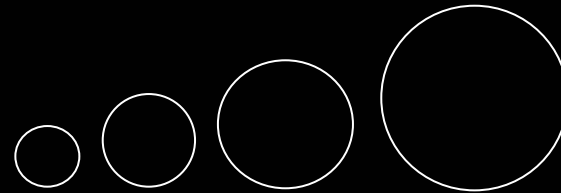


Phase II Laboratory Testing

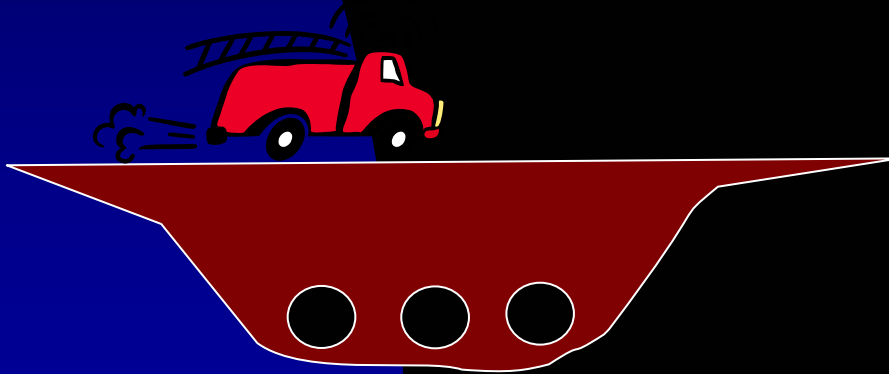
Key Issues



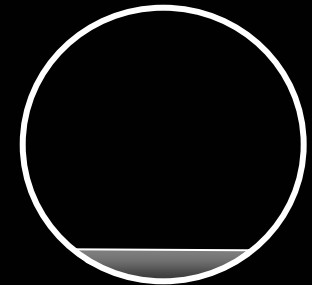
Composite Roughness Coefficients
(Flow vs. Depth relationship)



Size-scale effects by testing both small and large
diameter culverts (possibly up to 48-inch diameter).



Loss coefficients for multi-barrel culverts
(size and spacing, approach flow non-uniformity, etc.)



Loss coefficients for
rehabilitated culverts



Supplemental Material Sources

Several culvert manufactures have agreed to provide free culvert and end treatment materials for the project

- **Advanced Drainage Systems, Inc.**
- **Construction Products, Inc.**
- **Mountain States Concrete Pipe Assoc.**



Presentation of Results

- **A description of the experimental design justifying the scaling techniques and model dimensions.**
- **A compendium of experimental data on CD ROM**
- **A set of design charts and graphs similar to those in the Appendix of HDS 5.**
- **Equations and coefficients that can be used to directly calculate values of the design parameters.**