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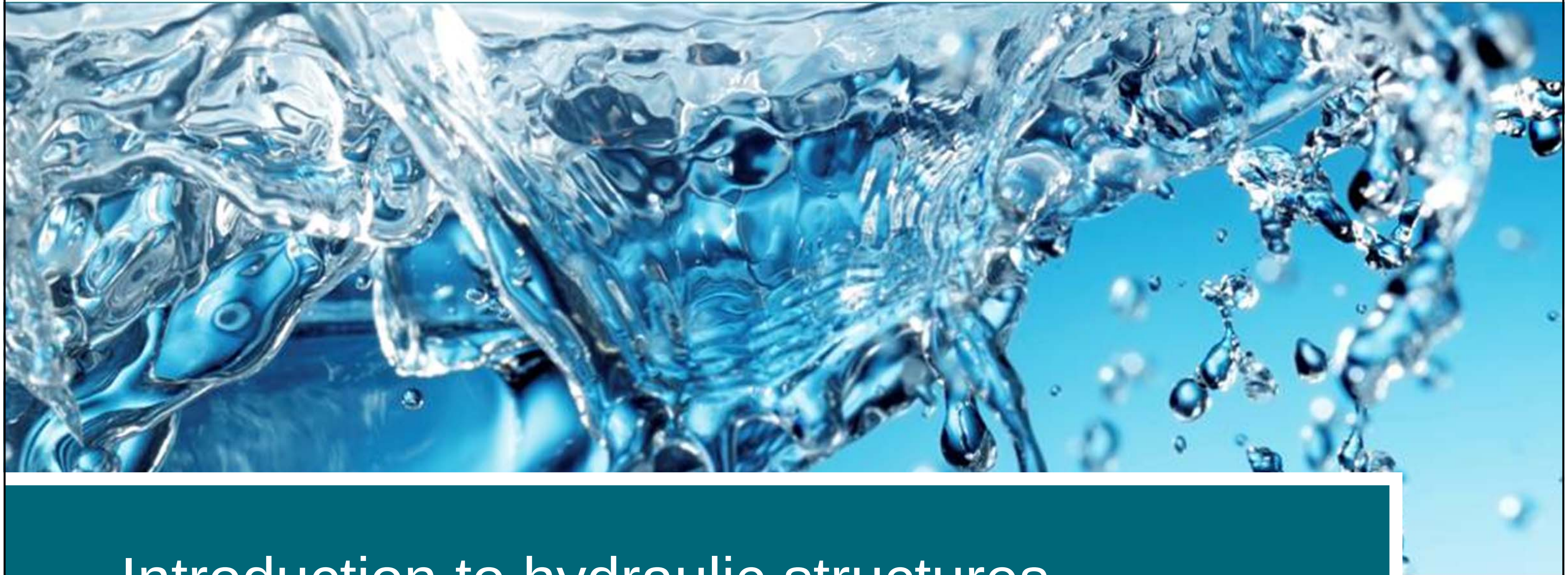
Working with water



Introduction to hydraulic structures

Darren Lumbroso, HR Wallingford

Function

- River control with known stage discharge relationship
- Maintenance of minimum water levels
- Flow measurement (partial or full range of flow)
- Spillway (e.g. to flood relief channel)

Types of weirs

Overview

- > Triangular profile (Crump)
- > Flat - V
- > Sharp crested
- > Broad crested
- > Compound
- > Other (spillway, side weir, labyrinth weir, non standard)

Weir equations

Typical form – horizontal crest

The typical weir equation is:

$$Q = C\ L\ h^{3/2}$$

h gauged head above weir crest

L length of weir crest

C is a coefficient which includes two dimensional effects and upstream velocity head (often obtained experimentally)

Weir equations

Typical form – horizontal crest

Typical Coefficient values

> $C \approx 1.5$ for a broad crested weir

> $C \approx 1.8$ for a sharp crested weir

> $C = C_d \sqrt{g}$

- C_d is the discharge coefficient (non-dimensional)

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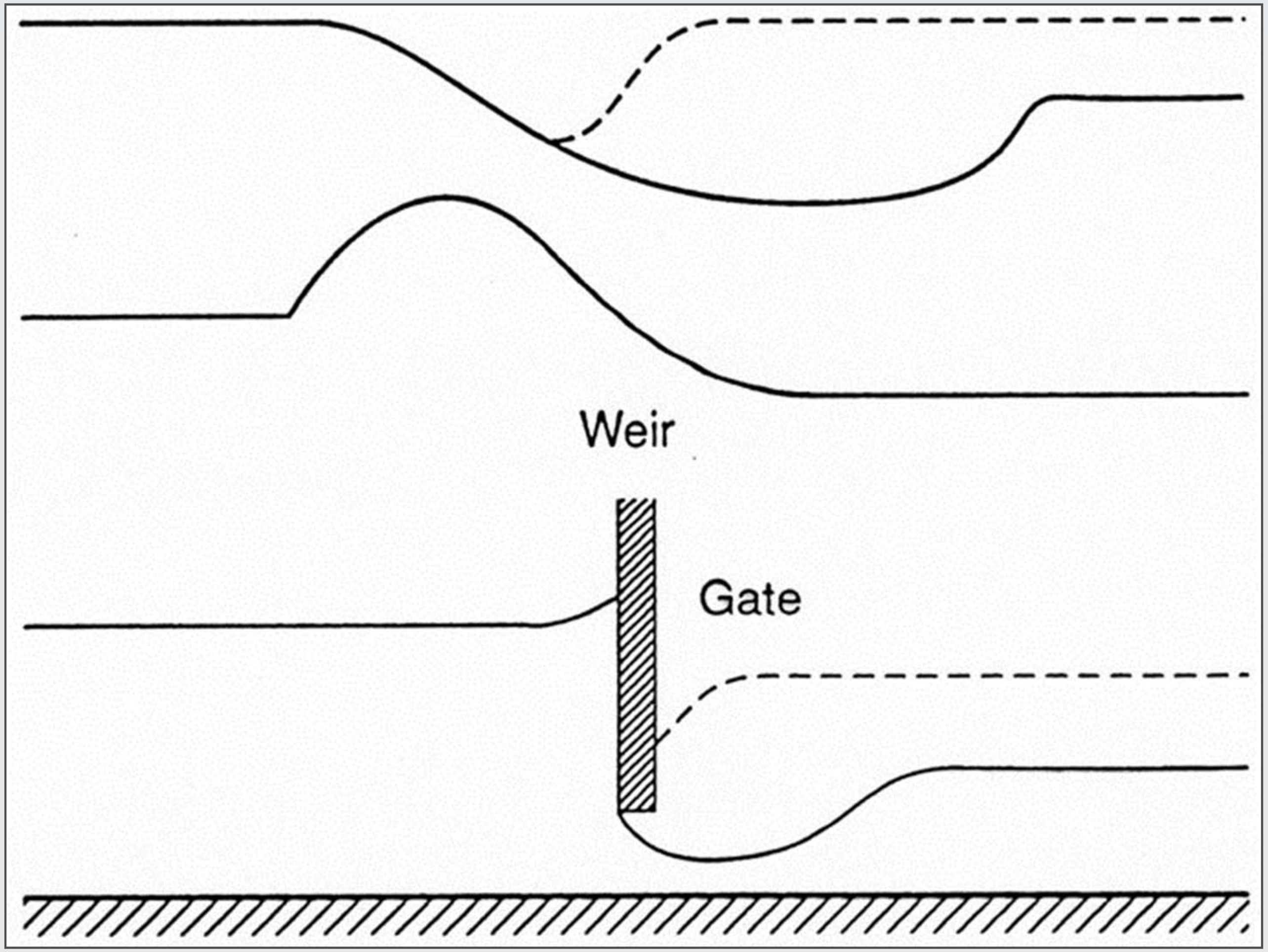
Weir equations

- Each type of structure has a discharge equation incorporating C_d
- C_d will vary from structure to structure and will depend upon flow conditions (i.e. flow depth over weir, height of weir etc.)
- For specific calculations ensure that you use the appropriate equations (refer textbooks)

Drowning of controls



Equations of flow are modified using "drowning functions"

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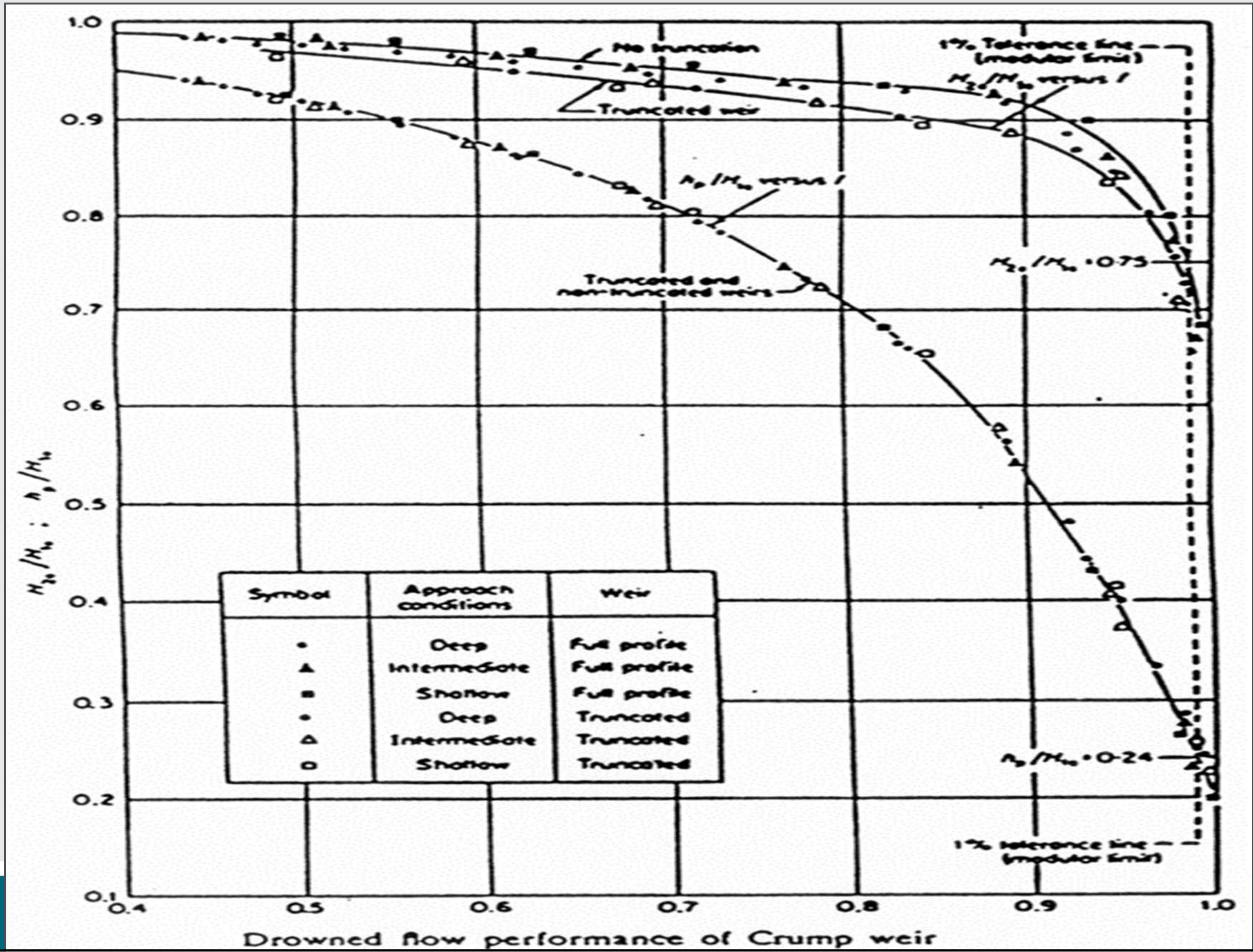
Drowned weir flow

Crump and triangular weirs



Gates

Overview

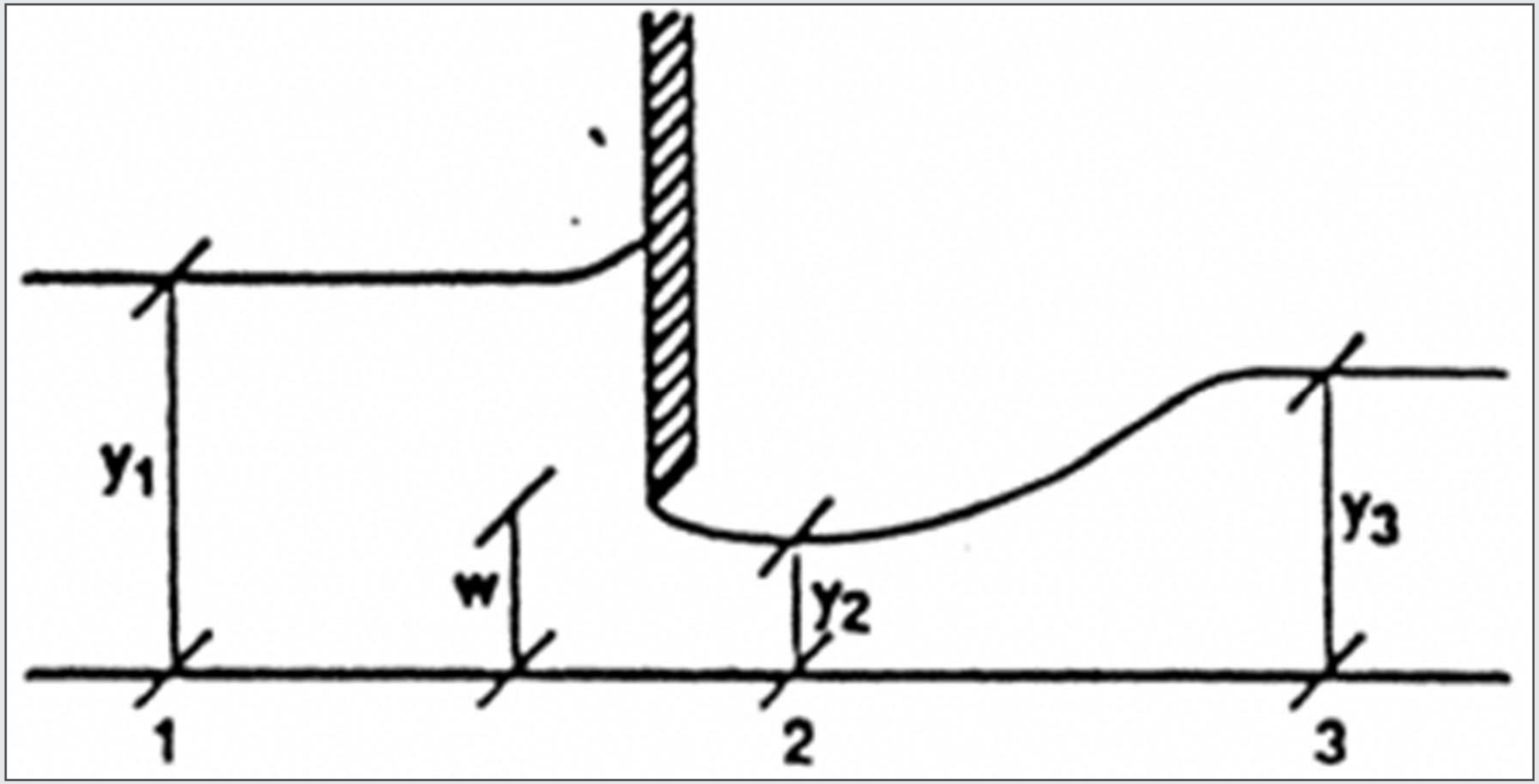
Function

- Flow regulation
- Control of upstream level

Types

- Vertical sluice (underflow)
- Radial (underflow)
- Flap weir (overflow)
- Vertical sluice (underflow and overflow)
- Other (movable weir, float operated etc)

Vertical sluice gates



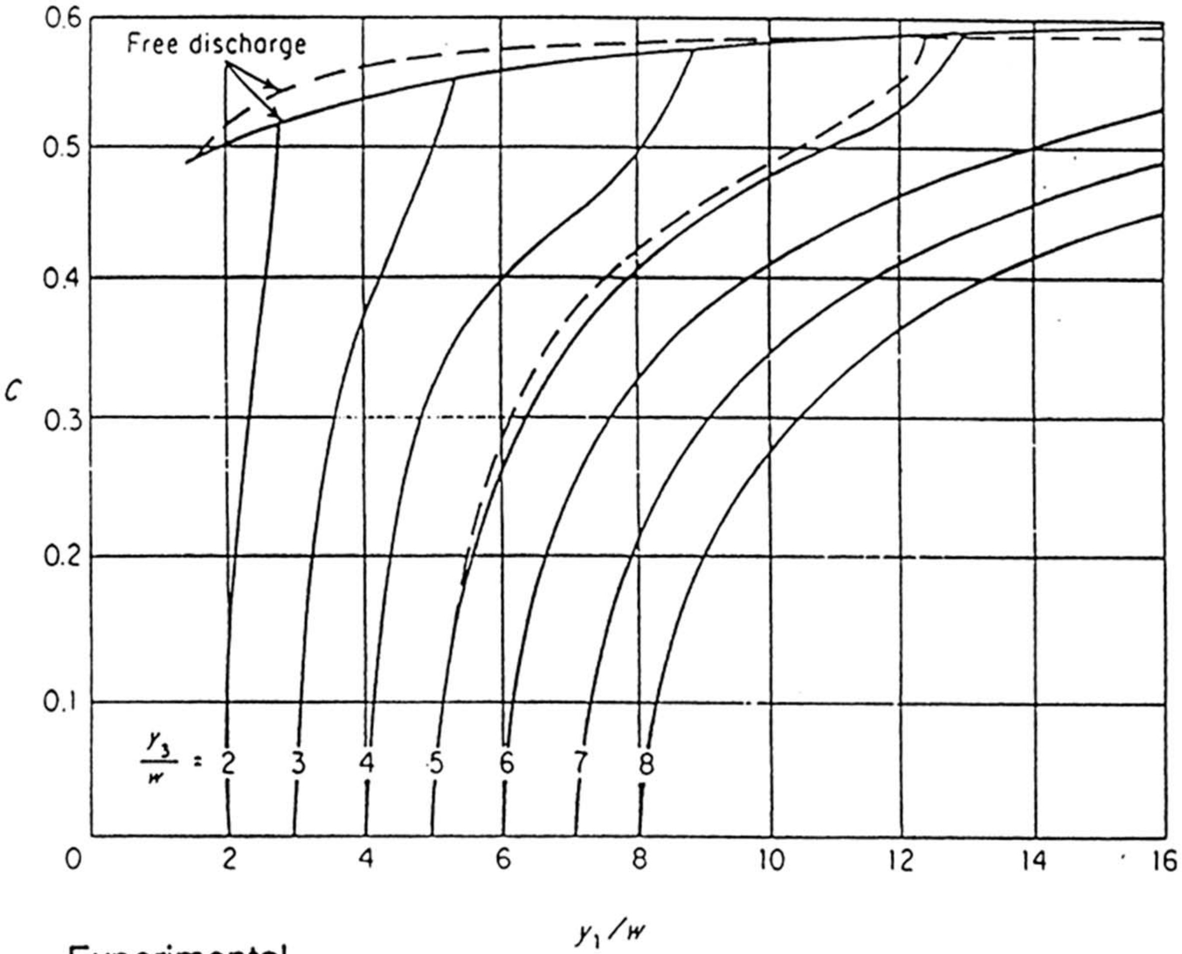
Undrowned $Q = C\,w\,B\,(2gy_1)^{1/2}$

$C = C_c / (1 + C_c\,w/y_1)^{1/2} \approx 0.6$

Drowned C depends on y_1/w and y_3/w

Vertical sluice gates

Value of C for Vertical Sluice Gate
(after Henry H R, Discussion on "Diffusion of submerged jets" Trans. ASCE Vol 115 p 687)



——— Experimental
– – – – Application of energy equation from Sections 1 – 2 and momentum equation from Sections 2 – 3

Overview

> Conveyance of flow through obstructions

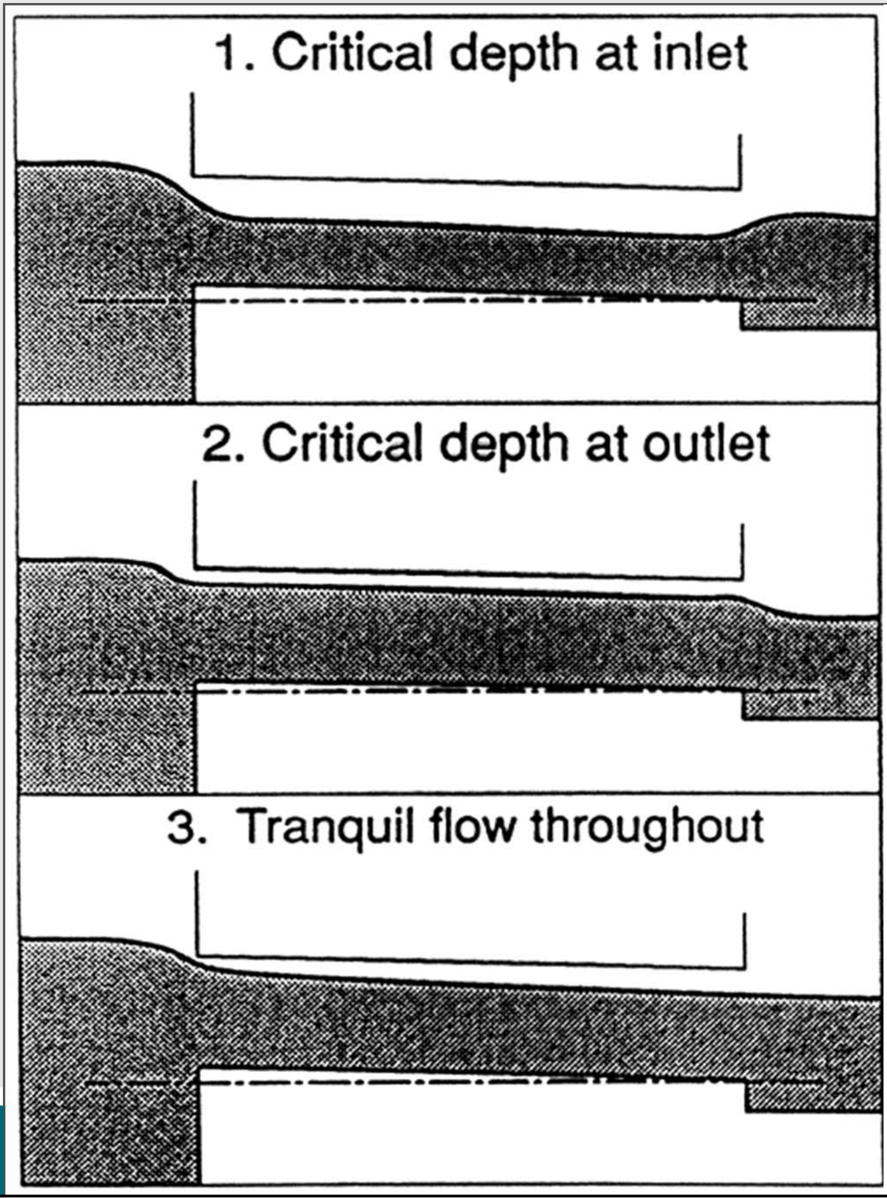
> Used in channels or on flood plains

> Types include circular (pipe), box or ‘pipe-arch’

> Six basic flow types

> See software (Day 3) and design guidelines

Classification of culvert flow



Design considerations

- > Small pipes are prone to blockage
- > Access for maintenance
- > Screens
- > Future channel improvements

Overview

Headloss at bridges

Overview

- Low stone arch type bridge

  Yarnell's equation for arch bridges

- High, flat deck, rectangular opening type bridge

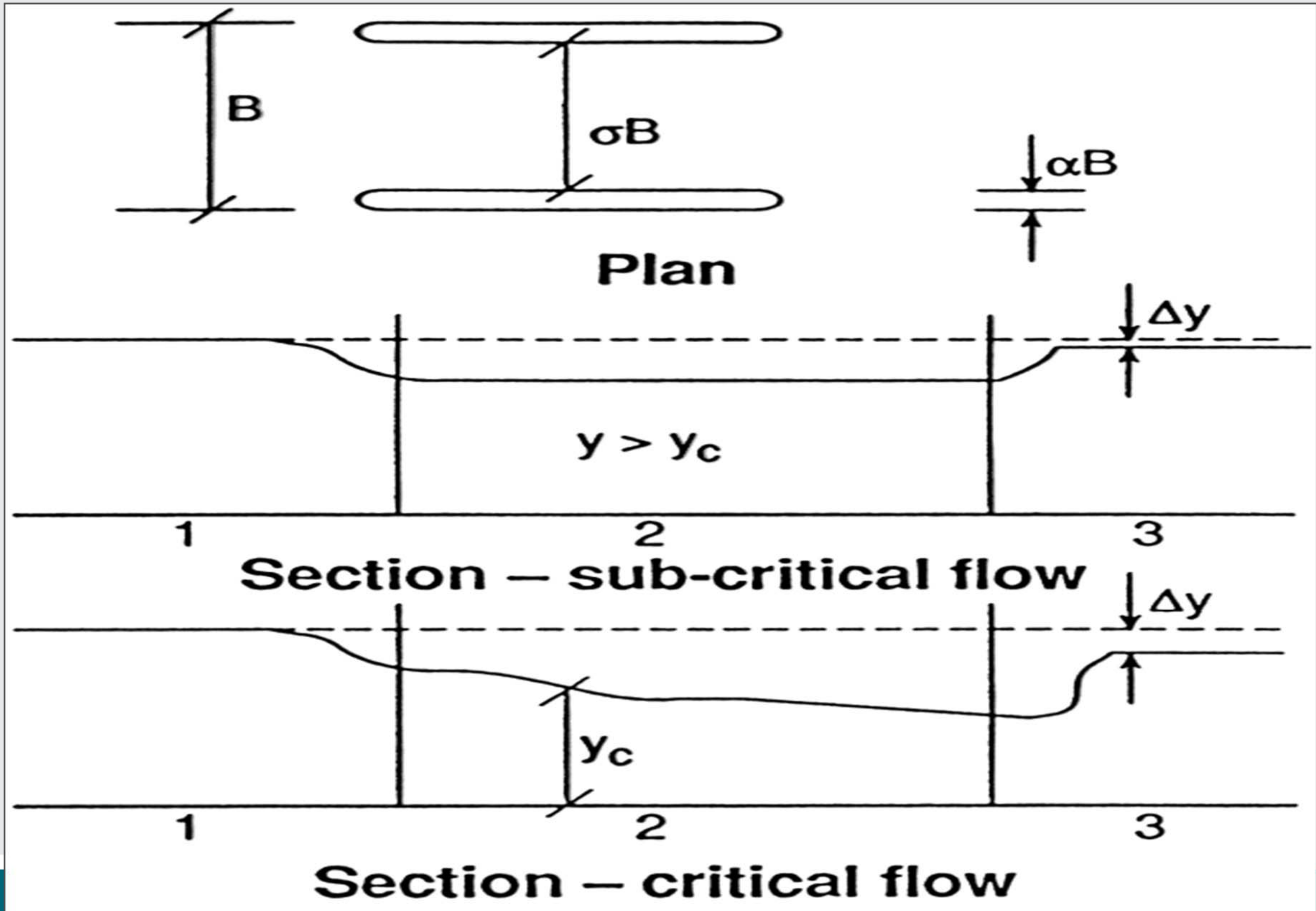
  USBPR method for modern bridges

Stone arch type bridges

Yarnell's approach

Stone arch type bridges

Yarnell's approach



Stone arch type bridges

Yarnell's approach

> Sub-critical flow:

> To estimate headloss at bridge, Δy:

$$\Delta y/y_3 = KF_3^2 [K + 5F_3^2 - 0.6][\alpha + 15 \alpha^4]$$

> α is the proportion of flow area blocked

> K varies between 0.9 and 1.25 depending upon pier shape:

0.9 = semicircular nose and tail

1.25 = square nose and tail

USBPR approach

Overview

$\Delta y = k\alpha_2 v_2^2/2g + \alpha_1[\,(A_2/A_3)^2 - (A_2/A_1)^2\,]\, v_2^2/2g$

where:

α_2 energy coefficient under the bridge

α_1 energy coefficient downstream

Note α has a different meaning in this equation from Yarnell's equation

k total backwater coefficient, where:

$k = k_b + k_p + k_e + k_s$

k_b = base coefficient, k_p = effects of piers

k_e = effect of eccentricity, k_s = effect of skew

Design considerations

Overview

> Deck above flood level

> Piers smooth and aligned with the flow

> Scour at piers

> Flood plain culvert design

> Flood plain storage

> Runoff and pollution

> Temporary works

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Overview

- > Protection of hydraulic structures – if really necessary
- > Safety
- > Bars 50 mm to 150 mm spacing
- > Clean by raking
- > Head losses are:
  - – small when clean
  - – large when blocked

Screens

Fish passes

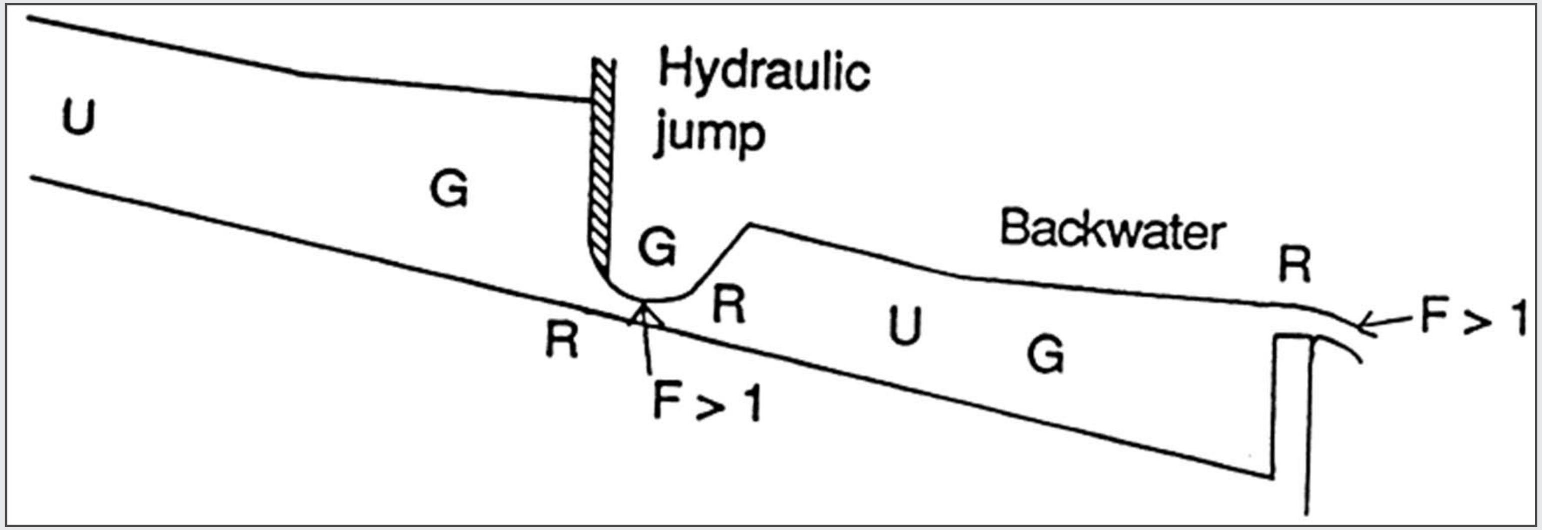
Overview

> Allow fish to bypass man made obstacles

- divide single leap into several smaller leaps
- sloping channel - baffles to reduce velocity

> Fish attracted by strong flows

Impact on water level



Flow zones:

U	Uniform flow (constant depth)
G	Gradually varied flow
R	Rapidly varied flow
F	Froude number

Design considerations

> Range of discharge
> Afflux - available head loss is often limited
> Range of upstream and downstream levels
> Approach and exit conditions
> Energy dissipation
> Erosion, scour, bed and bank protection
> Hydrostatic uplift and seepage
> Cavitation, vibration etc.
> Construction requirements (e.g. river diversion)

Further reading (on CD)

Federal highways Administration

Hydraulic design of highway culverts

Hydraulic design of energy dissipators for culverts and channels

Hydraulic design of safe bridges

Introduction to highway hydraulics

River engineering for highway encroachments - Highways in the river environment

Urban drainage design manual

Evaluation of scour at bridges

Debris control structures

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Any questions?

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