# Bridge Afflux (Backwater) at Piers by Yarnell's Equation

Rise in water level upstream of bridge piers in subcritical flow by Yarnell's equation, from the downstream depth, velocity, pier shape and obstruction ratio.

**Method:** Yarnell pier backwater equation

## Input parameters

Unit system: SI

| Parameter | Value | Unit |
|---|---|---|
| Depth downstream of the bridge | 3.0000 | m |
| Mean velocity downstream | 1.8000 | m/s |
| Share of the flow area blocked by the piers | 12.000 | % |
| Pier shape | Semicircular nose and tail (0.9) | |

## Calculated results

| Parameter | Value | Unit |
|---|---|---|
| Froude number downstream | 0.33186 | |
| Afflux (rise upstream) | 102.59 | mm |

**Notes for this case**

• Yarnell's tests on model piers give the backwater as $\Delta y = 2K(K + 10Fr_3^2 - 0.6)(\alpha + 15\alpha^4)\, Fr_3^2\, y_3$, where $y_3$ and $Fr_3$ are downstream of the bridge, α is the share of the unobstructed flow area blocked by the piers and K depends on the pier shape. It applies to subcritical flow through the piers only, not to flow against the deck or through a contracted opening.

## Formula and method

$$\Delta y = 2K\left(K + 10Fr_3^2 - 0.6\right)\left(\alpha + 15\alpha^4\right) Fr_3^2\, y_3$$

### Variables

| | | |
|---|---|---|
| $y_3$ | Depth downstream of the bridge | m |
| $V_3$ | Mean velocity downstream | m/s |
| $\alpha$ | Share of the flow area blocked by the piers | - |
| $K$ | Pier shape | - |
| $Fr_3$ | Froude number downstream | - |
| $\Delta y$ | Afflux (rise upstream) | m |

### Method and standards

Yarnell afflux.

### Assumptions and limits

- Subcritical flow; class A flow through the piers.

### References

Yarnell pier backwater equation

## Report details

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|---|---|
| Report reference | FCC-9MHY-0Y5P (the same inputs always give the same reference) |
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| Calculator | Bridge Afflux (Backwater) at Piers by Yarnell's Equation |
| Method last reviewed | 17 November 2026 |
| Software release | FireCAD Calc, release of 22 November 2026 |
| Release checks | 3 reference cases of this calculator, computed independently, are checked on every release |

Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

### This calculator online

https://calc.firecad.com/civil/hydraulics/bridge-afflux-yarnell

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.