# Gradually Varied Flow: Backwater Length in a Rectangular Channel

Normal and critical depths and the distance between two depths of a backwater or drawdown profile in a rectangular channel (GVF equation).

**Method:** Gradually varied flow equation dy/dx = (S₀ − S_f)/(1 − Fr²) (Chow, Open-Channel Hydraulics (McGraw-Hill, 1959), ch. 9–10)

## Input parameters

Unit system: SI

| Parameter | Value | Unit |
|---|---|---|
| Discharge | 72,000 | m³/h |
| Channel width | 10.000 | m |
| Manning's n | 0.025000 | |
| Bed slope | 4.0000e-04 | |
| Depth at the control (start) | 3.0000 | m |
| Depth at the end | 2.3000 | m |

## Calculated results

| Parameter | Value | Unit |
|---|---|---|
| Normal depth | 1.9803 | m |
| Critical depth | 0.74162 | m |
| Distance between $y_1$ and $y_2$ (upstream +) | 3,172.3 | m |

**Notes for this case**

• dx/dy = (1 − Fr²)/(S₀ − S_f) integrated by Simpson's rule (the limit of the direct step method). For a mild-slope backwater (M1) from a dam or weir, $y_1$ is the depth at the structure and the distance is measured upstream. Rectangular section; Manning friction.

## Formula and method

$$\frac{dx}{dy} = \frac{1 - Fr^2}{S_0 - S_f}, \quad S_f = \left(\frac{nQ}{AR^{2/3}}\right)^2, \quad Fr^2 = \frac{Q^2}{gb^2y^3}$$

### Variables

| | | |
|---|---|---|
| $Q$ | Discharge | m³/s |
| $b$ | Channel width | m |
| $n$ | Manning's n | - |
| $S_0$ | Bed slope | - |
| $y_1$ | Depth at the control (start) | m |
| $y_2$ | Depth at the end | m |
| $y_n$ | Normal depth | m |
| $y_c$ | Critical depth | m |
| $\Delta x$ | Distance between $y_1$ and $y_2$ (upstream +) | m |

### Method and standards

GVF equation.

### Assumptions and limits

- Rectangular prismatic channel; steady flow.
- A depth very close to normal depth makes the integral converge slowly; a result whose Simpson estimate changes by more than 1

% when the step is halved is flagged.

### References

• Gradually varied flow equation dy/dx = ($S_0$ − S_f)/(1 − $Fr^2$) (Chow, Open-Channel Hydraulics (McGraw-Hill, 1959), ch. 9–10)

## Report details

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|---|---|
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| Release checks | 2 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/backwater-length-gvf

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.