PipeCalc4b
Pipe calculator for partial flow

12/5/2025 by E Shiomoto

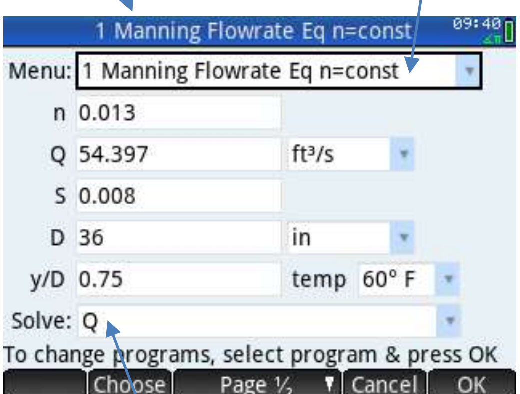
This program calculates the unknown variable for Manning n=constant, Manning n=f(D), Colebrook, Q=VA, and other equations for a circular pipe flowing partially full. The results are displayed on the calculator's print terminal. To switch programs, select the new program from the Menu on the INPUT screen and press the OK tab. To rerun the same program, press the Esc key to exit the terminal, and press the Enter key to rerun the program.

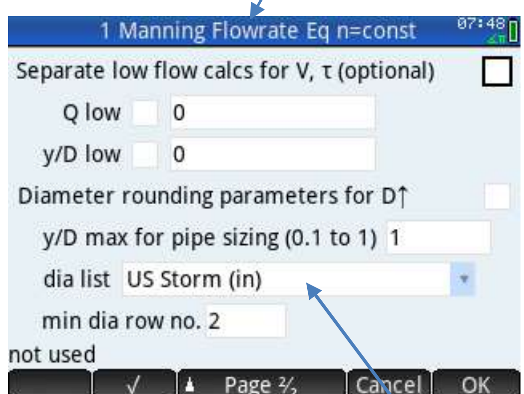
The Menu box is used to change programs. To change the program, select a new program from the list and press the OK tab.

1 Manning Flowrate Eq n=const
2 Manning Velocity Eq n=const
3 Manning Flowrate Eq n=f(D)
4 Manning Velocity Eq n=f(D)
5 Colebrook Flowrate Eq
6 Colebrook Velocity Eq
7 S min program
8 Q=VA Eq
9 Critical Flow Eq
10 Shear Stress Eq
11 Raths−McCauley sand particle
12 Q/Qf ⇆ y/D Conversions
13 Q Conversions
14 Set no. of digits

Low flow inputs and diameter rounding settings are shown on the second page of the input screen. These options are only available for the Manning and Colebrook flowrate programs.

Current program in use





n
Q
S
D
y/D
D↑, y/D given n Q S
clear inputs
clear terminal
view terminal
view pipe diameter list

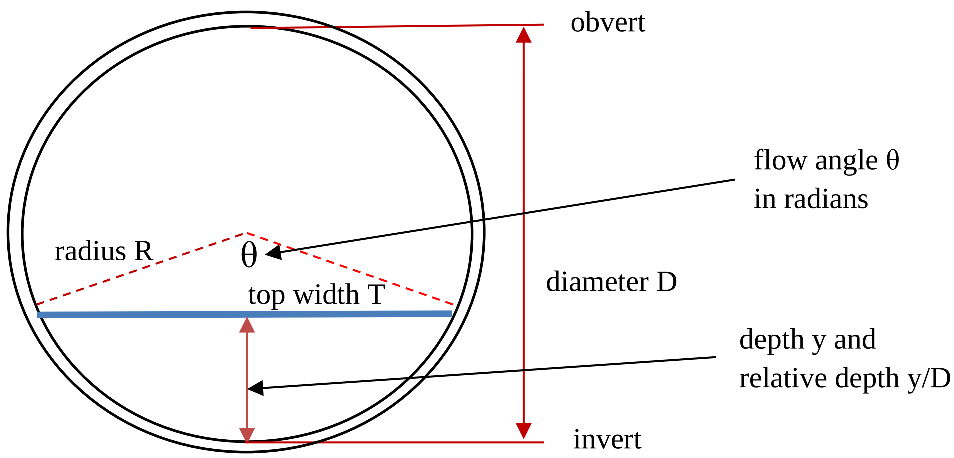
To solve for the unknown variable, input the known values and units. Select the variable to be solved from the Solve menu. Then, press the OK tab.

If the solve variable has units, select the units to be use.

The results will be displayed on the print terminal.

To run the program again, press the Esc key to exit the print terminal. Then, press the Enter key to run the program

US Storm (in)
US Storm (mm, soft)
US Sewer (in)
US Sewer (mm, soft)
US RCP (in)
US VCP (in)
US Gravity Drain PVC 1 (in)
US Gravity Drain PVC 2 (in)
UK Composite (mm)
Aus Composite (mm)
Aus RCP Class 4 (mm)
Ger Composite (mm)


obvert
flow angle θ
in radians
radius R
θ
top width T
diameter D
depth y and
relative depth y/D
invert

Contents

1. Instructions

Calculator System Settings and Operations

At the start of the program, the calculator will change the app angle mode to radians and the Home number format to floating with 4 digits (default). At the end of the program, the calculator will restore the previous angle mode and number format. The number of digits can be changed using program *14 Set no. of digits*.

When the program solves for the unknown variable, the results are displayed on the calculator's print terminal. When the program is run a second time, the results are added to the bottom of the previous text. The print terminal will hold about 100 lines of text. To clear the print terminal, select "clear print terminal" form the menu and press the OK tab. To view the print terminal, select view menu from the "menu" on the INPUT screen.

This program was used with software version 2.4, software build date 2025-09-15, and software revision 15515. The program was edited on a Windows computer.

This program was written with the "period" used as the decimal point, and will not work when the comma is used as the decimal point.

The program size is 601 KB. This program will run on a G1 physical calculator, but the program cannot be edited on a G1 physical calculator. However, the program code can be edited and more importantly checked for complier errors on the virtual calculator.

Changing Programs

The name of the current program is displayed in the title of the input screen. To switch between the various programs, select the new program from the "Menu" choose list and then press the OK tab located in the lower right corner of the screen. The input screen of the new program will display the input values and units from the previous program, where applicable.

Rerun the program

When the program ends, the print terminal is displayed with the calculated results. To rerun the program, press the Esc key to exit the print terminal, then press the Enter key to run the program. Another way to rerun the program is to press the Enter key twice. Alternatively, the program can be launched by pressing the Toolbox key, and then pressing the User tab, and the selecting PipeCalc.

When the program is run a second time, the program will run the last program that was used. The previous input entries and unit selections are displayed to facilitate chain calculations.

To clear the previous inputs, select "clear inputs" from the Solve input box, and press the OK tab. "clear inputs" does not change the previous unit selections.

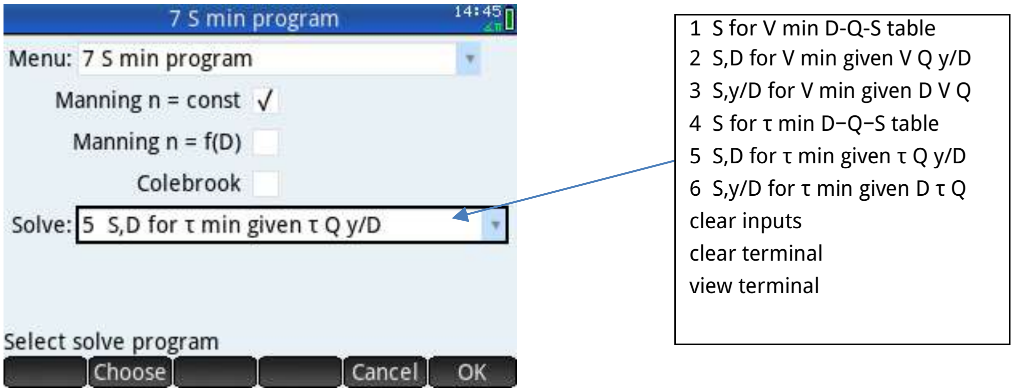
Exit the Program

To exit the program from the input screen, press the Cancel tab on the input screen, or press the Esc key.

To exit the print terminal and return to the Home screen, press the Esc key or press the Home key.

S min program

One of the programs in PipeCalc is the "S min program". The program allows the user to run a set of minimum slope programs for either V_{min} or τ_{min} for the Manning n=const, Manning n=f(D), and Colebrook equations.



Set no. of digits program

This program allows the user to set the number of digits displayed on the input screen and printed on the print terminal.

Manning and Colebrook equations

This program calculates Manning's equation in SI units, where the Manning k constant is the exact value of 1. The program then converts the values to English units, as necessary. Because of this, the program's results will be slightly different from other programs that use a rounded Manning's k value of 1.49 or 1.486. The use of the exact Manning's k value not only effects the value of Q and V, but can affect other Manning's parameters.

$$V = \frac{k\, D^{2/3}\, S^{1/2}\, (\theta - sin(\theta))^{2/3}}{2^{4/3}\, N\, \theta^{2/3}},$$ where k=1 for metric calculations

$$Q = \frac{k\, D^{8/3}\, S^{1/2}\, (\theta - sin(\theta))^{5/3}}{2^{13/3}\, N\, \theta^{2/3}},$$ where k=1 for metric calculations, see footnote[1]

$$\theta = 2 * acos\left(1 - 2 * \frac{y}{D}\right),$$ where θ is in radians. y is the depth. Note that θ is for the full angle, and not the half angle, as used in some publications. See footnote[2]

[1] This equation is algebraically equivalent to the Manning (constant n) equation in Water-Resources Engineering, 3rd Ed., Pearson, 2013 by David Chin, page 218. Note that the $2^{13/3}$ constant is equal to the 20.16 constant used in Water-Resources Engineering.

[2] Water-Resources Engineering, 3rd Ed., Pearson, 2013 by David Chin, page 222, example 6.4. Also, in *Urban Drainage*, by D Butler and JW Davies, 3rd Ed., Spon Press, UK, 2011, equation 8.17 and figure 8.7 on page 162.

There are several versions of the Colebrook-White equation. This program uses the version with the 3.7 and 2.51 constants.

$$\frac{1}{\sqrt{f}} = -2\, log_{10}\left(\frac{k_s}{3.7\, D} + \frac{2.51}{Re\, \sqrt{f}}\right)$$ see footnote[3]

$$Re = \frac{4\, R_h\, V}{\upsilon}$$ see footnote[4]

$$\Psi = \frac{(\theta - sin\, \theta)}{\theta}$$

$$V = -2\sqrt{2\, g\, S\, \Psi\, D}\; log_{10}\left(\frac{k_s}{3.7\, \Psi\, D} + \frac{2.51\, \nu}{\Psi\, D\, \sqrt{2\, g\, S\, \Psi\, D}}\right)$$ see footnote[5]

$$Q = V\, A$$

<u>Program background</u>

PipeCalc was written as a replacement for the Field's Hydraulic Calculator and the HP-41 Pipe Slide-Rule program.

2. Solve for the unknown variable

In general, you can solve for any one variable of an equation on PipeCalc, provided the other variables are known. Simply, run PipeCalc. Switch to the desired equation. Enter the values and units of the known variables. Specify the variable to be solved in the "Solve" box. If the solve variable has units, specify the units of the solve variable. Finally, press the OK tab located in the lower right corner of the screen. The program will solve for the unknown variable and display the results on the print terminal.

<u>Problem</u>

Determine the discharge rate in a 24 in concrete pipe on a slope of 0.008 that has a relative depth of y/D = 0.45. (Use the Manning equation and assume n = 0.014 for a concrete pipe)

To switch to the "Manning Flowrate Eq n=const" program, select "Manning Flowrate Eq n=const" in menu box, and press the OK tab.

On the input screen for the Manning flowrate equation, the variables n, Q, S, D, and y/D are displayed. Note that input variables Q and D have units. Below the input variables is a "Solve" drop box that list all of the variables. There is a water temperature box near the lower right corner of the input screen, that is used to determine the equivalent ks value. The input screen second page has optional inputs for low

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3 PipeCalc4 was changed to use the Colebrook equation from *Urban Drainage*, by D Butler and JW Davies, 3rd Ed., Spon Press, UK, 2011, equation 8.9 on page 154. In contrast, the *Tables for the Hydraulic Design of Pipes, Sewers and Channels*, 7th Ed, Vol 1, Thomas Telford London, UK, 1998 by HR Wallingford and DIH Barr, uses a Colebrook equation with a 3.71 constant instead of 3.7. As a result, PipeCalc will give slightly different results for full flow when compared to the *Tables for the Hydraulic Design of Pipes, Sewers and Channels*. Note that both of these Colebrook equations are slightly different from the Colebrook equation listed in ASCE Manual 60, *Gravity Sanitary Sewer Design and Construction*, 2nd Ed., 2007, ASCE publication, equation 5-20 on page 127.

4 Reynold's number for partial flow is from ASCE Manual 60, *Gravity Sanitary Sewer Design and Construction*, 2nd Ed., 2007, ASCE publication, equation 5-24, page 127. R_h is the hydraulic radius. ν is the kinematic viscosity.

5 Velocity equation for partial flow from *Urban Drainage*, by D Butler and JW Davies, 3rd Ed., Spon Press, UK, 2011, equation 8.19 on page 166. ν is the kinematic viscosity.

flows and diameter rounding that are not used in this example. The second page of the input screen is used in the Manning Flowrate Eq n=const, Manning Flowrate Eq n=f(D), and Colebrook Flowrate Eq programs.

In this problem, n, S, D, and y/D are the known variables, and Q is the unknown variable.

Enter the value and units of the known variables. When solving for Q, you need to enter the units of Q. In the solve box, select Q. Finally, press the OK tab located in the lower right-hand corner.

Input screen for Manning Flowrate Eq n=const

```
Menu:   1 Manning Flowrate Eq n=const
   n:   0.014
   Q:   0       ft^3/s
   S:   0.008
   D:   24      in
 y/D:   0.45                  temp 60° F
Solve:  Q
```

```
Separate low flow calcs for V, τ  (optional)
      Q low ❑  0
    y/D low ❑  0
 Diameter rounding parameters for D↑
    y/D max for pipe sizing (0.1 to 1):  1
    dia list:  US Storm (in)
    min dia row no.:  2
```

The calculator indicates the flowrate Q = 7.8257 ft^3/s.

Print Terminal

```
———————————— PipeCalc4b ————————————
01 Manning Flowrate Eq n=const
02 Solve: Q
  ▹ Manning n = 0.014
    flowrate Q = 7.8257_(ft^3/s)✱
  ▹ slope S = 0.008
    slope ratio = 1 : 125
  ▹ diameter D = 24_in
  ▹ relative depth y/D = 0.45
    depth y = 10.8_in
    central angle θ = 2.9413_rad
  ▹ water temp = 60° F
    ———
    velocity V = 5.7075_(ft/s)
    ave shear stress τ = 0.23257_(lbf/ft²)
    froude no. = 1.2122
    (equivalent ks = 2.5359_mm)
```

```
    area A = 1.3711_ft^2
    hydraulic radius Rh = 0.46617_ft
    wetted perimeter P = 2.9413_ft
    top width T = 1.99_ft
Q full = 18.788_(ft^3/s)   y/D = 1 & 0.81963
Q peak = 20.21_(ft^3/s)   y/D = 0.93818
V full = 5.9803_(ft/s)   y/D = 1 & 0.5
V peak = 6.8178_(ft/s)   y/D = 0.8128
critical rel. depth (y/D crit) = 0.49766
critical depth (y crit) = 11.944_in
kinematic viscosity vk = 12.170E-6_(ft^2/s)
density ρ = 1.9383E0_(slug/ft^3)
Notes
• The calculation of τ uses the approximate
equation, where sin(θ)=S.
```

3. Solve for depth of flow using the Colebrook flowrate equation

Determine the depth of flow for a 500 mm concrete storm pipe on a slope of 0.01 m/m with a discharge rate of 0.118 m^3/s. (assume roughness ks = 0.6 mm for a concrete pipe)

In this problem, the Colebrook flowrate equation program used to solve for depth y. Depth y is not part of the variables used in the Colebrook flowrate equation. So, we need to solve for the relative depth y/D. After the program solves for relative depth y/D, the program will calculate depth y.

To solve this problem, switch to the Colebrook Flowrate Eq program. Input the known variables values and units. Select the water temperature. Select y/D as the solve variable. Finally, press the OK tab. Note that the inputs on page 2 are not used for this example.

Input screen for Colebrook Flowrate Eq n=const

Menu:	5 Colebrook Flowrate Eq n=const		
ks:	0.6	mm	
Q:	0.118	m^3/s	
S:	0.01		
D:	500	mm	
y/D:	0		temp 15° C
Solve:	y/D		

Separate low flow calcs for V, τ (optional)
Q low ❑ 0
y/D low ❑ 0
Diameter rounding parameters for D↑
y/D max for pipe sizing (0.1 to 1): 1
dia list: US Storm (in)
min dia row no.: 2

The print terminal indicates the relative depth y/D = 0.35814 and depth y = 179.07 mm.

Print Terminal

```
------------ PipeCalc4b ------------
05 Colebrook Flowrate Eq
05 Solve: y/D
  ▹ roughness ks = 0.6_mm
  ▹ flowrate Q = 0.118_(m^3/s)
  ▹ slope S = 0.01
    slope ratio = 1 : 100
  ▹ diameter D = 500_mm
    relative depth y/D = 0.35814✶
    depth y = 179.07_mm
    central angle θ = 2.5662_rad
  ▹ water temp = 15° C
    ---
    velocity V = 1.8674_(m/s)
    ave shear stress τ = 9.6504_Pa
    froude no. = 1.6425
    (equivalent n = 0.01142)
```

```
    area A = 0.06319_m^2
    hydraulic radius Rh = 0.0985_m
    wetted perimeter P = 0.64156_m
    top width T = 0.47945_m
Q full = 0.42614_(m^3/s)   y/D = 1 & 0.82692
Q peak = 0.45576_(m^3/s)   y/D = 0.94081
V full = 2.1703_(m/s)   y/D = 1 & 0.5
V peak = 2.455_(m/s)   y/D = 0.8128
critical rel. depth (y/D crit) = 0.46379
critical depth (y crit) = 231.89_mm
kinematic viscosity vk = 1.1390E-6_Pa
density ρ = 999.10E0_(kg/m^3)
Notes
• The calculation of τ uses the approximate
equation, where sin(θ)=S.
```

4. Solve for depth of flow given Q min and Q max

For a 24 in diameter pipe at a slope of 0.10 feet per hundred with a pipe roughness of n = 0.013, determine the depth of flow and velocity for the following flowrates: Q max = 3.9 MGD and Q min = 0.9 MGD.

If necessary, switch to the Manning Flowrate Eq n=const program.

On the input screen, Q min is entered on the 2nd page under "Separate low flow calcs". The checkbox adjacent to Q min must be checked. When entering the value for Q min, use the same units as with Q, which in this case is in MGD.

Input screen for Manning Flowrate Eq n=const

Menu:	1 Manning Flowrate Eq n=const		
n:	0.013		
Q:	3.9	MGD	
S:	0.001		
D:	24	in	
y/D:	0		temp 70° F
Solve:	y/D		

Separate low flow calcs for V, τ (optional)
Q low ☑ 0.9
y/D low ❑ 0
Diameter rounding parameters for D↑
y/D max for pipe sizing (0.1 to 1): 1
dia list: US Storm (in)
min dia row no.: 2

The print terminal indicates: For Q max = 3.9 MGD, y/D = 0.70404, y = 16.897 in, and V = 2.5528 ft/s. For Q low = 0.9 MGD, y/D = 0.29907, y = 7.1778 in, and V = 1.7643 ft/s.

Print Terminal

```
------------ PipeCalc4b ------------
01 Manning Flowrate Eq n=const
05 Solve: y/D
 ▹ Manning n = 0.013
 ▹ flowrate Q = 3.9_(MgalUS/d)
 ▹ slope S = 0.001
   slope ratio = 1 : 1000
 ▹ diameter D = 24_in
   relative depth y/D = 0.70404✶
   depth y = 16.897_in
   central angle θ = 3.9823_rad
 ▹ water temp = 70° F
   ---
   velocity V = 2.5528_(ft/s)
   ave shear stress τ = 0.03698_(lbf/ft²)
   froude no. = 0.39556
   (equivalent ks = 1.3758_mm)
   area A = 2.3637_ft^2
   hydraulic radius Rh = 0.59355_ft
```

```
   wetted perimeter P = 3.9823_ft
   top width T = 1.8259_ft
Low flow calcs for Q low = 0.9_(MgalUS/d)
   V = 1.7643_(ft/s)
   τ = 0.02125_(lbf/ft²)
   y/D = 0.29907
   y = 7.1778_in
Q full = 4.6234_(MgalUS/d)   y/D = 1 & 0.81963
Q peak = 4.9734_(MgalUS/d)   y/D = 0.93818
V full = 2.277_(ft/s)   y/D = 1 & 0.5
V peak = 2.5959_(ft/s)   y/D = 0.8128
critical rel. depth (y/D crit) = 0.43441
critical depth (y crit) = 10.426_in
kinematic viscosity vk = 10.590E-6_(ft^2/s)
density ρ = 1.9364E0_(slug/ft^3)
Notes
● The calculation of τ uses the approximate
equation, where sin(θ)=S.
```

5. Sizing a pipe using chain calculations

PipeCalc supports successive chain calculations. The program will retain the last values of the known and solved variables. (On the HP-41 Pipe Slide Rule, the previous input values were not saved, and one had to enter all of the inputs every time the program was run.)

Problem

Size a storm pipe to handle a flow rate of 18.6 cfs, where roughness n = 0.013 and a slope S = 0.0015. Determine the velocity of flow.

answer: D = 36 in, y/D = 0.62832, depth y = 22.62 in, and velocity V = 3.9774 ft/s.

For this problem, the Manning equation is used twice: 1) to solve for the calculated diameter, where the calculated diameter is manually rounded up, and 2) to solve for the relative depth y/D and velocity.

Run the PipeCalc program. If necessary, switch to the Manning Flow Equation program by selecting the Manning Flow Eq from the menu and then press the OK tab.

1) Solve for the diameter

Enter the following on the Manning flowrate input screen. The diameter is the variable to be solved, so set the diameter units to inch. The program will ignore the current value of the diameter. For the slope, you can enter "0.0015" or key in the sequence "0.15 ÷ 100 Enter". To size the pipe for full flow, set y/D = 1. Finally, set the solve box to "D", and press the OK tab.

Input screen for Manning Flowrate Eq n=const

Menu:	1 Manning Flowrate Eq n=const
n:	0.013
Q:	18.6 ft^3/s
S:	0.0015
D:	0 in
y/D:	1 temp 60° F
Solve:	D

Separate low flow calcs for V, τ (optional)
Q low ❑ 0
y/D low ❑ 0
Diameter rounding parameters for D↑
y/D max for pipe sizing (0.1 to 1): 1
dia list: US Composite1_in
min dia row no.: 2

The print terminal indicates the diameter D = 31.829 in.

Print Terminal

```
------------ PipeCalc4b ------------
01 Manning Flowrate Eq n=const
04 Solve: D
 ▹ Manning n = 0.013
 ▹ flowrate Q = 18.6_(ft^3/s)
 ▹ slope S = 0.0015
   slope ratio = 1 : 666.67
   diameter D = 31.829_in✶
 ▹ relative depth y/D = 1
   depth y = 31.829_in
   central angle θ = 6.2832_rad
 ▹ water temp = 60° F
   ---
   velocity V = 3.3663_(ft/s)
   ave shear stress τ = 0.06203_(lbf/ft²)
   froude no. = not applic.
   (equivalent ks = 1.3424_mm)
```

```
   area A = 5.5254_ft^2
   hydraulic radius Rh = 0.6631_ft
   wetted perimeter P = 8.3327_ft
   top width T = not applic.
Q full = 18.6_(ft^3/s)   y/D = 1 & 0.81963
Q peak = 20.008_(ft^3/s)   y/D = 0.93818
V full = 3.3663_(ft/s)   y/D = 1 & 0.5
V peak = 3.8376_(ft/s)   y/D = 0.8128
critical rel. depth (y/D crit) = 0.54114
critical depth (y crit) = 17.224_in
kinematic viscosity vk = 12.170E-6_(ft^2/s)
density ρ = 1.9383E0_(slug/ft^3)
Notes
• The calculation of τ uses the approximate
equation, where sin(θ)=S.
```

Round the storm pipe diameter upwards to 36 in.

2) Solve for the relative depth y/D

Rerun PipeCalc and solve for the depth of flow using the rounded diameter of 36 inch.

PipeCalc can be rerun by pressing the Esc key to exit the print terminal, and pressing the Enter key to rerun the program. The program's input screen will display the last values and units.

On the input screen, change the diameter to be 36 in. Change Solve to y/D. When solving for y/D, the program will ignore the previous value of y/D. Press the OK tab.

Input screen for Manning Flowrate Eq n=const

Menu:	1 Manning Flowrate Eq n=const
n:	0.013
Q:	18.6 ft^3/s
S:	0.0015
D:	36 in
y/D:	1 temp 60° F
Solve:	y/D

Separate low flow calcs for V, τ (optional)
Q low ❑ 0
y/D low ❑ 0
Diameter rounding parameters for D↑
y/D max for pipe sizing (0.1 to 1): 1
dia list: US Composite1_in
min dia row no.: 2

The print terminal indicates that for a 36 in pipe, the relative depth y/D = 0.62832, depth y = 22.62 in, and velocity V = 3.9774 ft/s.

Print Terminal

```
------------ PipeCalc4b ------------
01 Manning Flowrate Eq n=const
05 Solve: y/D
  ▹ Manning n = 0.013
  ▹ flowrate Q = 18.6_(ft^3/s)
  ▹ slope S = 0.0015
    slope ratio = 1 : 666.67
  ▹ diameter D = 36_in
    relative depth y/D = 0.62832✶
    depth y = 22.62_in
    central angle θ = 3.6607_rad
  ▹ water temp = 60° F
    ---
    velocity V = 3.9774_(ft/s)
    ave shear stress τ = 0.07967_(lbf/ft²)
    froude no. = 0.55215
    (equivalent ks = 1.2472_mm)
```

```
    area A = 4.6764_ft^2
    hydraulic radius Rh = 0.85164_ft
    wetted perimeter P = 5.491_ft
    top width T = 2.8995_ft
Q full = 25.831_(ft^3/s)    y/D = 1 & 0.81963
Q peak = 27.786_(ft^3/s)    y/D = 0.93818
V full = 3.6543_(ft/s)    y/D = 1 & 0.5
V peak = 4.166_(ft/s)    y/D = 0.8128
critical rel. depth (y/D crit) = 0.4606
critical depth (y crit) = 16.581_in
kinematic viscosity vk = 12.170E-6_(ft^2/s)
density ρ = 1.9383E0_(slug/ft^3)
Notes
• The calculation of τ uses the approximate
equation, where sin(θ)=S.
```

6. Sizing a pipe using the D↑ auto sizing with pipe diameter lists

The D↑ auto sizing option is only available on the Manning and Colebrook flowrate equations. D↑ means solve for the diameter and round upwards based on a predefined diameter list, and then solve for the actual depth. To use the D↑ option, the diameter rounding parameters on page 2 of the input screen must be specified.

Predefined diameter lists

The D↑ auto sizing option rounds the calculated diameter based on a predefined diameter list that must be specified on page 2 of the input screen. The diameter lists used in PipeCalc include the inside and nominal diameters. For most diameter lists, the inside diameter equals the nominal diameters. However, for some pipes, the inside diameter can be different from its nominal diameter, such as in the *US gravity drain PVC 1 and 2*, and the *Aus RCP Cl-4 (mm)* diameter lists. However, the difference between the inside and nominal diameter tends to have a small effect on the flowrate calculations. So, using the actual diameters is generally not done. These pipe diameter lists were added for testing purposes.

The *US Storm (in)* diameter list does not contain a 21", 27", 33" and 39" diameters. The *US Sewer (in)* diameter list does not contain a 33" and 39" diameters.

The program contains soft metric versions of the *US Storm (in)* and *US Sewer (in)* diameter lists. For the *US Storm (mm, soft)* and *US Sewer (mm, soft)* diameter lists, the inside and nominal diameters are in millimeters, where the English diameters were converted to mm and rounded to the nearest 5 mm. For these soft metric lists, the inside diameter equals the nominal diameter. So, the inside diameter in these diameter lists are not equal to the actual inside diameters.

PipeCalc can perform mix unit calculations. So, one can use the D↑ auto sizing option for metric calculation with the *US Storm (in)* diameter list.

The UK, Australia and Germany pipe diameter lists are generic in nature and may not accurately represent the pipe diameters used in those countries. These lists were added for testing purposes.

Viewing the pipe diameter lists

The diameter lists can be viewed by setting solve to "view pipe diameter list" and then pressing the OK tab. Then, on the "view pipe diameter list" input screen, select "US Composite in" and press the OK tab. The diameter list will be printed on the print terminal. Row no. 2 always represents the smallest diameter on the diameter list.

The pipe diameter lists can only be viewed on the flowrate programs.

```
Terminal                                   09:52
------------ PipeCalc4b ------------
Diameter List = US Gravity Drain PCV2 in
where row 1 = units
row    Actual ID    Nominal Dia
1      1_in          SDR-26, PS-115
2      3.891         4
3      5.793         6
4      7.754         8
5      9.692         10
6      11.538        12
7      14.124        15
8      17.261        18
9      20.349        21
10     22.891        24
```

Problem

Size a storm pipe to handle a flow rate of 18.6 cfs, where roughness n = 0.013 and a slope S = 0.0015. Determine V full. (This problem is the same as in the previous example, but is solved using the D↑ auto sizing program.)

If necessary, switch to the *Manning Flowrate Eq n=const* program.

For this problem, Solve is set to *D↑,y/D given n Q S*. y/D max is set to 1 for full flow. The diameter list is set to *US Storm (in)*. The minimum diameter row number is set to 2, which represents the smallest diameter in the diameter list. Enter n, Q and S. Note that the D↑ auto sizing program is only as good as the diameter list. The diameters in the *US Storm (in)* list may not be representative of the locally available storm pipes.

Input screen for Manning Flowrate Eq n=const

Menu:	1 Manning Flowrate Eq n=const
n:	0.013
Q:	18.6 ft^3/s
S:	0.0015
D:	0 in
y/D:	0 temp 60° F
Solve:	D↑,y/D given n Q S

Separate low flow calcs for V, τ (optional)
Q low ❑ 0
y/D low ❑ 0
Diameter rounding parameters for D↑
y/D max for pipe sizing (0.1 to 1): 1
dia list: US Storm (in)
min dia row no.: 2

The print terminal indicates the diameter D = 36 in, relative depth y/D = 0.62832, and depth y = 22.62 in. V_{full} = 3.6543 ft/s, which is greater than the minimum velocity for self-cleaning. Therefore, the design is OK.

Print Terminal

```
------------ PipeCalc4b ------------
01 Manning Flowrate Eq n=const
06 Solve: D↑, y/D  given  n Q S
  ▹ Manning n = 0.013
  ▹ flowrate Q = 18.6_(ft^3/s)
  ▹ slope S = 0.0015
    slope ratio = 1 : 666.67
    nominal diameter D = 36_in✶
    inside diameter ID = 36_in
    (calculated diameter = 31.829_in)
  ▹ y/D max for pipe sizing = 1
  ▹ dia. list = US Storm (in)
  ▹ minimum diameter row no. = 2
    minimum diameter = 4_in
    relative depth y/D = 0.62832✶
    depth y = 22.62_in
    central angle θ = 3.6607_rad
  ▹ water temp = 60° F
    ---
    velocity V = 3.9774_(ft/s)
    ave shear stress τ = 0.07967_(lbf/ft²)
```

```
    froude no. = 0.55215
    (equivalent ks = 1.2472_mm)
    area A = 4.6764_ft^2
    hydraulic radius Rh = 0.85164_ft
    wetted perimeter P = 5.491_ft
    top width T = 2.8995_ft
Q full = 25.831_(ft^3/s)   y/D = 1 & 0.81963
Q peak = 27.786_(ft^3/s)   y/D = 0.93818
V full = 3.6543_(ft/s)   y/D = 1 & 0.5
V peak = 4.166_(ft/s)   y/D = 0.8128
critical rel. depth (y/D crit) = 0.4606
critical depth (y crit) = 16.581_in
kinematic viscosity vk = 12.170E-6_(ft^2/s)
density ρ = 1.9383E0_(slug/ft^3)
Notes
● The calculation of τ uses the approximate
equation, where sin(θ)=S.
```

7. Size a pipe for y/D max = 0.75 using the D↑ auto sizing option

Size a storm pipe to handle 83 l/s under gravity flow, where y/D max = 0.75, and the available slope is 0.006. Use ks = 0.6 mm.

For this problem, use the Colebrook flowrate equation with the *D↑,y/D given n Q S* solve option.   Enter ks, Q and S. Set "y/D max for pipe sizing" to 0.75. The diameter list is set to "UK Composite mm". No minimum pipe diameter was specified, so set "min dia row no." = 2, which corresponds to a 100 mm pipe. 100 mm is the smallest diameter in the "UK Composite mm" diameter list.

Input screen for Colebrook Flowrate Eq

Menu:	5 Colebrook Flowrate Eq		
ks:	0.6	mm	
Q:	83	l/s	
S:	0.006		
D:	0	mm	
y/D:	0		temp 15° C
Solve:	D↑,y/D given ks Q S		

Separate low flow calcs for V, τ (optional)

Q low ❑ 0

y/D low ❑ 0

Diameter rounding parameters for D↑

y/D max for pipe sizing (0.1 to 1): 0.75

dia list: UK Composite (mm)

min dia row no.: 2

The print terminal indicates the diameter D↑ = 375 mm, relative depth y/D = 0.52212, and depth y = 195.79 mm.

Print Terminal

```
------------ PipeCalc4b ------------
05 Colebrook Flowrate Eq
06 Solve: D↑, y/D  given  ks Q S
 ▹ roughness ks = 0.6_mm
 ▹ flowrate Q = 83_(l/s)
 ▹ slope S = 0.006
   slope ratio = 1 : 166.67
   nominal diameter D = 375_mm✶
   inside diameter ID = 375_mm
   (calculated diameter = 307.49_mm)
 ▹ y/D max for pipe sizing = 0.75
 ▹ dia. list = UK Composite (mm)
 ▹ minimum diameter row no. = 2
   minimum diameter = 100_mm
   relative depth y/D = 0.52212✶
   depth y = 195.79_mm
   central angle θ = 3.2301_rad
 ▹ water temp = 15° C
   ---
   velocity V = 1.4229_(m/s)
```

```
   ave shear stress τ = 5.6621_Pa
   froude no. = 1.1515
   (equivalent n = 0.01144)
   area A = 0.05833_m^2
   hydraulic radius Rh = 0.09632_m
   wetted perimeter P = 0.60564_m
   top width T = 0.37463_m
Q full = 154.48_(l/s)    y/D = 1 & 0.82569
Q peak = 165.38_(l/s)    y/D = 0.94039
V full = 1.3987_(m/s)    y/D = 1 & 0.5
V peak = 1.5842_(m/s)    y/D = 0.8128
critical rel. depth (y/D crit) = 0.56213
critical depth (y crit) = 210.8_mm
kinematic viscosity vk = 1.1390E-6_Pa
density ρ = 999.10E0_(kg/m^3)
Notes
● The calculation of τ uses the approximate
equation, where sin(θ)=S.
```

8. Solve S,D for τ min (approx. method)

Given an average flow of 2.25 l/s, and a maximum flow of 6.25 l/s, determine the slope and pipe diameter required for a minimum tractive force of 1 Pa and a maximum relative depth of y/D = 0.7. Manning's roughness = 0.013.

Step 1, solve for the slope

Assume y/D min is 0.2.

Switch to the "S min program". On the S min input screen, checkmark the "Manning n = const" and select the "S,D (τ min) given τ Q y/D" solve option. Then press the OK tab.

Input screen for 7 S min program

```
Menu:  7 S min program
    Manning n = const ☑
      Manning n = f(D) ❑
              Colebrook ❑
Solve:   5  S,D  (τ min)  given   τ  Q  y/D
```

On the 2nd input screen for *S,D (τ min) given τ Q y/D* solve option, input the following and press the OK tab.

Input screen for *05 S,D (τ min) given τ Q y/D*

n:	0.013
τ :	1 Pa
Q:	2.25 l/s
D unit:	mm
y/D min:	0.2
temp:	15° C

The print terminal indicates the approx. slope S = 0.00388.

Print Terminal

```
------------ PipeCalc4b ------------
07 S min program
05 S,D for τ min given τ Q y/D
Manning's Eq n=const
 ▹ Manning n = 0.013
 ▹ ave shear stress τ = 1.0_(N/m²)
   velocity V = 0.42373_(m/s)
 ▹ flowrate Q = 2.25_(l/s)
   slope S = 0.00388✶
   slope ratio = 1 : 257.47
   diameter D = 217.91_mm✶(a)
 ▹ relative depth y/D = 0.2
   central angle θ = 1.8546_rad
   depth y = 43.582_mm
 ▹ water temp = 15° C
   ---
   froude no. = 0.7753
   (equivalent ks = 1.5498_mm)
   area A = 0.00531_m^2
```

```
   hydraulic radius Rh = 0.02628_m
   wetted perimeter P = 0.20207_m
   top width T = 0.17433_m
Q full = 25.693_(l/s)   y/D = 1 & 0.81963
Q peak = 27.638_(l/s)   y/D = 0.93818
V full = 0.68893_(m/s)   y/D = 1 & 0.5
V peak = 0.7854_(m/s)   y/D = 0.8128
A full = 0.03729_m^2
critical rel. depth Yc/D = 0.17566
critical depth Yc = 38.278_mm
kin viscosity VK = 1.1390E-6_Pa
density ρ = 999.10E0_(kg/m^3)
Notes
• The calculation of τ uses the approximate
equation, where sin(θ)=S.
(a)  D is the calculated diameter, and is
generally not used, as the pipe diameter is
usually sized by Q max.
```

Step 2, solve for the diameter

Switch to the *Manning Flowrate Eq n=const* equation. On the input screen enter n, Q max, Q min, S, y/D min, y/D max and other information shown, and press the OK tab.

Input screen for Manning Flowrate Eq

Menu:	1 Manning Flowrate Eq n=const	
n:	0.013	
Q:	6.25 l/s	
S:	0.00388	
D:	0 mm	
y/D:	0	temp 15° C
Solve:	D↑,y/D given n Q S	

Separate low flow calcs for V, τ (optional)
- Q low ☑ 2.25
- y/D low ❑ 0

Diameter rounding parameters for D↑
- y/D max for pipe sizing (0.1 to 1): 0.7
- dia list: Aus Composite (mm)
- min dia row no.: 2

The print terminal indicates the diameter D = 150 mm and relative depth y/D = 0.59223. For the low flows, V = 0.43989 m/s, τ = 1.0577 N/m^2 and y/D = 0.33138.

Print Terminal

```
------------ PipeCalc4b ------------
01 Manning Flowrate Eq n=const
06 Solve: D↑, y/D  given  n Q S
  ▹ Manning n = 0.013
  ▹ flowrate Q = 6.25_(l/s)
  ▹ slope S = 0.00388
    slope ratio = 1 : 257.47
    nominal diameter D = 150_mm✱
    inside diameter ID = 150_mm
    (calculated diameter = 137.08_mm)
  ▹ y/D max for pipe sizing = 0.7
  ▹ dia. list = Aus Composite_mm
  ▹ minimum diameter row no. = 2
    minimum diameter = 100_mm
    relative depth y/D = 0.59223✱
    depth y = 88.834_mm
    central angle θ = 3.5126_rad
  ▹ water temp = 15° C
    ---
    velocity V = 0.57344_(m/s)
    ave shear stress τ = 1.5743_Pa
    froude no. = 0.67348
    (equivalent ks = 1.6168_mm)
```

```
    area A = 0.0109_m^2
    hydraulic radius Rh = 0.04137_m
    wetted perimeter P = 0.26345_m
    top width T = 0.14743_m
Low flow calcs for Q low = 2.25_(l/s)
    V = 0.43989_(m/s)
    τ = 1.0577_(N/m²)
    y/D = 0.33138
    y = 49.707_mm
Q full = 9.4912_(l/s)    y/D = 1 & 0.81963
Q peak = 10.21_(l/s)    y/D = 0.93818
V full = 0.53709_(m/s)    y/D = 1 & 0.5
V peak = 0.6123_(m/s)    y/D = 0.8128
critical rel. depth (y/D crit) = 0.48155
critical depth (y crit) = 72.232_mm
kinematic viscosity vk = 1.1390E-6_Pa
density ρ = 999.10E0_(kg/m^3)
Notes
• The calculation of τ uses the approximate
equation, where sin(θ)=S.
```

9. Solve S,y/D for τ min

In the previous problem, $S_{\tau\ min}$ and D were solved using an approximate method. Now that diameter is known, the exact $S_{\tau\ min}$ and y/D can be solved using the *S,y/D for τ min given D τ Q* solve option in the S min program.

Run the *S,y/D for τ min given D τ Q* solve option in the S min program. Enter n = 0.013, D = 150 mm, τ min = 1 Pa, Q min = 2.25 l/s, and temp = 15° C. Finally press the OK tab.

Input screen for 7 S min program

```
Menu:  7 S min program
     Manning n = const  ☑
       Manning n = f(D)  ❏
                Colebrook ❏
Solve:   6 S,y/D for τ min given  D τ  Q
```

On the 2nd input screen for *S,D (τ min) given τ Q y/D* solve option, input the following and press the OK tab.

Input screen for *06 S,y/D for τ min given D τ Q*

n:	0.013	
D:	150	mm
T min:	1	Pa
Q min:	2.25	l/s
temp:	15° C	

The print terminal indicates the slope for τ min equals 0.00362 at a relative depth of 0.33762, which is a little different from the approx. method.

Print Terminal

```
------------ PipeCalc4b ------------
07 S min program
06 S,y/D for τ min given D τ Q
Manning's Eq n=const
 ▹ Manning n = 0.013
 ▹ ave shear stress τ = 1_(N/m²)
   velocity V = 0.42877_(m/s)
 ▹ flowrate Q = 2.25_(l/s)
   slope S = 0.00362✶
   slope ratio = 1 : 276.41
 ▹ diameter D = 150_mm
   relative depth y/D = 0.33762✶
   central angle θ = 2.4801_rad
   depth y = 50.643_mm
 ▹ water temp = 15° C
   ---
   froude no. = 0.71193
   (equivalent ks = 1.56_mm)
```

```
   area A = 0.00525_m^2
   hydraulic radius Rh = 0.02821_m
   wetted perimeter P = 0.18601_m
   top width T = 0.14187_m
Q full = 9.1602_(l/s)    y/D = 1 & 0.81963
Q peak = 9.8537_(l/s)    y/D = 0.93818
V full = 0.51836_(m/s)    y/D = 1 & 0.5
V peak = 0.59095_(m/s)    y/D = 0.8128
A full = 0.01767_m^2
critical rel. depth Yc/D = 0.28329
critical depth Yc = 42.493_mm
kin viscosity VK = 1.1390E-6_Pa
density ρ = 999.10E0_(kg/m^3)
Notes
• The calculation of τ uses the approximate
equation, where sin(θ)=S.
```

10. Q Conversion example

Convert 6.2 cfs to an equivalent rate in MGD.

Switch to the *Q Conversions* program. On the input screen enter Q1 = 6.2 cfs. Enter Q3 units = MGD. Press the OK tab.

Input screen for *Q Conversions* program

```
Menu:   13  Q Conversions
  Q1:   6.2       ft^3/s
  Q3:   0         MGD
Solve:  Q3
```

The print terminal indicates the flowrate is equal to 4.0072 MGD.

Print Terminal

```
------------ PipeCalc4b ------------13 Q
Conversions
 ▹ flowrate Q1 = 6.2_(ft^3/s)
   flowrate Q3 = 4.0072_(MgalUS/d)✶
```

11. Revisions

Fixed a number format display error. Added the use of the actual and nominal diameters.

12. Program comments

Internal unit variables and unit handling

Unit variables are a list that contains the SI value part, SI unit part, user value part, user unit part, number that identifies if the variable is an input variable or solve variable, and input and output flags. The SI unit part is predefined in the variable declarations.

After data is inputted on the input screen, the program stores the user value part and user unit part into the unit variable. The program then calculates the SI value part. From this point on, all calculations in the program are done using the SI value part. After solving for the unknown variable, the SI values are converted back to the user's units. The results are printed on the print terminal using the user value part multiplied by the unit part.

Diameter rounding adjustment

PipeCalc uses a diameter rounding adjustment of 0.6 mm. In the D↑ rounding procedure, 0.6 mm is subtracted from the calculated diameter, when rounding the diameter upwards. The HP-41 Pipe Slide Rule program used a diameter rounding adjustment of 0.003 in.