Base Flow Index: Worked example 5.4

Table of Contents

# Loading the Data

Three years of daily flow (1995 to 1997) from the Ray at Grendon Underwood (UK) have been selected. The base flow separation is done for the whole three-year period, whereas the BFI is calculated for the mid-year 1996. This ensures that days at the start and end of the calculation year are included. In [Table 5.7](#table) the calculation steps are illustrated using data from the beginning of the record.

library(tidyverse)  
library(lubridate)  
library(hydroDrought)  
  
ray <- international %>%  
 filter(river == "Ray") %>%  
 select(data) %>%  
 unnest(data) %>%  
 mutate(  
 year = water\_year(time)  
 ) %>%  
 filter(year >= 1995, year <= 1997)

# Calculation

1. The daily flows,  m3s-1, are divided into non-overlapping blocks of five days (Column 1 and 2, [Table 5.7](#table)).

* ray <- ray %>%  
   mutate(  
  block = ((row\_number() - 1) %/% 5) + 1  
   ) %>%  
   print()
* ## # A tibble: 1,096 x 4  
  ## time discharge year block  
  ## <date> <dbl> <dbl> <dbl>  
  ## 1 1995-01-01 0.109 1995 1  
  ## 2 1995-01-02 0.063 1995 1  
  ## 3 1995-01-03 0.043 1995 1  
  ## 4 1995-01-04 0.039 1995 1  
  ## 5 1995-01-05 0.229 1995 1  
  ## 6 1995-01-06 0.186 1995 2  
  ## 7 1995-01-07 0.116 1995 2  
  ## 8 1995-01-08 0.111 1995 2  
  ## 9 1995-01-09 0.095 1995 2  
  ## 10 1995-01-10 0.123 1995 2  
  ## # … with 1,086 more rows

1. Mark the minima of each of these blocks and let them be called , … (Column 3, [Table 5.7](#table)). Consider in turn (, , ), … (, , ). In each case, if 0.9·central value ≤ outer values, then the central value is identified as a turning point for the base flow line (bold lines in [Table 5.7](#table)). Continue this procedure until the whole time series has been analysed.

* points <- ray %>%  
   group\_by(block) %>%  
   slice\_min(discharge, with\_ties = FALSE) %>%  
   ungroup() %>%  
   rename(Qmin = discharge) %>%  
   mutate(  
  Qmin.red = 0.9 \* Qmin,  
  is.turning.point = Qmin.red <= lag(Qmin) & Qmin.red <= lead(Qmin)  
   )

1. Join the turning points by straight lines to form the base flow separation line and assign to each day a base flow value , by linear interpolation between the turning points. If, on any day, the base flow estimated by this line exceeds the total flow, the base flow is set to be equal to the total flow , on that day.

* tp <- points %>%  
   filter(is.turning.point) %>%  
   select(time, Qmin)   
    
  baseflow <- ray %>%  
   mutate(  
  baseflow = approx(x = tp$time, y = tp$Qmin, xout = time)$y,   
  baseflow = pmin(baseflow, discharge)  
   )

1. Calculate the volume of water () beneath the base flow hydrograph between the first and last date of interest. The volume (m3) is simply derived as the sum of the daily base flow values multiplied by 86 400 (the number of seconds per day).
2. Calculate the corresponding volume of water beneath the recorded hydrograph (). The volume (m3) is obtained by summing the daily flow values between the first and the last dates inclusive.

* volume <- baseflow %>%  
   filter(year == 1996) %>%  
   na.omit() %>%  
   summarise(  
  total = sum(discharge) \* 86400,  
  baseflow = sum(baseflow) \* 86400  
   )

1. The BFI is then .

bfi <- volume$baseflow / volume$total  
bfi

## [1] 0.2024139

Table 5.7 Calculation of the base flow separation line from time series of daily flow; non-overlapping 5-day blocks are indicated by alternating background colors and turning points are marked bold.

1 . Date

2 . Daily flow

3 . Qmin

4 . 0.9 \* Qmin

5 . Base flow

1995-01-01

0.109

1995-01-02

0.063

1995-01-03

0.043

1995-01-04

0.039

0.039

0.0351

1995-01-05

0.229

1995-01-06

0.186

1995-01-07

0.116

1995-01-08

0.111

1995-01-09

0.095

0.095

0.0855

1995-01-10

0.123

1995-01-11

0.178

1995-01-12

0.091

1995-01-13

0.076

1995-01-14

0.073

1995-01-15

0.062

0.062

0.0558

1995-01-16

0.054

0.054

0.0486

0.054

1995-01-17

1.060

0.056

1995-01-18

0.856

0.058

1995-01-19

1.050

0.060

1995-01-20

1.340

0.062

1995-01-21

1.640

0.064

1995-01-22

1.350

0.067

1995-01-23

0.559

0.069

1995-01-24

0.255

0.255

0.2295

0.071

1995-01-25

0.644

0.073

1995-01-26

0.793

0.075

1995-01-27

0.896

0.077

1995-01-28

0.631

0.079

1995-01-29

1.000

0.081

1995-01-30

0.492

0.492

0.4428

0.083

1995-01-31

0.377

0.085

1995-02-01

1.670

0.087

1995-02-02

0.448

0.090

1995-02-03

0.237

0.092

1995-02-04

0.163

0.163

0.1467

0.094

1995-02-05

0.123

0.096

1995-02-06

0.102

0.098

1995-02-07

0.100

0.100

0.0900

0.100

1995-02-08

0.151

0.107

1995-02-09

0.178

0.115

# Results

1. The first and second turning points are found on day 1995-01-16 and day 1995-01-16 (Column 4, [Table 5.7](#table)), respectively, and a linear interpolation is used to estimate the base flow at time steps (days) between these dates (Column 5, [Table 5.7](#table)). The daily base flow separation line is subsequently calculated for the whole period by linear interpolation between all turning points.
2. The volume beneath the base flow line, , for 1996 is found to be 348 494.5 m3, whereas the volume of the total flow, , is 1 721 693 m3. The resultant BFI is 0.20. The base flow separation line for River Ray in 1996 is shown in Figure 5.4 of the book.

# Fast Track

The base flow for a given time series can also be calculated directly using the function baseflow(), optionally with a different choice of the block length ( days) or the turning point factor or parameter () for the central value. The default values are tp.factor = 0.9 and block.len = 5, which can be adopted to the type of flow regime studied and changed accordingly by the user.

bf <- ray %>%  
 select(time, discharge) %>%  
 mutate(  
 baseflow = baseflow(discharge, tp.factor = 0.9, block.len = 5)  
 ) %>%  
 filter(year(time) == 1996) %>%  
 print()

## # A tibble: 366 x 3  
## time discharge baseflow  
## <date> <dbl> <dbl>  
## 1 1996-01-01 0.19 0.0332  
## 2 1996-01-02 0.224 0.0326  
## 3 1996-01-03 0.189 0.0320  
## 4 1996-01-04 0.145 0.0314  
## 5 1996-01-05 0.221 0.0308  
## 6 1996-01-06 0.385 0.0302  
## 7 1996-01-07 0.567 0.0296  
## 8 1996-01-08 0.463 0.0291  
## 9 1996-01-09 1.38 0.0285  
## 10 1996-01-10 0.475 0.0279  
## # … with 356 more rows

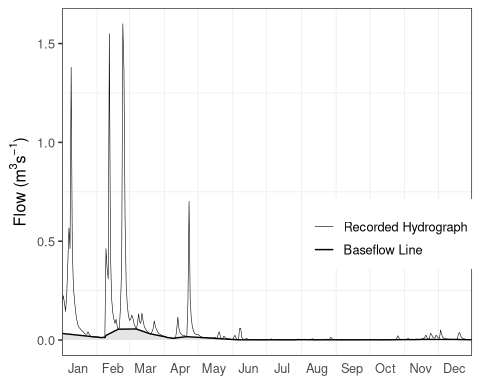


Figure 5.4 Annual recorded hydrograph and calculated continuous base flow line for UK river Ray in year 1996 based on the BFI separation procedure (Worked Example 5.3).