Example computation of 7-day low flows for climate year and summer season

Dave Lorenz

July 26, 2017

Abstract

This example illustrates retrieving daily values data from NWISWeb and computing the 7-day low flow values for each climate year (the year ending March 31) and summer season (beginning June and ending September). This example uses daily flow data from USGS station 05484500, Raccoon River at Van Meter, Iowa through water year 2012 (September 30, 2012).

Contents

1 Introduction

These examples use data from NWISWeb. The data are retrieved in the following code.

```
> # Load the DVstats package and retrieve the data
> library(DVstats)
> library(dataRetrieval)
> library(smwrBase) # needed for screenData and other functions
> library(smwrGraphs) # needed to create the graphs
> RRVM <- renameNWISColumns(readNWISdv("05484500", "00060", endDate="2012-09-30"))
> # The screenData function is useful to review for
> # complete record, default is by calendar year.
> with(RRVM, screenData(Date, Flow))
```

```
Table of incomplete DVs:
      Month.number
Year    1  2  3  4  5 6 7 8 9 10 11 12
  1915 31 28 31 24
  1916
  1917
  1918
  1919
  1920
  1921
  1922
  1923
  1924
  1925
  1926
  1927
  1928
  1929
  1930
  1931
  1932
  1933
  1934
  1935
  1936
  1937
  1938
  1939
  1940
  1941
```

1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987

```
   1988
   1989
   1990
   1991
   1992
   1993
   1994
   1995
   1996
   1997
 [ reached getOption("max.print") -- omitted 15 rows ]
Date of first value: 1915-04-25
Date of last value: 2012-09-30

> # The record is complete, beginning 1915-04-25
```

2 Compute the climate year 7-day low flows

The `dvStat` function is used to compute user-defined summary statistics for daily values. Each summary statistic requires a new call to `dvStat`. The arguments to `dvStat` include `x`, which is the daily value to be summarized; `Dates`, the date for each value in `x`; `Start` and `End`, that can be used to extract the data for a user-defined period of time; `by`, a grouping variable; `pre`, any preprocessing function; `stat`, the summary statistical function—it must return a single value and must accept the `na.rm` argument; `na.rm`, the value to use for the `na.rm` argument to `stat`; `STAID`, any name the user wants to use for the station; and any additional arguments to `pre`. For interactive use, it is easiest to use the function `with` to make specifying columns easier.

To compute climate year statistics, the `by` argument can be defined by the `climateYear` function supplying the same data as for the `Dates`.

To compute 7-day (or other) running averages, `pre` should be set to `movingAve` and its arguments `span` and `pos` should be set to 7 and "trailing" as shown in the example below.

By default, the statistic (`stat`) in `min`, which will give the low flows.

```
> # Compute the 7-day low flow for each climate year.
> RRVM7ClimY <- with(RRVM,
+    dvStat(Flow, Date,
+      by=climateYear(Date),
+      pre=movingAve,
+      STAID="05484500",
+      span=7, pos="trailing"))
> # print the first and last few rows of the output
> head(RRVM7ClimY)

     STAID Group Nobs       min        Date
1 05484500  1916  342 380.00000 1915-12-26
2 05484500  1917  365  53.00000 1917-01-27
3 05484500  1918  365  42.00000 1918-02-07
4 05484500  1919  365  40.85714 1918-10-09
5 05484500  1920  366  89.71429 1919-09-16
6 05484500  1921  365 289.85714 1920-10-11


> tail(RRVM7ClimY)

      STAID Group Nobs      min        Date
93 05484500  2008  366 414.8571 2007-08-04
94 05484500  2009  365 482.5714 2008-09-23
95 05484500  2010  365 425.0000 2009-09-23
```

```
96 05484500   2011   365 529.5714 2011-02-14
97 05484500   2012   366 176.8571 2012-01-25
98 05484500   2013   183 109.0000 2012-08-25
```

The data are the station id, STAID; the year or season, group as a factor; the number of observations used to compute the statistic, Nobs; the statistic, min in this case; and the date of the value, Date. The date of the value is the first day for the minimum average flow for the preceding 7 days,

The first and last rows are incomplete, as indicated by the number of observations that were used (Nobs). To use only complete climate years, the data can be subsetted by extracting only those rows where Nobs is greater than or equal to 365 (leap years have 366 days). Alternatively, Start and End could be set to the climate year start and end dates, but one would still need to possibly subset for incomplete years in the record.

```
> # Extract complete climate year data.
> RRVM7ClimY <- subset(RRVM7ClimY, Nobs >= 365)
> # print the first and last few rows of the output
> head(RRVM7ClimY)


     STAID Group Nobs       min       Date
2 05484500  1917  365  53.00000 1917-01-27
3 05484500  1918  365  42.00000 1918-02-07
4 05484500  1919  365  40.85714 1918-10-09
5 05484500  1920  366  89.71429 1919-09-16
6 05484500  1921  365 289.85714 1920-10-11
7 05484500  1922  365 150.00000 1922-02-07


> tail(RRVM7ClimY)


      STAID Group Nobs      min       Date
92 05484500  2007  365 198.2857 2006-08-09
93 05484500  2008  366 414.8571 2007-08-04
94 05484500  2009  365 482.5714 2008-09-23
95 05484500  2010  365 425.0000 2009-09-23
96 05484500  2011  365 529.5714 2011-02-14
97 05484500  2012  366 176.8571 2012-01-25


> # Change the name of the statistic
> names(RRVM7ClimY)[4] <- "LowQ7"
```

3 Plots and summary of the climate year data

The probability and time-series plots can instructive. Use the `Date` column instead of `Group` because `Group` is a factor and can't be treated as a date.

```
> # setSweave is required for the vignette.
> setSweave("SevenDay_01", 5, 5)
> with(RRVM7ClimY, probPlot(LowQ7, yaxis.log=T, xlabels=5))
> graphics.off()
```
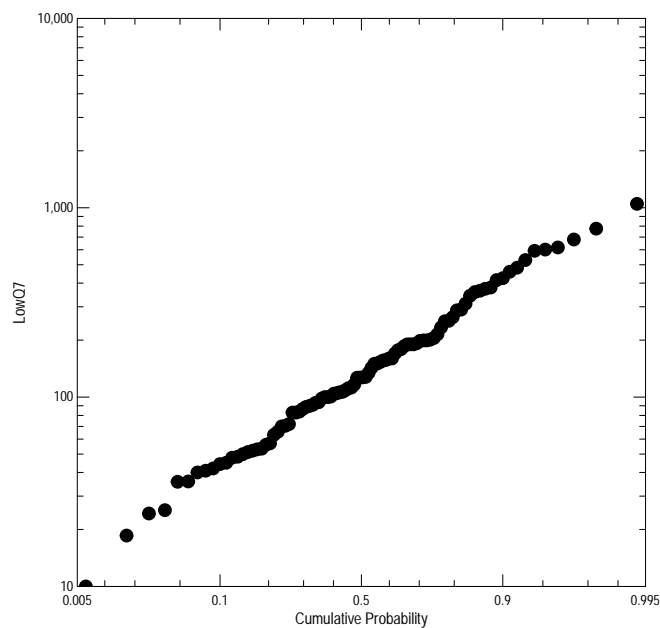

Figure 1. The probability plot.

```
> # setSweave is required for the vignette.
> setSweave("SevenDay_02", 5, 5)
> with(RRVM7ClimY, timePlot(Date, LowQ7,
+   Plot=list(what="points")))
> graphics.off()
```
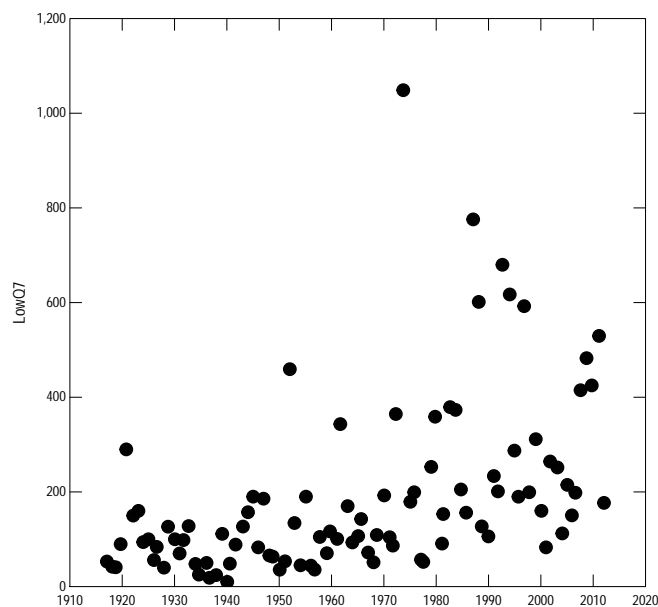
Figure 2. The time-series plot.

Figure 2 suggests a trend of increasing low-flows over time. Some applications of low-flow analysis can require a trend analysis to establish a base period. A thorough trend analysis would include an analysis of the relation of flows to precipitation and possibly land use changes and is beyond the scope of this vignette.

A useful summary statistic for annual series is a table of the number of occurances of the lowest flows by month.For these data, most low flows occur during the winter months.

```
> with(RRVM7ClimY, table(month(Date, label=TRUE)))

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
 25  18   1   1   1   0   2   8  16  12   0  12
```

4 Compute the summer season 7-day low flows

To compute seasonal statistics, the `by` argument can be defined by the `seasonYear` function supplying the same data as for the `Dates` and setting the beginning and ending months by the `start.month` and `end.month` arguments, which are "June' and "September" by default.

```
> # Compute the 7-day low flow for each climate year.
> RRVM7Summ <- with(RRVM,
+   dvStat(Flow, Date,
+     by=seasonYear(Date),
+     pre=movingAve,
+     STAID="05484500",
+     span=7, pos="trailing"))
> # print the first and last few rows of the output
> head(RRVM7Summ)


     STAID Group Nobs       min       Date
1 05484500  1915  122 920.71429 1915-09-08
2 05484500  1916  122  87.00000 1916-09-01
3 05484500  1917  122 188.42857 1917-09-03
4 05484500  1918  122  46.85714 1918-09-30
5 05484500  1919  122  89.71429 1919-09-16
6 05484500  1920  122 327.71429 1920-08-19


> tail(RRVM7Summ)


      STAID Group Nobs       min       Date
93 05484500  2007  122  414.8571 2007-08-04
94 05484500  2008  122  482.5714 2008-09-23
95 05484500  2009  122  425.0000 2009-09-23
96 05484500  2010  122 2148.5714 2010-09-18
97 05484500  2011  122  245.4286 2011-09-30
98 05484500  2012  122  109.0000 2012-08-25
```

The first and last rows are complete in this case because the streamflow record started in April of 1915 and continued through September of 2012. Note that there is a disconnect between the summer period year and the climate year. For example, the summer period year 2000 is actually in the 2001 climate year. This example will retain all of the data. But will rename column 4.

```
> # Change the name of the statistic
> names(RRVM7Summ)[4] <- "LowQ7"
```

5 Quick plots of the summer data

The probability and time-series plots can instructive. Use the `Date` column instead of `Group` because `Group` is a factor and can't be treated as a date.

```
> # setSweave is required for the vignette.
> setSweave("SevenDay_03", 5, 5)
> with(RRVM7Summ, probPlot(LowQ7, yaxis.log=T, xlabels=5))
> graphics.off()
```
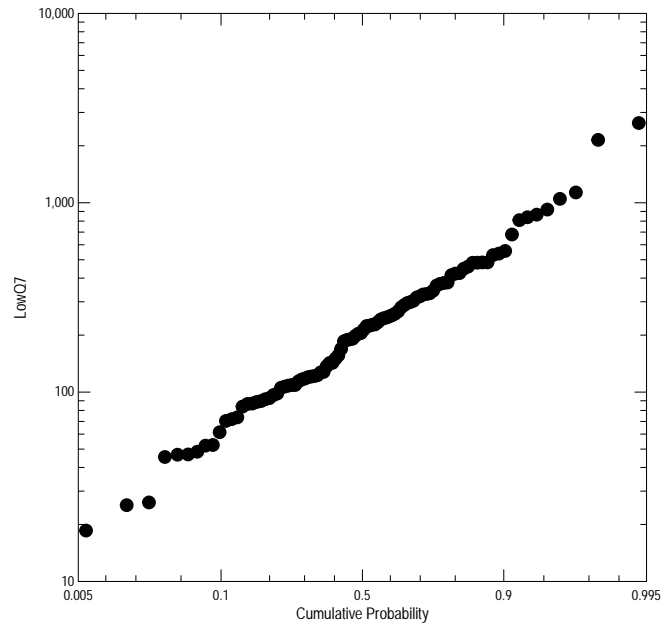

Figure 3. The probability plot of summer low flows.

```
> # setSweave is required for the vignette.
> setSweave("SevenDay_04", 5, 5)
> with(RRVM7Summ, timePlot(Date, LowQ7,
+     Plot=list(what="points")))
> graphics.off()
```
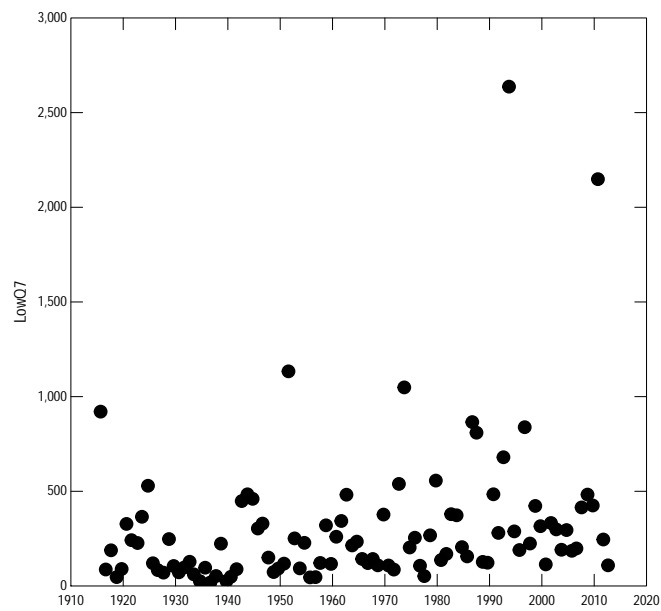

Figure 4. The time-series plot of summer low flows.

6 Compute the frequency analyses

The function `freqAnal` will perform a frequency analysis of low-flow data. It tries to fit 3 distributions—the log-Pearson type III, a 3-parameter log-normal, and the log-generalized extreme value. The log-Pearson type III distribution is fit using the method of moments–compute the mean, standard deviation, and skew of the logarithms of the data. The other distributions are fit using the method of maximum likelihood. The default distribution selection procedure preferentially selects the log-Pearson type III, then the 3-parameter log-normal, with the log-generalized extreme value as the last choice.

```
> # The Annual analysis
> RRVM7ClimY.frq <- with(RRVM7ClimY, freqAnal(LowQ7, id=Group,
+     desc="Annual 7-day Low Flow", STAID="05484500"))
> # The Summer analysis
> RRVM7Summ.frq <- with(RRVM7Summ, freqAnal(LowQ7, id=Group,
+     desc="Summer 7-day Low Flow", STAID="05484500"))
```

The respective reports are generated on the next two pages.

```
> # The Annual analysis
> print(RRVM7ClimY.frq)

Frequency analysis for 05484500
Statistics for Annual 7-day Low Flow

Descriptive statistics based on 96 non-zero values
    1940     1937     1938     1935     1950     1957     1928     1919
   10.00    18.57    24.29    25.29    35.71    35.86    40.00    40.86
    1918     1956     1954     1934     1941     1936     1968     1978
   42.00    44.29    45.00    47.86    48.43    50.00    51.29    52.14
    1917     1951     1926     1977     1949     1948     1931     1959
   53.00    53.43    56.00    57.00    63.29    65.71    70.00    70.57
    1967     2001     1946     1927     1972     1942     1920     1981
   72.00    82.86    82.86    83.86    86.57    88.71    89.71    90.86
    1964     1924     1932     1925     1930     1961     1971     1958
   93.29    94.00    98.29   100.00   100.00   100.71   104.29   104.86
    1990     1965     1969     1939     2004     1960     1929     1943
  106.00   106.71   109.00   111.43   112.33   116.57   126.57   126.86
    1989     1933     1953     1966     1922     2006     1982     1986
  127.14   127.86   134.29   142.71   150.00   150.43   153.29   156.14
    1944     2000     1923     1963     2012     1975     1947     1996
  157.14   160.00   160.00   170.00   176.86   179.14   185.71   189.86
    1945     1955     1970     2007     1976     1998     1992     1985
  190.00   190.00   192.57   198.29   199.29   199.29   201.14   205.14
    2005     1991     2003     1979     2002     1995     1921     1999
  214.86   233.57   251.66   252.86   264.29   287.29   289.86   311.43
    1962     1980     1973     1984     1983     2008     2010     1952
  343.29   358.86   364.57   373.29   379.14   414.86   425.00   459.29
    2009     2011     1997     1988     1994     1993     1987     1974
  482.57   529.57   592.43   601.43   617.14   679.86   775.71  1048.71
        Sample mean: 188.9
Sample std. dev.: 181.9

    Log-Pearson type III analysis.
             Mean common logs = 2.114
Standard deviation common logs = 0.3831
         Skewness common logs = -0.06243
PPCC:0.9969
Estimated data:
      Mean: 188.1
Std. Dev.: 182.9

    3-parameter Log-normal analysis.
             Mean common logs = 2.123
Standard deviation common logs = 0.3733
```

```
               Offset (lambda) = -1.832
PPCC:0.997
Estimated data:
     Mean: 187.6
Std. Dev.: 183

    Log-generalized extreme value analysis.
Location = 4.568
   Scale = 0.8909
   Shape = -0.3063
PPCC:0.9965
Estimated data:
     Mean: 187.2
Std. Dev.: 172.5
```

The frequency analysis estimates will be made using the log-Pearson type III method.
No zero values in these data, no conditional adjustment needed.

```
> # The Summer analysis
> print(RRVM7Summ.frq)

Frequency analysis for 05484500
Statistics for Summer 7-day Low Flow

Descriptive statistics based on 98 non-zero values
    1936    1934    1939    1955    1956    1918    1940    1977
   18.57   25.29   26.14   45.43   46.71   46.86   48.43   52.14
    1937    1933    1927    1930    1948    1926    1971    1916
   52.57   61.43   70.43   72.00   73.57   83.86   86.57   87.00
    1941    1919    1949    1953    1935    1931    1929    1976
   88.71   89.71   91.71   93.00   96.43   98.29  105.43  106.86
    1970    2012    1968    2000    1959    1950    1925    1966
  108.14  109.00  109.00  114.00  116.57  118.00  120.00  120.86
    1957    1989    1988    1932    1980    1967    1965    1947
  121.57  122.86  127.14  127.86  136.86  142.43  142.71  150.00
    1985    1981    2005    1917    1995    2003    2006    1974
  156.14  169.29  185.71  188.43  189.86  191.29  198.29  203.29
    1984    1963    1938    1997    1922    1954    1964    1921
  205.14  214.14  223.43  224.14  226.86  227.86  234.29  242.00
    2011    1928    1952    1975    1960    1978    1991    1994
  245.43  247.71  251.29  254.86  260.00  267.43  280.29  288.29
    2004    2002    1945    1999    1958    1920    1946    2001
  295.29  298.86  303.57  315.86  320.29  327.71  329.57  332.57
    1961    1923    1983    1969    1982    2007    1998    2009
  343.29  365.43  373.29  377.14  379.14  414.86  422.71  425.00
    1942    1944    1962    2008    1943    1990    1924    1972
  448.43  460.14  482.00  482.57  484.14  484.29  529.29  539.00
    1979    1992    1987    1996    1986    1915    1973    1951
  556.57  679.86  809.43  838.57  865.57  920.71 1048.71 1133.57
    2010    1993
 2148.57 2637.14
     Sample mean: 308.2
Sample std. dev.: 378.7


    Log-Pearson type III analysis.
             Mean common logs = 2.299
Standard deviation common logs = 0.4004
         Skewness common logs = 0.08179
PPCC:0.996
Estimated data:
     Mean: 302.4
Std. Dev.: 330.4


    3-parameter Log-normal analysis.
```

15

```
            Mean common logs = 2.293
Standard deviation common logs = 0.4044
               Offset (lambda) = 1.968
PPCC:0.9958
Estimated data:
     Mean: 299.7
Std. Dev.: 317.8


   Log-generalized extreme value analysis.
Location = 4.951
   Scale = 0.9087
   Shape = -0.2379
PPCC:0.9946
Estimated data:
     Mean: 308
Std. Dev.: 336.4
```

```
The frequency analysis estimates will be made using the log-Pearson type III method.
No zero values in these data, no conditional adjustment needed.
```

In both cases, the log-Pearson type III distribution was selected. The probability plot correlation coefficient is very close to 1, suggesting a very good fit. The plot function can be used to assess the selected fit.

```
> # The Annual analysis
> setSweave("SevenDay_05", 5, 5)
> plot(RRVM7ClimY.frq, which="default", set.up=FALSE)
> graphics.off()
```
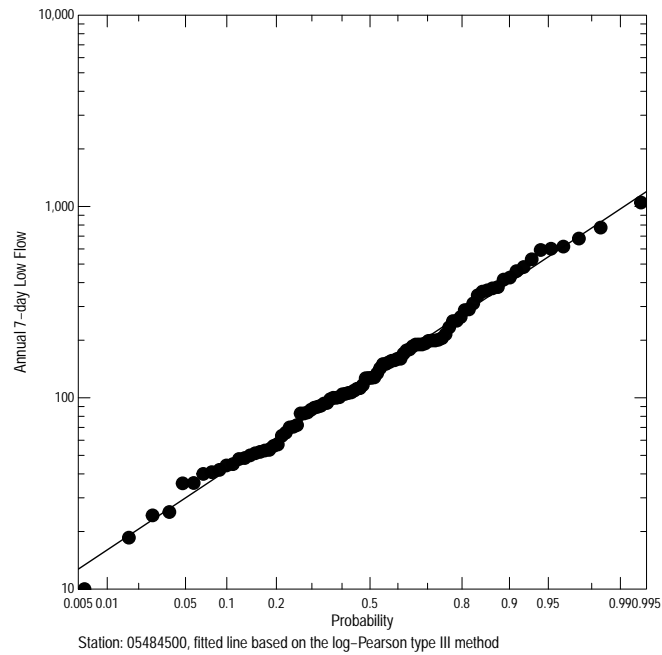

Figure 5. The log-Pearson type III fit to the annual data.

17

```
> # The Annual analysis
> setSweave("SevenDay_06", 5, 5)
> plot(RRVM7Summ.frq, which="default", set.up=FALSE)
> graphics.off()
```
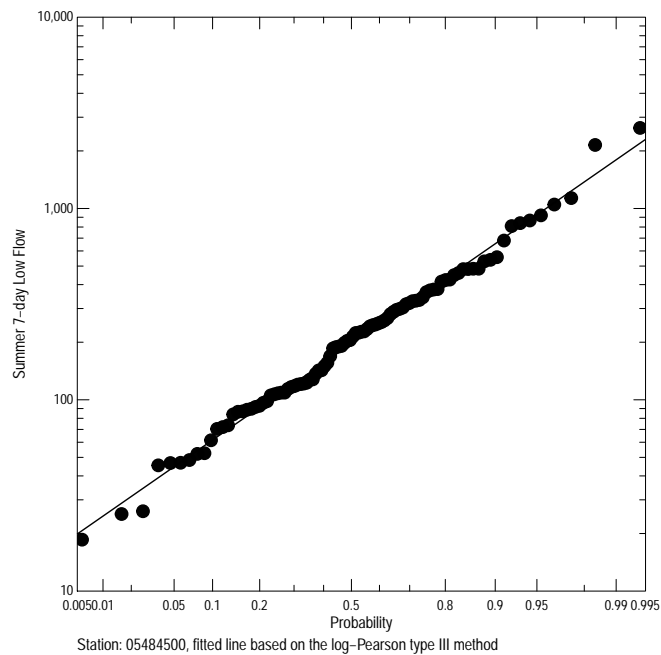

Figure 6. The log-Pearson type III fit to the summer data.

     The fit is very good in both cases. The more traditional low-flow graphs (on a normal probability scale) and estimated values for selected annual or seasonal probabilties are shown on the final two pages.

```
> # The Annual analysis
> predict(RRVM7ClimY.frq)

    Probs       Est
1    0.01  16.02798
2    0.02  20.61119
3    0.05  29.97855
4    0.10  41.71026
5    0.20  62.01630
6    0.50 131.13997
7    0.80 273.72653
8    0.90 400.06716
9    0.96 597.32020
10   0.98 772.21728
11   0.99 971.50529

> setSweave("SevenDay_07", 5, 5)
> plot(RRVM7ClimY.frq, which="default", set.up=FALSE)
> graphics.off()
```
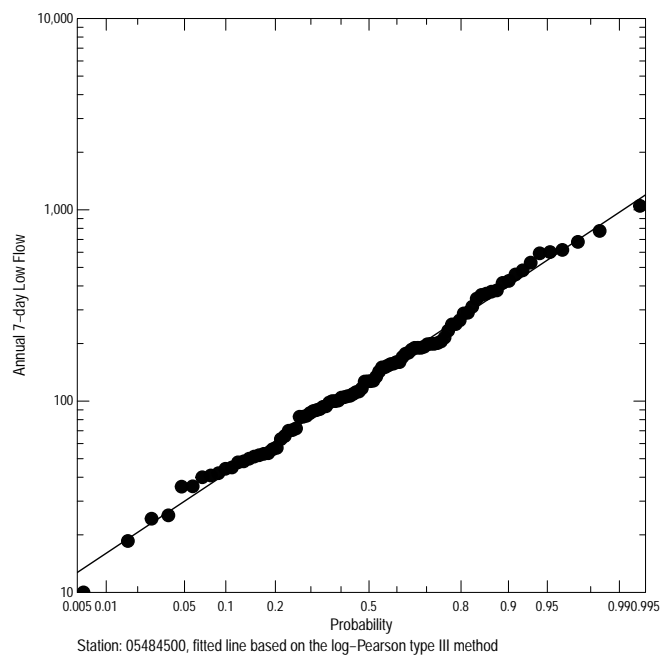

Figure 7. The log-Pearson type III estiamtes for the annual data.

```
> # The Summer analysis
> predict(RRVM7Summ.frq)

    Probs        Est
1    0.01    24.65300
2    0.02    31.22726
3    0.05    44.67016
4    0.10    61.61250
5    0.20    91.34380
6    0.50   196.64310
7    0.80   430.93313
8    0.90   654.05639
9    0.96  1026.14193
10   0.98  1376.76497
11   0.99  1797.02664

> setSweave("SevenDay_08", 5, 5)
> plot(RRVM7Summ.frq, set.up=FALSE)
> graphics.off()
```
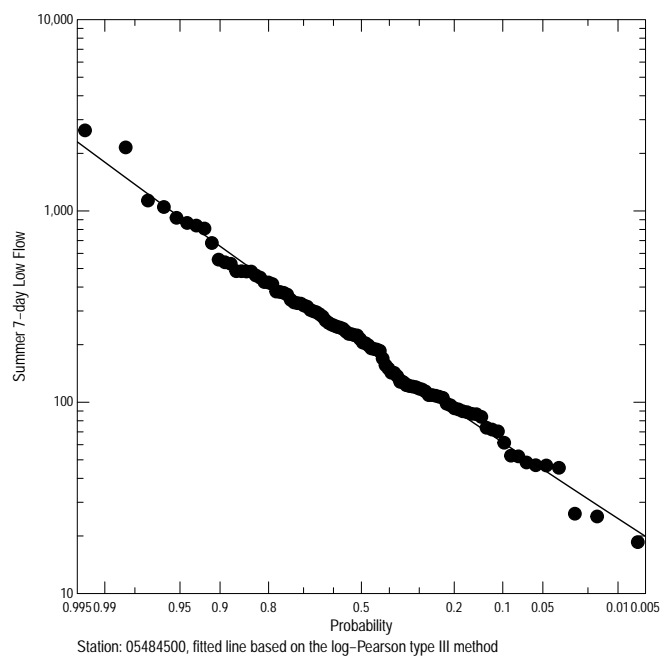

Figure 8. The log-Pearson type III estimates for the summer data.