CEE 6400 HW # 1

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①

① i $I = 0.00042\,H + 0.00026\,H \cdot P$

$\Rightarrow 0.00042 \times (\text{mm}) \quad \Rightarrow \left(0.00026 \times \frac{1}{\text{mm}}\right) \times \text{mm} \times \text{mm}$

$\Rightarrow 0.00042 \times \left(\frac{1}{25.4}\right)\text{in} \quad \Rightarrow 0.0026 \times \frac{1 \times \cancel{25.4}}{1 \times 1} \times \frac{1}{\cancel{25.4}}\,\text{in} \times \frac{1}{25}$

$\Rightarrow 0.000016\,H + 0.00010\,HP$

ii $B = 0.00061 \cdot p \cdot \left(\frac{T_s - T_a}{e_s - e_a}\right)$

$\Rightarrow [1] = \left(0.00061 \cdot \frac{1}{\text{mb}\,(°C)}\right) \cdot \text{mm} \cdot \frac{(°C)}{\text{mb}}$

$\Rightarrow 0.00061 \cdot \frac{\left(\frac{1}{25.4}\right) P_{inHg} \cdot (32 + 1 \times 1.8)°F}{1 \cdot P_{inHg} \cdot \left(32 + (T_c \times 1.8)\right)°F \left(\frac{1}{33.8639}\right) P_{inHg}}$

P_{mb}

P_{mmH}

°C

$32 + (T_c \times$

$\Rightarrow 0.0061 \times 1.33$

$\Rightarrow 0.0081$

$B = 0.0081\,p \left(\frac{T_s - T_a}{e_s - e_a}\right)$

iii $R_n = (0.83 \cdot K_{in}) - 54$

$\Rightarrow \frac{cal}{cm^2 d} = 0.83 \cdot \frac{cal}{cm^2 d} - 54 \cdot \frac{cal}{cm^2 d}$

$1\ cal = 4.2\ J$
$= 4.2\ Ws$

$\Rightarrow \frac{W}{m^2} = 0.83 \cdot \frac{(1 \cdot 4.2)\ W\cancel{s}}{((10^{-2})^2)\ m^2 (24 \times 60 \times 60)\ \cancel{s}} - 54 \cdot \frac{(1 \cdot 4.2)\ W\cancel{s}}{(10^{-2})^2\ m^2\ (24 \times 60 \times 60)\ \cancel{s}}$

$\Rightarrow \frac{W}{m^2} = 0.83 \times (0.0281) - 54\ (0.028)$

$\Rightarrow R_n = 0.023\ K_{in} - 1.5$

iv $E = \frac{3.64}{T_a} \cdot \frac{u_a}{\left[\ln\left(\frac{z_m}{z_0}\right)\right]^2} (e_a^* - e_a)$

$\frac{cm}{d} = 3.64 \times \frac{K}{mb} \cdot \frac{1}{K} \cdot \frac{km}{d} \cdot \frac{1}{\left(\frac{cm}{cm}\right)^2} \cdot (mb)$

$T_K = T_c + 273$
$1\ KPa = 10\ mb$

$\frac{mm}{s} = 3.64 \frac{(T_K - 273)\ °C}{0.1\ kPa} \times \frac{1}{(T_K - 273)\ °C} \times \frac{10^6\ mm}{24 \times 60 \times 60\ s}\ 0.1\ kPa$

$E = 42.13\ \frac{u_a}{T_a} \frac{(e_a^* - e_a)}{\left(\ln\left[\frac{z_m}{z_0}\right]\right)^2}$

(3)

(2) a) Avg Residence time of water in land phase : $\frac{\text{Vol}}{\text{rate}}$

$$= \frac{421 \times 10^6 \ km^3}{(113 \times 10^3) \ km^3 \ yr^{-1}} = 3725.7 \ yr$$

b) Avg residence time of water in rivers & lakes : $\frac{\text{Vol}}{\text{rate}}$

$$= \frac{178 \times 10^3 \ km^3}{40 \times 10^3 \ km^3 \ yr^{-1}} = 4.45 \ yr$$

(3) a) Connecticut

$A = 20370 \ km^2$, $\mu_P = 1100 \ mm/yr$, $\varepsilon_P = 11\%$, $\mu_Q = 386 \ m^3/s$, $e_Q = 5\%$

$\mu_{ET} = \mu_P - \mu_Q$

$\mu_P = 1100 \ mm/yr$

$$\mu_Q = \frac{386 \ m^3/s}{20370 \ km^2} = \frac{386 \times 10^9 \ mm^3/s}{20370 \times (10^6)^2 \ mm^2 \left(\frac{1}{365 \times 60 \times 24 \times 60} \right) yr}$$

$= \frac{386}{20370} \times 31536 = 597.59 \ mm/yr$

$M_{ET} = M_p - M_Q = 1100 - 597.59 = \underline{\underline{502.41 \ mm/yr}}$

$\% \ \text{error} = \frac{(0.1 \times 1100) + (0.05 \times 597.59)}{502.41} \cdot 100 = 27.84\%$

b) Yukon

$A = 932400 \ km^2, \ P_{Avg} = 570 \ mm/yr, \ \varepsilon_p = 20\%, \ Q_{Avg} = 5100 \ m^3/s, \ \varepsilon_p = 10\%$

$M_Q = \frac{5100 \ m^3/s}{932400 \ km^2} = \frac{5100}{932400} \times 31536 = 172.49 \ mm/yr$

$M_{ET} = 570 - 172.49 = \underline{\underline{397.51 \ mm/yr}}$

$\% \ \text{err} = \frac{(0.2 \times 570 + 0.1 \times 172.49)}{397.51} \cdot 100 = 33.02\%$

(5)

c) Euphrates

$A = 261100\ km^2$, $P_{avg} = 300\ mm/yr$, $\varepsilon_P = 10\%$, $Q_{Avg} = 911\ m^3/s$, $\varepsilon_Q = 10\%$

$$M_Q = \frac{911\ m^3/s}{261100\ km^2} = \frac{911 \times 31536}{261100} = 110.03\ mm/yr$$

$$M_{ET} = 300 - 110.03 = \underline{\underline{189.97\ mm/yr}}$$

$$\%\ err = \left(\frac{0.1 \times 300 + 0.1 \times 110.03}{189.97}\right) \cdot 100 = 21.58\%$$

d) Mekong

$A = 663{,}000\ km^2$, $P_{Avg} = 1460\ mm/yr$, $\varepsilon_p = 15\%$, $Q_{Avg} = 13200$, $\varepsilon_Q = 5\%$

$$M_Q = \frac{13200\ m^3/s}{663000\ km^2} = \frac{13200}{663000} \times 31536 = 627.87\ mm/yr$$

$$M_{ET} = 1460 - 627.87 = \underline{\underline{832.13\ mm/yr}}$$

$$\%\ err = \left(\frac{0.15 \times 1460 + 0.05 \times 627.87}{832.13}\right) \cdot 100 = 30.09\%$$

ii a) Continent

μ_{ET} : 502 mm/yr : $\underline{\underline{50.2 \text{ cm/yr}}}$ Vs 40 ⇒ diff : +25%

b) Yukon

μ_{ET} 397.51 mm/yr : $\underline{\underline{39.751 \text{ cm/y}}}$ Vs 40 ⇒ diff : +0.625%

c) Euphrates

μ_{ET} : 189.97 mm/yr : $\underline{\underline{18.9 \text{ cm/y}}}$ Vs 20 ⇒ diff : -5.5%

d) Mekong

μ_{ET} 832 mm/yr : $\underline{\underline{83.2 \text{ cm/yr}}}$ Vs 80 ⇒ diff : 4%

∴ They compare reasonably well

iii 95% abs & relative uncertainties in ET

a) Continent

$$S_P = \frac{0.1 \times 1100}{2} = 55 \text{ mm yr}^{-1}$$

$$S_Q = \frac{0.05 \times 597.59}{2} = 14.94 \text{ mm y}^{-1}$$

$$S_{ET} = \sqrt{(55)^2 + (14.94)^2} = 56.99 \text{ mm yr}^{-1}$$

$$M_{ET} = \frac{2 \times 56.99}{502.41} = 0.23$$

$$\therefore P_r\{502.41 - 0.23(502.41)\} \le \mu_{ET} \le h(515 + 0.23 \times 502.41)\}$$

$$= P_r\{\underline{\underline{386.86 \text{ mm y}^{-1}\} \le \mu_{ET} \le 630.55}}\} = 0.95$$

(7)

b) Tigris

$S_p = \frac{0.2 \times 570}{2} = 57 \ mm/yr^{-1}$

$S_b = \frac{0.1 \times 172.49}{2} = 8.62 \ mm/yr^{-1}$

$S_{ET} = \sqrt{(57)^2 + (8.62)^2} = 57.65 \ mmyr^{-1}$

$\mu_{ET} = \frac{57.65 \times 2}{397.51} = 0.29$

$Pr\{282.23 \ mmyr^{-1} \le \mu_{ET} \le 512.79 \ mmyr^{-1}\} = 0.95$

c) Euphrates

$S_p = \frac{0.1 \times 300}{2} = 15$

$S_R = \frac{0.1 \times 110.03}{2} = 5.50$

$S_{ET} = \sqrt{(15)^2 + (5.50)^2} = 15.98 \ mmyr^{-1}$

$\mu_{ET} = \frac{2 \times 15.98}{189.97} = 0.17$

$Pr\{157.68 \ mmyr^{-1} \le \mu_{ET} \le 222.26 \ mmyr^{-1}\} = 0.95$

d) <u>Mekong</u>

$$S_P = \frac{0.15 \times 1460}{2} = 109.5 \text{ mm/yr}^{-1}$$

$$S_Q = \frac{0.05 \times 627.87}{2} = 15.7 \text{ mm/yr}$$

$$S_{ET} = \sqrt{(109.5)^2 + (15.7)^2} = 110.62 \text{ mmyr}^{-1}$$

$$M_{ET} = \frac{2 \times 110.62}{832.13} = 0.27$$

$$P_R\{607.95 \text{ mmyr}^{-1} \leq M_{ET} \leq 1056.81 \text{ mmyr}^{-1}\} = 0.95$$

4. USGS StreamStats for a region around Cherry Creek, Denver, CO

StreamStats Report

Region ID:

CO

Workspace ID:

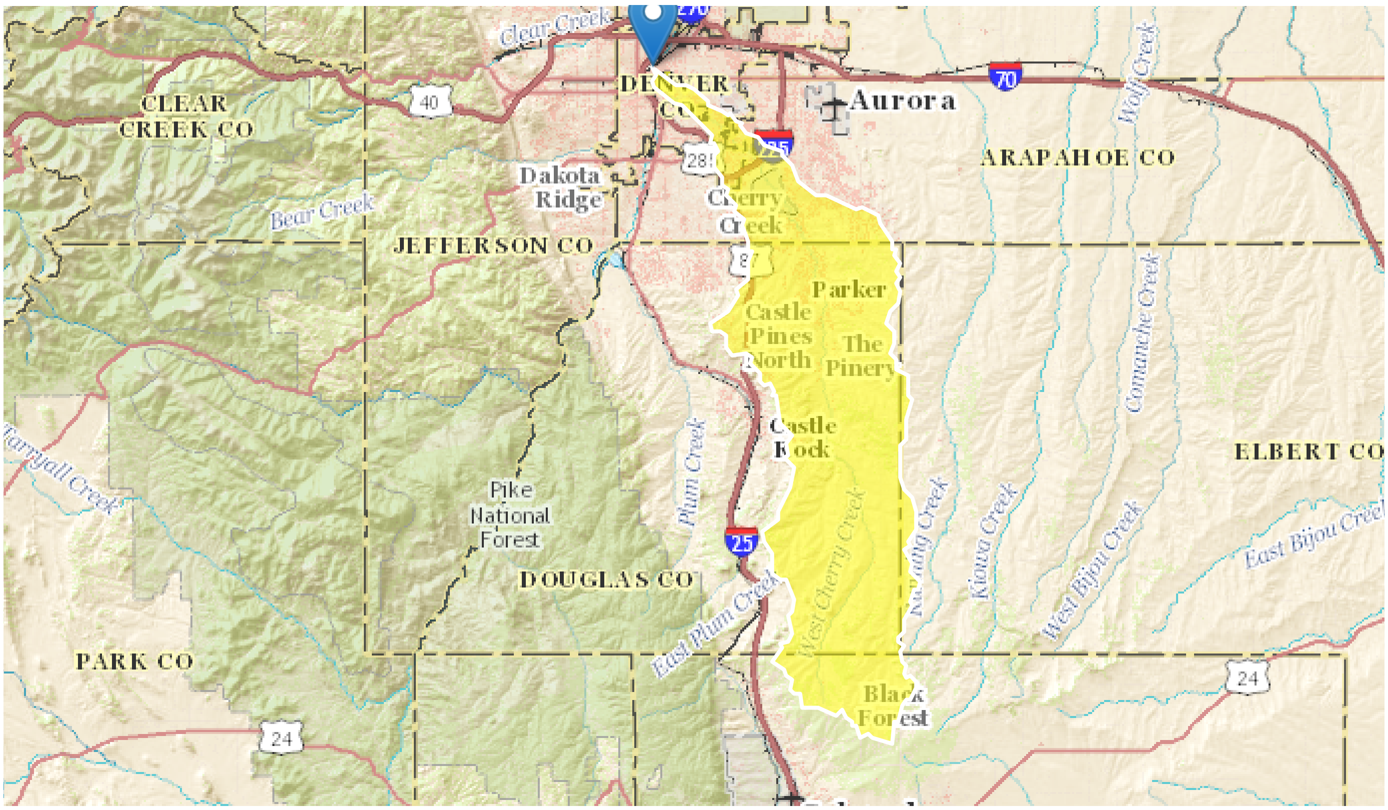
CO20160907112021238000

Clicked Point (Latitude, Longitude):

39.75123,-105.00492

Time:

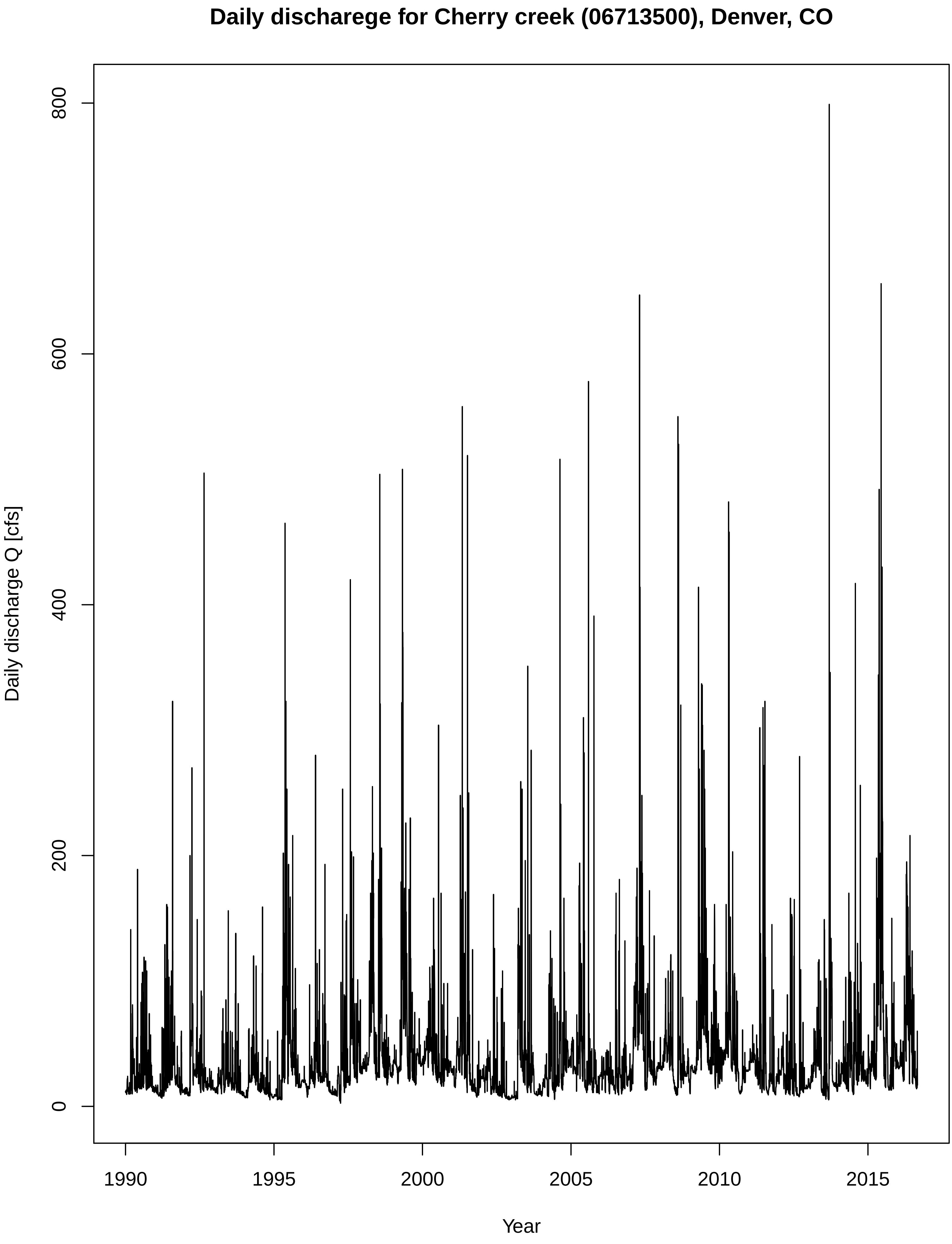
2016-09-07 11:24:17 -0600



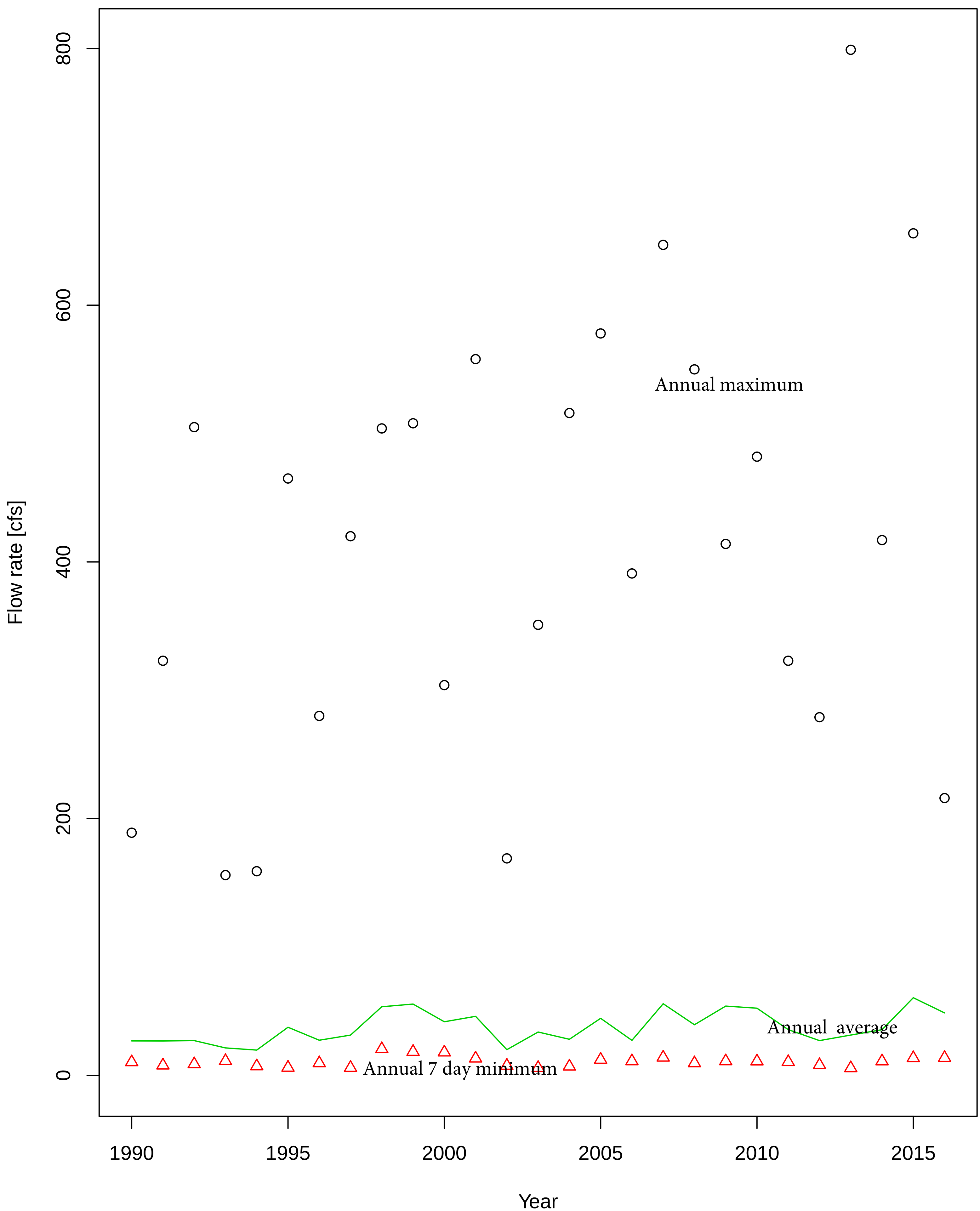
Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	410	square miles
PRECIP	Mean Annual Precipitation	19.66	inches
I6H100Y	6-hour precipitation that is expected to occur on average once in 100 years	3.46	inches
ELEV	Mean Basin Elevation	6510	feet
BSLDEM10M	Mean basin slope computed from 10 m DEM	7.42	percent
EL7500	Percent of area above 7500 ft	3.36	percent
OUTLETELEV	Elevation of the stream outlet in feet above NAVD88.	5193	feet
STATSCLAY	Percentage of clay soils from STATSGO	18.42	percent

5. Daily discharge of a USGS station for the past 20 years

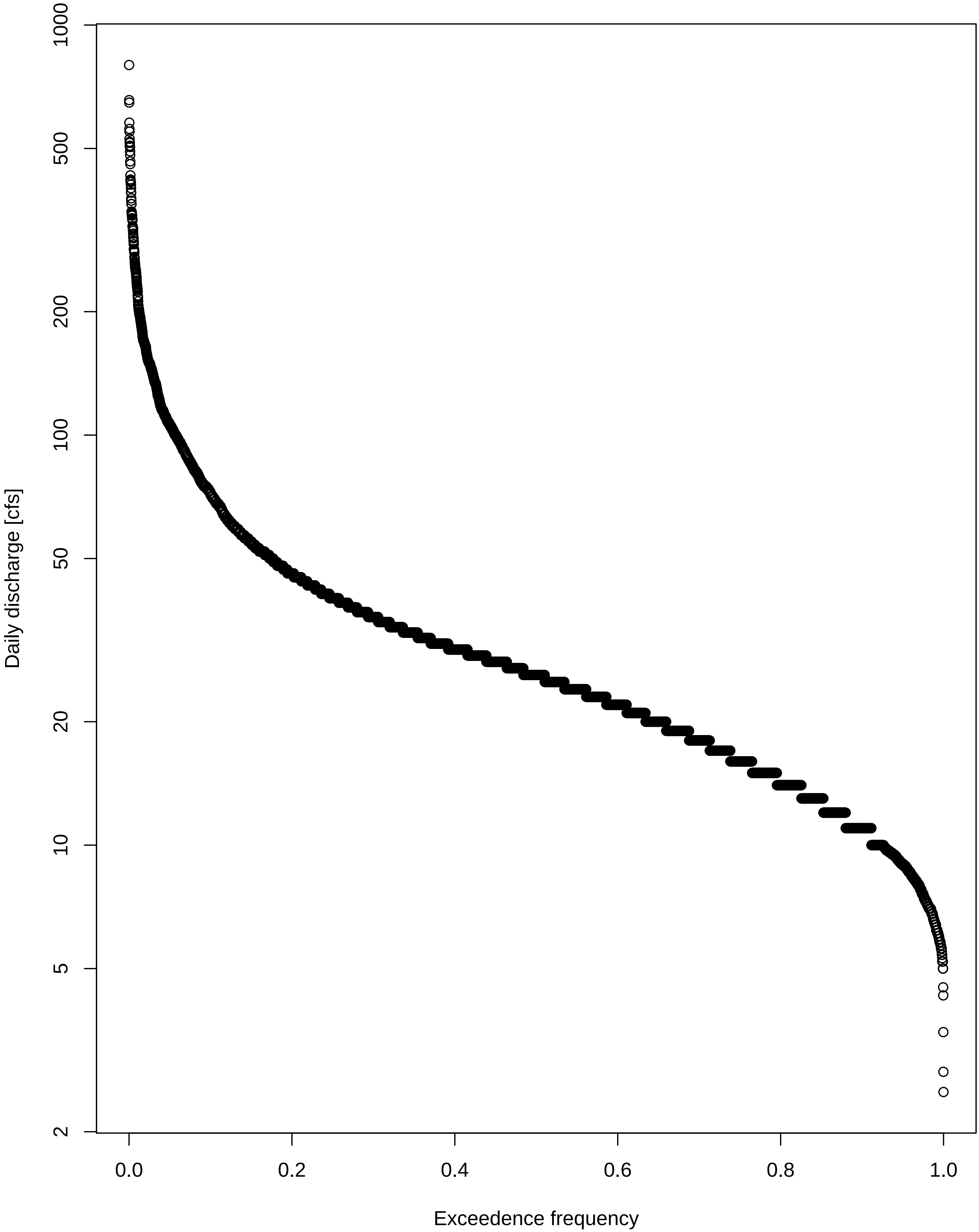


6. Annual maximum, average, 7 day minimum

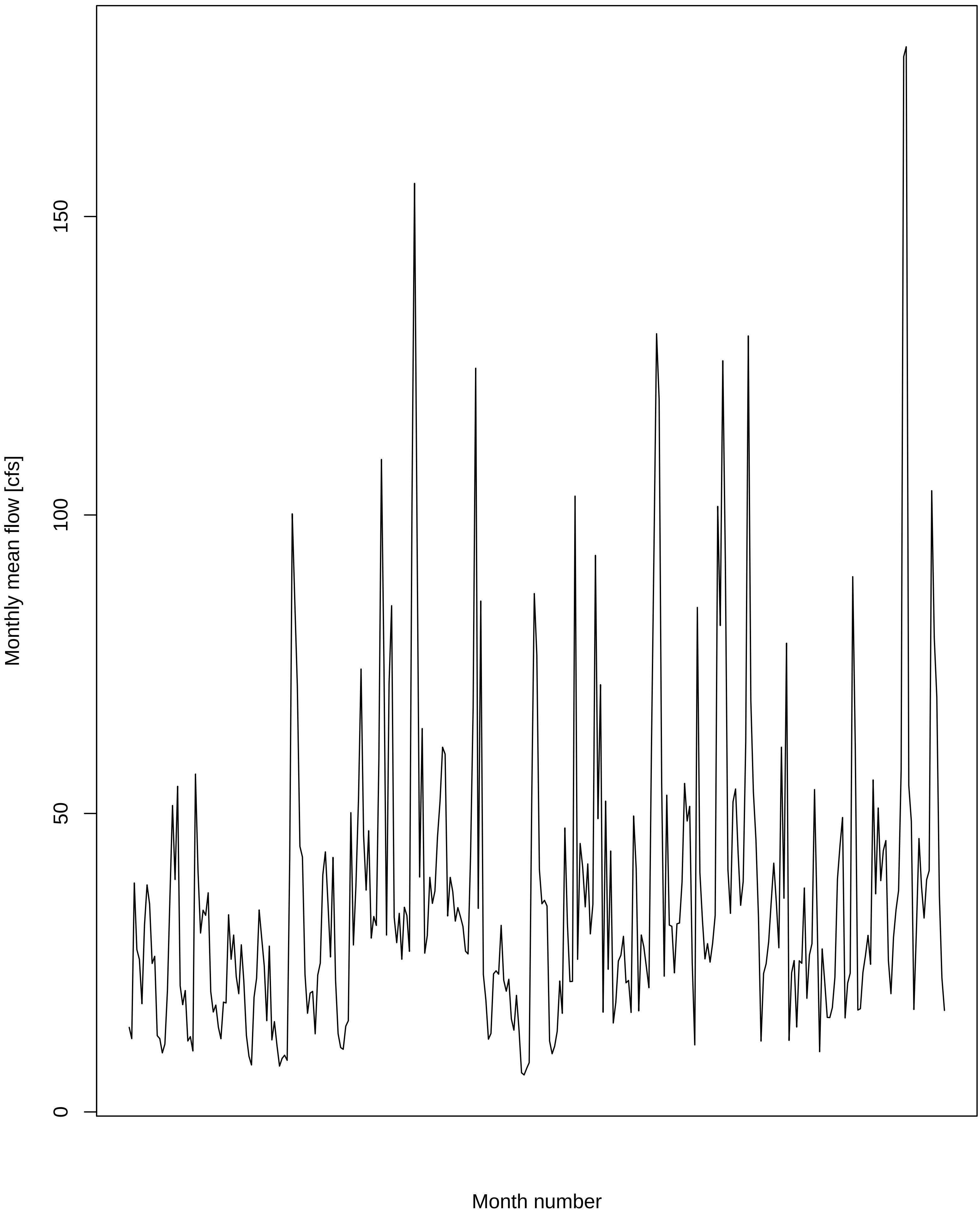


7. Flow duration curve

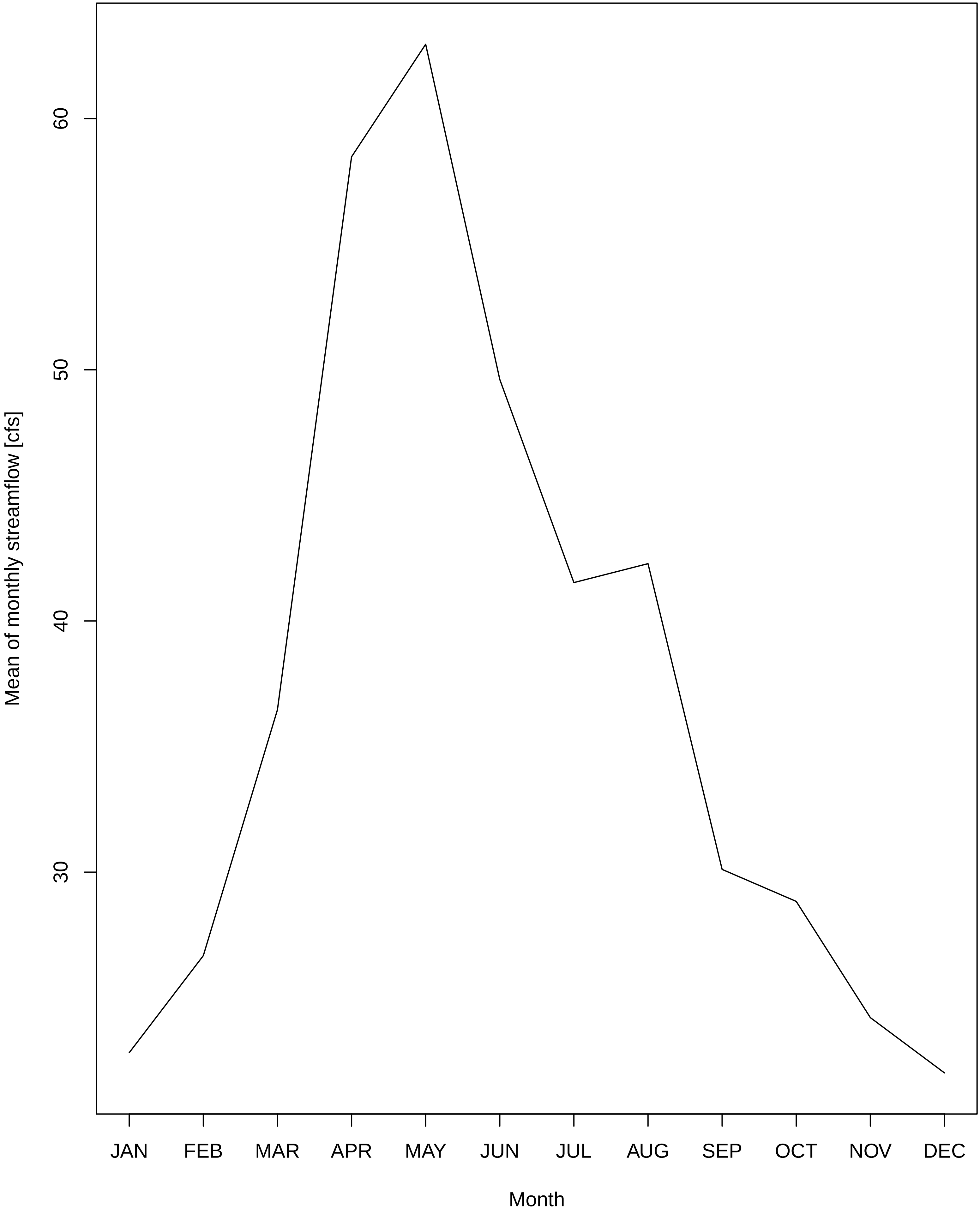
Daily flow that has a probability of exceeding 90% is ~ 11cfs



8. a) Monthly mean streamflow



8. b) Mean monthly streamflow



```
##Importing dataretrieval, ggplot tools
library(dataRetrieval)
library(ggplot2)

##Retrieve daily discharge for last 20 years
siteNo <- "06713500"
pCode <- "00060"
start.date <- "1990-01-01"
end.date <- "2016-09-01"
cherry_creek = readNWISdv(siteNo,"00060",start.date,end.date)


##Problem 5: Time series of daily discharge
Q=cherry_creek$X_00060_00003
dt=cherry_creek$Date
plot(dt,Q,type="l", xlab="Year", ylab="Daily discharge Q [cfs]")
title(main="Daily discharege for Cherry creek (06713500), Denver, CO")


##Problem 6: Average annual flow, peak flow, annual 7 day minimum flow
yy=as.numeric(format.Date(dt,"%Y")) #year
mo=as.numeric(format.Date(dt,"%m")) #month
wy=ifelse(mo>=10,yy+1,yy)
yrseq=unique(wy) #unique years
Qmean=rep(NA,length(yrseq)) #Annual Flow
Q7=rep(NA,length(yrseq)) #Annual 7 day min
Qmax=rep(NA,length(yrseq)) # Annual peak flow
#n=7 moving average function
ma7 <- function(x,n=7){filter(x,rep(1/n,n), sides=2)}
for(i in 1:length(yrseq)){
  yr=yrseq[i]
  #Average annual flow
  Qmean[i]=mean(Q[wy==yr])
  #Annual Peak flow
  Qmax[i]=max(Q[wy==yr])
  #Average 7 day minimum, which is the lowest of the flow rate sequence of 7 day
moving average daily discharge values
  Q7temp = Q[wy==yr]
  Q7[i] = min(ma7(Q7temp),na.rm=TRUE)
}
plot(yrseq,Qmax,ylim=c(0,max(Qmax)), ylab="Flow rate [cfs]", xlab = "Year")
lines(yrseq,Qmean, col = 3)
points(yrseq,Q7,pch=2,col=2)


##Problem 7: Flow duration curve
x=sort(Qmean)
n=length(Qmean)
nmid=n/2+0.5
x[nmid]
median(Qmean)
p=(1:n-0.4)/(n+0.2)
approx(p,x,0.25)
approx(p,x,0.75)
```

```
quantile(Qmean,probs=c(0.25,0.5,0.75))
quantile(Q7,probs=c(0.25,0.5,0.75))
mean(Qmean)
sd(Qmean)
sd(Qmean)/mean(Qmean)
Qs=sort(Q)
n=length(Qs)
p=((1:n)-0.4)/(n+0.2)
plot(1-p,Qs,log="y",xlab="Exceedence frequency",ylab="Daily discharge [cfs]")
#To find daily flow that has a exceedance greater than 0.90
exceed = round(1-p,3)
q90 = mean(Qs[which(exceed == 0.900)])
print(q90)


##Problem 8: Monthly mean streamflow
# Monthly mean streamflow
yrmo=yy*100+mo
yrmoseq=unique(yrmo)
Qmonth=rep(NA,length(yrmoseq))
for(i in 1:length(yrmoseq)){
  ii=yrmoseq[i]
  Qmonth[i]=mean(Q[yrmo==ii])
}
plot(1:length(yrmoseq),Qmonth,type="l", xlab ="Month number", ylab = "Monthly
mean flow [cfs]", xaxt ='n')

#Mean of monthly streamflows
year=trunc(yrmoseq/100)
month=yrmoseq-year*100
Qmm=rep(NA,12)
for(mm in 1:12){
  Qmm[mm]=mean(Qmonth[month==mm])
}
plot(1:12,Qmm,type="l", xlab = "Month", ylab = "Mean of monthly streamflow
[cfs]", xaxt = 'n')
axis(side = 1, c(1:12), labels = c("JAN", "FEB", "MAR", "APR", "MAY", "JUN",
"JUL", "AUG", "SEP", "OCT", "NOV", "DEC"))
```