RWater Module 5

How does Urbanization effects Streamflow over Time

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Learning Goals

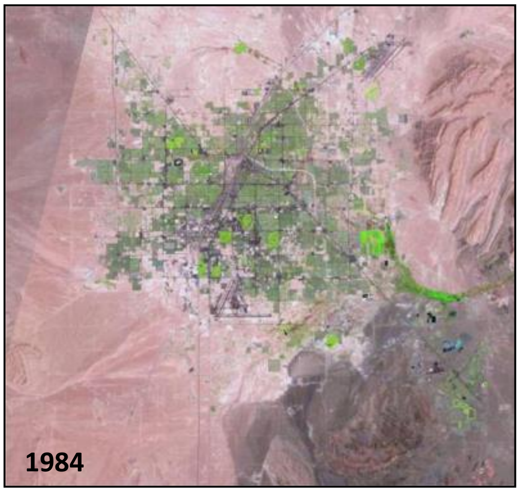
Urbanization refers to the concentration of human population into discrete areas, leading to transformation of land for residential, commercial and transportation purposes. Such changes in landuse result into unprecedented changes in ecosystems and environmental processes. From the previous modules, we have come to know that flow pattern in a stream can be affected by any of the three major factors: climatic, geographic as well as human induced changes. Urbanization falls into the 'human factor' category. After completing this module, students will be able to:

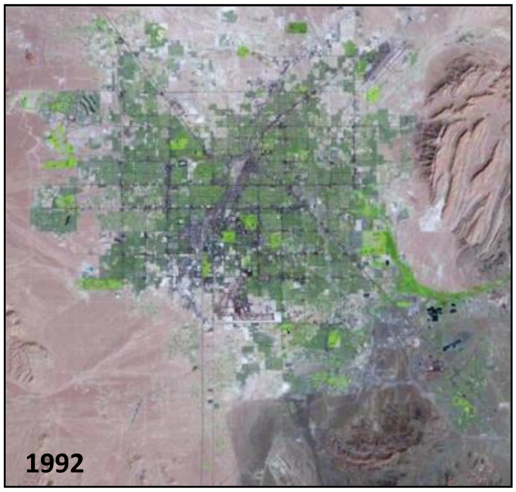
i. see the trend of landuse change in Las Vegas, Nevada, the fastest growing city in the United States over the past two decades
ii. visualize the possible changes in streamflow for a small watershed in the same area, being caused by this ongoing process of urbanization

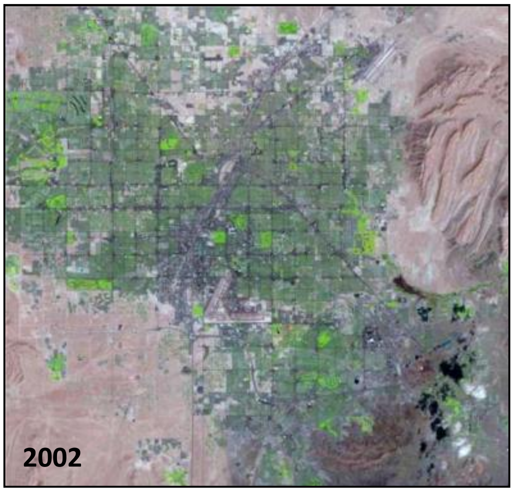
Visualizing Urbanization Trend in an Area: Example of Las Vegas

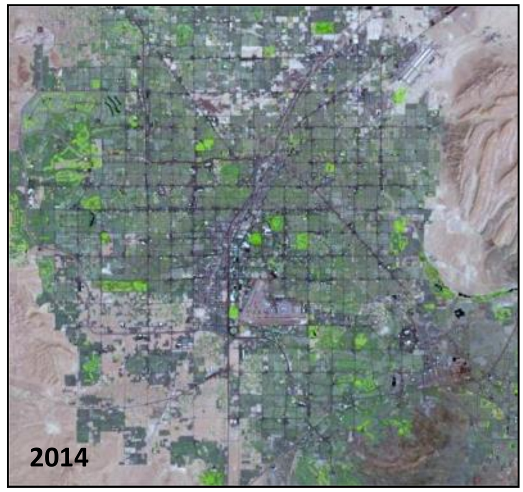
The Landsat program is a NASA enterprise for acquisition of satellite imagery of the Earth surface. Following are the true-color Landsat satellite images for Las Vegas, being obtained from http://landsatlook.usgs.gov/, over a period from 1984 to 2014. As these images suggest, Las Vegas has been experiencing rapid urbanization since 1984. In these images, buildings and paved areas appear in gray shades, the clearest example are the sites adjacent to the famous 'Vegas Strip' along the center diagonal and McCarran International Airport near the bottom center of each image. Grass-covered land, such as parks and golf courses, appears in green.

A video clip showing these ongoing changes can be played from the Google Earth Engine by clicking in the following link: https://earthengine.google.org/#intro/LasVegas. Run in slow motion for best visualization.









Changes in Streamflow with Urbanization

In areas of little development such as agricultural or forests, a hydrograph will rise slowly during the rainfall and gradually decrease as well. This is due to the higher amount of infiltration of the rain water into the soil, less runoff, and increased interception by vegetation. In urban areas, impervious surfaces (highways, streets, parking lots, sidewalks, and buildings) now cover large areas of the ground that was "used to" absorb rain water. These covered surfaces no more allow rain water to infiltrate into the ground, rather majority portion of the rain quickly routes to the nearby stream in the form of surface runoff (see Figure 1 below). As a result, peak discharge goes high, meaning more water in the stream. Also, time between the peak rainfall and peak discharge (called lag time) decreases drastically, that is, a hydrograph tends to peak quickly and drop quickly as well which we generally call “Flash Flooding”. This phenomenon has also been discussed in Module 4 using a hypothetical example of surface imperviousness.

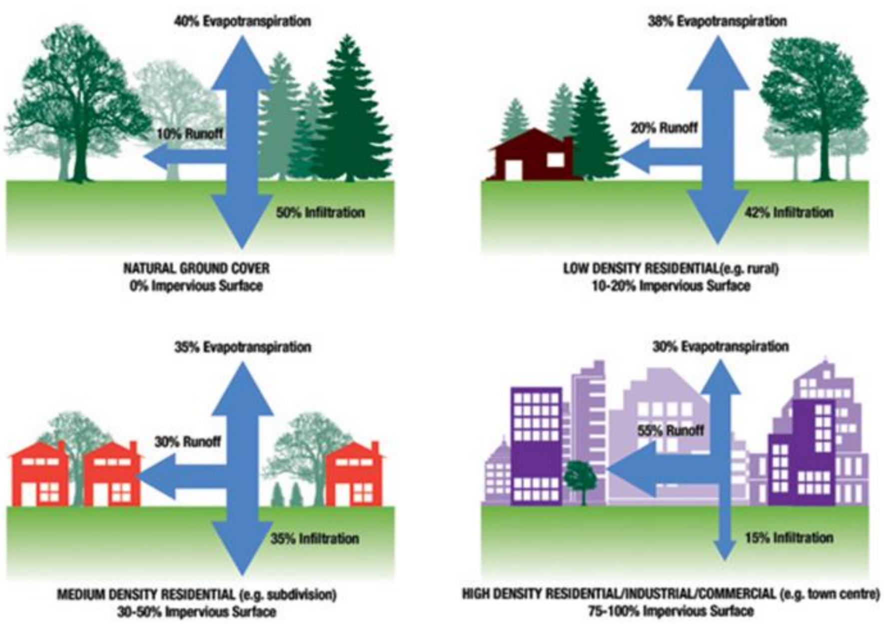


Figure 1. Source: Arnold and Gibbons (1996), APA Journal

Now, in order to understand the urbanization effect from a real-time situation we are going to download the streamflow data at a particular USGS gage station in the Las Vegas city area and compare between a past and a more recent time frame (1971-1980 and 2001-2010, respectively). The station we will be taking here as an example is the USGS 09419700, which is the outlet for the watershed called Las Vegas Wash near Pabco Road.

Streamflow data can be downloaded directly by following the script. In addition, two pre-processed rainfall datasets for both the time frames are required for this module. Each step of the RWater script given below is associated with relevant explanations (lines followed by # sign).

```
### STEP 1
### Removing previously used scripts from RWater
cat("\014")
### Removing all previously generated datasets and plots
rm(list = ls())
dev.off()

### STEP 2
### Loading a specific library called 'waterData' into RWater
library(waterData)

### STEP 3
### Get some information about the USGS site having ID no. 09419700
    ### We are storing the information under the name 'vegasinfo'
site<-c("09419700")
vegasinfo<-siteInfo(site)
    ### Click on 'vegasinfo' in the workspace (upper right)
    ### You can now see the name, latitude and longitude of the station

### STEP 4
### Downloading streamflow data directly from USGS
    # importDVs is the function that calls the data from USGS website
    # "00060" and "00003" indicates 'Streamflow' and 'Mean Daily Data' respectively
    # Here, we will download mean daily streamflow data for two different periods
    # Provide a range of date within sdate and edate in YYYY-MM-DD format
    # Save the downloaded data with a name 'vegasflow71.80' and 'vegasflow01.10'
vegasflow71.80<-importDVs("09419700", code="00060", stat="00003",
                     sdate="1971-01-01", edate="1980-12-31")
vegasflow01.10<-importDVs("09419700", code="00060", stat="00003",
                          sdate="2001-01-01", edate="2010-12-31")

### STEP 5
### Load given rainfall datasets from your working directory
    # The rainfall data that we will be using is from McCarran International Airport, Nevada
    # Two rainfall datasets for the two distinct period (1971-1980 and 2001-2010)
    # File names are 'vegasrain71.80' and 'vegasrain01.10' respectively
    # Suppose, these files are stored in the working directory called 'RWater Workshop 2014'
    # We have to locate these files by writing the following lines. Place your login ID accordingly
vegasrain71.80=read.csv("/home/drinet/yourloginID/RWater Workshop 2014/vegasrain71.80.csv",
                    header = TRUE, stringsAsFactors = FALSE)
vegasrain01.10=read.csv("/home/drinet/yourloginID/RWater Workshop 2014/vegasrain01.10.csv",
                         header = TRUE, stringsAsFactors = FALSE)

### STEP 6
### Plotting the Rainfall Hyetograh and Streamflow Hydrograph
    # We will plot rainfall hyetograph in a reverse Y axis
    # We can modify the maximum limit of the X and Y axes, line color as well as the title of the graph etc.

# First plot is for the period 1971-1980
par(mfrow=c(2,1))
par(mar=c(5, 4, 4, 8) + 0.1)
barplot(vegasrain71.80$Rainfall.mm.,vegasrain71.80$Date,space = c(0,1),width = 0.5,ylim=rev(c(0,120)),
        xlab="Days in year 1971-1980", ylab="Rainfall(mm)",
        main="Las Vegas Wash at Pabco Rd, NV (1971-1980)", axes=TRUE,las=1,
        xaxt="n",col="blue", border="blue")
par(new=T)
plot(vegasflow71.80$val,type="l",pch=21, col="red", lty=12,lwd=1.5,yaxt="n", ylim=c(0,3000),
     xlab="",ylab="",axes=T)
axis(side=4)
mtext("Streamflow(cfs)",side=4, cex.lab=1,las=3,line=3, col="black")
legend(2000,3500,"Streamflow", col = "red", lwd=1.5, lty=12, bty="n")
legend(2000,3000,"Rainfall", col = "blue", lwd=7, lty=1, bty="n")
border=c("black")
```

```
# Second plot is for the period 2001-2010
barplot(vegasrain01.10$Rainfall.mm.,vegasrain01.10$Date,space = c(0,1),width = 0.5,ylim=rev(c(0,120)),
        xlab="Days in year 2001-2010", ylab="Rainfall(mm)",
        main="Las Vegas Wash at Pabco Rd, NV (2001-2010)", axes=TRUE,las=1,xaxt="n",
        col="blue", border="blue")
par(new=T)
plot(vegasflow01.10$val,type="l",pch=21, col="red", lty=12,lwd=1.5,yaxt="n", ylim=c(0,3000),
     xlab="",ylab="",axes=T)
axis(side=4)
mtext("Streamflow(cfs)",side=4, cex.lab=1,las=3,line=3, col="black")
legend(2000,3500,"Streamflow", col = "red", lwd=1.5, lty=12, bty="n")
legend(2000,3000,"Rainfall", col = "blue", lwd=7, lty=1, bty="n")
border=c("black")
```

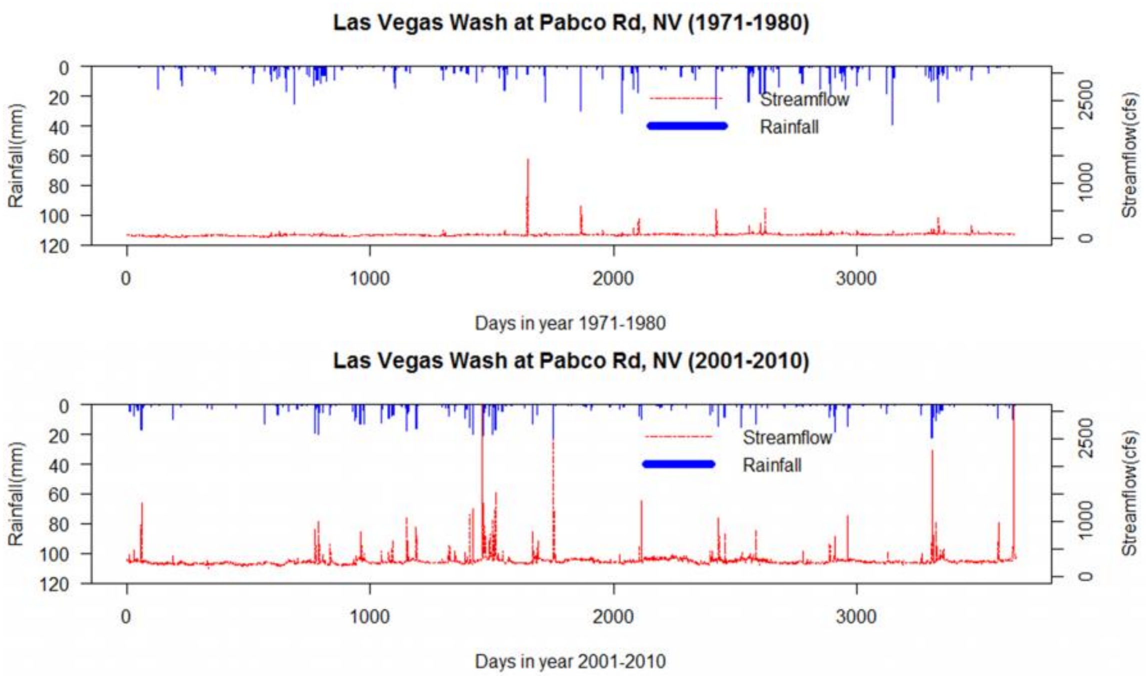


Figure 2

Let us now compare the two graphs which we have just created. Read the graphs carefully and comment on the following statements by stating TRUE or FALSE:

(i) No drastic changes in the streamflow between the two periods. **TRUE/ FALSE**

(ii) Extreme flows have become more frequent in the recent time period (2001-2010), even under the same rainfall condition. That means, for the same rainfall magnitude or intensity, this particular stream is exhibiting hike in the streamflow values compared to what it showed in the past. **TRUE/ FALSE**

These findings can be clarified if we split the whole time frame and re-do the plotting for a very short period of time. In this case, we will compare the streamflow values of February, 1980 and January, 2010.

```
### STEP 8
### subsetting a date range directly from the downloaded streamflow data
    # We need another R library called 'xts' for subsetting
    # We will subset both the streamflow and rainfall datasets
    # Data only for February,1980 and January,2010 is extracted
    # The new subset datasets are given appropriate names
library(xts)
vegasflowFEB1980<-subset(vegasflow71.80,dates>="1980-02-01"&dates<"1980-03-01")
vegasrainFEB1980<-subset(vegasrain71.80,Date>="1980-02-01"&Date<"1980-03-01")
vegasflowJAN2010<-subset(vegasflow01.10,dates>="2010-01-01"&dates<="2010-01-31")
vegasrainJAN2010<-subset(vegasrain01.10,Date>="2010-01-01"&Date<="2010-01-31")
```

```
### STEP 9
### Plotting a segment of the whole downloaded time series

# First plot is for February,1980

par(mar=c(5, 4, 4, 8) + 0.1)
barplot(vegasrainFEB1980$Rainfall.mm.,vegasrainFEB1980$Date,space = c(0,1),width = 0.5,ylim=rev(c(0,100)),
        xlab="Days (Feb, 1980)", ylab="Rainfall(mm)",
        main="Las Vegas Wash at Pabco Rd, NV (February 1980)", axes=TRUE,las=1,xaxt="n",
        col="blue", border="blue")
par(new=T)
plot(vegasflowFEB1980$val,type="l",pch=21, col="red", lty=1,lwd=1.5,yaxt="n", ylim=c(0,1000),
     xlab="",ylab="",axes=T)
axis(side=4)
mtext("Streamflow(cfs)",side=4, cex.lab=1,las=3,line=3, col="black")
legend(5,1000,"Streamflow", col = "red", lwd=1.5, lty=1, bty="n")
legend(5,800,"Rainfall", col = "blue", lwd=7, lty=1, bty="n")
border=c("black")

# Second plot is for January,2010
barplot(vegasrainJAN2010$Rainfall.mm.,vegasrainJAN2010$Date,space = c(0,1),width = 0.5,ylim=rev(c(0,100)),
        xlab="Days (Jan, 2010)", ylab="Rainfall(mm)",
        main="Las Vegas Wash at Pabco Rd, NV (January 2010)", axes=TRUE,las=1,xaxt="n",
        col="blue", border="blue")
par(new=T)
plot(vegasflowJAN2010$val,type="l",pch=21, col="red", lty=1,lwd=1.5,yaxt="n", ylim=c(0,3000),
     xlab="",ylab="",axes=T)
axis(side=4)
mtext("Streamflow(cfs)",side=4, cex.lab=1,las=3,line=3, col="black")
legend(5,3000,"Streamflow", col = "red", lwd=1.5, lty=1, bty="n")
legend(5,2500,"Rainfall", col = "blue", lwd=7, lty=1, bty="n")
border=c("black")
```

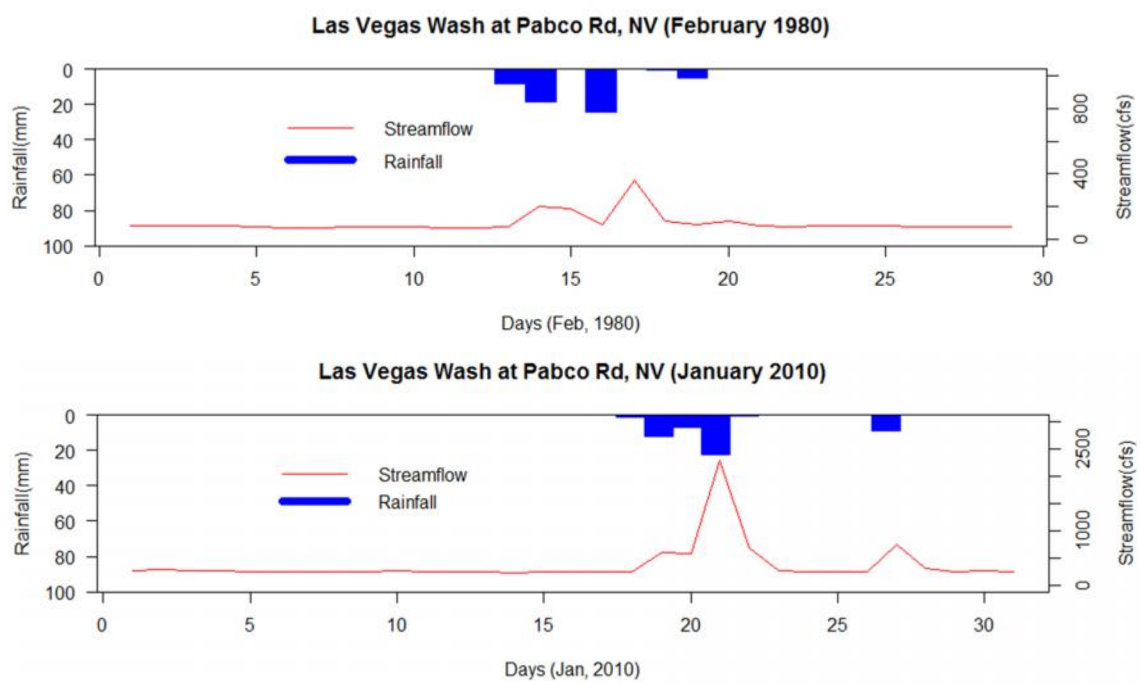


Figure 3

The two plots which you have just created show the streamflow hydrograph of the Las Vegas Wash river in a pre-development and post-development event. Note that, the rainfall pattern in these two separate events is nearly the same. However, what differences can you see in the respective streamflow response?