Section 6-1

Determination of Elevation Zones

Introduction

Elevation zones are used in mountainous areas primarily to model differences in the amount of s now that occurs and the timing of the resulting snowmelt. A watershed could be divided into el evation zones solely based on variations in the amount of rainfall and resulting runoff, but this se ldom is the reason for using elevation zones in the United States. As far as what each elevation zone represents and methods for selecting the separating elevations, the United States can be divi ded into 2 general regions for discussion purposes. First is the intermountain west, i.e. the area east of the Pacific crest over to the plains, in other words, the Rocky Mountains and the east side of the Sierra Nevada and Cascade ranges. Basins in this region are typically dominated by sno wmelt runoff and elevation zones are primarily used to separate the portion of the watershed that contributes significant runoff every year from those that normally don't produce much runoff exc ept during an exceptionally large snow year. Second are mountainous regions where runoff is t ypically generated at all elevation zones and rainfall is a significant factor in runoff production. This includes a few areas in the eastern U.S., primarily in the northeast, the Pacific coastal drain ages, and much of Alaska.

Intermountain West

In much of this region the annual hydrograph, at least from those watersheds that produce enoug h runoff to generate satisfactory or at least marginal results with a lumped, conceptual model, ge nerally shows a large rise beginning in the spring that is the result of snowmelt and only a few re sponses at other times of the year caused by rainfall. Most basins in this region produce signifi cant amounts of baseflow, thus there is typically a long recession following the snowmelt period. Rainfall in this region infrequently produces significant amounts of runoff over large areas (as opposed to small scale thunderstorms). Such events occur primarily in the northern part of the r egion due to moisture coming over the mountains from the Pacific northwest and in the southern part of the region due to moisture moving up from the south into Arizona, New Mexico, and sout hwestern Colorado. The primary reason for using elevation zones in this region is to separate t he portion of each watershed that produces significant runoff every year from the part that gener ates runoff only during years with large snow accumulations. Throughout this region two eleva tion zones should be sufficient.

A method for selecting the elevation at which to divide the watersheds in this region is based on areal snow cover information and hydrograph response. The following data are needed:

1. Areal snow cover images at various dates just prior to and throughout the snowmelt period . These images are produced by the NOHRSC from analysis of satellite data. The images should be from a number of years with varying amounts of snow cover, though years with be low normal snow amounts are of most value.

2. Mean daily flow hydrographs for the watershed for the same years as the areal snow cover data.

The steps to follow are:

1. For each date with an areal snow cover image, determine the average snowline elevation over the watershed. Typically this elevation is similar for all watersheds within the river basin, but differences can occur due to factors that affect the accumulation and melt processes, such as slope, aspect, vegetative cover, and prevailing storm direction. The CAP should contain a method to access these images and determine the snowline elevation.

2. Tabulate the snowline elevations on the hydrograph plots for the watershed for each date. The snowline will typically be lowest prior to the onset of melt, but will also move down the mountains after periods of snowfall during the melt season

3. By examining all the years, select the elevation above which snow exists just prior to the beginning of significant runoff during almost all years. This is the elevation to use to separate the zones for modeling. During years with considerable snow and above normal runoff, the snowline at the onset of significant runoff will be lower than that during below normal runoff years. What one is looking for is the highest snowline elevation just prior to the beginning of significant runoff during all the years or, in other words, the elevation above which snow melt always produces a rise in the hydrograph. This elevation is usually determined by looking at some of the below normal runoff years and possibly averaging the snowline elevations prior to significant runoff for these years. If there is a very low snow year, i.e. runoff far below normal, it is probably best to ignore that year. When later modeling such a low snow year hopefully the snowmelt runoff volume will be reasonable, though the timing of melt will be too early since the snow during that year is really only in the upper part of the upper zone.

Figure 6-1-1 shows an example of a below normal runoff year for the Animas River above Durango, Colorado which could be used to determine the elevation separating the upper and lower zones. In this case, the snowline was at about 10,000 feet just prior to the onset of significant runoff. The use of this zonal split elevation resulted in good simulation results. Figure 6-1-2 shows the snowline elevations for an above average snow year for the same basin. It can be seen that significant runoff was generated due to snowmelt at elevations below 10,000 feet. By splitting the watershed at 10,000 enabled the models to properly simulate both of these years. In water year 1981 very little runoff was generated from snowmelt in the lower zone while in 1985 this zone produced significant runoff. The upper zone produced runoff during both years. Figure 6-1-3 shows simulation results for the lowest snow year on record, 1977. The snowline elevation prior to melt during this year was over 11,000 feet and was significantly higher than for other low snow years and thus not used when deciding where to

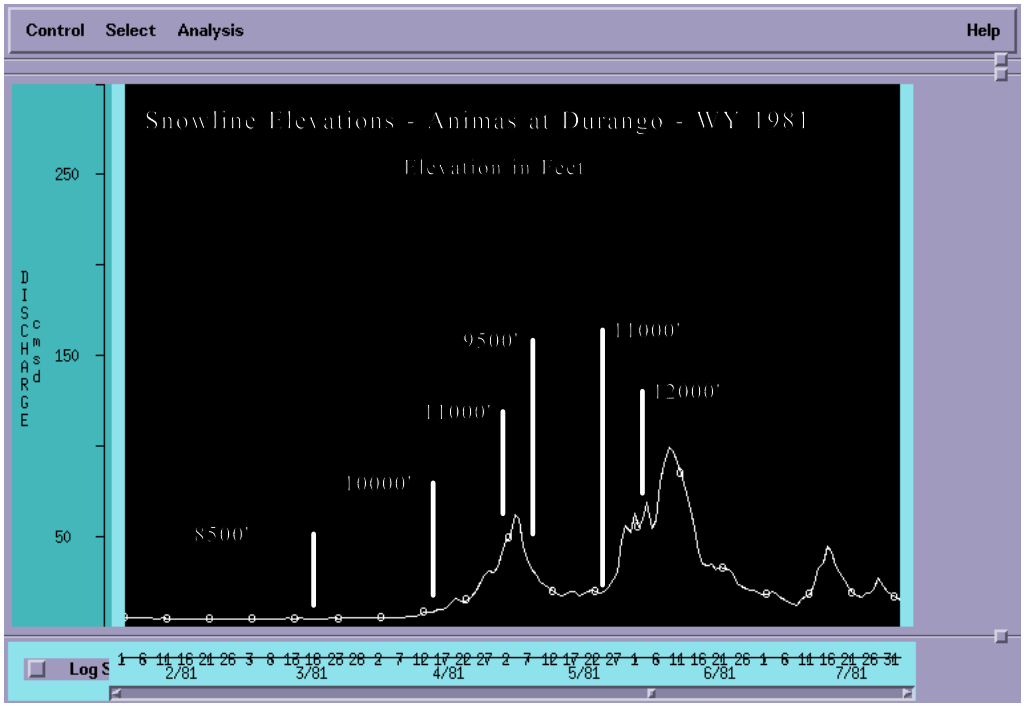
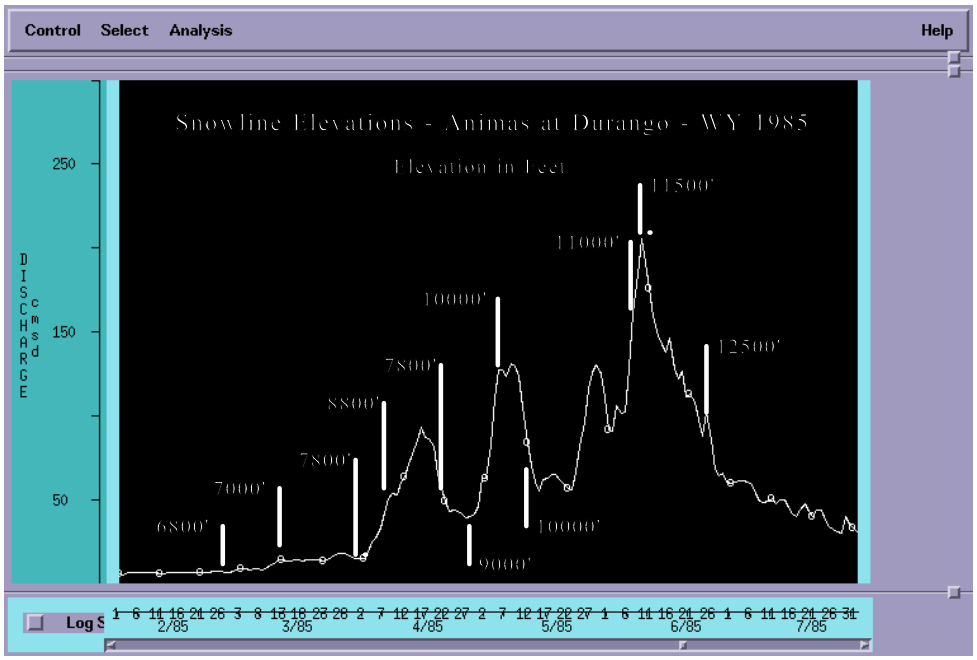


Figure 6-1-1. Snowline elevations during a below normal runoff year.

Figure 6-1-2. Snowline elevations during an above normal runoff year.



divide the two zones. The snowmelt runoff volume for this year was simulated quite reasonabl y, but as expected the timing of the melt is early. Three elevation zones could be used to better simulate such a small year, but generally the added benefits don't justify the added work of oper ationally maintaining the state variables for an extra zone.

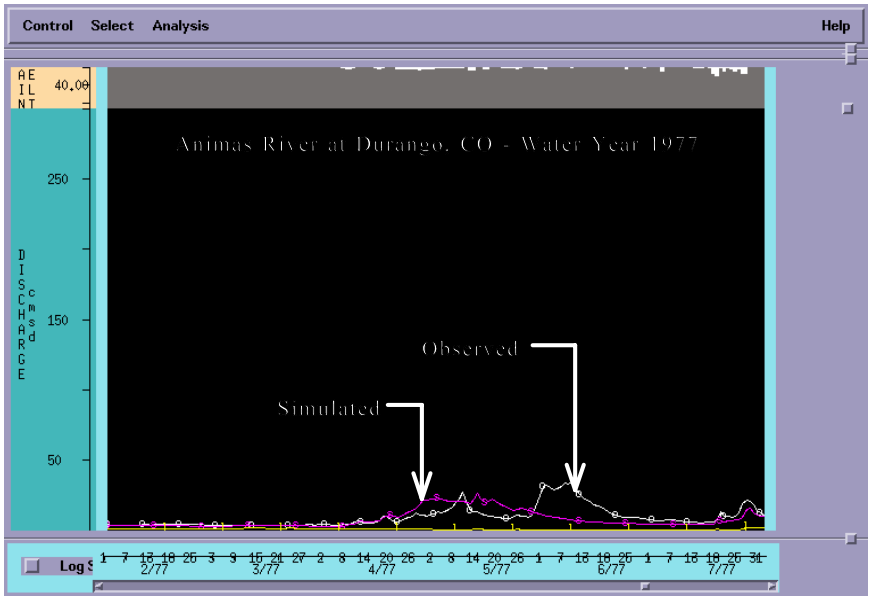


Figure 6-1-3. Typical response during the simulation of a very low snow year.

In addition to areal snow cover data and the response of the hydrograph, vegetation information can be very helpful in selecting the elevation separating the 2 elevation zones in the intermountai n west. The type of vegetation that grows at a particular location is highly dependent on the pre vailing moisture supply. Thus, in many cases there will be a transition from one type of vegetat ion to another at the elevation separating where runoff occurs almost every year and where it onl y occurs during very wet years. In much of the intermountain west this is the elevation where t he transition from pines to a predominately fir-spruce forest occurs. In the southern part of the region, e.g. the Mogollon Rim area of Arizona, there is only a small portion of the area that prod

uces significant snow runoff every year and has predominately fir-spruce forests, thus it may be better to split the watersheds at a slightly lower elevation where the transition from pinon pine-juniper to ponderosa pine forests occur. CAP should contain information on the types of forest cover and the distribution of vegetative types with elevation.

Northeast, Pacific Coast, and Alaska

In the northeastern part of the United States, the Pacific Coast drainages which primarily involve the west side of the Sierra Nevada and Cascade ranges, and Alaska, significant runoff is generated at all elevations, but the amount and timing of snowmelt runoff varies considerably with elevation. During most storm events precipitation occurs at all elevations, but in many cases there is a transition from rain at the lower elevations to snow at the higher locations. Thus, in these regions elevation zones are needed to properly model the accumulation and ablation of the snow cover throughout the watersheds. The general breakdown in zones that you are trying to achieve in these regions are:

- zone where there is a significant snow cover during all years,
- zone where a significant snow cover exists only during substantial parts of some years,
- zone where snow seldom occurs and any snow cover exists for only short periods,
- zone that is permanently covered by snow and ice, i.e. glaciated areas which occur in some Pacific northwest basins and frequently in Alaska.

In the northeastern United States there are only a few areas with a significant range in elevation to justify using multiple zones. This primarily occurs in the White Mountain region of New Hampshire and possibly in a few watersheds in Maine, the Andirondack region in New York, and the Allegany highlands of West Virginia. In the southern Appalachian Mountains there are significant elevation differences, but snow is typically hydrologically unimportant. In the northeast 2 zones are sufficient when they are needed at all. Along the Pacific Coast and over portions of Alaska only 2 of these elevation zones comprise the vast majority of the drainage area and thus are sufficient for modeling. In glaciated basins in Alaska and fairly frequently in other parts of these regions, however, 3 or even all 4 zones exist and need to be included. In some of the watersheds a snow cover exists over the entire drainage every winter, but there is still a significant difference in the amount and timing of snowmelt with elevation. This is especially true in Alaska. In these cases, 2 elevation zones are still needed to model the seasonal snow cover and its contribution to runoff. If glaciers are present in these watersheds, then a third zone would be required.

The elevations used to separate the elevation zones in this region are primarily determined by examining areal snow cover information from NOHRSC and snow depth and water equivalent data at various locations. These data can be examined for a number of years and a subjective determination made as to what elevations to use to separate the zones. The elevations selected shoul

d be able to be used over a fairly wide area. Along the Pacific Coast the elevations separating t he zones should likely decrease as one goes further north as average temperatures generally decr ease and thus snow is more likely to accumulate at lower elevations. In Alaskan basins where t here is substantial snow cover over the entire drainage every year, the tree line elevation may be a reasonable place to separate the zones.