IV.2.3-SNOW-17 INFLUENCE OF HYDRO-17 SNOW MODEL PARAMETER VALUES ON MODEL RESPONSE

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Introduction

This Section discusses the influence that the SNOW-17 snow model parameter values have on model response with special emphasis on the effect of the parameters on model response as depicted by the daily flow hydrograph.

The discussion focuses on the characteristics of model response that help distinguish the effects of one parameter from those of the other parameters. The discussion also emphasizes those parameters that have the most significant influence on model response. These are the main parameters that the user should be adjusting during the calibration process.

The remainder of this Section is divided into three parts. The first part discusses the influence of the major snow parameters on model response. The other parts describe the effects of the minor snow parameters and other parameters that are related to the snow model. Soil moisture accounting and channel parameters also influence model response during the snow season. However in this Section only the effects of the snow model parameters are discussed. It is assumed that all soil moisture accounting and channel parameters are held constant.

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Major Parameters

The major parameters of the snow model are those that generally have the greatest influence on model response. Most of the effort while calibrating the snow model should be devoted to finding proper values for these parameters. The major snow model parameters are described in Chapter II.2-SNOW-17 [Hyperlink].

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1. **SCF** - The snow correction factor, SCF, is the main snow model parameter affecting the volume of snowmelt runoff. The melt factors and the other timing parameters also have a small effect on volume since the rate of melt and the date that snow cover outflow occurs have some effect on how much of the meltwater runs off immediately and how much enters soil moisture storage and eventually is lost by evapotranspiration. The daily ground melt parameter, DAYGM, also affects snowmelt runoff volume in the sense that it determines how much of the snow cover is lost during accumulation periods at a slow continuous rate and how much remains to become snowmelt runoff during periods of surface melt.

   The effect of SCF begins to show up when bare ground first appears which normally is near the end of the melt season. When there is 100 percent snow cover it is immaterial as to how much snow there is. Thus SCF has no effect on model response when there is complete cover. Since the areal extent of the snow cover is related to the amount of snow changing SCF will change the date when bare ground first occurs. The areal depletion curve also influences model response only after bare ground begins to appear. The difference between the effect of SCF and the effect of the areal depletion curve is that SCF affects the volume of snowmelt runoff while the depletion the depletion curve primarily affects the timing. The effect of SCF on streamflow during a melt season is illustrated in Figure 1 [Bookmark].

   In watersheds with shallow or intermittent snow cover the variability in the snow correction factor is usually greater than in areas that typically have a deep snow cover. This is because a deep snow cover is the result of many snowfall events whereas a shallow snow cover is normally the product of only a few or in some cases only one storm. The more snowfall events that go into producing snow cover the more likely that the average snow correction factor for that accumulation period is close to the long-term average which is the parameter SCF. In an area with an intermittent snow cover SCF can affect model response several times during a single snow season rather than just at the end of the melt season as in an area with distinct accumulation and melt seasons. This situation is illustrated in Figure 2 [Bookmark].

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2. **MFMAX and MFMIN** - The parameters MFMAX and MFMIN determine the current melt factor which in turn controls the rate of snowmelt during non-rain periods. This melt rate is generally the single most important factor affecting the timing of snowmelt runoff. The effect of the melt factor can be best isolated during the period after melt is well underway and before a significant amount of bare ground appears. During the ripening period the heat deficit and the liquid water content as well as the melt rate influence model response. The areal depletion curve has a significant effect on timing once the areal extent of the snow cover drops below 100 percent. Thus the interval from the time when the snow cover is ripe up to the time when bare ground appears is the period to examine when evaluating the melt factor. The parameter MFMAX has a greater effect on the melt factor after March 21 whereas MFMIN has a greater effect prior to that date. Thus melt rates at various times of the year should be checked before adjusting MFMAX or MFMIN. Figure 3 [Bookmark] and Figure 4 [Bookmark] illustrate the effect of the parameters MFMAX and MFMIN on a watershed where melt typically occurs in the spring and on a watershed where there are intermittent melt periods throughout the winter and early spring.

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3. **UADJ** - The parameter UADJ which is the average wind function during rain-on-snow events is obviously used to compute melt during rain-on-snow periods. The amount of rain is not important in terms of the effect of UADJ on model response as long as it is above the threshold of 2.5 MM in 6 hours. The air temperature during the period is important. This is because the computed melt is primarily a function of the air temperature (see Equation 16 in Chapter II.2-SNOW-17 [Hyperlink]). Thus UADJ can have a significant effect on model response during rain-on-snow periods only when the air temperature is well above zero DEGC. It should also be noted that the parameter UADJ affects only a portion of the melt during rain-on-snow periods (see Equation 16 in Chapter II.2-SNOW-17 [Hyperlink]). The radiation and rain melt terms are dependent on only the air temperature. UADJ appears only in the turbulent transfer terms. Thus for example if UADJ is reduced by 50 percent the reduction in melt will be less than 50 percent. Figure 5 [Bookmark] illustrates the effect of UADJ on streamflow. Figure 5 includes rain-on-snow events with temperatures just barely above zero DEGC and with temperatures well above zero DEGC.

   In some areas significant rain-on-snow is a relatively rare phenomenon. In such areas UADJ becomes a minor parameter of the snow model and should be treated as such and the initial estimate of UADJ should be preserved unless there is very clear evidence that it should be changed. If UADJ is adjusted in such areas the number of adjustments should be kept to a minimum.

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4. **SI and the areal depletion curve** - The parameter SI and the snow cover areal depletion curve affect model response whenever there is

less than 100 percent of the area covered by snow. SI and the areal depletion curve are important when a sizable portion (more than about 20 to 20 percent bare ground) of the area is bare of snow. Thus in general SI and the areal depletion curve affect the timing of snowmelt runoff during the later portion of the melt season. The parameter SI determines when bare ground begins to appear and therefore when the areal depletion curve is used. If SI is greater than the maximum water-equivalent that occurs during a given year then for that year the areal depletion curve will be used as soon as the snow cover begins to ablate. If SI is greater than the maximum water-equivalent that occurs during the entire period of record then the areal depletion curve is used as soon as ablation begins every year. In this case further increases in SI will have not effect whatsoever on model response. Thus when SI is greater than the maximum water-equivalent during the period of record the actual value of SI is unimportant while the shape of the areal depletion curve is very important. At the other extreme if SI is very small relative to the typical maximum water-equivalent of the snow cover the shape of the areal depletion cure becomes unimportant. However in most cases the value of SI and the shape of the areal depletion curve are both important. Figure 6 [Bookmark] illustrates the effect of SI and the areal depletion curve on the computed daily flow hydrograph.

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It should be noted that the same case is used in Figure 1, Figure 3 and Figure 6 to illustrate the effect of the snow correction factor the melt factors and the areal depletion curve respectively on streamflow for an area with distinct accumulation and melt seasons. This allows the user to easily compare the effects of these parameters on streamflow. In all three figures the solid line is the same. It is clear from these figures that of these critical snow model parameters only the melt factors MFMAX and MFMIN affect runoff when there is complete snow cover. The snow correction factor SCF as well as SI and the depletion curve affect runoff only after bare ground appears the difference being that SCF affects volume while SI and the depletion curve primarily affect the timing of the runoff.

The effects of SI and the areal depletion curve and the effects of the parameters which control snowmelt when there is complete areal snow cover (primarily MFMAX and MFMIN) are sometimes difficult to separate in an area where during most years bare ground appears soon after ablation begins. This is because there is not prolonged period of complete cover that can be used to determine the proper values for the melt factors. Instead the timing of snowmelt runoff during most of each melt season is controlled by both the 100 percent cover melt rate and the areal extent of the snow cover. Figure 7 [Bookmark] illustrates such a case by showing similar simulations produced by using different combinations of MFMAX and the shape of the areal depletion curve. The examples shown in Figure 7 came from the calibration of the Eagle River below Gypsum, Colorado. In the early stages of the calibration the initial values of the melt factors as determined by applying the snow model to snow course data were preserved as much as possible while the shape of the areal depletion curve was altered. This resulted in parameter set A. Later because the shape of the areal depletion curve seemed somewhat physically inconsistent the melt factors and the depletion curve were changed to the values listed as parameter set B. However even with these changes the overall simulation results were very similar. Based on 20 years of data the RMS to mean flow ratio and the correlation for both parameter sets were about 0.45 and 0.95 respectively. This problem can be partially overcome by selecting subareas which remain at 100 percent snow cover for a significant part of the melt season during most years. However when sizable amounts of bare ground almost always appear somewhere in the watershed soon after ablation begins then the problem of separating the effects of the melt factors from the effects of the areal depletion curve will still exist in at least one subarea.

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Minor Parameters

The minor parameters of the snow model are those which have the least influence on model response. Adequate estimates of these parameters can normally be obtained from a knowledge of the climatic and physiographic characteristics of the area. The number of adjustments to these parameters during the calibration process should be kept to a minimum. Adjustments should be made only when there is very clear evidence that a change is needed. Because these parameters have less effect on model response than the major snow model parameters a detailed discussion of the effect of each parameter is unnecessary. Only those which undergo minor adjustments rather frequently are discussed in detail.

The parameter TIPM is seldom altered during calibration. As discussed in Chapter IV.2.2-SNOW-17 [Hyperlink] TIPM is usually fixed and any adjustment to the rate of energy exchange during non-melt periods is made by changing the maximum negative melt factor NMF. The non-rain melt base temperature MBASE is almost always fixed at the beginning and not altered during calibration. The effect on model response of changes in MBASE is similar to the effect of changing the elevation of the MAT time series TAELEV. The user would usually adjust TAELEV since this is normally the more likely of the two values to be in error especially in mountainous areas. The effect of TAELEV on model response is discussed in the last part of this section. The effect of PXTEMP (the temperature used to delineate rain from snow) on model response depends on the number of periods during which the form of precipitation is changed and on the amount of precipitation during each period. There is no predictable response except that increasing PXTEMP will cause more precipitation to be classified as snow and decreasing PXTEMP will result in more rain. The value of PXTEMP should be changed only when many more events are mis-classified as rain than as snow or vice versa. Once the number of mis-classifications of rain and snow are reasonably equal further corrections of the form of precipitation require changing the appropriate MAT values.

The minor snow model parameters which need to be discussed in more detail are NMF, PLWHC and DAYGM.

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1. **NMF and PLWHC** - The maximum negative melt factor NMF and the

percent liquid-water-holding-capacity PLWHC can affect model response in a similar manner. Both parameters are associated with the ripening process. Thus they both affect model response whenever surface melt or rain occurs and the snow cover is not yet ripe such as at the beginning of the melt season or during a rain on fresh snow event or a mid-winter thaw. The existence of a heat deficit or the liquid water capacity not being satisfied will cause some or all of the meltwater or rain to be retained in the snow cover rather than becoming snow cover outflow. The parameter NMF is important in determining the magnitude of the heat deficit though a portion of the heat deficit is the result of the heat content of snowfall. Thus even if NMF is set to zero a heat deficit will still occur during the snow season. The parameter PLWHC controls how much liquid water the snow cover can hold before outflow occurs. Meltwater or rain must first reduce the heat deficit to zero and then satisfy the liquid-water-holding-capacity before snow cover outflow occurs and runoff can be generated.

Both parameters have a significant effect on model response only when conditions are just right. The negative melt factor has the greatest effect when the transition from very cold weather to a snowmelt period or a rain-on-snow event is rather sudden. When there is a gradual transition the magnitude of the heat deficit prior to the onset of the warming trend is unimportant in regard to model response. The liquid-water-holding-capacity has the most impact on model response when the snow is dry (i.e. no liquid water in the snow) just prior to a significant period of snowmelt or a large rain-on-snow event. When there are small additions to liquid water storage due to melt or rain throughout the winter so that the snow is fairly well saturated prior to significant rain or melt then the liquid-water-holding-capacity of the snow has little effect on model response. Thus the determination of whether one or both of these parameters should be adjusted requires a careful examination of the state of the snow cover prior to a significant period of snowmelt or a large rain-on-snow event. When the snow cover is dry and a large heat deficit exists prior to rain or melt NMF and PLWHC are likely to have similar effects on model response. However by examining ripening periods over several years the user can usually determine which of these parameters should be adjusted. When it is clear that either NMF or PLWHC should be adjusted but not clear as to which one should be changed it is probably more logical to adjust NMF in areas with deep snow because slush layers have a small effect on liquid water storage in deep snow and to adjust PLWHC in areas with shallow snow because a shallow snow cover has a limited amount of heat storage capacity. Figure 8 [Bookmark] shows two cases that illustrate the effect of NMF and PLWHC on model response. In one case both parameters have a similar effect while in the other the effect of NMF is more pronounced than the effect of PLWHC.

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2. **DAYGM** - The effect of the amount of daily ground melt varies with soil moisture conditions. If the tension water storages are not full during the winter most of the ground melt will go into slow increasing tension water thus reducing the soil moisture deficit which will affect model response at the beginning of the melt

season. However there are other parameters that have much more influence on model response at the beginning of the melt season because of the manner in which they influence the soil moisture deficit or snow cover outflow. Thus it is difficult to justify changes in DAYGM when soil moisture tension water storages are not full during the accumulation season.

When tension water storages are full during the winter most of the ground melt enters the free water storages and increases runoff primarily baseflow. Thus ground melt will affect the volume of runoff during the winter especially when there are few runoff events. Table 1 [Bookmark] shows the effect of DAYGM on monthly runoff volumes during the winter. The reduction in DAYGM from 0.3 to 0.15 MM per day amounts to about 4.5 MM of melt per month. The snow correction factor SCF was reduced from 1.3 to 1.2 when DAYGM was decreased. The change in SCF is needed because more snow is available to contribute to runoff during the melt season when less snow is lost by ground melt during the winter. Therefore to keep the volume of melt season runoff nearly the same SCF must be reduced.

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Table 1. Effect of parameter DAYGM on monthly runoff volumes during the winter when soil moisture tension water storages are full (values are for a 4 year period)

Average monthly streamflow volume error in MM

Month	DAYGM = 0.3	DAYGM = 0.15
December	4.6	1.8
January	5.3	2.1
February	4.6	0.7

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Other Related Parameters

There are two parameters that are not part of the snow model but are related to the model and are sometimes changed during the calibration process. These parameters are the elevation of the MAT time series, TAELEV and the effective forest cover EFC.

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1. **TAELEV** - During the computation of mean areal temperature in mountainous areas the temperature stations are usually weighted so that the resulting MAT time series supposedly corresponds to some specific elevation usually the mean elevation of the subarea or watershed. However the MAT time series may not correspond to this elevation because of errors arising during the MAT computational process or because of differences in temperature (caused by climatic or physiographic factors) between the area as a whole and the individual temperature stations. Also a different elevation may be more appropriate due to the typical snow cover distribution. In addition in non-mountainous areas the temperatures at the measuring stations may be biased estimates of the mean areal temperature. This is especially likely in a heavily conifer-forested watershed where daytime temperatures are cooler and

nighttime temperatures are warmer under the forest canopy than corresponding temperatures at a more exposed location typical of most measuring sites. In all these cases the temperature time series used by the snow model can be adjusted by altering the elevation of the MAT time series TAELEV in conjunction with appropriate lapse rates. The net effect of changing TAELEV is to increase or decrease the computed melt by a relatively fixed amount and in the process change the date that surface melt begins.

A response that indicates that TAELEV should be changed is when snowmelt is too high early in the melt season and too low later or vice versa. If this response cannot be corrected by changing other snow model parameters such as NMF, PLWHC, MFMAX or MFMIN the both TAELEV and the melt factor must be changed. If TAELEV is decreased the melt factor needs to be increased or vice versa. The adjustment to TAELEV should generally not exceed a couple of hundred meters if the MAT time series was properly computed. Figure 9 [Bookmark] illustrates the effect on model response of changing TAELEV and the melt factor.

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2. **EFC** - The effective forest cover EFC indicates how much of the snow-covered area can lose water by evapotranspiration. Thus the parameter EFC can affect the volume of snowmelt runoff if there is still sufficient snow on the ground when the ET demand becomes significant. Most errors in snowmelt runoff volume can be corrected by changing the snow correction factor SCF. However if the error in snowmelt runoff volume is different during years when the snow cover lasts longer than usual the user should consider changing the value of EFC.

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Summary

The major parameters of the snow model generally have the most effect on model response and thus should usually be the first parameters to be changed during the calibration process. In many cases only the major parameters need to be changed. In some cases adjustments should be made to the minor parameters NMF and PLWHC or the elevation of the MAT time series TAELEV. Changes to the other snow model parameters should be avoided unless there is very clear evidence that an adjustment is needed.

Figure 1. Effect of parameter SCF on streamflow during a melt season

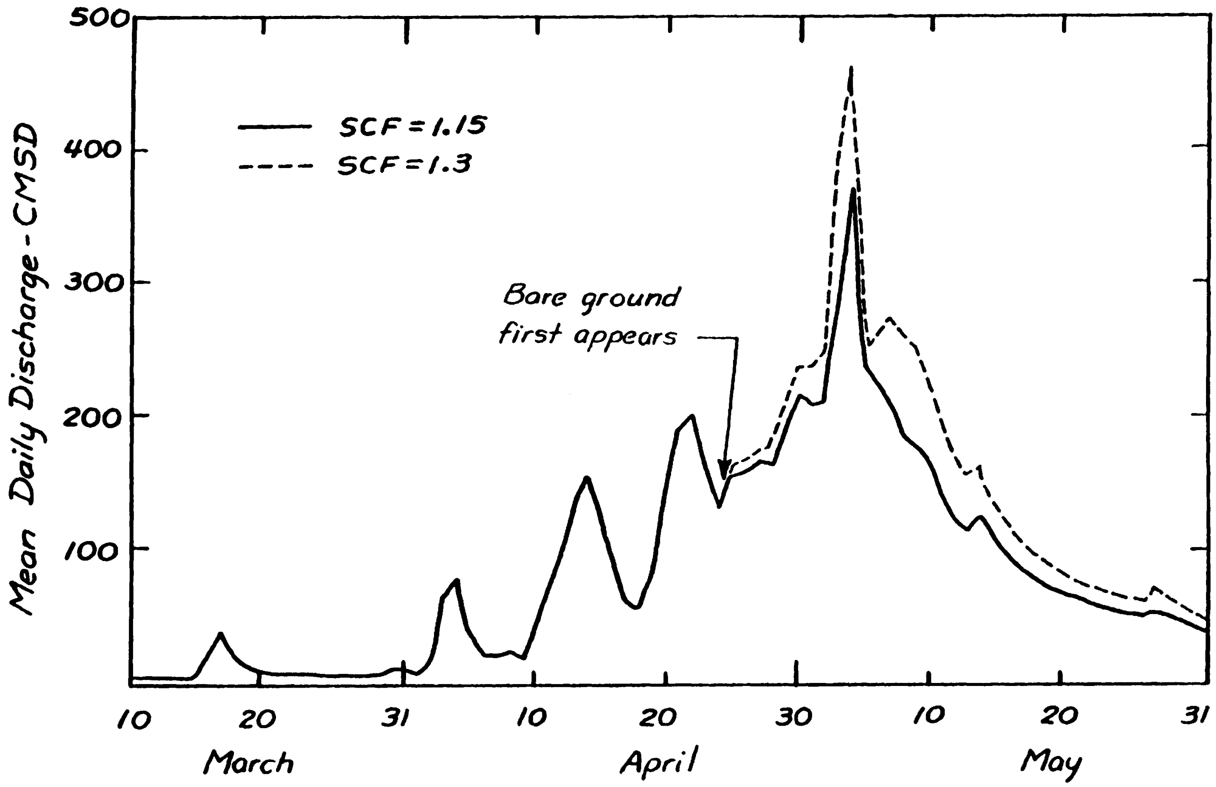

Figure 1. Illustration of the effect of the snow correction factor, SCF, on streamflow during a snowmelt season. Streamflow volume is increased by 55 mm when using SCF = 1.3.

Figure 2. Effect of parameter SCF on streamflow for a basin with intermittent snow cover

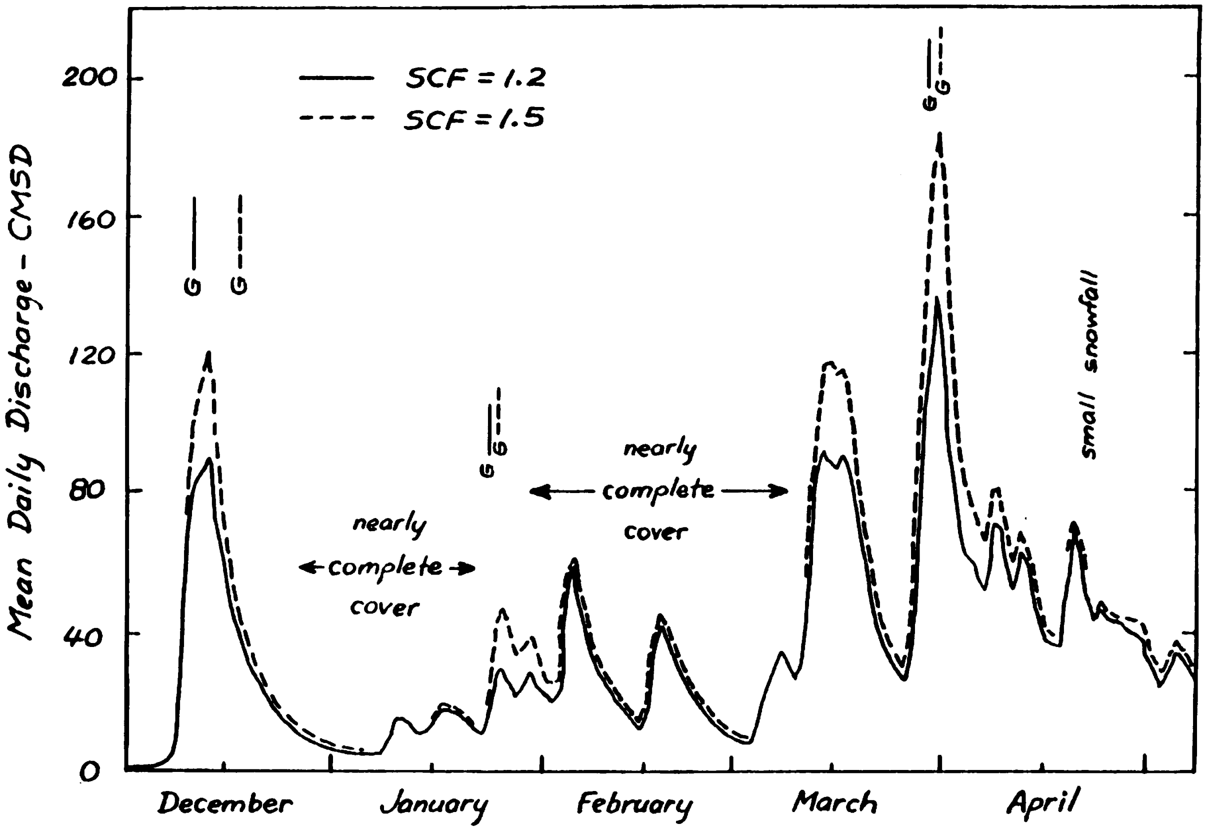

Figure 2. Illustration of the effect of the parameter SCF on streamflow for a basin with intermittent snow cover. Streamflow volume is increased by 61 mm when using SCF = 1.5. The symbol (G) indicates the date that the snow cover is completely gone.

Figure 3. Effect of parameters MFMAX and MFMIN on streamflow for a basin where snowmelt occurs in the spring

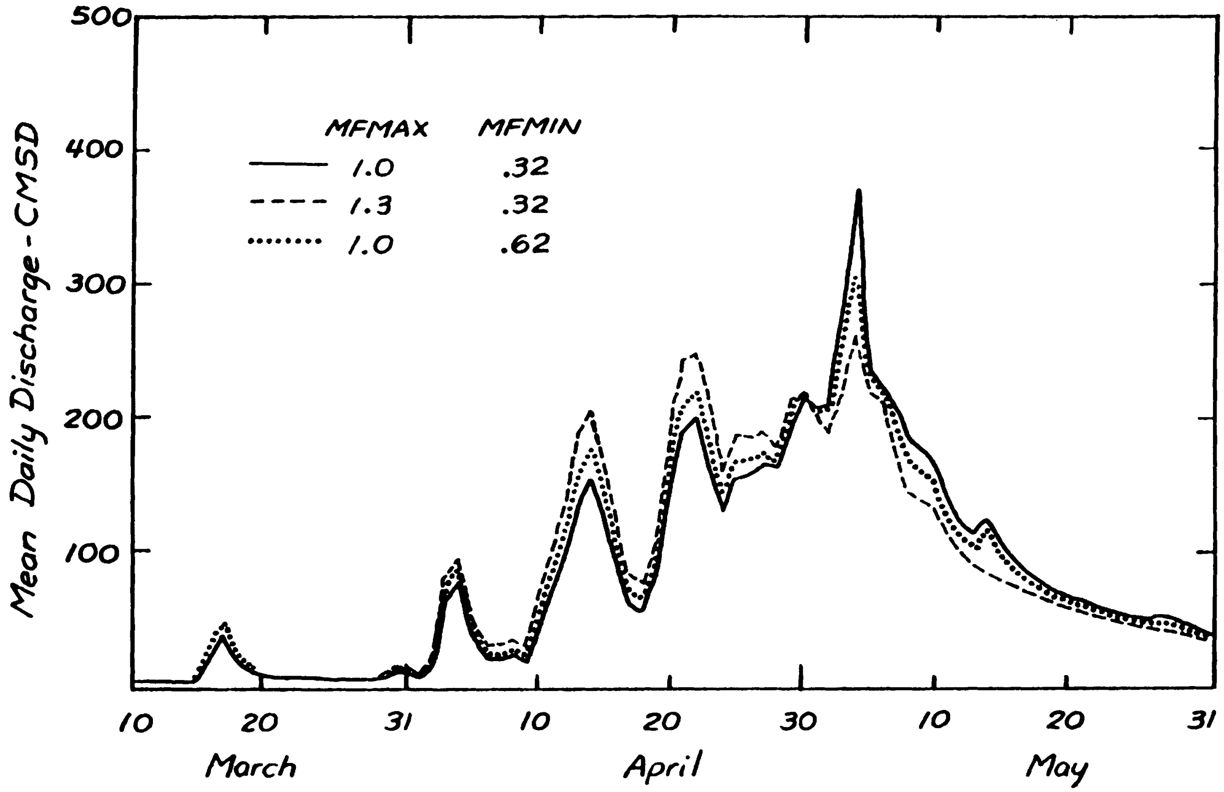

Figure 3. Illustration of the effect of the parameters MFMAX and MFMIN on streamflow for a basin where snowmelt occurs in the spring. Changes in the melt factors did not affect streamflow volume at all.

Figure 4. Effect of parameters MFMAX and MFMIN on streamflow for a basin where intermittent snowmelt occurs in winter and early spring

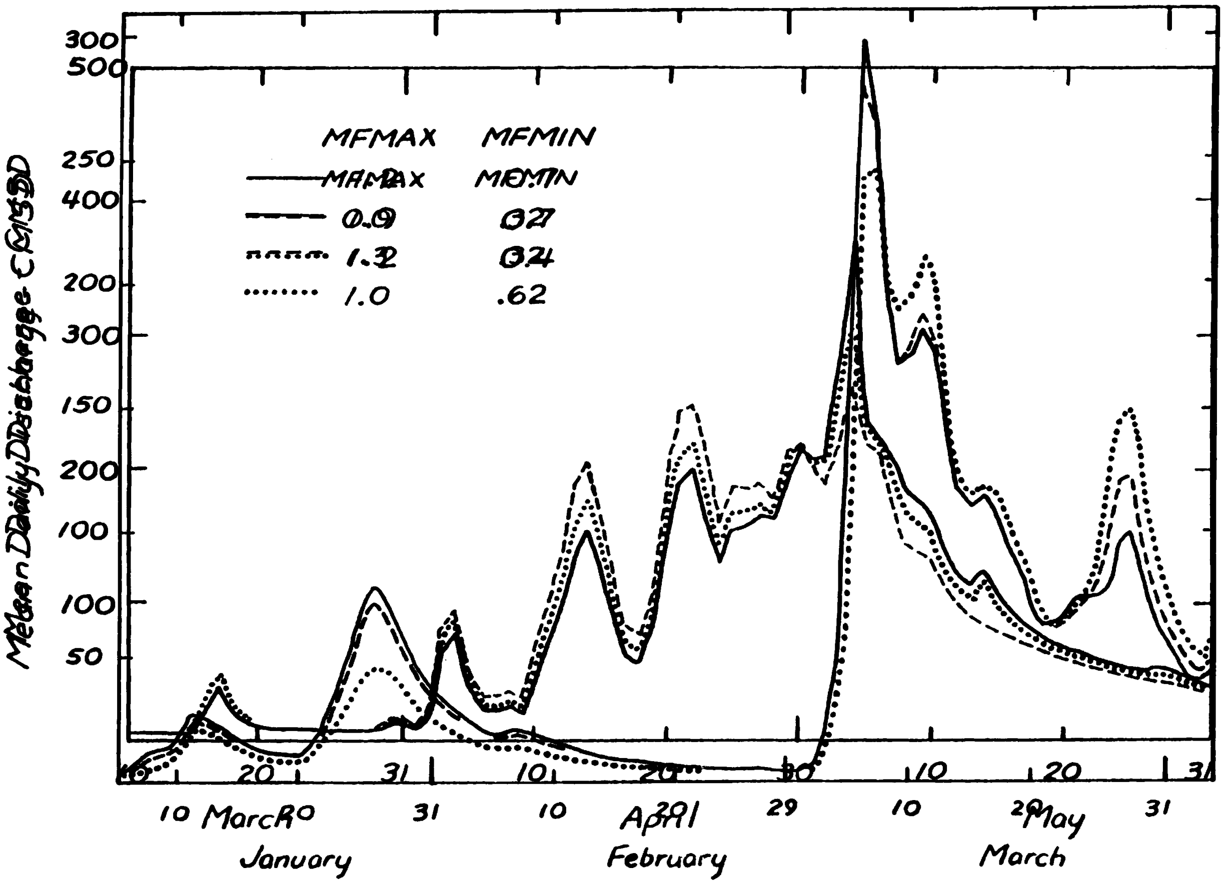

Figure 3. Illustration of the effect of the parameters MFMAX and MFMIN on streamflow for a basin where snowmelt occurs in the spring. Changes in the melt factors did not affect streamflow volume at all.

Figure 4. Illustration of the effect of the parameters MFMAX and MFMIN on streamflow for a basin where intermittent snowmelt occurs during the winter and early spring. Snow cover exists until the end of March. Changes in the melt factors have a negligible effect on streamflow volume.

Figure 5. Effect of parameter UADJ on streamflow

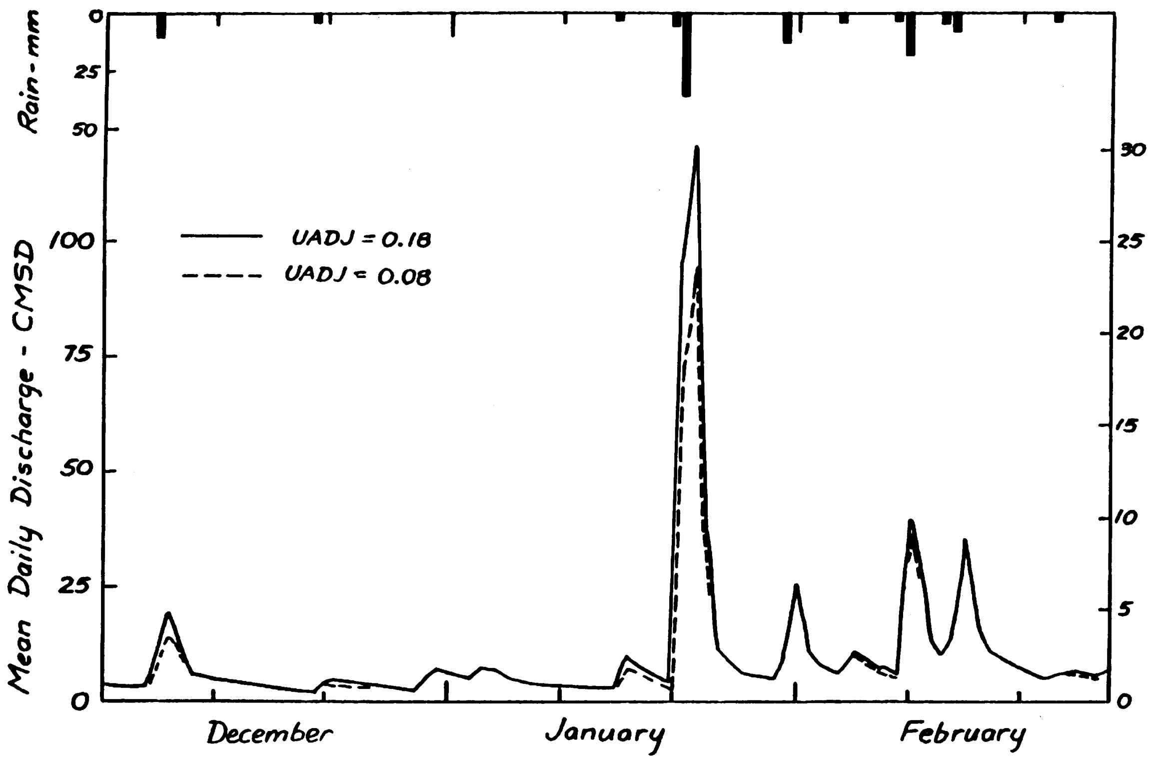

Figure 5. Illustration of the effect of the parameter UADJ, the average wind function during rain-on-snow periods, on model response. Snow is on the ground during the entire 3-month period.

Figure 6. Effect of parameter SI and the areal depletion curve on streamflow

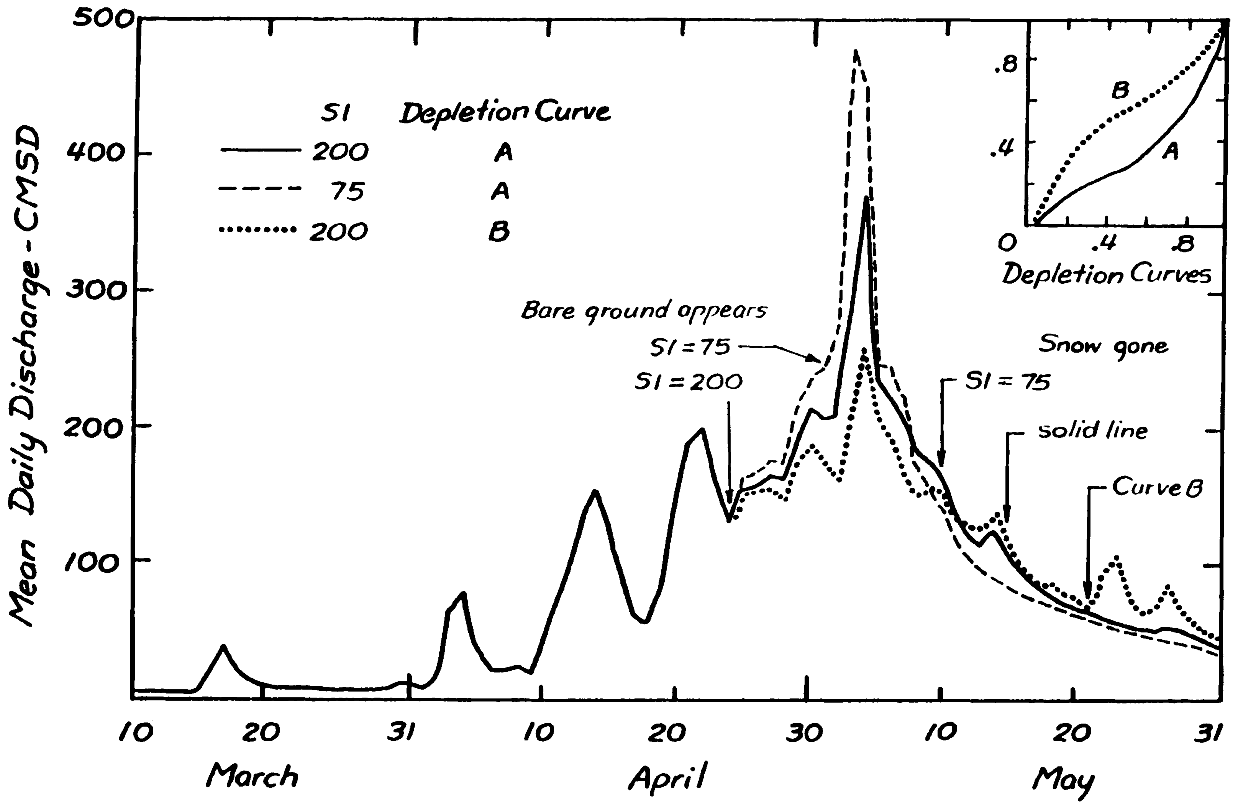

Figure 6. Illustration of the effect of SI and the areal depletion curve on streamflow. Change in SI to 75 mm increased streamflow volume by 8 mm, while change to depletion curve B decreased volume by 7 mm.

Figure 7. Interdependency of melt factor and areal depletion curve on streamflow in basins where bare ground appears soon after ablation begins

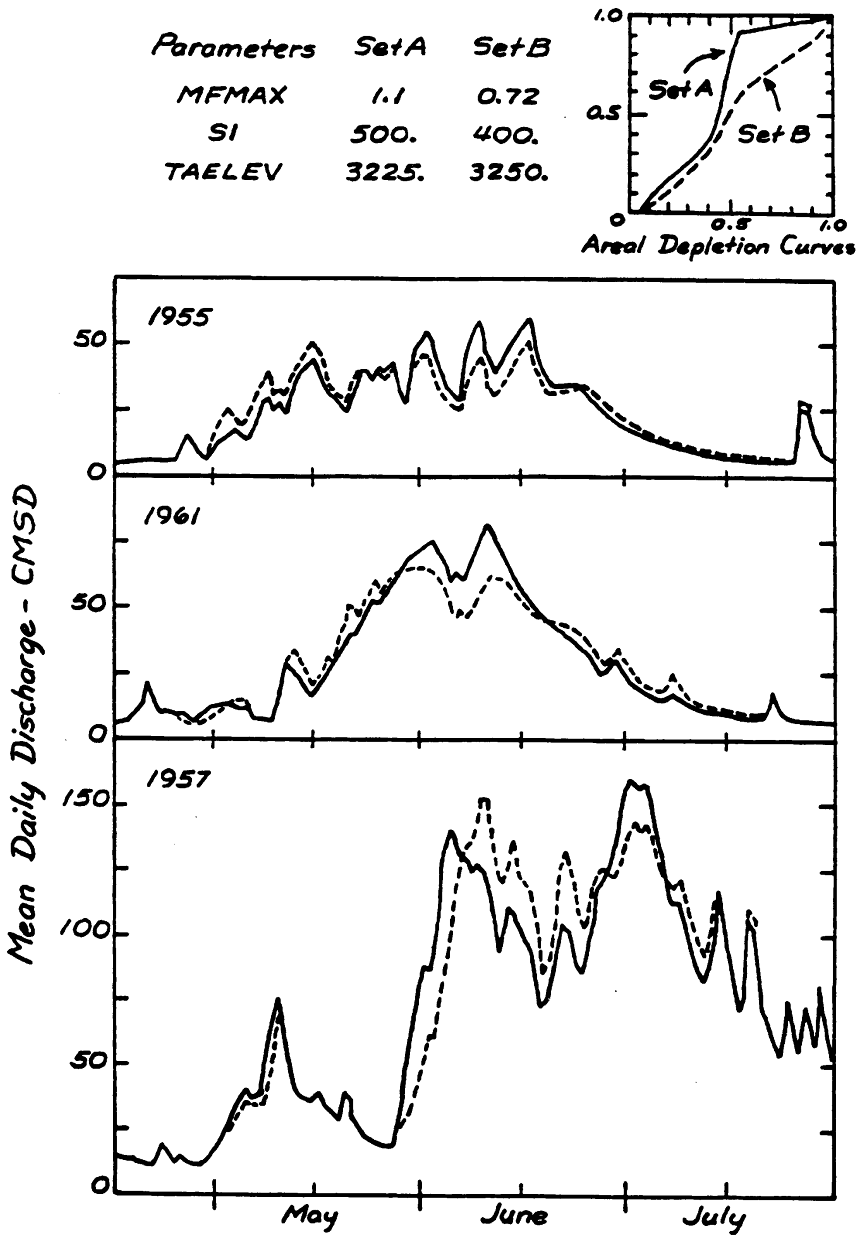

Figure 7. Illustration of the interdependency of the melt factor and the areal depletion curve in basins where bare ground appears soon after ablation begins, from the calibration of the Eagle River below Gypsum, Colorado. Solid line is based on parameter set A and dashed line is based on set B. All other model parameters were the same for both runs.

Figure 8. Effect of parameters NMF and PLWHC on streamflow

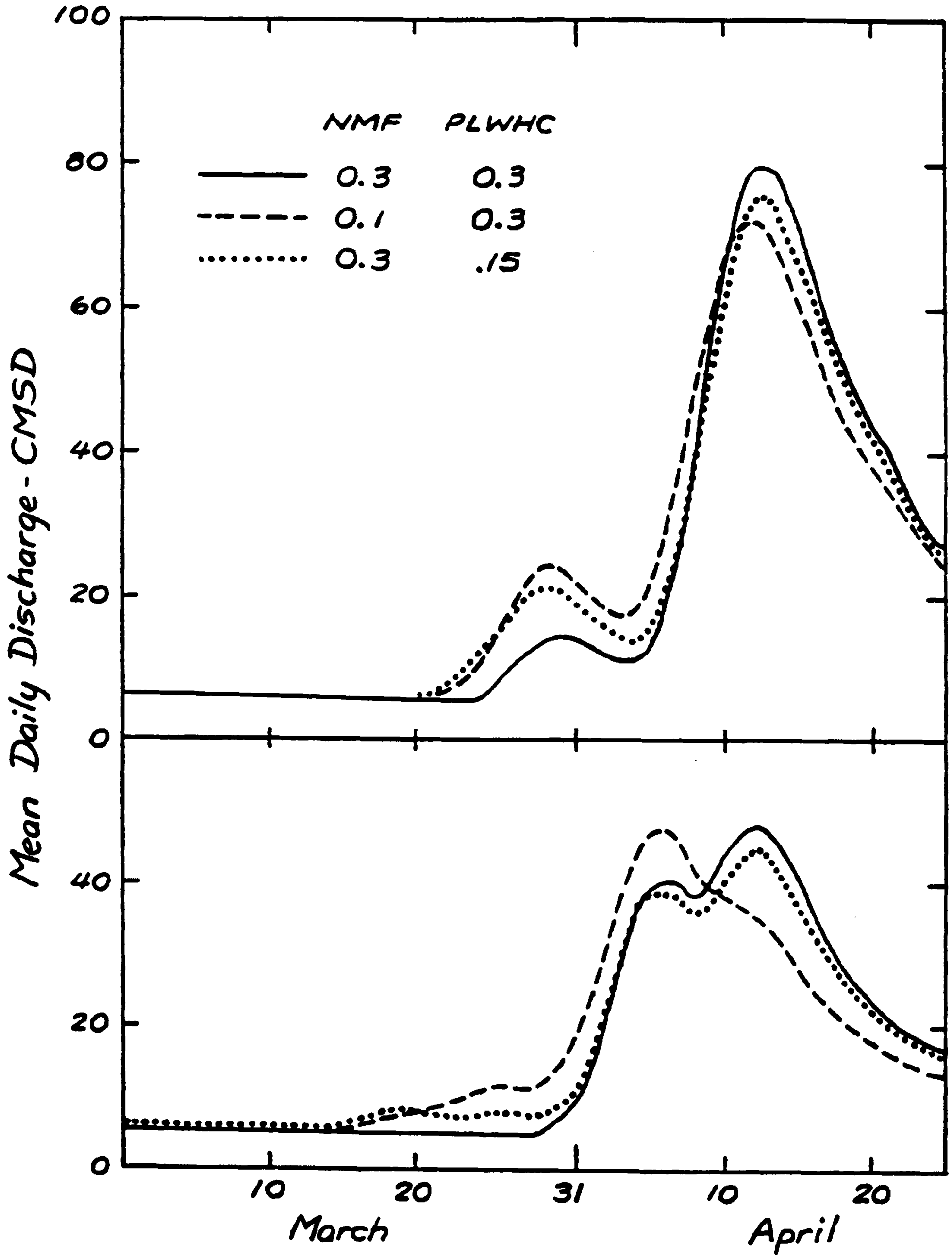

Figure 8. Illustration of the effect of the parameters NMF and PLWHC on streamflow. These are fairly extreme examples. Normally NMF and PLWHC do not have this much effect on streamflow. The change in streamflow volume is neglibile.

Figure 9. Effect of parameters TAELEV, MFMAX and MFMIN on streamflow

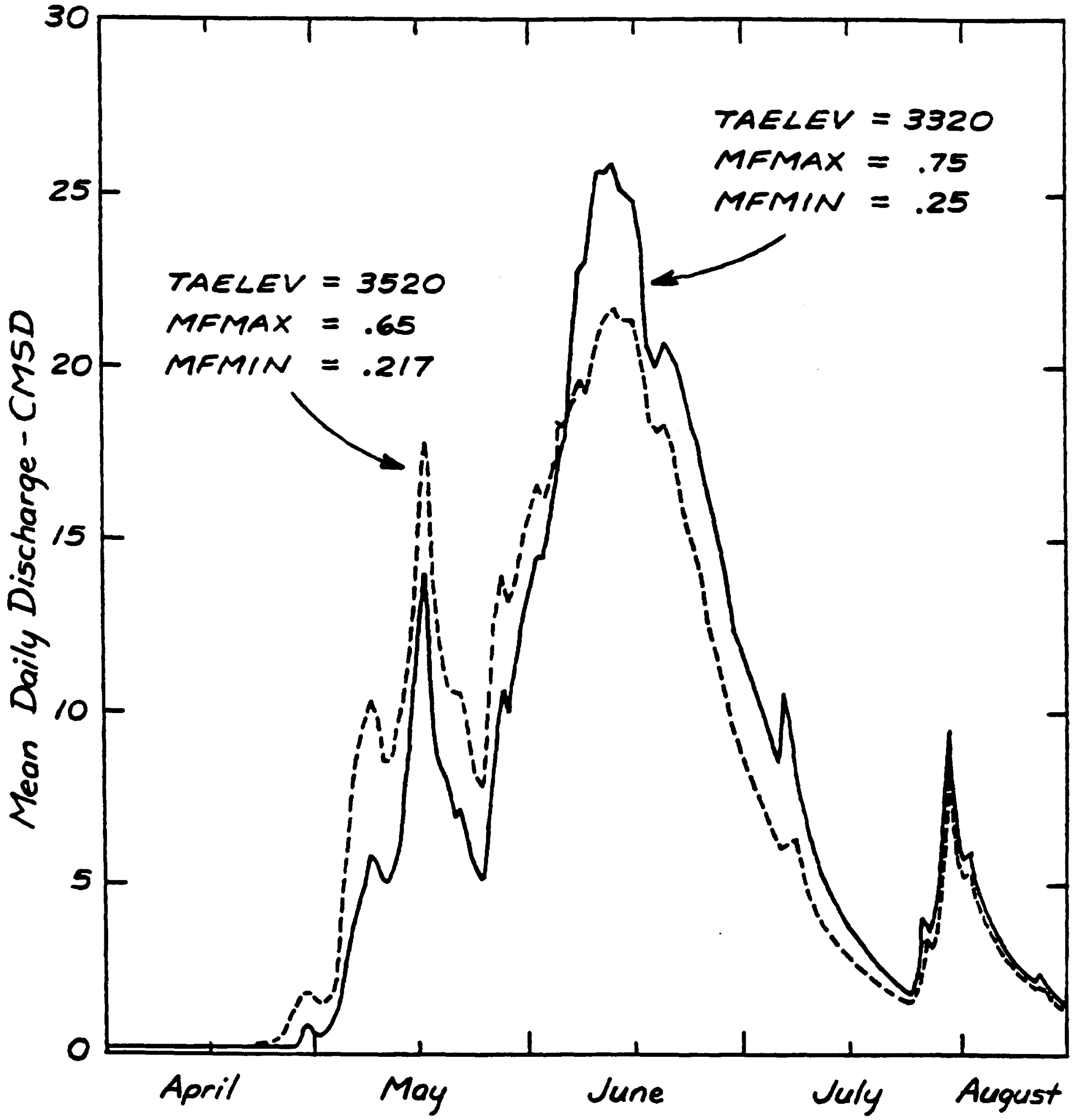

Figure 9. Illustration of the effect on model response of changing both TAELEV and the melt factors. The dashed line is somewhat similar to the response obtained by increasing the melt factors except that in this case melt begins sooner and is proportionally greater in the early part of the melt season than during the latter part because TAELEV is increased rather than the melt factors. The lapse rates for the four 6-hour periods are -0.3, -0.6, -0.8, and -0.5 °C per 100m.

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