APPLICATION OF SNOWCOVERED AREA TO RUNOFF FORECASTING IN THE SOUTHERN SIERRA NEVADA

by

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INTRODUCTION

Many of you have just attended the "Final Workshop on the Operational Application of Satellite Snowcover Observations" sponsored by the National Aeronautics and Space Administration, which has been held in conjunction with the Western Snow Conference this year. This paper describes work done in California's southern Sierra Nevada utilizing snowcovered area as one parameter to assist in describing both the volume and time-distribution of snowmelt runoff.

HISTORICAL BACKGROUND

The concept of using snowcovered area or snow line within a watershed as an index to runoff volume and timing of snowmelt runoff is certainly not a new one, and has always seemd to have some element of logic to those interested in the relationship between snowpack and streamflow. The first application of observation of snow line from the valley floor to an estimate of resulting quantity of snowmelt runoff is probably lost in antiquity. Snow survey lore has it that the legendary George "Pappy" Lewis observed the snow line of the eastern high Sierra from his Los Angeles Department of Water and Power office at Independence, California and mysteriously applied those observations to projections of water supply. Pappy Lewis obtained data on snow line from surface and aircraft photographs as an index to snowcover which could be used as one input parameter to his forecasts. Much of the technique, highly dependent upon George Lewis' judgement and experience, is now lost to future generations of forecasters.

In 1937, Harry L. Potts, Denver Water Board, reported to Western Snow Conference on a series of photographs taken at intervals throughout the year at the same point of a high range near Hoosier Pass, Colorado. Percentage of area covered by snow was calculated and related to remaining runoff volume. Potts reported again in 1944, suggesting that experience over a ten year period indicated that predictions to total streamflow could be made from a photograph taken on May 1. Ralph L. Parshall (then an irrigation engineer with the Soil Conservation Service, Fort Collins, Co.) reported on the promising relationship between streamflow and snowcovered area as determined from photographic methods.

Observation of snow line on the western slope of the Sierra Nevada was initiated during the 1940's under the California Cooperative Snow Survey Program. Observers systematically noted snow line along Sierra transportation routes (roads and railways) and transmitted results by penny postcard for near-real-time utilization in water supply forecasting. This data collection procedure has since been abaondoned in favor of other more sophisticated techniques, possibly as a result of the very subjective nature of the observation.

During the heavy snow season of 1952, the U.S. Army Corps of Engineers initiated observation of snowcovered area from low flying aircraft in the southern Sierra Nevada in connection with the operation of reservoirs during the period of snowmelt. Initial work was done in the Kings River basin for operation of Pine Flat Reservoir. Observations extended to the Kern River in 1954 and eventually included the Kaweah and Tule River basins. Observations were taken more of less routinely following the beginning of snowmelt

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(usually about May 1) through the period of major snowmelt which might influence the timing of fill and spill of reservoirs. Snowcovered areas were sketched while in flight, using a transparent overlay on an aeronautical chart. The program continued for about 20 years, largely through the efforts of Glenn Castle of the Corps. In 1959, Walter J. Parsons and Glenn H. Castle reported on techniques for estimating the volume and timing of runoff during the melt season using snowcovered area as well as snowpack water content and other parameters. After Castle's retirement, the observation program continued for several years with change in personnel and was discontinued in 1973 with the exception of one observation in 1974. During 1978, the Corps resumed aircraft observations in the southern Sierra as a result of the unusually heavy snowpack condition and potential for spill of snowmelt runoff in reservoirs.

Aerial photography has long intrigued forecasters as a means of estimating and monitoring snowcovered area. There are many references to aerial photography in the Proceedings of the Western Snow Conference and elsewhere. Generally, photography at the scales commonly used for mapping purposes provides data which are far too cumbersome and generally too expensive, for real-time forecasting problems over large areas. In 1963, Harold Felgenhauer reported on the use of high altitude aerial photography of extremely high resolution which might be adaptable to analysis of snowcovered area. Costs at that time were too high to justify general usage.

The space age brought with it space vehicles of assorted types, men in space, and finally, men on the moon. Trailing along, almost as an after thought to the space program, was the potential use of satellite imagery to estimate snowcovered area within specific watersheds or in very general areas of large geographic size. In 1962, Richard D. Tarble, then with the Hydrologic Services of the U. S. Weather Bureau in Washington, displayed at the Western Snow Conference pictures of snowcover in the western United States from the TIROS IV Weather Satellite. In 1963, Tarble suggested the possibility of delineating and monitoring the area of snowcover in particular river basins from TIROS IV imagery.

In 1969, the Western Snow Conference was introduced to "Satellite Photography for Snow Surveillance in Western Mountains" by James C. Barnes and Clinton J. Bowley. Work by Barnes and Bowley in conjunction with research sponsored by the National Aeronautics and Space Administration has led to application of snowcovered area from satellite imagery to specific hydrologic problems through the Applications Systems Verification and Transfer (ASVT) project. This project has sponsored ASVT programs in four areas, Arizona, Colorado, the Pacific Northwest, and California. Much of the work in California has been conducted in the southern Sierra Nevada where about 20 years of aircraft observations of snowcovered area have been collected, representing a wide range of hydrologic situations.

Techniques for interpretation of satellite imagery for snowcovered area have been developed and described by Barnes and Bowley, Stan Schneider of NOAA, and others. Automated and semi-automated techniques for reducing imagery are being considered in some areas. The advent of satellite imagery from Landsat, NOAA, and GOES satellites as a relatively inexpensive bi-product of other space age activities has made snowcovered area from satellite sources readily available to the hydrologic forecaster.

BACKGROUND OF INVESTIGATION

General

Water originating from snowmelt in California's southern Sierra Nevada has high value for municipal and agricultural applications. Detailed information on the volume of rate of snowmelt runoff through operational hydrologic forecasts is important to water management. For half a century, measurements of snowpack water content have been made on a monthly basis in these watersheds for the purpose of estimating volume of run-off, and for over 20 years, aircraft observations of the areal extent of snowpack were made. Satellite observations of snowcover have been interpreted for each snowmelt season since 1973.

The high value of water has resulted in development of a data base and conventional procedures for volumetric and time-distribution forecasting which are presently developed to a relatively high degree of refinement. These factors, along with the historical period of aircraft observation of snowcovered area, made the southern Sierra an attractive area in which to test the impact of satellite observation of SCA on operational forecasting.

Scope

This paper describes the application of snowcovered area (SCA) derived from satellite imagery to (1) volumetric water supply forecasting and (2) hydrologic modeling of the time distribution of snowmelt runoff in the southern Sierra Nevada.

Analysis has been restricted to the period of snowmelt runoff and receding snow-covered area, nominally April 1st through the end of snowmelt. Evaluation of SCA data during the period of snowpack accumulation showed a very "transient" snow line which has little apparent impact on the observed runoff during the snowmelt season, and even less effect on forecast procedures. Even during the period of snowmelt, occasional cold storms will create a transient snow line which must be differentiated from the snow line resulting from the receding winter snowpack during the period of snowmelt.

Geographical Area

The Kings and Kern River basins have been subjected to intensive analysis regarding utilization of SCA in hydrologic forecasting. The Kings and Kern Rivers are adjacent watersheds (Figure 1) in the southern Sierra, ranging in elevation from below 1000 feet in the foothill area to over 14,000 feet along the Sierra crest, which is the eastern boundary for both watersheds. The Kings River has an east-west orientation with high subbasin divides and subbasin drainage in deep canyons. The Kern River has a north-south orientation with the Sierra crest along the eastern drainage boundary and the similarly high

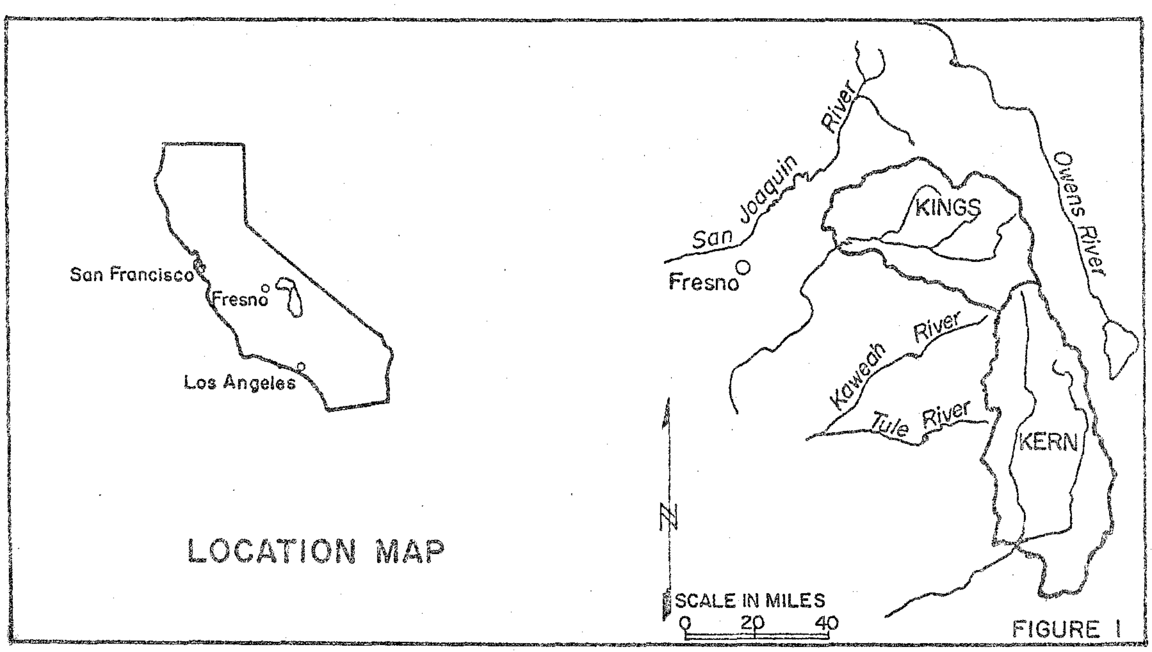


FIGURE 1

Great Western Divide along the western boundary of the basin. The Kern River is characterized by plateau areas with broad meadow areas and timbered slopes, although the North Fork heads in the steep rocky areas near the Kings-Kern divide and flows in a deep canyon for most of its length to Lake Isabella. About 75 percent of the Kings River average annual runoff of 1,568,000 acre-feet (about 19 inches of runoff) occur during the April-July snowmelt period. About 67 percent of the Kern River average annual runoff of 627,000 acre-feet (about 5.7 inches) occurs during the April-July snowmelt.

VOLUMETRIC WATER SUPPLY FORECASTS

Procedures

Application of SCA was investigated for volumetric water supply forecasting on the Kings and Kern River basins as a supplemental data source for updating forecasts of remaining runoff only during the period of snowmelt subsequent to April 1. In preliminary analysis, a multiple regression technique was used to relate runoff subsequent to date of forecast to causitive parameters. The analysis was designed to develop and demonstrate a procedure for updating water supply forecasts during the period of snowmelt to reflect observed conditions of precipitation, runoff, and change in SCA with the intention of reducing residual error in remaining flow. Forecasts have historically been for the April-July snowmelt period and updated for observed precipitation during snowmelt. Only a limited amount of data is available from the high mountain watersheds on a continuing basis during the period of snowmelt. Observed precipitation, runoff, and depletion of SCA as the melt season progresses provide parameters on a near-real-time basis to reflect the progress of melt in the watershed.

Figure 2 illustrates variation in standard error, expressed as a percentage of April-July runoff for forecast updates, depicting the effective reduction of forecast error as the melt progresses and snowpack is depleted during the season. In analysis, it was assumed that precipitation subsequent to date of forecast was known. Change in standard error reflects improvement in forecast procedure, and not variability of weather subsequent to date of forecast. Updating procedures including SCA are shown as a solid line, while procedures without SCA are dashed. Standard error on both watersheds decreases appreciably as the season progresses. The addition of SCA as a parameter on the Kings River appears to offer little significant improvement in error during the melt season. On the Kern River, standard error declines as the season progresses but inclusion of SCA as a parameter appears to make a substantial decrease in the volumetric error of remaining runoff as the season progresses.

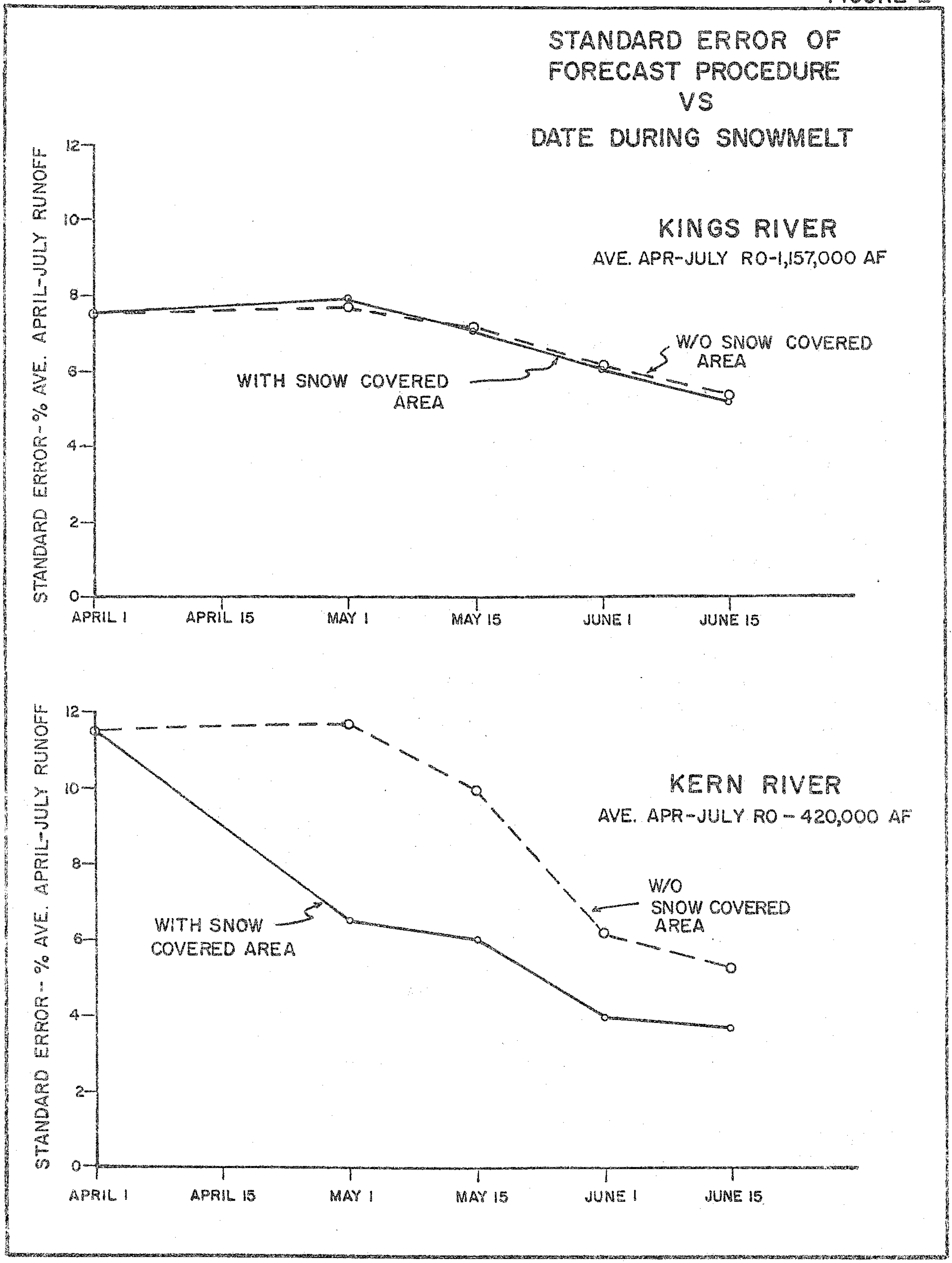
Analysis indicated that use of SCA as a parameter in forecasting snowmelt runoff may result in significant improvement of forecasting procedures under certain circumstances, providing a source of basic data measured directly in the watershed. It may be hypothesized that watershed characteristics as well as availability of data representative of the watershed are related to response of forecast procedures to SCA. Historically, forecast errors on the Kern River have been substantially larger (percentage-wise) than those on the Kings River. Inclusion of SCA during the period of snowpack depletion has allowed forecast accuracy on the two watersheds to be brought more in line with each other than was possible with conventional parameters alone. This suggests that SCA provides information pertinent to updating forecasts under some circumstances which may not be readily available from other data sources investigated here.

Operational Forecasting

Water supply forecasts utilizing SCA as a forecast parameter were prepared during the snowmelt period for the 1977 and 1978 water years.

1977. California experienced the driest water year of record on most streams during

FIGURE 2


STANDARD ERROR OF
FORECAST PROCEDURE
VS
DATE DURING SNOWMELT
KINGS RIVER
AVE. APR-JULY RO-1,157,000 AF
W/O SNOW COVERED AREA
WITH SNOW COVERED AREA
STANDARD ERROR-% AVE. APRIL-JULY RUNOFF
0
2
4
6
8
10
12
APRIL 1
APRIL 15
MAY 1
MAY 15
JUNE 1
JUNE 15
KERN RIVER
AVE. APR-JULY RO - 420,000 AF
W/O SNOW COVERED AREA
WITH SNOW COVERED AREA
STANDARD ERROR -- % AVE. APRIL-JULY RUNOFF
0
2
4
6
8
10
12
APRIL 1
APRIL 15
MAY 1
MAY 15
JUNE 1
JUNE 15

1977. This followed the near record dry 1976 water year. Snowcovered area observed was by far the smallest (20 perecent of average) for any season for which observations were available. Forecasts on the Kings and Kern Rivers using SCA as one forecast parameter verified well. However, any forecast procedure utilized during this critical drought period would have shown extremely dry conditions, so this season did little to actually confirm procedure reliability. Satellite observations indicated that as a result of unseasonal May storms the snow line had dropped from an unprecedented high of 10,000 feet on May 1 to below 7000 feet during the month. The amount of water content in the fresh snowpack was small and did little to relieve the drought situation. The occurrence of snow at low elevations during May did provide some interesting data on the accumulation and rapid melt of freshly fallen snow in the area below the receding seasonal snow line.

1978. Following the two extremely dry water years of 1976 and 1977, water year 1978 brought well above normal streamflow to the southern Sierra Nevada. Heavy precipitation during the winter months left a snowpack by April 1 representing over 175 percent of average water content at the higher elevations, but many of the winter storms were warm with relatively high freezing levels which resulted in snow lines much higher and snowcovered areas much smaller than might be anticipated with April 1 snowpack this heavy in the southern Sierra.

April was very cold with relatively heavy precipitation, further increasing the April-July snowmelt potential. May was dry with only slightly below average temperatures. The short periods of high temperature which normally result in heavy snowmelt runoff towards the end of May were absent, and snowmelt continued at relatively low rates through the month of May, resulting in less depletion of SCA than would normally occur. By mid-May, the greatest snowcovered area of record (receding winter snowpack) for that date was observed on both the Kings and Kern River watersheds (as compared with data from satellite imagery and adjusted aircraft observations dating back to 1952). Although by mid-June, snowcovered area on the Kings River was exceeded by that in 1967, the Kern River continued with the maximum snowcovered area of record for the remainder of the season. June remained cool with no extended periods of high temperatures, and June runoff, though large, was delayed to some extent. The delayed runoff with reduced runoff rates was advantageous to reservoir operators, since the filling and possible spilling of reservoirs in early June did not occur. Satellite imagery indicated that there was still some substantial snowpack left in certain protected high elevation portions of the watersheds well into August and some isolated snowfields persisted throughout the summer.

Forecasts utilizing SCA verified well, while conventional procedures tended to over forecast. Since SCA on April 1 was well below that which might have normally been anticipated, water supply forecasts for the Kings and Kern Rivers using SCA were substantially lower than those from conventional procedures. By May 1 forecasts were raised as the result of heavy precipitation during April but SCA forecasts were still substantially below the conventional forecast. Subsequent updates gave similar results. The record high SCA after May 15 was consistent with remaining volume of runoff still in the form of snowpack within the watersheds.

Conclusion - Volumetric Forecasts

The addition of snowcovered area as a parameter to the water supply forecast procedure seems to have contributed materially to forecast accuracy during the 1978 season with its unusual distribution of snowpack. Snowpack distribution may have been only one of several causes related to overforecast, but the updating procedure proved useful during the snowmelt season. It may be possible that other techniques could be utilized to index the snowpack distribution (such as high and low elevation snowpack indexes). Snowcovered area did, however, seem to provide at least a partial solution to the problem encountered in 1978.

HYDROLOGIC MODELING

General

The California Department of Water Resources currently operates for water management a hydrologic model to simulate daily runoff on the Kings River basin given observed conditions of daily precipitation, temperature, and other hydrologic parameters. The existing model consists of five basic sub models of varying complexity and influence on the overall hydrograph. The submodel of primary concern in the present investigation is that related to (5.) snowmelt flow.

Submodel	Magnitude of Contribution to Daily Hydrograph (Mean Daily Flow)
1. Summer Base Flow	100-300 cfs
2. Winter Base Flow	0-800 cfs
3. Recession Storage Flow	0-5000 cfs
4. Precipitation Flow*	0-50,000 cfs
5. Snowmelt Flow	0-25,000 cfs

*A major contribution during the snowmelt season only on rare occasions

Approach to SCA Snowmelt Submodel

The objective of this investigation was to develop techniques using SCA as a parameter to estimate the rate of snowmelt contribution as input to the Kings River hydrologic model. Although previous investigation leading to the Kings River model suggested that areal extent of snowcover influences rate of snowmelt runoff, the technique had not been developed to incorporate this parameter in the operational model. Utilization of SCA required a relationship between the rate of snowmelt contribution to the runoff hydrograph and temperature, SCA, and related parameters which would permit simulation of daily snowmelt runoff from the hydrologic model. The original snowmelt submodel was completely removed from the hydrologic model and replaced by the SCA submodel, since the basic techniques used in the two submodels differed conceptually.

The SCA snowmelt submodel is based upon the following premises:

. . . The technique was to be capable of transference to other similar watersheds given the comparable characteristics of those watersheds. It was hypothesized that the greatest degree of transference could be achieved through development of the snowmelt submodel by elevation bands or zones within the watershed, basing the melt procedures upon similar and differing characteristics of the zones as well as relative levels of energy input.

. . . Melt in any elevation zone in the basin can be related to air temperature within that zone.

. . . Melt of snowpack may occur at any point or elevation zone in the watershed (assuming air temperatures are above freezing in that zone), but runoff will occur from the snowpack in a given elevation zone only after the snowpack in that zone becomes fully "primed". For purposes of the snowmelt submodel, the effective "elevation of prime" represents that elevation above which no snowmelt is available to the snowmelt hydrograph.

. . . The rate at which snowmelt is made available to the snowmelt hydrograph is proportional to the area of fully primed snowpack within each elevation zone below the "elevation of prime" as well as the temperature within each zone.

Basic Data - Elevation Zones and Temperatures

The following comments refer specifically to basic data as related to the SCA snowmelt submodel.

In the developmental phase, SCA was interpreted from satellite imagery by 500 foot elevation bands or zones. It should be pointed out that the developmental model using elevation zones of snowpack is not particularly well suited to operational forecasting as the reduction of satellite imagery by 500 foot elevation zones is a time consuming process. This approach is better left to the research and developmental stages of analysis, while a more simplified approach to data reduction is more applicable to operational analysis during the forecast season. Fortunately, in the Kings River watershed, the basinwide SCA seems to provide an adequate index to be used in future operational work, while analysis by zones provides for a means of transference of techniques to other areas and watersheds.

Temperature used in analysis is mean daily surface air temperature derived from three stations in or adjacent to the watershed and adjusted to an approximate elevation of 7000 feet for analysis purposes. Air temperature is one of the few measurements related to the input of energy to the watershed which has been recorded systematically over the years. Fortunately, temperature appears to provide a good integration of the effect of available energy upon the snowpack under most conditions, both during accumulation and melt of the snowpack. Temperature within each elevation zone was based on the mean daily model temperature computed with a lapse rate of 3.5^{o}F per 1000 foot zone. Analysis indicated that a base temperature of 30^{o}F appeared to give the most satisfactory results. Melt was computed on the basis of the difference between the mean daily temperature (adjusted by lapse rate) and 30^{o}F.

Melt by Zones

The snowmelt submodel was first developed for that portion of the season after which the entire watershed was considered to be primed and producing melt. This simplified the process of developing and calibrating techniques to calculate melt by elevation zones. The same basic technique is utilized throughout the entire snowmelt season, but during the period of priming, only a portion of the snowcovered area in the watershed has the ability to produce water contributing to the runoff hydrograph.

Melt volume for each elevation zone is computed by an equation of the form:

$$QMELT_z = C_q C_z A_z P_z T_z$$

Where: $QMELT_z$ = daily melt volume from given elevation zone "z" in SFD (cubic feet per second per day)

C_q = coefficient to describe relationship between area, temperature, and melt. The value of C_q was about 1.2.

C_z = coefficient to adjust for the efficiency within the elevation zone. Values were near 1.0, probably dependent upon loss characteristics of the zone.

A_z = area within elevation zone in square miles.

P_z= percentage of the zone subject to melt on a given day limited by snowcovered area in zone and "elevation of prime" as described in a following section.

T_z= effective temperature above base within elevation zone "z".

The summation of QMELT from all zones is the output from the SCA snowmelt submodel and the required input for the Kings River hydrologic model. A value of QMELT for any elevation zone was calculated as zero (1) if there was no snowcovered area within the zone, and (2) if the temperature for the zone was less than 30^{O}F, or (3) if the effective elevation of prime was below the lower limit of the zone. Although analysis suggests that the relationship between temperature and melt is not linear, it appears to be sufficiently linear throughout the range of temperature where significant melt occurs that the assumption of the linear relationship is not detrimental. One degree F change in temperature with this relationship represents about 0.045 inches of QMELT as input to the basic hydrologic model. This figure does not appear at all inconsistent with observed depletion of snowpack of two inches per day with observed mean daily air temperature (corrected for elevation) in the order of 65^{O}F.

Melt During Prime

Analysis of melt volume and melt rate during the period of snowpack priming is complicated by the fact that the snowpack is not fully primed throughout the watershed, and therefore the watershed is not capable of producing runoff from the entire snowcovered area, no matter what the temperature. It has been assumed for purposes of the model that the watershed produces no snowmelt runoff above the "elevation of prime" and all of the runoff required to meet the observed hydrograph of snowmelt runoff comes from the area of the watershed which is snowcovered below the effective "elevation of prime". It was assumed that a given set of temperature and snowcovered area conditions would produce snowmelt volume equivalent to that derived from the relationship in section "Melt by Zones", and that any reduction or difference between the calculated and observed melt was attributable to the fact that no runoff occurred above an "elevation of prime", regardless of temperature.

To systematically develop relationships to describe the "elevation of prime", the basinwide melt was calculated from the relationship in section "Melt by Zones". Next, the volume of daily melt required to reproduce the observed hydrograph was estimated. The difference between the calculated and "observed melt volumes was then used to determine the elevation above which no snowmelt could occur if the "observed" runoff hydrograph were to be realized from "calculated" melt. This elevation was defined for purposes of the SCA snowmelt model as the effective "elevation of prime." The elevation of prime was then defined in terms of other measured or calculated parameters considered related to the priming process. Many combinations of parameters were tested to establish a relationship between "elevation of prime" and the following factors.

. . . Temperature -- A decayed accumulative temperature (0.96 daily decay factor) was based upon the accumulation of degree days above freezing at 7000 feet from January 1. This factor represented a measure of the accumulation of energy to which the snowpack might be subjected as reflected by air temperature.

. . . Date -- The date of the season also appears to reflect some measure of energy introduced to the snowpack that would be somewhat independent of temperature.

. . . Snowpack Water Content -- April 1 snowpack water content (expressed in percentage of average April 1 water content), updated for subsequent precipitation, was used to describe the amount of snowpack which must be primed before runoff would occur. The greater the water content of the snowpack, the slower the elevation of prime would rise.

The basic equation for computation of elevation of prime for the Kings River SCA snowmelt submodel took the following form:

$$E_p = 3.1 \times K \times (1.009)^D + .017 \times K \times (T1-100/K)$$

Where: E_p = the elevation of prime in 1000 feet

D = number of days since February 1

T1 = decayed accumulated temperature (degree days at 7000 feet) since January 1 with a decay factor of 0.96

K = a variable affecting the elevation of prime as related to snowpack water content (HSI). K decreases with increasing HSI.

HSI = high snow index expressed as a percentage of average April 1 water content, adjusted for subsequent precipitation

The resulting elevation of prime is the maximum elevation to which the watershed is capable of producing snowmelt runoff (for purposes of model computation) as of the given date.

Results

Simulated mean daily runoff for the Kings River computed as output from the model has been plotted for the 1973 snowmelt season in Figure 3. The plot represents mean daily discharge in cubic feet per second against time, April 1 through the end of snowmelt. Shown for comparison are the discharges calculated from the model and unimpaired discharges observed. The observed effective snow line and calculated elevation of prime are also delineated for comparison.

Calculation of discharges using the snowcovered area has given results which are entirely acceptable in analysis. In addition, the conceptual model appears to be more consistent with known hydrologic relationships than the formerly used snowmelt submodel, which represents at least an academically asthetic improvement over the original model as well as probably improvement in extrapolating results into extreme conditions. At this time, no further testing has been done on other watersheds, but it is believed that the conceptual model will have a high degree of transferability.

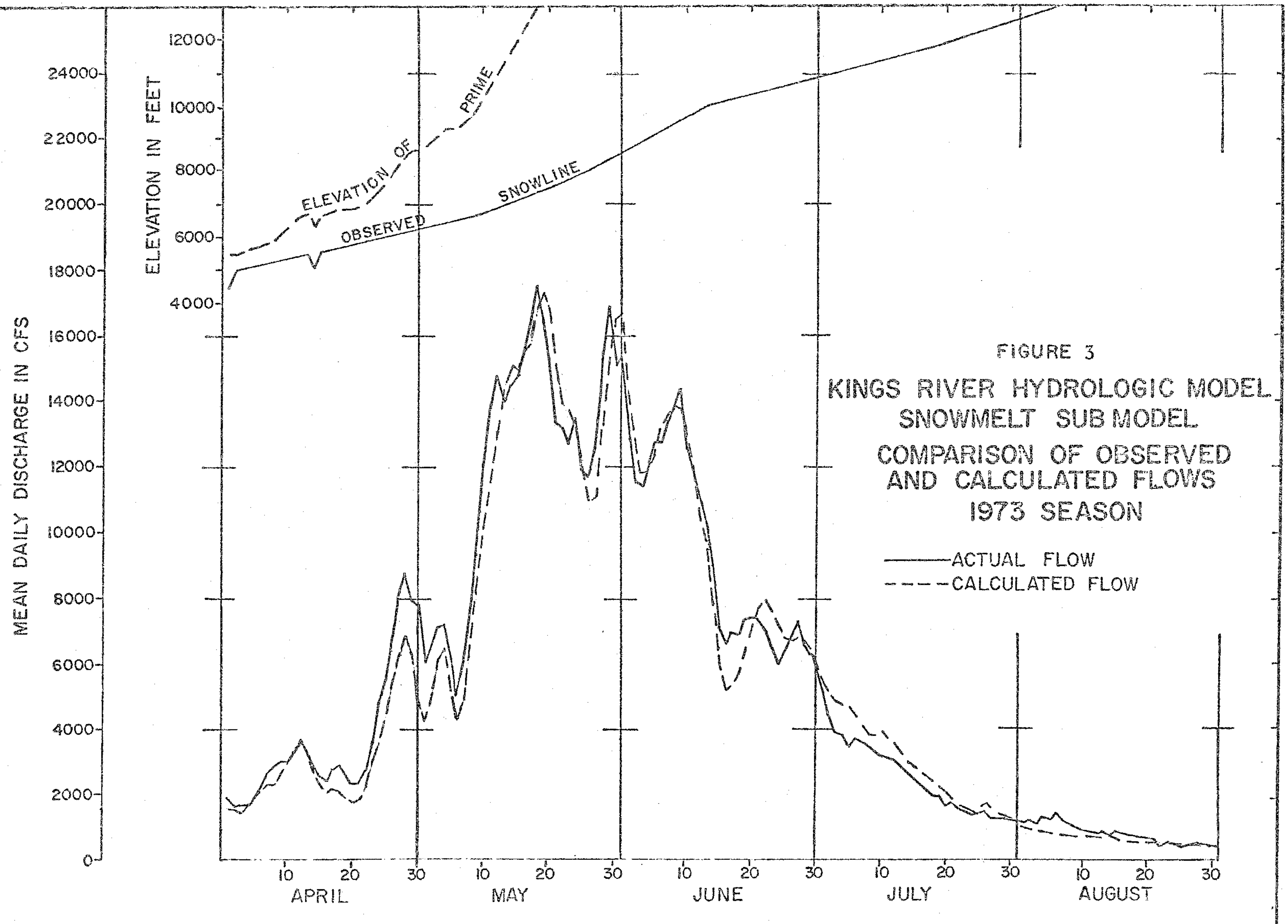
SUMMARY AND CONCLUSION

Investigation of water supply forecasting and hydrologic modeling in the southern Sierra indicates that snowcovered area can be a useful parameter in hydrologic analysis. Items related to utilization of SCA in hydrologic analysis may be summarized for the southern Sierra as follows:

. . . Data describing SCA appeared to have greatest hydrologic application during the period of snowmelt in the spring and early summer rather than during the period of snowpack accumulation. SCA provides a source of near real-time data from within the watershed during a period when snowpack conditions are changing rapidly and snowmelt runoff rates are high.

. . . SCA appears useful in water supply forecasting to supplement other basic data sources to update forecasts when other real-time data representative of the watershed are not readily available. SCA data may be most useful to detect and monitor conditions within the basin that depart from normal or experienced conditions.

. . . SCA provide basic data which can be related to the rate of snowmelt in the watershed to simulate snowmelt runoff through hydrologic modeling.



MEAN DAILY DISCHARGE IN CFS
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
24000
ELEVATION IN FEET
4000
6000
8000
10000
12000
ELEVATION OF PRIME
OBSERVED SNOWLINE
FIGURE 3
KINGS RIVER HYDROLOGIC MODEL
SNOWMELT SUB MODEL
COMPARISON OF OBSERVED AND CALCULATED FLOWS
1973 SEASON
ACTUAL FLOW
CALCULATED FLOW
10
20
30
APRIL
MAY
JUNE
JULY
AUGUST

It is not proposed here that SCA represents a major break through in data related to snowmelt runoff. Other data sources could possibly provide similar information in hydrologic analysis. However, SCA does provide for a continually updated data source which can describe one parameter related to snowmelt runoff within the watershed on a near real-time basis.

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