Paper No. 5

OPERATIONAL APPLICATIONS OF SATELLITE SNOWCOVER OBSERVATIONS IN RIO GRANDE DRAINAGE OF COLORADO

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ABSTRACT

It is hoped that snowcover as determined from satellite pictures can be used in streamflow forecasting. An improvement in forecasting is an improvement in management.

Various mapping techniques were tried and evaluated. There were many problems encountered such as distinguishing clouds from snow and snow under trees.

A partial solution to some of the problems involves ground reconnaissance and low air flights. Some problems go unanswered.

Snow areas, cloud cover and total areas were planimetered after transferring imagery by use of zoom transfer scope. These determinations were then compared to areas determined by use of a density slicer. Considerable adjustment is required for these two values to compare.

NOAA pictures were also utilized in the evaluation.

Forest cover is one of the parameters used in the modeling process. The determination of this percentage is being explored.

Introduction

In the past 5 years, the Western States in general and Colorado in particular have experienced phenomenal growth. There have been unprecedented demands and competition for the limited water resources available in this arid region. The demands come not only from within the state of Colorado but also from other states that want more and more of the waters of the interstate streams. Since the waters of these streams are apportioned among the states, it becomes imperative that accurate forecast models be developed. This would allow the maximum delivery of water to Colorado users and still permit the delivery of water to satisfy out-of-state obligations. The problem is nowhere more apparent than in the Rio Grande Basin where predictions of total annual and seasonal runoff must be made as early as March 1. Many other water users such as municipalities, power companies, ranchers, and farmers also need the information as soon as possible. These

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people use the first available forecasts in their planning and then use future forecasts to update plans. This use terminates for the farmer when his crops are planted but continues for others until end of snowmelt. About 80 percent of the water supplies of the West come from melting snow so accurate forecasts are extremely important. Total snow cover may prove to be a vital parameter in the forecasting model.

Objectives

The project discussed in this paper was undertaken to determine if satellite imagery could be used to improve forecasts and, hence, to improve management.

Secondary aspects of the project include applying LANDSAT imagery to associated land use problems that bear on runoff yield and water demand and monitoring various aspects of land use.

Procedure

It was decided to use two different investigating teams and to divide areas of responsibility.

First team, consisting of the Soil Conservation Service and the U.S. Bureau of Reclamation, would be responsible for the overall program and for obtaining imagery, ascertaining what data to collect, and determining the best methods to acquire the data.

Second team, under leadership of the Colorado Division of Water Resources, would provide the technical staff needed to develop the predictive models for runoff forecasting. Mr. Charles Leaf of M.W. Bittinger and Associates, Inc., a water and land resources consultant firm, would assist this team.

It was decided to use three large basins in Colorado in the analysis (Map #1): Rio Grande, Arkansas, and San Juan Basins.

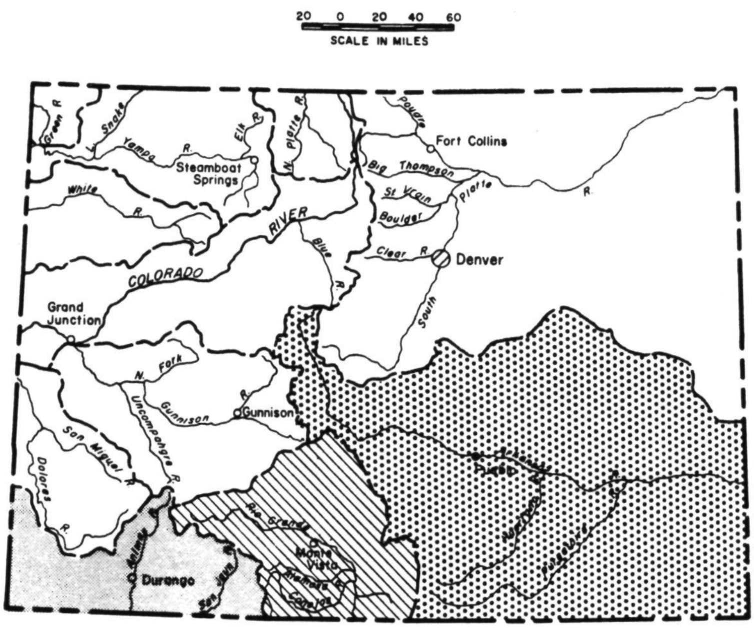
Rio Grande Basin

The primary target is the Rio Grande Basin (Map #2). The entire basin is being studied with the improvement of forecast accuracy as the prime objective. This area provides irrigation water to Colorado's San Luis Valley as well as to the area along the river throughout its course in New Mexico, Texas, and Mexico. The river is administered under the Rio Grande Compact between the three states as well as by an international agreement between the United States and Mexico. Extreme accuracy in estimating runoff is required to satisfy these objectives.

The Rio Grande Basin is being studied by using three sub-basins (Map #3): the mainstem of the Rio Grande above Del Norte, the Conejos River above Mogote, and the Culebra River above San Luis. These basins are being studied to determine if forecasts can be improved on smaller basins: Conejos, 730 square kilometers (282 square miles), and Culebra, 570 square kilometers

MAJOR BASINS BEING ANALYZED IN

COLORADO



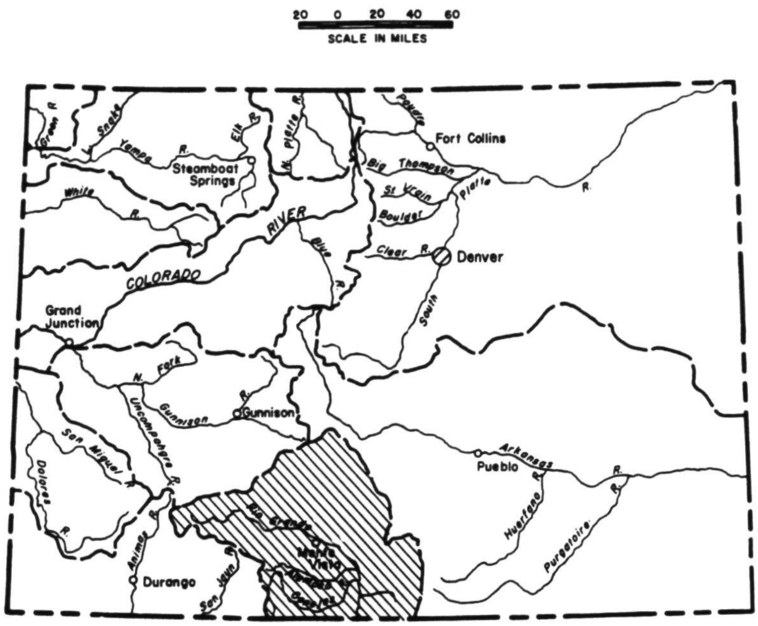
MAP #1

SAN JUAN DRAINAGE

RIO GRANDE DRAINAGE

ARKANSAS DRAINAGE

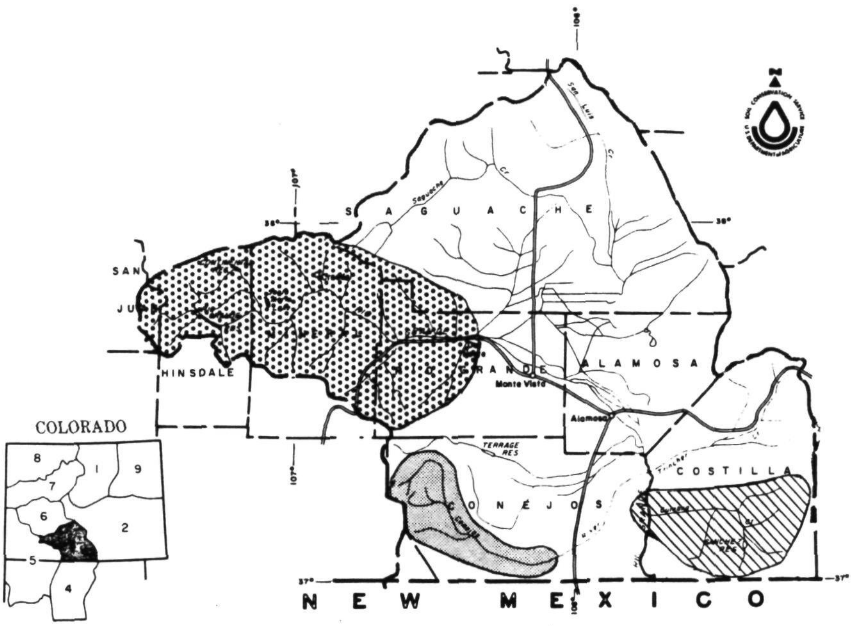
COLORADO



MAP #2

PRIMARY AREA BEING ANALYZED

THREE SUB-BASINS IN RIO GRANDE ARE BEING STUDIED



MAP #3

RIO GRANDE ABOVE DEL NORTE

CONEJOS ABOVE MOGOTE

CULEBRA ABOVE SAN LUIS

(220 square miles); as well as larger basins: Rio Grande, 3,419 square kilometers (1,320 square miles).

Conejos River Drainage

It was decided to concentrate the first efforts on the Conejos River Drainage (Figure 1). This is a small drainage of fairly high elevation (Figure 2), with an average of 1.5 meters (5 feet) of snow at medium elevations. This 730-square-kilometer (282-square-mile) area produces an average 246.6 hectometers^3 (200,000 acre-feet) of water annually.

The Conejos Basin contains mostly uplands with the river splitting the basin. Much of the drainage is 3,048 meters (10,000 feet) or more above sea level. There is very little irrigation and no diversions above the gaging station at Mogote. Platoro Reservoir is near the headwaters and is used to regulate flows.

Waters from the river provide irrigation for acreage in the San Luis Valley in Colorado and areas along its course in New Mexico. Without irrigation water, the valley is of little commercial value. It is covered by low sage and rabbitbrush. Several subdevelopments have sprung up in the valley. Where water is available, high-value truck crops such as lettuce, onions, and potatoes are grown.

This paper deals primarily with snow mapping in this drainage and covers our progress to date.

LANDSAT Images

LANDSAT 1 and 2 satellite images provide the bulk of information in our snow mapping operation. These 1:1,000,000 scale images have sufficient detail to allow an overlay to be made in a 1:250,000 scale which is our standard reference size. The finished 1:250,000 scale overlay is large enough to identify the snow area and small enough to be useful with the necessary optical equipment. The enlargements from the satellite images are made as overlays. All overlays are prepared using the Bausch and Lomb* zoom transfer scope. This instrument allows one to view simultaniously the satellite image and a drawing surface. Consistent orientation of the drainage boundaries is accomplished by aligning stream courses with a boundary overlay showing streams. This enables us to compare them with each other and with the U.S. Geological Survey (USGS) map at a scale of 1,250,000.

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*Trade names are used solely to provide specific information. Mention of a trade name does not constitute a guarantee of the product by the U.S. Department of Agriculture nor does it imply an endorsement by the Department over comparable products that are not named.

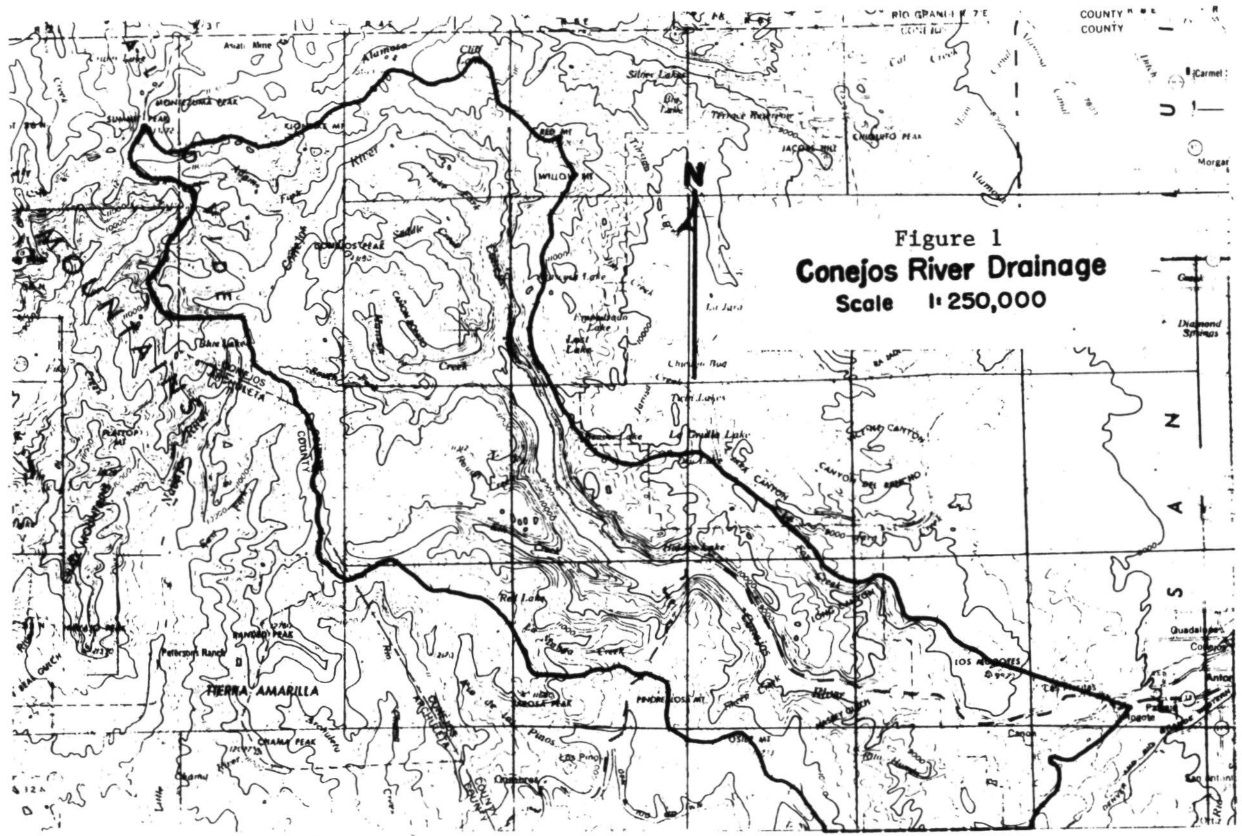


Figure 1
Conejos River Drainage
Scale 1:250,000

Figure 2

Conejos River Drainage

Scale 1: 250,000

Contour Overlay

In addition to overlays, a data color system is used to evaluate images. This instrument measures the amount of light transmitted through black-and-white satellite image transparency. The light intensity is broken into 12 discrete levels and displayed in 12 colors on a color monitor. Any color or combination of colors can be measured as a percentage of the area viewed. To make this area measurement meaningful, the areas outside the Conejos Drainage are masked. To accomplish this masking, an overlay is made by optically reducing the boundary of the Conejos with the zoom transfer scope. Great care must be taken in making the overlay because the pen width used in drawing is several hundredths of an inch thick and on the image one hundredth of an inch is approximately a tenth of a mile. Caution is required in orienting the overlay too, because the same errors are generated here.

In 1973, 33 satellite images were made available to us. Of these, 6 were of the Conejos Drainage and of the 6, 2 were usable for mapping. This figure reflects the normally heavy cloud cover in the San Juan Mountains. When snow covers the entire area no usable data is provided for our modeling and forecast procedures, so these passes are of little value.

In 1974, 22 images were received. Figure 3 indicates images received. Six of the images covered the Conejos and, again, only 2 were usable. This situation seems to have greatly improved with the addition of LANDSAT-2. With double the number of images available, more complete data in 1975 seems a certainty.

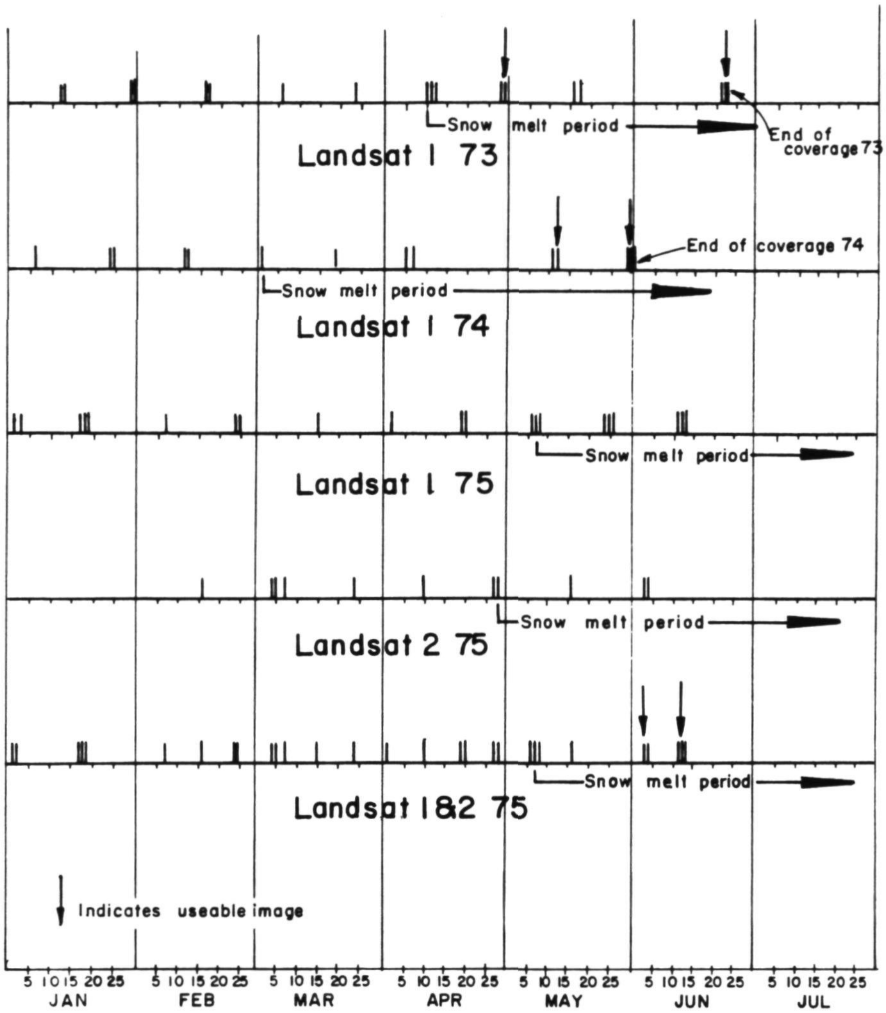
Figure 4 indicates the elapsed time during 1975 from the date each LANDSAT picture was taken until we received the imagery. The maximum time required was 53 days; and minimum, 14. Average period was 29 days. We do not know if any special rush period was tried or if this was routine. When and if the data is to be used operationally, a much shorter transmission period would be desirable.

Problems of Snow Mapping

Problems arise in differentiating snow from various rock and ground areas. Other problems occur if forest cover pattern is very complex. Many of these problems have been relieved by using medium-altitude aerial photography and low-level oblique aerial photos. The medium-altitude photos were obtained through the Colorado State Planning Office. The state has a number of medium-elevation photos made by the Hurd Company to aid in land use planning, and these were made available to us. The low-level oblique photos were shot by Robert Hansen, Head, Remote Sensing and Engineering Physics Section of the U.S. Bureau of Reclamation, on a flight in a U.S.B.R. plane. The flight was made to coincide with the June 3 satellite pass. The flights were close enough in time to allow us to gain more information as to the snow cover under trees. This flight was made by several members of the

Figure 3

USEABLE IMAGERY BY YEARS



Dates of Orbits for Images received 1973-74-75

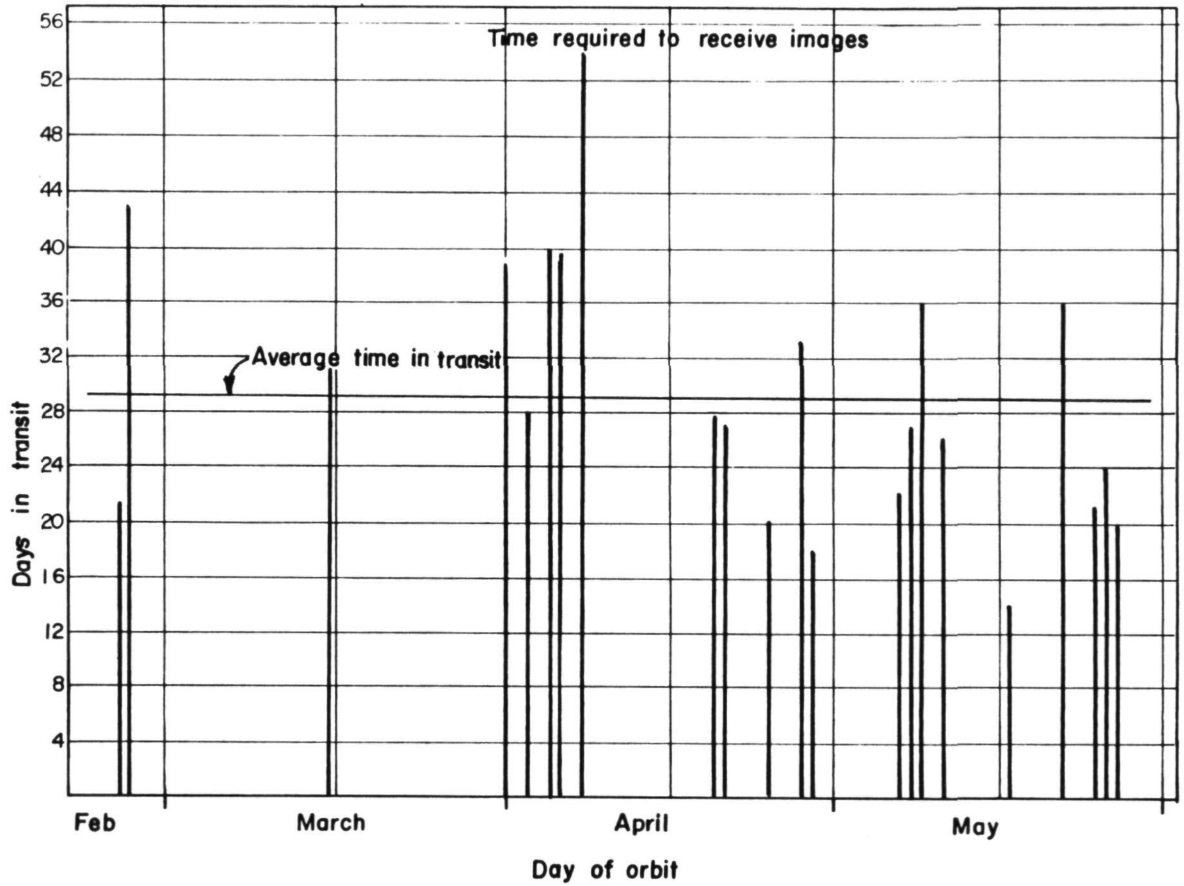

Time required to receive images
Average time in transit
Days in transit
56
52
48
44
40
36
32
28
24
20
16
12
8
4
Feb
March
April
May
Day of orbit

Figure 4

investigating team. This provides not only pictures to be used in later analysis, but gives one a feel for the area one cannot achieve in the office.

In the Platoro Reservoir area in the northern Conejos Drainage are several large areas of bare rock and soil. Also, some areas have extremely intricate snow patterns making differentiation between tree cover and melt patterns difficult. These areas are easily confused with snow, but by using the oblique photos these areas are quickly identified and disregarded in future snow mapping. Once identified these areas present no problems. This type of familiarity seems to provide very necessary information. Figure 5 shows the June 3 satellite imagery. This imagery is almost cloud-free so that the corresponding medium-elevation plane flight coincides extremely well.

The area near Cumbres Pass is one of our problem areas with heavy patterning. By using the Hurd aerial photos to determine tree cover and by using our small plane photos to determine snow patterns and amount of snow under trees, we can more accurately map snow cover from past and future images.

Comparison of Results

A difference in results is obtained between the visual overlays and the data color measurements. In two comparisons definite snow cover was 140 square kilometers (40.2 square miles) on the visual overlay and 137 square kilometers (53 square miles) on the data color image on the first set. On the second, the images indicated 159 square kilometers (61.4 square miles) on the overlay and 184 square kilometers (71 square miles) on the data color. These relations are 75 and 86 percent respectively.

When investigating probable or debatable snow areas we find a consistently greater area in the data color measurement than visual planimetering. This is to be expected as the density slicer uses all areas while with some experience, manual planimetering can eliminate some areas.

Future comparisons will be made to determine if these percentages will remain. If so, the density slicer could be used and an index established for use in our modeling procedures.

Forest Cover Evaluation

One of the parameters in the modeling program is the percentage of forest cover. Mr. Leaf, our modeler, divided the Conejos River Basin into ten watershed sub-units (Figure 6). These units are homogeneous in respect to slope, elevation, and aspect. Leaf will cover the modeling program more thoroughly in a later paper.

Mapping of tree cover was tried in two ways. In one method the tree cover outlines were traced from Hurd aerial photos. These tracings were photographically reduced to the 1:250,000

Figure 5
June 3 Satellite Imagery

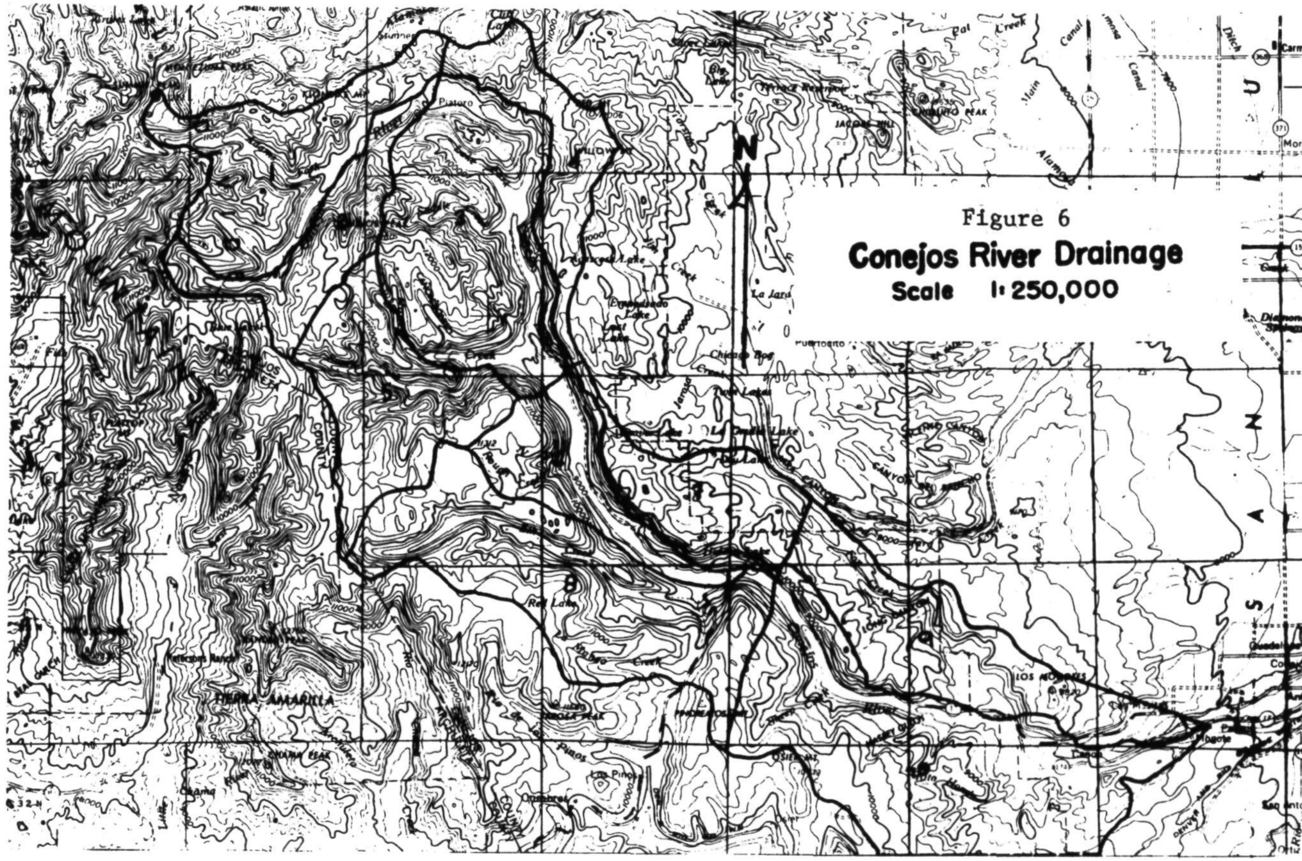


Figure 6
Conejos River Drainage
Scale 1:250,000

SUBDIVISIONS FOR TIMBER COVER

scale. The transparent reductions were assembled into a mosaic of the drainage. The forest areas were then planimetered and percentage of cover computed.

The other method was a mapping procedure using the zoom transfer scope and some summer images. This method was very similar to snow mapping. Using the zoom transfer scope, the intense lighting necessary for mapping washed out most detail from the low-contrast summer image. To correct this problem, photographs of the image were taken using a view camera and polaroid technical film. Great care was taken to ensure that the scale of the photo was exactly the same as the satellite image. By varying the length of exposure and time of development, a higher contrast and higher density photo was obtained. Forest cover was traced as in snow mapping and again planimetered. Percentage of forest cover was computed for each watershed sub-unit (Figure 7).

Both methods were evaluated. The overlays indicated a great deal of distortion was present in the edges of the Hurd photos. Although forested patches are easily identified and plotted, the distortion of the sides cannot be corrected.

We feel that the satellite images provide the best data; however, the Hurd photos provide good spot checks.

NOAA Images

In addition to LANDSAT images, NOAA weather satellite images have been used in various areas as supplemental data. Unfortunately, two problems have stopped us from using NOAA images more extensively. First there is a lack of land features in our area that are definite enough to allow us to orientate the drainage areas in the 1:5,000,000 NOAA scale. The other problem is severe distortion of the drainages as shown on the photographs. The areas in which we have the most interest appear very near the edge of the image.

Future Plans

Our plans are to continue our mapping on the other drainage areas in the basin. At this time it would seem that mapping of the snow cover can be accomplished. We are now trying to find the most simple and expeditious method of obtaining this data.

Conclusion

There is no substitute for experience. By looking at the satellite imagery, crossing the area by foot or car, personally observing from a plane, and viewing medium-elevation photos, one gains a knowledge of the area that is invaluable. Whether this can be accomplished in all areas of interest is debatable. Possibly new ideas to accomplish the mapping mission will be forthcoming from these experiences.

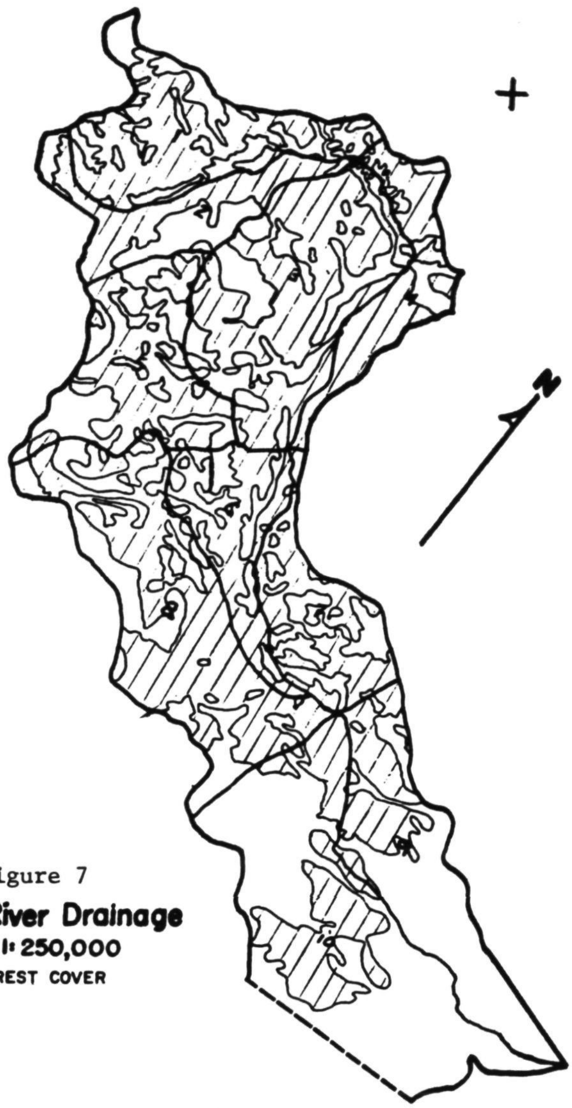


Figure 7

Conejos River Drainage

Scale 1:250,000

FOREST COVER

We are sure that total snow cover can be used as a variable in the forecast formula. How much it will improve forecasts is still unknown due to limited data. Whether the data will be available when needed is also a problem. With the addition of LANDSAT-2, our chances for cloud-free pictures are doubled, so we have high hopes.

Only time, experience, and education will tell.