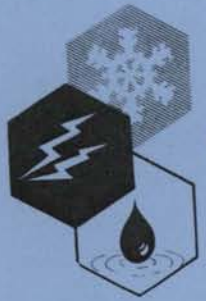
Research Technical Completion Report Project A-082-IDA

IDENTIFICATION OF SNOWCOVER DEPLETION PATTERNS USING SATELLITE IMAGERY

by
Dr. Leroy F. Heitz
Assistant Professor of Engineering Science



Idaho Water and Energy Resources Research Institute
University of Idaho
Moscow, Idaho
December 1982

The research on which this report is based was financed in part by the U.S. Department of the Interior, as authorized by the Water Research and Development Act of 1978 (P.L. 95-467).

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Submitted to
United States Department of the Interior
Washington, D.C. 20242

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ABSTRACT

The purpose of this research was to investigate whether there is a possibility of using satellite imagery to finely calibrate large scale basin runoff models. It is anticipated that by better understanding the snowcover depletion patterns in a basin the runoff models might be adjusted to better forecast both quantity and timing of runoff especially in the late stages of the snowmelt season. This forecasting of runoff is essential to the optimal operation of large multi-purpose, multi-reservoir water control systems.

While no actual field or laboratory research was carried out, as a result of this project, a detailed literature review was made and contacts were made with many agency officials. The literature review, agency contacts and various parts of this report will serve as springboards in efforts to secure future funding in this research area.

It appears that the Boise River Basin in Idaho would be the most likely candidate on which to develop the snowcover depletion pattern methodologies. The basin is well monitored as far as stream flows, it has a detailed hydrometerological instrumentation system and a detailed runoff model (Streamflow Synthesis and Reservoir Regulation Model, SSARR) is already operational for the basin. This report contains both project plans and budgets for complete studies of the snowcover depletion phenomena on the Boise Basin.

INTRODUCTION

Much of the runoff experienced in the mountainous regions of the Pacific Northwest comes from snowmelt. The Federal and State Agencies that are charged with the operation of the many water control systems in the region must be able to predict the timing and quantity of this snowmelt runoff if they are to successfully operate the river system in the region.

Because of the multipurpose nature of most water control projects there is always a delicate balance between conflicting operational objectives. The resolution of these conflicts depend a great deal on an accurate prediction of both timing and volume of runoff. An error in these predictions could be costly, resulting in such problems as failure to refill valuable irrigation and power storage space of filling of flood control storage too early in the season. Inaccuracies of this type can result in losses of power revenues, inadequate irrigation supplies, or damage to downstream properties due to flooding.

The timing and quantity of runoff depends on a myriad of climatological factors. Several computerized models have been developed to synthesize river flows using the most significant of these climatological factors. One of these models, SSARR (Streamflow Synthesis and Reservoir Regulation), was developed to model snowmelt runoff in the Columbia River Drainage to the Pacific Northwest (U.S. Army Corps of Engineers, 1972). This model can be considered as one of the better models as far as having a balance between sound process orientation and reasonable data requirements. In recent years it has become apparent that the SSARR model has some shortcomings in its snowmelt runoff

prediction capabilities, especially for late season runoff. (Personal Contacts U.S. Army Corps of Engineers and U.S. Bureau of Reclamation.)

It is the purpose of this research to determine if satellite imagery might be used to fine tune the SSARR model so that it will better forecast both quantity and timing of runoff especially in the late stages of the snowmelt season.

While no actual field or laboratory research was carried out, as a result of this project a detailed literature review was made and contacts were made with many agencies officials. The literature review and agency contacts will be used as a springboard in obtaining future funding in this research area. The U.S. Army Corps of Engineers has already expressed a keen interest in the project and will be attempting to fund some preliminary studies in this area in fiscal year 1983.

The objectives of this project are as follows:

I. Identify basins in Idaho and melt seasons where it would be advantageous to study snowcover depletion patterns.

II. Identify in a preliminary fashion what parameters might be useful in predicting snowcover depletion patterns.

III. Determine if existing predictive models might be modified to take advantage of new information obtained during the snowcover depletion studies.

IV. Develop a research plan for making a detailed study of the snowcover depletion problem. This part of the project will include time and cost estimates.

V. The final objective of the project was to make contacts with agencies concerned with water management. These contacts were made to gain ideas for future studies and to explore avenues of possible support from the various agencies.

PREVIOUS INVESTIGATION IN THIS AREA OF STUDY

The use of satellite imagery as a remote sensing tool is a rapidly expanding field. Literally hundreds of papers have been written on the single topic of using satellite imagery in predicting snowmelt runoff. A bibliography of references on this subject follows this report. A good share of these papers deal with using satellite imagery for real time predictions of runoff. While snowmelt predictions are an important aspect of the use of satellite imagery, there is very little material on use of imagery on past snowmelt events in an attempt to fine tune a runoff model for a particular part of the melt seasons on a single river basin.

Previous studies indicate several types of imagery are available that are adequate for use in snow covered area measurement. Data is available from high altitudes geosychronous satellites, low level satellites and from flights of high altitude aircraft. (Barnes, 1979) Studies indicate the imagery available from the Landsat Series of low altitude satellites appears to be the best compromise between picture resolution and coverage interval. The most significant problems that were disclosed in the literature review are concerned with quality and availability of imagery.

Problems with imagery quality are due largely to cloud cover during the melt season. Imagery availability is a function of the number of Landsat satellites operational at any given time. In the period 1972 to 1982 a maximum of two operational satellites were orbiting. Under these conditions coverage of a single area is provided every seven days. (Rango, 1980). When only one satellite is operational the period between satellite passovers is 14 days. Figure 1 shows the

OPERATIONAL LIFELINES OF LANDSAT SATELLITES

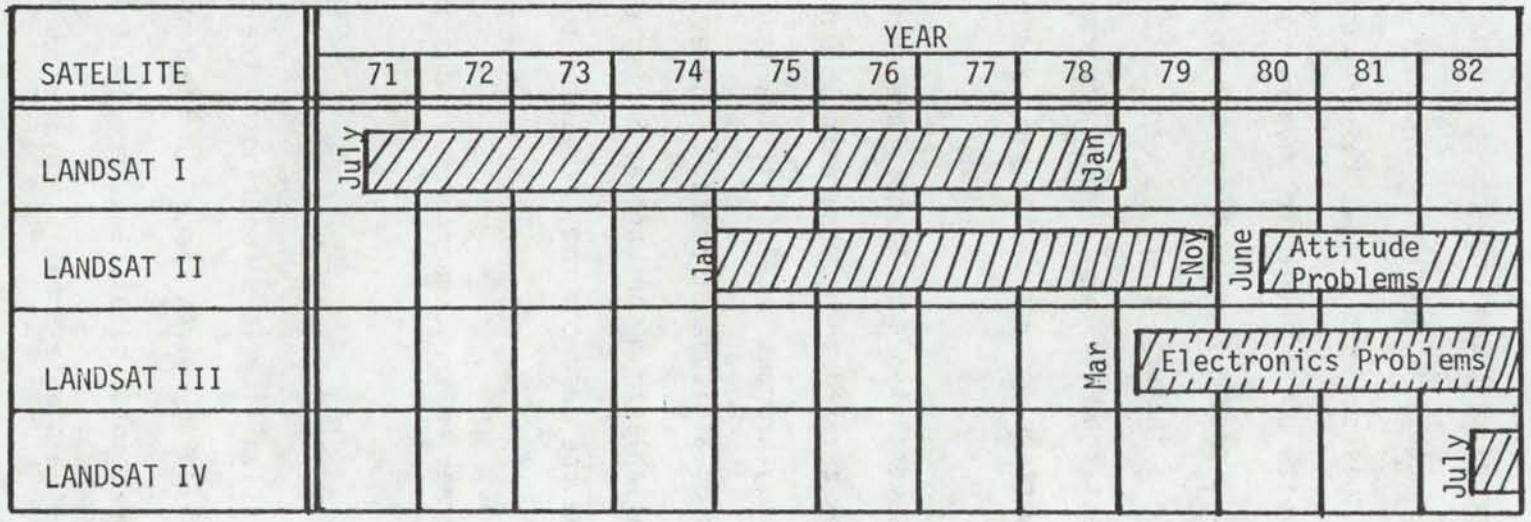

FIGURE 1

AVAILABILITY OF IMAGERY FROM LANDSAT SERIES OF SATELLITES

operational lifelines for the various satellites in the Landsat Series. Annotations are made showing times when special operational problems were present.

The most significant facts that were uncovered during the review of previous work were:

1. The quality of landsat imagery is such that snow covered areas can be and have been accurately mapped.

2. The availability of relatively cloud free imagery during the melt season may be a problem. The only sure way to choose acceptable imagery is to preview the scenes at the EROS, Sioux Falls, Iowa facility before purchasing.

3. It appears that no previous work has been done in the area of using the satellite imagery to fine tune a runoff prediction model such as the U.S. Army Corps of Engineers SSARR model.

STUDY BASINS AND SNOWMELT SEASONS

Contacts were made with both the U.S. Army Corps of Engineers, Walla Walla District, and the U.S. Bureau of Reclamation, Boise Regional Office. These contacts were made to determine which river basins would be best to use in carrying out the snowcover depletion pattern research. Army Corps official suggested both the Clearwater River Basin and the Boise River Basin as possible candidates for study. Of the two, they expressed the greatest interest in the Boise basin. Bureau of Reclamation personnel were in agreement that the Boise River Basin was one of their most important operational systems. Both agencies expressed that the SSARR model was particularly susceptible to late season runoff errors.

Because of the limitations in usable data, at this time it appears that all melt seasons from 1972 should be included for preliminary screening. Some melt seasons may be excluded from further consideration due to unavailability of usable imagery. The decision on exclusion of certain melt seasons should come after a complete review of available imagery is made at the EROS Data Center.

In view of Water Control Agency interests and data availability it is recommended that the Boise River Basin be the basin to use in developing the Snow Cover Depletion Methodologies. All melt seasons where adequate Landsat Imagery is available should be studied. If the study of the Boise Basin is successful and improvements to the SSARR model predictive capabilities can be made, then the techniques developed should be applied to other basins in Idaho and the Northwest.

FUTURE STUDIES

The first phase of any future studies will be to determine what usable imagery is available. As was discussed earlier, cloud cover over the test basin will be the deciding factor as to the usability of a particular Landsat Image. The staff at the EROS Data Center, where the imagery is stored, can provide some preliminary information on cloud cover, but in order to make a final determination on what imagery is usable it will be necessary for the investigators to visit the EROS Data Center to preview and select the usable imagery.

Once the usable imagery has been identified and secured the first major task will be to transfer the snow covered areas from the satellite photographs to overlays of common topographic maps. This transfer would be done using the Zoom Transfer Scope which is available at the University of Idaho, College of Forestry remote sensing lab. This instrument is especially designed for projecting photographs. It has the ability to change scales and adjust for distortion in both the X and Y directions. The staff at the remote sensing lab seem confident that the instrument can do the work that is required for this project.

Officials of the Walla Walla District of the U.S. Army Corps of Engineers are very interested in these first phases of the project. They are presently trying to secure funds to carry out these phases of the project. More information on the possibility of this funding source will be available after January 1983.

The next step in the project will be to compare the satellite snow covered areas with those documented using aerial snow flights and from snow surveys. Both the Corps of Engineers and Bureau of Reclamation

have promised full cooperation in supplying aerial snow survey and snow course data. It is invisioned that a set of snow covered area maps at the same scale as the maps developed from the satellite imagery will be developed using the aerial snow survey and snow course data.

The next phase of the study will involve physically measuring the identified snow covered areas. The Boise Basin will first be split into several subdrainages. Next the gross snow covered area will be measured for each subdrainage, following this the amount of snow covered area within certain elevation bands within each subdrainage will be determined. Next the elevation bands will be subdivided by direction of slope exposure and snow covered area determined as a function of slope exposure. Also the factor of forest canopy cover will be evaluated by further dividing the different slope exposures into areas of high and low densities of forest cover.

It is known that elevation, direction of slope exposure and forest canopy all affect the runoff process. By methodically quantifying the snow covered area as a function of these parameters the relationship between snowcovered areas and these parameters should become better understood. Other parameters such as accumulated degree days and percent of total annual runoff will also be used in trying to define the functional relationships that describe the depletion of the snowpack in the individual subbasins. During the course of these studies other variables affecting the snow cover depletion patterns may be uncovered. These will also be evaluated. Multiple regression analysis techniques will be used to quantify the functional relationships between the snow cover depletion patterns and those parameters identified as being significant.

The final phase of the study will involve developing methods of adjusting the SSARR model input variables so that a more accurate prediction of runof timing and volume is obtained. The use of distorted area elevation curves and dummy snow melt basins have been discussed as possible ways of tuning the model to exact basin conditions (conversations with Corps of Engineers officials). Many other possibilities will develop after a better understanding of the snow cover depletion pattern is developed in the first phases of the project. This final portion of the study will be done in close coordination with Corps of Engineers and Bureau of Reclamation officials so that the procedures developed are usable by those agencies that are using the model SSARR on a day to day forecasting basis.

STUDY PLANS

This portion of the report will deal primarily with the logistics, both time and monetary, of carrying on future studies in this research area. The financial and time plans will be used in proposals that will be submitted to various agencies for future funding.

Because it appears that support for the first phase of data collection will be funded separately by the Corps of Engineers, this phase has been separated from the rest of the study. A short description of what is to be accomplished and the financial and time plans for this phase of the study follows.

This first phase of the study will involve acquiring the necessary imagery and transferring the snow covered areas shown on the imagery to overlays to be used with U.S. Geological Topographic Maps. The basic objectives of this phase of the project will be to:

I. Travel to EROS Data Center, in Sioux Falls, South Dakota to determine which satellite imagery will be suitable for use in the studies.

II. Order suitable imagery from EROS Data Center.

III. Transfer snow covered area from satellite imagery to 1:250,000 scale overlays using the Zoom Transfer Scope.

IV. Reproduce one set of overlays for the sponsoring agency.

Figure 2 shows a proposed time schedule for completion of this first phase of the study. Table 1 shows a financial plan for carrying out the study.

FIGURE 2
PROPOSED TIME SCHEDULE
PHASE I
IDENTIFICATION OF SNOW COVER
DEPLETION PATTERNS USING
SATELLITE IMAGERY

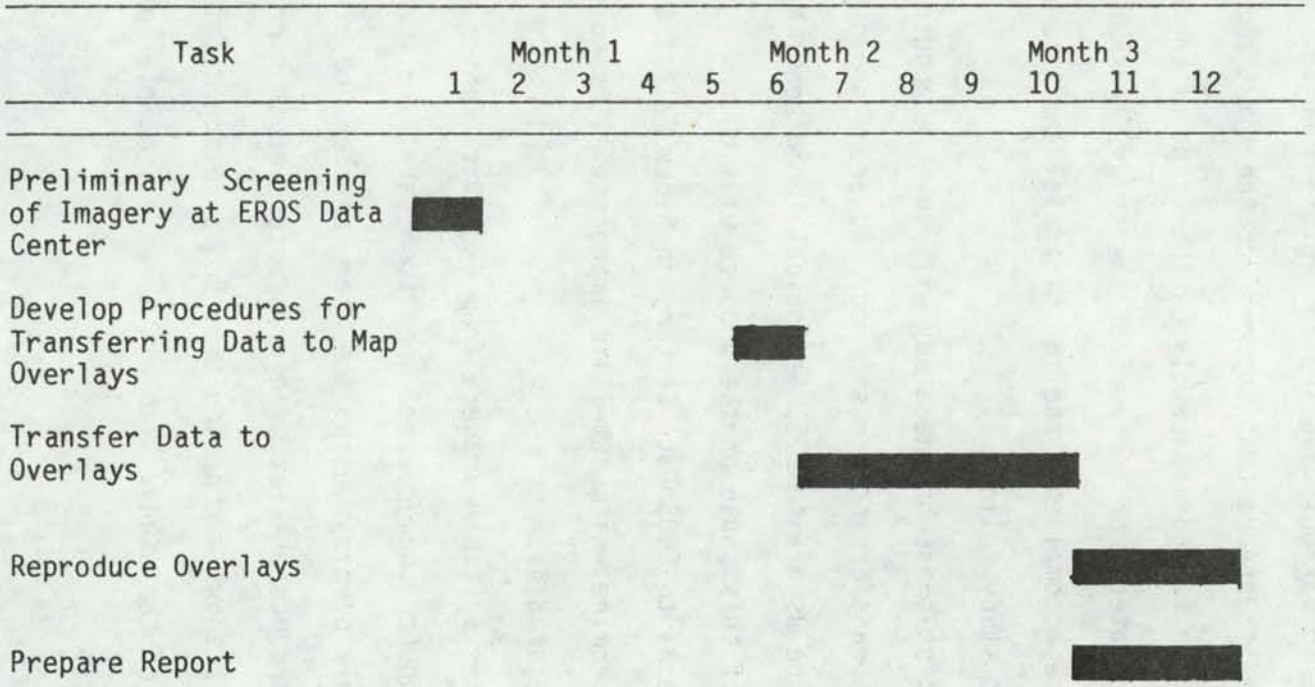

TABLE 1
PRELIMINARY BUDGET
FOR
PHASE I
Identification of
Snow Cover Depletion
Patterns Using Satellite Imagery

I. Salaries		
1. Professional		$ 3,000.00
2. Grad Student		---
3. Technicians		---
4. IH		1,500.00
Total Salaries		4,500.00
II. Employee Benefits	23% Staff 8% IH and Grads	810.00
III. Other Expenses		
1. Publication		50.00
2. Computer		---
3. Telephone		50.00
4. Supplies		150.00
5. Reproduce Overlays		250.00
IV. Travel		
One trip to EROS Data Center		600.00
One trip to Walla Walla		50.00
	Subtotal	6,460.00
V. Indirect	39.5% of Subtotal	2,551.70
VI. Capital Outlay Satellite Imagery		6,750.00
VII. Total		$15,761.70

The Second Phase of the study will involve analyzing the data generated in Phase I, and developing methods for adjusting the SSARR model so that it is a more accurate predictor of runoff.

The Basic Objectives of this study:

I. Compare satellite snow covered areas with snow flight data.

II. Measure snow covered areas in terms of gross basin area, by elevation band, by aspect of ground slope, by type of cover.

III. Perform regression analysis to idenfity trends in the snow cover depletion patterns.

IV. Develop methods of adjusting the SSARR model using the information developed in parts I, II, III. This objective will involve actually operating the model.

A proposed Time Schedule of work is shown in Figure 3. Proposed budgets for performing this phase of the study is shown in Tables 2 through 4. Tables 2 and 3 show budgets for the first and second years respectively. Table 4 shows the budget for the entire Phase II study. Table 5 shows the budget for the combined Phase I and II projects.

FIGURE 3
PROPOSED TIME SCHEDULE
PHASE II
IDENTIFICATION OF SNOW COVER
DEPLETION PATTERNS USING
SATELLITE IMAGERY

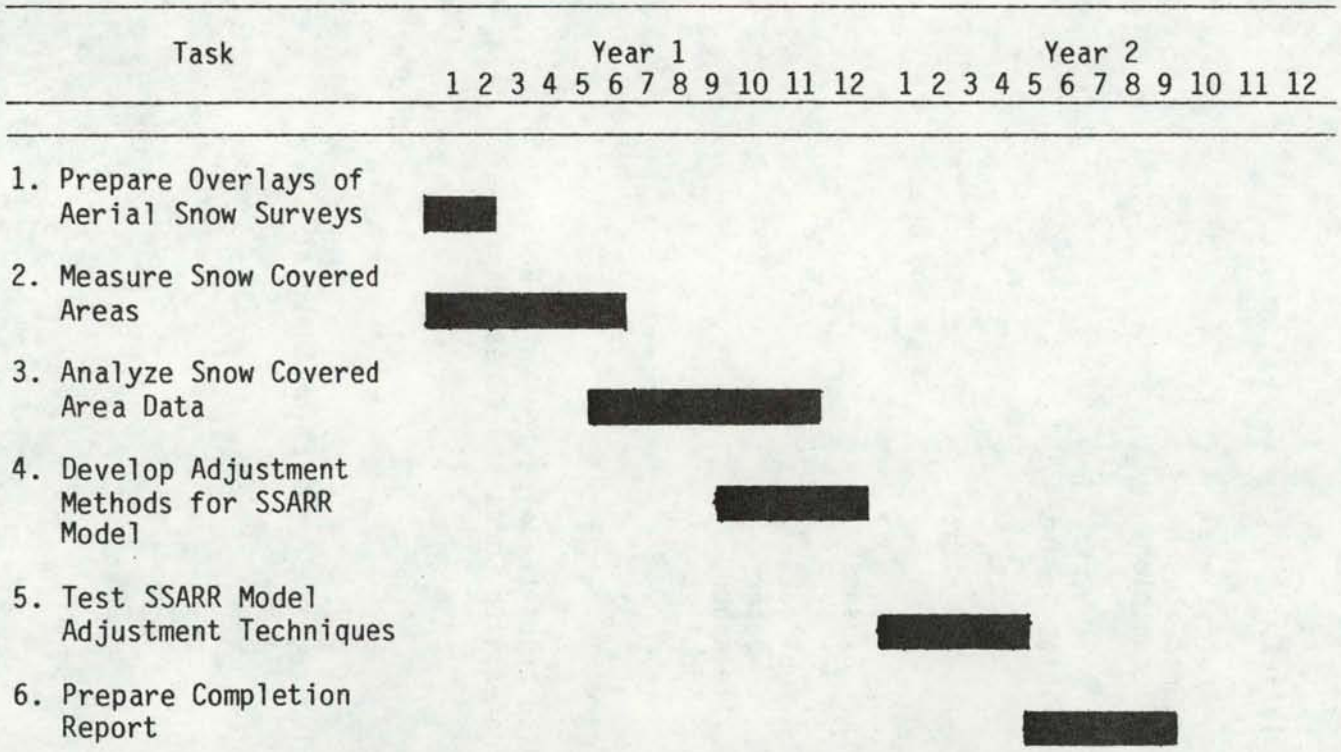

TABLE 2
PRELIMINARY BUDGET
PHASE II 1ST YEAR
IDENTIFICATION OF
SNOW COVER DEPLETION
PATTERNS USING SATELLITE IMAGERY

I. Salaries		
1. Professional		$ 8,583.00
2. Grad Student		8,186.00
3. Technicians		---
4. IH		2,000.00
Total Salaries		18,769.00
II. Employee Benefits	23% Staff 8% IH and Grads	2,788.97
III. Other Expenses		
1. Publication		100.00
2. Computer		500.00
3. Telephone		50.00
4. Supplies		100.00
IV. Travel		
Misc trips to Boise and Walla Walla to confer with Corps and Bureau personnel		250.00
	Subtotal	22,557.97
V. Indirect	39.5% of Subtotal	8,910.40
VII. Total		$31,468.37

TABLE 3
PRELIMINARY BUDGET
PHASE II 2ND YEAR
IDENTIFICATION OF
SNOW COVER DEPLETION
PATTERNS USING SATELLITE IMAGERY

I. Salaries		
1. Professional		$ 6,500.00
2. Grad Student		5,806.00
3. Technicians		---
4. IH		---
Total Salaries		12,306.00
II. Employee Benefits	23% Staff 8% IH and Grads	1,959.48
III. Other Expenses		
1. Publication		100.00
2. Computer		1,000.00
3. Telephone		50.00
4. Supplies		100.00
IV. Travel		
Misc trips to Boise and Walla Walla to confer with Corps and Bureau personnel		250.00
	Subtotal	15,765.48
V. Indirect	39.5% of Subtotal	6,227.36
VII. Total		$21,992.84

TABLE 4
PRELIMINARY BUDGET
TOTAL PHASE II
IDENTIFICATION OF
SNOW COVER DEPLETION
PATTERNS USING SATELLITE IMAGERY

I. Salaries		
1. Professional		$15,083.00
2. Grad Student		13,992.00
3. Technicians		---
4. IH		2,000
Total Salaries		31,075.00
II. Employee Benefits	23% Staff 8% IH and Grads	4,748.45
III. Other Expenses		
1. Publication		200.00
2. Computer		1,500.00
3. Telephone		100.00
4. Supplies		200.00
IV. Travel		
Misc trips to Boise and Walla Walla to confer with Corps and Bureau personnel		500.00
	Subtotal	38,323.45
V. Indirect	39.5% of Subtotal	15,137.76
VII. Total		$53,461.21

TABLE 5
PRELIMINARY BUDGET
TOTAL STUDY
IDENTIFICATION OF
SNOW COVER DEPLETION
PATTERNS USING SATELLITE IMAGERY

I. Salaries		
1. Professional		$18,083.00
2. Grad Student		13,992.00
3. Technicians		---
4. IH		3,500
Total Salaries		35,575.00
II. Employee Benefits	23% Staff 8% IH and Grads	5,558.45
III. Other Expenses		
1. Publication		250.00
2. Computer		1,500.00
3. Telephone		150.00
4. Supplies		350.00
5. Reproduce Overlays		250.00
IV. Travel		
One trip to EROS Data Center		600.00
Misc trips to Boise and Walla Walla to confer with Corps and Bureau of Reclamation officials		550.00
	Subtotal	44,783.45
V. Indirect	39.5% of Subtotal	17,689.46
VI. Capital Outlay - Satellite Imagery		6,750.00
VII. Total		$69,222.91

AGENCY CONTACTS

One of the major objectives of this study was to contact water management agency officials to obtain their insights into how further studies in the area of snow cover depletion should be carried out, and also to explore the possibilities for future funding.

The first contact that was made was with the Walla Walla District of the U.S. Army Corps of Engineers. Mr. Robert Rickel, Chief of the Hydrology Section, and Mr. David Reece, Chief of Reservoir Operations, attended a meeting at the Walla Walla District office where various aspects of the snow cover depletion problem were discussed. Rickel and Reece described the operational problems that exist during the late stages of snowmelt in the Boise and Clearwater Basin.

They expressed an interest in developing ways to adjust the SSARR model so that it would do a better job of predicting snowmelt runoff during the late stages of the melt season. They were interested in developing these methods in both the Clearwater and Boise Basins but felt that the Boise Basin should be studied if only one basin were examined.

Mr. Rickel suggested that some end of year (1982) money might be available for doing some of the preliminary work such as purchasing satellite imagery and delineating snow covered areas. He also pledged their full cooperation in providing access to their data or aerial snowflights.

Some time was also spent with Mr. Rick Emmert of the Reservoir Operations Section of the Corps of Engineers in Walla Walla. He has been working with the latest version of the SSARR model and had some very useful insights into how the model might be adjusted using the information that might be generated from further snow cover depletion studies.

Contact was also made with officials from the Bureau of Reclamation Regional Office in Boise, Idaho. This Agency, along with the Walla Walla District of the Corps of Engineers, is responsible for operation of the Boise River reservoir system. A meeting was held with Joe Winsman who works in the Reservoir Operations area. He was very interested in the Snowcover Depletion Study. The Bureau of Reclamation also use the SSARR model as part of their forecasting procedure and he described problems with the SSARR model similar to these experienced by the Corps of Engineers during the latter stages of snow melt in the Basin. Since the late season refill period is very important to their operation, he expressed an interest in any study that might enhance the SSARR models predictive capabilities.

The Bureau of Reclamation maintains a sophisticated Hydro-Meteorological data acquisition system in the Boise Basin. Mr. Winsman pledged that the Bureau would provide any of this hydromet data that might be required for the study.

Even though both the Corps of Engineers and Bureau of Reclamation expressed interest in the study only the Corps of Engineers expressed an interest in providing funding support for the study.

Early in September 1982 the Corps of Engineers offered to fund the first phase of the study using end-of-year funds. Because of the time restrictions that would have been placed on completion of the study the funding was turned down. The Corps of Engineers is still interested in this project and hopefully funding will be available so that at least phase I of the study can be completed in the summer of 1983. Other sources of funding such as the Bonneville Power Administration, and the Northwest Energy Planning Council will also be explored. This report will serve as the core document for any proposals that might be submitted to these agencies.

SUMMARY AND CONCLUSIONS

This study allowed the principle investigator to explore a relatively new research area and to do the required library research and make the contacts necessary to secure future funding in the area. It appears that the prospects are very favorable for securing funding for at least the first phase of the research outlined in this report. If this first phase data gathering can be accomplished favorably, the prospects will be brighter for obtaining support from other agencies for future work in this research area.

All of the original objectives set out in the research proposal have been met. The Boise Basin has been identified as the basin on which to develop the snowcover depletion pattern methodology. Sources, costs, and availability of imagery have been explored. It appears that adequate data at a reasonable price will be available to carry out the study. Parameters describing snow covered area as a function of elevation band, aspect of slope, forest cover, are all felt to be useful in describing the snow cover depletion problem. These factors will be examined if future studies are funded in this area.

Complete financial and time plans were developed for completing the proposed snow cover depletion research. The proposed research was split into two phases. The first being essentially a data gathering phase. The second being the analysis phase. This splitting was done because it was felt that obtaining funding for two smaller projects would be easier than trying to get funding for the entire project at one time.

Finally contacts were made with water management agency officials to obtain further insights into how the snow depletion problem should

be addressed. Also prospects of obtaining data and future funding were discussed. The Agency contacts were very successful. The Corps of Engineers and the Bureau of Reclamations promised cooperations with data and were very helpful in pointing out the exact areas where they felt research would be most profitable. The Corps of Engineers has also expressed an interest in funding the first phase data gathering portion of the study.

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16. Abstract

The purpose of this research was to investigate whether there is a possibility of using satellite imagery to finely calibrate large scale basin runoff models. It is anticipated that by better understanding the snowcover depletion patterns in a basin the runoff models might be adjusted to better forecast both quantity and timing of run-off especially in the late stages of the snowmelt season. This forecasting of runoff is essential to the optimal operation of large multi-purpose, multi-reservoir water control systems.

While no actual field or laboratory research was carried out, as a result of this project, a detailed literature review was made and contacts were made with many agency officials. The literature review, agency contacts and various parts of this report will serve as springboards in efforts to secure future funding in this research area.

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17a. Descriptors

*Remote sensing, Satellites, Snow cover, Snow melt, Ablation, Streamflow forecasting, Runoff forecasting.

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