TECHNICAL TERMINATION REPORT
Project A-034-IDA
Open File Series No. 203

Professor C. C. Warnick, Project Leader
July 1971 - June 1974

TECHNIQUES FOR DETERMINING AMOUNT AND DISTRIBUTION OF PRECIPITATION IN MOUNTAIN VALLEYS OF IDAHO

by

E. Woody Trihey
Idaho Water Resources Research Institute

Submitted to:

Office of Water Resources Research
United States Department of the Interior
Washington, D.C. 20240

June 1974

This project was supported primarily with funds provided by the Office of Water Resources Research as authorized under the Water Resources Research Act of 1964.

Idaho Water Resources Research Institute
University of Idaho
Moscow, Idaho

John S. Gladwell, Director

FOREWORD

This termination report represents an attempt to develop new techniques by which basin precipitation can be estimated. Unfortunately, due to circumstances described herein, it is not possible at this time to state anything other than, "further study is required." The procedures developed appear to be promising; however, until further work can be accomplished, the efforts must be assumed to be preliminary in nature.

ACKNOWLEDGMENTS

The author wishes to acknowledge Mr. Edwin Schlender, General Manager of the Raft River Rural Electric Cooperative in Malta, Idaho, whose contributions to the overall success of the field work were considerable. Mr. Schlender provided materials, manpower, tools, working and storage space, and a 4-wheel drive vehicle, as well as many helpful suggestions and ideas. Furthermore, his efforts in enlisting the good will and cooperation of local residents through phone calls, introductions and personal visits along with favorably publicizing the project through an article in the "Ruralite", a magazine of the public power companies in the area, were most helpful in expediting the field work.

Other assistance deserving of special recognition was provided by the Idaho Department of Water Administration. During the first year of the study a vehicle and a summer employee, Brent Clayborn were provided to assist with the installation of the temporary gage network. The Northwest Watershed Research Center of the Agricultural Research Service, U.S.D.A., Boise, Idaho installed two Belfort weighing rain gages in the basin specifically for this study. Also Mr. Walter Rawls, a hydrologist with the A.R.S. in Boise, actively participated on the graduate student's committee as an affiliate faculty member.

The author wishes to emphasize the cooperation of local landowners, Yale Montgomery, Roland Rose, Duane Campbell and Glen Berryman, upon whose property installations were maintained. All other gages were located at sites within the Sawtooth National Forest boundaries.

The assistance of graduate students David L. Curtis and David

H. Fortier while carrying out the field work should also be recognized as well as the guidance and counsel extended to the author by Dr. John S. Gladwell, Dr. Myron Molnau, and Professor C.C. Warnick.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Early settlement of the Raft River Valley occurred in the meadowland adjacent to the river and its tributary streams by cattlemen in the 1870's. Since summer range was available in the high country for herds wintered on the valley's bottomland, any development or change from cattle country was slow in coming. Farming in the valley was done primarily to support the local cattle herds until World War II. During the war dry land farming became well established along the western slopes of the Sublett and Black Pine Ranges.

The largest surge of development to date occurred (from 1948 through 1955) with the introduction of high lift pumping and irrigated agriculture to the basin. During this period ground water withdrawals increased from approximately 9,000 acre-feet/ year to well over 60,000 acre-feet/ year. This trend continued on through the 1960's until some 87,000 acres were irrigated with ground water. Pumping continued to increase to 235,000 acre-feet in 1966. (Walker, et.al., 1970). This rapid increase in withdrawal rate (1948-1966) resulted in a net water-level decline beneath some 235 square miles of the valley floor; exceeding 50 feet in several wells north of Malta. Because of the potential effect of these declines on established water rights, the basin was closed to further applications to appropriate ground water in 1963. The opposition to closure voiced by local interests and some ensuing litigation has served to underscore the need for more detailed information on the water resources of this basin. Three independent studies of the Raft River Basin, conducted over a period of several years, have shown water yields of 180,000, 320,000, and 140,000 acre-feet of water per year (Nace, et.al., 1960; Mundorff and Sisco, 1963; Walker, et.al., 1970). To help resolve issues stemming from this range of water yield estimates additional information was required on precipitation distribution in the basin. It was felt that a systematic measurement of precipitation with the subsequent preparation of an isohyetal map would confirm the general magnitude of the annual water input to this basin, thereby complementing the previous water yield studies and providing information for future management decisions.

Primarily as a result of the interest shown by the Director of the Idaho Department of Water Administration in obtaining substantive information relative to the management of the Raft River Basin's ground water resource, Professor John J. Peebles secured this allotment grant in July 1971. The study was envisioned as developing new techniques to determine precipitation distribution in mountainous valleys through correlation and regression analyses employing such parametric data as elevation, slope, aspect, cover class and soil type at the gage sites. Therefore the gages were deployed to facilitate these types of analyses rather than to serve as a conventional precipitation network. Professor Peebles resigned in the spring of 1972 and the continuity of his original plan of study was disrupted. Further, due to numerous gage malfunctions early in the project a credible data base was not obtained.

The author was introduced to this project in September of 1972, but did not become formally involved with it until July 1973. Considerable effort was expended improving upon the field installations themselves. Data presented in Tables 3 and 4 of the RESULTS section indicate the low-profile, ground level gages developed toward the end of this study capture meteoric water available at the site on an annual basis. Furthermore, they have been less subject to damage by vandals than conventional gages and are considered sufficiently reliable and capable of measuring annual true-ground precipitation to warrant further investigation. Several techniques are presented which possess considerable utility to those interested in establishing reconnaissance type precipitation networks.

DESCRIPTION OF THE STUDY AREA

The Raft River Basin lies in Cassia, Power and Oneida Counties in southcentral Idaho and in Box Elder County in northwestern Utah (Figure 1). It includes approximately 1500 square miles of which nearly 700 square miles is in the broad gently sloping river valley that extends southward from the Snake River Plain. The Raft River heads in the Goose Creek Mountains of Utah and flows northward about 80 miles where it joins the Snake River in the backwaters of Lake Walcott, a federal reclamation reservoir on the upper Snake River.

The climate of the Raft River Basin ranges from sub-humid in the high mountains to semi-arid on the valley floor. Recorded temperatures in the valley fall between -14•F and 99•F with the mean annual temperature for the lower Raft River Valley being between 45 and 48 degrees Fahrenheit. The average frost free period appears to be around 100 days. Average summertime humidity is estimated as 25% and the total probable evaporation from open-water surfaces would exceed 45 inches (Nace, et.al., 1960).

The Raft River Basin contains all or parts of five mountain ranges which play an important part in both the distribution and total amount of precipitation: The Sublett Range to the east, the Malta or Cotterell Range in the central part, the Albion Range to the west, the Black Pine Range to the southwest, and the Raft River Mountains to the south. All have a general north-south directional trend except the Raft River Mountains which lie in an east-west direction (Figure 1). With the exception of the Sublett Range, mountains in the Raft River Drainage rise approximately 5,000 feet above the valley floor to maximum elevations in

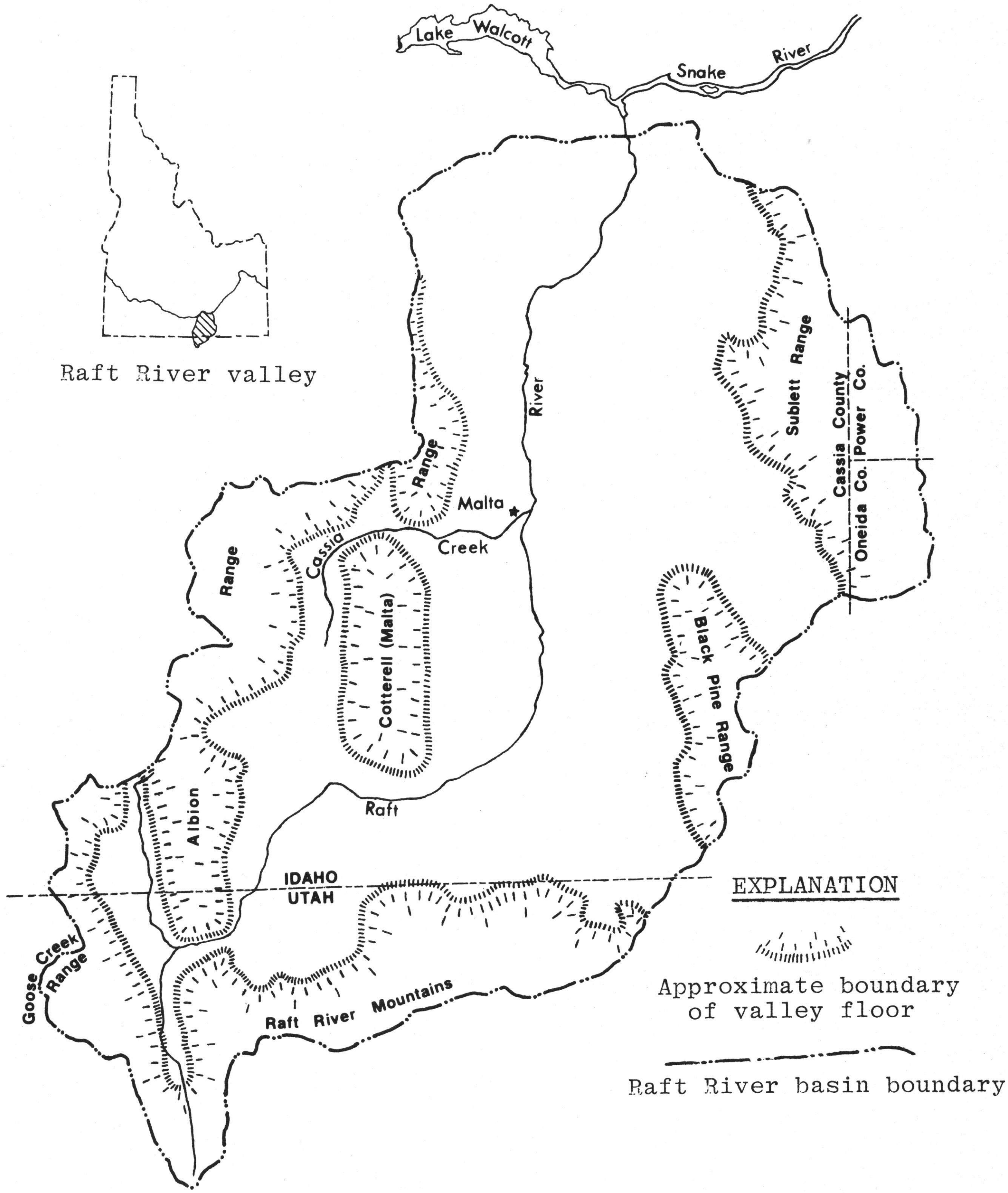

Figure 1. Location Map Raft River Basin

in the range of 10,000 feet mean sea level.

The Sublett Range forms the eastern boundary of the Raft River Basin and is the lowest of the mountains cited. Its maximum elevation is about 7,500 feet, and because of this, the range-like aspect of its neighbors is not as pronounced and it appears more like a broad plateau.

Most of the streamflow in the Raft River Basin is a result of snowmelt in the mountains and foothills. On occasion, summer thunderstorms contribute to spectacular runoff events, but runoff for summer storms is usually rather insignificant in comparison to spring snowmelt since most of the summer storm precipitation merely resupplies soil moisture. The average precipitation for the basin is about 15.5 inches. It has been estimated to vary from less than ten inches on the valley floor to more than 35 inches in the Raft River Mountains. (Walker, et.al., 1970).

Native grasses, other edible plants, and sage brush occur throughout the non-cultivated lowlands of the Raft River Basin. Giant rye-grass is abundant in parts of the higher basins which possess suitable soil and moisture conditions. Willows grow thickly along stream channels and in places possessing a high or perched water table if they are not artificially controlled. Juniper and large shrubs are abundant on the upland slopes with dense stands of aspen occurring near springs, seeps and at the heads of small valleys. Pine, fir, and hemlock can be found at high altitudes.

PROCEDURE

Field Work

During the summer and early fall of 1971 a temporary gaging network, consisting of 36 gages located at 24 sites, was established in the Raft River Basin (Figure 2). Legal descriptions of these sites are provided in Appendix 1. Because of the opportunity afforded to located gages in a variety of environments corresponding to increases in elevation, two areas were selected for intensive study. These areas were the north slope of the Raft River Mountains, southwest of Naf, Idaho, and the north and south slopes of Mount Harrison, southeast of Albion, Idaho. Of the 24 sites established, 16 are within these two areas. The remaining eight sites are scattered across the upper Raft River Valley.

The sites for locating gages in the intensive study areas were chosen mainly on the basis of elevation with slope, aspect, exposure and surrounding vegetation playing key yet subordinate roles. Gages were placed from 5,600 feet elevation to 9,100 feet on slopes ranging from zero to 26 degrees (table 1). Eight of the 24 sites had more than one type of gages installed to facilitate a comparison between standard gages and those being developed on this project.

The gages employed in this study were of the five basic types indicated in Table 1. Two were experimental designs intended to meet the requirements of a dependable, low-cost storage gage. Since the experimental gages have been in use, each has been modified once.

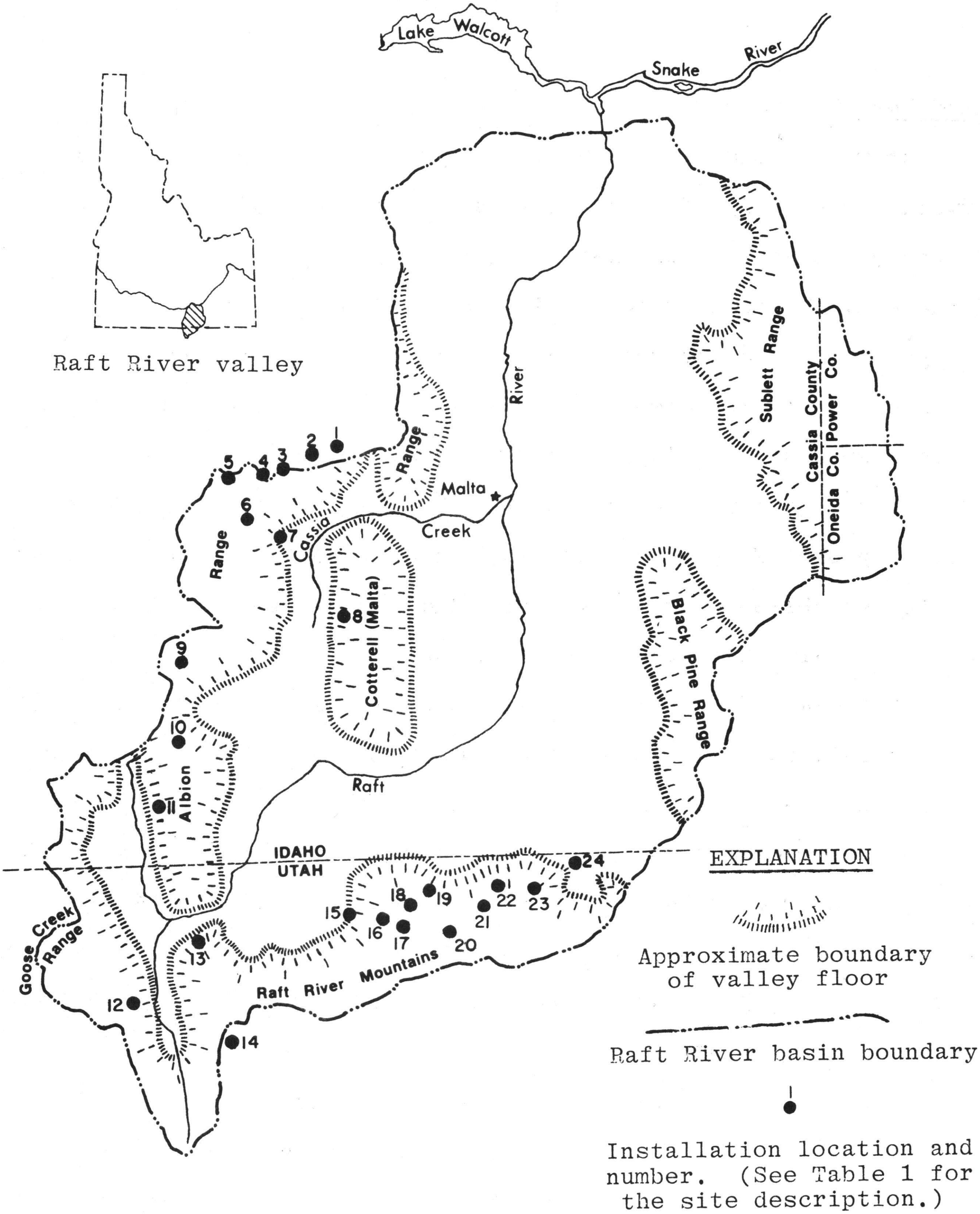

Figure 2. Project Gages in the Raft River Basin

TABLE 1

Project Gages in the Raft River Basin

Site Number	Name of Installation	Type of Gage	Elevation m.s.l.	Gage Height	Slope Degrees	Aspect
1	Albion	5 gallon pit	5800	6"	-3	North
2	Pine Creek	5 gallon pit	6680	6"	-9	Northeast
3	Connor Ridge	5 gallon pit	7980	6"	-6	Northwest
4	Howell Canyon	5 gallon pit 55 gallon drum 8" x 41"	8020	6" 6" 10'	0	Not defined
5	Mount Harrison	55 gallon drum Sacramento	8880	6" 10'	-3	Northeast
6	Cottonwood	5 gallon pit 8" x 41" storage	6920	6" 10'	-8	Southeast
7	Elba	5 gallon pit	5850	6"	-5	Southeast
8	Franks Hollow	5 gallon pit	6000	6"	-6	Northwest
9	Almo Park	55 gallon drum	8100	6"	-6	East
10	Emery Canyon	5 gallon pit	7000	6"	-12	East
11	Moulton	5 gallon pit	5980	6"	-5	Southwest
12	Cotton Thomas	5 gallon pit	6940	6"	-13	Northeast
13	Lynn Creek	5 gallon pit	6060	6"	0	Not defined
14	Dove Creek Pass	5 gallon pit	7320	6"	-13	East
15	Yost	Buried 8" x 24" Shielded Belfort Unshielded Belfort	6240	6" 10' 10'	0	Not defined
16	Bally Mountain	5 gallon pit	6760	6"	-4	Southwest
17	George Peak	5 gallon pit	8100	6"	-18	North
18	One Mile Summit	5 gallon pit 10' tower; 8" x 41"	7330	6" 10'	-17	Southeast
19	Standrod	5 gallon pit	6480	6"	-3	Northeast
20	Clear Creek	5 gallon pit 55 gallon drum Sacramento	9100	6" 6" 10'	-13	Northwest
21	Pinnacle	5 gallon pit 8" x 41" storage	8750	6" 10'	-10	North
22	Water Canyon	5 gallon pit	8060	6"	-19	North
23	Naf	5 gallon pit	7260	6"	-26	North
24	Campbells	Buried 8" x 24" 8" x 41" storage	5610	6" 7'	-4	Northeast

Use of the standard 8-inch diameter by 24 inch National Weather Service gage was modified slightly to allow it to serve as a precipitation storage gage. The measuring tube was removed and the gage mounted on a 12-inch diameter post projecting approximately three feet above the ground. A modified alter wind shield was also installed. The gage closely resembled a straight tube tower gage; the only significant difference being that the orifice of the modified installation was four feet above the ground rather than the more customary 10 feet (Figure 3).

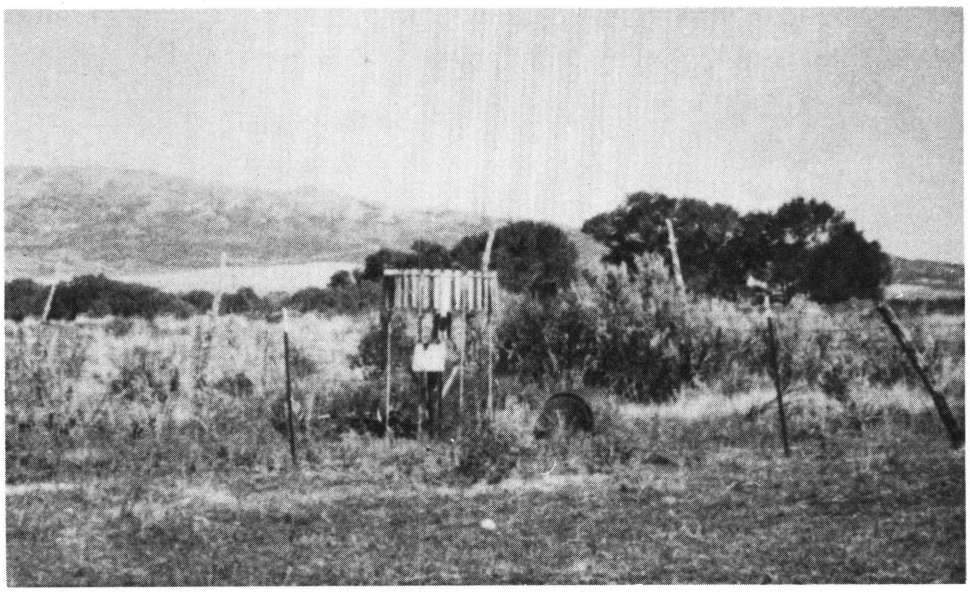

Figure 3. Photograph of Campbell Gage Installation.

Another modification of the standard National Weather Service gage was to again remove the measuring tube and to bury the gage so its orifice would project about six inches above the ground surface. As modified, the National Weather Service gage functioned in a manner similar to the experimental pit gages designed for use on this project and described later in this report.

The second type of gage used on the project was the Belfort Weighing Rain Gage Model 551 equipped with a battery operated 31-day chart drive mechanism. Two of these gages were mounted approximately 20 feet apart on twelve-inch diameter posts projecting seven feet above the ground so that the orifices of the installed gages would be approximately ten feet above the surface of the ground. These gages were installed and calibrated by personnel from the Northwest Water Research Center of the Agricultural Research Service in Boise, Idaho, and were to be serviced by local residents under the direction of the Agricultural Research Service.

The third type of gage used was mounted in a tower. Two are Sacramento type gages with the diameter of their storage area being larger than the diameter of their orifice. These were mounted atop wood frame structures such that the gage orifices were approximately ten feet above the ground surface and parrallel to it. Neither of the Sacramento gages were shielded (Figure 4).

Figure 4. Sacramento Gage installed at the Mount Harrison site.

In addition to the Sacramento gages, three standard light inch diameter by forty-one inch straight-tube storage gages were installed atop steel towers. All are installed such that the gage orifice is parallel with the ground surface and approximately 10 feet above it. Unlike the Sacramento gages, the straight tube storage gages are protected by a modified Alter shield (Figure 5).

Figure 5. Eight by forty-one inch storage gage mounted in a steel tower

The first type of experimental gage employed is referred to as a "pit gage". Since conventional gages mounted in towers or in other such unconcealed manners are easy prey for vandals, a low profile ground-level gage was desired. A two-inch collar was soldered atop a common eight-inch funnel which was then soldered

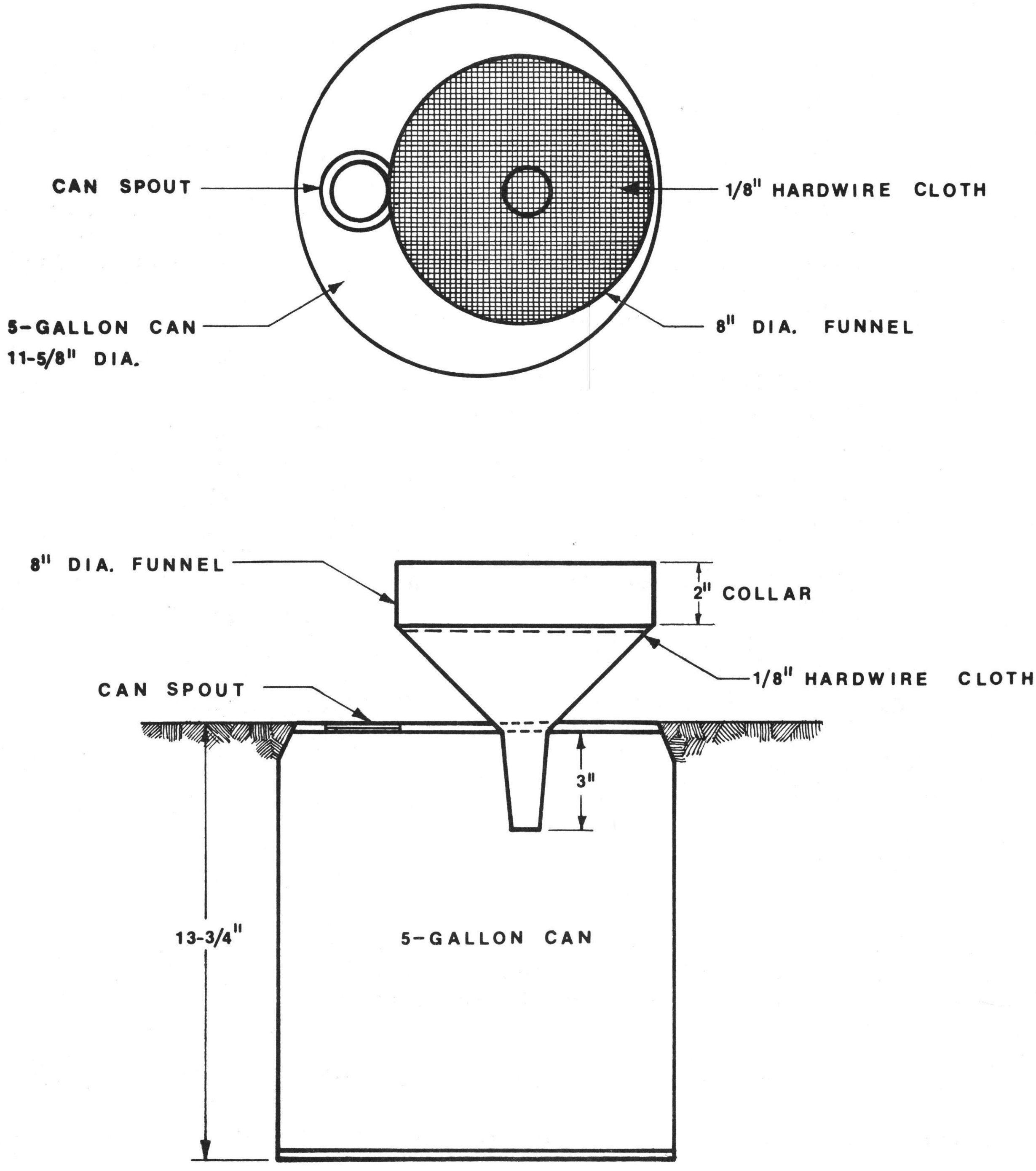

Figure 6. Five Gallon Pit Gage

into the top of a discarded five-gallon can (Figure 6). These gages were then placed in an excavation and back filled so that the top of the five-gallon can was level with the ground surface. In burying the gage in this manner, the orifice was appoximately six inches from the parallel to the ground surface. By the end of September 1971, twenty 5-gallon "pit gages" had been placed in the Raft River Basin. A photograph of a 5-gallon pit gage installation is presented as Figure 7.

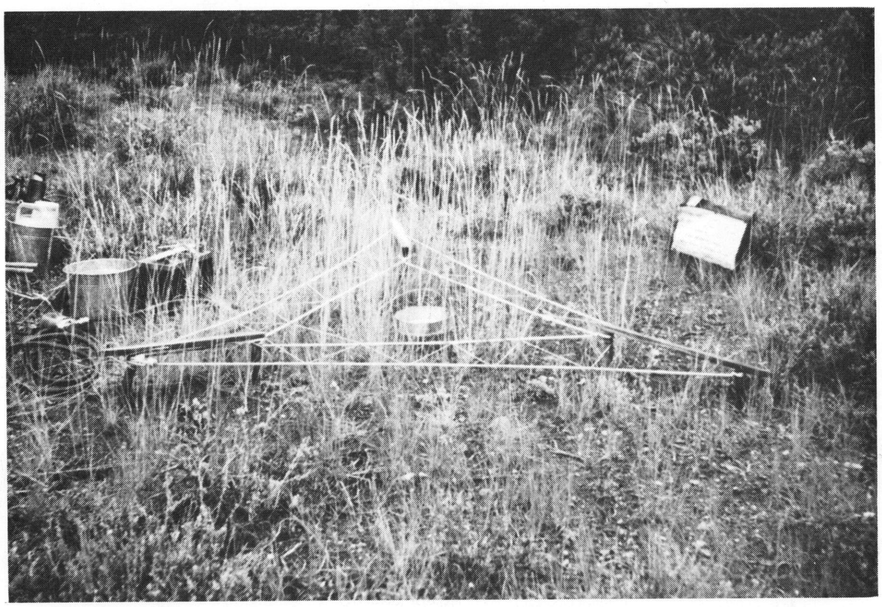

Figure 7. Photograph of 5-gallon pit gage installation with field apparatus in the background.

Inspection of these sites in July of 1972 revealed that precipitation had exceeded the storage capacity of the 5-gallon "pit gages" at nine locations. To prevent the recurrence of a similar event, a larger "pit gage" was assembled from a 10-gallon milk can and an altered eight-inch funnel (Figure 8).

The 10-gallon pit gage not only possessed over twice the storage capacity as the 5-gallon model, but proved to be easier to service. The latex caulk which provides a water tight seal between the funnel and the mild can is easily cut with a well-sharpened linoleum knife, thus allowing one to remove the entire funnel when servicing the gage. The opportunity which this provided for a visual inspection of the gage relieved a great deal of anxiety concerning the degree to which the gage was emptied of its contents.

To keep insects and rodents from becoming trapped inside the funnel and clogging it, a piece of hardwire cloth was placed inside the funnel just below the two-inch collar. Insects or small rodents landing inside the gage orifice were able to escape from sliding down the smooth sides of the funnel and clogging the constriction.

The second experimental gage installed is called a "drum gage" and was intended to function as a large volume pit gage. Installation of this gage consisted of burying a 55-gallon oil drum to a depth of approximately three-fourths its diameter, digging a trench for the collector hose and seating the catchment pan parallel with the ground surface on the uphill side of the installed drum (Figure 9). Drum gages were installed at four high elevation sites during August 1971. A later inspection of these installations in September of 1972 indicated that the technique used for installing these gages could also be improved upon. As a result, the four drum gages in service were exhumed in September of 1973 and repositioned as indicated in Figure 10.

In addition to repositioning the gage to eliminate such problems as air lock and collapsed collector hoses, the inside of the collector was also modified. As originally installed,

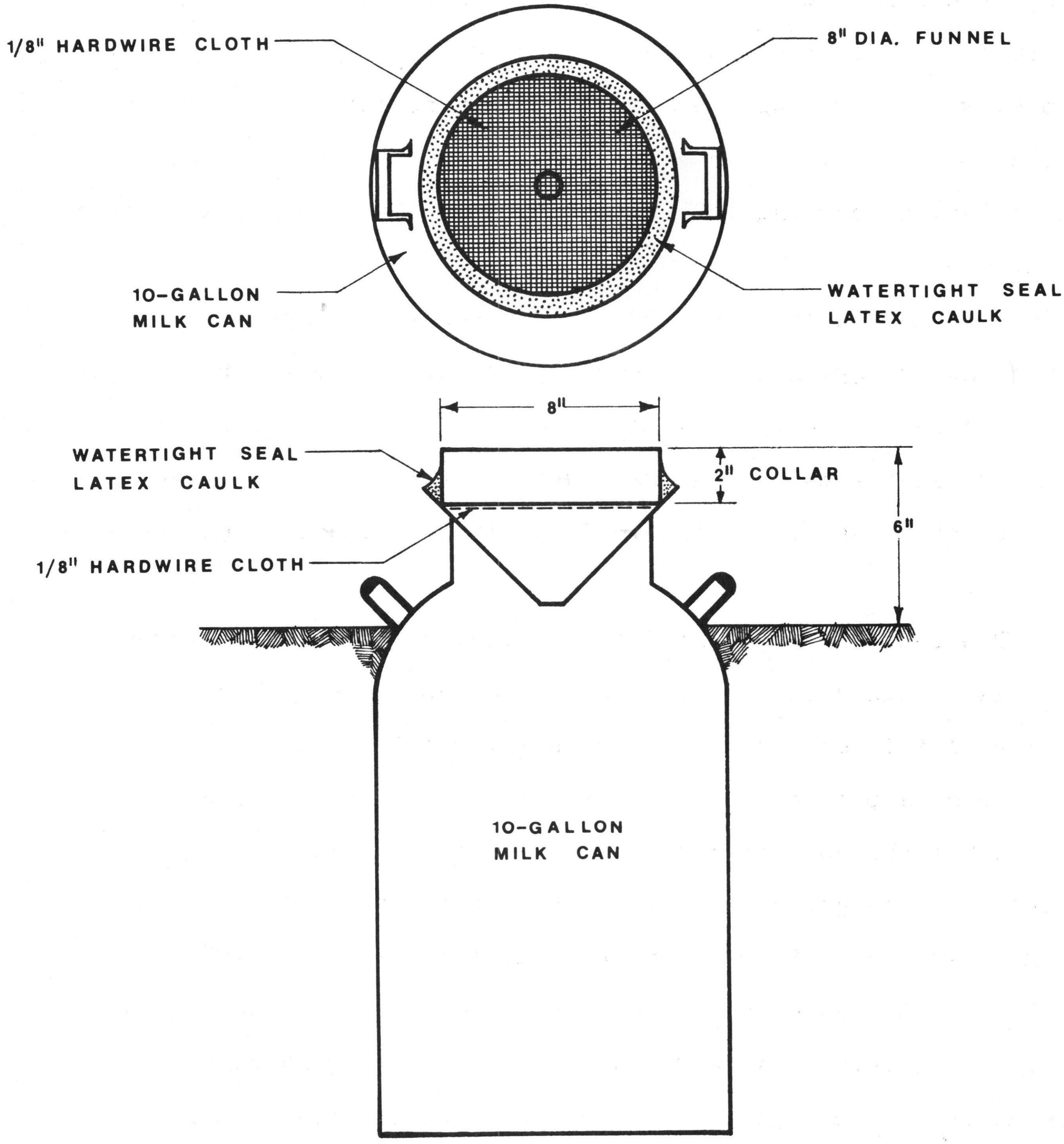

Figure 8. 10-Gallon Pit Gage

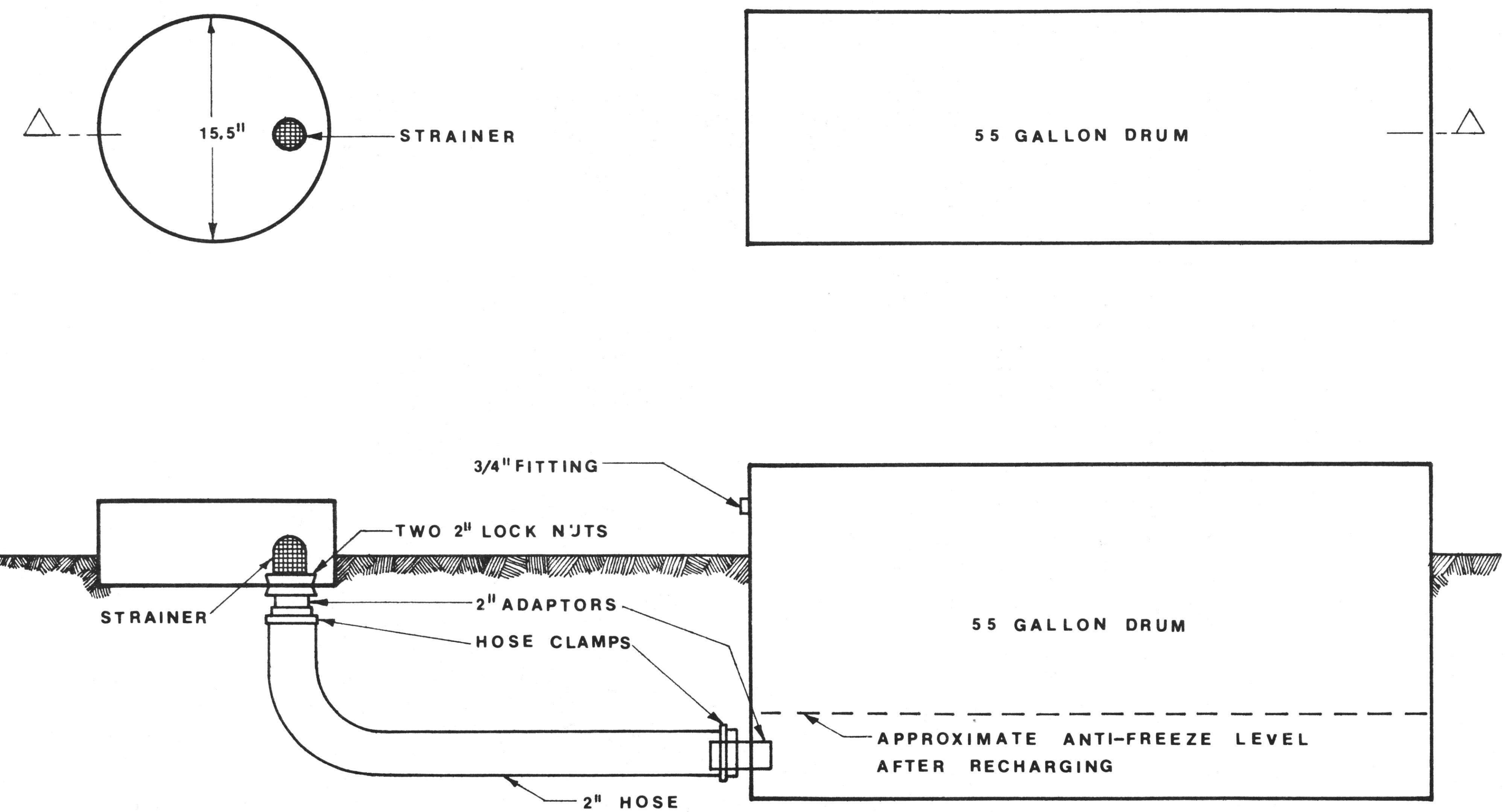

Figure 9. Drum Gage

the lock nut used to attach the collector hose to the catchment pan protruded approximately one-half inch above the bottom of the pan (Figure 9). Even with the catchment pan mounted parallel to the slope of the ground, precipitation from a minor storm could not enter the collector hose. Also, residual precipitation from any major storm would likewise be blocked from entering the collector hose by the protuding lock nut and lost to evaporation. Conceivably, all summer precipitation could be lost since it occurs as a result of high intensity short duration thunder showers. This oversight was remedied in September 1973 by covering the bottom of the catchment pan with latex caulk until it was built-up above the level of the lock nut as shown in Figure 11.

Figure 10. Modified drum installation gage.

An improvised cattle guard (Figure 12) was placed around the experimental gages at all but a few sites. These were enclosed by a barb-wire fence. Based on three years of service, these cattle guards are considered to function adequately. The inexpensive cotton rope and twine did not deteriorate with exposure to the elements, nor was it attacked by rodents. Only one ground level installation was disturbed during the study period. In this case the entire installation was destroyed by vandals.

Figure 11. Catchment pan at Clear Creek Meadows.

Tracks and grazing patterns around the other sites indicated that both domestic stock and wildlife avoided the immediate area of the gage. Figure 13 illustrates the effectiveness of the improvised cattle guard near one of the gage sites:

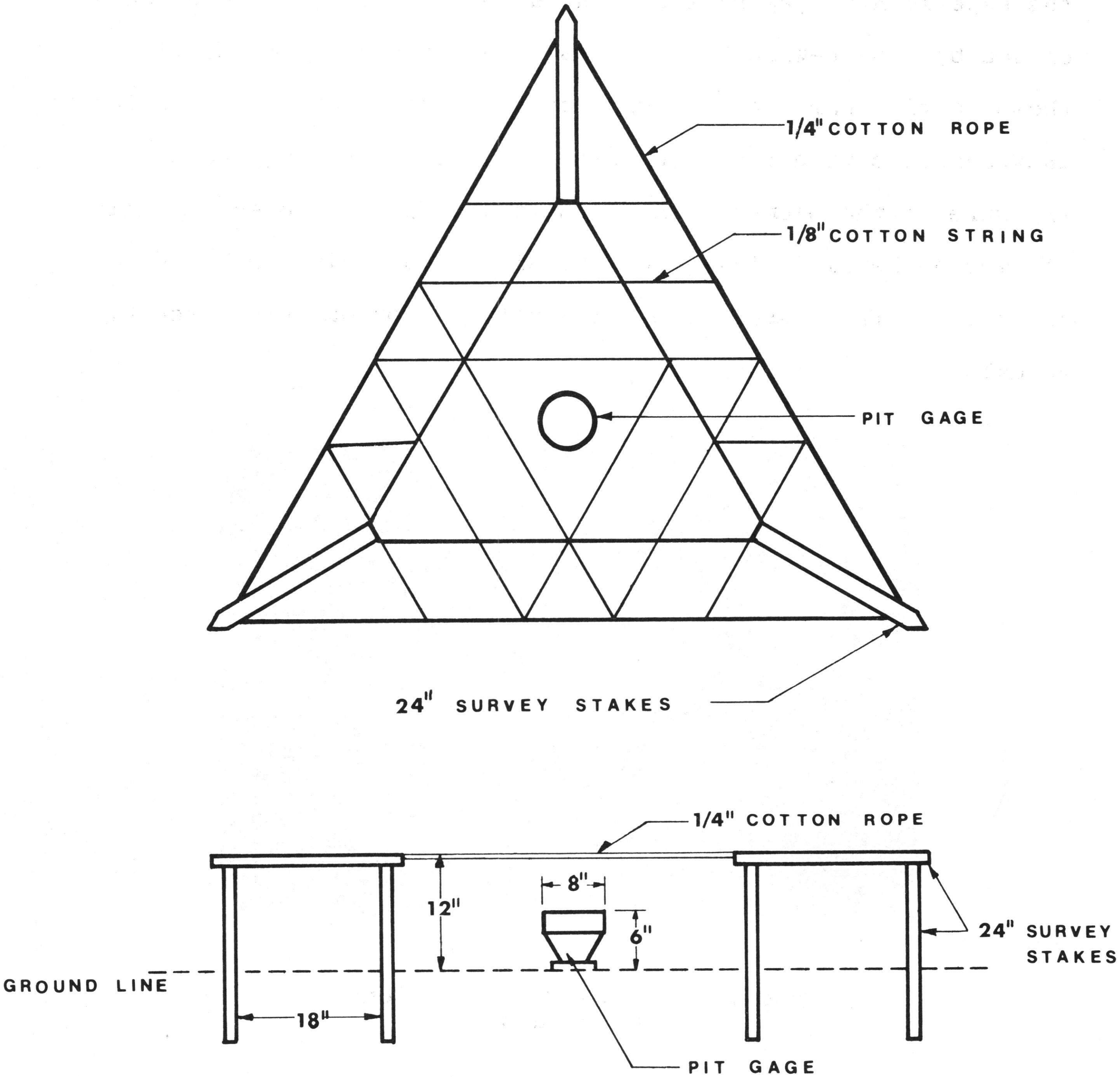

Figure 12. Cattle Guard

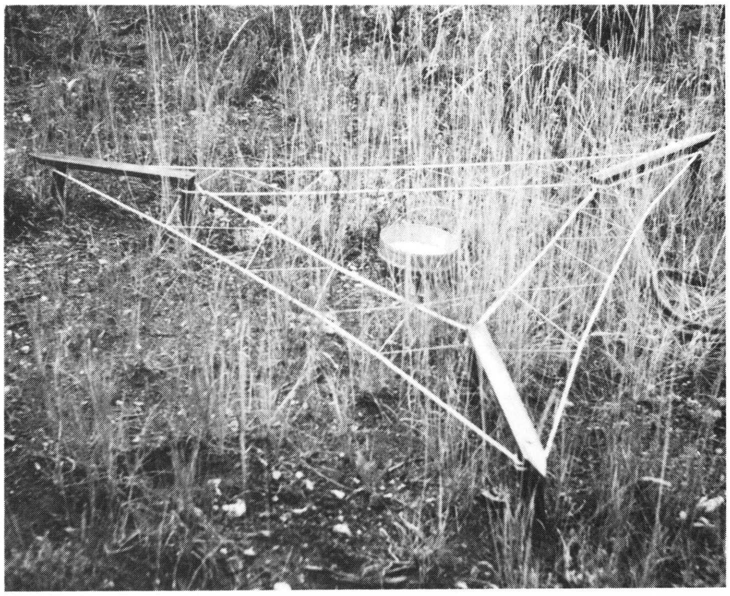

Figure 13. Photograph of protected vegetation near gage orifice.

Servicing the gages installed in the Raft River Basin was done on an annual basis. During the second and third weeks of September each site was visited, the contents of the gages were recorded, the gages were recharged and the overall installation was placed in a good state of repair.

The contents of the gage were pumped out with a portable marine pump operated by a 12-volt auto battery. A length of 5/8 inch garden hose was connected to the suction side of the pump and inserted into the gage. Similarly a second length of hose was connected to the discharge side of the pump and used to direct the contents of the gage into appropriate containers for weighing. A dairy scale equipped with an external adjustment for the contents of the gage to an accuracy of ± 0.1 pounds (Figure 14).

Figure 14. Graduate Student, David Fortier, pumping out the 55-gallon "drum gage" at the Clear Creek Meadows site.

After its contents had been pumped out and properly recorded, the gage was recharged with antifreeze and oil. The antifreeze was used to prevent damage to the gages by ice action during periods of freezing temperatures and the oil prevented evaporation during warmer weather.

Calculations indicate that one-gallon (9 pounds) of antifreeze would protect 30 inches of precipitation through an eight-inch orifice to a temperature of 21°F. Since the ground temperature beneath a snow pack rarely goes much below 32°F, a design temperature of 21°F was considered adequate for all buried gages.

However, it was not desirable to estimate the annual precipitation at the various gage locations and then calculate the particular amount of antifreeze required to recharge each of the 26 buried gages.

Some correlation was expected to exist between the elevation of the installations and both the amount of precipitation and the persistence of freezing weather. Thus elevation was selected as an index and used to facilitate recharging all gages. Table 2 shows the amount of antifreeze used to recharge the buried gages at various elevations. The use of Table 2 greatly expedited servicing the facilities and none of the buried gages showed any signs of freezing.

Tower gages were protected to -4°F to provide the same relative degree of protection that the buried gages enjoyed. Based on the premise that roughly 75% of the annual precipitation at the site would fall during months when freezing was likely to occur, an appropriate amount of antifreeze was calculated for each of the five tower gages recharged by project personnel. Tower gages received from 8.5 to 37.9 pounds of antifreeze.

TABLE 2

Antifreeze Used to Recharge Buried Gages in the Raft River Basin.

Gage Type	Elevation	Recharge
Pit Gage	5500 - 6500	3 pounds
	6500 - 7500	4.5 pounds
	above 7500	6 pounds
Drum Gage	all are above 7500	22.5 pounds

Hamilton and Andrews (1953) stated that 0.15 inches of light oil will stop all evaporation in gages without funnels. An amount of oil calculated as being equivalent to the recommended depth covering the liquid surface within the gage was placed in all gages. It was found that 1/2 pound of the light transformer oil used on this project not only offered adequate protection for the 5 and 10-gallon "pit gages" but was a convenient unit to work with. Likewise, two pounds were used in the drum gages and the Sacramento type tower gages. The straight tube tower gages and the standard eight-inch precipitation gages used on the project were recharged with 0.2 pounds of oil, again primarily as a matter of convenience.

RESULTS

Inspection of the sites in late July 1972, revealed that nine of the twenty 5-gallon pit gages installed during the late summer of 1971 had received precipitation in excess of their capacity. The frequency at which the 5-gallon gages were over-flown was attributed to (1) an above average snowfall during the winter of 1971-72; (2) the reliability of the information used to estimate annual precipitation when designing the gages; and (3) shortcomings in the actual design of the gages.

Since six of the nine gages which over-flowed were not at a multiple gage installation, no value for total precipitation was available at those stations for 1972. To compound the problem, one additional 5-gallon pit gage and two tower gages fell victim to vandals. A third tower gage was damaged by a snow slide and at least two drum gages and four pit gages were affected by internal air locks. The two Belfort recording gages installed by the Agricultural Research Service were not adequately maintained by local residents, thus no meaningful data were available from them. A summary of the information obtained from the precipitation net for 1972 is presented in Table 3. Note that a value is given for annual precipitation at various 5-gallon pit gage installations which exceeds the figure presented as the overflow capacity. This is due to the fact that these particular gages were emptied in late July 1972, as soon as it became apparent that a problem of this nature existed, and again in September 1972 just prior to being replaced with 10-gallon pit gages. The catch as of late July is indicated under the comments column as the overflow capacity of the gage.

TABLE 3

Data From Project Gages in the Raft River Basin
September 1971-September 1972

Number	Installation	Elevation m.s.l.	Type of Gage	Precipitation (inches)	Comments
1	Albion	5800	5 gallon pit	23.5	Gage overflow 21.0
2	Pine Creek	6680	5 gallon pit	15.4	Gage trampled
3	Connor Ridge	7980	5 gallon pit	19.7	
4	Howell Canyon	8020	5 gallon pit 55 gallon drum	23.1 12.9	Gage overflow 19.8' Air lock
5	Mount Harrison	8880	55 gallon drum Sacramento	63.1 78.1	
6	Cottonwood	6920	5 gallon pit 8" x 41" storage	22.9	Gage overflow 19.6 Bullet hole in tube
7	Elba	5850	5 gallon pit	14.6	Air lock
8	Franks Hollow	6000	5 gallon pit	22.9	Gage overflow 20.3
9	Almo Park	8100	55 gallon drum	10.0	Air lock
10	Emery Canyon	7000	5 gallon pit	12.6	
11	Moulton	5980	5 gallon pit	14.6	Air lock
12	Cotton Thomas	6940	5 gallon pit	22.7	
13	Lynn Creek	6060	5 gallon pit	21.3	
14	Dove Creek Pass	7320	5 gallon pit	22.2	Gage overflow 18.9
15	Yost	6240	Buried 8" x 24" Shielded Belfort Unshielded Belfort	16.8	 No record No record
16	Bally Mountain	6760	5 gallon pit	15.6	
17	George Peak	8100	5 gallon pit	24.2	Gage overflow 22.7
18	One Mile Summit	7330	5 gallon pit 8" x 41" storage	14.0	Air lock Bullet hole in tube
19	Standrod	6480	5 gallon pit	24.3	Gage overflow 21.8
20	Clear Creek	9100	5 gallon pit 55 gallon drum Sacramento	24.0 34.0 31.6	Gage overflow 20.6
21	Pinnacle	8750	5 gallon pit 8" x 41" storage	23.3 29.7	Gage overflow 21.1 Damaged by snowslide
22	Water Canyon	8060	5 gallon pit	19.8	
23	Naf	7260	5 gallon pit	14.1	Air lock
24	Campbells	5610	Buried 8" x 24" 8" x 41" storage	11.4 9.7	

The value given for annual precipitation is the sum of both the July and the September catch at these stations. Variations in overflow capacities can be attributed to the actual construction and installation of these gages.

Because of the frequency of gage overflows and other occurrences which resulted in the loss of data for the 1971-72 season, no analytical work was attempted. Instead emphasis was placed on modifying the installations to guard against subsequent losses. These modifications are explained in the preceding section of this report entitled PROCEDURE.

So that the graduate student working on this project could finish his MS/CE Thesis, the investigators asked for and received permission to use data collected in the Reynolds Creek Basin by members of the Northwest Watershed Research Center, Agricultural Research Service, U.S.D.A., Boise, Idaho. The data provided by the Agricultural Research Service was instrumental in allowing the student to analyze and discuss the relationship which exists between the confidence-interval for mean annual precipitation and gage density. A rational method of selecting gage sites to be used in network design was developed through correlation and regression analyses employing such parametric data as elevation, slope, aspect, cover class and soil type at the gage site. (Curtis 1973). A copy of the abstract from this thesis is included in this report as Appendix II. Originally, this type of an analysis was to be applied to the data collected in the Raft River Basin, but the inability to develop a credible base, as previously described, made such an analysis impossible.

The installations located in the Raft River Basin were visited again in the fall of 1973. Data recorded for the second season is listed in Table 4 and displayed graphically on the isohyetal sketch presented as Figure 15.

In their Pacific Northwest Water Resources Summary, the U.S. Geological Survey indicates precipitation for the 1973 water year was up to 125% the 1953-67 average for the basin. Considering the variation of the 1973 water year's precipitation from normal basin precipitation, a considerable degree of compatibility exists between the respective isohyetals presented in this report and the study by Walker (Figure 16). A marked difference does occur in the Mount Harrison area which is probably attributable to a difference in individual gage locations and the variability in the depth of the snow pack.

TABLE 4

Data From Project Gages in the Raft River Basin
September 1972-September 1973

Number	Installation	Elevation m.s.l.	Type of Gage	Precipitation (inches)	Comments
1	Albion	5800	10 gallon pit	20.2	
2	Pine Creek	6680	10 gallon pit	26.7	
3	Connor Ridge	7980	10 gallon pit	24.5	
4	Howell Canyon	8020	10 gallon pit	36.9	
			55 gallon drum	----	Air lock
5	Mount Harrison	8880	55 gallon drum	57.2	
			Sacramento	70.9	
6	Cottonwood	6920	10 gallon pit	24.2	
			10' tower; 8" x 41"	11.8	Tube leaking
7	Elba	5850	5 gallon pit	19.1	Evaporation suspected
8	Franks Hollow	6000	10 gallon pit	24.2	
9	Almo Park	8100	55 gallon drum	----	Air lock
10	Emery Canyon	7000	5 gallon pit	20.8	
11	Moulton	5980	5 gallon pit	18.1	
12	Cotton Thomas	6940	10 gallon pit	19.4	
13	Lynn Creek	6060	5 gallon pit	22.6	
14	Dove Creek Pass	7320	10 gallon pit	24.5	
15	Yost	6240	Buried 8" x 24"	16.8	
16	Bally Mountain	6760	5 gallon pit	22.6	
17	George Peak	8100	10 gallon pit	38.1	
18	One Mile Summit	7330	5 gallon pit	21.7	
19	Standrod	6480	10 gallon pit	25.2	
20	Clear Creek	9100	10 gallon pit	34.7	
			55 gallon drum	39.7	
			Sacramento	33.6	
21	Pinnacle	8750	10 gallon pit	39.9	
			10' tower; 8" x 41"		
22	Water Canyon	8060	5 gallon pit	20.2	
23	Naf	7250	5 gallon pit	19.2	
24	Campbells	5610	Buried 8" x 24"	19.2	
			7' tower; 8" x 41"	16.5	

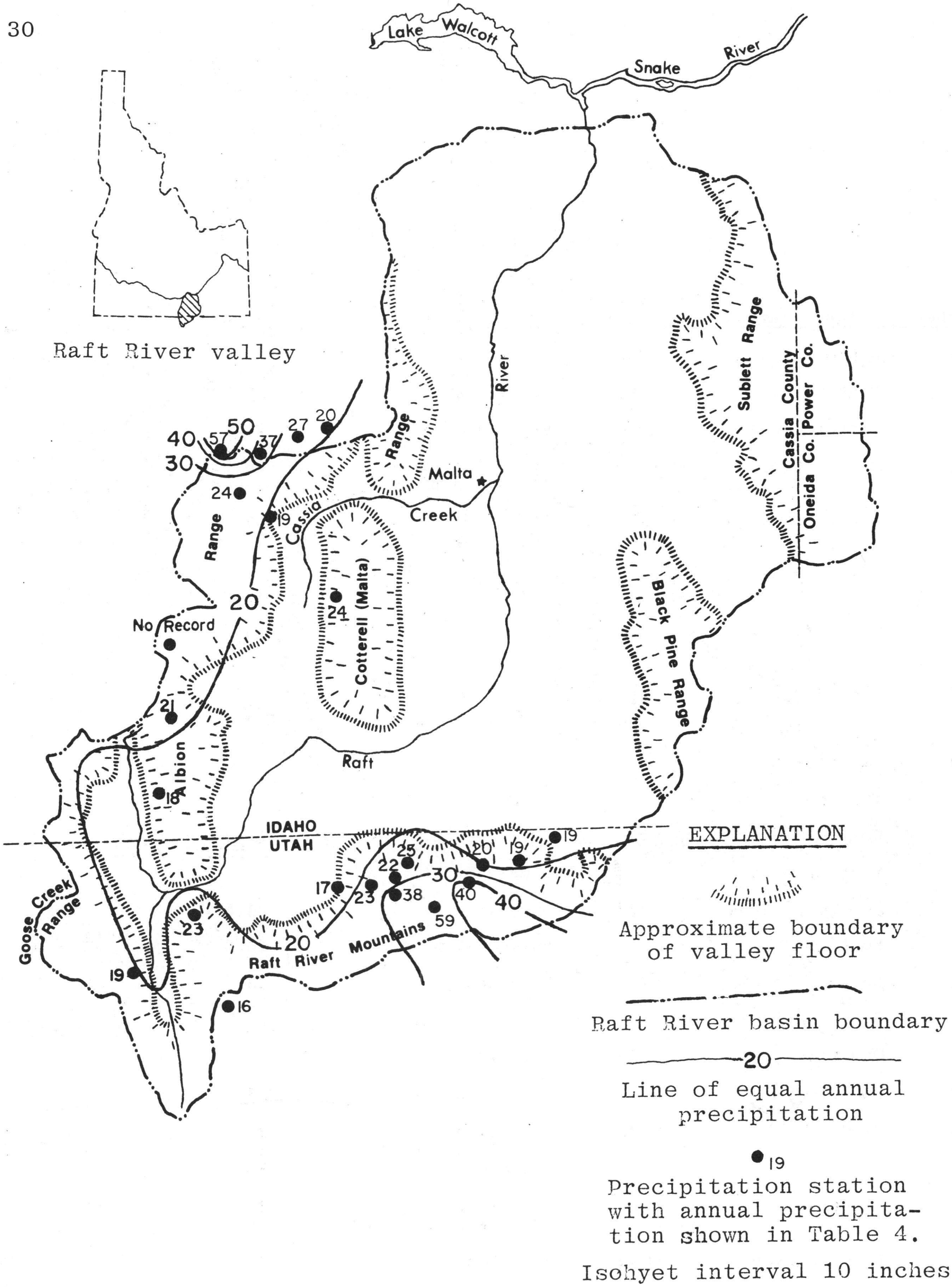

Figure 15. Sketch of 1972-73 Isohyetals for the Upper Raft River Basin

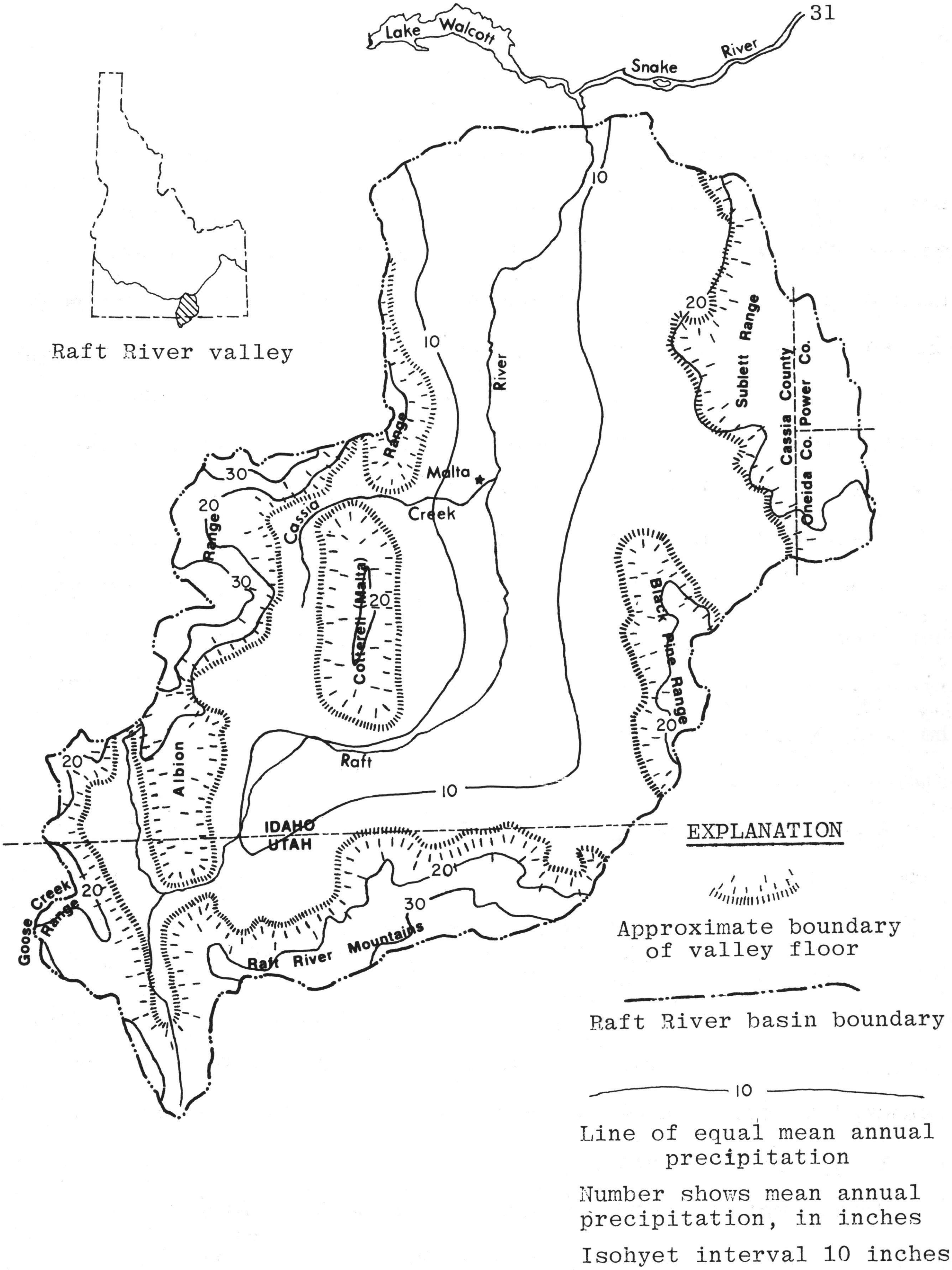

Figure 16. Isohyetal map of the Raft River Basin by Walker.

SUMMARY

The ground level gages developed during this study have proven to be far less susceptible to damage by vandals than conventional gages, have not been unduly bothered by grazing animals, are inexpensive, and capture available water at the site. Admittedly snow will blow across the orifice if the gage is capped, but so too is the snow being blown from the site and either deposited elsewhere or lost to sublimation. In any event, the melt water of the snow blown across the gage location will not be present at the site and therefore should not be considered in the precipitation estimate of that station. In those instances where the gage is buried beneath a deep snow pack, the melt water which percolated through the snow pack above the gage will enter the orifice to be considered in making an estimate of available water for the station.

Almost without exception, it can be stated that precipitation measured in a gage is less than the true value. This deficiency is primarily due to wind effects and the subsequent turbulence which is created at the gage orifice. Rainfall can be observed with a much higher degree of reliability than snow which is more easily influenced by wind. By locating installations in rather protected sites, wind should neither blow snow from the site nor bury it beneath deep drifts.

No attempt was made to calculate the water yield for the basin, however, it appears that the sketch presented as Figure 15 complements the isohyetal map presented by Walker (1970), and incorporated into this report as Figure 16.

BIBLIOGRAPHY

Anderson, Alfred L., 1931, "Geology and Mineral Resources of Eastern Cassia County, Idaho." Idaho Bureau of Mines and Geology, Bulletin No. 14, 169 pp.

Brown, M.J., and E.L. Peck, 1962, "Reliability of Precipatation Measurements as Related to Exposure," Journal of Applied Meteorology, 1: 203-207.

Curtis, David L., 1973, "Evaluation of Techniques for Determining Average Precipitation in Semi-Arid Valleys of Idaho," M.S. Thesis, Department of Civil Engineering, University of Idaho, 113 pp.

Curtis, D.L., C.C. Warnick, M. Molnau, and W.J. Rawls, 1973, "Precipitation Gage Placement in Mountainous Areas Based on Gage Site Characteristics," Proceedings paper presented at Annual Fall Meeting of the American Geophysical Union, San Francisco, California, December 11-13, 9 pp.

Grafton, C.R., and W.H. Dickerson, 1969, "Influence of Topography on Rainfall in West Virginia", Bulletin 1, Water Resources Research Institute, Appalachian Center, West Virginia University, Morgantown, 45 pp.

Hamilton, E.L., and L.A. Andrews, 1953, "Control of Evaporation from Rain Gages by Oil," Bulletin of the American Meteorological Society, 34: 202-204.

Hovind, E.L., 1965, "Precipitation Distribution Around a Windy Mountain Peak", Journal of Geophysical Research, 70: 3271-3278.

Mundorff, M.J., and H.G. Sisco, 1963,"Ground Water Use in the Raft River Basin, Idaho, with Special Reference to Irrigation Use", 1956-60, U.S. Geologic Survey Water-Supply Paper 1619-CC, 23 pp.

Nace, R.L., et. al., 1961, "Water Resources of the Raft River Basin,"Idaho-Utah, U.S. Geologic Survey Water-Supply Paper 1587, 138 pp.

Neff, Earl L., 1965, "Principles of Precipitation Network Design for Intensive Hydrologic Investigations," International Association of Scientific Hydrology, 67: 49-55.

Nicks, Arlin D., 1965, "Field Evaluation of Rain Gage Network Design Principles," International Association of Scientific Hydrology, 67: 82-93.

Peck, E.L., and M.J. Brown, 1962, "An Approach to the Development of Isohyetal Maps for Mountainous Areas", Journal of Geophysical Research, 67: 681-694.

Walker, E.H., L.C. Dutcher, S.O. Decker, and K.L. Dyer, 1970, "The Raft River Basin, Idaho-Utah, as of 1966", Water Information Bulletin No. 19, Idaho Department of Water Administration, 95 pp.

APPENDIX I

Legal descriptions of installations in the Raft River Basin, Cassia County, Idaho:

Alboin:
NE 1/4, NE 1/4, Sec. 33, T.12S; R.25E; Boise Meridian. 5.5 miles south-southeast of Alboin, Idaho, 0.9 miles southwest of State Highway 77, about 0.1 miles north of Sawtooth National Forest boundary marker on north side of Howell Canyon road, on a small flat between converging drainage channels south of a small willow grove in a heavy growth of sagebrush.

Almo Park:
NW 1/4, SE 1/4, Sec. 35, T.14S; R.23E; Boise Meridian. 6.9 miles northwest of Almo, Idaho, 0.2 miles northeast of a fork in the Almo Park road, 0.2 miles east of a dividing ridge, 300 ft. southeast of a bend where road enters aspen grove, about 150 ft. west of red and blue markings on west side of jeep trail, on relatively flat area, near the west side of a 5-acre clearing.

Bally Mountains:
SW 1/4, SE 1/4, Sec. 18, T.14N; R.14W; Salt Lake Meridian. 3.1 miles southeast of Yost, Utah, 0.9 miles west of One Mile Summit, about 300 ft. north of the Stanrod-Yost road, 100 ft. north of red and blue markings on north side of jeep trail, in a small clearing in juniper.

Campbell:
NE 1/4, SW 1/4, Sec. 36, T.15N, R.13W; Salt Lake Meridian. 2.0 miles south of Naf, Idaho, 0.2 miles west of Duane Campbell's house, about 300 ft. south-southwest of an abandoned schoolhouse.

Clear Creek Meadows:
SE 1/4, NE 1/4, Sec. 26, T.14N; R.14W; Salt Lake Meridian. 5.5 miles south of Stanrod, Utah, about 0.4 miles south-southeast of Summit in Clear Creek Meadows, on a gentle north slope, 100 feet southeast of a jeep trail to George Peak, just northwest of Clear Creek Meadows snow course.

Connor Ridge:
NW 1/4, SE 1/4, Sec. 1, T.13S; R.24E; Boise Meridian. 6.6 miles south-southwest of Albion, Idaho, 0.2 miles northeast of Connor Flat, 100 ft. north of the bend where Connor Ridge road turns from south to east.

Cotton Thomas:
NE 1/4, SE 1/4, Sec. 10, T.13N; R.17W; Salt Lake Meridian. 2.2 miles west-southwest of Lynn, Utah, 0.2 miles southeast of Lynn-Grouse Creek road, about 400 ft. southeast of a radio tower, 200 ft. east of a north-south ridge, 150 ft. southeast of a small swale, along an old road paralleling ridge.

Cottonwood:

NW 1/4, SW 1/4, Sec. 15, T.13S; R.24E; Boise Meridian. 5.2 miles west-northwest of Elba, Idaho, 1.7 miles south-southeast of Mount Harrison, 0.7 miles west of Cottonwood Creek, 100 ft. east of north-south fence, at the end of the road to upper Cottonwood Canyon.

Dove Creek Pass:

SE 1/4, SW 1/4, Sec. 22. T.13N; R.16W; Salt Lake Meridian. 5.0 miles southeast of Lynn, Utah, 0.3 miles north of Dove Creek Pass, 100 ft. east of dividing ridge, 100 ft. north of a road to a quarry, 50 ft. west of stake painted red and blue on west side of a road on the east side of and paralleling divide.

Elba:

SE 1/4, NE 1/4, Sec. 26, T.13S; R.24E; Boise Meridian. 2.9 miles west-northwest of Elba, Idaho, 0.4 miles north of Elba-Oakley road, 0.2 miles west of Cottonwood Creek, 150 ft. southeast of the road to upper Cottonwood Canyon.

Emery Canyon:

NW 1/4, NE 1/4, Sec. 26, T.15S; R.23E; Boise Meridian. 5.2 miles west of Almo, Idaho, 0.5 miles north-northeast of Emery Canyon Spring, about 300 ft. south of a small summit, 150 ft. west of red and blue marking on west side of road to the Almo Park.

Franks Hollow:

SW 1/4, SE 1/4, Sec. 16, T.14S; R.25E; Boise Meridian. 3.5 miles south-southeast of Elba, Idaho, 0.1 miles southwest of Franks Hollow, 0.1 miles west of point where road drops down into Franks Hollow from the south, about 100 ft. south of two stakes painted red and blue on south side of road, in small clearing in junipers.

George Peak:

SE 1/4, NE 1/4, Sec. 20, T.14N; R.14W; Salt Lake Meridian. 5.4 miles southwest of Stanrod, Utah, 0.8 miles southeast of One Mile Summit, about 150 ft. northeast of a rock painted red and blue on northeast side of Clear Creek Meadows - One Mile Summit jeep trail.

Howell Canyon:

SW 1/4, NE 1/4, Sec. 2, T.13S; R.24E; Boise Meridian. 6.7 miles south-southwest of Albion, Idaho, 0.5 miles northwest of Pomerelle Ski Lodge, 0.1 mile southeast of Mount Harrison road, in small clearing on Thompson Flat, at Howell Canyon Snow Course.

Lynn Creek:

NE 1/4, NW 1/4, Sec. 29, T.14W; R.16W; Salt Lake Meridian. 3.2 miles north-northeast of Lynn, Utah, 1.3 miles southeast of Lynn-Yost road, 300 ft. north of Lynn Spring road, 200 ft. south of east-west fencing marking north boundary of Forest Service land, about 100 ft. west of Lynn Creek, 75 ft east of stake painted red and blue on east side of jeep road, in small clearing in juniper.

Moulton:
SE 1/4, NE 1/4, Sec. 22, T.16S; R.23E; Boise Meridian. 7.6 miles south-west of Almo, Idaho. 1.1 miles northeast of the site of Moulton, Idaho, about 250 ft. west of fence on line between Sections 22 and 23, 200 ft. south of rock painted red and blue on south side of Almo-Lynn road.

Mount Harrison:
SE 1/4, SW 1/4, Sec. 4, T.13S; R.24E; Boise Meridian. 8.0 miles southwest of Albion, Idaho, 0.5 miles north of Mount Harrison, 0.4 miles southwest of south end of Lake Cleveland, 0.2 miles north of Mount Harrison road, on flat in the bottom of a small depression.

Naf:
SE 1/4, NE 1/4, Sec. 9, T.14N; R.13W; Salt Lake Meridian. 4.3 miles southwest of Naf, Idaho, about 0.1 miles north of a rock painted red and blue on the north side of a jeep trail to Clear Creek Meadows, on the north slope of a ridge, 300 ft. south of a crook in small canyon, on line between small lone pine (on east) and small mahogany grove (on west).

One Mile Summit:
SE 1/4, SW 1/4, Sec. 17, T.14N; R.14W; Salt Lake Meridian. 5.4 miles southwest of Stanrod, Utah, 1.2 miles southwest of One Mile Summit, 100 ft. northwest of One Mile Summit snow course, 30 ft. northwest of Stanrod-Yost road.

Pine Creek:
NE 1/4, SE 1/4, Sec. 31, T.12S; R.25E; Boise Meridian. 5.6 miles south of Albion, Idaho, 0.2 miles east-southeast of bridge where road crosses Howell Canyon, 0.1 miles west of Pine Creek, on a gentle north slope, about 300 ft. south of a large tree marked with red and blue paint of south side of Howell Canyon road.

Pinnacle:
SE 1/4, NW 1/4, Sec. 18, T.14N; R.13W; Salt Lake Meridian. 3.8 miles southeast of Stanrod, Utah, 1.5 miles south-southwest of Pinnacle Peak, 1.1 miles east-northeast from the junction in SW 1/4 Sec. 13 with jeep trail to Clear Creek Meadows, on a gentle north slope, at the edge of timber.

Stanrod:
SE 1/4, NE 1/4, Sec. 9, T.14N; R.14W; Salt Lake Meridian. 3.3 miles southwest of Stanrod, Utah, 0.9 miles northeast of One Mile Guard Station, about 30 ft. southeast of rock painted red and blue on southeast side of Stanrod-Yost road, about 20 ft. southeast of One Mile Creek.

Water Canyon:
SW 1/4, NW 1/4, Sec. 8, T.14N; R.13W; Salt Lake Meridian. 3.3 miles southeast of Stanrod, Utah, 0.3 miles south of Pinnacle Peak, about 0.2 miles northeast of rock painted

red and blue on north side of jeep trail to Clear Creek Meadows, in swale near the head of Water Canyon, 100 ft. west of the highest stand of aspen.

Yost:

SE 1/4, NW 1/4, Sec. 14, T.14N; R.15W; Salt Lake Meridian. 1.4 miles south-southeast of Yost, Utah, 0.1 mile northeast of George Creek, about 300 ft. west of Stanrod-Yost road, 200 ft. southwest of the sheriff's house, just across a small stream.

APPENDIX II

ABSTRACT OF A M.S. THESIS

"Evaluation of Techniques for Determining Average Precipitation in Semiarid Valleys in Idaho"

By David Lawrence Curtis

The Raft River Basin in southcentral Idaho and the Reynolds Creek Experimental Watershed in southwest Idaho were studied to determine precipitation distribution in an attempt to develop better isohyetal maps for semiarid mountain valleys. Due to gage malfunctions in the Raft River network, only the data collected by the Agricultural Research Service on Reynolds Creek was analyzed.

Two methods were used to determine precipitation distribution. The computer isohyetal method worked well on Reynolds Creek but should be used only where a dense gage network is available. The Thiessen method was preferred in areas where gages are relatively spread out. The Thiessen method was also used to determine the relative accuracy of the mean precipitation estimate using less than the 45 gages available. A Multiple-regression equation was developed for selecting the point precipitation measurements to be used in estimates of average precipitation on the Reynolds Creek Experimental Watershed. Results indicated that no fewer than 20 gages should be used to obtain a good estimate of average precipitation.