DEVELOPMENT OF THE FULCRUM WEIGHING DEVICE FOR PRECIPITATION GAGES[1/]

By

Ronald E. Moreland[2/]

The Soil Conservation Service of the Department of Agriculture entered into a Memorandum of Understanding with the Bureau of Reclamation of the Department of Interior on July 1, 1966. This memorandum covers snow measurement operations for the Atmospheric Water Resources Program in the Jemez and San Pedro Mountains of New Mexico.

The Project area is in northern New Mexico about 65 miles north of Albuquerque, (fig. 1).

The general boundaries of the project are outlined in figure 2. There was only one snow course within the target area. There were seven other snow courses located nearby. It was decided to establish seven additional snow courses in the area between Cuba and Coyote along Highway #103. These 15 snow courses provide coverage over most of the area.

The project area is characterized by elevations of 7,000 feet at Cuba to 10,430 feet on the San Pedro Peaks. Nacimiento Peak is 9,791 feet. Most of the area is within the 8,000 to 9,500 foot level. Snow course elevations range from 8,200 to 9,800 feet. The average annual precipitation at Cuba is 14.98 inches; at Jemez Springs, 17.68 inches. Average January temperature at Cuba is about 26^{o}F; at Jemez Springs, about 33^{o}F. The average annual temperature is 47^{o} at Cuba (7,000') and 52^{o}F at Jemez Springs (6,200')

At the beginning of the program little or no climatological information was available in the target area within the project. But since that time data has been collected and analysis of the snow pillow recorder chart (fig. 3) for the 1968-69 and 1969-70 season gives some idea of the variation in snow water content. The maximum water content in 1968-69 was 15.3 inches (48 inches of snow); in 1969-70 the peak was 7.2 inches (37 inches of snow). The Soil Conservation Service precipitation gages indicated totals of 35.0 inches at Black Rock, 34.3 inches at Teakettle, and 31.1 inches at Resumidero for the calendar year 1969. The 1969-70 year is the data collection year analyzed in this paper.

At the end of the first snowfall season in 1967, it was determined that precipitation stations would be helpful at each newly established snow course along Highway #103. Snow melt was detected during much of the snowfall season, and precipitation stations on the snow courses could give additional information.

A new fulcrum weighing precipitation gage was developed for installation on the seven new snow courses. Anyone of you who has climbed a shielded precipitation stand to obtain a reading knows the difficulty of keeping the wind vanes from tearing your clothing or banging your head, besides carrying the weighing scales and hanging onto the stand. The fulcrum weighing device was designed to make the weighing procedure easier and faster while maintaining the accuracy of the direct weight measurement. The new gage permits the measurements to be made from the ground at all times.

The gage consists of an anchor in concrete and a leveling plate, a 6-foot by 3-inch standpipe, a special self-contained fulcrum weighing device, a 42-inch precipitation can with an 8-inch orifice and a 4-foot diameter windshield (figs. 4 and 5). A petcock enables the can to be drained without being removed. Access to the upper structure is by means of a portable 3/4-inch steel U that fits into the steel stand. The fulcrum lever length was checked for accuracy during development. Laboratory tests revealed that a lever length with a 2 to 1 ratio gave the most reliable results.

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2/ Assistant Snow Survey Supervisor for Colorado and New Mexico, SCS, Fort Collins, Colorado.

Figure 1.--Location Map

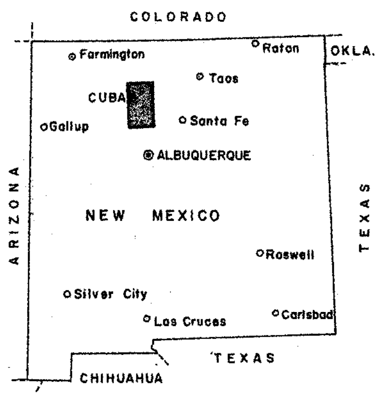


Figure 2.--Project Area Map

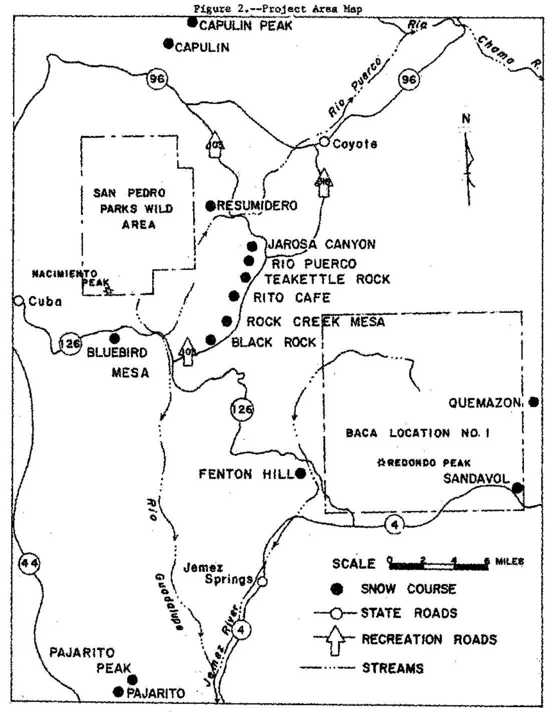


Figure 3. Snow pillow chart.

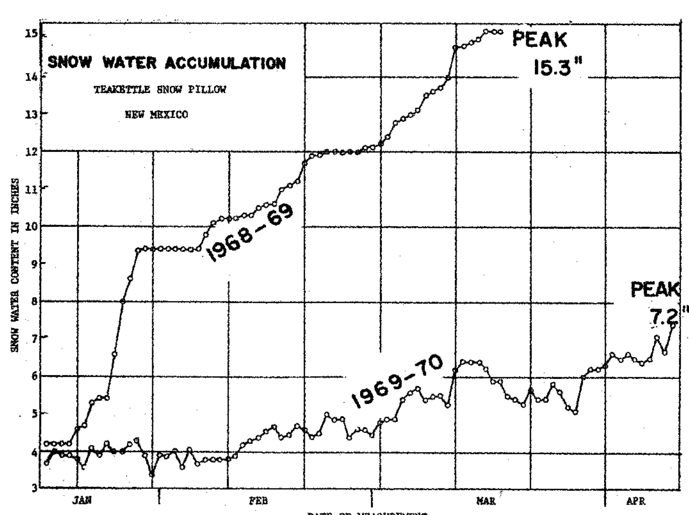
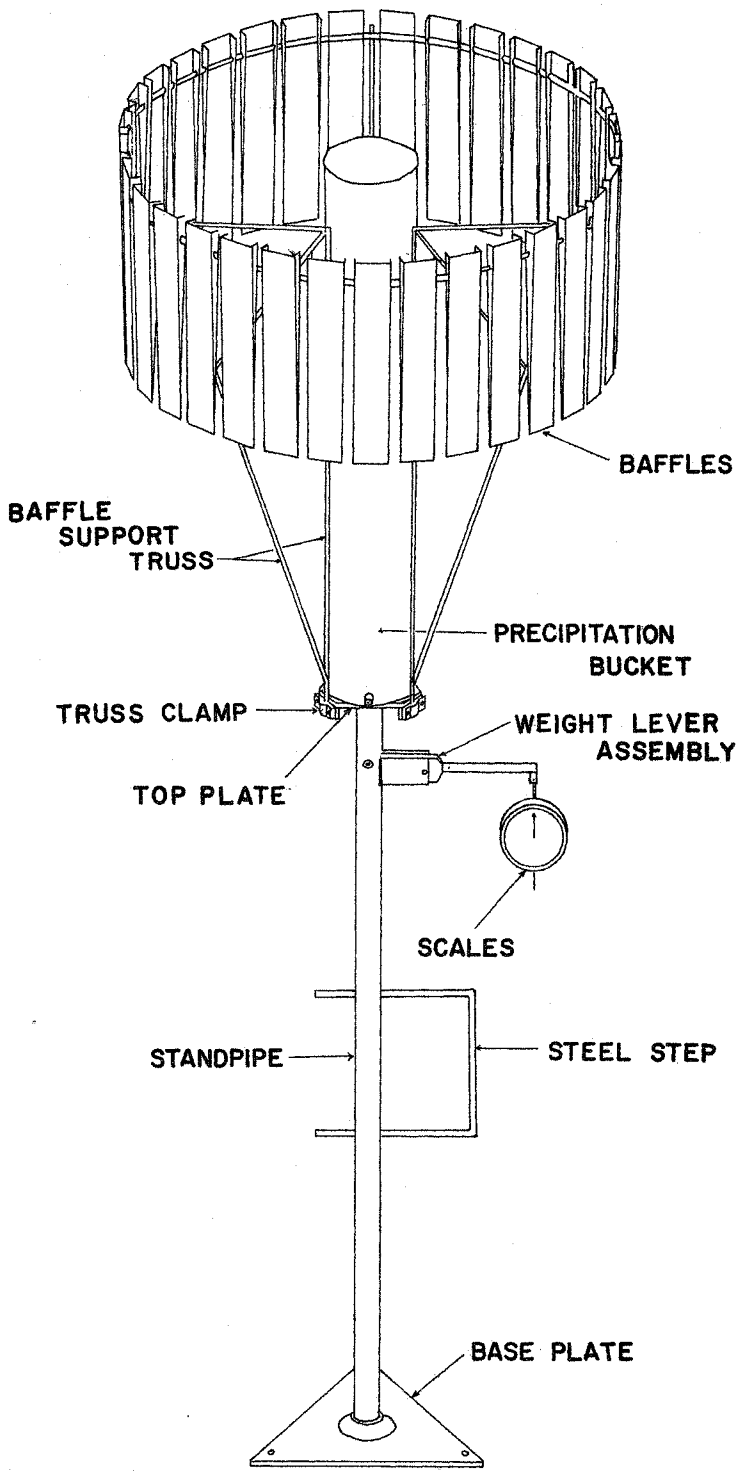


FIGURE 4. PRECIPITATION GAGE ASSEMBLY



These precipitation gages are located on Black Rocks, Rock Creek Mesa, Rito Cafe, Teakettle, Tio Puerco, Jarosa Canyon, and Resumidero snow courses. The gages were activated on November 10,1967. Measurement of these gages coincided with snow course measurement schedules, with additional measurements being made every 14 days during the remainder of the year.

Measurements were made by both the direct weight method and the fulcrum type measurements. Most of the fulcrum devices appeared to operate correctly, but some difficulties were encountered. After being exposed to the weather, the fork connecting the fulcrum device to the base plate began to bind, causing incorrect readings. All the units were inspected, and it appeared that an excessive amount of rust on the connecting fork and rod seemed to cause the difficulty. The fulcrum devices were returned to the manufacturer for modifications and improvements. At this time the forks were widened slightly, and all the moving mechanisms were chrome plated. The original pivot pin and the pin connecting the lever to the push rod were replaced with a stainless steel pin to provide the least possible friction.

The fulcrum devices were all reinstalled. Measurements during the modification period had been continued by the direct weight so no data was lost.

Measurements were taken by both methods to check the accuracies of all gages from November 25, 1969, through May 27, 1970. This period included 15 measuring dates on the seven precipitation gages for a total of 105 comparative readings. The range of water content is from 0 to 10 inches. The limit on the scales is 12 inches of water as the balance of the weight is required for the antifreeze solution. The gages are recharged when they reach their upper limit of 10 to 12 inches. Thus, readings for the study cover a complete span of weights between recharges.

For this study it was assumed that the direct weight readings were correct. All factors are constant with exception of the method of weight measurements. The fulcrum weights are compared to the direct weights. Weights for all 105 readings were taken with the same weighing scales and were obtained by the same person.

The data was run through the computer to obtain correlation coefficients for each precipitation gage. The coefficients are very high on the fulcrum weight to direct weight and also between individual precipitation stations. The correlation coefficients for fulcrum to direct weight on each gage are:

Black Rocks	.99747
Jarosa Canyon	.99819
Resumidero	.99870
Rio Puerco	.99787
Rito Cafe	.99915
Rock Creek	.9983
Teakettle	.99282

Correlations coefficients of .99 or above were obtained between all the individual stations.

The Rock Creek gage showed the highest correlation. The snow water accumulations are shown in figure 6. The readings were almost identical on all dates throughout the measurement period. Table 1 shows the study period with normalized data comparing the fulcrum to direct measurements on the Rock Creek gage. The average deviation is only 1.7 percent or 0.7 inches of water.

Black Rock has a high correlation, but the readings had the largest difference of any precipitation gage. This is apparent on the snow water accumulation chart (fig. 7) where 10 of the 15 readings show a difference of between -.5 to -1.0 inch. There are two errors apparent in this figure as the readings on December 18 and March 25 are less than the previous readings. Table 2 shows the normalized data comparing the fulcrum to direct measurements of the Black Rock gage. The average deviation is 9.2 percent, or 0.3 inches of water. This gage shows more deviation than any other gage.

The frequency distribution of all the measurements are shown in figure 8. Eighty-two percent of the readings are within plus or minus .5 inch, 75 percent are within plus or minus .4 inch, and 64 percent are within plus or minus .2 inch. The largest errors are

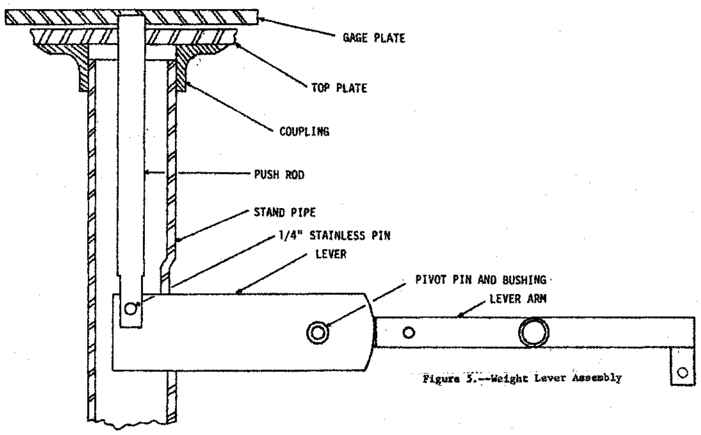


Figure 5.--Weight Lever Assembly

Figure 6.--Rock Creek Precipitation Gage Accumulation, 1969-70

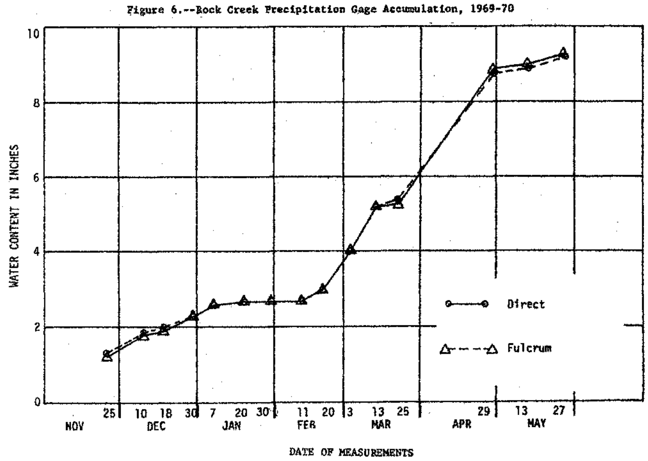


FIGURE 8
DISTRIBUTION OF MEASUREMENT DIFFERENCES
FULCRUM TO DIRECT

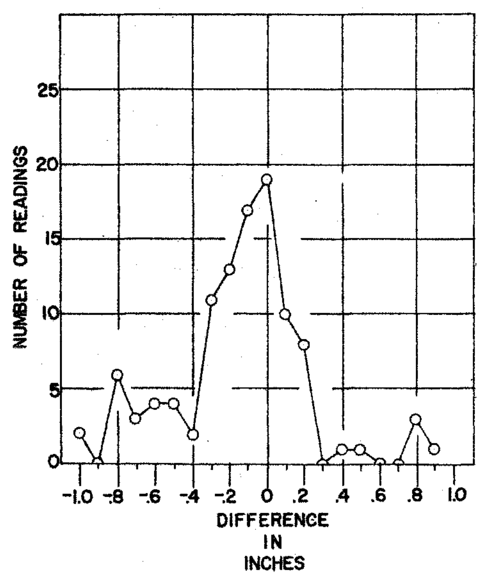
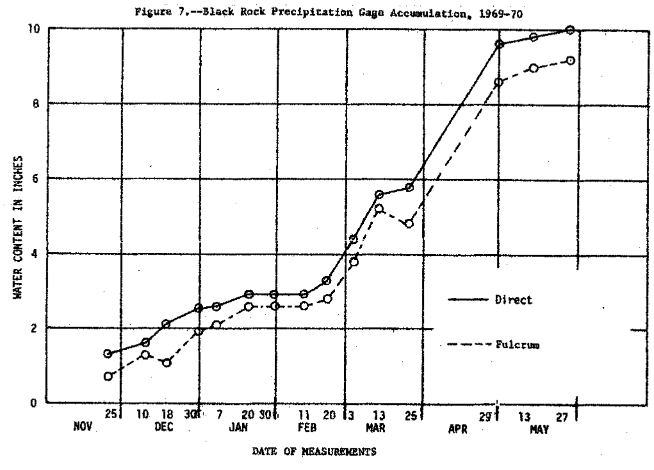


Figure 7.--Black Rock Precipitation Gage Accumulation, 1969-70



a -1.0 inch for underweighing and a +.9 inch for overweighing. The mean of all errors is a -.1 inch. The fulcrum devices show a tendency to underweigh more than overweigh. Sixty-two readings are on the minus side and 24 on the plus side. This may indicate that friction is no problem.

Table 1. Normalizing Fulcrum to Direct Weight on Rock Creek

Date	Rock Creek W.C. Inches Direct	Fulcrum	Fulcrum in % of Direct Weight	Difference from Avg. %	Water Content Difference from Avg.
11-25	1.2	1.3	108.3	7.5	.098
12-10	1.8	1.8	100.0	.8	.014
12-18	1.9	2.0	105.3	4.5	.090
12-30	2.3	2.3	100.0	.8	.018
1-7	2.6	2.6	100.0	.8	.021
1-19	2.7	2.7	100.0	.8	.021
1-30	2.7	2.7	100.0	.8	.021
2-11	2.7	2.7	100.0	.8	.021
2-20	3.0	3.0	100.0	.8	.024
3-3	4.0	4.0	100.0	.8	.032
3-13	5.2	5.2	100.0	.8	.042
3-25	5.3	5.4	101.9	1.1	.059
4-29	8.9	8.8	98.9	1.9	.167
5-13	9.0	8.9	98.9	1.9	.169
5-27	9.3	9.2	98.9	1.9	.175
Avg.	4.17	4.17	100.8	1.73	.07

Table 2. Normalizing Fulcrum to Direct Weight on Black Rock

Date	Black Rock W.C. Inches Direct	Fulcrum	Fulcrum in % of Direct Weight	Difference from Avg. %	Water Content Difference from Avg.
11-25	1.3	0.7	53.8	28.9	.20
12-10	1.6	1.3	81.3	1.4	.18
12-18	2.1	1.1	52.4	30.3	.33
12-30	2.5	1.9	76.0	6.7	.13
1-7	2.6	2.1	80.8	1.9	.05
1-20	2.9	2.6	89.6	6.9	.18
1-30	2.9	2.6	89.6	6.9	.18
2-11	2.9	2.6	89.6	6.9	.18
2-20	3.3	2.8	84.8	2.1	.06
3-3	4.4	3.8	86.4	3.7	.14
3-13	5.6	5.4	96.4	13.7	.74
3-25	5.8	5.0	86.2	3.5	.18
4-29	9.6	8.6	89.6	6.9	.59
5-13	9.8	9.0	91.8	9.1	.82
5-27	10.0	9.2	92.0	9.3	.86
Avg.	4.49	3.91	82.7	9.2	.03

Conclusions

If care is taken in weighing the precipitation gage by the fulcrum method, a high degree of accuracy can be achieved. Weights on these gages are now being obtained by the fulcrum method. Accuracy checks are made by taking direct weight measurements each time the gages are recharged. The time required to read by the fulcrum method was estimated to be 9 minutes less than weighing direct. This does not seem like much, but for these 105 readings the time saved would have been 2 man-days. For the complete year an estimated

3 man-days would have been saved. It is recognized that obtaining data within the accuracy desired is important regardless of the time saved. Cost of each precipitation gage at the time of installation was $260.

Future development in the fulcrum gage could include the addition of load cells or a transducer for on-site recorders and telemetry. This installation is relatively inexpensive for use in low to moderate snowfall zones.