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PRECIPITATION MONITORING AT THE REYNOLDS CREEK EXPERIMENTAL WATERSHED, IDAHO, USA

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ABSTRACT

An extensive precipitation database has been developed over the past 35 years with the first records starting in January 1962 and going through September 1996 from the Reynolds Creek Experimental Watershed located near the north end of the Owyhee Mountains in southwest Idaho. Precipitation ranges from 236 mm on the lowest elevations at the north end of the watershed to 1123 mm at the southwest corner of the watershed. The gauge network was changed in 1967-1968 from a single unshielded, universal-recording gauge at each location to the dual-gauge system that is presently used. The dual-gauge system consists of an unshielded and a shielded universal-recording gauge with orifices 3.05 m above the ground. The number of dual-gauge sites was reduced from the original 46 in 1968 to 17 by 1996. Also, several sites have been added and/or taken out of the network at various times for special studies. There are continuous 35 year records available for 12 sites, 20-32 year records available for 8 sites, 10-19 year records available for 25 sites, and 4-9 year records for 8 sites for a total of 53 sites. All of these data have been stored as breakpoint and hourly records in the USDA-ARS, Northwest Watershed Research Center database. These breakpoint and hourly data are available from the anonymous ftp site: *ftp.nwrc.ars.usda.gov*.

1. INTRODUCTION

Precipitation amounts and their spatial and seasonal variations are basic to all hydrologic and natural resource studies. The U. S. Department of Agriculture-Agricultural Research Service, Northwest Watershed Research Center (NWRC) operates a precipitation gauge network as an integral part of the hydrologic studies on the Reynolds Creek Experimental Watershed (RCEW) (Figure 1) [*Slaughter and Hanson,* 1998). The experimental area is a 239-km^2 watershed located in the Owyhee Mountains of southwest Idaho [*Flerchinger et al*., 1994; *Johnson et al.*, 1987; *Johnson, et al.*, 1982; *Robins et al.*, 1965; *Stephenson,* 1977]. The lowest elevation on the watershed is 1101 m; the eastern boundary rises to about 1525 m; the western to a peak of 2241 m. Reynolds Creek is a north-flowing tributary of the Snake River.

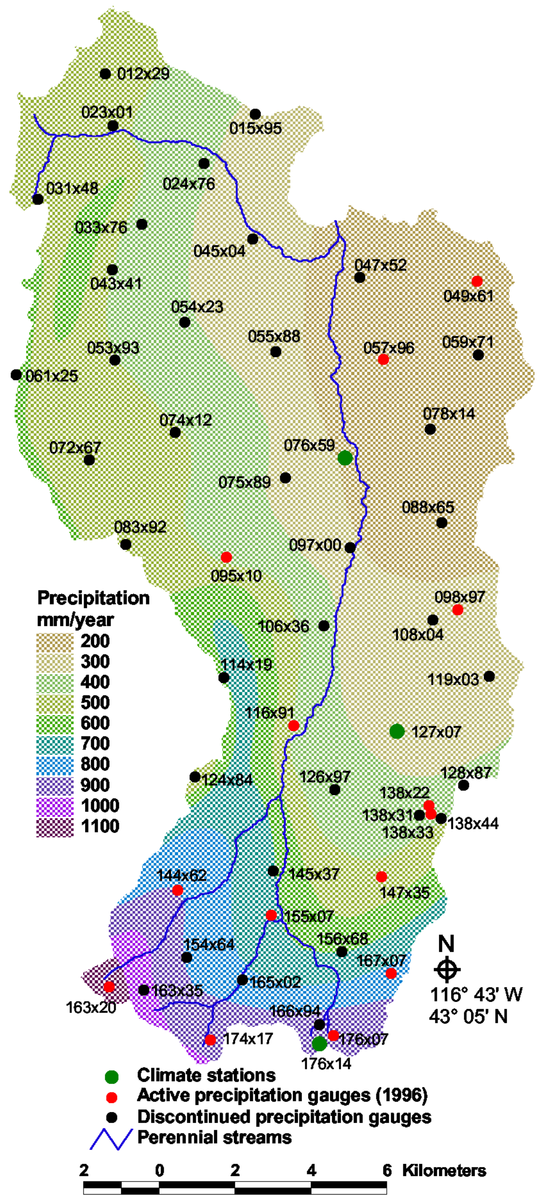

Figure 1. Location of dual-gauge precipitation measuring sites on the Reynolds Creek Experimental Watershed located in southwest Idaho, USA.

2. PRECIPITATION GAUGE NETWORK

The original gauge network, established in 1960-1961, consisted of 83 unshielded 12" (30.48 cm) weighing-recording gauges. Because most of the precipitation that falls on the higher elevations of RCEW is snow, there was a significant undercatch by the network of single, unshielded gauges. Undercatch of precipitation, especially of snow by gauges that are not protected naturally, is a major problem in obtaining accurate point measurements [*Hanson et al.*, 1996; *Hanson et al.*, 1999; *Larson and Peck*, 1974; *Neff* , 1977]. Undercatch of snow is especially acute in windy environments such as those encountered on areas within the RCEW. Therefore, during 1967-1968, the network was converted to 46 dual-gauge installations which were designed to more accurately measure snowfall [*Hamon*, 1971, *Hanson et al.*, 1999]. *Hamon* [1971] gives a complete listing of both the original gauge network and the dual-gauge network and maps of RCEW which show both gauge networks. Dual-gauge locations on the watershed are referenced to a grid as described by *Seyfried et al.* [2000]. The dual-gauge system consists of an unshielded and a shielded universal-recording gauge with orifices 3.05 m above ground (Figure 2). The shield is an Alter-type with the shield's baffles individually constrained at an angle of 30^o from vertical [*Hamon,* 1973*; Hanson,* 1989*; Hanson et al.,* 1999]. Between 1968 and 1993, the gauges were converted to 6" (15.24 cm) which doubled the accuracy of the record during that time.

Figure 2. Typical dual-gauge precipitation measuring site on the Reynolds Creek Experimental Watershed that consists of an unshielded and a shielded universal-recording gauged with their orifices at 3.05 m.

Between 1962 and 1995, most gauges were serviced weekly. Since 1995, precipitation gauges were serviced on an as needed basis depending on the amount of precipitation that was in the receiver bucket. All gauges were visited at least monthly to check for unexpected problems. All of the gauges in the network were cleaned and calibrated each fall prior to the snow season. Antifreeze was used in each receiver so that an accurate measurement was obtained during the winter and oil was used in the summer to reduce evaporation from the receivers which made reading the charts much easier.

Spatial location of each gauge site listed in Table 1 is within ± 5 m in the vertical direction and within ± 5 m in the horizontal direction. Some of the elevation differences between the GPS measured values and the corresponding digital elevation map elevations are due to the method of calculating the elevation of the gauge located in a particular grid cell located on the digital elevation map and also due to the accuracy of the GPS unit used to obtain these elevations.

Table 1. Precipitation network, Reynolds Creek Experimental Watershed, Idaho

	Location		Elevation		Data Record		
SITE ID	Easting (m)	Northing (m)	GPS (m)	DEM (m)	Begins	Dual Gauge Installed	Ends
012x29	514,030	4,793,587	1575	1581	01/01/1962	12/21/1967	12/31/1976
015x95	517,995	4,792,516	1392	1379	01/01/1962	02/07/1968	12/31/1976
023x01	514,232	4,792,210	1506	1482	01/01/1962	12/08/1967	12/31/1984
024x76	516,644	4,791,220	1331	1324	01/01/1962	02/07/1968	12/31/1976
031x48	512,258	4,790,259	1794	1789	01/01/1968	01/01/1968	12/31/1975
033x76	514,998	4,789,592	1437	1436	01/01/1962	01/24/1968	12/31/1978
043x41	514,218	4,788,407	1473	1462	01/01/1965	12/21/1967	12/31/1975
045x04	517,930	4,789,220	1228	1222	01/01/1965	02/07/1968	12/31/1975
047x52	520,763	4,788,203	1144	1132	01/01/1965	03/08/1968	12/31/1975
049x61[ab]	523,857	4,788,096	1285	1286	01/01/1965	03/08/1968	09/30/1996
053x93	514,284	4,785,992	1586	1516	01/01/1968	01/01/1968	12/31/1984
054x23	516,137	4,787,022	1356	1352	01/01/1965	01/25/1968	12/31/1975
055x88	518,535	4,786,229	1177	1168	01/01/1965	02/29/1968	12/31/1975
057x96[b]	521,391	4,786,033	1188	1186	01/01/1962	03/04/1968	09/30/1996
059x71	523,885	4,786,147	1341	1334	01/01/1965	03/06/1968	12/31/1975
061x25	511,681	4,785,632	1784	1794	01/01/1965	12/07/1967	12/31/1975
072x67	513,600	4,783,351	1593	1599	01/01/1965	11/22/1967	12/31/1975
074x12	515,878	4,784,083	1447	1436	01/01/1968	01/01/1968	12/31/1975

Table 1. Precipitation network, Reynolds Creek Experimental Watershed, Idaho (cont'd.)

	Location		Elevation		Data Record		
SITE ID	Easting (m)	Northing (m)	GPS (m)	DEM (m)	Begins	Dual Gauge Installed	Ends
075x89	518,793	4,782,905	1216	1205	01/01/1965	03/08/1968	12/31/1975
076x59[b]	520,367	4,783,418	1207	1202	01/01/1962	01/22/1968	09/30/1996
078x14	522,623	4,784,183	1304	1303	01/01/1965	03/06/1968	12/31/1975
083x92	514,571	4,781,140	1674	1681	01/01/1965	11/22/1967	12/31/1975
088x65	522,923	4,781,716	1327	1325	01/01/1962	02/07/1968	12/31/1984
095x10[b]	517,240	4,780,800	1491	1486	01/01/1962	12/20/1967	09/30/1996
097x00	520,504	4,781,047	1259	1241	01/01/1965	01/22/1968	12/31/1975
098x97[b]	523,353	4,779,404	1413	1417	03/17/1972	03/13/1972	09/30/1996
106x36	519,807	4,778,984	1302	1313	01/01/1968	01/18/1968	12/31/1975
108x04	522,689	4,779,129	1458	1472	01/01/1965	01/02/1968	12/31/1975
114x19	517,165	4,777,608	1808	1794	01/01/1962	11/20/1967	12/31/1984
116x91[b]	519,008	4,776,343	1459	1465	01/01/1962	01/18/968	09/30/1996
119x03	524,186	4,777,644	1617	1620	01/01/1965	03/07/1968	12/31/1975
124x84	516,399	4,774,981	1812	1803	01/01/1962	11/20/1967	12/31/1984
126x97	520,090	4,774,640	1674	1669	01/01/1962	03/22/1968	12/31/1984
127x07[b]	521,742	4,776,189	1652	1653	01/01/1962	02/13/1968	09/30/1996
128x87	523,498	4,774,772	1993	1990	01/01/1965	03/07/1968	12/31/1975
138x22[b]	522,594	4,774,226	1870	1866	10/13/1983	10/13/1983	09/30/1996
138x31	522,630	4,773,998	1900	1908	04/06/1972	04/06/1972	12/31/1975
138x33	522,328	4,773,974	1902	1902	10/08/1983	10/08/1983	09/30/1996
138x44	522,908	4,773,882	1956	1964	11/04/1983	11/04/1983	12/31/1994
144x62[b]	515,945	4,771,988	1815	1808	01/01/1962	11/17/1967	09/30/1996
145x37	518,473	4,772,498	1591	1581	01/01/1965	01/18/1968	12/31/1975
147x35[b]	521,336	4,772,334	1872	1868	01/01/1962	03/22/1968	09/30/1996
154x64	516,185	4,770,208	2089	2093	01/01/1968	01/01/1968	12/31/1975
155x07[b]	518,424	4,771,320	1654	1649	01/01/1962	01/18/1968	09/30/1996
156x68	520,285	4,770,365	1936	1928	01/01/1965	11/17/1967	12/31/1975

Table 1. Precipitation network, Reynolds Creek Experimental Watershed, Idaho (cont'd.)

	Location		Elevation		Data Record		
SITE ID	Easting (m)	Northing (m)	GPS (m)	DEM (m)	Begins	Dual Gauge Installed	Ends
163x20[b]	514,134	4,769,430	2170	2166	01/01/1962	10/26/1967	09/30/1996
163x35	515,042	4,769,342	2147	2152	01/01/1972	11/11/1970	12/31/1975
165x02	517,663	4,769,620	1824	1825	01/01/1969	01/01/1969	12/31/1975
166x94	519,690	4,768,437	2034	2035	01/01/1968	01/01/1968	12/31/1975
167x07[b]	521,596	4,769,779	2003	2009	01/01/1962	03/22/1968	09/30/1996
174x17[b]	516,815	4,768,026	2074	2076	01/01/1962	11/081968	09/30/1996
176x07[b]	520,055	4,768,117	2061	2067	01/01/1962	01/01/1968	09/30/1996
176x14[b]	519,693	4,767,923	2097	2097	01/01/1968	01/01/1968	09/30/1996

[a]Site not in operation from 01/01/1976 through 08/12/1979.
[b]Site currently in operation.

3. THE PRECIPITATION RECORD

3.1 Dual-Gauge Catch

The continuous precipitation records were computed for the dual-gauge sites using the following equation:

$$A = S^{B}U^{(1-B)} \tag{1}$$

where A is the computed precipitation, U is the unshielded precipitation catch, and S is the shielded precipitation catch. The coefficient "B" was found to be 1.7 by *Hamon* [1971] but based on further studies, *Hamon* [1972] set B at 1.8 which is used by the NWRC to obtain A in (1). *Hamon* [1971, 1973] gives a detailed account of the procedures that were used to obtain values for B.

3.2 1962-1967 Computed Precipitation

Computed precipitation prior to 1968 was computed from unshielded-gauge data from sites that were located at or near the dual-gauge sites listed in Table 1. For 10 years after the dual-gauges were installed, the prior unshielded gauges that were located at the three weather stations (Figure 1) were kept operational along with the dual-gauges so that a relationship could be determined between A in (1) and an original unshielded precipitation value. Computed precipitation A was then determined for 1962-1968 from unshielded-gauge data by regression techniques that incorporated seasonal (summer and winter) and elevation parameters. A double-mass curve analysis [*Searcy and Hardison,* 1960] was done on the data from each dual-gauge site to determine if the 1962-1967 adjusted record was significantly different from the record since 1968. There were no significant differences (p=0.05) between the earlier and later records.

3.3 The Precipitation Record

Figure 1 shows the dual-gauge sites on RCEW that are now in service and those with at least 4 years of record. At the present time, there are continuous records (January 1962 through September 1996) available for 12 sites, 20-32 year records available for 8 sites, 10-19 year records available for 25 sites, and 4-9 year records available for 8 sites for a total of 53 sites. Table 1 lists the dual-gauge sites by site number, location, elevation and dates of operation.

Prior to 1995, the record for each site was read by a chart reader. The record was then edited and a breakpoint record was stored in the NWRC data bank. Since 1995, the precipitation records have been stored electronically, edited by a data processing program and then a breakpoint record for each site was stored in the NWRC data bank.

Missing site information, due to clock stoppage etc., was estimated based on timing information from nearby sites and the total precipitation in the receiver which was measured during regular gauge servicing. Delayed precipitation input due to infrequent snow-capping of some of the high-elevation gauges was distributed across each of those events.

4. SPATIAL AND TEMPORAL PRECIPITATION CHARACTERISTICS

Precipitation data from six sites with 35 water-years (1963-1996) of record were used to develop the following RCEW precipitation spatial and temporal characteristics. Annual precipitation increased 887 mm, or 4.8 times, over a distance of only 17.6 km between sites 057x96 and 163x20 (Table 2). This precipitation distribution is associated with elevation and storm patterns [*Hanson et al.,* 1980]. Most of the major winter storms move onto the RCEW from the west and southwest, and thus there is more precipitation on the leeward slopes along the south and southwest sides of the watershed and less precipitation on the north and east sides. Monthly precipitation at sites 076x59 and 163x20 (Figure 3, Table 3) show how precipitation varies by month with elevation. July is the driest month at both sites and ranged from 8 mm at site 076x59 to 20 mm at site 163x20. The highest monthly precipitation was about 30 mm during June, November, December and January at site 076x59 and 177 mm during January at site 163x20. Generally, July, August and September are the driest months on the RCEW and November, December and January are the wettest.

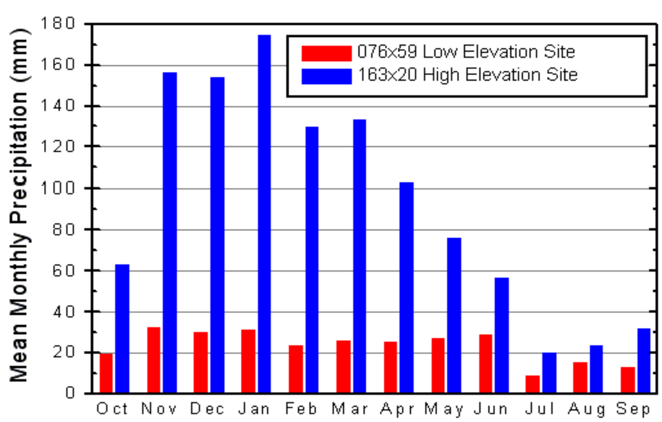

Figure 3. Mean monthly precipitation at sites 076X59 and 163X20 on Reynolds Creek Experimental Watershed.

Table 2. Average annual precipitation and elevation of six sites on the Reynolds Creek Experimental Watershed, Idaho

Site	Elevation (m)	Precipitation Annual (mm)	Precipitation % of Annual from snow	Snow Months
057x96	1188	236	20	D,J
076x59	1207	275	22	D,J
116x91	1459	471	34	D,J,F
155x07	1654	712	63	N,D,J,F
176x07	2061	994	76	N,D,J,F,M,A
163x20	2170	1123	76	N,D,J,F,M,A

Months when the mean monthly temperature was ≤1° C were considered snow months, *Cooley et al.* [1988], *Hanson and Johnson* [1993]

Table 3. Monthly and water year precipitation characteristics for sites 076x59 and 163x20 on the Reynolds Creek Experimental Watershed, Idaho

	Oct (mm)	Nov (mm)	Dec (mm)	Jan (mm)	Feb (mm)	Mar (mm)	Apr (mm)	May (mm)	Jun (mm)	Jul (mm)	Aug (mm)	Sep (mm)	Water Year (mm)
Site 076x59 (Elevation: 1207 m)													
1984	20	54	76	15	22	36	17	14	48	13	25	13	353
1992	17	36	4	6	4	4	19	9	49	5	0	6	159
1963-1996 mean	19	32	29	31	23	26	25	26	28	8	15	13	275
STD*	15	18	28	26	15	15	16	26	19	7	21	15	66
Site 163x20 (Elevation: 2170 m)													
1984	48	261	370	72	146	252	136	69	128	19	29	16	1546
1992	113	190	55	28	85	45	62	19	113	10	2	8	730
1963-1996 mean	63	156	154	177	128	133	104	75	57	20	24	32	1123
STD*	39	79	109	97	73	69	45	53	35	15	28	31	217

*Values computed from the complete data set.

As shown in Table 2, 20% of the of the annual precipitation that fell at the lower elevations was snow whereas at the high elevations 76% was snow. Monthly precipitation was considered snow when the mean monthly temperature was ≤1°C [*Cooley et al.*, 1988].

There was a very good relationship between average annual precipitation and elevation (Figure 4) for the six-site dataset that was analyzed for this data release. Figure 4 shows that the precipitation-elevation relationships depended on season. Winter storms produced considerable more precipitation at the higher elevations than at the low elevations. Precipitation increase with elevation was much less during the summer months (May-October) than during the winter months (November-April). On average, summer precipitation is more uniform across RCEW than winter precipitation.

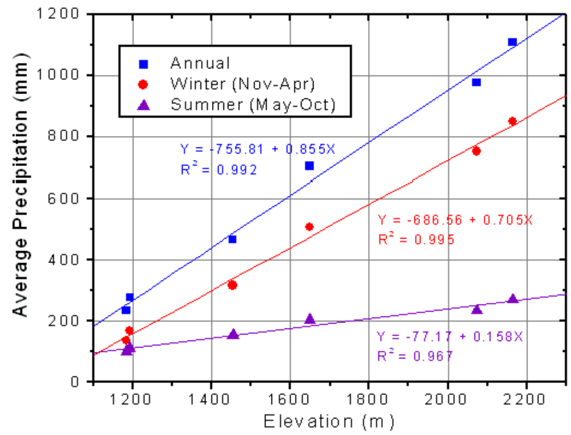

Figure 4. Relationships between seasonal and annual precipitation with elevation on the Reynolds Creek Experimental Watershed.

Monthly and water-year precipitation are displayed in Table 3 for the wet year, 1984, and the dry year, 1992, for sites 076x59 and 163x20. These data are presented to demonstrate the large monthly and year to year variations in precipitation that occur on the RCEW and to support other hydrologic results presented about the RCEW by *Marks et al.* [2000] and *Pierson et al.* [2000]. At both sites, the total precipitation during the wet water-year was more than twice the total precipitation during the dry year. Also of note is that at both sites, the November-April precipitation was 2.7 to 3 times greater during the wet year than during the dry year.

Depth-duration-frequency precipitation amounts developed for sites 076x59 and 163x20 also help describe the precipitation characteristics as they relate to location on the RCEW. The annual maximum 5-, 10-, and 30-min, and 1-, 6-, 12-, and 24-hour precipitation intensities for 2-, 5-, 10-, 25-, 50-, and 100-yr return periods are shown in Table 4. For the 5- and 10-min durations, the low elevation site (076x59) had slightly higher depths than the high elevation site (163x20). The depths were about the same for both sites for the 30-min and 1-hour durations while the depths for the 6- through 24-hour depths were greatest for the higher elevation site. In fact, the 24-hour depths computed for the high elevation site were about 2 ½ times greater than those for the low elevation site. These intensity differences are due to the different climatic regimes that prevail at the two sites. Rain is the predominant form of precipitation at the low elevation site while snow is predominant at the higher elevation site that receives four times as much precipitation annually as the other site. Also, a high proportion of the annual precipitation falls during mid-winter at the high elevation site which is not the case at the low elevation site where the monthly precipitation is relatively uniform from November through June.

Table 4. Depth-duration-frequency for sites 076X59 and 163X20on the Reynolds Creek Experimental Watershed, Idaho

Return period	2 yr (mm)	5 yr (mm)	10 yr (mm)	25 yr (mm)	50 yr (mm)	100 yr (mm)
			Site 076X59 (Elevation: 1207 m)			
5 min	4.7	7.1	9.3	12	14	16
10 min	7.1	11	14	18	21	24
30 min	9.7	15	18	23	27	31
1 hr	11	17	20	25	29	33
6 hr	18	26	31	37	42	47
12 hr	21	29	35	43	49	54
24 hr	26	35	41	48	54	60
			Site 163X20 (Elevation: 2170 m)			
5 min	3.5	5.9	7.7	10	12	15
10 min	5.7	9.3	12	16	19	22
30 min	9.6	14	18	22	25	29
1 hr	12	17	20	24	27	30
6 hr	31	38	42	47	50	53
12 hr	48	61	69	79	86	92
24 hr	69	89	103	118	129	140

5. DATA AVAILABILITY

Data from the 53 precipitation stations, including 16 currently in operation (049x61, 057x96, 076x59, 095x10, 098x97, 116x91, 127x07, 138x22, 144x62, 147x35, 155x07, 163x20, 167x07, 174x17, 176x07, and 176x14), 1 that was discontinued on Oct. 1, 1996 (138x33), and 36 that were discontinued prior to Oct. 1, 1996 (Table 1), are available from the anonymous ftp site *ftp.nwrc.ars.usda.gov* maintained by the USDA Agricultural Research Service, Northwest Watershed Research Center in Boise, Idaho, USA. Data are located in the directory *publicdatabase/precip*, in ASCII files that have been compressed using a "zip" utility. Each file has a <26>-line ascii header providing brief information on file contents, location (Easting and Northing, UTM zone 11), both the GPS elevation and the DEM elevation (see *Seyfried et al.*, 2000), time format, and period of record, column contents and units, missing data key, contact, citation and disclaimer information. An ASCII README file in the same directory gives a detailed description of the file format and contents. Both the hourly and breakpoint precipitation data are stored in 53 separate files (one for each precipitation station) identified by the data type and station ID (eg.: "breakpoint076x59precipitation.txt" or ”hourly076x59precipitation.txt"). Each record in the file consists of a line containing month, day, year, hour, minute, unshielded precipition (mm), shielded precipitation (mm), and computed precipitation (mm).

Any publications which are generated from these data should cite this publication, and acknowledge the USDA-ARS Northwest Watershed Research Center as the source. In addition we request that you notify NWRC of all publications, including theses and dissertations, which use or refer to these data. Citations may be sent by email to: *publicdatabase@nwrc.ars.usda.gov* or by mail to: USDA-ARS Northwest Watershed Research Center, 800 Park Blvd., Suite 105, Boise, ID 83712-7716. Your cooperation in this matter will promote further research and cooperation, help to validate the usefulness of the ARS experimental watersheds and data collection activities, and influence agency policy regarding future data collection.

6. SUMMARY

An unique precipitation database has been developed and made available on the web for the 35 year record, January 1962 through September 1996, for the Reynolds Creek Experimental Watershed located in the Owyhee Mountains in southwest Idaho, USA. Precipitation on this watershed, operated by the USDA-Agricultural Research Service, ranges from 236 mm on the lowest elevations at the north end of the watershed to 1123 mm at the southwest corner of the watershed. Data from 53 gauging sites that have been in operation or that are still in operation in the watershed are stored as breakpoint and hourly records in the USDA-ARS, Northwest Watershed Research Center database. These data are available from the anonymous ftp site: *ftp.nwrc.ars.usda.gov*.

7. DISCLAIMER

The mention of trade names or commercial products does not constitute endorsement or recommendation for use. The Agricultural Research Service (ARS) is a research organization. There are no legal mandates for the agency to collect or to distribute data collected for specific research projects. These data are being made available to the research community to promote the general knowledge of the processes relating to our country's natural resources.

8. ACKNOWLEDGMENTS

I would like to acknowledge Delbert Coon and David Robertson for servicing and maintaining the precipitation gauges during adverse weather and working conditions for over 30 years. This dedication resulted in a very complete 35 year precipitation record from the Reynolds Creek Experimental Watershed.

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