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Results of precipitation monitoring at Yucca Mountain

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Title: Results of Precipitation Monitoring at Yucca Mountain

Task ORD-FY04-007

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1.0 ABSTRACT

This is the final report presenting precipitation data collected under task ORD-FYO4-007 "Precipitation Monitoring at Yucca Mountain". This task acquired data using tipping bucket rain gauges to measure, with known accuracy, the accumulation and timing of precipitation in the vicinity of Yucca Mountain. Operation of the tipping bucket precipitation monitoring network was assumed by the Harry Reid Center for Environmental Studies (HRC) at the University of Nevada, Las Vegas (UNLV) in March of 2001. Precipitation monitoring data collection concluded June of 2008. All data presented in this report were collected during that time.

2.0 INTRODUCTION

Precipitation is one of the most basic hydrologic parameters, providing a major source of infiltration to the unsaturated zone, as well as a potential source of recharge for the saturated zone. Yucca Mountain precipitation data are needed to characterize present-day net infiltration rates that are used to develop predictive climate models. Data from this network has been used as a part of the overall work supporting the net infiltration modeling, the *Simulation of Net Infiltration for Modern and Potential Future Climates*, and the Performance Confirmation Plan.

The precipitation monitoring network consists of a total of 19 tipping bucket gauges at various locations in the vicinity of Yucca Mountain (Figure 1). Sixteen of these gauges are located within the boundaries of the Nevada Test Site (NTS). Three additional gauges are located in Crater Flats, which is monitored by the Bureau of Land Management (BLM). Geographic coordinates for each rain gauge station can be found in Table 1.

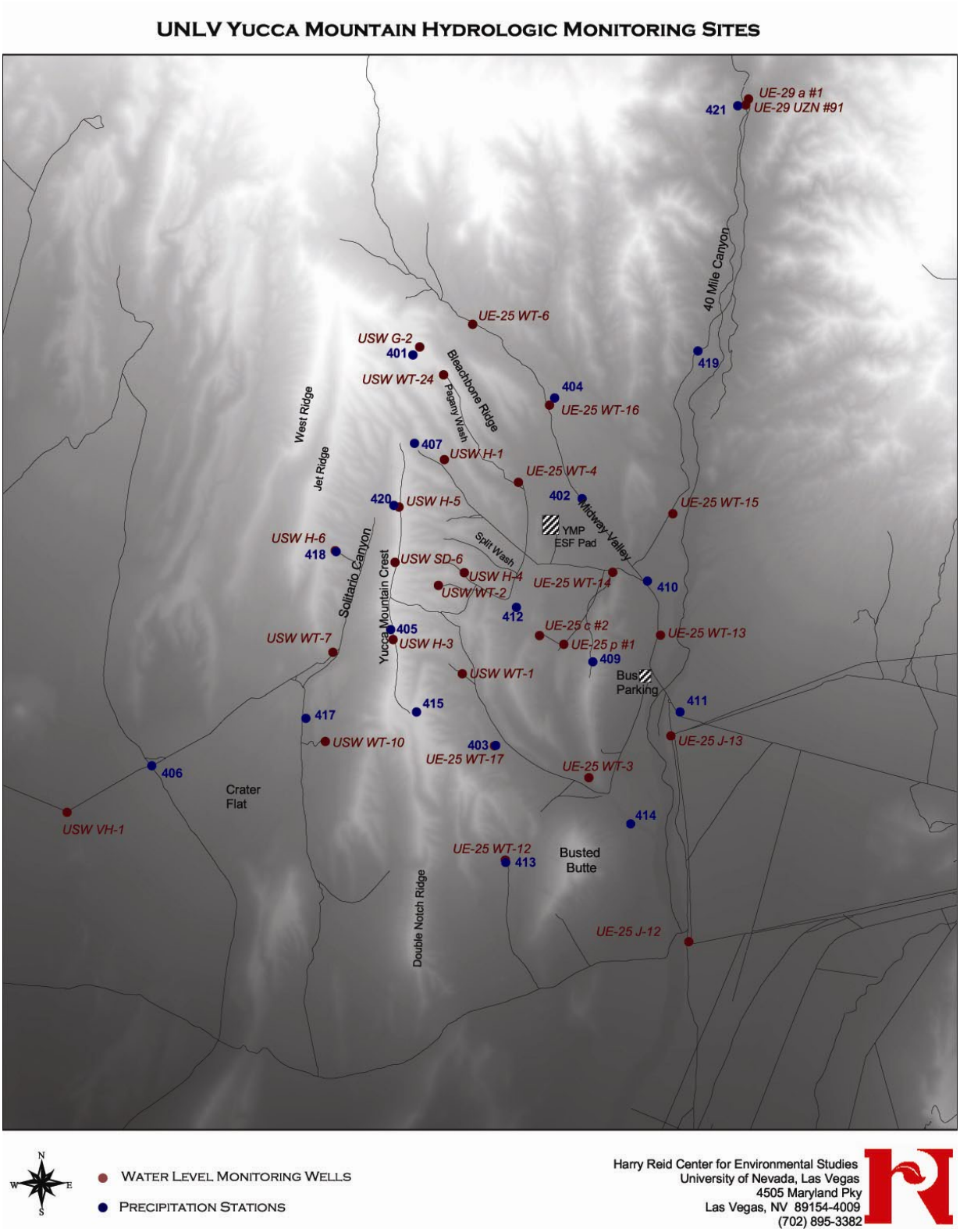


Figure 1. Map of Yucca Mountain Precipitation Gauge Network.

Table 1. Station Location Coordinates

Station ID	Northing	Easting
401	36 53.27'N	116 27.73'W
402	36 51.47'N	116 25.11'W
403	36 48.28'N	116 26.48'W
404	36 52.72'N	116 25.52'W
405	36 43.83'N	116 28.11'W
406	36 48.13'N	116 31.77'W
407	36 52.14'N	116 27.73'W
409	36 49.42'N	116 24.93'W
410	36 50.42'N	116 21.11'W
411	36 48.78'N	116 23.58'W
412	36 50.12'N	116 23.13'W
413	36 46.88'N	116 26.31'W
414	36 47.37'N	116 24.37'W
415	36 48.79'N	116 27.72'W
417	36 48.52'N	116 30.44'W
418	36 48.17'N	116 29.43'W
419	36 53.33'N	116 23.26'W

Data Source: MOL.20020408.0317

3.0 EQUIPMENT AND METHODS

3.1 Station Configuration

The precipitation monitoring network consists of 19 field stations, each consisting of a tipping bucket rain gauge, datalogger, storage module, enclosure for both the datalogger and the storage module, a 12-volt battery, battery charger and a solar panel.

Tipping bucket rain gauges used on this task include standard gauges and propane heated gauges manufactured by Qualimetrics Inc. and electrically heated gauges manufactured by Hydrologic Services Inc. Hydrologic Services Inc. gauges are outfitted with a Campbell Scientific air temperature sensor and a Vaisala barometric pressure transducer. Rain gauge stations and their associated equipment, manufacturers, and model numbers are shown in Table 2.

The two most recent additions to the network, Station 421 (brought online 11/29/05) and Station 420 (brought online 01/12/06), are located at the northern reach of Forty Mile Wash and the north end of the Yucca Mountain Crest, respectively. These two stations were the only stations equipped with the Hydrologic Services monitors. All remaining stations were equipped with Qualimetrics gauges.

Each gauge, regardless of model, has a simple twin-bucket mechanism causing the buckets to tip when a known volume of water (in most gauges, 0.01 inches) is collected. The tipping bucket closes a switch, sending an electronic signal to the datalogger, which records the quantity of precipitation, the date and the time of each tip.

All dataloggers and storage modules in use with this network are manufactured by Campbell Scientific Inc (CSI). A CSI storage module attached to the datalogger records a backup copy of all the data in the event of any datalogger complications.

Table 2. Rain gauge stations with associated equipment, model numbers and manufacturers located at each site.

Rain Gauge Station	Gauge Type	Gauge Manufacturer	Gauge Model	Datalogger Model	Temperature Sensor Model	Barometric Sensor Model
401	Propane heated	Qualimetrics	6041-B	CR10	NA	NA
402	Standard	Qualimetrics	6011-B	CR10	NA	NA
403	Standard	Qualimetrics	6011-B	CR10	NA	NA
404	Standard	Qualimetrics	6011-B	CR10	NA	NA
405	Propane heated	Qualimetrics	6041-B	CR10	NA	NA
406	Standard	Qualimetrics	6011-B	CR10	NA	NA
407	Standard	Qualimetrics	6011-B	CR10	NA	NA
409	Propane heated	Qualimetrics	6011-B	CR10	NA	NA
410	Standard	Qualimetrics	6011-B	CR10	NA	NA
411	Standard	Qualimetrics	6011-B	CR10	NA	NA
412	Standard	Qualimetrics	6011-B	CR10X	NA	NA
413	Standard	Qualimetrics	6011-B	CR10	NA	NA
414	Standard	Qualimetrics	6011-B	CR10	NA	NA
415	Standard	Qualimetrics	6011-A	CR10	NA	NA
417	Standard	Qualimetrics	6011-B	CR10	NA	NA
418	Standard	Qualimetrics	6011-B	CR10	NA	NA
419	Standard	Qualimetrics	6011-B	CR10	NA	NA
420	Heated Gauge	Hydrologic Services	TB3LP	CR10	107-L	PTB101B
421	Heated Gauge	Hydrologic Services	TB3LP	CR10X	107-L	PTB101B

Gauges are installed on cement pads at ground surface. This aids in keeping the gauge clear of any surrounding obstacles (e.g. large bushes, datalogger enclosures, work benches) and prevents wind turbulence and interferences with rainfall patterns. Stations 401, 405, and 415 are equipped with additional wind guards to minimize the effects of wind turbulence around the gauge. Theses guards also aid to increase the catchment of precipitation falling as snow. All gauge orifices are at least 12" from the ground, minimizing splash-in associated with ground deflected precipitation. All gauges also have coarse mesh screens. Theses are designed to cover the inner gauge orifice and aid in preventing debris from blocking precipitation flow into the tipping buckets.

The gauge network was established following the U.S. Environmental Protection Agency (EPA) 1995 "*Onsite Program Guidance for Regulatory Modeling Applications and Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV, Meteorological Measurements*." (TIC# 210292). Previously installed gauges were installed in accordance to technical procedure YMP-USGS-HP-180. Upon HRC acquiring this task, all gauge installation was done in accordance with approved Nevada System of Higher Education (NSHE) procedure IPLV-032, *Precipitation Monitoring Using Tipping Bucket Rain Gauges*.

3.2 Protective Measures

Since the data acquired on this task cannot be reproduced through testing and experimentation, several protective measures were taken to ensure the integrity of the equipment and the data. Datalogger units are stored in raised enclosures, protecting equipment from inclement weather. Ground level wiring was insulated by PVC pipe in order to guard it from severed connections as a result of rodent activity.

Access to most stations is restricted due to their location on the NTS; the three additional offsite stations at Crater Flat are not subject to tampering due to their remote location on BLM monitored land. In the event of a tampering incident, the integrity of the data was ensured, first, through the automatic creation of a backup copy of the data written to the storage module, and, second, through the incorporation of a program identifier that indicates any programming changes. Data are also visually checked upon each site visit to ensure that there were no inconsistencies that might indicate a problem.

4.0 PRECIPITATION DATA

4.1 Precision and Accuracy

Most gauges in use in this network are precise to 0.01 inches (0.254mm) and have an accuracy of $\pm$10%. This is consistent with accepted guidelines for meteorological monitoring. Data recorded at Station 402 after 08/31/2001 was recorded in millimeters, but for consistency, all data will be reported in inches. These data have a resolution of 0.1 mm. This is also consistent with the operational standard of $\pm$10% accuracy.

4.2 Data Qualification

The following submitted data are included in this report:

Table 3. Data Traceability Identifiers

Period of Record	Data Tracking Number	Status	Originator
07/01/2003–12/31/2003	MO0408UCC007AB.001	Q	UNLV-HRC
01/01/2004-12/31/2004	MO0504UCC007AB.002	Q	UNLV-HRC
01/01/2005-12/31/2005	MO0604UCC007AB.003	Q	UNLV-HRC
01/01/2006-12/31/2006	MO0708UCC007AB.004	Q	UNLV-HRC
01/01/2007-08/31/2007	MO0711UCC007AB.005	Q	UNLV-HRC
09/01/2007-08/04/2008	007NM.001	Non-Q	UNLV-HRC

4.3 QA Compliance

All data acquired on this task by HRC personnel are detailed in procedure IPLV-032. Electronic data were controlled in accordance with QAP-3.1, *Control of Electronic Data*. Duplicate copies of the data reside in the datalogger memory until overwritten. Duplicate copies are sent to an external storage module, which remains at the physical site of the data collection. All storage modules remain on site until they are due for calibration. Upon returning from the field, data that is downloaded either from the storage module or the datalogger is then downloaded to the network server, which is regularly backed up. Files are visually verified after each transfer. Work is documented in accordance with IPLV-032.

Qualified data was acquired on this task until August 31, 2007. After that date, Task ORD-FY04-007 was downgraded to non-qualified status, and all subsequent data collected after the last qualified data submittal has been designated as such and archived with the Yucca Mountain Records Processing Center.

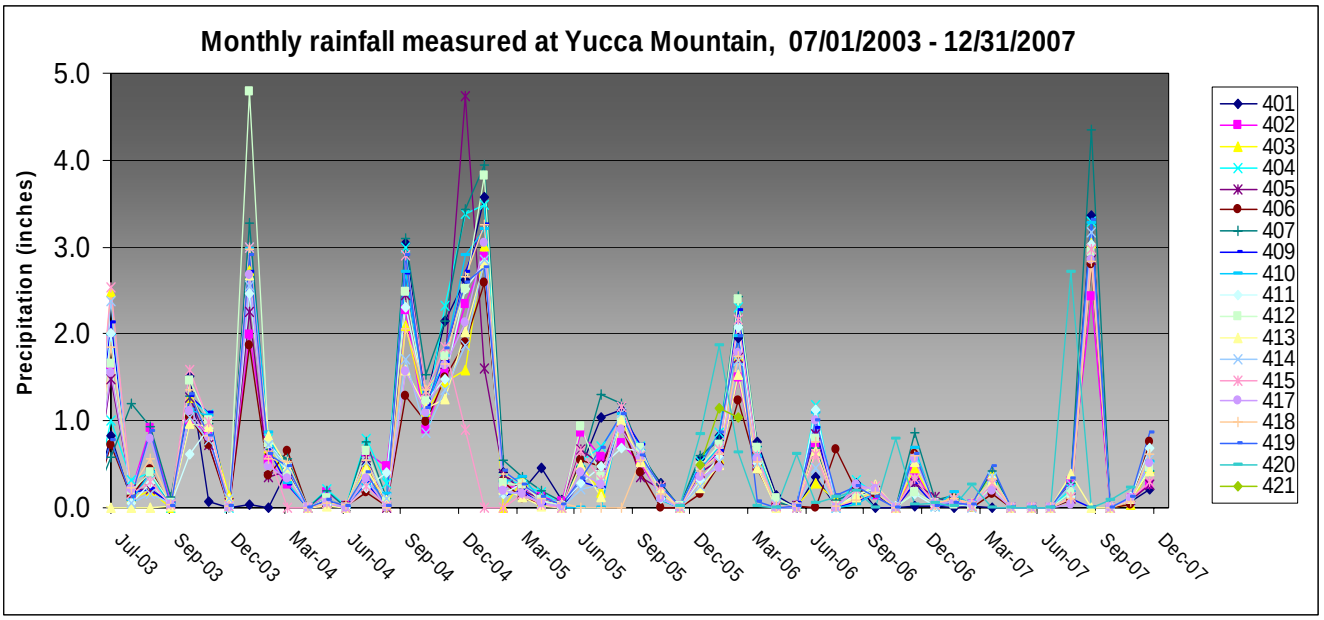
5.0 RESULTS

Data are presented below as a sum of monthly precipitation. As a result individual storm events that are logged over multiple months will be represented as precipitation during the individual months rather than separated as an individual storm event.

The annual averages by water year (6.06 in) and by calendar year (6.10 in) developed from Tables 3 and 4 are in agreement with the long-term regional averages of 6.5 in/yr (165 mm/yr) (Hevesi and Flint, 1998).

The arid climate of the Yucca Mountain region is characterized by convective summer rainfall. The winter months are characteristic of lower intensity but longer duration periods of precipitation. These low pressure dominated weather systems may occur during the summer-

winter or winter-summer transition periods as well. These seasonal variations are visible even during limited recorded periods of time such as what is presented here.



Data Source: MO0408UCC007AB.001, MO0504UCC007AB.002, MO0604UCC007AB.003, MO0708UCC007AB.004, MO0711UCC007AB.005, 007NM.001.

Figure 2. Yucca Mountain Precipitation by Station, July 1, 2003 through December 31, 2007.

Table 4: Annual Average Precipitation by Calendar Year

CALENDAR YEAR (Jan 1st – Dec 31st)	1999	2000	2001	2002	2003	2004	2005	2006	2007
Average Annual Rainfall (in)	5.12	7.44	5.70	1.07	7.84	9.56	8.60	5.29	4.31
Median Annual Rainfall (in)	5.42	7.17	5.62	1.03	7.92	9.38	8.65	5.19	4.14
Min	2.60	4.12	2.15	0.57	4.63	6.88	4.07	4.01	3.52
Max	7.18	9.63	8.63	1.51	9.69	12.35	12.44	6.96	5.85

Table 5: Annual Average Precipitation by Water Year

WATER YEAR (Nov 1st – Oct 31st)	1999/ 2000	2000/ 2001	2001/ 2002	2002/ 2003	2003/ 2004	2004/ 2005	2005/ 2006	2006/ 2007
Average Annual Rainfall by Water Year (in)	6.38	6.16	1.11	6.31	6.42	13.08	5.40	4.27
Median Annual Rainfall by Water Year (in)	6.31	6.07	1.06	6.26	6.57	12.79	5.56	4.81

Min	4.02	2.48	0.56	3.30	2.68	9.31	3.63	2.72
Max	8.08	9.28	1.84	7.95	9.25	18.30	6.91	6.36

6.0 REFERENCES

Hevesi, JA and Flint, AL, 1998. "Geostatistical Model for Estimating Precipitation and Recharge in the Yucca Mountain Region, Nevada – California." U.S. Geological Survey Water Resources Investigations Report 96-4123. Denver, Colorado:U.S. Geological Survey, p.54. MOL.19981209.0399.

U.S. Environmental Protection Agency (EPA), 1995. "Onsite Program Guidance for Regulatory Modeling Applications and Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV, Meteorological Measurements." TIC# 210292

7.0 APPENDIX: Annual Precipitation Data

Table 6: Annual Precipitation by Recording Station

	ANNUAL RAINFALL BY WATER YEAR BY RECORDING STATION																	
Water Year	**401**	**402**	**403**	**404**	**405**	**406**	**407**	**409**	**410**	**411**	**412**	**413**	**414**	**415**	**417**	**418**	**419**	**420**
1999/00	5.91	7.79	6.31	7.51	5.77	5.37	6.76	4.02	7.75	6.89	7.32	4.92	5.50	6.06	5.82	8.08	6.64	
2000/01	4.89	7.54	5.34	9.28	5.96	2.48	6.02	4.94	6.54	4.05	6.65	6.07	5.58	6.71	7.04	7.71	7.91	
2001/02	1.13	1.29	1.00	1.60	0.98	0.56	1.50	0.95	1.05	1.15	1.22	0.77	0.85	1.15	0.82	1.06	1.84	
2002/03	5.67	6.15	6.26	6.18	5.69	4.53	7.95	7.04	7.67	6.88	6.44	3.30	7.06	7.68	5.91	6.60	6.20	
2003/04	2.68	6.02	6.68	7.86	5.81	4.86	7.93	6.48	6.78	5.94	9.25	6.57	6.36	6.58	5.83	6.91	6.65	
2004/05	16.21	12.79	11.23	16.28	14.57	10.70	18.30	13.49	13.50	12.33	14.76	10.81	10.59	9.31	11.47	11.81	14.19	
2005/06	5.77	4.40	4.39	6.75	4.84	3.63	6.44	5.80	5.57	5.52	6.16	6.91	4.47	5.56	5.09	4.91	5.63	
2006/07	3.70	3.57	4.18	4.58	3.72	3.80	6.18	0.77	4.59	3.75	3.66	4.13	4.47	3.88	3.77	4.05	4.85	3.88
7 year average	5.75	6.19	5.67	7.50	5.92	4.49	7.64	5.44	6.68	5.81	6.93	5.44	5.61	5.87	5.72	6.39	6.74	3.88