Memo

Water & Earth Technologies, Inc.
Water Resources and Environmental Consulting

Date: January 10, 2008

To: Kevin Stewart and Chad Kudym

From: Markus Ritsch

Subject: **2007 Annual ALERT Data Analysis Summary Report**

I. Executive Summary

The Urban Drainage and Flood Control District (District) operates a flood detection network consisting of remote monitoring stations that report hydrologic information using the Automated Local Evaluation in Real-Time (ALERT) radio protocol. Rainfall, water level, and weather data are processed in real-time to support flood mitigation activities within the District.

In 2007, Water & Earth Technologies, Inc. (WET) provided monthly analysis of the District's ALERT database for quality assurance and control. ALERT data received by the District's ALERT 2 base station were analyzed to quantify the performance of individual stations, to assess the general health of the telemetry system, to estimate hourly radio traffic loading rates, and to calculate rainfall timer and event reporting characteristics.

The monitoring network is fully operational during the "flood season" which extends from April 1 through September 30. Portions of the network are operational year-round. Most of the District's stations are winterized beginning in October and are returned to operation in March.

II. ALERT Data Source

Raw ALERT data records were extracted from the Nova Star 4.0 base station (ALERT 2) and analyzed for the period January 1 through December 31, 2007.

III. General System-Wide Reporting Summary

A total of 2,413,934 individual data records were analyzed for the year (Table 1). The month of May had the most ALERT data reports. As would be expected, the winter months experienced fewer reports than did the spring and summer months. The system has a fairly consistent base load of approximately 160,000 reports per month throughout the year. The total number of reports received in 2007 was greater than 2006. This is due to the fact that more stations were received by the District in 2007. Gages in the Hayman area and new gages in the District were added in 2007.

Table 1. Monthly Distribution of ALERT Data Reports

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2006	193,406	158,525	175,112	196,823	189,737	194,975	193,304	212,475	189,640	193,871	164,044	161,131	2,223,043
2007	164,551	161,869	191,094	208,964	242,905	212,431	211,404	213,458	192,610	218,744	194,229	201,675	2,413,934

Shading in light yellow denotes peak month of reporting.

The distribution of ALERT reports received during the "flood season" is shown (Table 2). Over the long-term, data received at the base station is dominated by meteorological sensors.

Table 2. Distribution of Reports among Sensor Groups (period April 1 through September 30)

Sensor Group	Reports	Percent of Total
Meteorological (RH, AT, Wind, BP, Solar)	857,811	66.96%
Water level (PT, Shaft encoder, etc.)	219,581	17.14%
Rain	87,818	6.85%
Repeater reports/Sensor status reports	76,455	5.97%
Other sensor reports (fuel moisture, etc.)	39,422	3.08%
TOTAL	**1,281,087**	**100.00%**

Data reports received by the Nova Star base station are checked against some basic quality control thresholds. Of all the ALERT reports received during the "flood season", ninety-nine percent were flagged as "good" by the Nova Star validation process (Table 3). Roughly one percent of the total data reports were flagged as "bad". The primary source of invalid reports during the 2007 "flood season" was the wind reporting at Squaw Mountain (ALERT sensor IDs 2189 and 2187).

Table 3. Data Validation Summary (period April 1 through September 30)

Records by Validation Type	Data Type	Reports	Percent
Good	0	1,265,978	98.82%
Questionable	1	15,109	1.18%
	Total	1,281,087	100.00%

A. Radio Traffic Loading

The system-wide radio traffic loading during the "flood season" was approximately 6,915 reports per day with an average hourly loading of about 288 reports. Hours of peak radio traffic were determined (Table 4).

Reports received at the base station differs from total ALERT radio traffic because reports lost to contention are not included (Table 4). The actual traffic loading is typically higher than the reports received at the base.

Two large storm periods are evident. One storm occurred in the evening of May 14 and a second large storm occurred in the late afternoon of July 27. A third, shorter duration event is also evident on August 5.

Table 4. Peak Radio Traffic Loading

Occurrence of Peak Loading (hour beginning)	Reports Per Hour (received at base)
May 14, 2007 – 7:00 PM	1,236
May 14, 2007 – 8:00 PM	973
August 5, 2007 – 6:00 PM	1,013
July 27, 2007 – 5:00 PM	913
July 27, 2007 – 6:00 PM	909

The peak hour of radio traffic occurred on May 14 from 7:00 pm to 8:00 pm. During this hour, 1,236 ALERT reports were received at the base station. The actual radio traffic loading may have been as high as 1,500 reports when contentious and "unknown" reports are considered.

Peak and hourly average data reception rates are shown for the year (Figure 1).

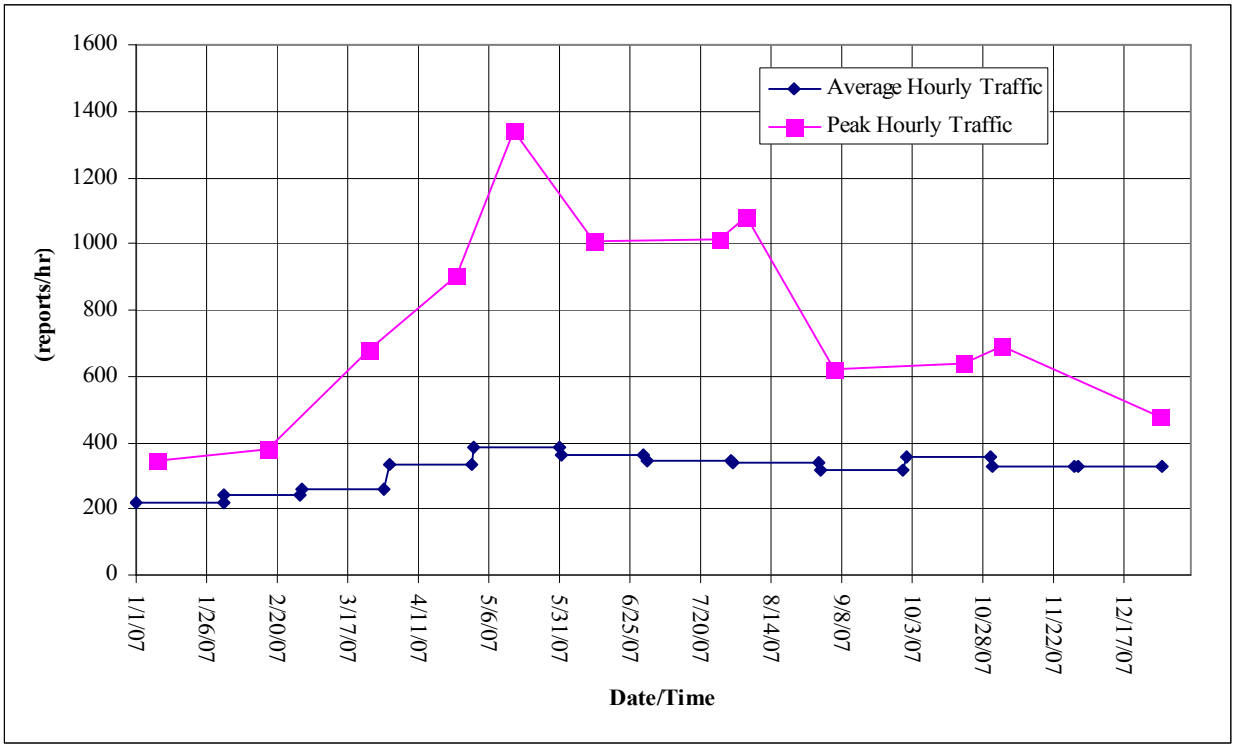

Figure 1. Peak and Hourly Average Data Reception Rates (reports received at base station)

B. Distribution of Reports during Heavy Traffic Periods

During non-rain periods and over the long-term, the radio traffic is dominated by reports from meteorological sensors (Table 2), specifically wind sensors. The distribution of ALERT reports during a peak traffic period, however, looks quite different. The peak hours of radio traffic are typically dominated by reports from precipitation and water level sensors.

The peak hour of traffic occurred on May 14th from 7:00 pm to 8:00 pm. The period of heaviest traffic was generally a four hour period from 7:00 PM to 11:00 PM. The ALERT data for the 4-hour period was examined more closely to characterize the distribution of sensor reports (Table 5).

Table 5. Distribution of Reports during the Peak Traffic Period (May 14, 2007, 7:00 PM to 11:00 PM)

Sensor Group	Reports	Percent
Water Level Pressure Transducer	1,555	43.05%
Precipitation	994	27.52%
Wind Gust	192	5.32%
Water Level Float	191	5.29%
Wind Speed Average & Azimuth	170	4.71%
Temperature	135	3.74%
Relative Humidity	91	2.52%
Wind Direction	64	1.47%
Wind Speed Average	58	1.61%
Battery Voltage HSE	53	1.47%
Battery Voltage Digital	22	0.61%
Barometric Pressure	17	0.47%
Solar Radiation	15	0.42%
Hayman Precipitation	11	0.30%
Handar 585 ALARM Status	10	0.28%
Fuel Moisture	8	0.22%
Fuel Temperature	8	0.22%
Battery Voltage Analog	7	0.19%
Repeater Pass List	3	0.08%
12Hr Status Report	2	0.06%
Longmont Flow Gage	2	0.06%
Test	2	0.06%
Longmont Water Level PT	1	0.03%
Repeater Status Report	1	0.03%
Total	**3,612**	**100%**

IV. Rain Sensor Monthly Timer Reporting Summary

Non-incrementing timer reports from rain sensors were analyzed. The analysis assumes that all rain sensors have a 12-hour timer reporting interval. A summary showing those rain sensors with the worst timer reporting characteristics for each month of the year are shown (Table 6). Sensors having poor timer performance in multiple months are shaded with unique colors. Sensors with poor reporting characteristics in multiple months can be identified.

Table 6. Monthly Summary of Sensors with Poor Timer Performance

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct*	Nov*	Dec
750	1330	2310	1810	1810	1810	1810	1600	1330	2340	1500	410
4470	1460	1710	540	310	1710	4560	410	1340	2250	1530	2190
4560	2330	2350	310	540	4470	2350	1350	1360	2230	1620	4470
4240	4170	2240	850	850	1500	2250	2190	1370	2240	600	4560
4510	4470	2250	1710	1710	4290	4200	4820	2310	2310	610	140
				900	540	4240	4830	1030	2360	1320	4510

* - Many stations are taken out-of-service for the winter beginning in October which influences timer performance.

Sensor ID 1460 has a 24-hour timer reporting interval and is not included in the timer reporting analysis.

Sensor ID 1810 has an 18-hour timer reporting interval and is not included in the timer reporting analysis after the month of July.

V. Rain Sensor Event Reporting Summary

A. District-Wide Total Tip Count Statistics

The incrementing rainfall reports from all 1-mm rain sensors were quantified to determine the District-wide mean total tip count (Table 7). The annual average precipitation experienced District-wide in 2007 was higher than 2006. The month experiencing the highest precipitation in 2007 was May.

Table 7. Monthly Summary of District-Wide Mean Total 1-mm Tip Count

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
2006	4.62	5.92	18.39	20.47	19.44	13.75	74.03	46.89	24.17	41.13	5.04	16.45	24.19
2007	11.56	5.40	29.75	65.03	68.30	15.87	36.20	46.38	22.13	29.50	6.54	11.29	29.00

Shading in light yellow denotes peak month of reporting.

B. Incrementing Tip Reporting Summary

The incrementing tip reports received from the District's rain sensors were analyzed for each month of the year (Table 8). The system-wide reception rate of incrementing tip reports for the year was approximately 88 percent. A total of 43,758 incrementing reports were received and a total of 49,589 were expected.

The month of August had the worst reception rate of incrementing tip reports. Many rain sensors experienced a large jump in sequential count between August 23 and August 25, 2007. During this period, the Blue Mountain radio repeater was not in operation due to a lightning strike. For this reason, the reporting performance is poor in August.

Other than August, the month with the worst reception rate is May. This is also the month with the highest radio traffic and the largest number of total reports. It stands to reason that data loss due to contention increases as the total traffic loading increases.

Table 8. Monthly Incrementing Tip Reports Received from All Rain Sensors

Month	Received	Expected	Reception Rate (%)
January	843	873	96.56%
February	372	386	96.37%
March	4,080	4,461	91.46%
April	8,483	9,625	88.14%
May	8,738	10,171	85.91%
June	2,063	2,333	88.43%
July	4,778	5,285	90.41%
August	6,356	7,880	80.66%
September	3,051	3,297	92.54%
October	3,711	3,923	94.60%
November	452	497	90.95%
December	831	858	96.85%
TOTAL	**43,758**	**49,589**	**88.24%**

The rain sensors with the worst event reporting characteristics for each month of the year are shown (Table 9). Sensors identified as having poor event reporting performance characteristics in multiple months are shaded with unique colors.

Table 9. Monthly Summary of Sensors with Poor Event Performance

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug*	Sep	Oct	Nov	Dec
2320	1330	540	1350	860	1710	2370	1350	1810	1710	1920	4470
2190	4080	310	310	4710	1350	150	2310	520	860	4790	4790
4710	1640	4470	1100	1810	310	1700	540	1360	540	1700	4230
4090	4050	850	860	1350	1700	1350	1300	1700	850	4180	4270
4820	4180	4570	540	400	210	850	1920	1710	900	4770	4010
				4570	110	2340	840	1350	1100	1810	4520

* Note that the outage of the Blue Mountain repeater caused a large data gap in the sequential count series for many sensors and thus the incrementing tip report performance statistics are skewed this month.

VI. General Observations for the Year

A. Timer and Event Reporting

The following rain sensors had poor **timer** reporting characteristics for multiple months throughout the year.

- Lyons Diversion NSV (ID 4560)
- Genesee Village (ID 2310)
- Guy Hill Ranch (ID 310)
- Parker/Mississippi (ID 540)
- Shop Creek (ID 1710)
- Little Narrows (ID 4470)

The following rain sensors had poor **event** reporting characteristics for multiple months throughout the year.

- Guy Hill Ranch (ID 310)
- Sand Creek at Colfax (ID 860)
- Chatfield COE (ID 1350)
- Cherry Creek at Champa (ID 1700)
- Shop Creek (ID 1710)
- Sand Creek at Mouth (ID 1810)

When looking at both monthly timer and event reporting, the sensors with consistently poor performance include Guy Hill Ranch (ID 310), Shop Creek (ID 1710), and Sand Creek at Mouth (ID 1810).

B. "Flood Season" Statistics

1. Rainfall accumulation

The entire network is operational from April 1 through October 1 which is the period generally referred to as the "flood season." The rain sensors recording the highest accumulation of precipitation during the "flood season" were:

- Temple Pond at DTC (ID 630) with 23.6 inches and
- Powers Park (ID 1500) with 22.8 inches.

Both Temple Pond and Powers Park are influenced by irrigation.

The rain sensors recording the highest accumulated precipitation for the "flood season" that were not influenced by irrigation sprinklers were:

- Murphy Creek Golf (ID 870) with 15.8 inches,
- Ward C-1 (ID 4710) with 14.3 inches,
- Haskins Gulch Confluence (ID 2820) with 13.1 inches, and
- Mission Viejo Park (ID 760) with 13.0 inches.

The average accumulated precipitation during the "flood season" was 10.25 inches. A graphical representation of the total accumulated precipitation for the period April 1 to October 1 is provided.

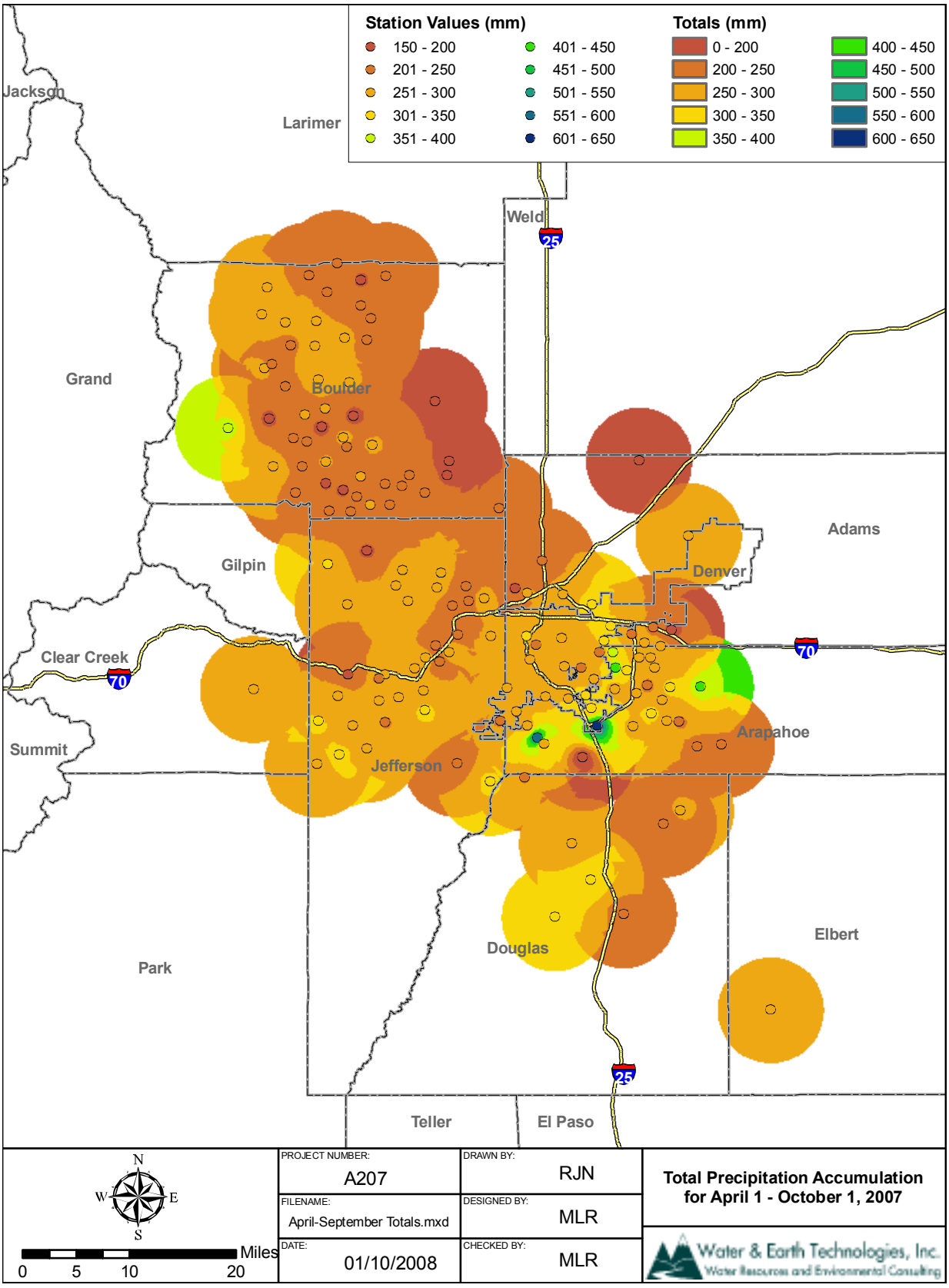

Figure 2. Total Accumulated Precipitation, April 1 to October 1, 2007

2. Reporting characteristics

The rain sensors with the worst reporting characteristics (combined timer and event reporting) during the "flood season" were:

- Sand Creek at Mouth (ID 1810),
- SBC at San Souci (ID 4830),
- Englewood Dam (ID 1600), and
- Guy Hill Ranch (ID 310).

The system-wide reporting characteristics for the "flood season" are summarized (Figure 3). The graphic below illustrates that approximately 80% of all data transmissions were successfully received from 98% of the District's rain monitoring network. Stated in another manner, 98% of the rain monitoring network had a data reception success rate of 80% or better.

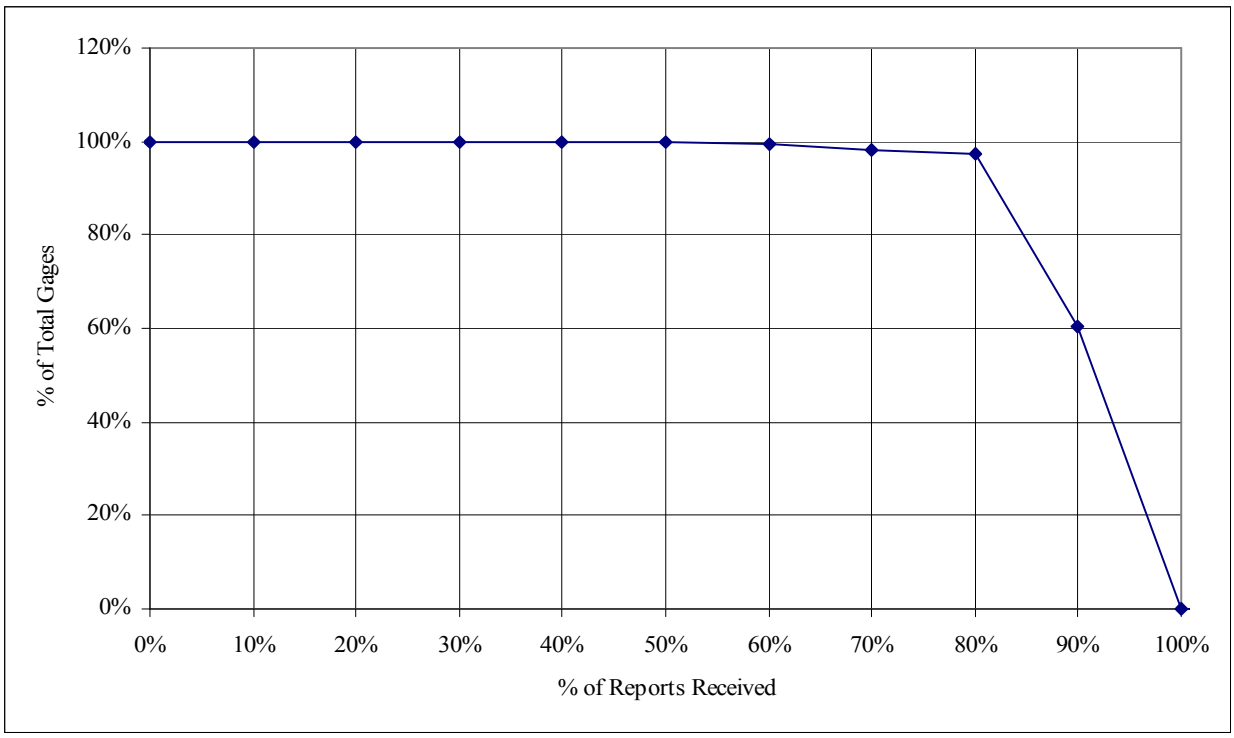

Figure 3. System-Wide Data Reception Success Rate

The rain timer reporting characteristics for the entire network for the period April 1 to October 1 is provided.

Overall, the District's monitoring network and telemetry system performed well in 2007.

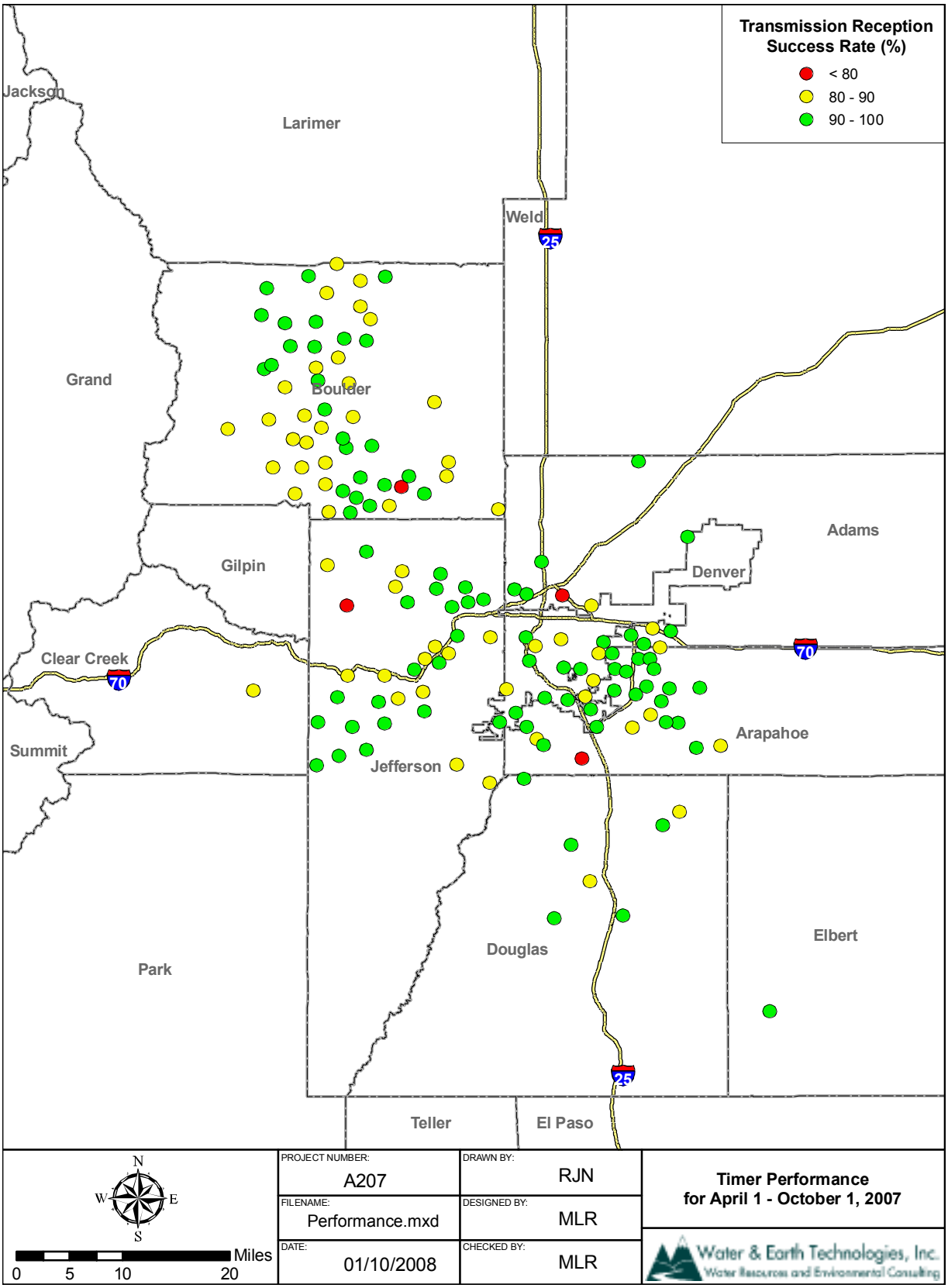

Figure 4. Timer Performance, April 1 to October 1, 2007