Date: January 20, 2009

To: Kevin Stewart

From: Markus Ritsch

Subject: **2011 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 2011, Water & Earth Technologies, Inc. (WET) provided monthly analysis of the District's legacy ALERT and ALERT2 (A2) protocol databases for quality assurance and control. Data records received by the District's Nova Star 5.0 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 was fully operational during the "flood season" which extends from April 1 through September 30. The District's stream and rain stations are winterized beginning in October. Portions of the network, weather stations and gages in Boulder County are operational year-round.

Legacy ALERT and A2 data records were extracted from the Nova Star 5.0 base station and analyzed for the period January 1 through December 31, 2011.

II. General System-Wide Reporting Summary

A total of 4,226,340 individual legacy ALERT data reports were received by the base station decoder and analyzed for the year (Table 1). The reports were tabulated from the NovaStar monthly received data logs (RecDataLog). The total includes reports from "unknown" sensors, i.e. sensors that are not defined in the database.

The radio loading has increased each year since 2006 which reflects the additional traffic from new stations installed each year. 2010 was the first year that the UDFCD exceeded 4 million total reports. 2011 was the first year that the total reports received in a single month exceeded 400,000!

Table 1. Monthly Distribution of Legacy 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	2,225,049
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
2008	221,176	218,689	246,487	253,827	289,334	287,100	277,303	301,916	271,014	274,395	255,380	265,239	3,161,860
2009	248,453	190,963	265,225	275,468	326,207	315,331	334,639	329,363	318,522	320,482	294,473	297,241	3,516,367
2010	287,480	262,656	337,042	371,445	368,950	353,819	360,234	357,912	335,128	342,035	306,400	340,233	4,023,334
2011	313,618	295,538	339,485	342,575	356,246	378,358	420,735	376,550	362,681	370,375	342,819	327,359	4,226,340

Shading in light yellow denotes peak month of reporting.

In 2011 a second radio channel was used to receive data reports using the new ALERT 2 (A2) data protocol. The A2 protocol is being tested to confirm and quantify its ability to more efficiently use the existing radio bandwidth. The A2 reports were received in parallel from each radio repeater in the UDFCD network. A comparison each month was made between the total received A2 reports relative to the legacy ALERT reports (Table 2).

Table 2. 2011 Monthly Comparison of Reports Received on the Legacy ALERT and A2 Channel

Source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
ALERT	313,618	295,538	339,485	342,575	356,246	378,358	420,735	376,550	362,681	370,375	342,819	327,359	4,226,340
A2	356,733	306,508	351,740	363,145	403,057	390,365	432,227	386,413	370,698	382,347	357,038	356,942	4,455,203
Diff (A2-A)	43,115	10,970	12,255	20,570	46,811	12,007	11,492	9,863	8,017	11,972	14,219	29,583	228,863
Comments	A2 testing accounts for 21,000 data reports on the A2 channel			Blue Mt Repeater ALERT channel audio mixer was having trouble	The ALERT base receiver had several periods where it was down					Blue Mt Repeater ALERT channel audio mixer was having trouble toward the end of the month		Blue Mt Repeater ALERT channel audio mixer was having trouble	

The difference in legacy ALERT and A2 reports is high in April, May, October and December. One possible explanation is that the legacy ALERT channel was not functioning at the Blue Mountain Repeater during portions of these months. OneRain has offered the following opinion.

OneRain, Thursday, 1/12/2012 3:04 PM – "Regarding the loss of "Legacy" ALERT data from weather stations during the period of Dec 3rd to the 5th. All 5 weather stations reporting through the West (Blue Mtn.) repeater on the station frequency of 169.500 MHz experienced this dropout. Blue Mtn. ID 140, Elbert ID 1440, Stapleton ID 1460, Marston ID 1520 and Aurora's Brighton ETO (hourly reporting) ID 1570. As reported in the End of Year reports for 2010 and 2011, we believe that this is due to a temperature sensitive component/device in the audio mixer (combines the output of both receivers, 169.500 and 169.525 MHz, into a single feed for retransmission) in the repeater. This does not affect ALERT 2 as that is fed digitally via a different circuit entirely. We have consulted with Hydrolynx and replaced the mixer circuit board in May of 2010 with marginal improvement (a few degrees F. change). Since this only affects performance at temperatures below 20 degrees F. (outside the traditional "flood season") it has not been a high priority. This in no way affects the "in season" comparison between legacy and ALERT 2 performance as the malfunction does not occur at those temperatures."

It is our opinion that the faulty audio mixer at the Blue Mountain Repeater and/or a faulty radio receiver at Diamond Hill did affect the "in season" comparison of legacy and A2 reports received by the UDFCD base station. Specifically the months of April, May and October contained periods where the legacy channel dropped out and legacy reports were under-counted. This opinion is based on the following analysis.

A. Data Received through Blue Mountain Repeater from Marston Lake North, ID 1521

The reception of legacy ALERT and A2 reports from Marson Lake North, ID 1521 was quantified for the entire year. The difference in daily reporting (A2 minus legacy ALERT) as received by the base station is shown (Figure 1). From this plot it would seem that the Blue Mountain repeater audio mixer or the radio receiver at Diamond Hill was having problems throughout the month of April and into May. The issues seem to be resolved beginning May 18, the legacy ALERT and A2 channels seem to be functioning correctly until October 26th when the legacy ALERT channel again drops out.

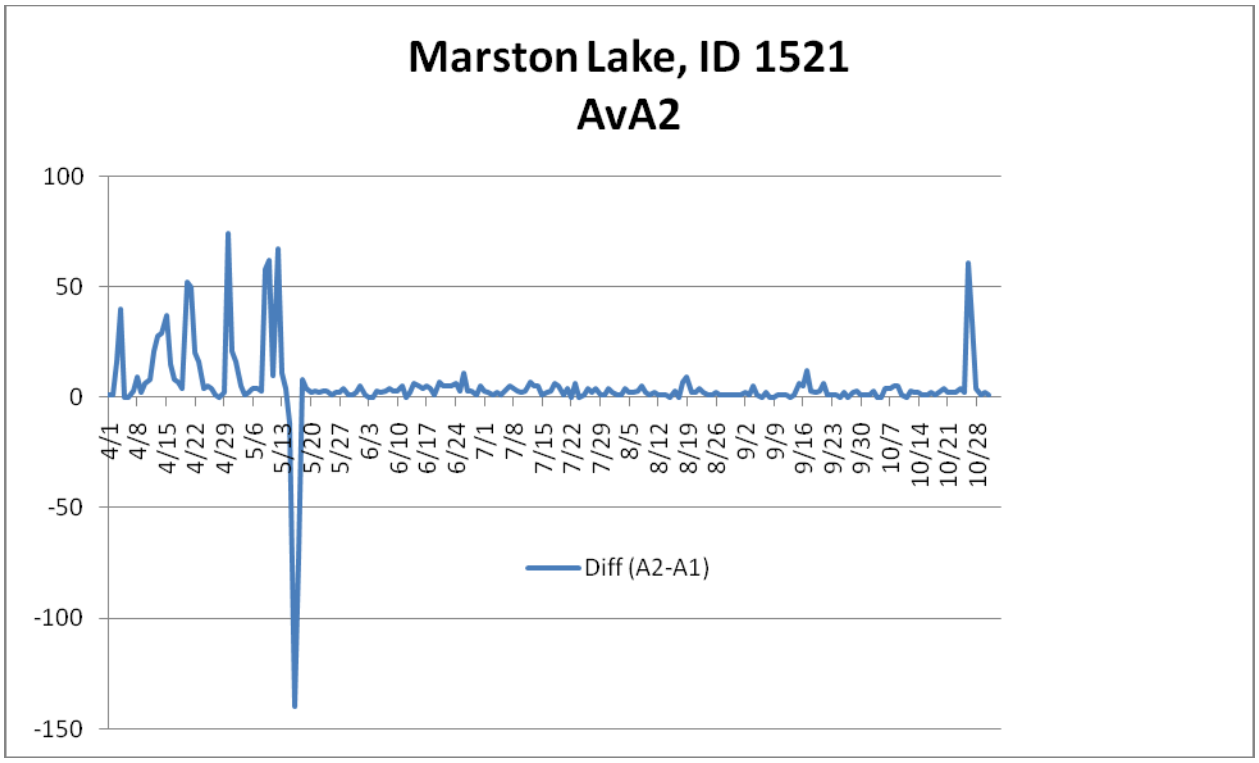


Figure 1. Daily Reception of ALERT vs ALERT2 from Marston Lake, Apr - Oct 2011 (difference plotted as A2 minus ALERT)

III. Flood Season Reporting Summary

The distribution of A2 reports received from April through October is shown (Table 3). The vast majority of reports (75%) come from atmospheric sensors (wind, temperature, relative humidity, and barometric pressure). Reports from water level sensors account for 10% of the total and 5% of the total reports come from precipitation sensors. The table below shows all sensors including those in the Hayman Burn area of Douglas County.

Table 3. Distribution of Reports among Sensor Groups (period April 1 through October 31)

Description	Reports	Percent
Wind Gust	449,328	16%
Temperature	437,878	16%
Relative Humidity	423,209	16%
Barometric Pressure	205,089	8%
Water Level PT-HSE	204,172	7%
Wind Speed Average & Azimuth	151,495	6%
Wind Direction	151,350	6%
Wind Speed Average	147,701	5%
Precipitation	142,118	5%
Battery Voltage	140,913	5%
Solar Radiation	68,752	3%
Fuel Moisture	40,866	1%
Fuel Temperature	40,779	1%
Water Level Float	32,222	1%
Water Level PT	27,021	1%
Soil Moisture	20,429	1%
Repeater Status Report	17,283	1%
Wind ALERT	8,151	0%
Unknown	4,770	0%
Repeater Pass List	4,437	0%
Water Level	4,050	0%
12Hr Status Report	3,502	0%
Hayman Battery	2,232	0%
Handar 585 ALARM Status	445	0%
Solar Power	44	0%
ALERT/A2 Testing	15	0%
Longmont Flow Gage	1	0%
Total	**2,728,252**	**100%**

A. Radio Traffic Loading

For the year, the system-wide radio traffic loading averaged 12,749 reports per day and 531 reports per hour. This represents an increase over 2010 where the average daily traffic was 11,222 and the average hourly traffic was 468.

The hours of highest radio traffic as received by the base station are shown (Table 4). Reports received at the base station differ from total ALERT radio traffic because reports lost to contention are not included. The actual traffic loading is higher than the reports received at the base.

Two large storms are evident in July and a third large storm occurred in June.

Table 4. Hours of Peak Radio Traffic Loading

Occurrence of Peak Radio Traffic Loading	A2 Reports Per Hour (received at base)
July 7, 2011 (5:00 PM to 6:00 PM)	2,474
July 12, 2011 (9:00 PM to 10:00 PM)	1,961
June 20, 2011 (3:00 AM to 4:00 AM)	1,745
June 20, 2011 (4:00 AM to 5:00 AM)	1,665
May 11, 2011 (5:00 AM to 6:00 AM)	1,589

Peak and hourly average data reception rates for the year are shown (Figure 2).

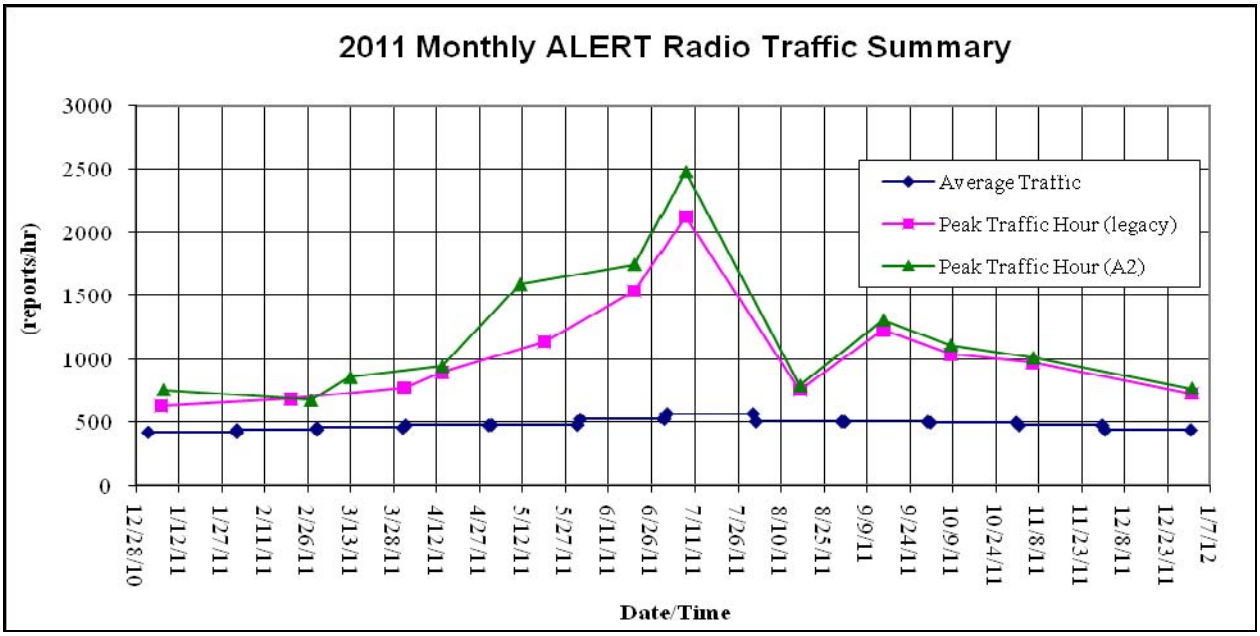


Figure 2. Peak and Hourly Average Data Reception Rates (reports received at base station)

B. Annual Peak Traffic Hour over the Past Several Years

Each year since 2006 WET has identified the peak hours of radio traffic for each month, April through October. The single heaviest hour of radio traffic occurring in each of the past six years is shown (Table 5).

Table 5. Occurrence of Peak Hour of Radio Traffic

Year	Month	Day	Hour	Reports/Hour
2006	August	13	21	1,107
2007	May	14	19	1,341
2008	August	16	10	1,595
2009	July	20	23	1,474
2010	June	12	1	1,852
2011	July	7	17	2,474

C. Distribution of Reports during Heavy Traffic Period

During non-rain periods and over the long-term, the radio traffic is dominated by reports from meteorological sensors (Table 3). The distribution of ALERT reports during a peak traffic period, however, looks quite different. The peak hours of radio traffic are dominated by reports from precipitation and water level sensors.

The peak period of traffic occurred on July 7 from 4:00 PM to 7:00 PM. The ALERT data for the 3-hour period was examined more closely to characterize the distribution of sensor reports (Table 6). Approximately 47% of the total reports received during the 3-hour period came from rain.

Table 6. Distribution of Reports during the Peak Traffic Period

Sensor Group	Reports	Percent
Rain Sensors	2,439	46.70%
Water Level Sensors	1,320	25.27%
Meteorologic Sensors	1,271	24.33%
Other	193	3.70%
Total	**5,223**	**100.00%**

IV. Rain Sensor Monthly Timer Reporting Summary (legacy ALERT)

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 are shown (Table 7).

Table 7. Flood Season Summary of Sensors with Poor Timer Performance

Apr	May	Jun	Jul	Aug	Sep
1700	1700	700	4300	4330	4330
3060	700	4710	4330	4850	2320
3030	540	4330	2750	2750	440
700	1710	1700	2280	2950	4490
3090	500	4270	870	540	4520
2970	710	4300	4270	2280	2270

The sensors with the worst timer performance in 2010 were:

- Hansen Rain (ID 4330)
- Ward C-1 (ID 4710)
- Toll Gate at 6th (ID 700)
- Cherry Creek at Champa (ID 1700)
- Big Elk Park (ID 4300)
- Castle Rock (ID 2750), and Kinney Peak (ID 2280)

V. Rain Sensor Event Reporting Summary (legacy ALERT)

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 8). The annual average precipitation experienced District-wide in 2010 was lower than 2009. The month experiencing the highest precipitation was April, followed by June. The District experienced heavy early season rainfall and very little rainfall toward the end of the year.

Table 8. 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
2008	4.05	7.38	12.26	20.57	54.82	26.06	16.43	90.20	37.54	19.59	2.82	9.24	25.08
2009	6.33	3.11	11.37	59.26	63.45	68.00	65.00	20.00	27.29	30.24	11.00	5.60	30.89
2010	5.97	11.90	32.54	70.57	39.63	56.04	50.23	31.01	4.18	18.31	8.30	3.31	27.67
2011	6.78	7.45	7.54	33.94	92.68	39.42	90.87	18.25	37.67	25.73	10.41	13.59	32.03

Shading in yellow denotes peak month of reporting.

B. Incrementing Tip Reporting Summary

The incrementing tip reports received from the District's 1-mm rain sensors were analyzed for each month of the year (Table 9). The system-wide reception rate of incrementing tip reports for the year was approximately 89 percent. A total of 52,302 incrementing reports were received and a total of 60,059 were expected. The table below does not include the rain sensors located in the Hayman area of Douglas County nor does it include those sensors with rain buckets of 0.01 inch.

Table 9. Monthly Incrementing Tip Reports Received from All Rain Sensors

Month	Received	Expected	Reception Rate (%)
January	487	515	94.56%
February	855	916	93.34%
March	1,179	1,251	94.24%
April	5,190	5,804	89.42%
May	12,977	15,848	81.88%
June	5,835	6,780	86.06%
July	13,772	15,811	87.10%
August	2,902	3,103	93.52%
September	5,969	6,592	90.55%
October	1,549	1,698	91.22%
November	616	708	87.01%
December	971	1,033	94.00%
TOTAL	**52,302**	**60,059**	**87.08%**

C. Rain Sensor Event Performance

The rain sensors with the worst event reporting characteristics for each month are shown (Table 10).

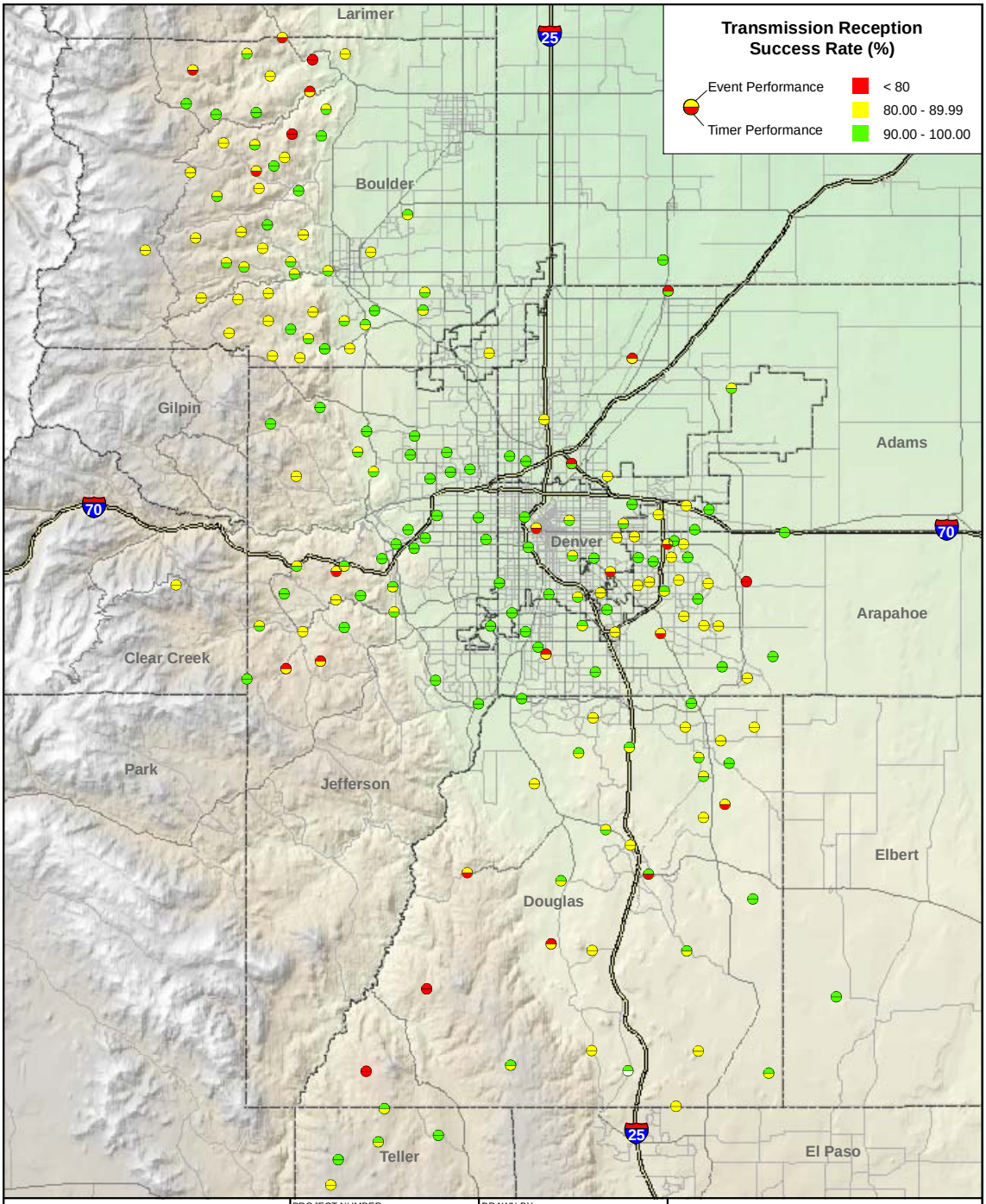
Table 10. Monthly Summary of Sensors with Poor Event Performance

Apr	May	Jun	Jul	Aug	Sep
1700	1620	2280	870	2980	2980
1620	1660	4300	4300	400	4490
2930	810	4330	4330	4330	4330
2990	650	4270	2980	2270	4240
4330	940	2980	4490	2240	4470
2950	1900	310	4790	4530	330

The sensors with the worst event performance were Dakan Road (ID 2980) and Hansen Rain (ID 4330).

D. Transmission Reception Success Rate

A spatial representation of both the timer and event transmission reception rates is shown below.



VI. General Observations for the Year

A. "Flood Season" Statistics

1. Rainfall accumulation

The rain sensors recording the highest accumulated precipitation during the "flood season" were:

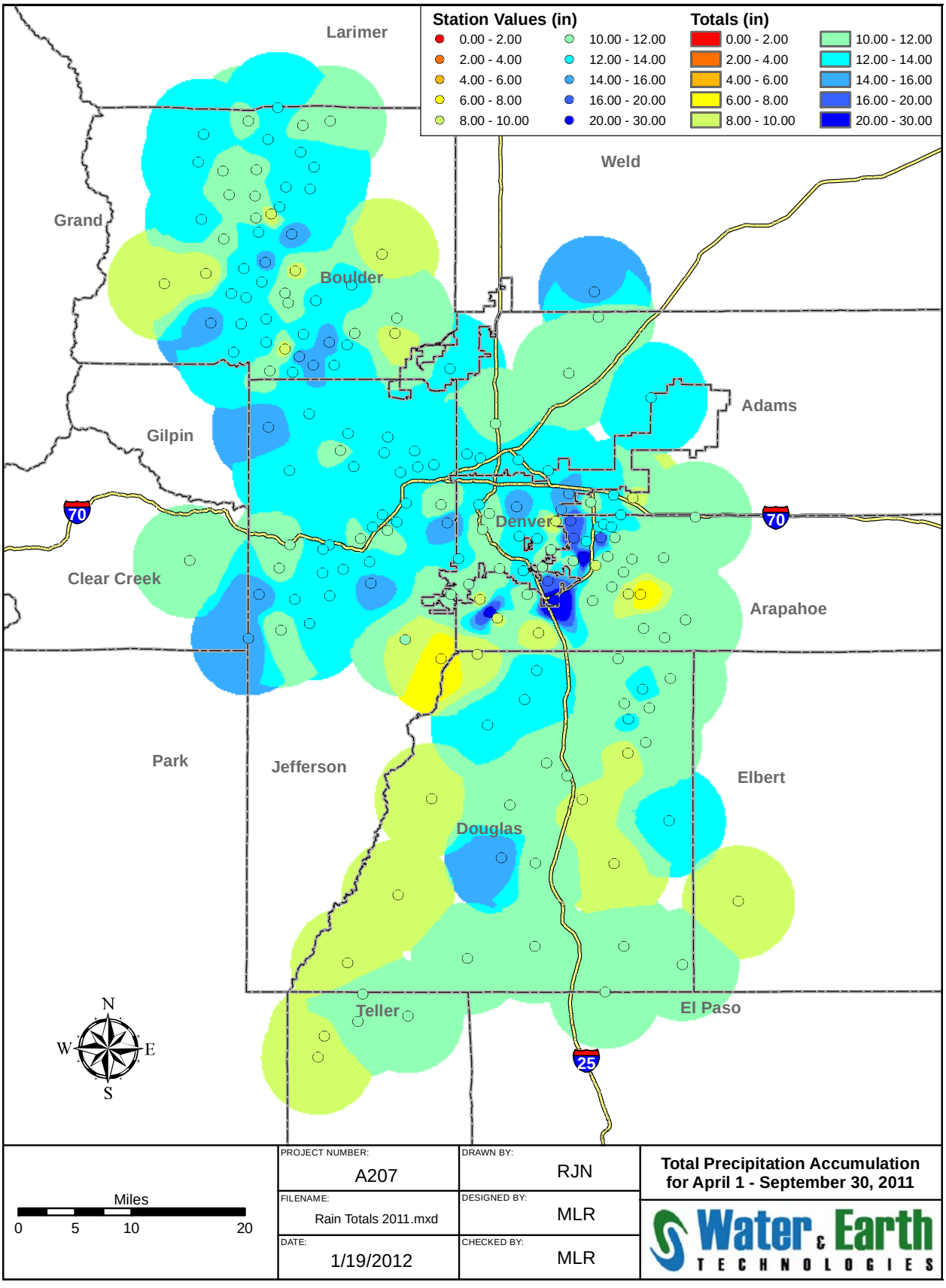
- Temple Pond at DTC (ID 630) with 24.8 inches
- Utah Park (ID 430) with 23.1 inches
- Powers Park (ID 1500) with 20.1 inches
- Havana Park (ID 500) with 18.8 inches
- Expo Park (ID 420) with 17.1 inches

Expo Park, Utah Park, Temple Pond and Powers Park are all influenced by irrigation throughout the year as indicated on the UDFCD web site.

Those rain sensors with the highest accumulation for the "flood season" that were not influenced by irrigation include:

- Aurora Town Hall (ID 920) with 16.7 inches,
- Goldsmith at Eastman (ID 640) with 16.1 inches,
- Lakewood CC (ID 1550) with 15.8 inches

The average accumulated precipitation during the "flood season" was 12.0 inches. A spatial representation of the total accumulated precipitation for the "flood season" is shown below.


Station Values (in)
0.00 - 2.00
2.00 - 4.00
4.00 - 6.00
6.00 - 8.00
8.00 - 10.00
10.00 - 12.00
12.00 - 14.00
14.00 - 16.00
16.00 - 20.00
20.00 - 30.00
Totals (in)
0.00 - 2.00
2.00 - 4.00
4.00 - 6.00
6.00 - 8.00
8.00 - 10.00
10.00 - 12.00
12.00 - 14.00
14.00 - 16.00
16.00 - 20.00
20.00 - 30.00
Larimer
Weld
Grand
Boulder
Adams
Gilpin
Denver
70
Clear Creek
Arapahoe
Park
Jefferson
Elbert
Douglas
Teller
El Paso
25
N
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Miles
0
5
10
20
PROJECT NUMBER:
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DRAWN BY:
RJN
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Rain Totals 2011.mxd
DESIGNED BY:
MLR
DATE:
1/19/2012
CHECKED BY:
MLR
Total Precipitation Accumulation for April 1 - September 30, 2011
Water & Earth TECHNOLOGIES

2. Peak Rainfall Intensity/Rainfall Alarms

Rainfall alarms are active when the following rates are exceeded at any single station within the District:

- 0.5 inches in 10 minutes
- 1.0 inches in 1 hour
- 3.0 inches in 2 hours
- 5.0 inches in 6 hours

Rainfall alarm thresholds were exceeded a total of 163 times. The 6 hour threshold and the 2 hour threshold were not exceeded. A summary of the rainfall alarms experienced this year are provided (Table 11).

Table 11. Rainfall Alarms Summary

Date	Exceedence of 10-min, 1-hr and 6-hr alarm criteria	Peak 10 minute accumulation (in)	Peak 1 hour accumulation (in)	Peak 2 hour accumulation (in)	Peak 6 hour accumulation (in)
May 18	3	0.59	1.14	< 3.0	1.69
June 17	3	0.59	1.06	< 3.0	1.10
June 19	1	0.51	0.78	< 3.0	0.95
June 20	6	0.71	1.18	< 3.0	1.97
July 6	1	0.67	0.71	< 3.0	0.87
July 7	65	1.30	2.80	2.87	3.30
July 8	5	0.87	1.54	< 3.0	1.73
July 9	2	0.59	0.91	< 3.0	1.22
July 10	1	0.51	0.63	< 3.0	0.63
July 11	3	0.59	1.02	< 3.0	1.26
July 12	29	0.91	1.22	< 3.0	1.34
July 13	13	0.63	1.58	< 3.0	2.76
July 14	14	0.67	1.61	< 3.0	1.69
July 17	1	0.55	0.91	< 3.0	0.95
July 19	3	0.51	0.91	< 3.0	1.38
July 26	1	0.51	0.67	< 3.0	0.75
July 29	1	0.75	0.91	< 3.0	0.91
Aug 2	1	0.59	0.67	< 3.0	1.22
Aug 3	3	0.63	1.18	< 3.0	1.34
Aug 4	3	0.59	1.22	< 3.0	1.34
Aug 16	1	0.59	0.91	< 3.0	0.91
Aug 20	1	0.43	1.14	< 3.0	1.18
Sep 2	1	0.59	0.71	< 3.0	0.71
Total	**162**				