Memo

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

Date: January 26, 2009

To: Kevin Stewart

From: Markus Ritsch

Subject: **2010 Annual Legacy 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 2010, Water & Earth Technologies, Inc. (WET) provided monthly analysis of the District's legacy ALERT and 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, mostly weather stations and gages in Boulder County are operational year-round.

II. ALERT Data Source

Legacy ALERT data records were extracted from the Nova Star 5.0 base station and analyzed for the period January 1 through December 31, 2010. A summary report was completed each month.

III. General System-Wide Reporting Summary

A total of 4,023,334 individual 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.

In 2006 the average monthly load was 185,420 reports. In 2007 the average monthly load was 201,161. In 2008, the monthly load increased to approximately 263,488 reports. In 2009 the average monthly load was 293,030 reports. In 2010 the average monthly load was 335,278. 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!

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	2,225,049
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

Shading in light yellow denotes peak month of reporting.

IV. Flood Season Reporting Summary

The distribution of ALERT reports received from April through October is shown (Table 2). The vast majority of reports (77%) come from atmospheric sensors (wind, temperature, relative humidity, and barometric pressure). Reports from water level sensors account for 9% of the total and 5% of the total reports come from precipitation sensors. The table below shows all sensors including those in the Hayman area of Douglas County.

Table 2. Distribution of Reports among Sensor Groups (period April 1 through October 31)

Sensor Group	Reports	Percent
Wind Gust	385,528	15.98%
Relative Humidity	382,853	15.87%
Temperature	387,762	16.07%
Water Level PT-HSE	158,474	6.57%
Barometric Pressure	168,704	6.99%
Wind Direction	147,137	6.10%
Wind Speed Average & Azimuth	164,718	6.83%
Precipitation	122,563	5.08%
Wind Speed Average	144,288	5.98%
Solar Radiation	67,388	2.79%
Battery Voltage HSE	53,574	2.22%
Water Level Float	30,228	1.26%
Battery Voltage Digital	26,282	1.10%
Fuel Temperature	40,183	1.67%
Fuel Moisture	40,005	1.66%
Battery Voltage Analog	25,020	1.03%
Water Level PT	23,077	0.95%
Soil Moisture	20,092	0.83%
Battery	4,888	0.20%
Repeater Status Report	4,528	0.19%
Wing Gust	5,043	0.21%
12Hr Status Report	2,817	0.12%
Repeater Pass List	4,176	0.17%
Battery Voltage	855	0.04%
Handar 585 ALARM Status	920	0.04%
Water Level	1,112	0.05%
Total	**2,412,215**	**100.00%**

A. Radio Traffic Loading

The system-wide radio traffic loading during the **2009** "flood season" was approximately 10,380 reports per day with an average hourly loading of about 432 reports. The system-wide radio traffic loading during the **2010** "flood season" was approximately 11,222 reports per day with an average hourly loading of about 468 reports. The 2010 daily traffic load increased by approximately 1,000 reports from 2009.

The specific hours of highest radio traffic loading as received by the base station were determined and are shown (Table 3). 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 typically higher than the reports received at the base.

Several large storms are evident in June and July.

Table 3. Hours of Peak Radio Traffic Loading

Occurrence of Peak Radio Traffic Loading	Reports Per Hour (received at base)
July 30, 2010 (7:00 PM to 8:00 PM)	1,638
July 30, 2010 (6:00 PM to 7:00 PM)	1,612
June 12, 2010 (1:00 AM to 2:00 AM)	1,609
June 12, 2010 (12:00 AM to 1:00 AM)	1,568
July 29, 2010 (4:00 PM to 5:00 PM)	1,544

In **2008**, the peak hour of radio traffic occurred on August 16 from 10:00 AM to 11:00 AM when 1,486 ALERT reports were received at the base station. In **2009**, the peak hour of radio traffic occurred on July 20 between 11:00 PM and midnight when 1,474 reports were received. In **2010**, the peak hour of radio traffic occurred on July 30 between 7:00 PM and 8:00 PM when 1,638 reports were received. The actual radio traffic loading may have been as high as 1,800-2,000 reports when contentious and "unknown" reports are considered.

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

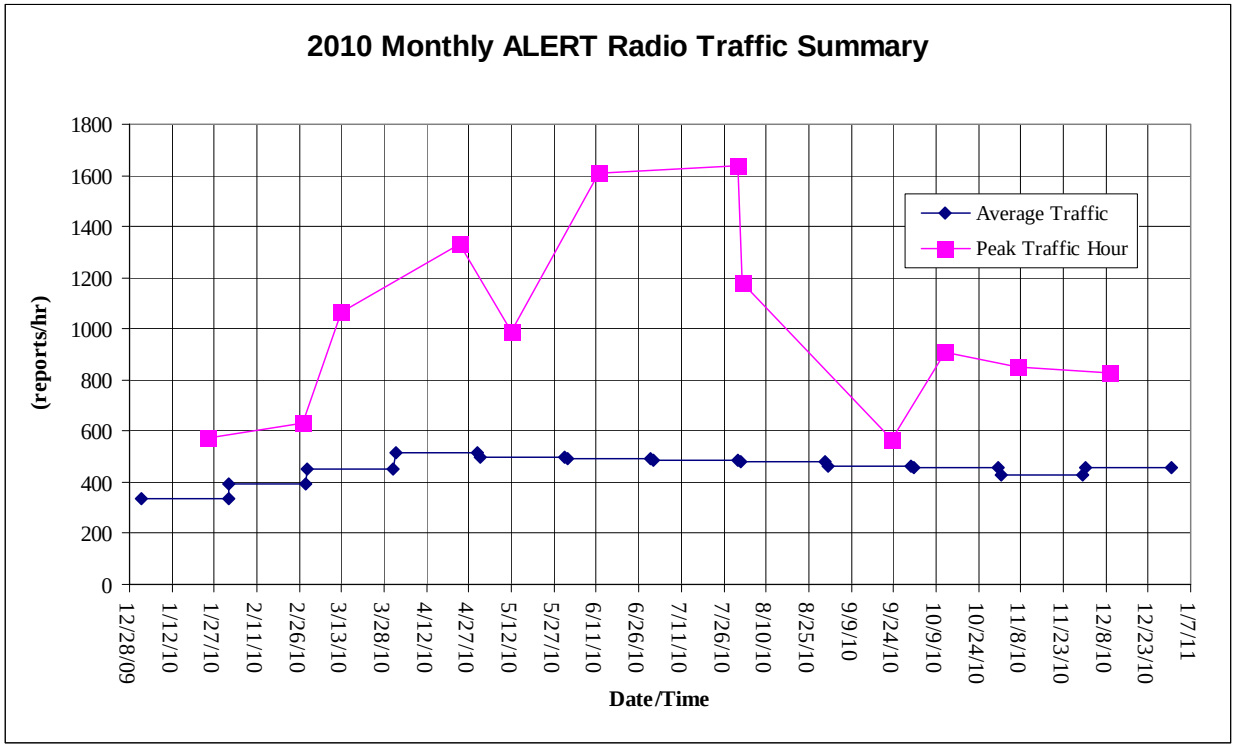


Figure 1. Peak and Hourly Average Data Reception Rates (reports received at base station)

B. Distribution of Reports during Heavy Traffic Period

During non-rain periods and over the long-term, the radio traffic is dominated by reports from meteorological sensors (Table 2). 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 30 from 6:00 PM to 8:00 PM. The ALERT data for the 2-hour period was examined more closely to characterize the distribution of sensor reports (Table 4). Approximately 60% of the total reports received during the 2-hour period came from rain and water level sensors

Table 4. Distribution of Reports during the Peak Traffic Period

Sensor Group	Reports	Percent
Rain Sensors	518	26.20%
Water Level Sensors	649	32.83%
Meteorologic Sensors	715	36.17%
Other	95	4.80%
Total	**1,977**	**100.00%**

V. 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 are shown (Table 5).

Table 5. Flood Season Summary of Sensors with Poor Timer Performance

Apr	May	Jun	Jul	Aug	Sep
2970	2970	2970	2980	2980	2230
3010	700	1710	2930	2930	4270
700	2240	4330	2990	2990	4040
4860	4330	2270	3020	3020	4330
4330	4490	2240	2810	2810	2240
4170	4270	4470	4330	4330	1710

The sensors with the worst timer performance in 2010 were:

- Indian Ruins (ID 4330)
- Cold Spring Gulch Confluence (ID 2240)
- Rampart Range Road (ID 2970)

VI. 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 6). 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 6. 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

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 7). The system-wide reception rate of incrementing tip reports for the year was approximately 89 percent. A total of 47,202 incrementing reports were received and a total of 53,029 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 7. Monthly Incrementing Tip Reports Received from All Rain Sensors

Month	Received	Expected	Reception Rate (%)
January	351	418	83.97%
February	1,321	1,463	90.29%
March	4,613	5,336	86.45%
April	10,198	11,715	87.05%
May	6,116	6,618	92.41%
June	8,254	9,414	87.68%
July	7,546	8,438	89.43%
August	4,730	5,178	91.35%
September	635	665	95.49%
October	2,776	3,057	90.81%
November	488	548	89.05%
December	174	179	97.21%
TOTAL	**47,202**	**53,029**	**89.01%**

The months of heaviest rain: April, May, June and July had slightly worse reception rates for incrementing reports due to the higher volume of radio traffic. It seems that the reception rate is certainly a function of total traffic loading but it is also a function of other variables, such as storm type, intensity, and extent.

C. Rain Sensor Event Performance

The rain sensors with the worst event reporting characteristics for each month of the current year, 2009, are shown (Table 8).

Table 8. Monthly Summary of Sensors with Poor Event Performance

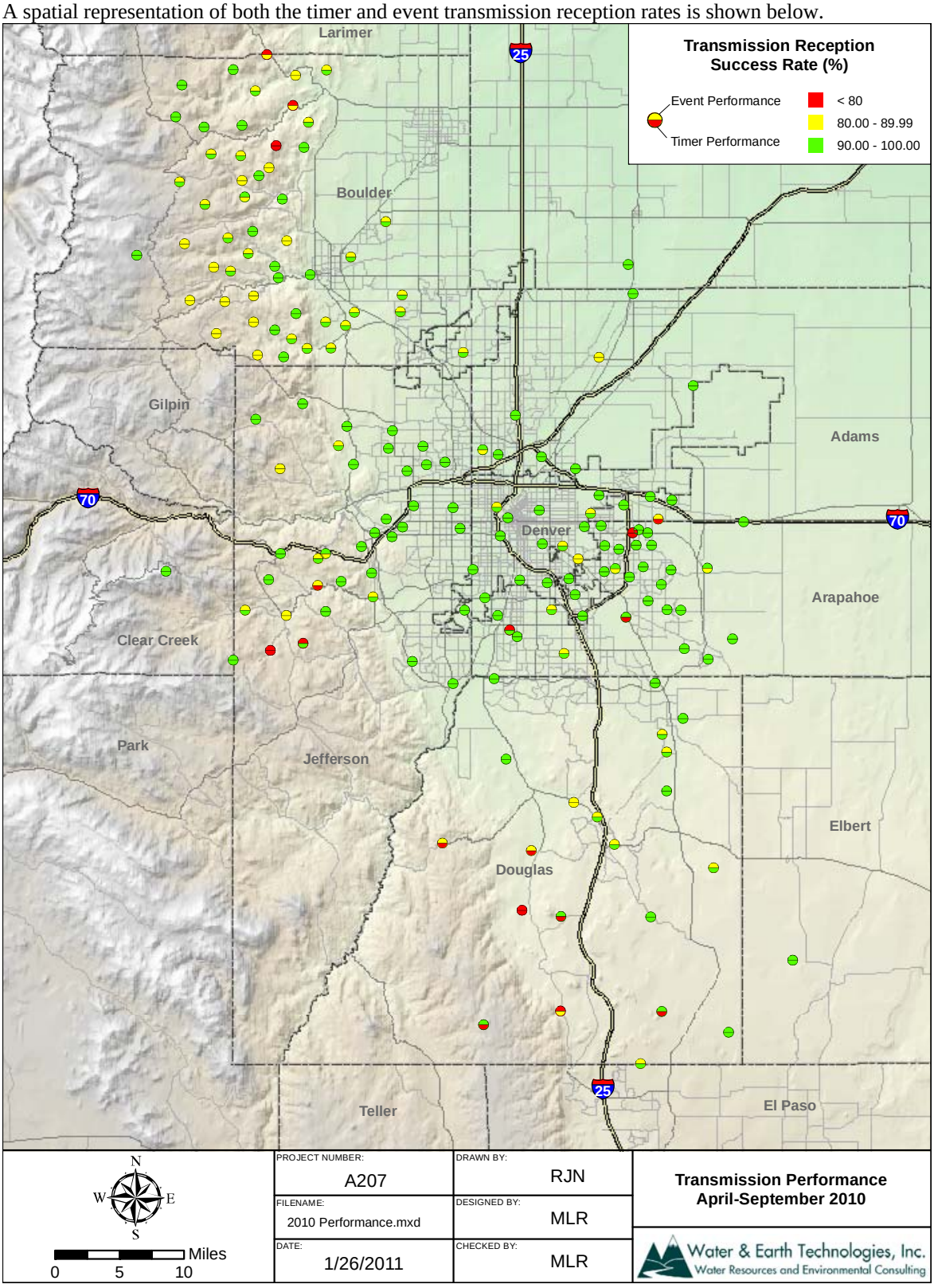
Apr	May	Jun	Jul	Aug	Sep
2970	700	2900	870	2270	110
700	2280	2190	540	2980	2970
940	2970	2930	2980	2280	720
430	2980	4330	2900	4090	1900
2900	2190	2980	4330	310	2270
4330	2240	2970	2230	4330	4040

The sensors with the worst event performance were:

- Russelville Gulch (ID 2900)
- Rampart Range Road (ID 2970)
- Dakan Road (ID 2980)
- Indian Ruins (ID 4330)

D. Transmission Reception Success Rate

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



VII. 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:

- Powers Park (ID 1500) with 58.9 inches
- Temple Pond at DTC (ID 630) with 23.0 inches
- Utah Park (ID 430) with 19.4 inches
- Sampson Gulch (ID 940) with 16.6 inches
- Expo Park (ID 420) with 15.75 inches

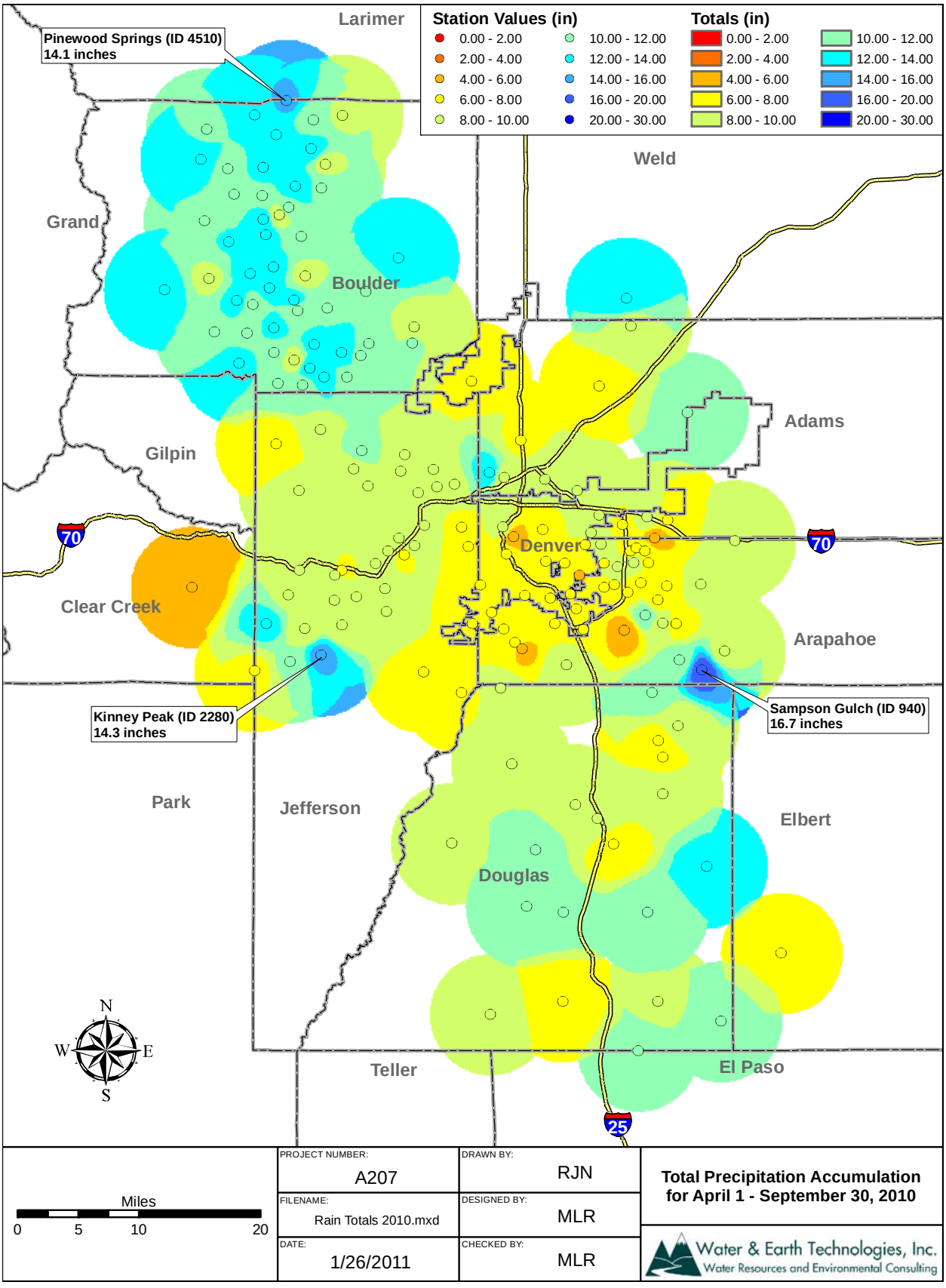
Powers Park, Utah Park, Temple Pond and Powers Park are all influenced by irrigation throughout the year as indicated on the UDFCD web site.

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

- Sampson Gulch (ID 940) with 16.65 inches,
- Kinney Peak (ID 2280) with 14.25 inches,
- Pinewood Springs (ID 4510) with 14.09 inches

The average accumulated precipitation during the "flood season" was 11.2 inches. A spatial representation of the total accumulated precipitation for the "flood season" is shown below.

It is interesting to note that Sampson Gulch was also the highest recording rain gage in 2009. Although this station is not included in the list of stations influenced by irrigation on the UDFCD web site, it is possible that this station is in fact influenced by sprinkler irrigation water.



	PROJECT NUMBER: A207	DRAWN BY: RJN	**Total Precipitation Accumulation for April 1 - September 30, 2010**
	FILENAME: Rain Totals 2010.mxd	DESIGNED BY: MLR	
	DATE: 1/26/2011	CHECKED BY: MLR	Water & Earth Technologies, Inc. Water Resources and Environmental Consulting

2. Peak Rainfall Intensity/Rainfall Alarms

Rainfall rate alarms occurred on 14 days Between April 1 and September 30. Rainfall alarms are active when the following rates are exceeded at any single station:

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

The 10 minute and 1 hour thresholds were exceeded 58 times. The 2 hour and 6 hour thresholds were not exceeded. A summary of the rainfall alarms experienced this year are provided (Table 9).

Table 9. Rainfall Alarms Summary

Date	Total number of alarms triggered	Peak 10 minute accumulation (in)	Peak 1 hour accumulation (in)	Peak 6 hour accumulation (in)
April 6	1	0.51	0.75	1.34
June 11	4	0.71	1.10	2.09
June 14	2	0.75	1.10	1.10
July 4	5	0.63	1.54	2.56
July 6	4	0.91	1.02	1.02
July 20	3	0.67	1.14	1.30
July 30	14	0.75	1.69	1.81
July 31	4	0.71	1.61	1.81
Aug 1	6	0.78	1.93	2.32
Aug 4	7	0.63	1.30	1.42
Aug 6	3	0.63	0.75	0.75
Aug 9	1	0.51	0.83	0.98
Aug 16	2	0.83	0.95	0.95
Aug 23	2	0.79	0.87	0.87
Total	**58**			