Memo

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

Date: January 12, 2009

To: Kevin Stewart

From: Markus Ritsch

Subject: **2009 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 2009, Water & Earth Technologies, Inc. (WET) provided monthly analyses 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 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, are operational year-round.

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, 2009.

III. General System-Wide Reporting Summary

A total of 3,516,367 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. The radio loading has increased each year since 2006 which reflects the additional traffic from new remote stations installed each year.

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

Shading in light yellow denotes peak month of reporting.

IV. Flood Season Reporting Summary

The distribution of ALERT reports received during the flood season (April through September) is shown (Table 2). The vast majority of reports (74%) come from atmospheric sensors (wind, temperature, relative humidity, and barometric pressure). Reports from water level sensors account for 10% of the total and 6% 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 September 30)

Sensor Group	Reports	Percent
Wind Gust	310,397	16%
Relative Humidity	290,958	15%
Temperature	289,501	15%
Water Level PT-HSE	142,496	8%
Barometric Pressure	128,238	7%
Wind Direction	117,902	6%
Wind Speed Average & Azimuth	112,789	6%
Precipitation	106,016	6%
Wind Speed Average	100,702	5%
Solar Radiation	53,803	3%
Battery Voltage HSE	45,350	2%
Water Level Float	28,683	2%
Battery Voltage Digital	25,994	1%
Fuel Temperature	24,300	1%
Fuel Moisture	24,171	1%
Battery Voltage Analog	21,746	1%
Water Level PT	18,713	1%
Soil Moisture	14,641	1%
Battery	8,893	0%
Repeater Status Report	8,710	0%
Wing Gust	3,955	0%
Longmont Flow Gage	3,566	0%
12Hr Status Report	3,546	0%
Repeater Pass List	3,542	0%
Hayman Battery	3,473	0%
Battery Voltage	1,465	0%
Hayman Stage	503	0%
Longmont Water Level PT	443	0%
Handar 585 ALARM Status	414	0%
Water Level	317	0%
Solar Power	42	0%
Total	**1,895,269**	**100%**

A. Radio Traffic Loading

The system-wide radio traffic loading during the **2008** "flood season" was approximately 9,202 reports per day with an average hourly loading of about 383 reports. 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 daily traffic load increased by approximately 1,000 reports in 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 July.

Table 3. Hours of Peak Radio Traffic Loading

Occurrence of Peak Radio Traffic Loading	Reports Per Hour (received at base)
July 20, 2009 (11:00 PM to Midnight)	1,474
July 3, 2009 (5:00 PM to 6:00 PM)	1,302
July 10, 2009 (9:00 PM to 10:00 PM)	1,224
June 2, 2009 (5:00 AM to 6:00 AM)	1,138
July 20, 2009 (10:00 PM to 11:00 PM)	1,118

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. The actual radio traffic loading may have been as high as 1,700-1,800 reports when contentious and "unknown" reports are considered.

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

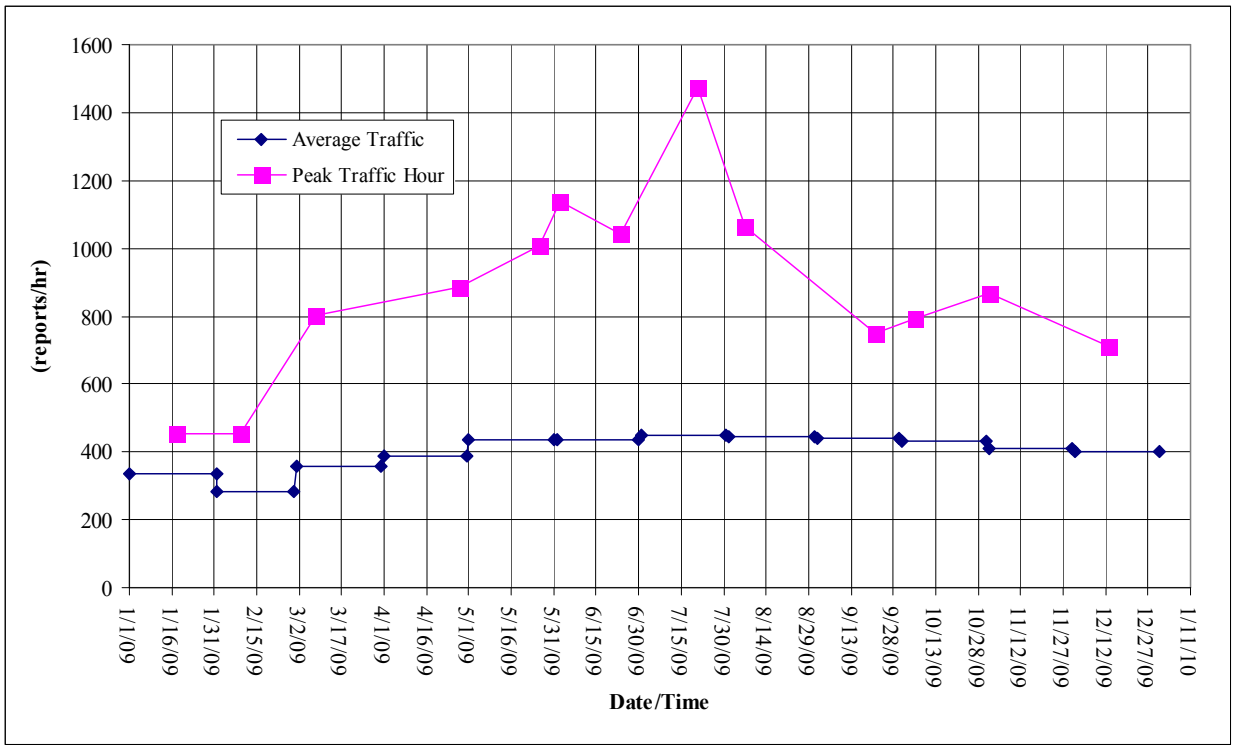


Figure 1. Peak and Hourly Average Data Reception Rates (reports received at base station)

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), 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 period of traffic occurred on July 20 from 10:00 PM to midnight. The ALERT data for the 2-hour period was examined more closely to characterize the distribution of sensor reports (Table 4). Approximately 70% 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	960	37%
Water Level Sensors	851	33%
Meteorologic Sensors	653	25%
Other	128	5%
Total	**2,592**	**100%**

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 of 2009 are shown (Table 5).

Table 5. Monthly Summary of Sensors with Poor Timer Performance

Jan*	Feb*	Mar*	Apr	May	Jun	Jul	Aug	Sep	Oct*	Nov*	Dec
2850	4030	2840	1360	1350	2900	2270	1350	920	2970	220	220
1650	4200	1020	1640	2850	2270	2370	920	1700	920	300	4030
1810	4490	1040	2270	2270	2850	2850	2360	2970	700	440	920
4250	4520	1720	1600	410	410	1350	2350	2900	2920	510	4470
4790	4790	1030	2850	540	540	1530	2900	4330	1480	520	2970
4300	4020	1550	1350	2320	1350	110	1460	1480	2900	530	4330

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

The sensors with the worst timer performance in 2009 were:

- Cub Creek below Blue (ID 2270)
- Cherry Creek below Bayou Gulch (ID 2850)
- Chatfield COE (ID 1350)
- Aurora Town Hall Weather (ID 920)
- Russelville Gulch (ID 2900)

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 2009 was higher than 2008. The month experiencing the highest precipitation in 2009 was June, followed by July.

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

Shading in yellow denotes peak month of reporting.

B. Incrementing Tip Reporting Summary

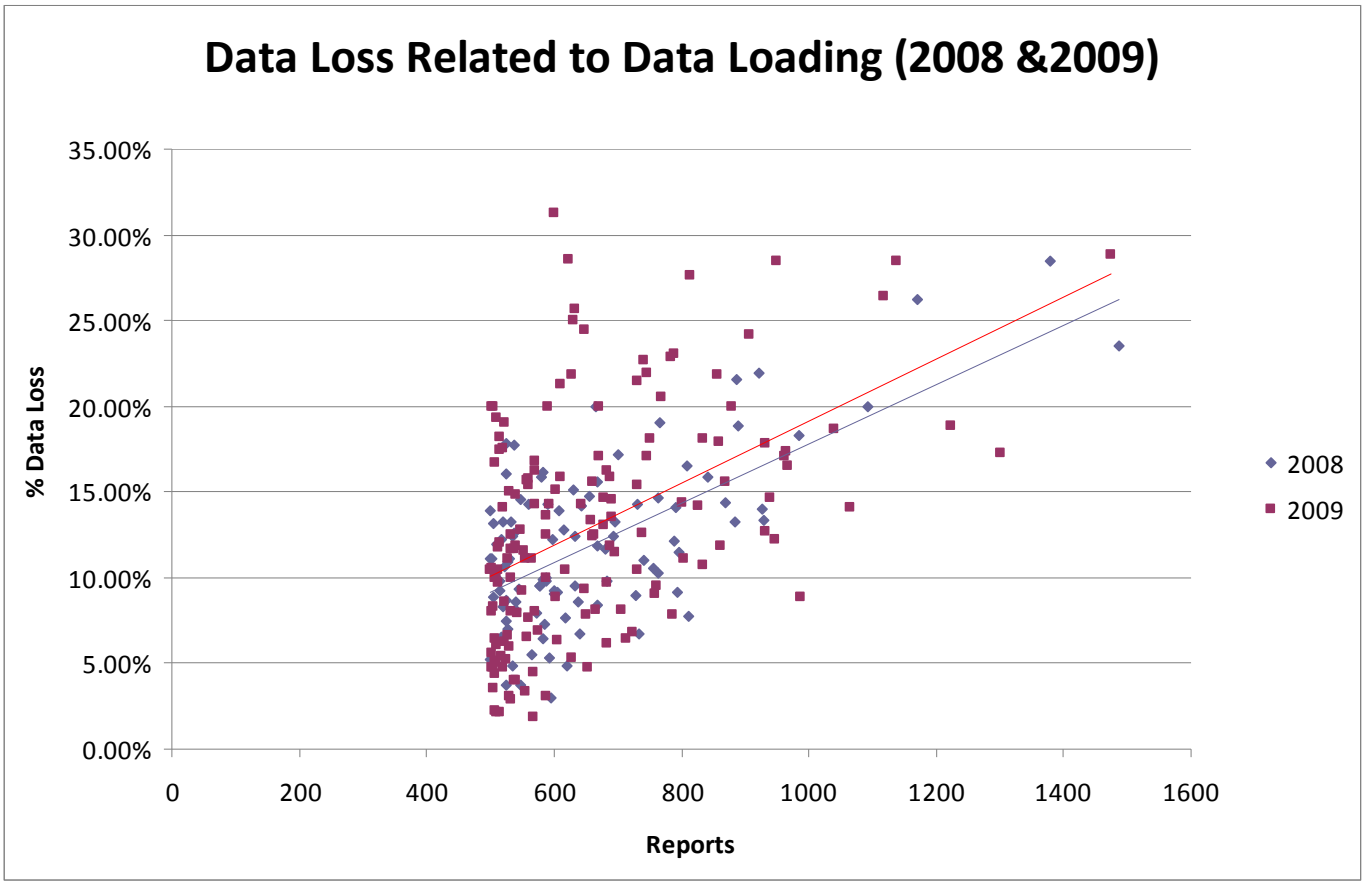
The incrementing tip reports received from the District's 1-mm rain sensors were analyzed for each month of the year (Table 7). The system-wide reception rate of incrementing tip reports for the year was approximately 86 percent. A total of 48,711 incrementing reports were received and a total of 56,361 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	373	399	93.48%
February	176	224	78.57%
March	1269	1444	87.88%
April	7730	8771	88.13%
May	7840	9390	83.49%
June	9573	11320	84.57%
July	9048	10671	84.79%
August	2812	3194	88.04%
September	4055	4503	90.05%
October	4561	4980	91.59%
November	893	1056	84.56%
December	381	409	93.15%
TOTAL	**48711**	**56361**	**86.43%**

The months of heaviest rain: May, June and July had relatively poor reception rates for incrementing reports due to the high 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.

Each hour exceeding 500 reports was analyzed to quantify the number of missing rain reports for that hour. The following plot shows the loss of data as a function of data loading for both 2008 and 2009. This plot shows that the data loss was greater in 2009 as was the variability in loss as a function of loading.



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

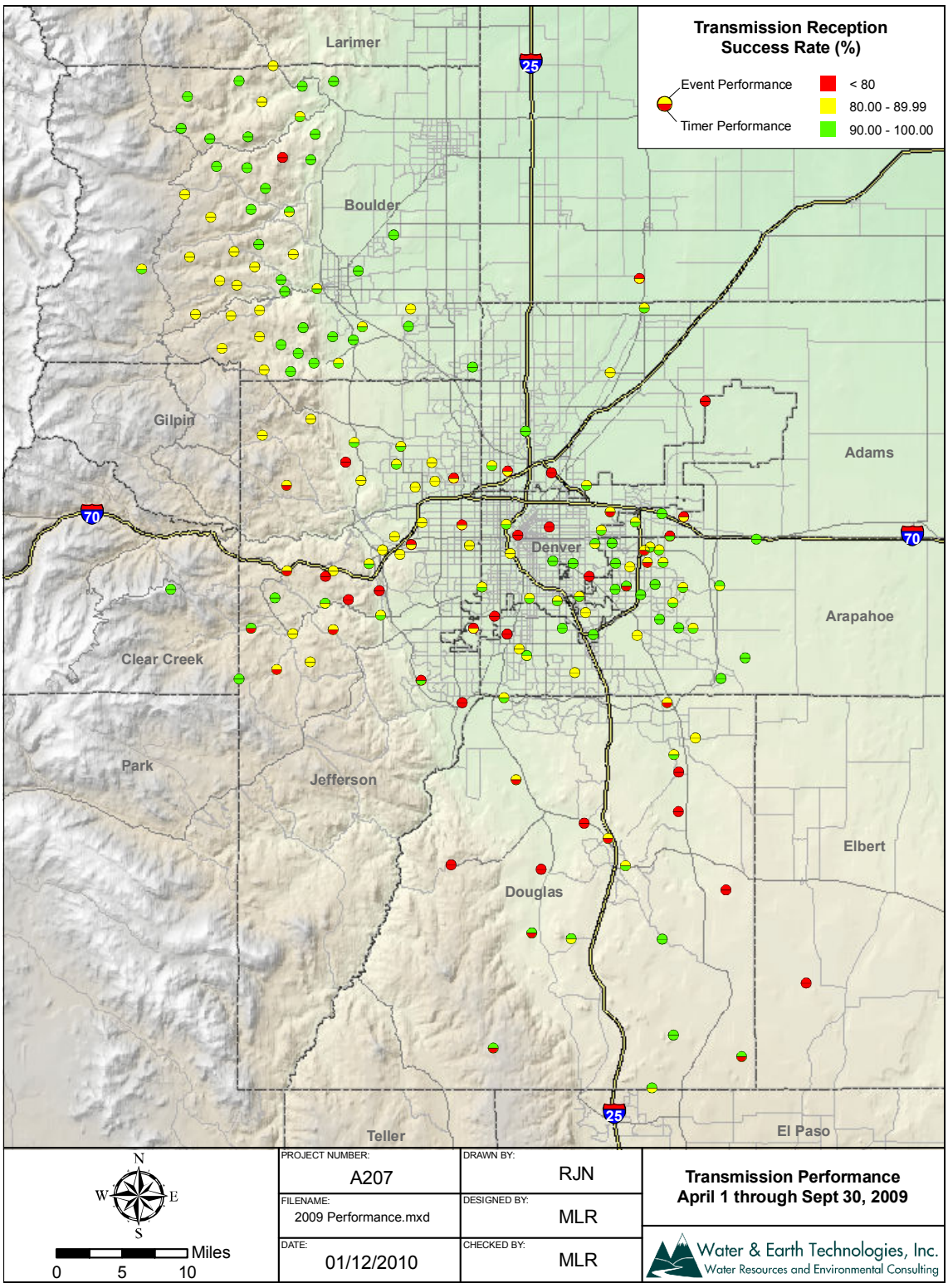
Jan	Feb*	Mar*	Apr**	May	Jun	Jul	Aug	Sep	Oct*	Nov	Dec
140	4030	860	860	110	2900	2900	2900	2900	1570	1460	1460
4490	4470	840	840	1350	540	2320	2810	1460	2210	700	1420
1420	4490	700	1640	2320	2320	2820	2320	1570	1480	1480	1520
4040	4110	2840	2850	2850	110	110	2820	1440	1460	1520	4330
4160	4510	1340	700	540	1350	1350	1350	1520	1520	4330	4470
4470	4790	920	1350	1810	2350	2370	1640	4330	220	2210	4520

The sensors with the worst event performance were:

- Chatfield COE (ID 1350)
- Choke Cherry Reservoir (ID 2320)
- Russelville Gulch (ID 2900)
- Marston Lake North (ID 1520)
- Urban Farm (ID 1460)
- 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:

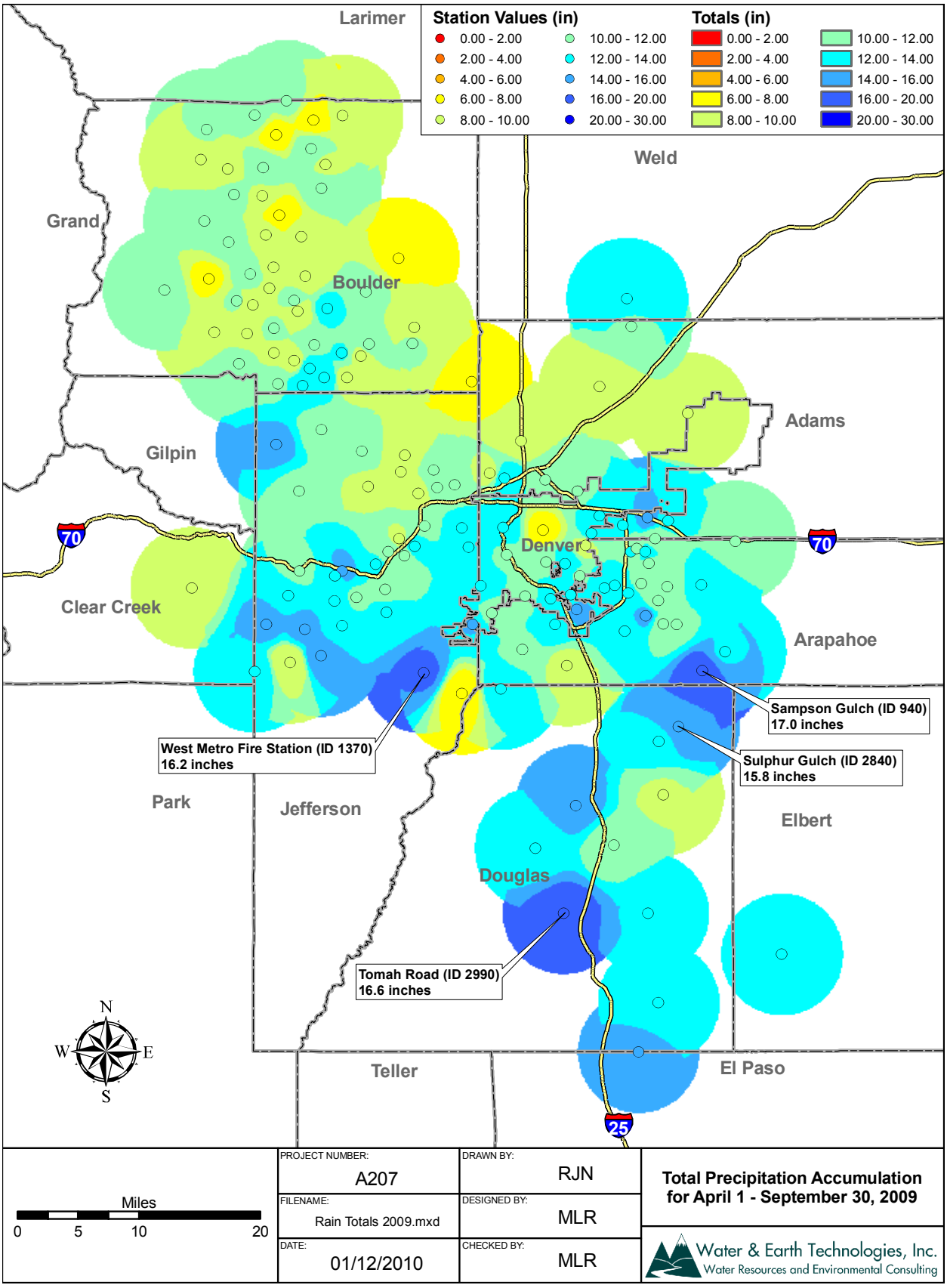
- Expo Park (ID 420) with 31.9 inches
- Temple Pond at DTC (ID 630) with 24.6 inches and
- Powers Park (ID 1500) with 20.3 inches
- Aurora Town Hall (ID 920) with 18.0 inches.

Expo Park, Temple Pond and Powers Park are all influenced by irrigation throughout the year. Aurora Town Hall had a problem with a new sensor that recorded rainfall when birds walked on the sensor pad.

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

- Sampson Gulch (ID 940) with 17.0 inches,
- Tomah Road (ID 2990) with 16.6 inches,
- West Metro Fire Station 13 (ID 1370) with 16.2 inches,
- Sulphur Gulch (ID 2840) with 15.8 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.


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
Clear Creek
Arapahoe
Sampson Gulch (ID 940)
17.0 inches
West Metro Fire Station (ID 1370)
16.2 inches
Sulphur Gulch (ID 2840)
15.8 inches
Park
Jefferson
Elbert
Douglas
Tomah Road (ID 2990)
16.6 inches
Teller
El Paso
70
70
25
N
W
E
S
Miles
0
5
10
20
PROJECT NUMBER:
A207
DRAWN BY:
RJN
FILENAME:
Rain Totals 2009.mxd
DESIGNED BY:
MLR
DATE:
01/12/2010
CHECKED BY:
MLR
Total Precipitation Accumulation
for April 1 - September 30, 2009
Water & Earth Technologies, Inc.
Water Resources and Environmental Consulting

2. Peak Rainfall Intensity/Rainfall Alarms

Rainfall rate alarms occurred on 28 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 175 times in 2009. 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)	Station
May 23	5	0.55	1.57	Upper Sloan Detention (1400)
May 24	11	0.63	1.30	Lakewood CC (1550)
May 25	2	0.55	1.34	Expo Park (420)
May 31	1	0.51	<1.00	Brighton ETO (1570)
June 11	5	0.75	<1.00	Sand Creek at mouth (1810)
June 13	2	0.59	1.14	Elbert (1440)
June 14	9	0.75	1.50	Hidden Lake (1300)
June 23	9	0.59	1.85	Sulphur Gulch (2840)
June 24	4	0.59	1.34	LDC at 64th (1310)
June 25	8	0.90	1.38	Parker/Mississippi (540)
June 26	1	0.59	<1.00	Gold Hill (4150)
July 2	1	0.51	<1.00	Van Bibber (330)
July 3	23	0.98	1.14	Idledale (2350)
July 4	6	0.55	1.06	Haskins Gulch (2820)
July 6	5	0.98	1.81	Fire Station 12 (840)
July 10	22	0.71	1.30	Expo Park (420)
July 11	1	0.59	1.06	Elbert (1440)
July 13	1	0.79	<1.00	Sulphur Gulch (2840)
July 20	36	0.79	1.57	Brighton (1920)
July 21	2	0.62	<1.00	Spring Valley Road (2930)
July 25	2	0.51	1.53	Morrison (2330)
July 27	1	0.51	<1.00	Piney at Liverpool (2920)
July 28	3	0.55	<1.00	Hansen (4330)
Aug 6	7	0.67	1.30	Goldsmith @ Easton (640)
Aug 9	1	0.51	<1.00	Diamond Hill (1420)
Aug 17	2	0.51	1.14	CC below Bayou Gulch (2850)
Aug 25	3	0.71	1.10	Mission Viejo Park (760)
Sep 5	2	0.51	<1.00	Piney at Liverpool (950)
Total	**175**			