Date: February 4, 2013

To: Kevin Stewart

From: Markus Ritsch

Subject: **2012 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 2012, Water & Earth Technologies, Inc. (WET) provided monthly analyses 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 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.

II. General System-Wide Reporting Summary

A total of 4,301,763 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	4,226,339
2012	233,014	298,809	368,057	378,331	400,307	401,549	409,224	387,512	383,168	369,686	335,603	336,503	4,301,763

Shading in yellow denotes peak month of reporting

In 2012 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. 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	233,014	298,809	368,057	378,331	400,307	401,549	409,224	387,512	383,168	369,686	335,603	336,503	4,301,763
A2	233,014	313,696	369,832	389,826	412,611	375,799	423,520	400,027	392,926	389,472	353,339	369,978	4,424,040
Diff (A2-A)	0	14,887	1,775	11,495	12,304	-25,750	14,296	12,515	9,758	19,786	17,736	33,475	122,277
Comments	A2 feed was down for the entire month	A2 feed was down on the 24th	A2 feed was down early March			A2 data feed was down from 6/8-6/12					A2 data feed was down		

On February 10, 2012, WET implemented an automated daily metric between the A2 reports and legacy reports received by the NovaStar 5 base station. Each day the ratio of A2 reports relative to legacy reports was computed and emailed to Markus Ritsch. This allowed for the evaluation on a daily basis of both A2 and legacy telemetry systems including reception hardware and software. A plot of the daily ratios is shown below. In general, the A2 reports exceeded the legacy reports by approximately 2 percent on a daily basis. Periods of A2 reception outage are clearly evident. Also interesting is the fact that the legacy reporting gets worse in the winter months.

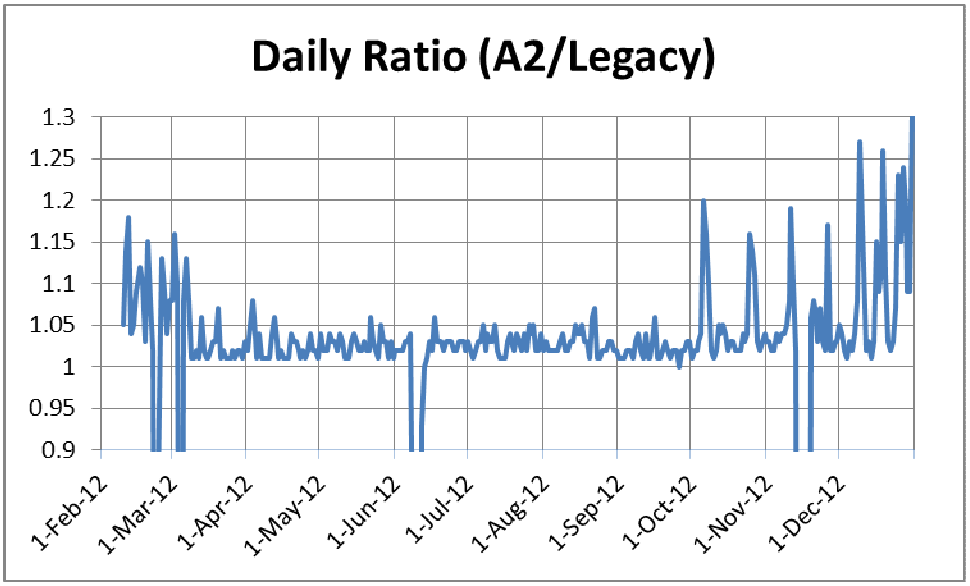


Figure 1. Daily Reception Ratio of A2 vs Legacy ALERT

OneRain believes that the loss of legacy ALERT reports during the colder months is due to a temperature sensitive component/device in the audio mixer (combines the output of two receivers, 169.500 and 169.525 MHz, into a single feed for retransmission) of several repeaters. ALERT 2 is not affected as it uses a digital feed via a different circuit entirely. Since this only affects performance at temperatures below 20 degrees F. (outside the traditional "flood season") it has not been a high priority to fix. This in no way affects the "in season" comparison between legacy and ALERT 2 performance as the malfunction does not occur at those temperatures.

III. Flood Season Reporting Summary

The distribution of legacy reports received from April through September 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 7% 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 (April 1 through October 15)

Description	Reports	Percent
Wind Data	858,860	34%
Temperature	446,195	18%
Relative Humidity	395,356	16%
Barometric Pressure	204,631	8%
Water Level	169,866	7%
Battery Voltage	135,519	5%
Precipitation	117,268	5%
Solar Radiation	64,606	3%
Fuel Temperature	37,683	1%
Fuel Moisture	37,627	1%
Unknown	20,004	1%
Soil Moisture	18,069	1%
Repeater Status Report	15,712	1%
Flasher Status	6,050	0%
Repeater Pass List	3,922	0%
12Hr Status Report	3,156	0%
Hayman Battery	2,067	0%
Handar 585 ALARM Status	1,359	0%
Evapotranspiration	1,344	0%
Solar Power	33	0%
Dewpoint Temperature	17	0%
ALERT/A2 Testing	4	0%
Longmont Flow Gage	2	0%
Total	**2,539,350**	**100%**

A. Radio Traffic Loading

For the year, the system-wide radio traffic loading averaged 12,825 reports per day and 534 reports per hour. This represents an increase over 2011 where the average daily traffic was 12,749 and the average hourly traffic was 531.

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, one in June and a second in July.

Table 4. Hours of Peak Radio Traffic Loading

Occurrence of Peak Radio Traffic Loading	Legacy Reports	A2 Reports
July 7, 2012 (5:00 PM to 6:00 PM)	1,865	2,200
June 7, 2012 (12:00 AM to 1:00 AM)	1,478	1,561
July 7, 2012 (4:00 PM to 5:00 PM)	1,395	1,576
Sept 12, 2012 (5:00 AM to 6:00 AM)	1,284	1,404
June 7, 2012 (1:00 AM to 2:00 AM)	1,251	1,357

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

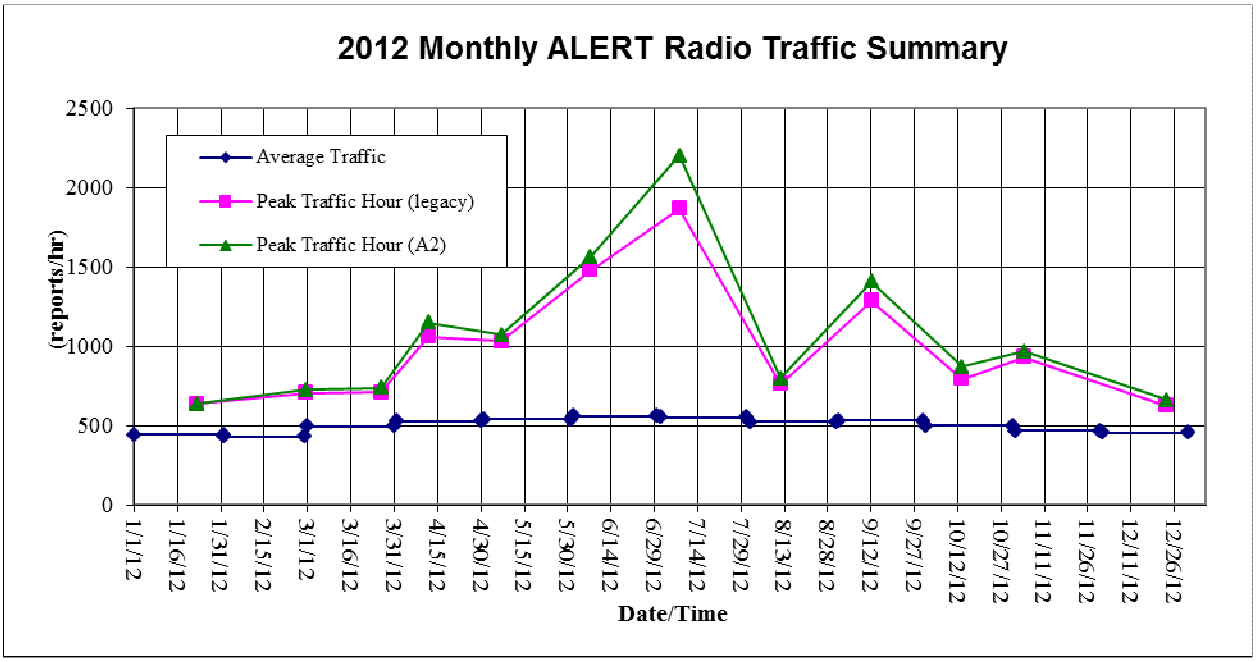


Figure 2. Peak and Hourly Average Data Reception Rates (reports received at base station)

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). It is interesting to note that the peak hour of radio traffic in 2011 is exactly the same as that in 2012.

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
2012	July	7	17	2,200

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 42% 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	1,834	42.22%
Water Level Sensors	1,226	28.22%
Meteorologic Sensors	1,051	24.19%
Other	233	5.36%
Total	**4,344**	**99.99%**

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 are shown (Table 7).

Table 7. Sensors with Poor Timer Performance

May	Jun	Jul	Aug	Sep
1710	1660	1660	2270	1640
2230	2950	2790	2320	2900
4870	540	4330	3090	2270
1900	1710	2270	4330	2190
1660	4330	2320	870	2320
4330	2320	4870	4270	1660

The sensors with consistently poor timer performance in 2012 were:

- SPR at Henderson (1660)
- Choke Cherry Reservoir (2320)
- Cub Creek below Blue (2270)
- Hansen Rain (ID 4330) – also performed poorly in 2011

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 8). The annual average precipitation experienced District-wide in 2012 was the lowest since we began performing these analyses in 2006. July was the month of heaviest rainfall in 2012.

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
2012	4.89	13.57	2.35	30.17	38.97	19.35	73.03	11.31	48.81	22.32	2.98	4.18	22.66

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 93 percent. A total of 40,224 incrementing reports were received and a total of 43,177 were expected. The table below does not 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	330	357	92.44%
February	823	950	86.63%
March	121	127	95.28%
April	5,401	5,692	94.89%
May	6,594	6,898	95.59%
June	3,110	3,345	92.97%
July	11,830	13,073	90.49%
August	1,854	1,968	94.21%
September	8,272	8,786	94.15%
October	1,467	1,540	95.26%
November	152	161	94.41%
December	270	280	96.43%
TOTAL	**40,224**	**43,177**	**93.16%**

C. Rain Sensor Event Performance

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

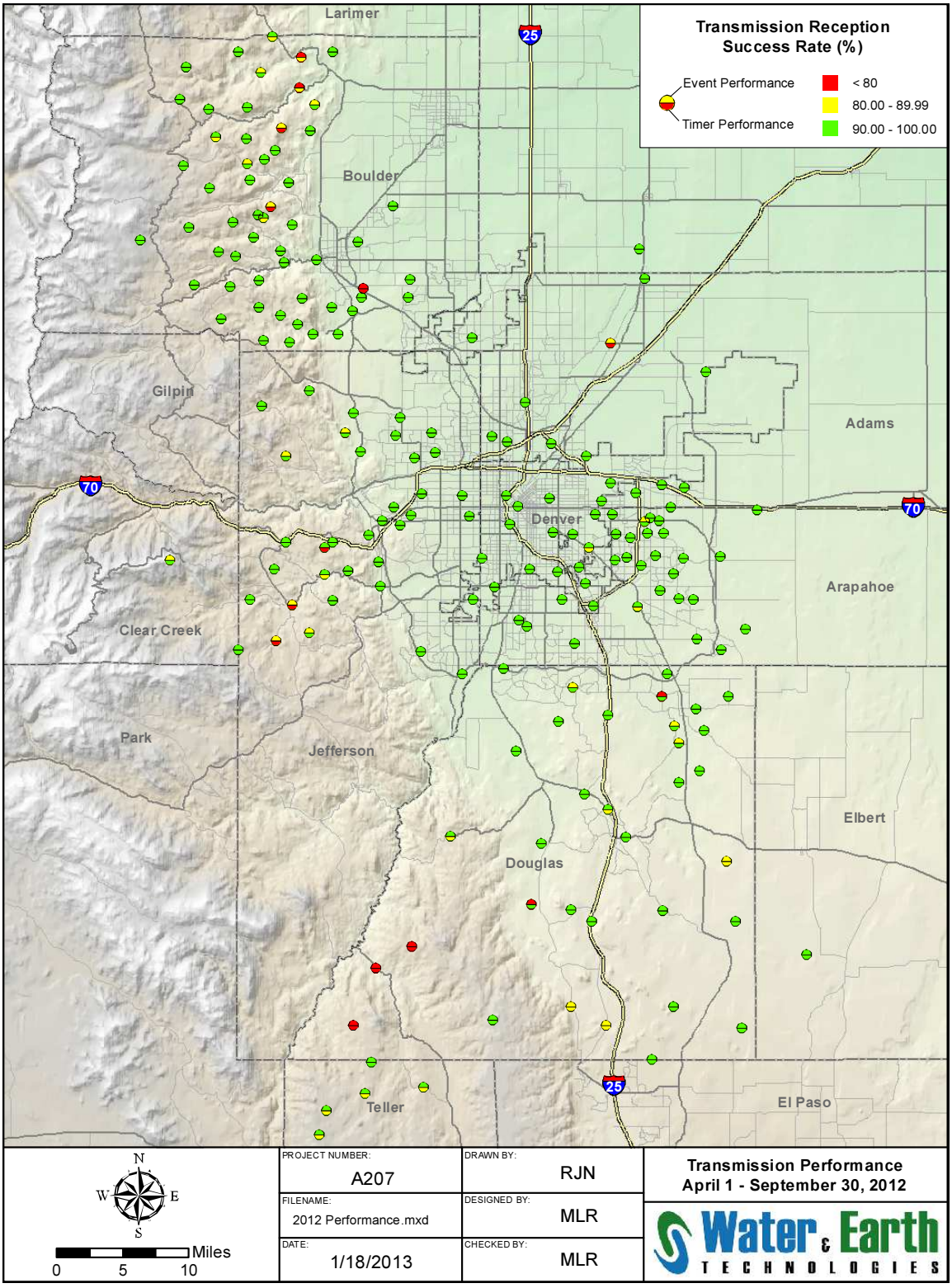
Table 10. Sensors with Poor Event Performance

Apr	May	Jun	Jul	Aug	Sep
4490	2270	700	3070	3070	3070
2980	4870	2970	4470	4790	110
1660	4470	3070	4330	2860	2980
3010	2980	400	2980	4490	310
2320	310	2730	4870	2980	4490
4470	2280	4330	2870	620	2790

The sensors with the worst event performance were Dakan Road (ID 2980) and Newlin Gulch (ID 3070). Upgrades are planned by WET for both of these stations in 2013 to improve their reporting characteristics.

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 27.6 inches
- Utah Park (ID 430) with 17.0 inches
- Powers Park (ID 1500) with 17.4 inches

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:

- Weather Ward C-1 (ID 4710) with 16.9 inches,
- Goldsmith at Eastman (ID 640) with 14.2 inches,
- Haskins Gulch Conf (ID 2820) with 15.1 inches

2. Peak Rainfall Intensity/Rainfall Alarms

Rainfall alarms are active when the following rates are exceeded at any single station within the entire 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 for the 10-min and 1-hr periods were exceeded a total of 108 times. A summary of the peak rainfall accumulations experienced this year are provided (Table 11).

Table 11. Rainfall Alarms Summary

Date	Exceedence of 10-min, 1-hr and 6-hr alarms	Peak 10 minute accumulation (in)	Peak 1 hour accumulation (in)	Peak 6 hour accumulation (in)
June 6	19	0.827 (ID 2820)	2.598 (ID 2820)	3.78 (ID 2820)
June 7	13	0.866 (ID 1520)	1.929 (ID 1520)	3.82 (ID 2820)
June 13	1	0.630 (ID 3090)	< 1.00	< 3.00
July 5	2	0.591 (ID 4880)	< 1.00	< 3.00
July 6	9	0.669 (ID 2990)	2.244 (ID 2990)	< 3.00
July 7	43	1.063 (ID 3070)	2.283 (ID 4570)	3.23 (ID 4570)
July 8	1	0.512 (ID 1050)	< 1.00	< 3.00
July 9	2	0.591 (ID 530)	1.260 (ID 530)	< 3.00
July 30	10	0.984 (ID 4710)	1.260 (ID 3040)	< 3.00
July 31	3	0.669 (ID 3030)	< 1.00	< 3.00
Aug 1	1	0.630 (ID 3070)	< 1.00	< 3.00
Aug 2	1	0.512 (ID 2270)	< 1.00	< 3.00
Sep 25	2	0.630 (ID 940)	1.260 (ID 940)	< 3.00
Sep 26	1	0.551 (ID 1360)	< 1.00	< 3.00
TOTAL	**108**			