January 2, 2006

Kevin Stewart
Urban Drainage and Flood Control District
Suite 156-B
2480 West 26th Avenue
Denver, CO 80211

Re: ALERT Gaging System Maintenance Agreement 05-013.2, Final Report

Dear Kevin,

OneRain is pleased to present you with the accompanying OneRain's ALERT Gaging System 2005 Final Report. The purpose of the Report is to summarize the ALERT system maintenance activities completed by OneRain in 2005 on behalf of the Urban Drainage and Flood Control District (UDFCD) under Agreement 05-01.23.

The accompanying Report includes recommendations for future direction of the District's flood detection network. Since the network has steadily increased in size over the years and because there are increasing opportunities for multiple users of these data, OneRain recommends further analyzing and improving on the overall architecture of the system as well as developing better QA/QC techniques. A specific set of recommendations for the 2006 season are included.

We have enjoyed this past year greatly, as we have the many preceding ones, and we look forward to our continued collaboration with the UDFCD. Please contact me with any questions.

Sincerely,

Ilse Gayl, President & CEO

cc: Jake Emerson, Earl Weiler

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ALERT Gaging System Maintenance
Agreement 05-01.23

Annual Report
January 2, 2006

Presented To
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Urban Drainage and Flood Control District
Denver, Colorado

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EXECUTIVE SUMMARY

The purpose of this report is to summarize the ALERT system maintenance activities completed by OneRain in 2005 on behalf of the Urban Drainage and Flood Control District (UDFCD) under Agreement 05-01.23.

This report includes recommendations for future direction of the District's flood detection network. Since the network has steadily increased in size over the years and because there are increasing opportunities for multiple users of these data, OneRain recommends further analyzing and improving on the overall architecture of the system as well as developing better QA/QC techniques.

Maintenance activities on the ALERT real-time monitoring network for 2005 have been completed. During the 2005 operating season, OneRain generated 810 maintenance reports for the UDFCD network. Of these, a total of 95 (11.8%) service calls were generated: 20 (21%) were unscheduled District service calls and 75 (79%) were unscheduled OneRain Incorporated service calls; the remaining visits were documented standard maintenance activities.

The overall percentage of service calls during the field season increased compared to 2004. The following sites required the most "unscheduled" visits:

- Englewood Dam (site 1600) 6 visits
- Sand Creek Mouth (site 1810) 5 visits
- Kelly Dam (site 410) 4 visits
- SPR @ Union (site 1640) 3 visits
- Gold Hill Repeater (site 8015) 3 visits

The 21 trips to these 5 sites accounted for 22% of all unscheduled service calls for 2005.

MAINTENANCE ACTIVITY SUMMARY

Site Additions

One additional site was added to the network in 2005. The Stapleton site is a reincarnation of the original Urban Farm weather station. This site includes nearly all of the same equipment and sensors, and maintains the original base ID of 1460. There were a few changes from the original to the new installation. The telemetry system is now controlled by a Blue Water Design CommEngine which replaces the much older ALERT serial interface (ASI) board. This site now includes the following sensors (and sensor IDs):

- Rain (1460)

- Relative Humidity (1461)
- Temperature (1462)
- Barometric Pressure (1463)
- Solar Radiation (1464)
- Wind Speed (1465)
- Wind Direction (1466)
- Peak Wind Speed (1467)
- Battery Voltage (1468)
- Soil Moisture (1471)

The site is located in the City and County of Denver maintenance yard on the southeast corner of Smith Street and Havana Way. The site's latitude is 39 (46' 03.55"), and its longitude is 104 (52' 01.0") (using the WGS84 datum).

Figure 1, Stapleton Weather Station

Damaged Equipment and Site Reinstallations

The pressure transducer (PT) cable on site 100 was cut due to construction near Carr St. OneRain replaced the PT and reconstructed the riser assembly.

The Holly Dam site (1610) was struck by lightning. This was a direct hit and all of the components were destroyed. The equipment for this site is included in the equipment recommendations section (Appendix C).

The Leyden Confluence site (210) was damaged by construction near the confluence of Leyden and Ralston Creeks. OneRain removed the PT and riser assembly, and replacement will occur after completion of construction work in the area.

Construction workers restructuring the stream at Harvard Gulch cut the PT cable on the Harvard/Jackson site (610). OneRain replaced the PT and riser assembly.

The Maple Grove Reservoir (1000) antenna mast was damaged (presumably by vandals). OneRain replaced the mast assembly.

The Sand Creek Park (1800) standpipe was hit by a car (see Figure 2). According to the gentlemen who lives across the street, the perpetrator was a young man who thought that he should be somewhere other than in police custody. OneRain replaced the standpipe and re-ran the PT conduit to a more secure location.

Figure 2, Sand Creek Park, damaged standpipe

Removals Requested Prior to Construction Activity

OneRain removed the Sportsplex (320) standpipe and PT prior to construction along West 58th Ave. Replacement is pending completion of this construction activity.

Already a holdover from 2004, the Castle Oaks site (2830) reinstallation is still pending completion of the bridge construction on Castle Oaks Drive.

OneRain removed the equipment from the site at South Boulder Creek below Gross Reservoir (4370) prior to building replacement. The original equipment has been reinstalled in the new structure and OneRain constructed a new antenna mount to accommodate the concrete roof eave. Please see Figures 3 and 4, below.

Figure 3, South Boulder Creek at Gross, new building exterior with antenna mount

Figure 4, South Boulder Creek at Gross, inside new structure

Rehabilitation

OneRain re-built the Blue Mountain weather station (140) and the West Repeater (950) in May. The original standpipe had been modified to accommodate a taller mast for the DB-224, but the unintended consequence was the introduction of fatigue from cyclic loading. Ultimately, the standpipe was compromised by fatigue failure. The equipment was remounted in a large NEMA enclosure on a section of Rohn-25 tower.

OneRain selected a larger enclosure to allow the transmitter "cans" to rest side by side (rather than one on top of the other) and to permit ease of maintenance in what can often be a harsh environment. Please see Figure 5, below.

Figure 5, Blue Mountain/West repeater remount

PT Failures/Replacements

Overall PT failures were about average for the 2005 field season. Although a total of 10 PTs failed, 4 were due to external causes. OneRain has noted a higher than acceptable failure rate of the GE-Druck PTs over the past few years. For this reason, we will be recommending replacements manufactured by Esterline (formerly KPSI Pressure Systems). This has been a very reliable

device in many of our other applications, and the company's service and warranties are top notch.

- Carr St. (site 100) damaged, Druck PT, having been in service for 4 years.
- Leyden Confluence (site 210) damaged, Keller PT, having been in service for 10 years. Replacement pending.
- Montview (site 400) Druck PT, failed after having been in service for 5 ½ years.
- Kelly Dam (site 410) Druck PT, failed after 2 yrs of service. OneRain replaced the signal conditioning module as well, and the new PT failed after only 3 months.
- Expo Park (site 420) Druck PT, failed after having been in service for 4 years.
- Harvard/Jackson (site 610) Druck PT, damaged after having been in service for 4 years.
- Holly Dam (site 1610) Druck PT, struck by lightning after 4 years of service. The replacement is pending.
- Sand Creek Park (site 1800) Druck PT, failed after 11 months of service.
- Little Narrows (site 4470) Druck PT, failed after 10 months of service despite being pulled 3 feet above water level for the winter.

Repeater Upgrade Update

All seven of the 50386 repeaters have been upgraded by HydroLynx, bringing them fully within the manufacturer's current specification. The last units were modified and deployed at start up and all have been operating with the following exceptions:

- Chokecherry (2320) had a failure in January requiring a return to the vendor for repair two months after modification.
- Eagle Ridge (4520) had a failure in July requiring a return to the vendor for repair three months after modification.
- Gold Hill (8015) had a failure in July requiring a return to the vendor for repair three months after modification.
- Smoky Hill had a "lock up" event in November requiring a manual reset 11 months after modification.
- Smoky Hill had another "lock up" requiring a manual reset in December.

- Eagle Ridge had a partial "lock up" (rain and battery stopped reporting) requiring a manual reset in December.

Only the Louisville, West (Blue Mountain) and Lee Hill repeaters did not have some catastrophic failure during the course of the year post-upgrade. Also, the bit-shifting phenomenon still persists, but at a reduced level. It seldom repeats frequently enough to get past the software safeguards and trigger alarms. While these failures are inconvenient, OneRain does not recommend replacing these units. The expense would be greater than the potential benefit of transitioning to another manufacturer. However, should a new repeater requirement arise in the future, OneRain would recommend the use of the High Sierra 3300 series repeater.

Miscellaneous Activity of Note

Repeater Switch

The AutoSwitch application was installed and working well until a timing conflict arose with database maintenance activity on the new PC, resulting in false failures being reported. Our hypothesis was that the daily database maintenance was taking an excessive amount of time, thus delaying the transfer of data to the AutoSwitch scripts. This problem seems to have been corrected since mid-December when UDFCD staff cut down the size of the archive database on the DIADvisor machine. Since this time there have been no false alarms.

Narrow Band Compliance

The District's narrow banding effort is nearly complete. There remain only three Sierra-Misco 5050 transmitters in service in the UDFCD system. These Boulder County sites are Magnolia (4090), the Justice Center (4360) and the Boulder Jail (4550). Please see Appendix C for the full list of hardware replacement recommendations.

Handar 585 Transmitter Replacement

The UDFCD system includes 18 sites that are in excess of 14 years old. These Handar 585 units are no longer supported by any manufacturer. The following table summarizes the older sites (see Table 1, below):

Table 1, UDFCD Sites with Equipment Older than 14 Years

Site ID	Site Name	Sensors*	Model	Purchase Date
130	Simms Street	S	585 B Rev G	1/1/1990
150	Knott Creek	P	585 B Rev G	1/1/1990
220	Upper Leyden	P	585 B Rev G	1/1/1990
330	Van Bibber @ 93	PS	585 B Rev G	1/1/1990
750	Quincy Reservoir	PW	585 B Rev G	1/1/1991
1110	Gunbarrel	PS	585 B Rev G	1/1/1991
1630	S Platte @ Dart	E	585 C Rev G	1/1/1990
1720	Cherry Cr @ Steele	PS	585 B Rev G	1/1/1991
2230	Bear Creek @ Cub	PS	585 B Rev G	1/1/1991
2240	Cold Spring Gulch	PS	585 B Rev G	1/1/1991
2250	Rosedale	PS	585 B	1/1/1990
2260	Brook Forest	P	585 B Rev G	1/1/1991
2270	Cub Ck below Blue	PS	585 B Rev G	1/1/1991
2280	Kinney Peak	P	585 B Rev G	1/1/1991
2310	Genesee Village	P	585 B Rev J	1/1/1991
2350	Idledale	P	585 B	1/1/1991
2360	Indian Hills	P	585 B Rev G	1/1/1991
2370	Red Rocks	PS	585 B Rev G	1/1/1991

*PW = rain and weather array, E = shaft encoder, PS = rain and stage, P = rain

Since the enclosures ("cans") and attached connectors for all of these units are still in good condition, OneRain could replace the transmitter, controller and datalogger components with up-to-date hardware. This can be done for a lower overall cost than completely replacing 585 with new off-the-shelf units. OneRain recommends using the following major hardware components for this task:

- Midland (formerly Maxon) RF transceiver
- Blue Water Design CommEngine (ALERT controller), this device also handles all rain and battery reporting
- Campbell Scientific CR200 datalogger, for sites with pressure transducer and shaft encoder devices
- Campbell Scientific CR10X, for weather station sites

The advantage of this method is that programmable datalogger functionality is added only to those sites that need it. For the five rain-only sites a CommEngine and radio will suffice.

Base Station Equipment Move

The secondary receiver at Diamond Hill was moved from its third floor office overhead to the Flood Prediction Center office, also on the third floor. During this time, OneRain also verified the operation of the receiver and the antenna's VSWR (voltage standing wave ratio, an indication of the antenna's ability to transfer RF signals).

Access Concerns

At Kelly Dam (410) it appears the access road is being reclaimed, both up onto the dam crest standpipe location and over to the bottom of the detention area PT location. This will make maintenance visits in the future more difficult. Please see Figures 6 and 7, below.

Figure 6, Kelly Dam access road reclamation

Figure 7, Kelly Dam PT access reclamation

The Slaughterhouse site (1620), located southeast of the intersection of South Broadway and East Orchard Road in Littleton, is adjacent to a car dealership lot. The dealership recently planted a tree in front of the access gate for this site. The standpipe can be accessed from the parking lot if a parking space is open, but otherwise there is no close access.

Tipping Bucket Replacement

During the 2005 season the District had 22 of the old-style, soldered tipping buckets in the field. These rain sensors are easily damaged if accumulated water freezes in the bucket which can certainly occur in the spring and fall. OneRain recommends that the District continue with the annual replacement schedule and upgrade ten of these units this year.

FCC Licensing

To date, OneRain has received confirmation for renewed or extended licensing on 166 sites under 31 different call signs. There were four call signs that required attention this year:

- Original 23 Call Signs are effective until 29 July 2014
- WPPA516 is effective until 23 September 2014
- WPPA678 is effective until 24 September 2014
- WPQI652 is effective until 28 July 2015

Of the six new sites that OneRain applied for on behalf of the District in 2005, we have now received approval for five and one is still pending. Please see Appendix A: FCC Licensing Summary.

Smoky Hill Repeater

Mid-year OneRain met with representatives from Nextel regarding space on a tower extension that was to be build adjacent to the Cherry Creek Water District building on Smoky Hill Road. The intent behind this effort was to raise the repeater antenna to improve reception at both OneRain's headquarters and at Diamond Hill. Unfortunately Nextel wanted to charge $500 per month for this privilege, so the idea has been put on hold.

Sand Creek at Colfax

OneRain currently has the District's purchase order for the installation of this site and will complete the work in the first quarter of 2006, or as soon as possible given the 2006 contract process.

FUTURE AREAS OF INTEREST

During the second half of 2005, the District initiated a monthly meeting between OneRain and UDFCD staff. During these meeting we discussed future direction for the system, current operational issues, and resolved any unfinished business items. This section covers some of the topics covered in those monthly meetings.

System Architecture

It has been a number of years since OneRain has completed a full architecture review of the District's ALERT system. The benefits of such a review would include information gathering for planning of future system expansion, channel usage during peak traffic events, and failure mitigation by identifying alternate and redundant data paths. OneRain recommends that the District conduct a comprehensive system review in 2006. The output of this analysis would be a set of detailed recommendations for long-term planning and improvement of the ALERT flood detection network.

An audit of this depth will take approximately one man-week of effort and will include, but not be limited to, the following areas:

- The spatial distribution of ALERT sites relative to repeaters
  - Detailed study to gather radio path loss data from each site to a repeater or base station
  - Identify sites where there is only one path to the base station
  - Identify target locations for new redundant paths (repeater, concentrator)
- The spatial distribution of ALERT sensor types
  - Graphical overlay representation of sensor distribution
  - Use 100-year event for theoretical rain traffic analysis
- The distribution and magnitude of weather events
  - Gather data on mean storm size, orientation, and direction of movement
  - Run a "nearest neighbor" analysis
  - Provide statistics on rain gage density
  - Look at the effect of storms moving across the District on traffic loading across multiple repeaters
- Baseline and peak traffic analysis
  - Poisson analysis (probability of message collisions)
  - Reference storm properties and their effect on channel loading
- Additional analyses
  - Bit errors
  - RF traffic analysis based on storm movement across the District

Data Analysis and QA/QC

Currently the data analysis section of the District's ALERT gaging system maintenance contract reads:

> *CONSULTANT shall evaluate rain and stream gage data reliability following precipitation events that cumulate an inch or more of precipitation at ten (10) or more rain gages within seven (7) consecutive days. Based on the analysis results, any equipment suspected faulty should be scheduled for service in accordance with this Agreement. CONSULTANT shall provide DISTRICT with a brief written summary of the system status and recommend remedial actions following each data analysis.*
>
> *CONSULTANT shall periodically check the database and operational status of the DISTRICT's base station via the website http://alert.udfcd.org. Status checks may coincide with the data analysis referenced in [the paragraph] above. Any problems noted shall be reported immediately to DISTRICT.*

Over the course of 2005 there were two events that met the criteria of the first paragraph above; June 3 and August 3-4.

On June 3, 29 gages reported over one inch of precipitation, and four more over 0.95 inches, resulting from a few intense storm cells. One cell near Lyons dropped 2.3 inches at Little Narrows. The second storm line started in the south metropolitan area and spread northeast through Aurora. A third storm line moved through Brighton. OneRain found three gages noticeably lower than their neighbors. Kelly Dam (410) was found to have debris between the bucket and the housing which hindered movement. Parker & Mississippi (540) and Quincy Reservoir (750) were slightly out of level. Additionally, Dry Creek at 64th (1310) was low relative to nearby gages. OneRain found that the switch arm was hitting the switch body. All were inspected and corrected by June 8, 2005.

The August analysis was rather short as the only site that gave any indication of misreporting was Upper Sloan (1400). Data analysis showed that there was a lag in the rain reports; it transmitted an appropriate amount of rainfall relative to its neighbors, but over a delayed period. Upon on-site inspection OneRain found that the funnel was plugged with bird "effluent."

OneRain has conducted periodic system checks on a daily basis. The main focus of these routine checks has been to ensure that the repeaters, the backbone of the ALERT network, are fully operational. On some days a field technician will check the system via the http://alert.udfcd.org site, and other days they will use OneRain's DIADvisor system. Other analyses include:

- Port statistics, indicates the presence of un-decoded traffic

- Traffic loading, maximum and minimum traffic hours
- Over-reporting sensors
- Under- or non-reporting sensors
- Spurious data, can indicate bit errors
- Alarms, sensors that have exceeded their alarm threshold

The District will genuinely benefit from more detailed time-based and event-based data analyses. Regular inspection of the data will help both the District and its hydro-met contractors to qualify raw data better before they are used in critical flood predictions or analyses of system wide meteorological trends. OneRain recommends the following types of analyses:

- Site availability (based on timer reports)
- Sensor availability (based on expected timed transmissions)
- Nearest neighbor analyses
  - Rain gages
  - Weather sensors (where appropriate)
- Radar rainfall correlation
- Hydro-met validation
  - Maximum, minimum value
  - Maximum, minimum rate of change
  - Maximum difference from neighbors
  - Stream runoff validation (Q based on ratings where appropriate)

A product that OneRain has discussed with the District is a free service managed by NOAA called the Meteorological Assimilation Data Ingest System (MADIS). This is a QA/QC system that the District currently has access to, and it could be used to further check the ALERT hydro-met data set. There is no plan in place now for OneRain to use this system (access is not publicly available), but this could be a useful tool for OneRain and UDFCD to develop jointly. OneRain proposes to establish with UDFCD the requirement for such an application, and OneRain will then dedicate resources to completing the application in 2006.

Weather Sensors

Calibration and Replacement

The District's ALERT flood warning system has expanded its user base significantly since inception. Today, the system gathers much more than just rain and stage data. Since the network of ALERT gages is maintained on an

ongoing basis and the platforms that deliver this data are perfectly suited for gathering other environmental information weather, the volume of data has increased significantly. Also, the scrutiny of more eyes inspecting this data has helped to make the system more robust and the data of higher quality.

The original primary purpose of the UDFCD network was not to maintain weather (meteorological) data (i.e., barometric pressure, temperature, humidity [dew point], wind, solar radiation, etc.), but a growing number of these sensor suites have been installed in recent years. Inclusion of these sensor suites, in some cases, helped to fund the initial installation of new hydro-met stations.

Because of the high quality of manufacturing of these sensors, there has not been a high demand for calibration other than periodic "one point" checks. Many of these weather sensors have now been in the field for almost ten years and have not received the full calibration attention that they deserve.

OneRain recommends establishing a met-sensor calibration schedule in 2006. The sensors that are of particular interest to the District and its contractors should be sent back to a certified service center for multi-point calibration. The service center should have the capability to provide a calibration certificate traceable to the National Institute of Standards and Technology (NIST).

CONCLUSION

This year's maintenance activities included a higher than average number of service calls, primarily due to repeater failures, PT fallout, construction damage and lightning. OneRain has made every effort this year to catch site and sensor problems as soon as they arise. There were still 21 service request generated by the District. Many of these related to meteorological instruments, and others were "pet" stations for users of the District's data. While we pride ourselves in being diligent and conscientious about monitoring the system, it is good to know that others are helping us keep an eye on things!

The recommendations in the body of this report, and listed in the table below, are aimed primarily at further improving this data QA/QC and monitoring system. OneRain's interest is in making this top-notch system even better.

Table 2, Recommendations Summary

Recommendation	Description	Action
PT Replacement	Switch from GE-Druck to KPSI as existing sensors require replacement	KPSI sensors for future purchase[1]
Repeater Upgrade	The number of repeater failures has been poor this year, but there is not sufficient cause for replacement.	Continue to monitor
Narrow Band Compliance	There are three transmitters in the system that are outside of the FCC's standard for compliance.	Replace transmitters[1]
Handar 585 Replacement	There are several of these transmitters in the system that are in excess of 14 years old and are no longer supported by a manufacturer.	Replace transmitters[1]
Site Access	Kelly Dam (410) is no longer readily accessible by service vehicle.	Modify unit maintenance fee
Tipping Buckets	There are 22 soldered buckets in the system	Replace 10 units[1]
FCC Licensing	One call sign is still pending approval with the FCC.	Continue to monitor
Smoky Hill Repeater	Investigate path losses from Smoky to Diamond Hill.	Architecture review / system audit
System Architecture Analysis	Perform an audit of system data and make recommendations about future system improvements in reliability and data quality.	OneRain to present proposal
Data Analysis	Develop further data analysis techniques to ensure that the District's data quality is maintained at the highest level.	OneRain to present proposal
Weather Sensors	Establish a plan for weather sensor calibration starting with the District's highest value sensing locations.	Establish calibration plan

[1]See Appendix C: Equipment Recommendations.

APPENDIX A: FCC LICENSING SUMMARY

The following table summarizes all of the FCC license renewals that OneRain coordinated on behalf of the District in 2005. The six site licenses that are currently pending are expected to be approved in the next two months.

Table 1, FCC License Renewals Summary

ID#	Site Name	Call Sign	Submitted	FCC File No.	Approved	Expires
650 840 850 860 870 900	Iliff Pond Aurora FS #12 Flying J Sand Creek Murphy Creek Aurora Reservoir Wx	Pending	17 Aug 2005	2282319		
1300 1310 1320 1330 1340 1350	Hidden Lake Little Dry Creek @ 64th SPR @ Mausoleum Roslyn Sanderson Gulch Chatfield Dam	WQDV 522	23 Aug 2005	2288056	8 Nov 2005	8 Nov 2015
1360 1370 1440 1480 1500 1520	Denver Zoo FS #13 Elbert Wx DIA @ Third Creek Powers Park Marston Lake	WQDL 342	22 Aug 2005	2286730	22 Sep 2005	22 Sep 2015
1530 2190 2320 2840 4550 4810	Bear Crk @ Lowell Squaw Mountain Choke Cherry Reservoir Sulphur Gulch Boulder Jail Shanahan Ridge	WQDV 780	23 Aug 2005	2287679	9 Nov 2005	9 Nov 2015
4820 4830 4840 8000 8005 8015	Doudy Draw SBC @ San Souci SBC @ Canyon Ditch Blue Mountain Rptr Smoky Hill Rptr Gold Hill Repeater	WQDV 742	23 Aug 2005	2287962	9 Nov 2005	9 Nov 2015
9100	Diamond Hill Control Station	WQDV 521	23 Aug 2005	2287991	8 Nov 2005	8 Nov 2015

APPENDIX B: 2005 PT CALIBRATION HISTORY

The following table summarizes calibration information for pressure transducers in the UDFCD.

Table 1, UDFCD PT Calibrations

Maintenance Record #	Sensor ID	Slope	Calibration Offset	Standard Error	Calibration Date
202408	413	0.0111	-0.0456	0.0118	9/8/2005 10:57:22 AM
202403	403	0.0111	0.0041	0.0035	8/26/2005 1:43:04 PM
202361	403	0.0117	0.4356	0.1035	8/17/2005 12:33:46 PM
202360	413	0.012	-0.6636	0.1484	8/17/2005 11:04:04 AM
202329	1303	0.0147	-0.0344	0.0106	8/11/2005 8:53:31 AM
202240	4473	0.0117	0.3165	0.0745	6/30/2005 10:29:38 AM
202184	1803	0.01	-0.0066	0.0038	6/23/2005 12:28:26 PM
202178	413	0.0104	0.2814	0.0672	6/22/2005 12:28:41 PM
202172	1533	0.0102	0.2679	0.0821	6/13/2005 2:01:53 PM
202134	2813	0.0091	-0.0285	0.0086	5/25/2005 9:44:53 AM
202121	813	0.0108	-0.023	0.0073	5/23/2005 2:09:26 PM
202119	1803	0.01	0.4071	0.094	5/23/2005 12:32:52 PM
202110	1103	0.0188	0.9011	0.2206	5/20/2005 10:42:41 AM
202029	4453	0.0113	-0.0671	0.0213	4/6/2005 2:48:35 PM
202021	2273	0.0919	-0.7012	0.1151	3/24/2005 11:22:44 AM
202017	1323	0.0103	-0.1907	0.0816	3/22/2005 3:42:47 PM
202015	613	0.01	0.1078	0.0192	3/22/2005 1:20:10 PM
202014	103	0.0099	-0.1006	0.022	3/18/2005 1:04:05 PM
201973	1103	0.019	0.3504	0.1055	3/7/2005 9:52:58 AM

APPENDIX C: EQUIPMENT RECOMMENDATIONS

The items listed below are in order according to OneRain's recommendation of priority:

1. Spare Radios.
   - Due to nearby lightning strikes and non-warranty component failures, the UDFCD system lost five radios during the course of this year. The unit price listed below is with the distributor's discount.
   - Total Price: 5 x $237 = $1,185

2. Pressure Transducer Replacements and Spares.
   - Since the quality of the GE-Druck sensors has decreased over the past two years, OneRain recommends replacing these sensors with KPSI units as they fail. For sites where lightning is a significant concern, sensors with lightning should be installed.
   - Lightning surge protection modules cost an additional $375 (approximate), and the transducer head is 10" long and 1" in diameter. According to the manufacturer, "*transducers installed with this option have a lifetime warranty against damage due to voltage surge.*"
   - All of the PTs listed below include lightning protection.
   - 160, 2 x $1,270
   - 120, 1 x $1,220
   - 100, 1 x $1,195
   - Total Price: $4,955

3. Transmitter Spares.
   - 3 High Sierra Electronics 3206 ALERT transmitters
   - One replaces the Holly Dam transmitter destroyed by lightning
   - Two additional units bring the spares for this transmitter type to 10%.
   - Total Price: 3 x $2,706 = $8,118

4. Handar 585 Replacements.
   - Replacement will retain the original enclosure and will include a new FCC-compliant radio, Blue Water Design transmitter controller

(CommEngine) and, where sensors other than rain are required, a Campbell Scientific datalogger.

- Since these platforms are among the oldest in the system and have been subject to wear and tear for nearly 15 years, they are more likely to fail than their younger counterparts. Direct replacement by spare equipment is not practical because the connectors are different.
- OneRain does not recommend replacing the weather station at Quincy at this time.
- Since funds are limited we would recommend starting with the rain only sites, as these would provide the greatest cost savings.
- 7 Rain-only = 7 x $1,710 = $11,970
- 10 Rain and stage (encoder or PT) = 10 x $2,320 = $23,200
- Total Price: $35,780

5. Relative Humidity and Air Temperature Sensor Replacement.
   - The majority of the RH/AT sensors in the system are still supported by the original manufacturers (Vaisala [Handar], and HydroLynx).
   - There are eight Sierra-Misco sensors in the system that are over seven years old, and cannot be calibrated.
   - Total Price: 8 x $1,165 = $9,320

6. Tipping Bucket Replacements.
   - Ongoing replacement schedule of 10 per year
   - Total Price: 10 x $306 = $3060