

# Radar Rainfall Analysis

## August 2020 Summary Report



Prepared for 3 Rivers Wet Weather

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## Glossary

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**Average Difference (AD)** – Average of the absolute percentage differences between the rain gauge data and uncalibrated radar data sampled over the gauges.

**Bias Correction Factor** – Bias is a systematic error that can be corrected through calibration. The correction factor is the sum of the gauges divided by the sum of the sampled radar values over the gauges.

**Calibrated Average Difference (CAD)** – Average of the absolute percentage differences between the rain gauges and local bias calibrated radar data sampled over the gauges.

**Cumulative Distribution Plot (CDP)** – A graph depicting the accumulation of a rain gauge and the unadjusted/adjusted radar over that gauge.

**Decibels of Reflectance (dBZ)** – The logarithmic scale for measuring radar reflectivity factor or a measure of reflectivity of a radar signal off a remote object.

**Gauge Adjusted Radar Rainfall (GARR)** – Bias corrected radar rainfall through comparison with rain gauges.

**KCCX** – Federal Communications Commission (FCC) call sign for the NEXRAD near State College, PA.

**KPBZ** – Federal Communications Commission (FCC) call sign for the NEXRAD near Pittsburgh, PA.

**Level II** – The Level II radar products are the highest resolution, and consist of the base data that includes reflectivity measured in decibels of reflectance (dBZ) among Doppler velocity and spectrum width.

**Level III** – The Level III radar products are derivative products from Level II, and consist of horizontal and vertical reflectivity among other products.

**Local Bias (LB)** – An approach to adjusting radar rainfall that uses the ratio of gauge to radar accumulations from surrounding gauges, with the closest gauge having the most weight.

**Minimum Storm Total Threshold (MSTT)** – A check used to remove radar/gauge pairs whose cumulative radar and/or gauge values for a given event period were below 0.05 inches.

**Next Generation RADAR (NEXRAD)** – A network of S-band (10.5-cm wavelength) radars operated by the National Weather Service.

**Radio Detection and Ranging (RADAR)** – An electronic instrument used for the detection and ranging of distant objects of such composition that they scatter or reflect radio energy.

**Radar-Gauge (RG)** – A pair of rainfall accumulations measured by the rain gauge and the radar rainfall accumulation sampled above the gauge.

**Z-R relationship** – An empirical relationship between radar reflectivity factor  $Z$  ( $\text{mm}^6 \text{m}^{-3}$ ) and rain rate  $R$  ( $\text{mm hr}^{-1}$ ). Radar reflectivity factor is dependent on the rain drop size distribution. [ $Z = aR^b$ , where  $a$  and  $b$  are empirically derived constants]

- **Convective** – generally used for convective (i.e. thunderstorms) rainfall [ $Z = 300R^{1.4}$ ]
- **Eastern U.S. Cool Stratiform** – generally used for cool season, non-convective rainfall that occurs east of the Continental Divide [ $Z = 130R^{2.0}$ ]

## Overview

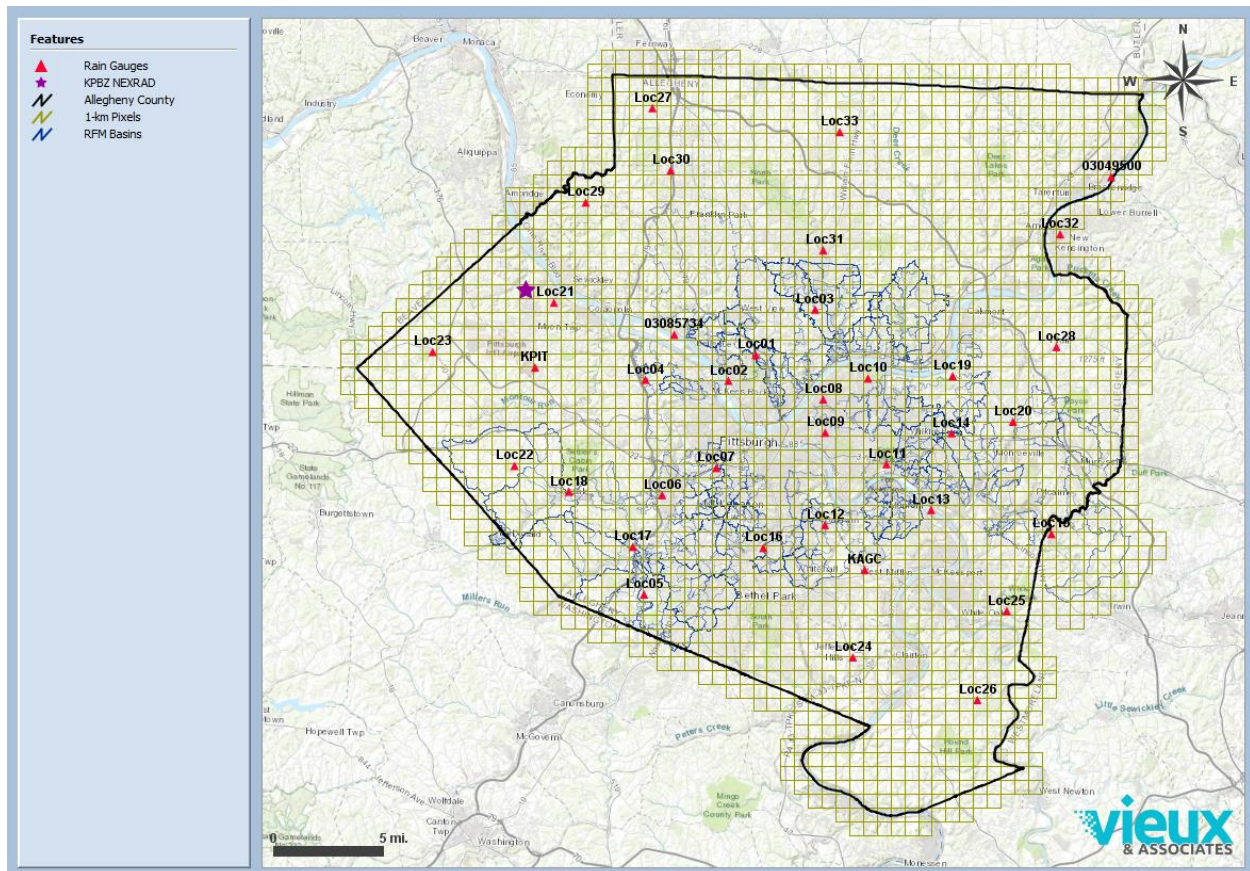
Vieux & Associates, Inc. (Vieux) processes radar and rain gauge data for 3 Rivers Wet Weather (3RWW). During each month, radar and rain gauge data are segmented into qualified storm event periods and then Quality Controlled (QC). To produce QC gauge-adjusted radar rainfall (GARR), both radar and rain gauge data are reviewed manually to remove inconsistent data. While only qualified rainfall events are included in this report, the RainVieux online database contains continuous data where QC rain gauge and radar data are available during the inter-event periods. QC is performed to remove anomalous radar data and inconsistent rain gauges during both the qualified and inter-event periods.

Radar data used in production of GARR is produced by the National Weather Service (NWS) Next Generation Radar (NEXRAD) system. NEXRAD Level II radar data are often referred to as Base Data and contain the full spatial/temporal/data resolution data from the radar. Level II radar data measures reflectivity in decibels of reflectance (dBZ), and at a spatial resolution of 0.5-degree by 0.25-km every 4 – 10 minutes with a data resolution of 0.5 dBZ amounting to 256 data levels of data. Level III reflectivity radar data have the same data and temporal resolution, but a reduced spatial resolution of 1-degree by 1-km.

The primary radar data source used to process this period was Level II NEXRAD data from KPBZ located near Pittsburgh, PA. The succession of data used gives priority to Level II followed by Level III products. If KPBZ Level II NEXRAD data are unavailable, then KPBZ Level III Q1 is substituted. If no radar data are available from KPBZ, then Level III Q0 NEXRAD data from KCCX (State College, PA) are used. In the event that all radar sources are unavailable or if the radar provides insufficient rainfall information, then a gauge-only product that spatially distributes point rainfall estimates is used. All radar data were processed into five-minute increments.

Because the radar measures reflectivity in polar coordinates centered on the radar installation, the 1-degree azimuth increases in width as range increases from the radar. Range resolution of the Level II radar data is 1-km and is measured out to 230 km from the radar. Due to the proximity of KPBZ to the study area, the polar coordinates defining horizontal resolution over Allegheny County range from 0.1 – 0.9 km, whereas KCCX ranges from 2.5 – 3.6 km. The radar data represented in these polar coordinates are sampled through spatial averaging into a Cartesian grid of uniform resolution, i.e. 1x1 km. An advantage of the Cartesian grid is that one radar can be substituted for the other without changing the grid resolution, as would be necessary if polar coordinates were used for output of rainfall information at 1x1 km spatial resolution. The Cartesian grid used was defined by a 1-km<sup>2</sup> grid domain shapefile containing 2313 1-km<sup>2</sup> pixels covering the study area. CDM Smith provided two basin shapefiles consisting of 440 RFM basins and 871 RFM sheds that are located within the 1-km<sup>2</sup> pixel domain.

Rain gauge data from as many as 37 gauges were used to adjust the radar. 3RWW provided rain data in 5-minute increments for 33 stations. In addition, rain gauge data were obtained from two United States Geological Survey (USGS) stations and two NWS Automated Surface Observing System (ASOS) stations. Figure 1 depicts the spatial distribution of the rain gauge network, KPBZ NEXRAD, RFM basins and 1-km<sup>2</sup> pixels. For the gauges shown in Figure 1, the ID, name and source of each gauge is listed in Table 1. Radar data review, preparation and sampling the radar over the gauges and 1-km<sup>2</sup> pixels were achieved using software developed at Vieux.



**Figure 1. Spatial Distribution of the Rain Gauge Network, KPBZ NEXRAD, RFM Basins and 1-km<sup>2</sup> Pixels**

**Table 1. Rain Gauge ID, Name and Source**

Gauge ID	Gauge Name	Source
Loc01	PWSA-Montana St.	3RWW
Loc02	ALCOSAN WWTP Lab	3RWW
Loc03	Shaler Munic Bldg	3RWW
Loc04	Kennedy Twp PS	3RWW
Loc05	Upper St. Clair	3RWW
Loc06	Carnegie Transit Time	3RWW
Loc07	Greentree Munic Bldg	3RWW
Loc08	AC Health Dept Bldg	3RWW
Loc09	Univ of Pittsburgh	3RWW
Loc10	PWSA-Highland Park	3RWW
Loc11	M-46 Access Shaft	3RWW
Loc12	Baldwin	3RWW
Loc13	M-59 Access Shaft	3RWW

Gauge ID	Gauge Name	Source
Loc14	Churchill Munic Bldg	3RWW
Loc15	Trafford Maint Bldg	3RWW
Loc16	Castle Shannon	3RWW
Loc17	Chartiers Pump Station	3RWW
Loc18	Oakdale Pump Station	3RWW
Loc19	Sandy Creek Eq Facility	3RWW
Loc20	Gascola Eq Facility	3RWW
Loc21	Moon TWP	3RWW
Loc22	North Fayette TWP	3RWW
Loc23	Clinton Munic Bldg	3RWW
Loc24	Jefferson Hills	3RWW
Loc25	White Oak Public Works Bldg	3RWW
Loc26	Elizabeth TWP Municipal Bldg	3RWW
Loc27	Marshall TWP	3RWW
Loc28	Plum Municipal Bldg	3RWW
Loc29	Bell Acres Munic Bldg	3RWW
Loc30	McCandless Twn Hall	3RWW
Loc31	Hampton Municipal Bldg	3RWW
Loc32	Arnold	3RWW
Loc33	Richland TWP	3RWW
KAGC	Pittsburgh Allegheny Cty	NWS - ASOS
KPIT	Greater Pittsburgh Int'l	NWS - ASOS
03049500	Allegheny River at Natrona	USGS
03085734	Ohio River at Emsworth Dam Lower Pool at Emsworth	USGS

The 37 rain gauges and the two NWS NEXRAD radars are used to produce gauge-adjusted radar rainfall (GARR). The methodology used in production of the GARR and the dataset metadata are described in the following sections.

## Methodology

Radar and rain gauge data are segmented into qualified storm event periods and then Quality Controlled (QC). Qualified rainfall events are defined based on the storm event definition where, for any given hour, at least 50% of all working 3RWW gauges have an accumulation of 0.05 inches. Only qualified rainfall events are included in the report, while the RainVieux online database contains continuous data. Both the qualified and inter-event periods receive QC to remove anomalous radar data and inconsistent rain gauges.

Statistical control of the data makes radar rainfall measurements more accurate. By statistical comparison between the radar and rain gauge accumulations during a GARR period, certain gauges may be identified as statistical outliers and excluded for all or part of an event. Radar data

is enhanced by correcting it for systematic errors called bias, which helps improve the accuracy of the rainfall product. The bias correction factors are multiplicative factors applied to the radar that enhances the accuracy of the radar rainfall for any accumulation period. By adjusting the radar data with rain gauge data, better maps of rainfall are produced than either sensor system could produce alone.

In the production of GARR, radar rainfall is bias corrected through comparison with rain gauge accumulations. To the extent possible, individual gauges are combined to cover the target area for use in bias adjustment. The method of adjustment depends on the hydrologic application and the spatial extent of the area of interest. The local bias (LB) approach to adjusting the radar rainfall uses the ratio of gauge to radar accumulations from surrounding gauges with the closest gauge having the most weight. The LB approach distributes the variation of bias over the region, and is computed and applied within each event period.

The LB uses the ratio between the sum of each gauge divided by the sum of the sampled radar values over each gauge. Gauge and radar accumulations were computed for each event period. A minimum storm total threshold (MSTT) check was used to remove radar/gauge (RG) pairs whose R or G cumulative values for a given event period were below a chosen threshold (i.e. 0.05 inches for this study). The remaining RG pairs were then checked for statistical outliers. Those RG pairs with individual bias ( $G/R$ ) or average difference ( $((G-R)/G)$ ) values greater than three standard deviations from the mean were then excluded from being used to adjust the radar.

After RG pairs have been removed on an event basis by either the MSTT, outlier check or gauge performance review, there must be at least two remaining RG pairs to proceed with gauge-adjustment of the radar. The individual biases of the remaining RG pairs are then distributed spatially over the analysis area using the LB weighted distance method. The resulting LB value over each radar bin is the multiplicative factor that adjusts the radar. For example, a bias of 1.5 can be interpreted as a 33% underestimation by the radar. The statistical measures reported are 1) average difference (AD) and 2) calibrated average difference (CAD). Both of these statistical measures are expressed as an absolute percentage about the mean of  $G/R$  accumulations for each event period. GARR is then spatially aggregated from the final adjusted radar bins to the basins and 1-km<sup>2</sup> pixels using an area-averaged technique.

After bias correction, though generally small, differences between rain gauge and radar rainfall accumulations still exist due to sampling differences or local meteorological conditions among other reasons. A major reason for departures is that radar collects data by averaging reflectivity over a 1-degree by 1-km sample volume, while rain gauges measure at a point. Another source of difference is that radar measures above the ground, while rain gauges measure close to the ground. Further, updrafts and downdrafts during storms can decrease or increase rain rates, respectively. However, radar cannot detect local wind effects, while rain gauges can be affected. Differences between the radar data and the rain gauge data are also affected by precipitation processes associated with the type of storm, which also are affected by the season of the year.

## Metadata

Data accompanying this document provides a continuous rainfall record of all 2313 1-km pixels, 440 RFM basins and 871 RFM sheds in 15-minute intervals. The data are provided in CSV format for the period from 2020-08-01 00:00 EDT to 2020-09-01 00:00 EDT. Shapefiles of the 1-km pixels, RFM basins and RFM sheds are located in the Shapefiles subfolder.

### 1-km<sup>2</sup> Pixel CSV metadata:

- Individual CSV files are provided for each pixel.
- The pixel filenames use a "Ryymm\_" (i.e. R, year, month) prefix in front of the pixel ID.
- The comma-delimited text files contain a header row in the 1st row and time/data values beginning on the 2nd row.
- The time/data columns consist of Month, Day, Year, Hour, Minute, Rainfall and Source, where R represents EOM GARR quality.
- Time stamps are in EST/EDT.
- Data values represent 15-min accumulation (inches) at end of interval.
- The 1-km Pixel ID field that was used from the shapefile DBF is "PIXEL".

### Basin CSV metadata:

- Individual CSV files are provided for each RFM Basin and RFM Shed.
- The RFM Basin filenames use a "P-" prefix and a "yyyymmG" (i.e. year, month, G) suffix in front and after the RFM Basin ID.
- The RFM Shed filenames use a "P-" prefix and a "yyyymmN" (i.e. year, month, N) suffix in front and after the RFM Shed ID.
- The comma-delimited text files contain a header row in the 1st row and time/data values beginning on the 2nd row.
- The 1st column contains the date (yyyy/mm/dd hh:mm) and the 2nd column contains the corresponding rainfall value.
- Time stamps are in EST/EDT.
- Data values represent 15-min accumulation (inches) at end of interval.
- The RFM Basin ID field that was used from the shapefile DBF is "DS\_METERNA".
- The RFM Shed ID field that was used from the shapefile DBF is "DELINID".

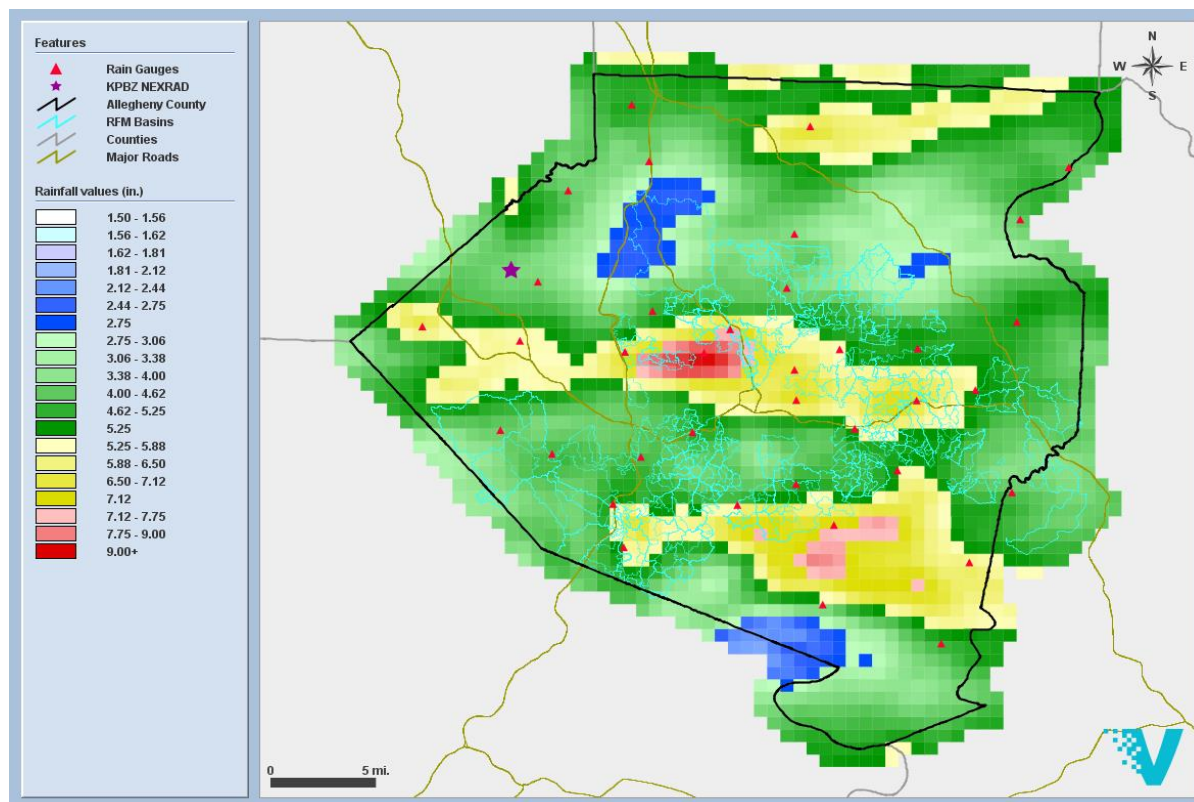
### Shapefile metadata:

- NAD 1983, State Plane Pennsylvania South (feet).



## Gauge-Adjusted Radar Rainfall (GARR)

Rainfall totals for August 2020 are shown in Figure 2. The rainfall amounts for the 2313 1-km<sup>2</sup> pixels range from 2.0 to 9.0 inches with a mean of 4.6 inches. The rainfall amounts for the 440 RFM basins range from 2.8 to 9.0 inches with a mean of 4.9 inches. The rainfall amounts for the 871 RFM sheds range from 2.8 to 9.1 inches with a mean of 5.1 inches.



**Figure 2. GARR Storm Total for August 2020**

GARR was processed continuously at five-minute increments and covers the period from 2020-08-01 00:00 EDT to 2020-09-01 00:00 EDT. Five rainfall events were identified as having met the storm definition during August 2020. The GARR statistics for each event are listed in Table 2. Five of the events were split into multiple sub-event periods to improve gauge-adjustment of the radar, resulting in a total of twenty-four event and sub-event periods. The events that were split into multiple periods are shown in the **Event#** column with the letter "a", "b", "c", etc. appended to the event number (e.g., E1a, E1b, E1c). The **Source** column shows what rainfall source was used to produce GARR for each event or sub-event period. The listed **Event Date** shown in Table 2 corresponds to the day or portion of the day when most of the rainfall occurred for that GARR event period. All five rainfall events are discussed in more detail in the following Events section.

The **Bias** value shown in Table 2 is the sum of the gauges divided by the sum of the sampled radar values over the gauges. Those rain events with the lowest CAD values shown in Table 2 represent the best agreement between GARR and gauge values for all radar/gauge pairs used to adjust the radar. On average, lower values of CAD imply higher statistical confidence in the reliability of the

dataset. Typically, stratiform rainfall events (i.e., low spatial variability) have lower CAD values than convective rainfall events (i.e., high spatial variability). Based on all twenty-four event and sub-event periods, the event CAD averaged 2.1%, indicating that the mean GARR agrees with the mean gauge accumulation to within  $\pm 1.0\%$ .

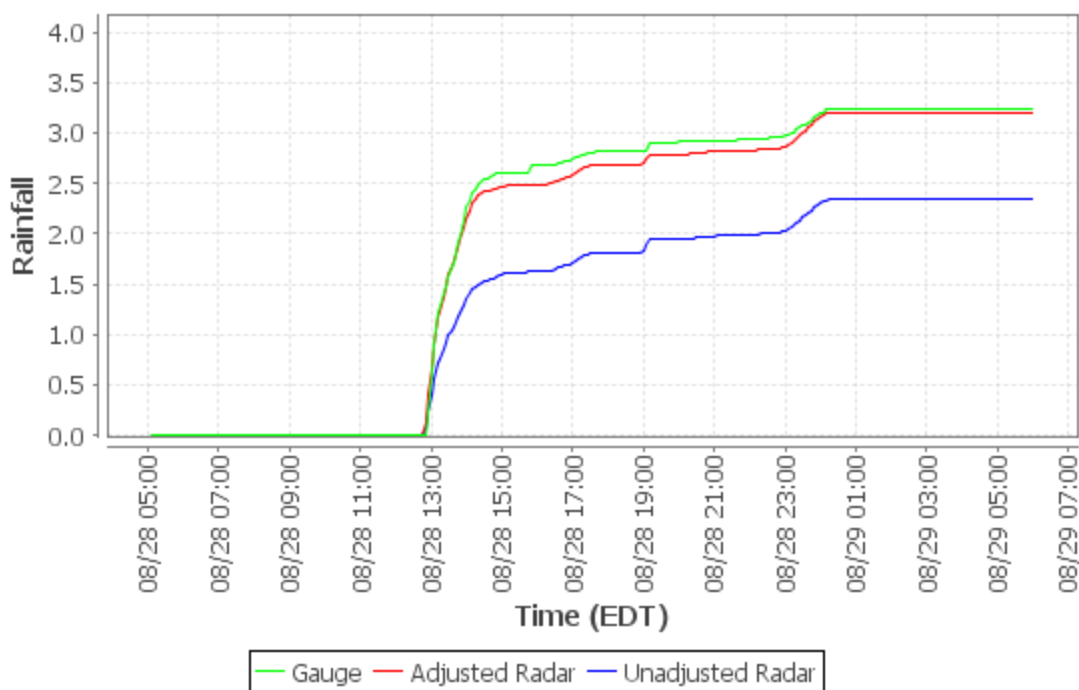
**Table 2. Storm Events and GARR Statistics**

Event #	Source	Event Date	Start Time (EDT)	End Time (EDT)	Gauges Used (37)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
<a href="#">E1a</a>	KPBZ LII	2020-08-01	2020-08-01 06:05	2020-08-01 12:00	2	0.012	0.859	14.1	0.0
<a href="#">E1b</a>	KPBZ LII	2020-08-01	2020-08-01 12:05	2020-08-01 16:00	21	0.150	0.931	27.7	2.8
<a href="#">E1c</a>	KPBZ LII	2020-08-01	2020-08-01 16:05	2020-08-01 18:00	5	0.049	1.251	30.3	0.7
<a href="#">E1d</a>	KPBZ LII	2020-08-01	2020-08-01 18:05	2020-08-01 22:00	16	0.301	0.990	20.1	1.7
<a href="#">E1e</a>	KPBZ LII	2020-08-01	2020-08-01 22:05	2020-08-02 06:00	27	0.275	1.012	15.0	2.3
<a href="#">E2a</a>	KPBZ LII	2020-08-04	2020-08-04 06:05	2020-08-04 18:00	18	0.172	1.069	23.1	1.5
<a href="#">E2b</a>	KPBZ LII	2020-08-04	2020-08-04 18:05	2020-08-04 21:00	22	0.093	0.636	59.0	5.1
<a href="#">E2c</a>	KPBZ LII	2020-08-04	2020-08-04 21:05	2020-08-05 03:00	2	0.011	1.449	29.3	0.7
<a href="#">E3a</a>	KPBZ LII	2020-08-25	2020-08-25 12:05	2020-08-25 15:45	4	0.035	0.669	54.0	0.2
<a href="#">E3b</a>	KPBZ LII	2020-08-25	2020-08-25 15:50	2020-08-25 16:00	2	0.024	0.815	22.1	0.0
<a href="#">E3c</a>	KPBZ LII	2020-08-25	2020-08-25 16:05	2020-08-25 21:00	20	0.099	0.524	96.4	4.5
<a href="#">E4a</a>	KPBZ LII	2020-08-27	2020-08-27 08:05	2020-08-27 13:00	14	0.084	1.114	23.2	1.3
<a href="#">E4b</a>	KPBZ LII	2020-08-27	2020-08-27 13:05	2020-08-27 16:00	12	0.055	0.969	19.5	5.6
<a href="#">E4c</a>	KPBZ LII	2020-08-27	2020-08-27 16:05	2020-08-27 22:00	15	0.494	1.077	22.4	1.9
<a href="#">E4d</a>	KPBZ LII	2020-08-27	2020-08-27 22:05	2020-08-28 05:00	4	0.108	0.888	19.4	1.1
<a href="#">E5a</a>	KPBZ LII	2020-08-28	2020-08-28 05:05	2020-08-28 12:30	7	0.187	1.106	31.5	2.3
<a href="#">E5b</a>	KPBZ LII	2020-08-28	2020-08-28 12:35	2020-08-28 13:15	19	0.298	1.338	23.9	3.1

Event #	Source	Event Date	Start Time (EDT)	End Time (EDT)	Gauges Used (37)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
<a href="#">E5c</a>	KPBZ LII	2020-08-28	2020-08-28 13:20	2020-08-28 14:30	24	0.307	1.445	27.3	3.4
<a href="#">E5d</a>	KPBZ LII	2020-08-28	2020-08-28 14:35	2020-08-28 15:30	17	0.100	0.896	32.4	1.9
<a href="#">E5e</a>	KPBZ LII	2020-08-28	2020-08-28 15:35	2020-08-28 18:30	20	0.258	1.109	14.8	1.4
<a href="#">E5f</a>	KPBZ LII	2020-08-28	2020-08-28 18:35	2020-08-28 19:45	17	0.048	0.847	22.3	3.7
<a href="#">E5g</a>	KPBZ LII	2020-08-28	2020-08-28 19:50	2020-08-28 21:45	18	0.141	0.904	19.5	1.7
<a href="#">E5h</a>	KPBZ LII	2020-08-28	2020-08-28 21:50	2020-08-28 22:45	12	0.055	0.696	42.6	1.8
<a href="#">E5i</a>	KPBZ LII	2020-08-28	2020-08-28 22:50	2020-08-29 06:00	28	0.389	1.152	12.5	1.0

Statistical review of the data can provide an indication of data quality. Depending on the quality of the radar and gauge data, CAD values for individual events less than 10% are considered excellent, 10 - 20% are considered good, and 20 - 30% are considered fair. However, CAD may not serve as a reliable indicator of data quality when abrupt changes in bias occur within the analysis period, particularly when compensating over- and under-estimation results due to using an assumed Z-R relationship throughout the period while atmospheric conditions merit different Z-R coefficients. The effects from abrupt changes in Z-R are mitigated by splitting the event periods.

Rain gauges were analyzed to identify those that were not consistent with the radar or surrounding gauges. Cumulative Distribution Plots (CDPs) at each gauge location showing gauge, unadjusted radar and GARR values were produced for each rainfall event and are presented in Appendices C - G. CDPs are useful for visualizing rain gauge performance. Figure 3 shows the rainfall accumulation at the Univ of Pittsburgh (Loc09) gauge during the 2020-08-28 event as measured by the gauge (green), unadjusted radar (blue), and gauge-adjusted radar (red). Rain gauges that are not performing consistently with the radar or surrounding gauges have characteristics such as clogs, synchronization or other mechanical/transmission malfunctions that can be visually identified in the CDP graph.



**Figure 3. CDP Showing Rain Gauge Versus Unadjusted Radar Versus GARR**

Reasons for not using gauges in rainfall analysis include clogs, significant under- or over-reporting of rainfall, gauges that stop reporting during rainfall, or a combination of these reasons. A list of possible reasons for not using a gauge based on CDP analysis is shown in Table 3. Those gauges that were excluded from analysis based on gauge performance are shown in [Appendix A](#). Additional gauges were not used to adjust the radar for a given event or sub-event period if they did not meet the statistical criteria outlined in the Methodology section. A list of reasons for not using a gauge based on statistical criteria is shown in Table 4. The gauges listed in [Appendix B](#) did not meet statistical criteria for gauge-adjustment of the radar and were not used to adjust the radar.

**Table 3. Reasons for Gauge Exclusion Based on Performance**

Reason	Explanation
Clog (C)	Gauge appeared to be clogged
Zero (Z)	Gauge did not report any rainfall while radar rainfall estimates reported significant rainfall
Stop (S)	Gauge appeared to stop reporting rainfall while radar rainfall estimates reported significant rainfall
Over (O)	Gauge appeared to significantly over-report rainfall as compared to radar rainfall estimates and surrounding gauges (e.g. anomalously high rainfall values caused by field calibration, data transmission error, or switch malfunctions)
Under (U)	Gauge appeared to significantly under-report as compared to radar rainfall estimates and surrounding Gauges (e.g. half-tipper)
Sync (SY)	Gauge appeared to be reporting out-of-sync with the radar rainfall estimates

Reason	Explanation
Frozen/Melt (F/M)	Gauge not reporting properly due to frozen or melting precipitation
Other (T)	Combination of multiple reasons
No Data (ND)	Gauge reported "no data" for a significant amount of time

**Table 4. Reasons for Gauge Exclusion Based on Statistical Criteria**

Reason	Explanation
Minimum Storm Total Threshold (MSTT)	The radar or gauge cumulative sum during the event or sub-event period was less than MSTT
Outlier Based on Mean Field Bias (OMFB)	The RG pair bias ( $G/R$ ) was greater than three standard deviations from the mean bias (e.g. $G \gg R$ )
Outlier Based on Average Difference (OAD)	The RG pair average difference ( $(G-R)/G$ ) was greater than three standard deviations from the mean average difference (e.g. $G \ll R$ )

A synopsis for each event is described below in terms of the specific processing protocol applied to each event period as well as specific GARR information.

## Events

### Event 1: 2020-08-01

The analysis period was from 2020-08-01 06:00 EDT to 2020-08-02 06:00 EDT. The event was then split into five sub-event periods at 2020-08-01 12:00 EDT, 2020-08-01 16:00 EDT, 2020-08-01 18:00 EDT and 2020-08-01 22:00 EDT to improve gauge adjustment of the radar.

The gauges listed in [Appendix A](#) were not used to adjust the radar due to inconsistencies between the gauge and the radar or surrounding gauges, or they did not have data available for this event. The gauges listed in [Appendix B](#) were not used to adjust the radar since they did not meet statistical criteria for gauge-adjustment.

A convective Z-R relationship was used to convert radar reflectivity to rainfall rates. Table 5 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Tables 6 - 10 summarize the results for each RG pair used for final radar adjustment, where  $G_i$  is the gauge estimate,  $R_i$  is the non-adjusted radar estimate,  $R_i^*$  is the GARR estimate, and  $\text{Diff}^*$  (%) is the percent difference between the gauge and GARR estimate. Those gauges not used to adjust the radar are shown at the bottom of the table and are highlighted in red. The specific reason for gauge exclusion is displayed in the Flag column. Figures 4 - 8 show the scatter plots of the gauge-adjusted RG pairs. Those gauges not used to adjust the radar are shown in red. Figure 9 depicts the GARR storm total over the 1-km<sup>2</sup> pixels. The GARR amounts for the 2313 1-km<sup>2</sup> pixels range from 0.1 - 2.1 inches with a mean of 0.8 inches. The GARR amounts for the 440 RFM basins range from 0.2 - 1.7 inches with a mean of 0.8 inches. The GARR amounts for the 871 RFM sheds range from

0.2 - 1.7 inches with a mean of 0.7 inches. Table 11 shows the Depth Duration Frequency (DDF) maximum values for the 1-km<sup>2</sup> pixels.

**Table 5. GARR Statistics for Event 1**

Event #	Radar	Event Date	Start Time (EDT)	End Time (EDT)	Gauges Used (37)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E1a	KPBZ LII	2020-08-01	2020-08-01 06:05	2020-08-01 12:00	2	0.012	0.859	14.1	0.0
E1b	KPBZ LII	2020-08-01	2020-08-01 12:05	2020-08-01 16:00	21	0.150	0.931	27.7	2.8
E1c	KPBZ LII	2020-08-01	2020-08-01 16:05	2020-08-01 18:00	5	0.049	1.251	30.3	0.7
E1d	KPBZ LII	2020-08-01	2020-08-01 18:05	2020-08-01 22:00	16	0.301	0.990	20.1	1.7
E1e	KPBZ LII	2020-08-01	2020-08-01 22:05	2020-08-02 06:00	27	0.275	1.012	15.0	2.3

**Table 6. Summary of Individual RG Pairs for Event 1a**

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc21</a>	Moon TWP	0.05	0.05	0.05	0.00	0.0	
<a href="#">Loc27</a>	Marshall TWP	0.07	0.09	0.07	0.00	0.0	
<a href="#">03049500</a>	Allegheny River at Natrona	0.00	---	---	---	---	MSTT
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.00	---	---	---	---	MSTT
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.00	---	---	---	---	ND
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.02	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	0.00	---	---	---	---	MSTT
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.00	---	---	---	---	MSTT
<a href="#">Loc03</a>	Shaler Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc04</a>	Kennedy Twp PS	0.02	---	---	---	---	MSTT
<a href="#">Loc05</a>	Upper St. Clair	0.00	---	---	---	---	MSTT
<a href="#">Loc06</a>	Carnegie Transit Time	0.00	---	---	---	---	MSTT
<a href="#">Loc07</a>	Greentree Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc08</a>	AC Health Dept Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc09</a>	Univ of Pittsburgh	0.00	---	---	---	---	MSTT
<a href="#">Loc10</a>	PWSA-Highland Park	ND	---	---	---	---	ND
<a href="#">Loc11</a>	M-46 Access Shaft	0.00	---	---	---	---	MSTT
<a href="#">Loc12</a>	Baldwin	0.00	---	---	---	---	MSTT

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc13</a>	M-59 Access Shaft	0.00	---	---	---	---	MSTT
<a href="#">Loc14</a>	Churchill Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc15</a>	Trafford Maint Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc16</a>	Castle Shannon	0.00	---	---	---	---	MSTT
<a href="#">Loc17</a>	Chartiers Pump Station	ND	---	---	---	---	ND
<a href="#">Loc18</a>	Oakdale Pump Station	0.01	---	---	---	---	MSTT
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc20</a>	Gascola Eq Facility	0.00	---	---	---	---	MSTT
<a href="#">Loc22</a>	North Fayette TWP	0.02	---	---	---	---	MSTT
<a href="#">Loc23</a>	Clinton Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc24</a>	Jefferson Hills	0.00	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc28</a>	Plum Municipal Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.18	---	---	---	---	C
<a href="#">Loc30</a>	McCandless Twn Hall	0.02	---	---	---	---	MSTT
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc32</a>	Arnold	0.00	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	0.00	---	---	---	---	MSTT

**Table 7. Summary of Individual RG Pairs for Event 1b**

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc09</a>	Univ of Pittsburgh	0.07	0.08	0.08	-0.01	-14.3	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.09	0.15	0.10	-0.01	-11.1	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.34	0.46	0.36	-0.02	-5.9	
<a href="#">Loc04</a>	Kennedy Twp PS	0.54	0.63	0.57	-0.03	-5.6	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.41	0.38	0.41	0.00	0.0	
<a href="#">Loc05</a>	Upper St. Clair	0.14	0.11	0.14	0.00	0.0	
<a href="#">Loc06</a>	Carnegie Transit Time	0.33	0.28	0.33	0.00	0.0	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.20	0.17	0.20	0.00	0.0	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.05	0.09	0.05	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.08	0.06	0.08	0.00	0.0	
<a href="#">Loc21</a>	Moon TWP	0.10	0.10	0.10	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.26	0.35	0.26	0.00	0.0	



Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc23</a>	Clinton Munic Bldg	0.48	0.47	0.48	0.00	0.0	
<a href="#">Loc27</a>	Marshall TWP	0.08	0.12	0.08	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.05	0.10	0.05	0.00	0.0	
<a href="#">Loc30</a>	McCandless Twn Hall	0.17	0.22	0.17	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.05	0.07	0.05	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.20	0.21	0.20	0.00	0.0	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.87	0.85	0.85	0.02	2.3	
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.65	0.68	0.63	0.02	3.1	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.11	0.09	0.10	0.01	9.1	
<a href="#">03049500</a>	Allegheny River at Natrona	0.00	---	---	---	---	Z
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.03	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	0.26	---	---	---	---	U
<a href="#">Loc10</a>	PWSA-Highland Park	ND	---	---	---	---	ND
<a href="#">Loc11</a>	M-46 Access Shaft	0.04	---	---	---	---	MSTT
<a href="#">Loc12</a>	Baldwin	0.03	---	---	---	---	MSTT
<a href="#">Loc13</a>	M-59 Access Shaft	0.02	---	---	---	---	MSTT
<a href="#">Loc15</a>	Trafford Maint Bldg	0.02	---	---	---	---	MSTT
<a href="#">Loc17</a>	Chartiers Pump Station	ND	---	---	---	---	ND
<a href="#">Loc18</a>	Oakdale Pump Station	0.49	---	---	---	---	O
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc20</a>	Gascola Eq Facility	0.03	---	---	---	---	MSTT
<a href="#">Loc24</a>	Jefferson Hills	0.01	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.01	---	---	---	---	MSTT
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.01	---	---	---	---	MSTT
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.52	---	---	---	---	C

**Table 8. Summary of Individual RG Pairs for Event 1c**

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc21</a>	Moon TWP	0.30	0.20	0.30	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.30	0.26	0.30	0.00	0.0	
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.29	0.34	0.29	0.00	0.0	
<a href="#">Loc27</a>	Marshall TWP	0.22	0.12	0.22	0.00	0.0	
<a href="#">Loc30</a>	McCandless Twn Hall	0.16	0.10	0.16	0.00	0.0	



<b>Gauge ID</b>	<b>Name</b>	<b>G<sub>i</sub> (in)</b>	<b>R<sub>i</sub> (in)</b>	<b>R<sub>i</sub>* (in)</b>	<b>Diff* (in)</b>	<b>Diff* (%)</b>	<b>Flag</b>
<a href="#">03049500</a>	Allegheny River at Natrona	0.00	---	---	---	---	MSTT
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.01	---	---	---	---	MSTT
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.00	---	---	---	---	MSTT
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.04	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	0.00	---	---	---	---	MSTT
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.00	---	---	---	---	MSTT
<a href="#">Loc03</a>	Shaler Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc04</a>	Kennedy Twp PS	0.00	---	---	---	---	MSTT
<a href="#">Loc05</a>	Upper St. Clair	0.00	---	---	---	---	MSTT
<a href="#">Loc06</a>	Carnegie Transit Time	0.00	---	---	---	---	MSTT
<a href="#">Loc07</a>	Greentree Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc08</a>	AC Health Dept Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc09</a>	Univ of Pittsburgh	0.00	---	---	---	---	MSTT
<a href="#">Loc10</a>	PWSA-Highland Park	ND	---	---	---	---	ND
<a href="#">Loc11</a>	M-46 Access Shaft	0.01	---	---	---	---	MSTT
<a href="#">Loc12</a>	Baldwin	0.00	---	---	---	---	MSTT
<a href="#">Loc13</a>	M-59 Access Shaft	0.00	---	---	---	---	MSTT
<a href="#">Loc14</a>	Churchill Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc15</a>	Trafford Maint Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc16</a>	Castle Shannon	0.00	---	---	---	---	MSTT
<a href="#">Loc17</a>	Chartiers Pump Station	ND	---	---	---	---	ND
<a href="#">Loc18</a>	Oakdale Pump Station	0.00	---	---	---	---	MSTT
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc20</a>	Gascola Eq Facility	0.00	---	---	---	---	MSTT
<a href="#">Loc22</a>	North Fayette TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc24</a>	Jefferson Hills	0.00	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc28</a>	Plum Municipal Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.38	---	---	---	---	C
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc32</a>	Arnold	0.00	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	0.05	---	---	---	---	MSTT

**Table 9. Summary of Individual RG Pairs for Event 1d**

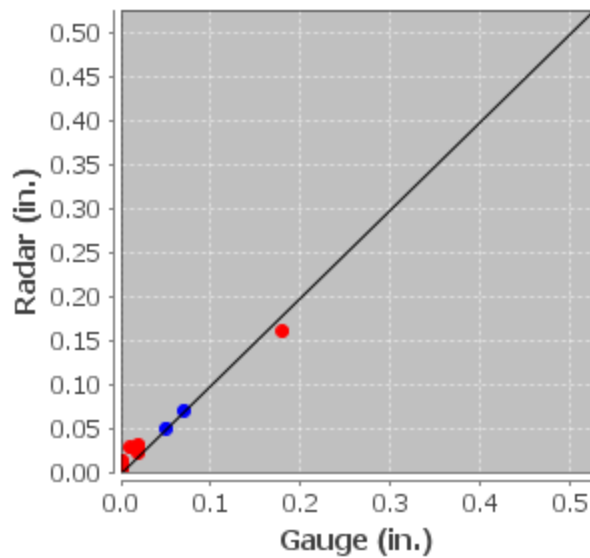
<b>Gauge ID</b>	<b>Name</b>	<b>G<sub>i</sub> (in)</b>	<b>R<sub>i</sub> (in)</b>	<b>R<sub>i</sub>* (in)</b>	<b>Diff* (in)</b>	<b>Diff* (%)</b>	<b>Flag</b>
<a href="#">Loc30</a>	McCandless Twn Hall	0.18	0.29	0.19	-0.01	-5.6	
<a href="#">Loc21</a>	Moon TWP	0.48	0.48	0.50	-0.02	-4.2	
<a href="#">Loc14</a>	Churchill Munic Bldg	1.17	1.30	1.21	-0.04	-3.4	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.42	0.71	0.43	-0.01	-2.4	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	1.14	1.05	1.14	0.00	0.0	
<a href="#">Loc05</a>	Upper St. Clair	0.07	0.05	0.07	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.48	0.43	0.48	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.05	0.05	0.05	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.23	0.30	0.23	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.91	0.81	0.91	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.09	0.11	0.09	0.00	0.0	
<a href="#">Loc11</a>	M-46 Access Shaft	1.23	1.13	1.22	0.01	0.8	
<a href="#">Loc13</a>	M-59 Access Shaft	1.39	1.25	1.37	0.02	1.4	
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.63	0.67	0.62	0.01	1.6	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.46	0.33	0.44	0.02	4.3	
<a href="#">Loc27</a>	Marshall TWP	0.44	0.50	0.42	0.02	4.5	
<a href="#">03049500</a>	Allegheny River at Natrona	0.05	---	---	---	---	U
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.02	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	0.04	---	---	---	---	MSTT
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.04	---	---	---	---	MSTT
<a href="#">Loc03</a>	Shaler Munic Bldg	0.04	---	---	---	---	MSTT
<a href="#">Loc04</a>	Kennedy Twp PS	0.04	---	---	---	---	MSTT
<a href="#">Loc06</a>	Carnegie Transit Time	0.03	---	---	---	---	MSTT
<a href="#">Loc07</a>	Greentree Munic Bldg	0.03	---	---	---	---	MSTT
<a href="#">Loc08</a>	AC Health Dept Bldg	0.03	---	---	---	---	MSTT
<a href="#">Loc09</a>	Univ of Pittsburgh	0.03	---	---	---	---	MSTT
<a href="#">Loc10</a>	PWSA-Highland Park	ND	---	---	---	---	ND
<a href="#">Loc12</a>	Baldwin	0.75	---	---	---	---	U
<a href="#">Loc17</a>	Chartiers Pump Station	ND	---	---	---	---	ND
<a href="#">Loc18</a>	Oakdale Pump Station	0.04	---	---	---	---	MSTT
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc20</a>	Gascola Eq Facility	0.94	---	---	---	---	U
<a href="#">Loc24</a>	Jefferson Hills	0.10	---	---	---	---	OAD
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.30	---	---	---	---	C
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.62	---	---	---	---	C

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.04	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	0.03	---	---	---	---	MSTT

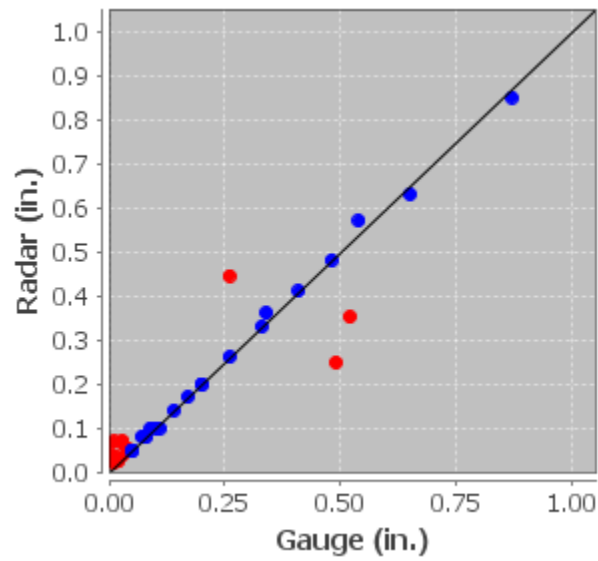
**Table 10. Summary of Individual RG Pairs for Event 1e**

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc09</a>	Univ of Pittsburgh	0.10	0.14	0.11	-0.01	-10.0	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.35	0.43	0.38	-0.03	-8.6	
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.28	0.29	0.29	-0.01	-3.6	
<a href="#">Loc30</a>	McCandless Twn Hall	0.32	0.37	0.33	-0.01	-3.1	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.07	0.07	0.07	0.00	0.0	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.42	0.41	0.42	0.00	0.0	
<a href="#">Loc06</a>	Carnegie Transit Time	0.44	0.40	0.44	0.00	0.0	
<a href="#">Loc11</a>	M-46 Access Shaft	0.07	0.08	0.07	0.00	0.0	
<a href="#">Loc12</a>	Baldwin	0.06	0.07	0.06	0.00	0.0	
<a href="#">Loc13</a>	M-59 Access Shaft	0.05	0.07	0.05	0.00	0.0	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.05	0.06	0.05	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.34	0.28	0.34	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.11	0.14	0.11	0.00	0.0	
<a href="#">Loc18</a>	Oakdale Pump Station	0.36	0.39	0.36	0.00	0.0	
<a href="#">Loc20</a>	Gascola Eq Facility	0.05	0.05	0.05	0.00	0.0	
<a href="#">Loc21</a>	Moon TWP	0.43	0.40	0.43	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.35	0.40	0.35	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.38	0.35	0.38	0.00	0.0	
<a href="#">Loc24</a>	Jefferson Hills	0.15	0.11	0.15	0.00	0.0	
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.49	0.36	0.49	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.39	0.46	0.39	0.00	0.0	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.49	0.44	0.48	0.01	2.0	
<a href="#">Loc27</a>	Marshall TWP	0.43	0.41	0.42	0.01	2.3	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.34	0.29	0.33	0.01	2.9	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.29	0.27	0.28	0.01	3.4	
<a href="#">Loc04</a>	Kennedy Twp PS	0.40	0.37	0.38	0.02	5.0	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.16	0.19	0.15	0.01	6.3	
<a href="#">03049500</a>	Allegheny River at Natrona	0.01	---	---	---	---	MSTT

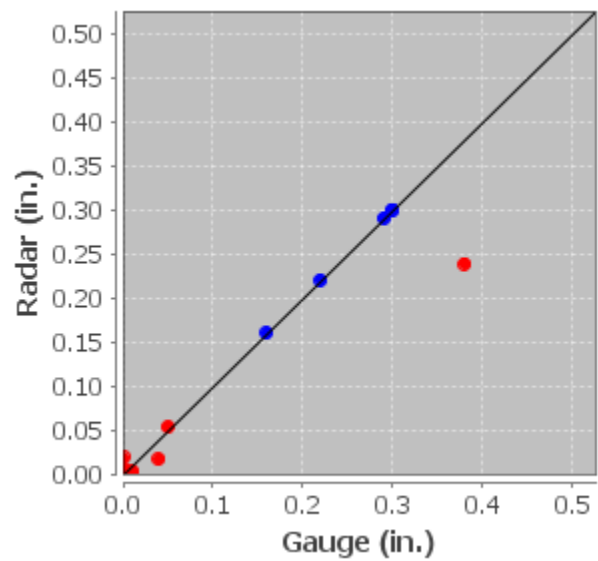
Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc01</a>	PWSA-Montana St.	0.35	---	---	---	---	U
<a href="#">Loc05</a>	Upper St. Clair	0.24	---	---	---	---	U
<a href="#">Loc10</a>	PWSA-Highland Park	ND	---	---	---	---	ND
<a href="#">Loc17</a>	Chartiers Pump Station	ND	---	---	---	---	ND
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.40	---	---	---	---	C
<a href="#">Loc28</a>	Plum Municipal Bldg	0.06	---	---	---	---	MSTT
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.63	---	---	---	---	C
<a href="#">Loc32</a>	Arnold	0.02	---	---	---	---	MSTT



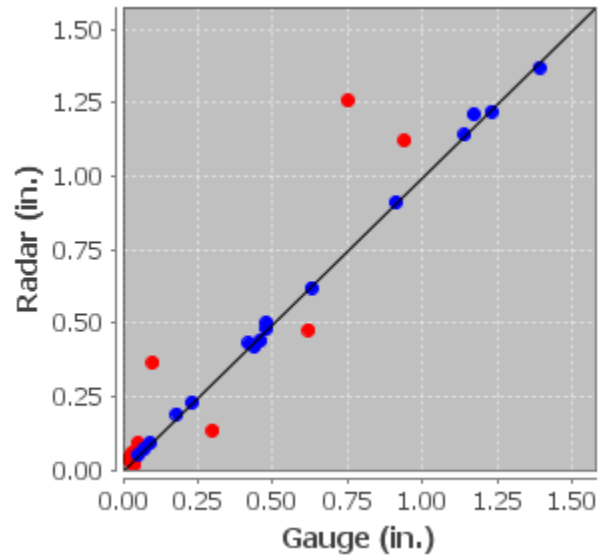
**Figure 4. Scatter Plot of RG Pairs for Event 1a**



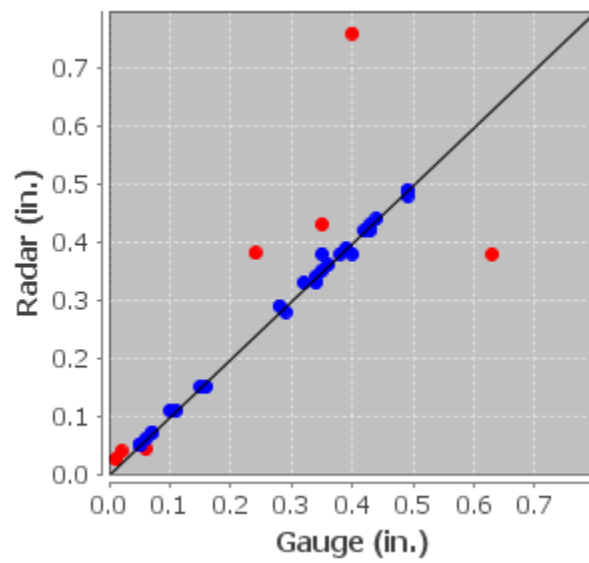
**Figure 5. Scatter Plot of RG Pairs for Event 1b**



**Figure 6. Scatter Plot of RG Pairs for Event 1c**



**Figure 7. Scatter Plot of RG Pairs for Event 1d**



**Figure 8. Scatter Plot of RG Pairs for Event 1e**



The gauges listed in [Appendix B](#) were not used to adjust the radar since they did not meet statistical criteria for gauge-adjustment.

A convective Z-R relationship was used to convert radar reflectivity to rainfall rates. Table 12 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Tables 13 - 15 summarize the results for each RG pair used for final radar adjustment, where  $G_i$  is the gauge estimate,  $R_i$  is the non-adjusted radar estimate,  $R_i^*$  is the GARR estimate, and  $\text{Diff}^*$  (%) is the percent difference between the gauge and GARR estimate. Those gauges not used to adjust the radar are shown at the bottom of the table and are highlighted in red. The specific reason for gauge exclusion is displayed in the Flag column. Figures 10 - 12 show the scatter plots of the gauge-adjusted RG pairs. Those gauges not used to adjust the radar are shown in red. Figure 13 depicts the GARR storm total over the 1-km<sup>2</sup> pixels. The GARR amounts for the 2313 1-km<sup>2</sup> pixels range from 0.0 - 1.4 inches with a mean of 0.3 inches. The GARR amounts for the 440 RFM basins range from 0.1 - 1.0 inches with a mean of 0.3 inches. The GARR amounts for the 871 RFM sheds range from 0.1 - 1.0 inches with a mean of 0.4 inches. Table 16 shows the Depth Duration Frequency (DDF) maximum values for the 1-km<sup>2</sup> pixels.

**Table 12. GARR Statistics for Event 2**

Event #	Radar	Event Date	Start Time (EDT)	End Time (EDT)	Gauges Used (37)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E2a	KPBZ LII	2020-08-04	2020-08-04 06:05	2020-08-04 18:00	18	0.172	1.069	23.1	1.5
E2b	KPBZ LII	2020-08-04	2020-08-04 18:05	2020-08-04 21:00	22	0.093	0.636	59.0	5.1
E2c	KPBZ LII	2020-08-04	2020-08-04 21:05	2020-08-05 03:00	2	0.011	1.449	29.3	0.7

**Table 13. Summary of Individual RG Pairs for Event 2a**

Gauge ID	Name	$G_i$ (in)	$R_i$ (in)	$R_i^*$ (in)	$\text{Diff}^*$ (in)	$\text{Diff}^*$ (%)	Flag
<a href="#">Loc04</a>	Kennedy Twp PS	0.32	0.45	0.33	-0.01	-3.1	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.67	0.68	0.69	-0.02	-3.0	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.38	0.41	0.39	-0.01	-2.6	
<a href="#">Loc20</a>	Gascola Eq Facility	0.40	0.45	0.41	-0.01	-2.5	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.10	0.14	0.10	0.00	0.0	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.09	0.06	0.09	0.00	0.0	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.12	0.12	0.12	0.00	0.0	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.17	0.11	0.17	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.26	0.20	0.26	0.00	0.0	
<a href="#">Loc18</a>	Oakdale Pump Station	0.12	0.07	0.12	0.00	0.0	



Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc21</a>	Moon TWP	0.06	0.06	0.06	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.17	0.19	0.17	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.17	0.14	0.17	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.06	0.09	0.06	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.05	0.06	0.05	0.00	0.0	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.69	0.64	0.67	0.02	2.9	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.60	0.56	0.58	0.02	3.3	
<a href="#">Loc22</a>	North Fayette TWP	0.57	0.27	0.55	0.02	3.5	
<a href="#">03049500</a>	Allegheny River at Natrona	0.00	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	0.30	---	---	---	---	U
<a href="#">Loc05</a>	Upper St. Clair	0.01	---	---	---	---	MSTT
<a href="#">Loc06</a>	Carnegie Transit Time	0.01	---	---	---	---	MSTT
<a href="#">Loc10</a>	PWSA-Highland Park	ND	---	---	---	---	ND
<a href="#">Loc11</a>	M-46 Access Shaft	0.02	---	---	---	---	MSTT
<a href="#">Loc12</a>	Baldwin	0.00	---	---	---	---	MSTT
<a href="#">Loc13</a>	M-59 Access Shaft	0.06	---	---	---	---	OAD
<a href="#">Loc14</a>	Churchill Munic Bldg	0.29	---	---	---	---	C
<a href="#">Loc16</a>	Castle Shannon	0.00	---	---	---	---	MSTT
<a href="#">Loc17</a>	Chartiers Pump Station	ND	---	---	---	---	ND
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc24</a>	Jefferson Hills	0.01	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.04	---	---	---	---	MSTT
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.03	---	---	---	---	C
<a href="#">Loc27</a>	Marshall TWP	0.03	---	---	---	---	MSTT
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.02	---	---	---	---	C
<a href="#">Loc30</a>	McCandless Twn Hall	0.01	---	---	---	---	MSTT
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.04	---	---	---	---	MSTT

**Table 14. Summary of Individual RG Pairs for Event 2b**

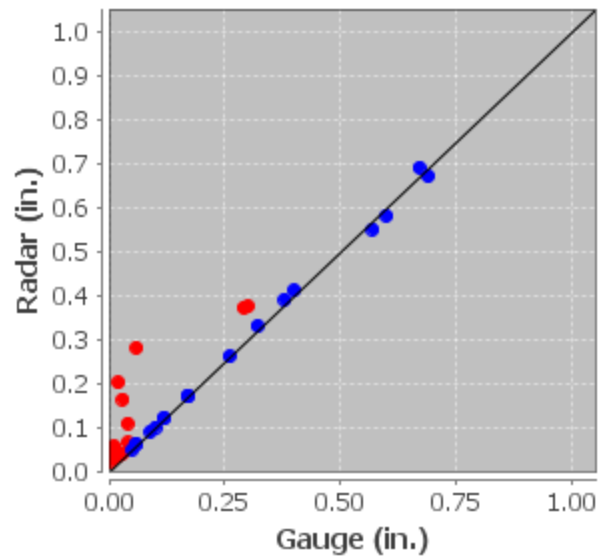
Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc08</a>	AC Health Dept Bldg	0.05	0.11	0.06	-0.01	-20.0	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.07	0.15	0.08	-0.01	-14.3	
<a href="#">Loc04</a>	Kennedy Twp PS	0.11	0.25	0.12	-0.01	-9.1	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.11	0.25	0.12	-0.01	-9.1	

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.22	0.33	0.23	-0.01	-4.5	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.05	0.11	0.05	0.00	0.0	
<a href="#">Loc01</a>	PWSA-Montana St.	0.10	0.11	0.10	0.00	0.0	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.05	0.06	0.05	0.00	0.0	
<a href="#">Loc11</a>	M-46 Access Shaft	0.13	0.19	0.13	0.00	0.0	
<a href="#">Loc13</a>	M-59 Access Shaft	0.06	0.10	0.06	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.15	0.19	0.15	0.00	0.0	
<a href="#">Loc20</a>	Gascola Eq Facility	0.11	0.14	0.11	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.18	0.44	0.18	0.00	0.0	
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.35	0.69	0.35	0.00	0.0	
<a href="#">Loc27</a>	Marshall TWP	0.05	0.07	0.05	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.06	0.08	0.06	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.05	0.07	0.05	0.00	0.0	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.17	0.19	0.16	0.01	5.9	
<a href="#">Loc21</a>	Moon TWP	0.15	0.14	0.14	0.01	6.7	
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.14	0.13	0.13	0.01	7.1	
<a href="#">Loc12</a>	Baldwin	0.17	0.18	0.15	0.02	11.8	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.16	0.24	0.14	0.02	12.5	
<a href="#">03049500</a>	Allegheny River at Natrona	0.01	---	---	---	---	U
<a href="#">Loc05</a>	Upper St. Clair	0.05	---	---	---	---	U
<a href="#">Loc06</a>	Carnegie Transit Time	0.00	---	---	---	---	MSTT
<a href="#">Loc10</a>	PWSA-Highland Park	ND	---	---	---	---	ND
<a href="#">Loc14</a>	Churchill Munic Bldg	0.04	---	---	---	---	C
<a href="#">Loc15</a>	Trafford Maint Bldg	0.05	---	---	---	---	MSTT
<a href="#">Loc17</a>	Chartiers Pump Station	ND	---	---	---	---	ND
<a href="#">Loc18</a>	Oakdale Pump Station	0.00	---	---	---	---	MSTT
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc22</a>	North Fayette TWP	0.01	---	---	---	---	MSTT
<a href="#">Loc24</a>	Jefferson Hills	0.01	---	---	---	---	MSTT
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.02	---	---	---	---	C
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.11	---	---	---	---	C
<a href="#">Loc30</a>	McCandless Twn Hall	0.04	---	---	---	---	MSTT
<a href="#">Loc32</a>	Arnold	0.04	---	---	---	---	MSTT

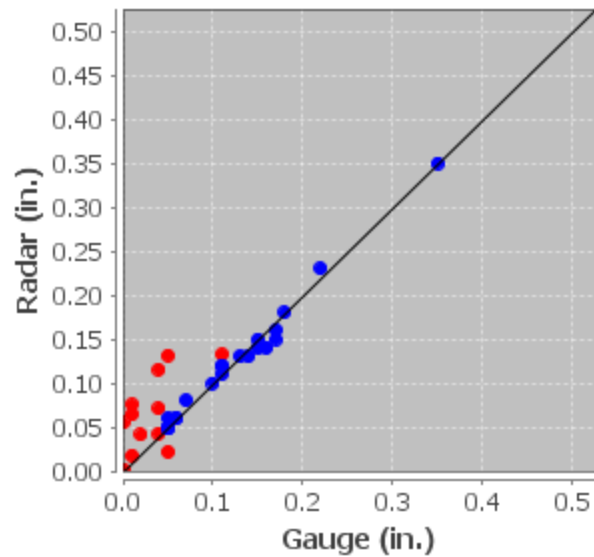
**Table 15. Summary of Individual RG Pairs for Event 2c**

<b>Gauge ID</b>	<b>Name</b>	<b>G<sub>i</sub> (in)</b>	<b>R<sub>i</sub> (in)</b>	<b>R<sub>i</sub>* (in)</b>	<b>Diff* (in)</b>	<b>Diff* (%)</b>	<b>Flag</b>
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.06	0.07	0.06	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.13	0.07	0.13	0.00	0.0	
<a href="#">03049500</a>	Allegheny River at Natrona	0.00	---	---	---	---	MSTT
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.02	---	---	---	---	MSTT
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.00	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	0.00	---	---	---	---	MSTT
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.01	---	---	---	---	MSTT
<a href="#">Loc03</a>	Shaler Munic Bldg	0.02	---	---	---	---	MSTT
<a href="#">Loc04</a>	Kennedy Twp PS	0.04	---	---	---	---	MSTT
<a href="#">Loc05</a>	Upper St. Clair	0.00	---	---	---	---	MSTT
<a href="#">Loc06</a>	Carnegie Transit Time	0.01	---	---	---	---	MSTT
<a href="#">Loc07</a>	Greentree Munic Bldg	0.01	---	---	---	---	MSTT
<a href="#">Loc08</a>	AC Health Dept Bldg	0.01	---	---	---	---	MSTT
<a href="#">Loc09</a>	Univ of Pittsburgh	0.01	---	---	---	---	MSTT
<a href="#">Loc10</a>	PWSA-Highland Park	ND	---	---	---	---	ND
<a href="#">Loc11</a>	M-46 Access Shaft	0.01	---	---	---	---	MSTT
<a href="#">Loc12</a>	Baldwin	0.00	---	---	---	---	MSTT
<a href="#">Loc13</a>	M-59 Access Shaft	0.00	---	---	---	---	MSTT
<a href="#">Loc14</a>	Churchill Munic Bldg	0.02	---	---	---	---	C
<a href="#">Loc15</a>	Trafford Maint Bldg	0.03	---	---	---	---	MSTT
<a href="#">Loc16</a>	Castle Shannon	0.00	---	---	---	---	MSTT
<a href="#">Loc17</a>	Chartiers Pump Station	ND	---	---	---	---	ND
<a href="#">Loc18</a>	Oakdale Pump Station	0.00	---	---	---	---	MSTT
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc20</a>	Gascola Eq Facility	0.00	---	---	---	---	MSTT
<a href="#">Loc21</a>	Moon TWP	0.01	---	---	---	---	MSTT
<a href="#">Loc22</a>	North Fayette TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc24</a>	Jefferson Hills	0.00	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc27</a>	Marshall TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc28</a>	Plum Municipal Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.01	---	---	---	---	C
<a href="#">Loc30</a>	McCandless Twn Hall	0.00	---	---	---	---	MSTT
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.00	---	---	---	---	MSTT

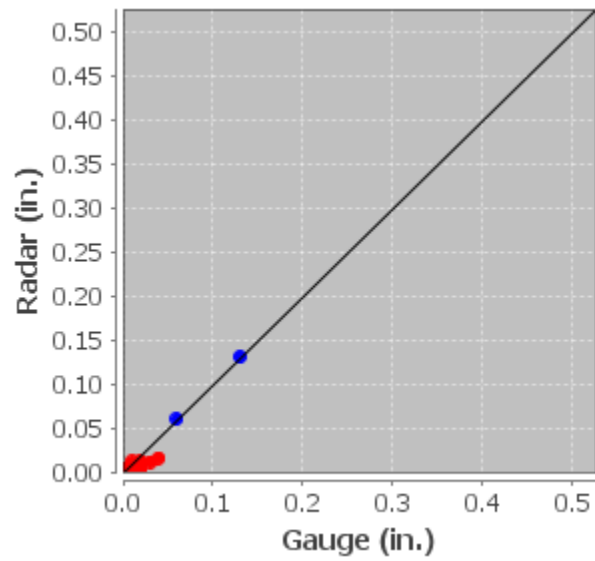
Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc32</a>	Arnold	0.00	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	0.01	---	---	---	---	MSTT



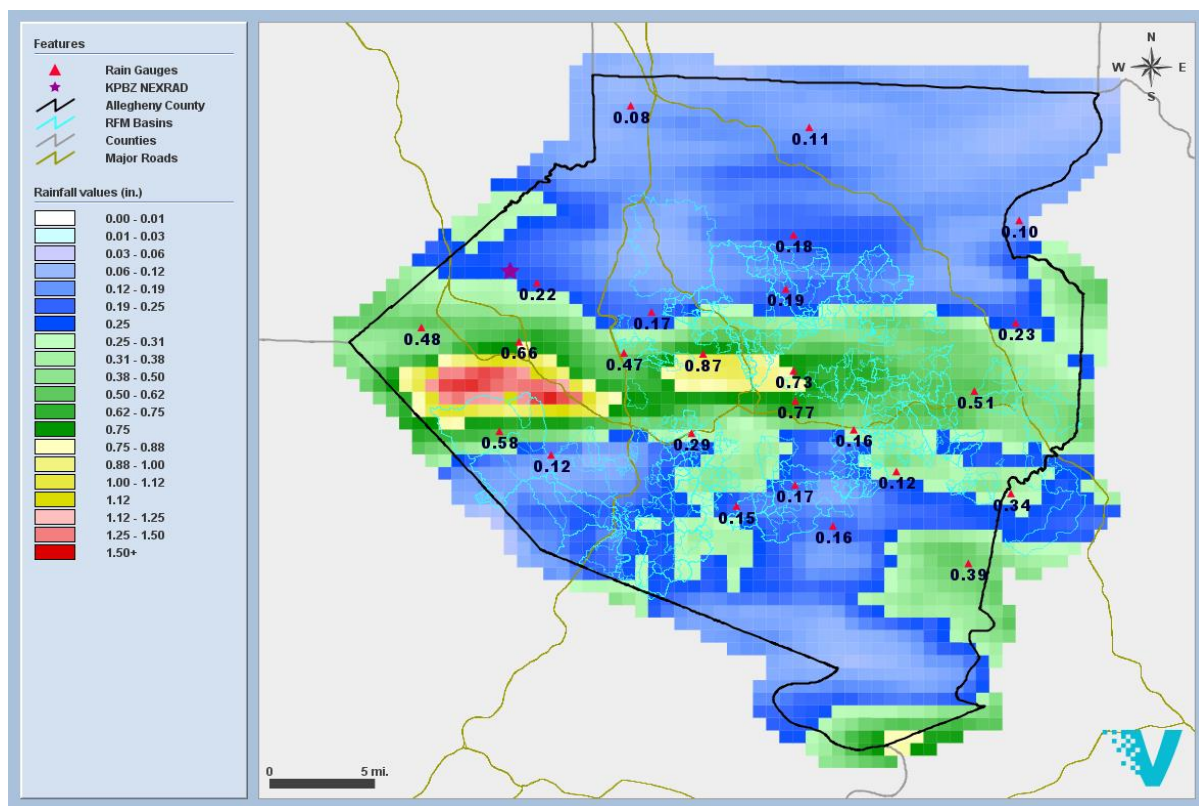
**Figure 10. Scatter Plot of RG Pairs for Event 2a**



**Figure 11. Scatter Plot of RG Pairs for Event 2b**



**Figure 12. Scatter Plot of RG Pairs for Event 2c**



**Figure 13. GARR Storm Total for Event 2**

**Table 16. Depth Duration Frequency Analyses for Event 2**

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	0.817	131138	2020-08-04 15:20	2 yr.
30 minutes	1.100	131138	2020-08-04 15:25	2 yr.
1 hour	1.151	131138	2020-08-04 15:50	1 yr.
2 hour	1.152	131138	2020-08-04 15:55	1 yr.
3 hour	1.152	131138	2020-08-04 15:55	<1 yr.
6 hour	1.442	131138	2020-08-04 19:15	1 yr.
12 hour	1.449	131138	2020-08-04 23:30	<1 yr.

**Event 3: 2020-08-25**

The analysis period was from 2020-08-25 12:00 EDT to 2020-08-25 21:00 EDT. The event was then split into three sub-event periods at 2020-08-25 15:45 EDT and 2020-08-25 16:00 EDT to improve gauge adjustment of the radar.

The gauges listed in [Appendix A](#) were not used to adjust the radar due to inconsistencies between the gauge and the radar or surrounding gauges, or they did not have data available for this event. The gauges listed in [Appendix B](#) were not used to adjust the radar since they did not meet statistical criteria for gauge-adjustment.

A convective Z-R relationship was used to convert radar reflectivity to rainfall rates. Table 17 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Tables 18 - 20 summarize the results for each RG pair used for final radar adjustment, where  $G_i$  is the gauge estimate,  $R_i$  is the non-adjusted radar estimate,  $R_i^*$  is the GARR estimate, and  $\text{Diff}^*$  (%) is the percent difference between the gauge and GARR estimate. Those gauges not used to adjust the radar are shown at the bottom of the table and are highlighted in red. The specific reason for gauge exclusion is displayed in the Flag column. Figures 14 - 16 show the scatter plots of the gauge-adjusted RG pairs. Those gauges not used to adjust the radar are shown in red. Figure 17 depicts the GARR storm total over the 1-km<sup>2</sup> pixels. The GARR amounts for the 2313 1-km<sup>2</sup> pixels range from 0.0 - 0.8 inches with a mean of 0.2 inches. The GARR amounts for the 440 RFM basins range from 0.0 - 0.8 inches with a mean of 0.2 inches. The GARR amounts for the 871 RFM sheds range from 0.0 - 0.8 inches with a mean of 0.2 inches. Table 21 shows the Depth Duration Frequency (DDF) maximum values for the 1-km<sup>2</sup> pixels.

**Table 17. GARR Statistics for Event 3**

Event #	Radar	Event Date	Start Time (EDT)	End Time (EDT)	Gauges Used (37)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E3a	KPBZ LII	2020-08-25	2020-08-25 12:05	2020-08-25 15:45	4	0.035	0.669	54.0	0.2
E3b	KPBZ LII	2020-08-25	2020-08-25 15:50	2020-08-25 16:00	2	0.024	0.815	22.1	0.0

Event #	Radar	Event Date	Start Time (EDT)	End Time (EDT)	Gauges Used (37)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E3c	KPBZ LII	2020-08-25	2020-08-25 16:05	2020-08-25 21:00	20	0.099	0.524	96.4	4.5

**Table 18. Summary of Individual RG Pairs for Event 3a**

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc03</a>	Shaler Munic Bldg	0.28	0.36	0.28	0.00	0.0	
<a href="#">Loc10</a>	PWSA-Highland Park	0.17	0.24	0.17	0.00	0.0	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.05	0.07	0.05	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.15	0.29	0.15	0.00	0.0	
<a href="#">03049500</a>	Allegheny River at Natrona	0.00	---	---	---	---	MSTT
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.02	---	---	---	---	MSTT
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.00	---	---	---	---	MSTT
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.00	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	0.00	---	---	---	---	ND
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.00	---	---	---	---	MSTT
<a href="#">Loc04</a>	Kennedy Twp PS	0.00	---	---	---	---	MSTT
<a href="#">Loc05</a>	Upper St. Clair	0.00	---	---	---	---	MSTT
<a href="#">Loc06</a>	Carnegie Transit Time	0.00	---	---	---	---	MSTT
<a href="#">Loc07</a>	Greentree Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc08</a>	AC Health Dept Bldg	0.02	---	---	---	---	MSTT
<a href="#">Loc09</a>	Univ of Pittsburgh	0.00	---	---	---	---	MSTT
<a href="#">Loc11</a>	M-46 Access Shaft	0.00	---	---	---	---	MSTT
<a href="#">Loc12</a>	Baldwin	0.00	---	---	---	---	MSTT
<a href="#">Loc13</a>	M-59 Access Shaft	0.01	---	---	---	---	MSTT
<a href="#">Loc15</a>	Trafford Maint Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc16</a>	Castle Shannon	0.00	---	---	---	---	MSTT
<a href="#">Loc17</a>	Chartiers Pump Station	0.00	---	---	---	---	MSTT
<a href="#">Loc18</a>	Oakdale Pump Station	0.00	---	---	---	---	MSTT
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc20</a>	Gascola Eq Facility	0.00	---	---	---	---	MSTT
<a href="#">Loc21</a>	Moon TWP	0.01	---	---	---	---	MSTT
<a href="#">Loc22</a>	North Fayette TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc23</a>	Clinton Munic Bldg	0.00	---	---	---	---	MSTT

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc24</a>	Jefferson Hills	0.00	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc27</a>	Marshall TWP	0.02	---	---	---	---	MSTT
<a href="#">Loc28</a>	Plum Municipal Bldg	0.01	---	---	---	---	MSTT
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.00	---	---	---	---	C
<a href="#">Loc30</a>	McCandless Twn Hall	0.00	---	---	---	---	MSTT
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.03	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	0.00	---	---	---	---	MSTT

**Table 19. Summary of Individual RG Pairs for Event 3b**

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc07</a>	Greentree Munic Bldg	0.17	0.24	0.17	0.00	0.0	
<a href="#">Loc20</a>	Gascola Eq Facility	0.14	0.14	0.14	0.00	0.0	
<a href="#">03049500</a>	Allegheny River at Natrona	0.00	---	---	---	---	MSTT
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.00	---	---	---	---	MSTT
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.00	---	---	---	---	MSTT
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.00	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	ND	---	---	---	---	ND
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.01	---	---	---	---	MSTT
<a href="#">Loc03</a>	Shaler Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc04</a>	Kennedy Twp PS	0.00	---	---	---	---	MSTT
<a href="#">Loc05</a>	Upper St. Clair	0.00	---	---	---	---	MSTT
<a href="#">Loc06</a>	Carnegie Transit Time	0.01	---	---	---	---	MSTT
<a href="#">Loc08</a>	AC Health Dept Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc09</a>	Univ of Pittsburgh	0.00	---	---	---	---	MSTT
<a href="#">Loc10</a>	PWSA-Highland Park	0.00	---	---	---	---	MSTT
<a href="#">Loc11</a>	M-46 Access Shaft	0.00	---	---	---	---	MSTT
<a href="#">Loc12</a>	Baldwin	0.03	---	---	---	---	MSTT
<a href="#">Loc13</a>	M-59 Access Shaft	0.00	---	---	---	---	MSTT
<a href="#">Loc14</a>	Churchill Munic Bldg	0.01	---	---	---	---	MSTT
<a href="#">Loc15</a>	Trafford Maint Bldg	0.01	---	---	---	---	MSTT
<a href="#">Loc16</a>	Castle Shannon	0.00	---	---	---	---	MSTT

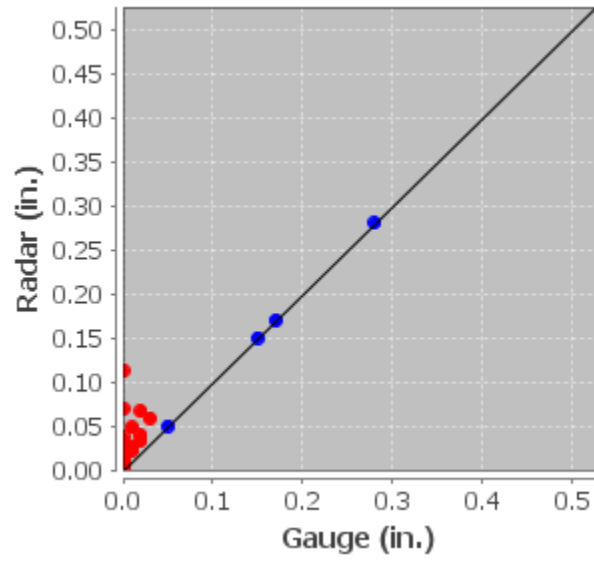


Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc17</a>	Chartiers Pump Station	0.00	---	---	---	---	MSTT
<a href="#">Loc18</a>	Oakdale Pump Station	0.00	---	---	---	---	MSTT
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc21</a>	Moon TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc22</a>	North Fayette TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc23</a>	Clinton Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc24</a>	Jefferson Hills	0.00	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc27</a>	Marshall TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc28</a>	Plum Municipal Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.13	---	---	---	---	O
<a href="#">Loc30</a>	McCandless Twn Hall	0.00	---	---	---	---	MSTT
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc32</a>	Arnold	0.00	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	0.00	---	---	---	---	MSTT

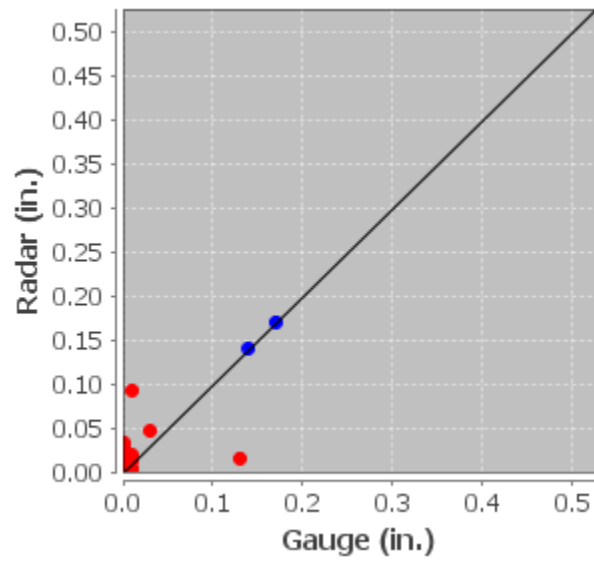
**Table 20. Summary of Individual RG Pairs for Event 3c**

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc10</a>	PWSA-Highland Park	0.34	0.83	0.40	-0.06	-17.6	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.13	0.26	0.15	-0.02	-15.4	
<a href="#">Loc20</a>	Gascola Eq Facility	0.10	0.27	0.11	-0.01	-10.0	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.11	0.22	0.12	-0.01	-9.1	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.13	0.41	0.14	-0.01	-7.7	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.12	0.19	0.12	0.00	0.0	
<a href="#">Loc05</a>	Upper St. Clair	0.14	0.29	0.14	0.00	0.0	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.27	0.43	0.27	0.00	0.0	
<a href="#">Loc12</a>	Baldwin	0.05	0.06	0.05	0.00	0.0	
<a href="#">Loc13</a>	M-59 Access Shaft	0.08	0.09	0.08	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.30	0.43	0.30	0.00	0.0	
<a href="#">Loc17</a>	Chartiers Pump Station	0.06	0.13	0.06	0.00	0.0	
<a href="#">Loc18</a>	Oakdale Pump Station	0.07	0.17	0.07	0.00	0.0	
<a href="#">Loc21</a>	Moon TWP	0.05	0.16	0.05	0.00	0.0	

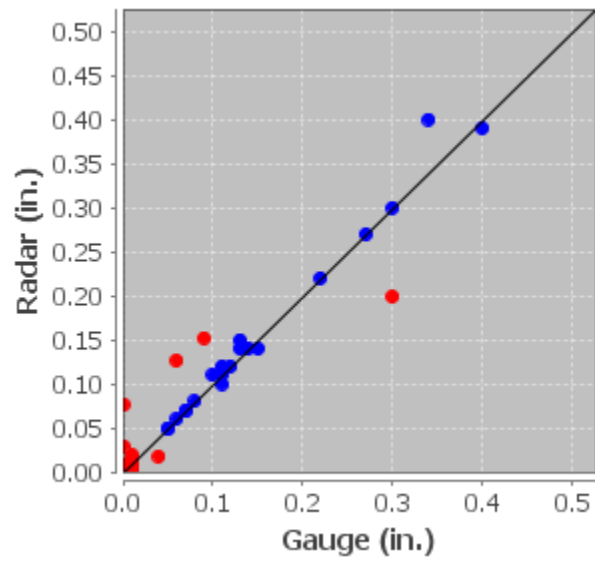
<b>Gauge ID</b>	<b>Name</b>	<b>G<sub>i</sub> (in)</b>	<b>R<sub>i</sub> (in)</b>	<b>R<sub>i</sub>* (in)</b>	<b>Diff* (in)</b>	<b>Diff* (%)</b>	<b>Flag</b>
<a href="#">Loc22</a>	North Fayette TWP	0.07	0.18	0.07	0.00	0.0	
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.22	0.39	0.22	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.11	0.19	0.11	0.00	0.0	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.40	0.73	0.39	0.01	2.5	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.15	0.19	0.14	0.01	6.7	
<a href="#">Loc04</a>	Kennedy Twp PS	0.11	0.14	0.10	0.01	9.1	
<a href="#">03049500</a>	Allegheny River at Natrona	0.09	---	---	---	---	U
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.01	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	ND	---	---	---	---	ND
<a href="#">Loc06</a>	Carnegie Transit Time	0.00	---	---	---	---	MSTT
<a href="#">Loc07</a>	Greentree Munic Bldg	0.01	---	---	---	---	MSTT
<a href="#">Loc11</a>	M-46 Access Shaft	0.06	---	---	---	---	U
<a href="#">Loc16</a>	Castle Shannon	0.01	---	---	---	---	MSTT
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc23</a>	Clinton Munic Bldg	0.04	---	---	---	---	MSTT
<a href="#">Loc24</a>	Jefferson Hills	0.00	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.30	---	---	---	---	C
<a href="#">Loc27</a>	Marshall TWP	0.01	---	---	---	---	MSTT
<a href="#">Loc28</a>	Plum Municipal Bldg	0.01	---	---	---	---	MSTT
<a href="#">Loc30</a>	McCandless Twn Hall	0.00	---	---	---	---	MSTT
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	0.01	---	---	---	---	MSTT



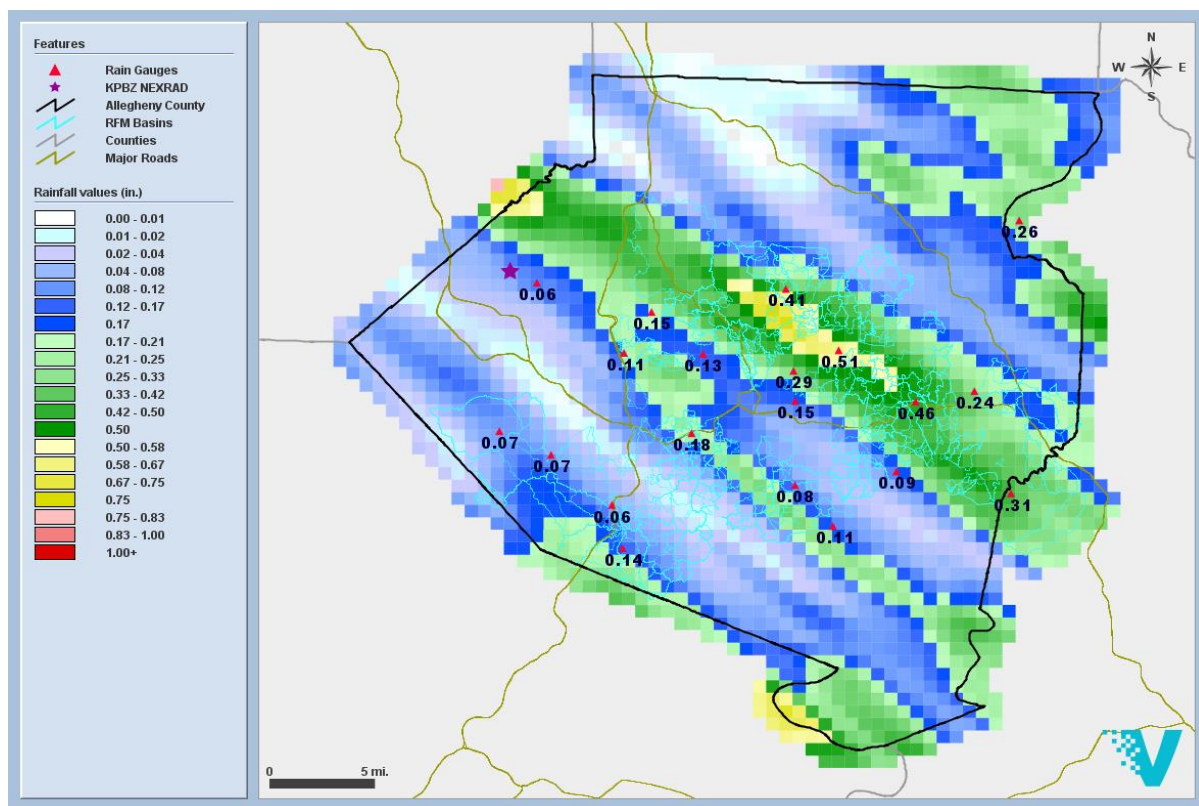
**Figure 14. Scatter Plot of RG Pairs for Event 3a**



**Figure 15. Scatter Plot of RG Pairs for Event 3b**



**Figure 16. Scatter Plot of RG Pairs for Event 3c**



**Figure 17. GARR Storm Total for Event 3**

**Table 21. Depth Duration Frequency Analyses for Event 3**

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	0.552	149163	2020-08-25 17:10	<1 yr.
30 minutes	0.583	149163	2020-08-25 17:15	<1 yr.
1 hour	0.683	149163	2020-08-25 17:50	<1 yr.
2 hour	0.757	127121	2020-08-25 16:15	<1 yr.
3 hour	0.757	127121	2020-08-25 16:15	<1 yr.
6 hour	0.757	127121	2020-08-25 18:00	<1 yr.

**Event 4: 2020-08-27**

The analysis period was from 2020-08-27 08:00 EDT to 2020-08-28 05:00 EDT. The event was then split into four sub-event periods at 2020-08-27 13:00 EDT, 2020-08-27 16:00 EDT and 2020-08-27 22:00 EDT to improve gauge adjustment of the radar.

The gauges listed in [Appendix A](#) were not used to adjust the radar due to inconsistencies between the gauge and the radar or surrounding gauges, or they did not have data available for this event. The gauges listed in [Appendix B](#) were not used to adjust the radar since they did not meet statistical criteria for gauge-adjustment.

A convective Z-R relationship was used to convert radar reflectivity to rainfall rates. Table 22 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Tables 23 - 26 summarize the results for each RG pair used for final radar adjustment, where  $G_i$  is the gauge estimate,  $R_i$  is the non-adjusted radar estimate,  $R_i^*$  is the GARR estimate, and  $\text{Diff}^*$  (%) is the percent difference between the gauge and GARR estimate. Those gauges not used to adjust the radar are shown at the bottom of the table and are highlighted in red. The specific reason for gauge exclusion is displayed in the Flag column. Figures 18 - 21 show the scatter plots of the gauge-adjusted RG pairs. Those gauges not used to adjust the radar are shown in red. Figure 22 depicts the GARR storm total over the 1-km<sup>2</sup> pixels. The GARR amounts for the 2313 1-km<sup>2</sup> pixels range from 0.1 - 2.0 inches with a mean of 0.7 inches. The GARR amounts for the 440 RFM basins range from 0.2 - 1.2 inches with a mean of 0.6 inches. The GARR amounts for the 871 RFM sheds range from 0.2 - 1.2 inches with a mean of 0.6 inches. Table 27 shows the Depth Duration Frequency (DDF) maximum values for the 1-km<sup>2</sup> pixels.

**Table 22. GARR Statistics for Event 4**

Event #	Radar	Event Date	Start Time (EDT)	End Time (EDT)	Gauges Used (37)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E4a	KPBZ LII	2020-08-27	2020-08-27 08:05	2020-08-27 13:00	14	0.084	1.114	23.2	1.3
E4b	KPBZ LII	2020-08-27	2020-08-27 13:05	2020-08-27 16:00	12	0.055	0.969	19.5	5.6

Event #	Radar	Event Date	Start Time (EDT)	End Time (EDT)	Gauges Used (37)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E4c	KPBZ LII	2020-08-27	2020-08-27 16:05	2020-08-27 22:00	15	0.494	1.077	22.4	1.9
E4d	KPBZ LII	2020-08-27	2020-08-27 22:05	2020-08-28 05:00	4	0.108	0.888	19.4	1.1

**Table 23. Summary of Individual RG Pairs for Event 4a**

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc09</a>	Univ of Pittsburgh	0.31	0.37	0.32	-0.01	-3.2	
<a href="#">03049500</a>	Allegheny River at Natrona	0.14	0.18	0.14	0.00	0.0	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.78	0.44	0.78	0.00	0.0	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.37	0.38	0.37	0.00	0.0	
<a href="#">Loc04</a>	Kennedy Twp PS	0.54	0.55	0.54	0.00	0.0	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.25	0.28	0.25	0.00	0.0	
<a href="#">Loc10</a>	PWSA-Highland Park	0.11	0.11	0.11	0.00	0.0	
<a href="#">Loc20</a>	Gascola Eq Facility	0.07	0.08	0.07	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.81	0.44	0.81	0.00	0.0	
<a href="#">Loc27</a>	Marshall TWP	0.23	0.28	0.23	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.06	0.11	0.06	0.00	0.0	
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.06	0.07	0.06	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.27	0.30	0.27	0.00	0.0	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.26	0.24	0.25	0.01	3.8	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.01	---	---	---	---	MSTT
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.00	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	ND	---	---	---	---	ND
<a href="#">Loc03</a>	Shaler Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc05</a>	Upper St. Clair	0.01	---	---	---	---	MSTT
<a href="#">Loc06</a>	Carnegie Transit Time	0.00	---	---	---	---	MSTT
<a href="#">Loc07</a>	Greentree Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc11</a>	M-46 Access Shaft	0.00	---	---	---	---	Z
<a href="#">Loc12</a>	Baldwin	0.00	---	---	---	---	ND
<a href="#">Loc13</a>	M-59 Access Shaft	0.00	---	---	---	---	MSTT
<a href="#">Loc15</a>	Trafford Maint Bldg	0.03	---	---	---	---	MSTT
<a href="#">Loc16</a>	Castle Shannon	0.00	---	---	---	---	MSTT
<a href="#">Loc17</a>	Chartiers Pump Station	0.01	---	---	---	---	MSTT

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc18</a>	Oakdale Pump Station	0.00	---	---	---	---	MSTT
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc21</a>	Moon TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc22</a>	North Fayette TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc24</a>	Jefferson Hills	0.00	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc30</a>	McCandless Twn Hall	0.03	---	---	---	---	MSTT
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.01	---	---	---	---	MSTT
<a href="#">Loc32</a>	Arnold	0.02	---	---	---	---	MSTT

**Table 24. Summary of Individual RG Pairs for Event 4b**

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc09</a>	Univ of Pittsburgh	0.15	0.25	0.20	-0.05	-33.3	
<a href="#">Loc10</a>	PWSA-Highland Park	0.17	0.21	0.18	-0.01	-5.9	
<a href="#">Loc20</a>	Gascola Eq Facility	0.20	0.21	0.21	-0.01	-5.0	
<a href="#">Loc04</a>	Kennedy Twp PS	0.06	0.10	0.06	0.00	0.0	
<a href="#">Loc05</a>	Upper St. Clair	0.40	0.34	0.40	0.00	0.0	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.06	0.06	0.06	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.08	0.08	0.08	0.00	0.0	
<a href="#">Loc24</a>	Jefferson Hills	0.18	0.20	0.18	0.00	0.0	
<a href="#">Loc27</a>	Marshall TWP	0.14	0.15	0.14	0.00	0.0	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.40	0.38	0.39	0.01	2.5	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.36	0.33	0.35	0.01	2.8	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.49	0.45	0.40	0.09	18.4	
<a href="#">03049500</a>	Allegheny River at Natrona	0.00	---	---	---	---	MSTT
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.00	---	---	---	---	MSTT
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.00	---	---	---	---	MSTT
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.00	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	ND	---	---	---	---	ND
<a href="#">Loc03</a>	Shaler Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc06</a>	Carnegie Transit Time	0.00	---	---	---	---	MSTT
<a href="#">Loc11</a>	M-46 Access Shaft	0.03	---	---	---	---	U

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc12</a>	Baldwin	ND	---	---	---	---	ND
<a href="#">Loc13</a>	M-59 Access Shaft	0.01	---	---	---	---	MSTT
<a href="#">Loc16</a>	Castle Shannon	0.01	---	---	---	---	MSTT
<a href="#">Loc17</a>	Chartiers Pump Station	0.04	---	---	---	---	MSTT
<a href="#">Loc18</a>	Oakdale Pump Station	0.00	---	---	---	---	MSTT
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc21</a>	Moon TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc22</a>	North Fayette TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc23</a>	Clinton Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.11	---	---	---	---	C
<a href="#">Loc28</a>	Plum Municipal Bldg	0.02	---	---	---	---	MSTT
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc30</a>	McCandless Twn Hall	0.01	---	---	---	---	MSTT
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc32</a>	Arnold	0.00	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	0.05	---	---	---	---	MSTT

**Table 25. Summary of Individual RG Pairs for Event 4c**

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc30</a>	McCandless Twn Hall	0.20	0.38	0.22	-0.02	-10.0	
<a href="#">Loc20</a>	Gascola Eq Facility	0.36	0.42	0.37	-0.01	-2.8	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.37	0.38	0.38	-0.01	-2.7	
<a href="#">Loc32</a>	Arnold	1.17	1.18	1.18	-0.01	-0.9	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.59	0.37	0.59	0.00	0.0	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.15	0.22	0.15	0.00	0.0	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.18	0.22	0.18	0.00	0.0	
<a href="#">Loc04</a>	Kennedy Twp PS	0.21	0.22	0.21	0.00	0.0	
<a href="#">Loc13</a>	M-59 Access Shaft	0.41	0.30	0.41	0.00	0.0	
<a href="#">Loc18</a>	Oakdale Pump Station	0.43	0.33	0.43	0.00	0.0	
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.31	0.29	0.31	0.00	0.0	
<a href="#">03049500</a>	Allegheny River at Natrona	0.91	0.79	0.90	0.01	1.1	
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.78	0.70	0.77	0.01	1.3	
<a href="#">Loc28</a>	Plum Municipal Bldg	1.32	0.98	1.30	0.02	1.5	

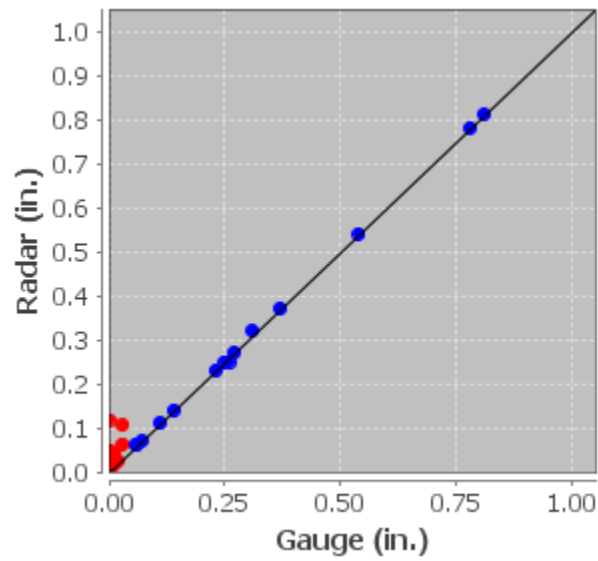


Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc27</a>	Marshall TWP	0.38	0.43	0.36	0.02	5.3	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.14	---	---	---	---	U
<a href="#">Loc01</a>	PWSA-Montana St.	ND	---	---	---	---	ND
<a href="#">Loc05</a>	Upper St. Clair	0.00	---	---	---	---	Z
<a href="#">Loc06</a>	Carnegie Transit Time	0.12	---	---	---	---	S
<a href="#">Loc07</a>	Greentree Munic Bldg	0.10	---	---	---	---	S
<a href="#">Loc08</a>	AC Health Dept Bldg	0.08	---	---	---	---	S
<a href="#">Loc09</a>	Univ of Pittsburgh	0.01	---	---	---	---	S
<a href="#">Loc10</a>	PWSA-Highland Park	0.07	---	---	---	---	S
<a href="#">Loc11</a>	M-46 Access Shaft	0.00	---	---	---	---	Z
<a href="#">Loc12</a>	Baldwin	ND	---	---	---	---	ND
<a href="#">Loc14</a>	Churchill Munic Bldg	0.00	---	---	---	---	Z
<a href="#">Loc15</a>	Trafford Maint Bldg	0.00	---	---	---	---	Z
<a href="#">Loc16</a>	Castle Shannon	0.00	---	---	---	---	Z
<a href="#">Loc17</a>	Chartiers Pump Station	0.00	---	---	---	---	Z
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc21</a>	Moon TWP	0.13	---	---	---	---	S
<a href="#">Loc22</a>	North Fayette TWP	0.03	---	---	---	---	S
<a href="#">Loc23</a>	Clinton Munic Bldg	0.10	---	---	---	---	S
<a href="#">Loc24</a>	Jefferson Hills	0.00	---	---	---	---	Z
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.00	---	---	---	---	Z
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.02	---	---	---	---	C
<a href="#">Loc33</a>	Richland TWP	0.07	---	---	---	---	ND

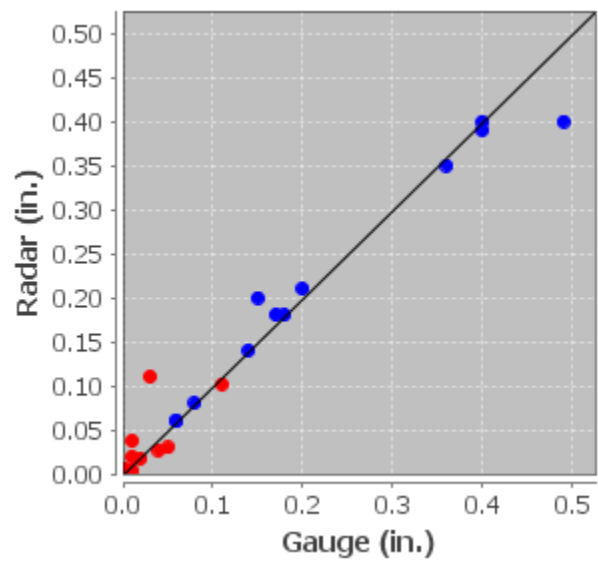
**Table 26. Summary of Individual RG Pairs for Event 4d**

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc27</a>	Marshall TWP	0.37	0.46	0.38	-0.01	-2.7	
<a href="#">03049500</a>	Allegheny River at Natrona	0.39	0.47	0.39	0.00	0.0	
<a href="#">Loc20</a>	Gascola Eq Facility	0.09	0.06	0.09	0.00	0.0	
<a href="#">Loc30</a>	McCandless Twn Hall	0.44	0.46	0.43	0.01	2.3	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.00	---	---	---	---	MSTT
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.00	---	---	---	---	MSTT

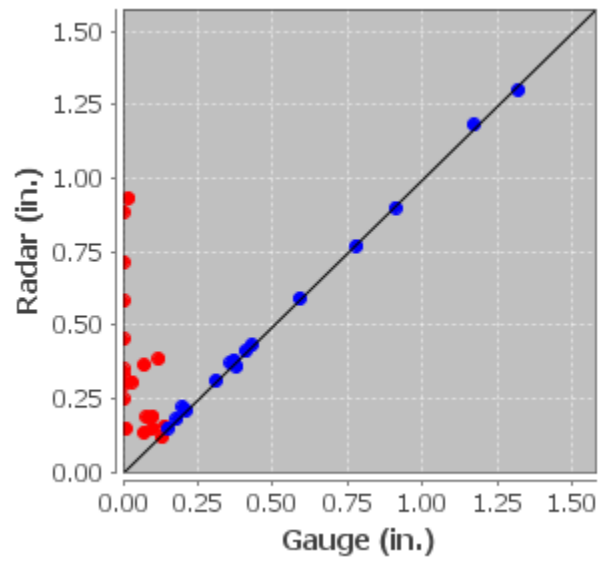
Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.00	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	ND	---	---	---	---	ND
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.00	---	---	---	---	MSTT
<a href="#">Loc03</a>	Shaler Munic Bldg	0.00	---	---	---	---	Z
<a href="#">Loc04</a>	Kennedy Twp PS	0.01	---	---	---	---	MSTT
<a href="#">Loc05</a>	Upper St. Clair	0.00	---	---	---	---	MSTT
<a href="#">Loc06</a>	Carnegie Transit Time	0.00	---	---	---	---	MSTT
<a href="#">Loc07</a>	Greentree Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc08</a>	AC Health Dept Bldg	0.00	---	---	---	---	Z
<a href="#">Loc09</a>	Univ of Pittsburgh	0.00	---	---	---	---	MSTT
<a href="#">Loc10</a>	PWSA-Highland Park	0.00	---	---	---	---	Z
<a href="#">Loc11</a>	M-46 Access Shaft	0.00	---	---	---	---	MSTT
<a href="#">Loc12</a>	Baldwin	ND	---	---	---	---	ND
<a href="#">Loc13</a>	M-59 Access Shaft	0.00	---	---	---	---	MSTT
<a href="#">Loc14</a>	Churchill Munic Bldg	0.00	---	---	---	---	Z
<a href="#">Loc15</a>	Trafford Maint Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc16</a>	Castle Shannon	0.00	---	---	---	---	MSTT
<a href="#">Loc17</a>	Chartiers Pump Station	0.00	---	---	---	---	MSTT
<a href="#">Loc18</a>	Oakdale Pump Station	0.00	---	---	---	---	MSTT
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc21</a>	Moon TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc22</a>	North Fayette TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc23</a>	Clinton Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc24</a>	Jefferson Hills	0.00	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc28</a>	Plum Municipal Bldg	0.04	---	---	---	---	MSTT
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.00	---	---	---	---	Z
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.00	---	---	---	---	Z
<a href="#">Loc32</a>	Arnold	0.00	---	---	---	---	Z
<a href="#">Loc33</a>	Richland TWP	ND	---	---	---	---	ND



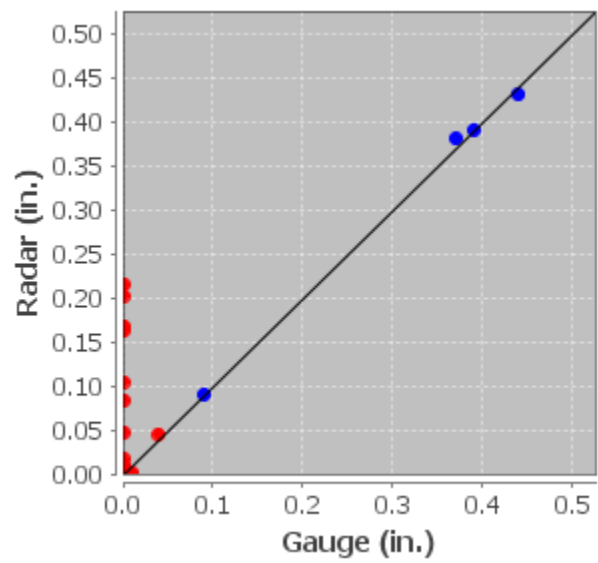
**Figure 18. Scatter Plot of RG Pairs for Event 4a**



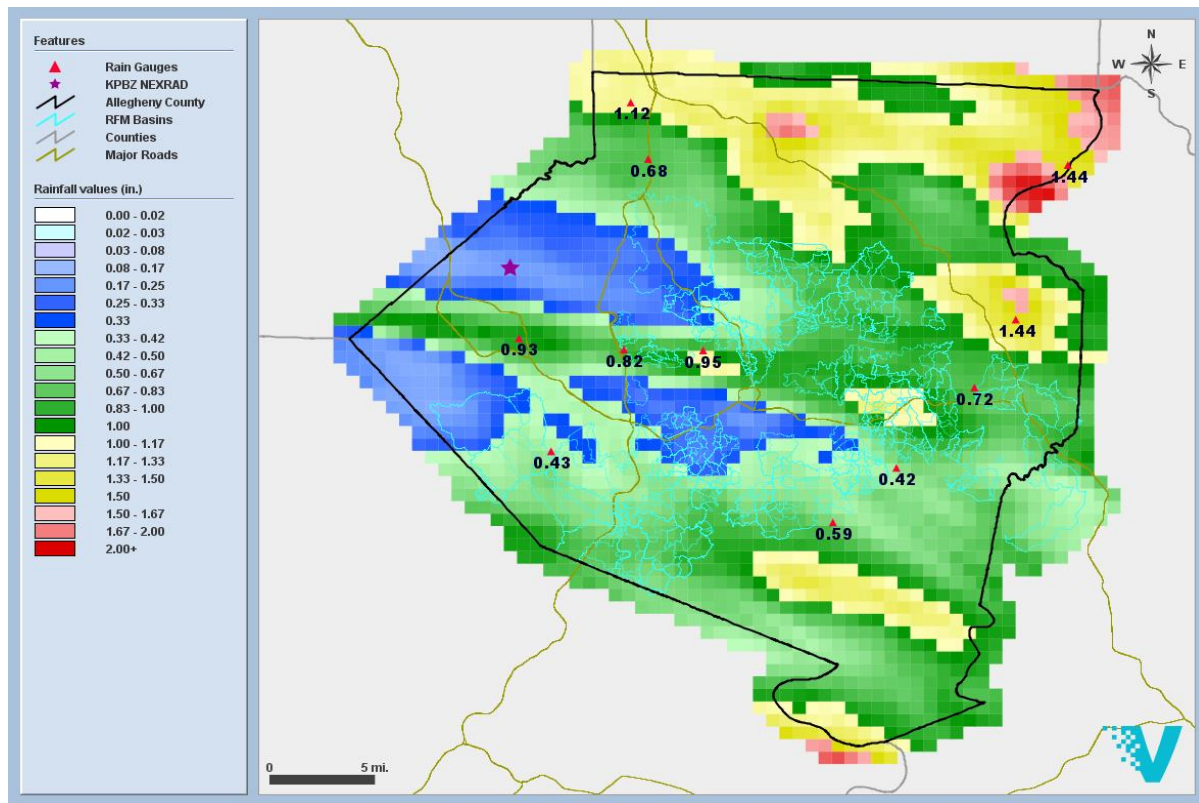
**Figure 19. Scatter Plot of RG Pairs for Event 4b**



**Figure 20. Scatter Plot of RG Pairs for Event 4c**



**Figure 21. Scatter Plot of RG Pairs for Event 4d**



**Figure 22. GARR Storm Total for Event 4**

**Table 27. Depth Duration Frequency Analyses for Event 4**

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	1.390	168123	2020-08-27 18:35	100 yr.
30 minutes	1.556	153167	2020-08-27 19:55	10 yr.
1 hour	1.725	153167	2020-08-27 20:15	5 yr.
2 hour	1.766	153167	2020-08-27 21:15	5 yr.
3 hour	1.766	153167	2020-08-27 21:15	2 yr.
6 hour	1.766	153167	2020-08-27 21:15	2 yr.
12 hour	1.813	168123	2020-08-28 02:25	1 yr.

## Event 5: 2020-08-28

The analysis period was from 2020-08-28 05:00 EDT to 2020-08-29 06:00 EDT. The event was then split into nine sub-event periods at 2020-08-28 12:30 EDT, 2020-08-28 13:15 EDT, 2020-08-28 14:30 EDT, 2020-08-28 15:30 EDT, 2020-08-28 18:30 EDT, 2020-08-28 19:45 EDT, 2020-08-28 21:45 EDT and 2020-08-28 22:45 EDT to improve gauge adjustment of the radar.

The gauges listed in [Appendix A](#) were not used to adjust the radar due to inconsistencies between the gauge and the radar or surrounding gauges, or they did not have data available for this event.

The gauges listed in [Appendix B](#) were not used to adjust the radar since they did not meet statistical criteria for gauge-adjustment.

A convective Z-R relationship was used to convert radar reflectivity to rainfall rates. Table 28 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Tables 29 - 37 summarize the results for each RG pair used for final radar adjustment, where  $G_i$  is the gauge estimate,  $R_i$  is the non-adjusted radar estimate,  $R_i^*$  is the GARR estimate, and  $\text{Diff}^*$  (%) is the percent difference between the gauge and GARR estimate. Those gauges not used to adjust the radar are shown at the bottom of the table and are highlighted in red. The specific reason for gauge exclusion is displayed in the Flag column. Figures 23 - 31 show the scatter plots of the gauge-adjusted RG pairs. Those gauges not used to adjust the radar are shown in red. Figure 32 depicts the GARR storm total over the 1-km<sup>2</sup> pixels. The GARR amounts for the 2313 1-km<sup>2</sup> pixels range from 0.8 - 4.2 inches with a mean of 1.8 inches. The GARR amounts for the 440 RFM basins range from 0.9 - 4.2 inches with a mean of 1.9 inches. The GARR amounts for the 871 RFM sheds range from 0.9 - 4.3 inches with a mean of 2.1 inches. Table 38 shows the Depth Duration Frequency (DDF) maximum values for the 1-km<sup>2</sup> pixels.

**Table 28. GARR Statistics for Event 5**

Event #	Radar	Event Date	Start Time (EDT)	End Time (EDT)	Gauges Used (37)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E5a	KPBZ LII	2020-08-28	2020-08-28 05:05	2020-08-28 12:30	7	0.187	1.106	31.5	2.3
E5b	KPBZ LII	2020-08-28	2020-08-28 12:35	2020-08-28 13:15	19	0.298	1.338	23.9	3.1
E5c	KPBZ LII	2020-08-28	2020-08-28 13:20	2020-08-28 14:30	24	0.307	1.445	27.3	3.4
E5d	KPBZ LII	2020-08-28	2020-08-28 14:35	2020-08-28 15:30	17	0.100	0.896	32.4	1.9
E5e	KPBZ LII	2020-08-28	2020-08-28 15:35	2020-08-28 18:30	20	0.258	1.109	14.8	1.4
E5f	KPBZ LII	2020-08-28	2020-08-28 18:35	2020-08-28 19:45	17	0.048	0.847	22.3	3.7
E5g	KPBZ LII	2020-08-28	2020-08-28 19:50	2020-08-28 21:45	18	0.141	0.904	19.5	1.7
E5h	KPBZ LII	2020-08-28	2020-08-28 21:50	2020-08-28 22:45	12	0.055	0.696	42.6	1.8
E5i	KPBZ LII	2020-08-28	2020-08-28 22:50	2020-08-29 06:00	28	0.389	1.152	12.5	1.0

**Table 29. Summary of Individual RG Pairs for Event 5a**

<b>Gauge ID</b>	<b>Name</b>	<b>G<sub>i</sub> (in)</b>	<b>R<sub>i</sub> (in)</b>	<b>R<sub>i</sub>* (in)</b>	<b>Diff* (in)</b>	<b>Diff* (%)</b>	<b>Flag</b>
<a href="#">Loc05</a>	Upper St. Clair	0.28	0.40	0.31	-0.03	-10.7	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.49	0.51	0.49	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.22	0.34	0.22	0.00	0.0	
<a href="#">Loc18</a>	Oakdale Pump Station	0.09	0.05	0.09	0.00	0.0	
<a href="#">Loc24</a>	Jefferson Hills	0.86	0.46	0.86	0.00	0.0	
<a href="#">Loc27</a>	Marshall TWP	0.29	0.21	0.29	0.00	0.0	
<a href="#">Loc17</a>	Chartiers Pump Station	0.33	0.35	0.32	0.01	3.0	
<a href="#">03049500</a>	Allegheny River at Natrona	0.00	---	---	---	---	MSTT
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.00	---	---	---	---	MSTT
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.60	---	---	---	---	U
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.00	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	ND	---	---	---	---	ND
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.00	---	---	---	---	MSTT
<a href="#">Loc03</a>	Shaler Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc04</a>	Kennedy Twp PS	0.00	---	---	---	---	MSTT
<a href="#">Loc06</a>	Carnegie Transit Time	0.00	---	---	---	---	MSTT
<a href="#">Loc07</a>	Greentree Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc08</a>	AC Health Dept Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc09</a>	Univ of Pittsburgh	0.00	---	---	---	---	MSTT
<a href="#">Loc10</a>	PWSA-Highland Park	0.00	---	---	---	---	MSTT
<a href="#">Loc11</a>	M-46 Access Shaft	0.00	---	---	---	---	MSTT
<a href="#">Loc12</a>	Baldwin	ND	---	---	---	---	ND
<a href="#">Loc13</a>	M-59 Access Shaft	0.00	---	---	---	---	MSTT
<a href="#">Loc14</a>	Churchill Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc20</a>	Gascola Eq Facility	0.00	---	---	---	---	MSTT
<a href="#">Loc21</a>	Moon TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc22</a>	North Fayette TWP	0.12	---	---	---	---	O
<a href="#">Loc23</a>	Clinton Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.00	---	---	---	---	Z
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.12	---	---	---	---	C
<a href="#">Loc28</a>	Plum Municipal Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc30</a>	McCandless Twn Hall	0.00	---	---	---	---	MSTT
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.00	---	---	---	---	MSTT

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc32</a>	Arnold	0.00	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	ND	---	---	---	---	ND

**Table 30. Summary of Individual RG Pairs for Event 5b**

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc17</a>	Chartiers Pump Station	0.34	0.40	0.38	-0.04	-11.8	
<a href="#">Loc11</a>	M-46 Access Shaft	0.76	0.62	0.82	-0.06	-7.9	
<a href="#">Loc21</a>	Moon TWP	0.15	0.18	0.16	-0.01	-6.7	
<a href="#">Loc10</a>	PWSA-Highland Park	0.91	0.62	0.94	-0.03	-3.3	
<a href="#">Loc20</a>	Gascola Eq Facility	0.63	0.59	0.65	-0.02	-3.2	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	1.73	1.10	1.73	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.34	0.34	0.34	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.54	0.44	0.54	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.59	0.44	0.59	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.35	0.41	0.35	0.00	0.0	
<a href="#">Loc30</a>	McCandless Twn Hall	0.09	0.07	0.09	0.00	0.0	
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.10	0.09	0.10	0.00	0.0	
<a href="#">Loc14</a>	Churchill Munic Bldg	1.03	0.77	1.01	0.02	1.9	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.96	0.57	0.94	0.02	2.1	
<a href="#">Loc18</a>	Oakdale Pump Station	0.43	0.27	0.42	0.01	2.3	
<a href="#">Loc09</a>	Univ of Pittsburgh	1.27	0.77	1.24	0.03	2.4	
<a href="#">Loc13</a>	M-59 Access Shaft	0.31	0.20	0.30	0.01	3.2	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.40	0.26	0.38	0.02	5.0	
<a href="#">Loc06</a>	Carnegie Transit Time	0.51	0.39	0.48	0.03	5.9	
<a href="#">03049500</a>	Allegheny River at Natrona	0.05	---	---	---	---	U
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.12	---	---	---	---	U
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.66	---	---	---	---	O
<a href="#">Loc01</a>	PWSA-Montana St.	ND	---	---	---	---	ND
<a href="#">Loc03</a>	Shaler Munic Bldg	0.01	---	---	---	---	U
<a href="#">Loc04</a>	Kennedy Twp PS	0.53	---	---	---	---	U
<a href="#">Loc05</a>	Upper St. Clair	0.00	---	---	---	---	MSTT
<a href="#">Loc07</a>	Greentree Munic Bldg	0.21	---	---	---	---	O
<a href="#">Loc12</a>	Baldwin	0.27	---	---	---	---	ND



Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc22</a>	North Fayette TWP	0.01	---	---	---	---	MSTT
<a href="#">Loc24</a>	Jefferson Hills	0.11	---	---	---	---	OAD
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.00	---	---	---	---	Z
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc27</a>	Marshall TWP	0.04	---	---	---	---	MSTT
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.09	---	---	---	---	O
<a href="#">Loc32</a>	Arnold	0.16	---	---	---	---	O
<a href="#">Loc33</a>	Richland TWP	ND	---	---	---	---	ND

**Table 31. Summary of Individual RG Pairs for Event 5c**

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc08</a>	AC Health Dept Bldg	0.90	0.69	1.03	-0.13	-14.4	
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.08	0.09	0.09	-0.01	-12.5	
<a href="#">Loc13</a>	M-59 Access Shaft	0.10	0.11	0.11	-0.01	-10.0	
<a href="#">Loc06</a>	Carnegie Transit Time	0.15	0.16	0.16	-0.01	-6.7	
<a href="#">Loc04</a>	Kennedy Twp PS	0.84	0.74	0.87	-0.03	-3.6	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.58	0.47	0.58	0.00	0.0	
<a href="#">Loc11</a>	M-46 Access Shaft	0.41	0.29	0.41	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.08	0.06	0.08	0.00	0.0	
<a href="#">Loc18</a>	Oakdale Pump Station	0.26	0.26	0.26	0.00	0.0	
<a href="#">Loc20</a>	Gascola Eq Facility	0.82	0.45	0.82	0.00	0.0	
<a href="#">Loc21</a>	Moon TWP	0.38	0.23	0.38	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.31	0.32	0.31	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.92	0.77	0.92	0.00	0.0	
<a href="#">Loc27</a>	Marshall TWP	0.09	0.05	0.09	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.51	0.29	0.51	0.00	0.0	
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.12	0.06	0.12	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.10	0.07	0.10	0.00	0.0	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	1.30	0.79	1.29	0.01	0.8	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	1.36	0.90	1.32	0.04	2.9	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.64	0.49	0.62	0.02	3.1	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.99	0.53	0.95	0.04	4.0	

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc03</a>	Shaler Munic Bldg	0.44	0.30	0.42	0.02	4.5	
<a href="#">Loc10</a>	PWSA-Highland Park	0.84	0.47	0.79	0.05	6.0	
<a href="#">Loc09</a>	Univ of Pittsburgh	1.28	0.76	1.18	0.10	7.8	
<a href="#">03049500</a>	Allegheny River at Natrona	0.03	---	---	---	---	MSTT
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.23	---	---	---	---	O
<a href="#">Loc01</a>	PWSA-Montana St.	ND	---	---	---	---	ND
<a href="#">Loc05</a>	Upper St. Clair	0.00	---	---	---	---	MSTT
<a href="#">Loc12</a>	Baldwin	0.03	---	---	---	---	MSTT
<a href="#">Loc16</a>	Castle Shannon	0.00	---	---	---	---	MSTT
<a href="#">Loc17</a>	Chartiers Pump Station	0.00	---	---	---	---	MSTT
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc24</a>	Jefferson Hills	0.02	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.00	---	---	---	---	Z
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.00	---	---	---	---	C
<a href="#">Loc30</a>	McCandless Twn Hall	0.04	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	ND	---	---	---	---	ND

**Table 32. Summary of Individual RG Pairs for Event 5d**

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc17</a>	Chartiers Pump Station	0.11	0.22	0.12	-0.01	-9.1	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.12	0.08	0.12	0.00	0.0	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.19	0.19	0.19	0.00	0.0	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.07	0.10	0.07	0.00	0.0	
<a href="#">Loc04</a>	Kennedy Twp PS	0.26	0.25	0.26	0.00	0.0	
<a href="#">Loc06</a>	Carnegie Transit Time	0.09	0.13	0.09	0.00	0.0	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.11	0.13	0.11	0.00	0.0	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.07	0.10	0.07	0.00	0.0	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.06	0.09	0.06	0.00	0.0	
<a href="#">Loc13</a>	M-59 Access Shaft	0.15	0.11	0.15	0.00	0.0	
<a href="#">Loc20</a>	Gascola Eq Facility	0.07	0.07	0.07	0.00	0.0	
<a href="#">Loc21</a>	Moon TWP	0.09	0.08	0.09	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.29	0.28	0.29	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.06	0.06	0.06	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.09	0.13	0.09	0.00	0.0	

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.05	0.10	0.05	0.00	0.0	
<a href="#">Loc18</a>	Oakdale Pump Station	0.18	0.16	0.17	0.01	5.6	
<a href="#">03049500</a>	Allegheny River at Natrona	0.03	---	---	---	---	U
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.05	---	---	---	---	MSTT
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.12	---	---	---	---	U
<a href="#">Loc01</a>	PWSA-Montana St.	ND	---	---	---	---	ND
<a href="#">Loc05</a>	Upper St. Clair	0.01	---	---	---	---	S
<a href="#">Loc10</a>	PWSA-Highland Park	0.04	---	---	---	---	MSTT
<a href="#">Loc11</a>	M-46 Access Shaft	0.03	---	---	---	---	MSTT
<a href="#">Loc12</a>	Baldwin	0.00	---	---	---	---	Z
<a href="#">Loc14</a>	Churchill Munic Bldg	0.04	---	---	---	---	MSTT
<a href="#">Loc15</a>	Trafford Maint Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc16</a>	Castle Shannon	0.00	---	---	---	---	Z
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc24</a>	Jefferson Hills	0.00	---	---	---	---	Z
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.00	---	---	---	---	Z
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.00	---	---	---	---	C
<a href="#">Loc27</a>	Marshall TWP	0.02	---	---	---	---	MSTT
<a href="#">Loc30</a>	McCandless Twn Hall	0.04	---	---	---	---	MSTT
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.02	---	---	---	---	U
<a href="#">Loc32</a>	Arnold	0.09	---	---	---	---	O
<a href="#">Loc33</a>	Richland TWP	ND	---	---	---	---	ND

**Table 33. Summary of Individual RG Pairs for Event 5e**

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc30</a>	McCandless Twn Hall	0.12	0.17	0.13	-0.01	-8.3	
<a href="#">Loc21</a>	Moon TWP	0.19	0.20	0.20	-0.01	-5.3	
<a href="#">Loc05</a>	Upper St. Clair	0.32	0.27	0.33	-0.01	-3.1	
<a href="#">03049500</a>	Allegheny River at Natrona	0.25	0.27	0.25	0.00	0.0	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.31	0.28	0.31	0.00	0.0	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.39	0.30	0.39	0.00	0.0	
<a href="#">Loc04</a>	Kennedy Twp PS	0.26	0.25	0.26	0.00	0.0	

<b>Gauge ID</b>	<b>Name</b>	<b>G<sub>i</sub> (in)</b>	<b>R<sub>i</sub> (in)</b>	<b>R<sub>i</sub>* (in)</b>	<b>Diff* (in)</b>	<b>Diff* (%)</b>	<b>Flag</b>
<a href="#">Loc13</a>	M-59 Access Shaft	0.27	0.27	0.27	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.30	0.27	0.30	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.26	0.24	0.26	0.00	0.0	
<a href="#">Loc18</a>	Oakdale Pump Station	0.20	0.14	0.20	0.00	0.0	
<a href="#">Loc20</a>	Gascola Eq Facility	0.21	0.24	0.21	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.15	0.11	0.15	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.43	0.29	0.43	0.00	0.0	
<a href="#">Loc24</a>	Jefferson Hills	0.31	0.27	0.31	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.24	0.23	0.24	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.22	0.23	0.22	0.00	0.0	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.44	0.36	0.43	0.01	2.3	
<a href="#">Loc17</a>	Chartiers Pump Station	0.39	0.29	0.38	0.01	2.6	
<a href="#">Loc27</a>	Marshall TWP	0.39	0.41	0.38	0.01	2.6	
<a href="#">Loc01</a>	PWSA-Montana St.	ND	---	---	---	---	ND
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.30	---	---	---	---	O
<a href="#">Loc03</a>	Shaler Munic Bldg	0.30	---	---	---	---	O
<a href="#">Loc06</a>	Carnegie Transit Time	0.26	---	---	---	---	O
<a href="#">Loc07</a>	Greentree Munic Bldg	0.22	---	---	---	---	O
<a href="#">Loc08</a>	AC Health Dept Bldg	0.21	---	---	---	---	O
<a href="#">Loc09</a>	Univ of Pittsburgh	0.21	---	---	---	---	O
<a href="#">Loc10</a>	PWSA-Highland Park	0.21	---	---	---	---	O
<a href="#">Loc11</a>	M-46 Access Shaft	0.32	---	---	---	---	O
<a href="#">Loc12</a>	Baldwin	0.43	---	---	---	---	O
<a href="#">Loc14</a>	Churchill Munic Bldg	0.27	---	---	---	---	O
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.00	---	---	---	---	Z
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.01	---	---	---	---	C
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.22	---	---	---	---	O
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.26	---	---	---	---	O
<a href="#">Loc33</a>	Richland TWP	0.02	---	---	---	---	ND

**Table 34. Summary of Individual RG Pairs for Event 5f**

<b>Gauge ID</b>	<b>Name</b>	<b>G<sub>i</sub> (in)</b>	<b>R<sub>i</sub> (in)</b>	<b>R<sub>i</sub>* (in)</b>	<b>Diff* (in)</b>	<b>Diff* (%)</b>	<b>Flag</b>
<a href="#">Loc09</a>	Univ of Pittsburgh	0.09	0.15	0.11	-0.02	-22.2	
<a href="#">Loc04</a>	Kennedy Twp PS	0.09	0.16	0.10	-0.01	-11.1	
<a href="#">03049500</a>	Allegheny River at Natrona	0.17	0.18	0.17	0.00	0.0	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.10	0.14	0.10	0.00	0.0	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.05	0.07	0.05	0.00	0.0	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.14	0.14	0.14	0.00	0.0	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.07	0.12	0.07	0.00	0.0	
<a href="#">Loc10</a>	PWSA-Highland Park	0.10	0.10	0.10	0.00	0.0	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.07	0.06	0.07	0.00	0.0	
<a href="#">Loc18</a>	Oakdale Pump Station	0.10	0.11	0.10	0.00	0.0	
<a href="#">Loc20</a>	Gascola Eq Facility	0.06	0.06	0.06	0.00	0.0	
<a href="#">Loc21</a>	Moon TWP	0.08	0.09	0.08	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.08	0.08	0.08	0.00	0.0	
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.12	0.12	0.12	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.16	0.17	0.16	0.00	0.0	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.12	0.16	0.11	0.01	8.3	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.15	0.15	0.13	0.02	13.3	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.02	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	ND	---	---	---	---	ND
<a href="#">Loc05</a>	Upper St. Clair	0.03	---	---	---	---	MSTT
<a href="#">Loc06</a>	Carnegie Transit Time	0.02	---	---	---	---	MSTT
<a href="#">Loc11</a>	M-46 Access Shaft	0.06	---	---	---	---	MSTT
<a href="#">Loc12</a>	Baldwin	0.00	---	---	---	---	MSTT
<a href="#">Loc13</a>	M-59 Access Shaft	0.02	---	---	---	---	MSTT
<a href="#">Loc15</a>	Trafford Maint Bldg	0.01	---	---	---	---	MSTT
<a href="#">Loc16</a>	Castle Shannon	0.02	---	---	---	---	MSTT
<a href="#">Loc17</a>	Chartiers Pump Station	0.01	---	---	---	---	MSTT
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc22</a>	North Fayette TWP	0.05	---	---	---	---	MSTT
<a href="#">Loc23</a>	Clinton Munic Bldg	0.04	---	---	---	---	MSTT
<a href="#">Loc24</a>	Jefferson Hills	0.00	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.00	---	---	---	---	C
<a href="#">Loc27</a>	Marshall TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.02	---	---	---	---	MSTT

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc30</a>	McCandless Twn Hall	0.01	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	0.02	---	---	---	---	MSTT

**Table 35. Summary of Individual RG Pairs for Event 5g**

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc17</a>	Chartiers Pump Station	0.09	0.11	0.10	-0.01	-11.1	
<a href="#">Loc27</a>	Marshall TWP	0.30	0.39	0.31	-0.01	-3.3	
<a href="#">03049500</a>	Allegheny River at Natrona	0.06	0.05	0.06	0.00	0.0	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.19	0.26	0.19	0.00	0.0	
<a href="#">Loc05</a>	Upper St. Clair	0.16	0.17	0.16	0.00	0.0	
<a href="#">Loc06</a>	Carnegie Transit Time	0.08	0.08	0.08	0.00	0.0	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.05	0.06	0.05	0.00	0.0	
<a href="#">Loc11</a>	M-46 Access Shaft	0.05	0.05	0.05	0.00	0.0	
<a href="#">Loc13</a>	M-59 Access Shaft	0.12	0.15	0.12	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.16	0.23	0.16	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.14	0.14	0.14	0.00	0.0	
<a href="#">Loc18</a>	Oakdale Pump Station	0.09	0.09	0.09	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.08	0.09	0.08	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.06	0.08	0.06	0.00	0.0	
<a href="#">Loc24</a>	Jefferson Hills	0.23	0.36	0.23	0.00	0.0	
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.16	0.16	0.16	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.77	0.59	0.77	0.00	0.0	
<a href="#">Loc30</a>	McCandless Twn Hall	0.46	0.52	0.45	0.01	2.2	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.01	---	---	---	---	MSTT
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.07	---	---	---	---	O
<a href="#">Loc01</a>	PWSA-Montana St.	ND	---	---	---	---	ND
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.03	---	---	---	---	MSTT
<a href="#">Loc03</a>	Shaler Munic Bldg	0.02	---	---	---	---	MSTT
<a href="#">Loc04</a>	Kennedy Twp PS	0.03	---	---	---	---	MSTT
<a href="#">Loc08</a>	AC Health Dept Bldg	0.03	---	---	---	---	MSTT
<a href="#">Loc09</a>	Univ of Pittsburgh	0.03	---	---	---	---	MSTT
<a href="#">Loc10</a>	PWSA-Highland Park	0.03	---	---	---	---	MSTT
<a href="#">Loc12</a>	Baldwin	0.00	---	---	---	---	Z

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc14</a>	Churchill Munic Bldg	0.03	---	---	---	---	MSTT
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc20</a>	Gascola Eq Facility	0.03	---	---	---	---	MSTT
<a href="#">Loc21</a>	Moon TWP	0.04	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.00	---	---	---	---	Z
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.00	---	---	---	---	C
<a href="#">Loc28</a>	Plum Municipal Bldg	0.02	---	---	---	---	MSTT
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.03	---	---	---	---	MSTT
<a href="#">Loc32</a>	Arnold	0.04	---	---	---	---	MSTT

**Table 36. Summary of Individual RG Pairs for Event 5h**

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc05</a>	Upper St. Clair	0.08	0.14	0.09	-0.01	-12.5	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.09	0.10	0.09	0.00	0.0	
<a href="#">Loc06</a>	Carnegie Transit Time	0.05	0.06	0.05	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.08	0.10	0.08	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.05	0.10	0.05	0.00	0.0	
<a href="#">Loc17</a>	Chartiers Pump Station	0.08	0.11	0.08	0.00	0.0	
<a href="#">Loc18</a>	Oakdale Pump Station	0.05	0.07	0.05	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.05	0.08	0.05	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.10	0.12	0.10	0.00	0.0	
<a href="#">Loc24</a>	Jefferson Hills	0.11	0.22	0.11	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.06	0.09	0.06	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.06	0.06	0.06	0.00	0.0	
<a href="#">03049500</a>	Allegheny River at Natrona	0.00	---	---	---	---	Z
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.01	---	---	---	---	MSTT
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.01	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	ND	---	---	---	---	ND
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.01	---	---	---	---	MSTT
<a href="#">Loc03</a>	Shaler Munic Bldg	0.01	---	---	---	---	MSTT
<a href="#">Loc04</a>	Kennedy Twp PS	0.01	---	---	---	---	MSTT
<a href="#">Loc07</a>	Greentree Munic Bldg	0.04	---	---	---	---	MSTT
<a href="#">Loc08</a>	AC Health Dept Bldg	0.02	---	---	---	---	MSTT

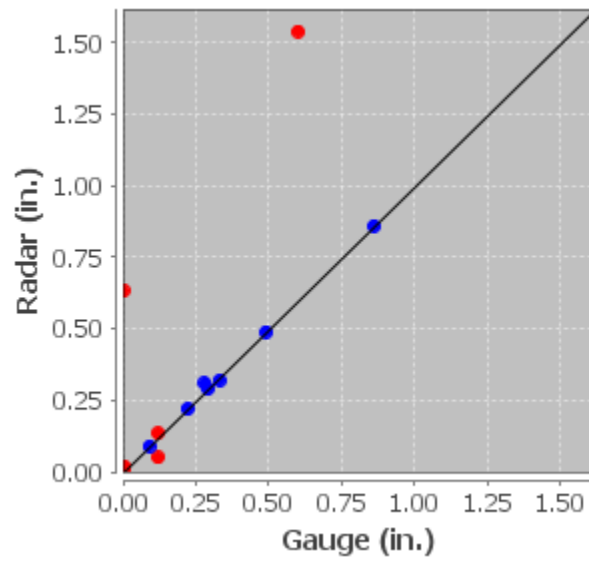
Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc09</a>	Univ of Pittsburgh	0.02	---	---	---	---	MSTT
<a href="#">Loc10</a>	PWSA-Highland Park	0.01	---	---	---	---	MSTT
<a href="#">Loc11</a>	M-46 Access Shaft	0.03	---	---	---	---	MSTT
<a href="#">Loc12</a>	Baldwin	0.00	---	---	---	---	Z
<a href="#">Loc13</a>	M-59 Access Shaft	0.03	---	---	---	---	MSTT
<a href="#">Loc14</a>	Churchill Munic Bldg	0.03	---	---	---	---	MSTT
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc20</a>	Gascola Eq Facility	0.03	---	---	---	---	MSTT
<a href="#">Loc21</a>	Moon TWP	0.01	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.00	---	---	---	---	Z
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.00	---	---	---	---	C
<a href="#">Loc27</a>	Marshall TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc28</a>	Plum Municipal Bldg	0.02	---	---	---	---	MSTT
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.03	---	---	---	---	MSTT
<a href="#">Loc30</a>	McCandless Twn Hall	0.03	---	---	---	---	MSTT
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.01	---	---	---	---	MSTT

**Table 37. Summary of Individual RG Pairs for Event 5i**

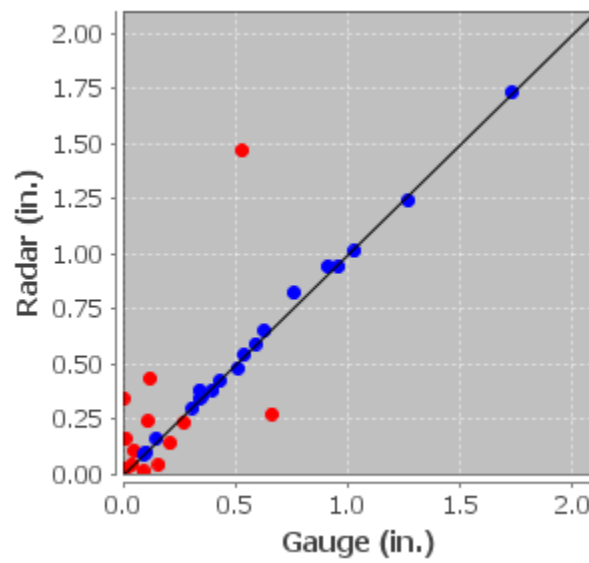
Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc08</a>	AC Health Dept Bldg	0.34	0.32	0.35	-0.01	-2.9	
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.36	0.33	0.37	-0.01	-2.8	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.38	0.33	0.39	-0.01	-2.6	
<a href="#">Loc20</a>	Gascola Eq Facility	0.39	0.39	0.40	-0.01	-2.6	
<a href="#">Loc11</a>	M-46 Access Shaft	0.41	0.40	0.42	-0.01	-2.4	
<a href="#">03049500</a>	Allegheny River at Natrona	0.44	0.28	0.44	0.00	0.0	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.38	0.38	0.38	0.00	0.0	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.41	0.37	0.41	0.00	0.0	
<a href="#">Loc04</a>	Kennedy Twp PS	0.40	0.39	0.40	0.00	0.0	
<a href="#">Loc05</a>	Upper St. Clair	0.32	0.27	0.32	0.00	0.0	
<a href="#">Loc13</a>	M-59 Access Shaft	0.39	0.38	0.39	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.37	0.36	0.37	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.37	0.34	0.37	0.00	0.0	
<a href="#">Loc17</a>	Chartiers Pump Station	0.34	0.28	0.34	0.00	0.0	
<a href="#">Loc18</a>	Oakdale Pump Station	0.41	0.32	0.41	0.00	0.0	



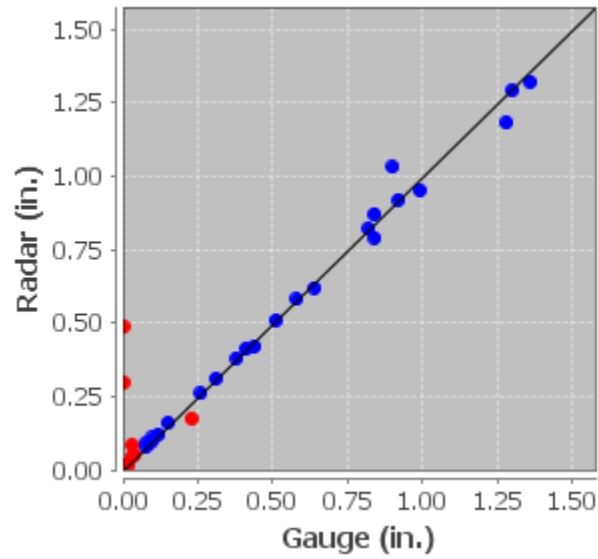
<b>Gauge ID</b>	<b>Name</b>	<b>G<sub>i</sub> (in)</b>	<b>R<sub>i</sub> (in)</b>	<b>R<sub>i</sub>* (in)</b>	<b>Diff* (in)</b>	<b>Diff* (%)</b>	<b>Flag</b>
<a href="#">Loc21</a>	Moon TWP	0.40	0.38	0.40	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.39	0.32	0.39	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.36	0.31	0.36	0.00	0.0	
<a href="#">Loc24</a>	Jefferson Hills	0.31	0.30	0.31	0.00	0.0	
<a href="#">Loc27</a>	Marshall TWP	0.33	0.31	0.33	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.35	0.29	0.35	0.00	0.0	
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.60	0.47	0.60	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.31	0.24	0.31	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.60	0.40	0.60	0.00	0.0	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.46	0.40	0.45	0.01	2.2	
<a href="#">Loc06</a>	Carnegie Transit Time	0.41	0.32	0.40	0.01	2.4	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.34	0.29	0.33	0.01	2.9	
<a href="#">Loc10</a>	PWSA-Highland Park	0.34	0.29	0.33	0.01	2.9	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.35	---	---	---	---	U
<a href="#">Loc01</a>	PWSA-Montana St.	ND	---	---	---	---	ND
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.31	---	---	---	---	U
<a href="#">Loc09</a>	Univ of Pittsburgh	0.28	---	---	---	---	U
<a href="#">Loc12</a>	Baldwin	0.00	---	---	---	---	Z
<a href="#">Loc19</a>	Sandy Creek Eq Facility	ND	---	---	---	---	ND
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.00	---	---	---	---	Z
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.01	---	---	---	---	C
<a href="#">Loc30</a>	McCandless Twn Hall	0.43	---	---	---	---	U



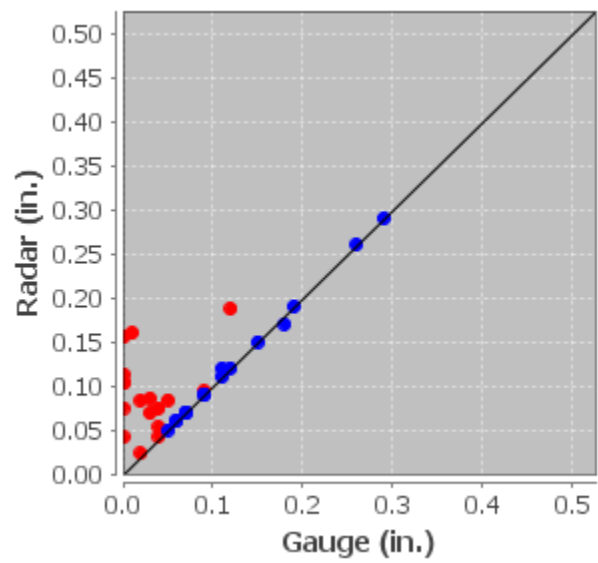
**Figure 23. Scatter Plot of RG Pairs for Event 5a**



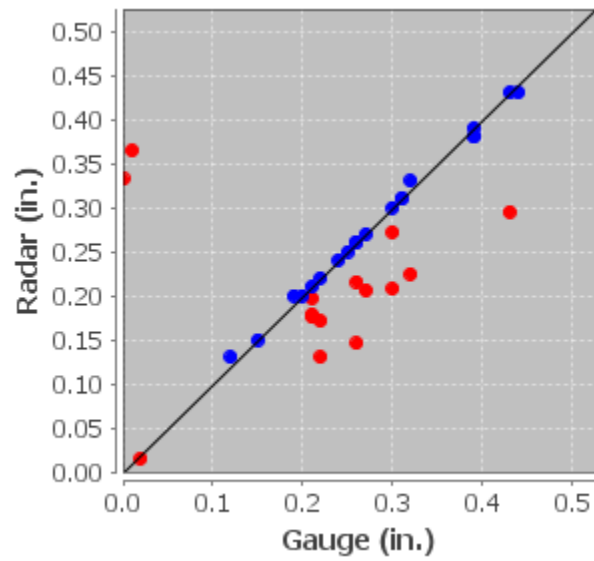
**Figure 24. Scatter Plot of RG Pairs for Event 5b**



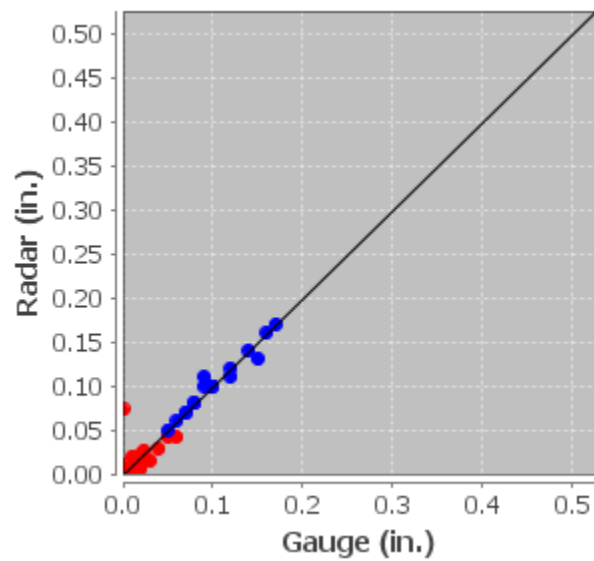
**Figure 25. Scatter Plot of RG Pairs for Event 5c**



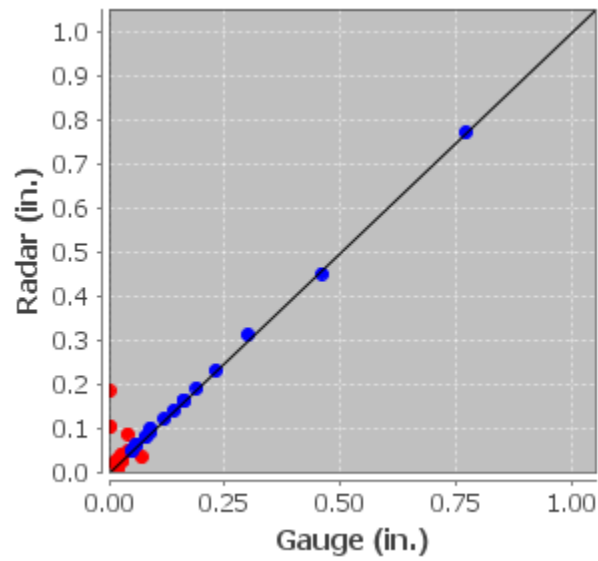
**Figure 26. Scatter Plot of RG Pairs for Event 5d**



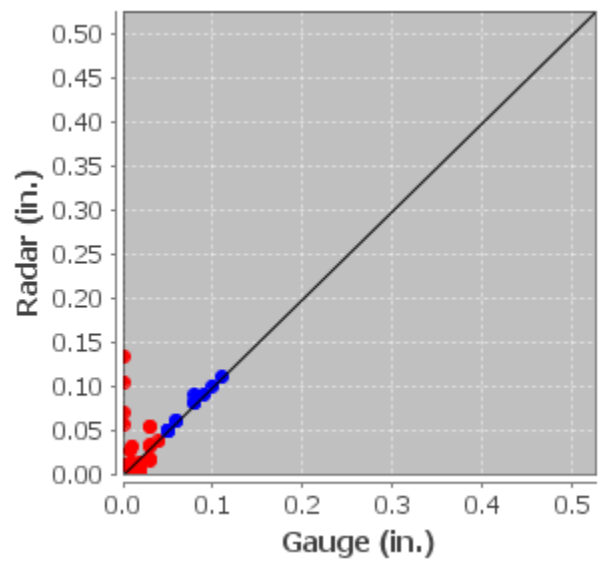
**Figure 27. Scatter Plot of RG Pairs for Event 5e**



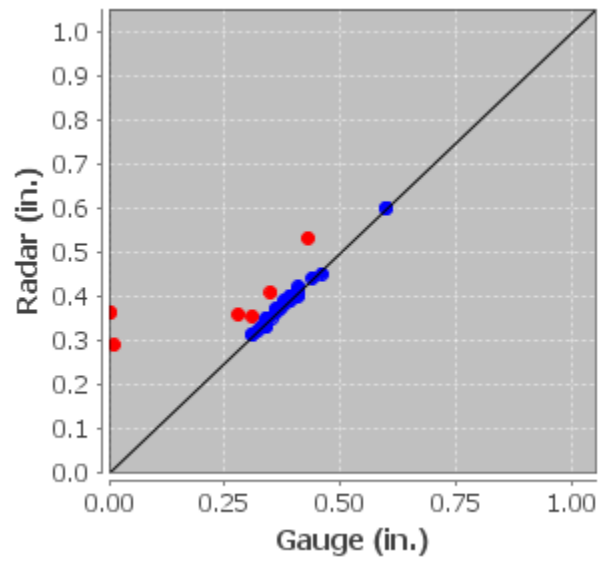
**Figure 28. Scatter Plot of RG Pairs for Event 5f**



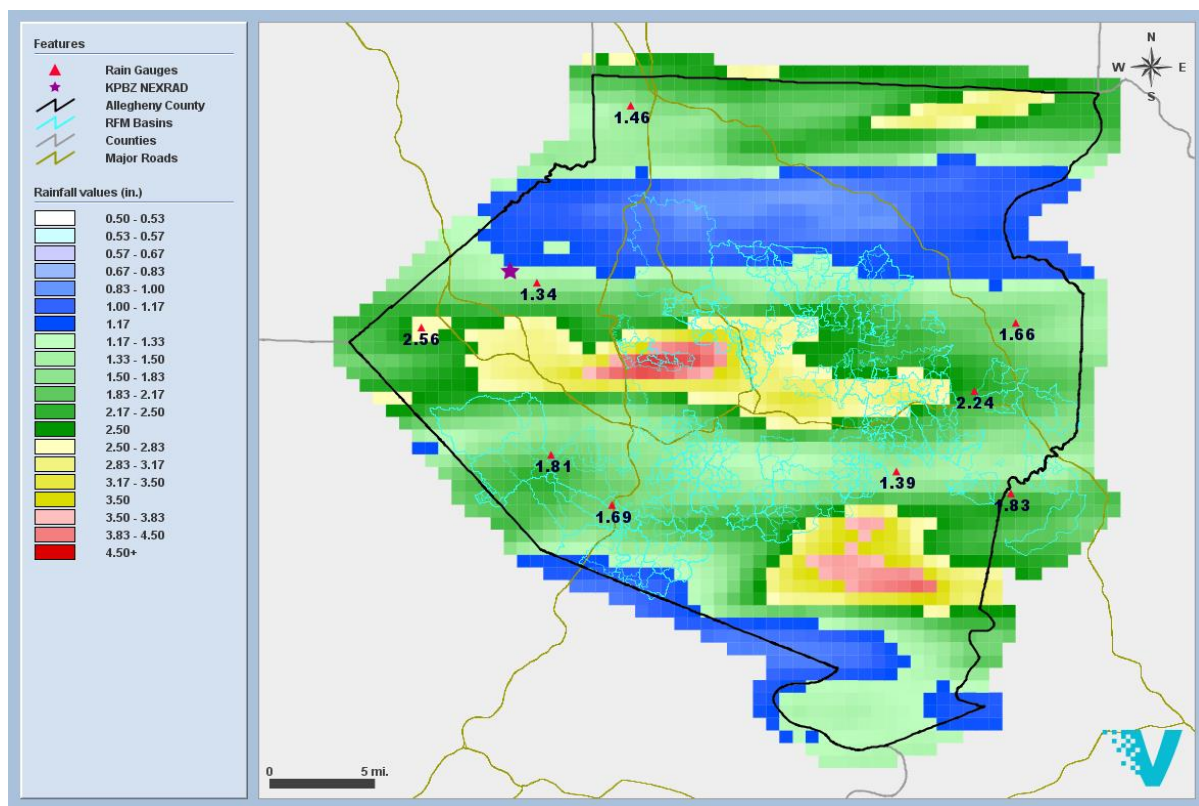
**Figure 29. Scatter Plot of RG Pairs for Event 5g**



**Figure 30. Scatter Plot of RG Pairs for Event 5h**



**Figure 31. Scatter Plot of RG Pairs for Event 5i**



**Figure 32. GARR Storm Total for Event 5**

**Table 38. Depth Duration Frequency Analyses for Event 5**

<b>Duration</b>	<b>Depth (in)</b>	<b>Pixel</b>	<b>Time (EDT)</b>	<b>Frequency</b>
15 minutes	1.417	153151	2020-08-28 12:10	100 yr.
30 minutes	2.078	139135	2020-08-28 13:15	100 yr.
1 hour	2.881	142135	2020-08-28 13:45	200 yr.
2 hour	3.384	139135	2020-08-28 14:40	200 yr.
3 hour	3.498	139135	2020-08-28 15:40	200 yr.
6 hour	3.777	139135	2020-08-28 18:40	100 yr.
12 hour	4.217	139135	2020-08-29 00:15	50 yr.
24 hour	4.217	139135	2020-08-29 05:00	25 yr.

## Appendices



[Appendix A](#) - Gauge Performance Exclusion Table  
[Appendix B](#) - Gauge Statistical Criteria Exclusion Table  
[Appendix C](#) - Event 1 (2020-08-01) CDPs  
[Appendix D](#) - Event 2 (2020-08-04) CDPs  
[Appendix E](#) - Event 3 (2020-08-25) CDPs  
[Appendix F](#) - Event 4 (2020-08-27) CDPs  
[Appendix G](#) - Event 5 (2020-08-28) CDPs

### Appendix A - Gauge Performance Exclusion Table

Reason	Explanation
Clog (C)	Gauge appeared to be clogged
Zero (Z)	Gauge did not report any rainfall while radar rainfall estimates reported significant rainfall
Stop (S)	Gauge appeared to stop reporting rainfall while radar rainfall estimates reported significant rainfall
Over (O)	Gauge appeared to significantly over-report rainfall as compared to radar rainfall estimates and surrounding gauges (e.g. anomalously high rainfall values caused by field calibration, data transmission error, or switch malfunctions)
Under (U)	Gauge appeared to significantly under-report as compared to radar rainfall estimates and surrounding Gauges (e.g. half-tipper)
Sync (SY)	Gauge appeared to be reporting out-of-sync with the radar rainfall estimates
Frozen/Melt (F/M)	Gauge not reporting properly due to frozen or melting precipitation
Other (T)	Combination of multiple reasons
No Data (ND)	Gauge reported "no data" for a significant amount of time

Event #	<a href="#">E1a</a>	<a href="#">E1b</a>	<a href="#">E1c</a>	<a href="#">E1d</a>	<a href="#">E1e</a>
Event Date	2020-08-01	2020-08-01	2020-08-01	2020-08-01	2020-08-01
Start Time (EDT)	2020-08-01 06:05	2020-08-01 12:05	2020-08-01 16:05	2020-08-01 18:05	2020-08-01 22:05
End Time (EDT)	2020-08-01 12:00	2020-08-01 16:00	2020-08-01 18:00	2020-08-01 22:00	2020-08-02 06:00
Loc01		U			U
Loc02					
Loc03					
Loc04					
Loc05					U
Loc06					
Loc07					
Loc08					
Loc09					
Loc10	ND	ND	ND	ND	ND
Loc11					
Loc12				U	
Loc13					
Loc14					
Loc15					
Loc16					
Loc17	ND	ND	ND	ND	ND
Loc18		O			
Loc19	ND	ND	ND	ND	ND
Loc20				U	
Loc21					
Loc22					
Loc23					
Loc24					
Loc25					
Loc26				C	C
Loc27					
Loc28					

Event #	<a href="#">E1a</a>	<a href="#">E1b</a>	<a href="#">E1c</a>	<a href="#">E1d</a>	<a href="#">E1e</a>
Event Date	2020-08-01	2020-08-01	2020-08-01	2020-08-01	2020-08-01
Start Time (EDT)	2020-08-01 06:05	2020-08-01 12:05	2020-08-01 16:05	2020-08-01 18:05	2020-08-01 22:05
End Time (EDT)	2020-08-01 12:00	2020-08-01 16:00	2020-08-01 18:00	2020-08-01 22:00	2020-08-02 06:00
Loc29	C	C	C	C	C
Loc30					
Loc31					
Loc32					
Loc33					
KAGC	ND				
KPIT					
03049500		Z		U	
03085734					

Event #	<a href="#">E2a</a>	<a href="#">E2b</a>	<a href="#">E2c</a>	<a href="#">E3a</a>	<a href="#">E3b</a>
Event Date	2020-08-04	2020-08-04	2020-08-04	2020-08-25	2020-08-25
Start Time (EDT)	2020-08-04 06:05	2020-08-04 18:05	2020-08-04 21:05	2020-08-25 12:05	2020-08-25 15:50
End Time (EDT)	2020-08-04 18:00	2020-08-04 21:00	2020-08-05 03:00	2020-08-25 15:45	2020-08-25 16:00
Loc01	U			ND	ND
Loc02					
Loc03					
Loc04					
Loc05		U			
Loc06					
Loc07					
Loc08					
Loc09					
Loc10	ND	ND	ND		
Loc11					
Loc12					
Loc13					
Loc14	C	C	C		
Loc15					
Loc16					
Loc17	ND	ND	ND		
Loc18					
Loc19	ND	ND	ND	ND	ND
Loc20					
Loc21					
Loc22					
Loc23					
Loc24					
Loc25					
Loc26	C	C			

Event #	<a href="#">E2a</a>	<a href="#">E2b</a>	<a href="#">E2c</a>	<a href="#">E3a</a>	<a href="#">E3b</a>
Event Date	2020-08-04	2020-08-04	2020-08-04	2020-08-25	2020-08-25
Start Time (EDT)	2020-08-04 06:05	2020-08-04 18:05	2020-08-04 21:05	2020-08-25 12:05	2020-08-25 15:50
End Time (EDT)	2020-08-04 18:00	2020-08-04 21:00	2020-08-05 03:00	2020-08-25 15:45	2020-08-25 16:00
Loc27					
Loc28					
Loc29	C	C	C	C	O
Loc30					
Loc31					
Loc32					
Loc33					
KAGC					
KPIT					
03049500		U			
03085734					

Event #	<a href="#">E3c</a>	<a href="#">E4a</a>	<a href="#">E4b</a>	<a href="#">E4c</a>	<a href="#">E4d</a>
Event Date	2020-08-25	2020-08-27	2020-08-27	2020-08-27	2020-08-27
Start Time (EDT)	2020-08-25 16:05	2020-08-27 08:05	2020-08-27 13:05	2020-08-27 16:05	2020-08-27 22:05
End Time (EDT)	2020-08-25 21:00	2020-08-27 13:00	2020-08-27 16:00	2020-08-27 22:00	2020-08-28 05:00
Loc01	ND	ND	ND	ND	ND
Loc02					
Loc03					Z
Loc04					
Loc05				Z	
Loc06				S	
Loc07				S	
Loc08				S	Z
Loc09				S	
Loc10				S	Z
Loc11	U	Z	U	Z	
Loc12		ND	ND	ND	ND
Loc13					
Loc14				Z	Z
Loc15				Z	
Loc16				Z	
Loc17				Z	
Loc18					
Loc19	ND	ND	ND	ND	ND
Loc20					
Loc21				S	
Loc22				S	
Loc23				S	
Loc24				Z	
Loc25				Z	
Loc26	C		C	C	

Event #	<a href="#">E3c</a>	<a href="#">E4a</a>	<a href="#">E4b</a>	<a href="#">E4c</a>	<a href="#">E4d</a>
Event Date	2020-08-25	2020-08-27	2020-08-27	2020-08-27	2020-08-27
Start Time (EDT)	2020-08-25 16:05	2020-08-27 08:05	2020-08-27 13:05	2020-08-27 16:05	2020-08-27 22:05
End Time (EDT)	2020-08-25 21:00	2020-08-27 13:00	2020-08-27 16:00	2020-08-27 22:00	2020-08-28 05:00
Loc27					
Loc28					
Loc29					Z
Loc30					
Loc31					Z
Loc32					Z
Loc33				ND	ND
KAGC					
KPIT					
03049500	U				
03085734				U	



Event #	<a href="#">E5a</a>	<a href="#">E5b</a>	<a href="#">E5c</a>	<a href="#">E5d</a>	<a href="#">E5e</a>
Event Date	2020-08-28	2020-08-28	2020-08-28	2020-08-28	2020-08-28
Start Time (EDT)	2020-08-28 05:05	2020-08-28 12:35	2020-08-28 13:20	2020-08-28 14:35	2020-08-28 15:35
End Time (EDT)	2020-08-28 12:30	2020-08-28 13:15	2020-08-28 14:30	2020-08-28 15:30	2020-08-28 18:30
Loc01	ND	ND	ND	ND	ND
Loc02					O
Loc03		U			O
Loc04		U			
Loc05				S	
Loc06					O
Loc07		O			O
Loc08					O
Loc09					O
Loc10					O
Loc11					O
Loc12	ND	ND		Z	O
Loc13					
Loc14					O
Loc15					
Loc16				Z	
Loc17					
Loc18					
Loc19	ND	ND	ND	ND	ND
Loc20					
Loc21					
Loc22	O				
Loc23					
Loc24				Z	
Loc25	Z	Z	Z	Z	Z
Loc26	C		C	C	C

Event #	<a href="#">E5a</a>	<a href="#">E5b</a>	<a href="#">E5c</a>	<a href="#">E5d</a>	<a href="#">E5e</a>
Event Date	2020-08-28	2020-08-28	2020-08-28	2020-08-28	2020-08-28
Start Time (EDT)	2020-08-28 05:05	2020-08-28 12:35	2020-08-28 13:20	2020-08-28 14:35	2020-08-28 15:35
End Time (EDT)	2020-08-28 12:30	2020-08-28 13:15	2020-08-28 14:30	2020-08-28 15:30	2020-08-28 18:30
Loc27					
Loc28					
Loc29		O			O
Loc30					
Loc31				U	O
Loc32		O		O	
Loc33	ND	ND	ND	ND	ND
KAGC	U	O	O	U	
KPIT					
03049500		U		U	
03085734		U			

Event #	<a href="#"><u>E5f</u></a>	<a href="#"><u>E5g</u></a>	<a href="#"><u>E5h</u></a>	<a href="#"><u>E5i</u></a>
Event Date	2020-08-28	2020-08-28	2020-08-28	2020-08-28
Start Time (EDT)	2020-08-28 18:35	2020-08-28 19:50	2020-08-28 21:50	2020-08-28 22:50
End Time (EDT)	2020-08-28 19:45	2020-08-28 21:45	2020-08-28 22:45	2020-08-29 06:00
Loc01	ND	ND	ND	ND
Loc02				U
Loc03				
Loc04				
Loc05				
Loc06				
Loc07				
Loc08				
Loc09				U
Loc10				
Loc11				
Loc12		Z	Z	Z
Loc13				
Loc14				
Loc15				
Loc16				
Loc17				
Loc18				
Loc19	ND	ND	ND	ND
Loc20				
Loc21				
Loc22				
Loc23				
Loc24				
Loc25		Z	Z	Z
Loc26	C	C	C	C
Loc27				
Loc28				

Event #	<a href="#">E5f</a>	<a href="#">E5g</a>	<a href="#">E5h</a>	<a href="#">E5i</a>
Event Date	2020-08-28	2020-08-28	2020-08-28	2020-08-28
Start Time (EDT)	2020-08-28 18:35	2020-08-28 19:50	2020-08-28 21:50	2020-08-28 22:50
End Time (EDT)	2020-08-28 19:45	2020-08-28 21:45	2020-08-28 22:45	2020-08-29 06:00
Loc29				
Loc30				U
Loc31				
Loc32				
Loc33				
KAGC				
KPIT		O		
03049500			Z	
03085734				U

## Appendix B - Gauge Statistical Criteria Exclusion Table

Reason	Explanation
Minimum Storm Total Threshold (MSTT)	The radar or gauge cumulative sum during the event or sub-event period was less than MSTT
Outlier Based on Mean Field Bias (OMFB)	The RG pair bias ( $G/R$ ) was greater than three standard deviations from the mean bias (e.g. $G \gg R$ )
Outlier Based on Average Difference (OAD)	The RG pair average difference ( $(G-R)/G$ ) was greater than three standard deviations from the mean average difference (e.g. $G \ll R$ )

Event #	<a href="#">E1a</a>	<a href="#">E1b</a>	<a href="#">E1c</a>	<a href="#">E1d</a>	<a href="#">E1e</a>
Event Date	2020-08-01	2020-08-01	2020-08-01	2020-08-01	2020-08-01
Start Time (EDT)	2020-08-01 06:05	2020-08-01 12:05	2020-08-01 16:05	2020-08-01 18:05	2020-08-01 22:05
End Time (EDT)	2020-08-01 12:00	2020-08-01 16:00	2020-08-01 18:00	2020-08-01 22:00	2020-08-02 06:00
Source	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII
Loc01	MSTT		MSTT	MSTT	
Loc02	MSTT		MSTT	MSTT	
Loc03	MSTT		MSTT	MSTT	
Loc04	MSTT		MSTT	MSTT	
Loc05	MSTT		MSTT		
Loc06	MSTT		MSTT	MSTT	
Loc07	MSTT		MSTT	MSTT	
Loc08	MSTT		MSTT	MSTT	
Loc09	MSTT		MSTT	MSTT	
Loc10					
Loc11	MSTT	MSTT	MSTT		
Loc12	MSTT	MSTT	MSTT		
Loc13	MSTT	MSTT	MSTT		
Loc14	MSTT		MSTT		
Loc15	MSTT	MSTT	MSTT		
Loc16	MSTT		MSTT		
Loc17					
Loc18	MSTT		MSTT	MSTT	
Loc19					
Loc20	MSTT	MSTT	MSTT		
Loc21					
Loc22	MSTT		MSTT		
Loc23	MSTT				
Loc24	MSTT	MSTT	MSTT	OAD	
Loc25	MSTT	MSTT	MSTT		
Loc26	MSTT	MSTT			
Loc27					

Event #	<a href="#">E1a</a>	<a href="#">E1b</a>	<a href="#">E1c</a>	<a href="#">E1d</a>	<a href="#">E1e</a>
Event Date	2020-08-01	2020-08-01	2020-08-01	2020-08-01	2020-08-01
Start Time (EDT)	2020-08-01 06:05	2020-08-01 12:05	2020-08-01 16:05	2020-08-01 18:05	2020-08-01 22:05
End Time (EDT)	2020-08-01 12:00	2020-08-01 16:00	2020-08-01 18:00	2020-08-01 22:00	2020-08-02 06:00
Source	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII
Loc28	MSTT		MSTT		MSTT
Loc29					
Loc30	MSTT				
Loc31	MSTT		MSTT	MSTT	
Loc32	MSTT		MSTT		MSTT
Loc33	MSTT		MSTT	MSTT	
KAGC		MSTT	MSTT		
KPIT	MSTT		MSTT		
03049500	MSTT		MSTT		MSTT
03085734	MSTT		MSTT	MSTT	

<b>Event #</b>	<b><u>E2a</u></b>	<b><u>E2b</u></b>	<b><u>E2c</u></b>	<b><u>E3a</u></b>	<b><u>E3b</u></b>
<b>Event Date</b>	<b>2020-08-04</b>	<b>2020-08-04</b>	<b>2020-08-04</b>	<b>2020-08-25</b>	<b>2020-08-25</b>
<b>Start Time (EDT)</b>	2020-08-04 06:05	2020-08-04 18:05	2020-08-04 21:05	2020-08-25 12:05	2020-08-25 15:50
<b>End Time (EDT)</b>	2020-08-04 18:00	2020-08-04 21:00	2020-08-05 03:00	2020-08-25 15:45	2020-08-25 16:00
<b>Source</b>	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII
Loc01			MSTT		
Loc02			MSTT	MSTT	MSTT
Loc03			MSTT		MSTT
Loc04			MSTT	MSTT	MSTT
Loc05	MSTT		MSTT	MSTT	MSTT
Loc06	MSTT	MSTT	MSTT	MSTT	MSTT
Loc07			MSTT	MSTT	
Loc08			MSTT	MSTT	MSTT
Loc09			MSTT	MSTT	MSTT
Loc10					MSTT
Loc11	MSTT		MSTT	MSTT	MSTT
Loc12	MSTT		MSTT	MSTT	MSTT
Loc13	OAD		MSTT	MSTT	MSTT
Loc14					MSTT
Loc15		MSTT	MSTT	MSTT	MSTT
Loc16	MSTT		MSTT	MSTT	MSTT
Loc17				MSTT	MSTT
Loc18		MSTT	MSTT	MSTT	MSTT
Loc19					
Loc20			MSTT	MSTT	
Loc21			MSTT	MSTT	MSTT
Loc22		MSTT	MSTT	MSTT	MSTT
Loc23				MSTT	MSTT
Loc24	MSTT	MSTT	MSTT	MSTT	MSTT
Loc25	MSTT		MSTT	MSTT	MSTT



Event #	<a href="#">E2a</a>	<a href="#">E2b</a>	<a href="#">E2c</a>	<a href="#">E3a</a>	<a href="#">E3b</a>
Event Date	2020-08-04	2020-08-04	2020-08-04	2020-08-25	2020-08-25
Start Time (EDT)	2020-08-04 06:05	2020-08-04 18:05	2020-08-04 21:05	2020-08-25 12:05	2020-08-25 15:50
End Time (EDT)	2020-08-04 18:00	2020-08-04 21:00	2020-08-05 03:00	2020-08-25 15:45	2020-08-25 16:00
Source	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII
Loc26			MSTT	MSTT	MSTT
Loc27	MSTT		MSTT	MSTT	MSTT
Loc28			MSTT	MSTT	MSTT
Loc29					
Loc30	MSTT	MSTT	MSTT	MSTT	MSTT
Loc31	MSTT		MSTT	MSTT	MSTT
Loc32		MSTT	MSTT		MSTT
Loc33			MSTT	MSTT	MSTT
KAGC			MSTT	MSTT	MSTT
KPIT				MSTT	MSTT
03049500	MSTT		MSTT	MSTT	MSTT
03085734			MSTT	MSTT	MSTT

<b>Event #</b>	<b><u>E3c</u></b>	<b><u>E4a</u></b>	<b><u>E4b</u></b>	<b><u>E4c</u></b>	<b><u>E4d</u></b>
<b>Event Date</b>	<b>2020-08-25</b>	<b>2020-08-27</b>	<b>2020-08-27</b>	<b>2020-08-27</b>	<b>2020-08-27</b>
<b>Start Time (EDT)</b>	2020-08-25 16:05	2020-08-27 08:05	2020-08-27 13:05	2020-08-27 16:05	2020-08-27 22:05
<b>End Time (EDT)</b>	2020-08-25 21:00	2020-08-27 13:00	2020-08-27 16:00	2020-08-27 22:00	2020-08-28 05:00
<b>Source</b>	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII
Loc01					
Loc02					MSTT
Loc03		MSTT	MSTT		
Loc04					MSTT
Loc05		MSTT			MSTT
Loc06	MSTT	MSTT	MSTT		MSTT
Loc07	MSTT	MSTT			MSTT
Loc08					
Loc09					MSTT
Loc10					
Loc11					MSTT
Loc12					
Loc13		MSTT	MSTT		MSTT
Loc14					
Loc15		MSTT			MSTT
Loc16	MSTT	MSTT	MSTT		MSTT
Loc17		MSTT	MSTT		MSTT
Loc18		MSTT	MSTT		MSTT
Loc19					
Loc20					
Loc21		MSTT	MSTT		MSTT
Loc22		MSTT	MSTT		MSTT
Loc23	MSTT		MSTT		MSTT
Loc24	MSTT	MSTT			MSTT
Loc25	MSTT	MSTT	MSTT		MSTT

Event #	<a href="#">E3c</a>	<a href="#">E4a</a>	<a href="#">E4b</a>	<a href="#">E4c</a>	<a href="#">E4d</a>
Event Date	2020-08-25	2020-08-27	2020-08-27	2020-08-27	2020-08-27
Start Time (EDT)	2020-08-25 16:05	2020-08-27 08:05	2020-08-27 13:05	2020-08-27 16:05	2020-08-27 22:05
End Time (EDT)	2020-08-25 21:00	2020-08-27 13:00	2020-08-27 16:00	2020-08-27 22:00	2020-08-28 05:00
Source	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII
Loc26		MSTT			MSTT
Loc27	MSTT				
Loc28	MSTT		MSTT		MSTT
Loc29			MSTT		
Loc30	MSTT	MSTT	MSTT		
Loc31	MSTT	MSTT	MSTT		
Loc32		MSTT	MSTT		
Loc33	MSTT		MSTT		
KAGC		MSTT	MSTT		MSTT
KPIT	MSTT		MSTT		MSTT
03049500			MSTT		
03085734		MSTT	MSTT		MSTT

Event #	<a href="#">E5a</a>	<a href="#">E5b</a>	<a href="#">E5c</a>	<a href="#">E5d</a>	<a href="#">E5e</a>
Event Date	2020-08-28	2020-08-28	2020-08-28	2020-08-28	2020-08-28
Start Time (EDT)	2020-08-28 05:05	2020-08-28 12:35	2020-08-28 13:20	2020-08-28 14:35	2020-08-28 15:35
End Time (EDT)	2020-08-28 12:30	2020-08-28 13:15	2020-08-28 14:30	2020-08-28 15:30	2020-08-28 18:30
Source	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII
Loc01					
Loc02	MSTT				
Loc03	MSTT				
Loc04	MSTT				
Loc05		MSTT	MSTT		
Loc06	MSTT				
Loc07	MSTT				
Loc08	MSTT				
Loc09	MSTT				
Loc10	MSTT			MSTT	
Loc11	MSTT			MSTT	
Loc12			MSTT		
Loc13	MSTT				
Loc14	MSTT			MSTT	
Loc15				MSTT	
Loc16			MSTT		
Loc17			MSTT		
Loc18					
Loc19					
Loc20	MSTT				
Loc21	MSTT				
Loc22		MSTT			
Loc23	MSTT				
Loc24		OAD	MSTT		
Loc25					

Event #	<a href="#">E5a</a>	<a href="#">E5b</a>	<a href="#">E5c</a>	<a href="#">E5d</a>	<a href="#">E5e</a>
Event Date	2020-08-28	2020-08-28	2020-08-28	2020-08-28	2020-08-28
Start Time (EDT)	2020-08-28 05:05	2020-08-28 12:35	2020-08-28 13:20	2020-08-28 14:35	2020-08-28 15:35
End Time (EDT)	2020-08-28 12:30	2020-08-28 13:15	2020-08-28 14:30	2020-08-28 15:30	2020-08-28 18:30
Source	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII
Loc26		MSTT			
Loc27		MSTT		MSTT	
Loc28	MSTT				
Loc29	MSTT				
Loc30	MSTT		MSTT	MSTT	
Loc31	MSTT				
Loc32	MSTT				
Loc33					
KAGC					
KPIT	MSTT				
03049500	MSTT		MSTT		
03085734	MSTT			MSTT	

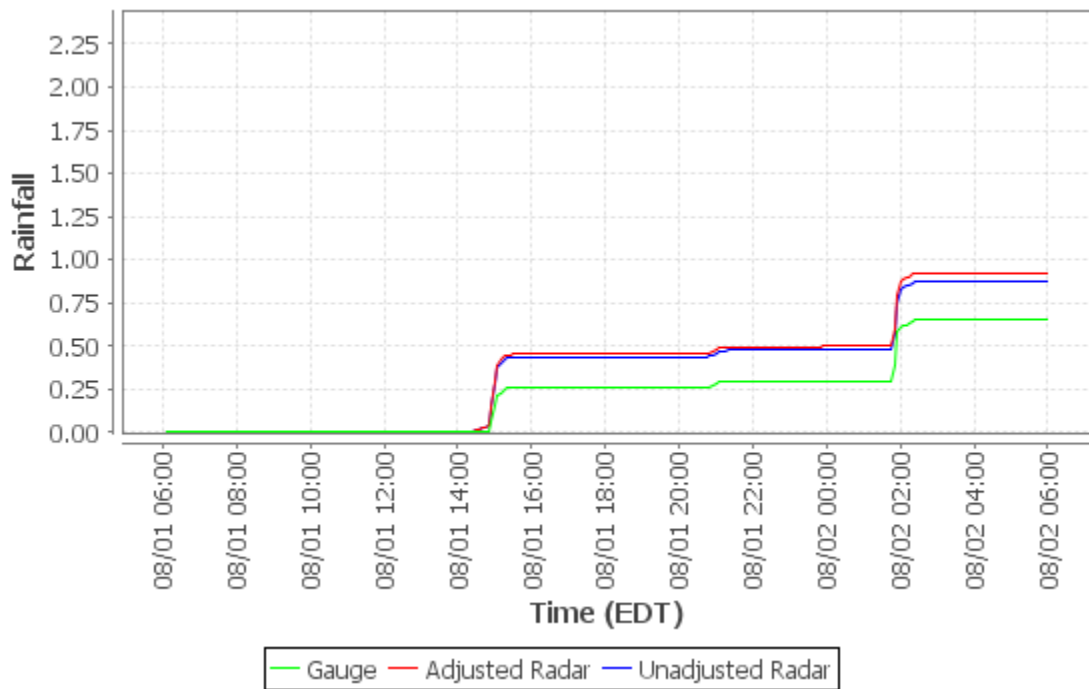
<b>Event #</b>	<b><a href="#">E5f</a></b>	<b><a href="#">E5g</a></b>	<b><a href="#">E5h</a></b>	<b><a href="#">E5i</a></b>
<b>Event Date</b>	<b>2020-08-28</b>	<b>2020-08-28</b>	<b>2020-08-28</b>	<b>2020-08-28</b>
<b>Start Time (EDT)</b>	2020-08-28 18:35	2020-08-28 19:50	2020-08-28 21:50	2020-08-28 22:50
<b>End Time (EDT)</b>	2020-08-28 19:45	2020-08-28 21:45	2020-08-28 22:45	2020-08-29 06:00
<b>Source</b>	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII
Loc01				
Loc02		MSTT	MSTT	
Loc03		MSTT	MSTT	
Loc04		MSTT	MSTT	
Loc05	MSTT			
Loc06	MSTT			
Loc07			MSTT	
Loc08		MSTT	MSTT	
Loc09		MSTT	MSTT	
Loc10		MSTT	MSTT	
Loc11	MSTT		MSTT	
Loc12	MSTT			
Loc13	MSTT		MSTT	
Loc14		MSTT	MSTT	
Loc15	MSTT			
Loc16	MSTT			
Loc17	MSTT			
Loc18				
Loc19				
Loc20		MSTT	MSTT	
Loc21		MSTT	MSTT	
Loc22	MSTT			
Loc23	MSTT			
Loc24	MSTT			
Loc25	MSTT			
Loc26				
Loc27	MSTT		MSTT	

Event #	<a href="#">E5f</a>	<a href="#">E5g</a>	<a href="#">E5h</a>	<a href="#">E5i</a>
Event Date	2020-08-28	2020-08-28	2020-08-28	2020-08-28
Start Time (EDT)	2020-08-28 18:35	2020-08-28 19:50	2020-08-28 21:50	2020-08-28 22:50
End Time (EDT)	2020-08-28 19:45	2020-08-28 21:45	2020-08-28 22:45	2020-08-29 06:00
Source	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII
Loc28		MSTT	MSTT	
Loc29	MSTT		MSTT	
Loc30	MSTT		MSTT	
Loc31		MSTT	MSTT	
Loc32		MSTT		
Loc33	MSTT			
KAGC	MSTT			
KPIT			MSTT	
03049500				
03085734		MSTT	MSTT	

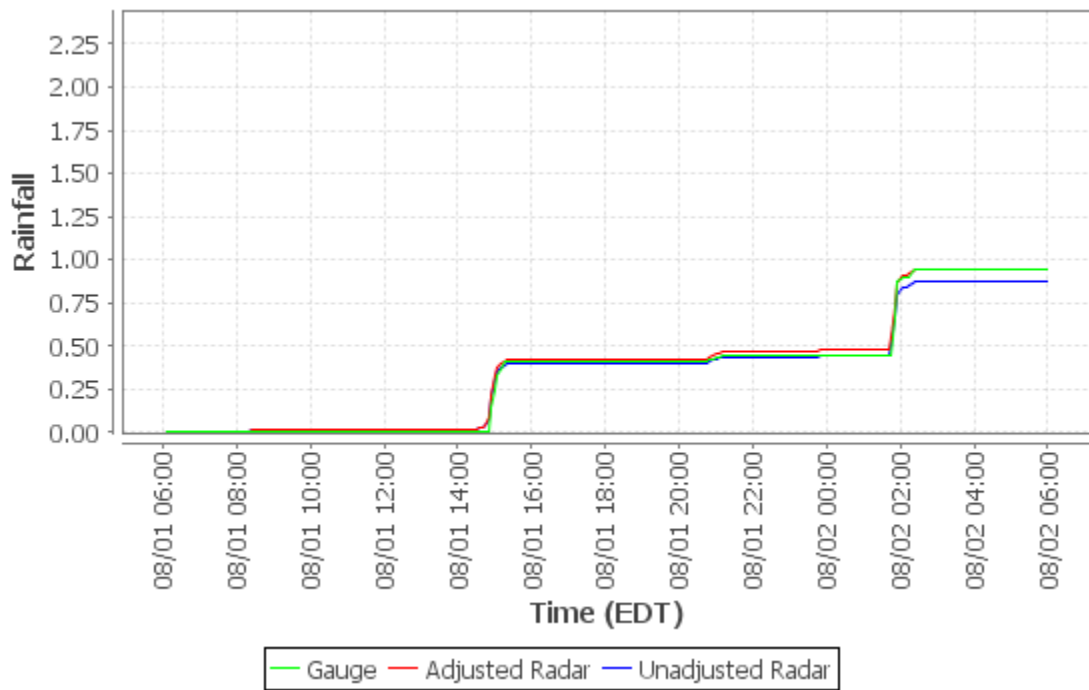
## **Appendix C - Event 1 (2020-08-01) CDPs**



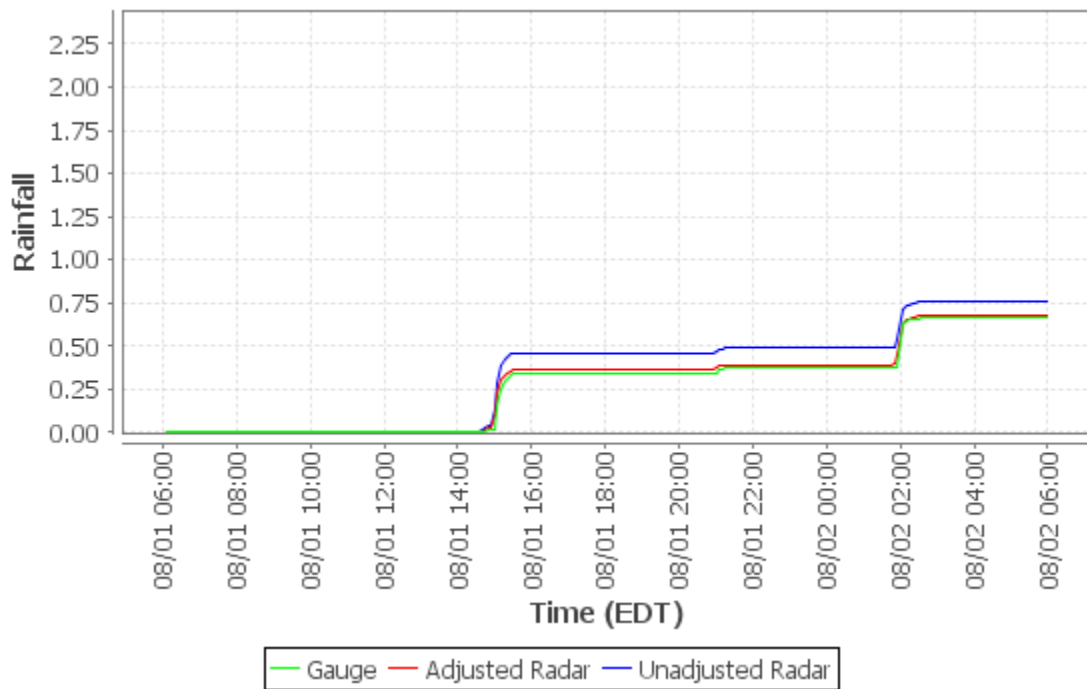
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



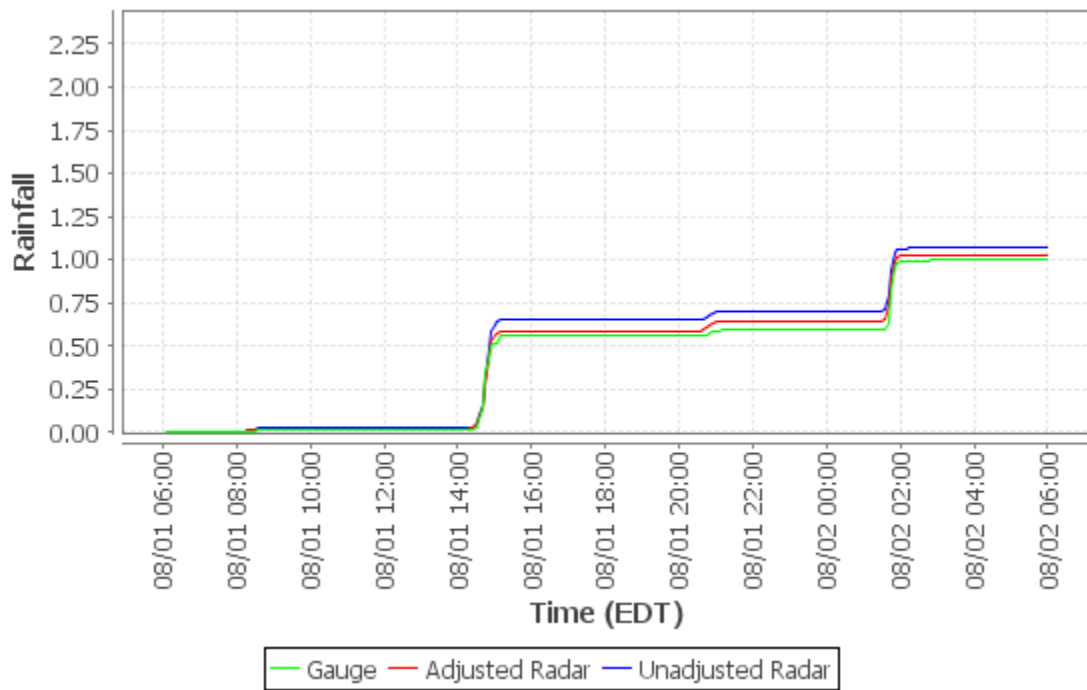
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



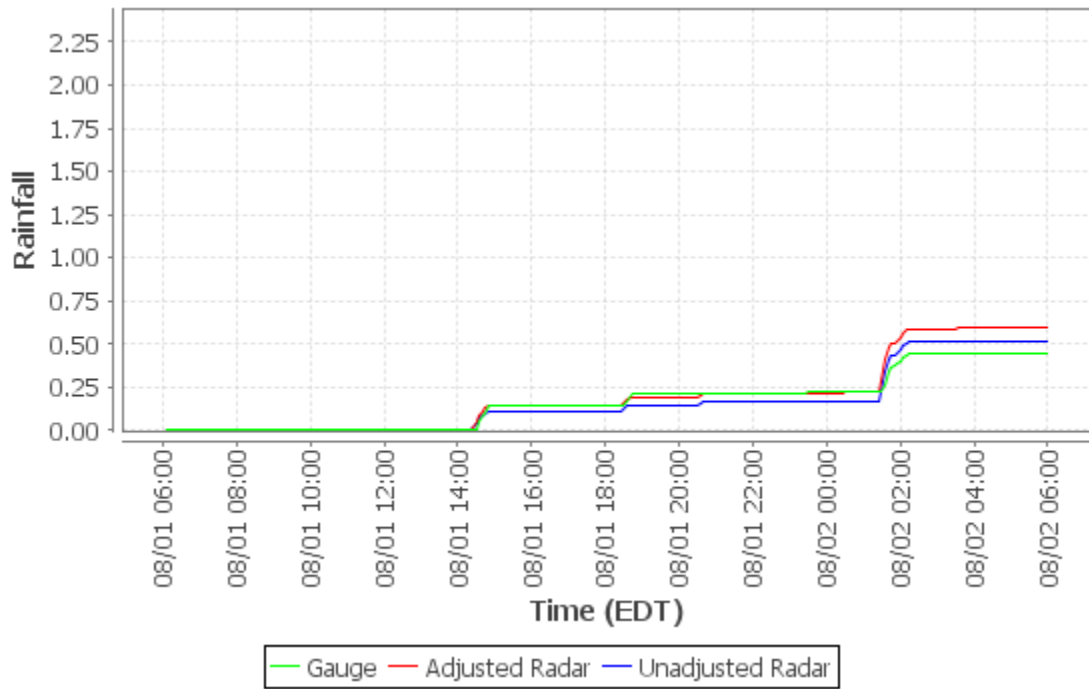
**Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)**



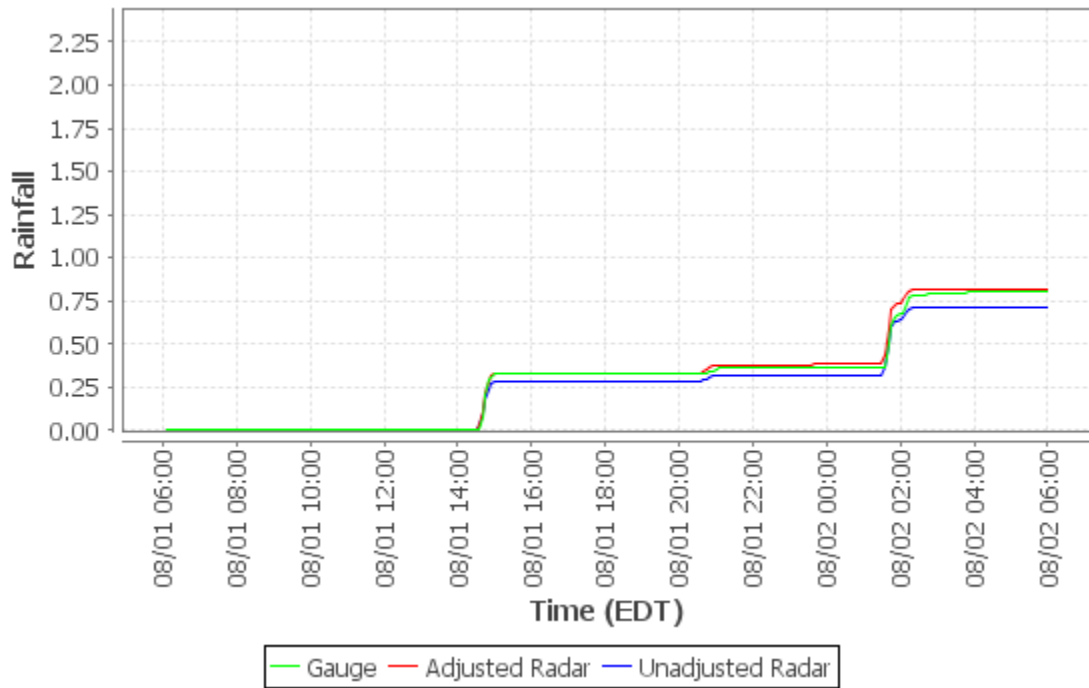
**Cumulative Distribution Plot - Kennedy Twp PS (Loc04)**



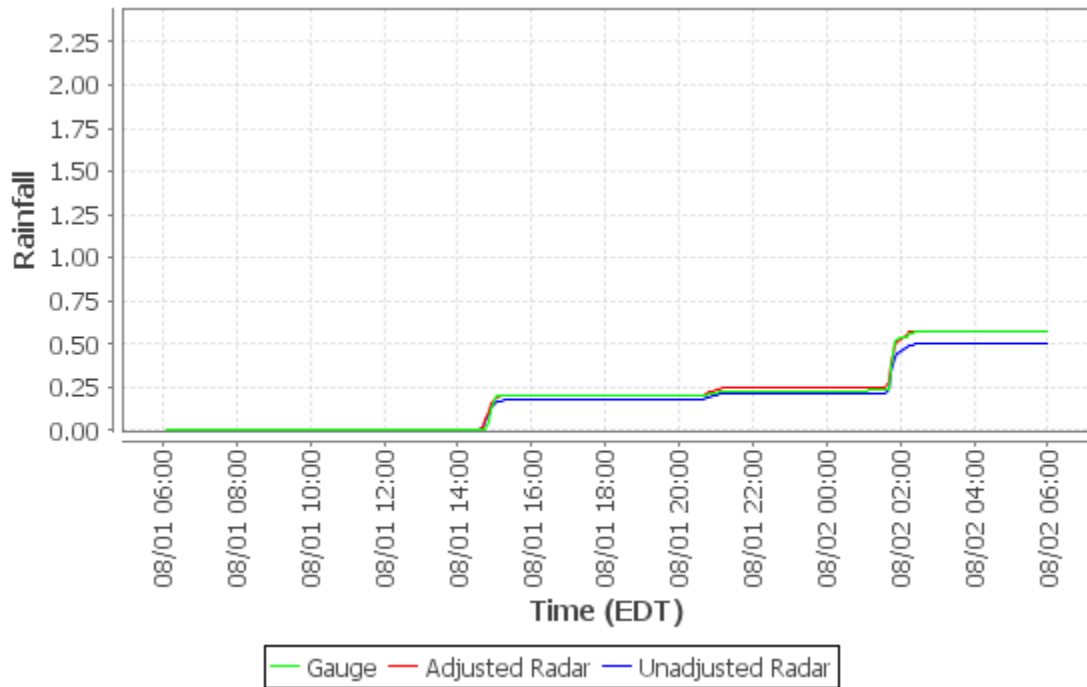
**Cumulative Distribution Plot - Upper St. Clair (Loc05)**



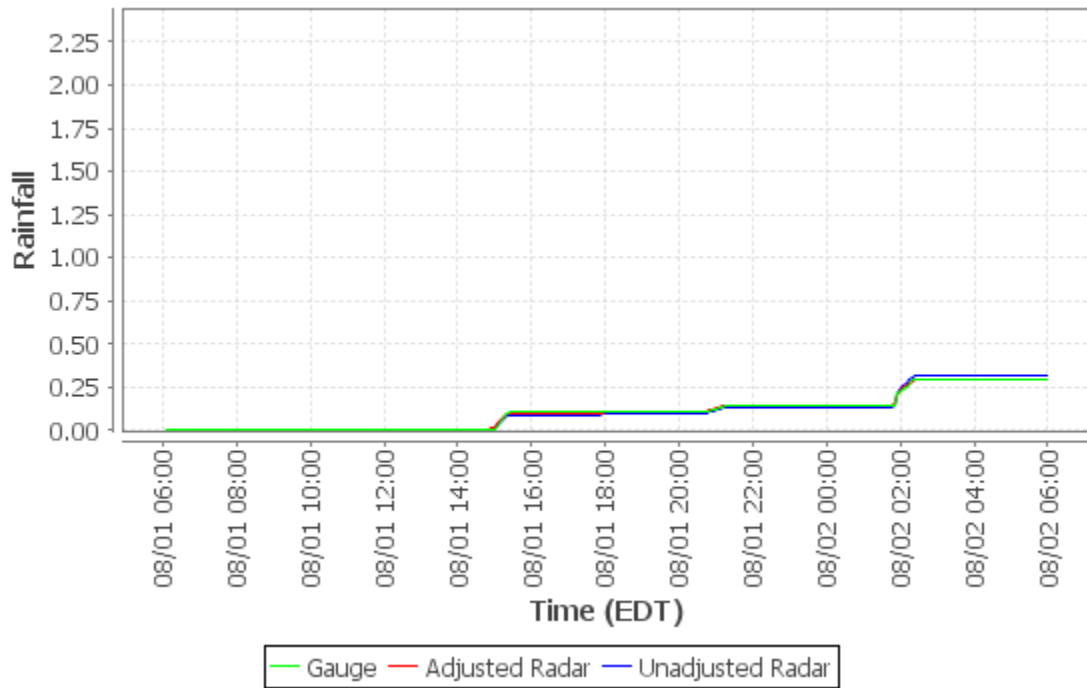
**Cumulative Distribution Plot - Carnegie Transit Time (Loc06)**



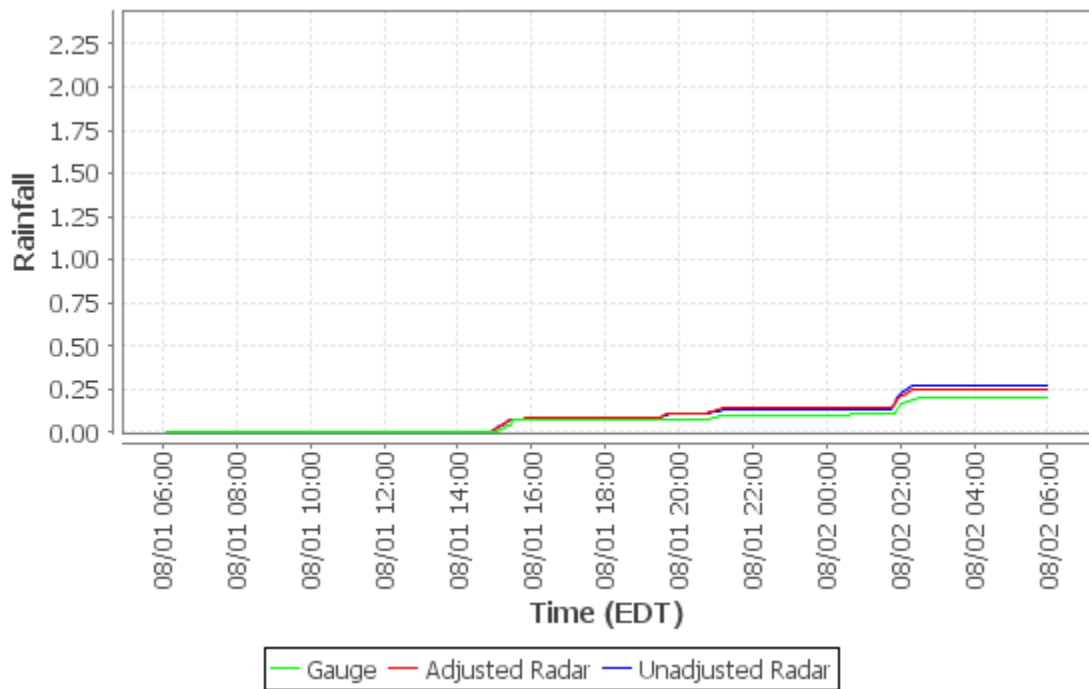
**Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)**



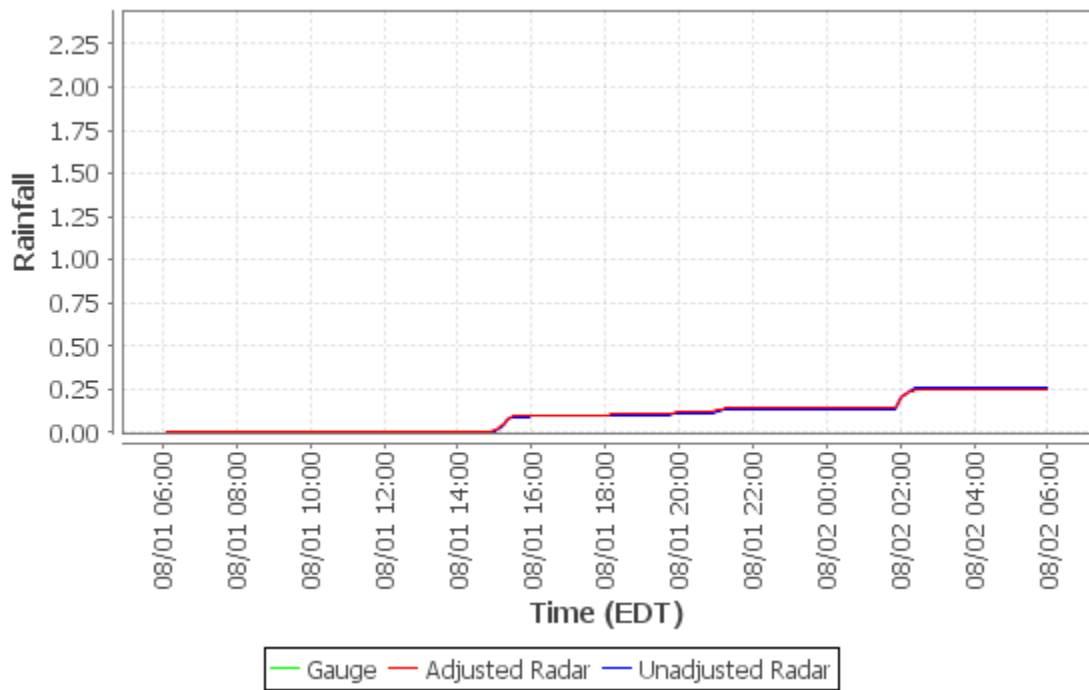
**Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)**



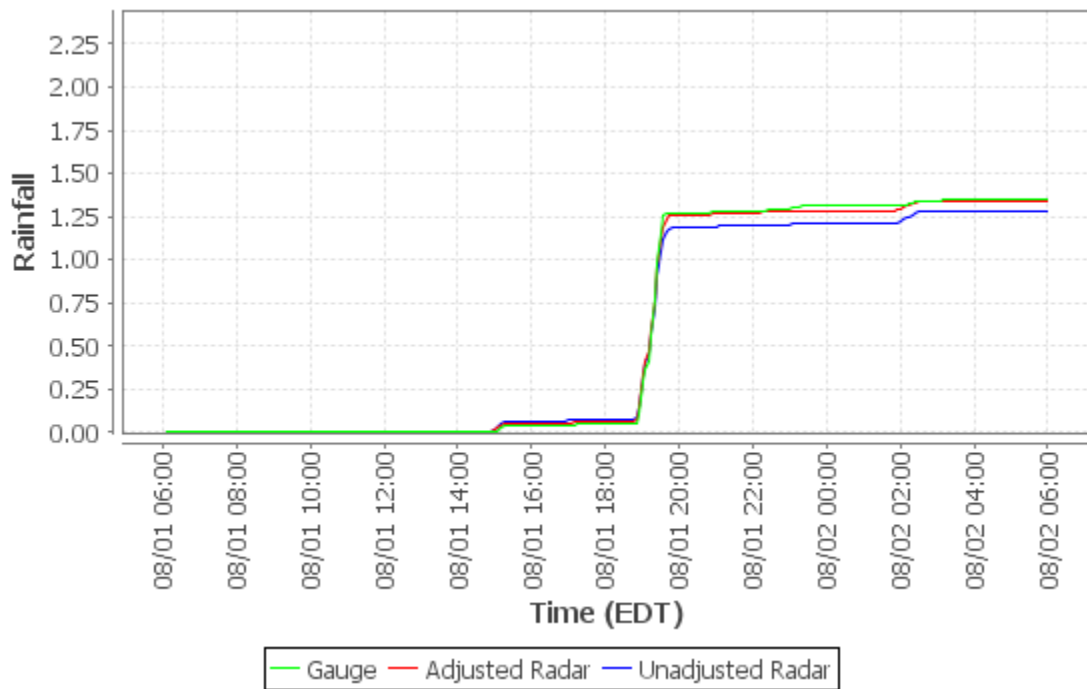
**Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)**



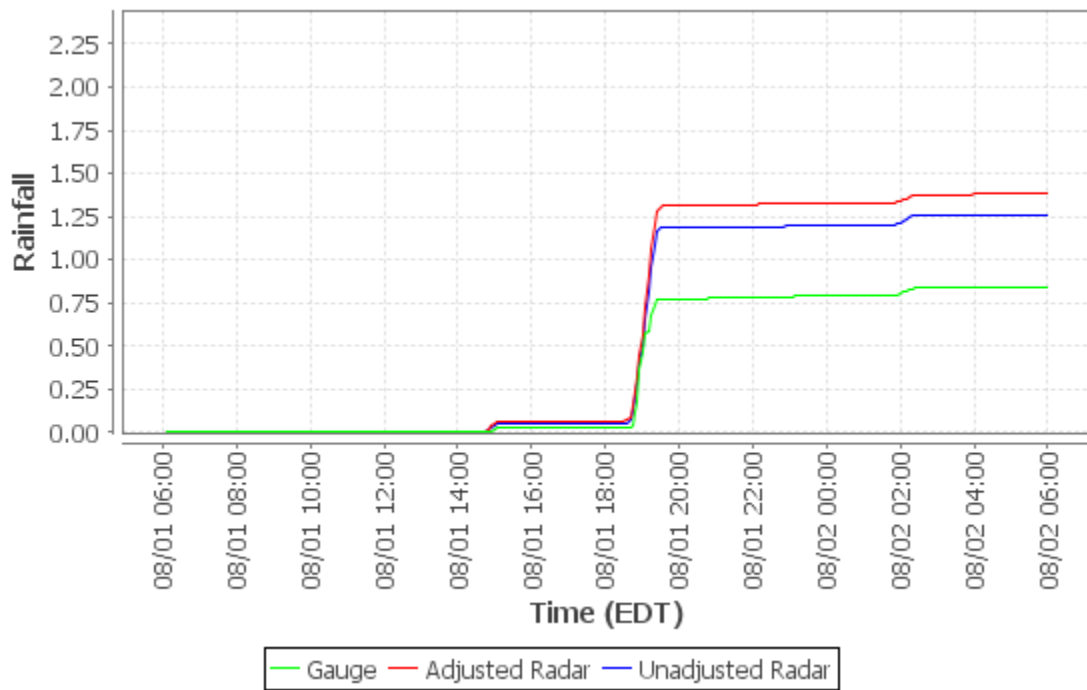
**Cumulative Distribution Plot - PWSA-Highland Park (Loc10)**



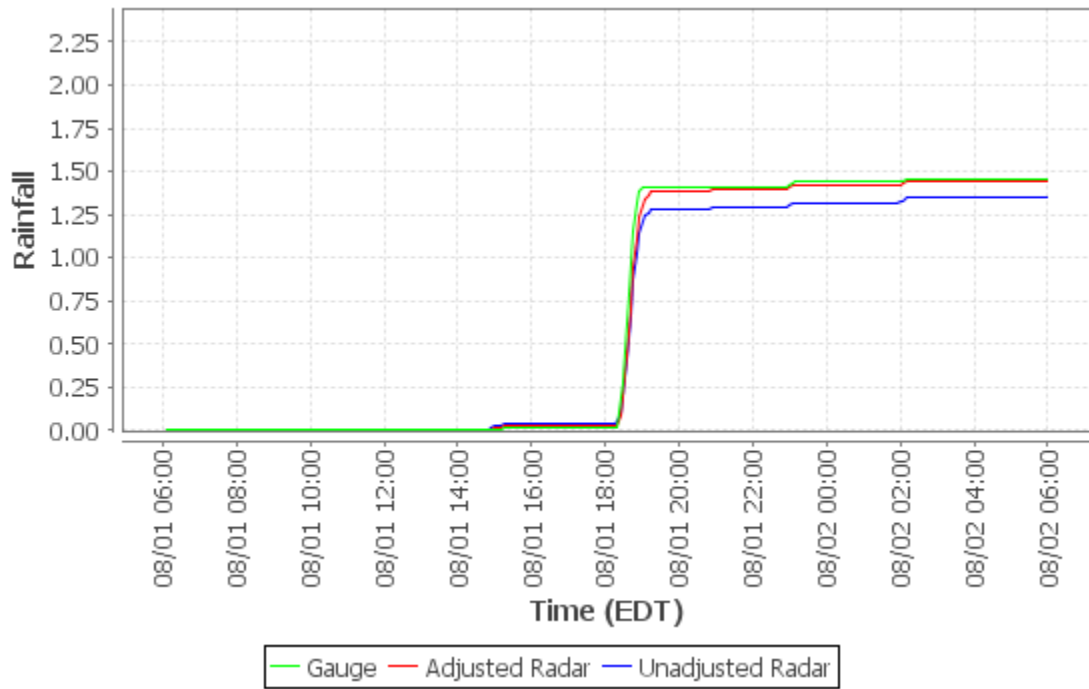
**Cumulative Distribution Plot - M-46 Access Shaft (Loc11)**



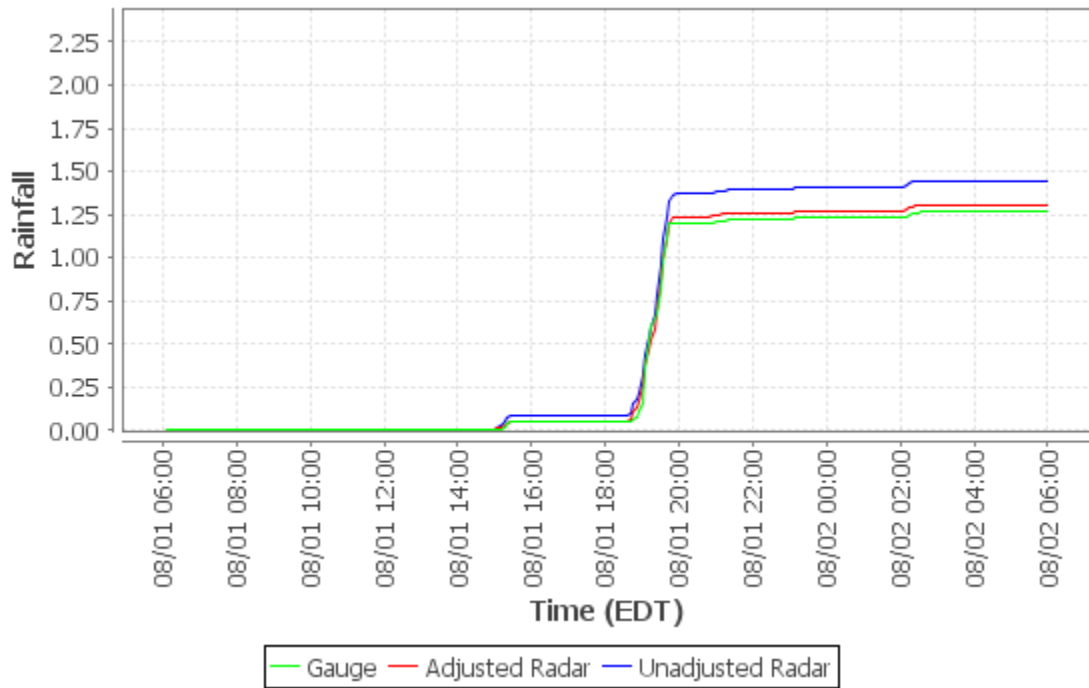
**Cumulative Distribution Plot - Baldwin (Loc12)**



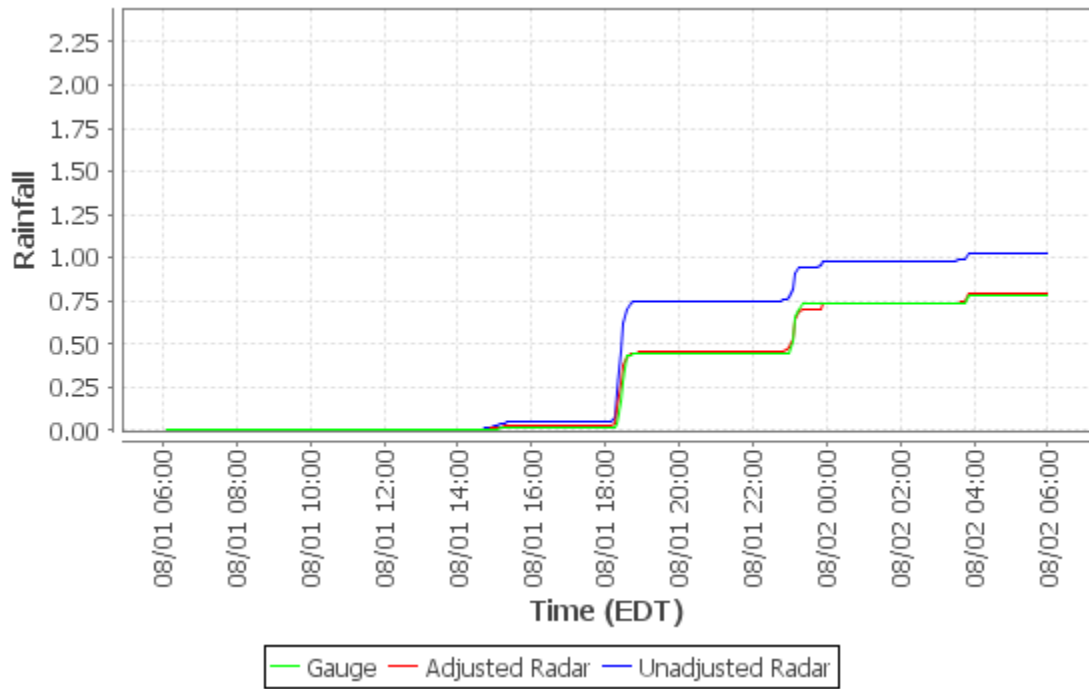
**Cumulative Distribution Plot - M-59 Access Shaft (Loc13)**



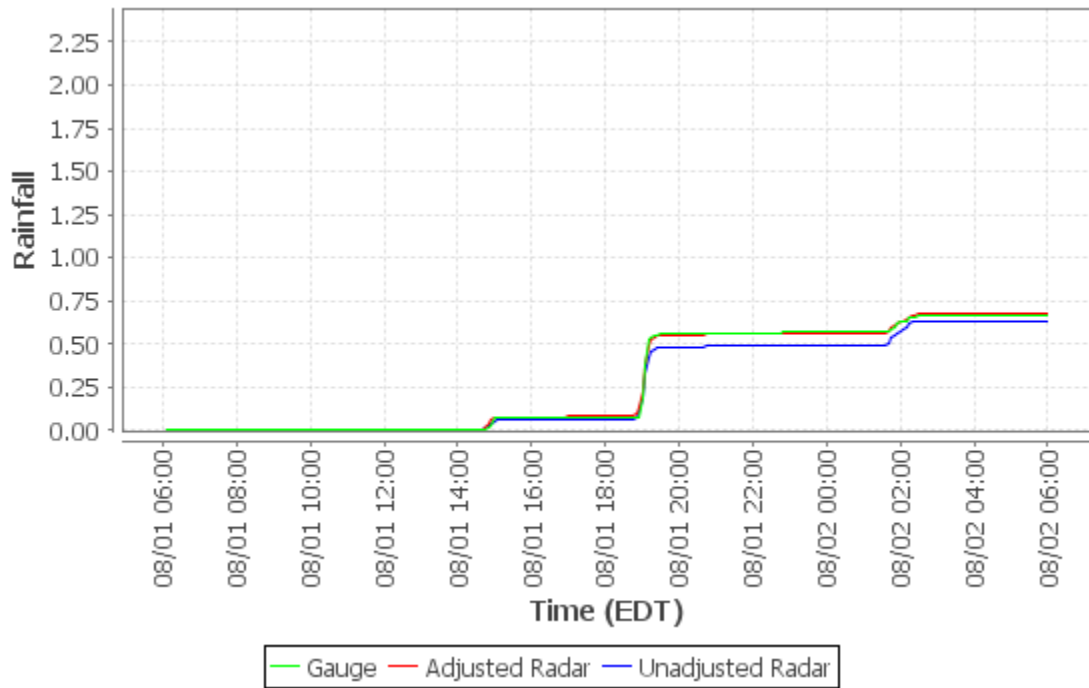
**Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)**



**Cumulative Distribution Plot - Trafford Maint Bldg (Loc15)**

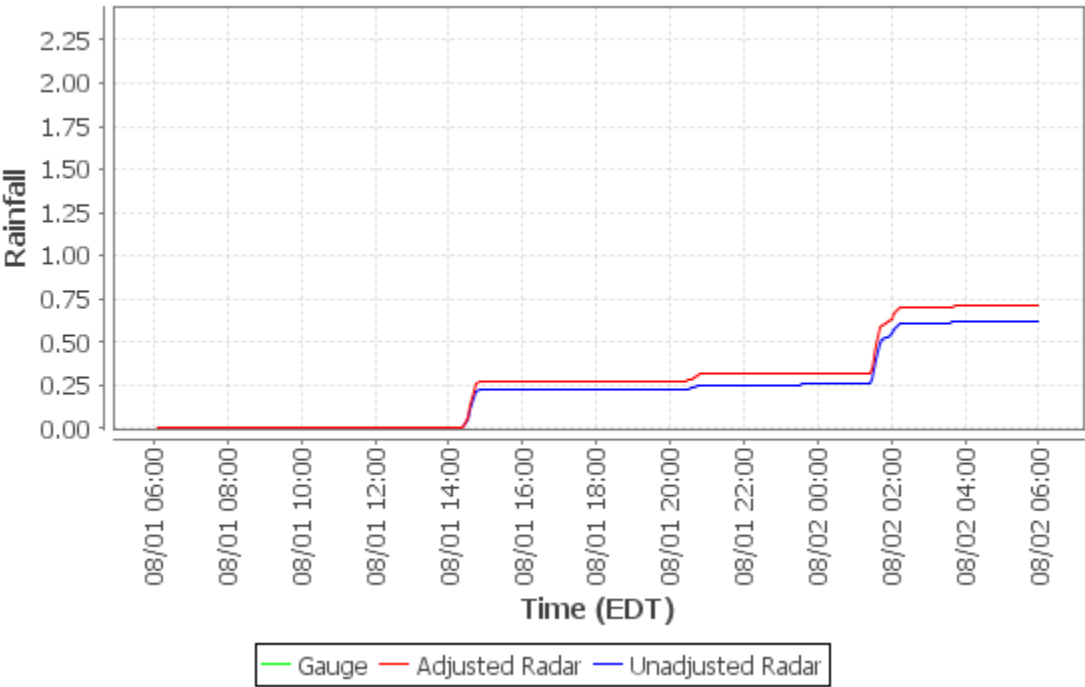


**Cumulative Distribution Plot - Castle Shannon (Loc16)**

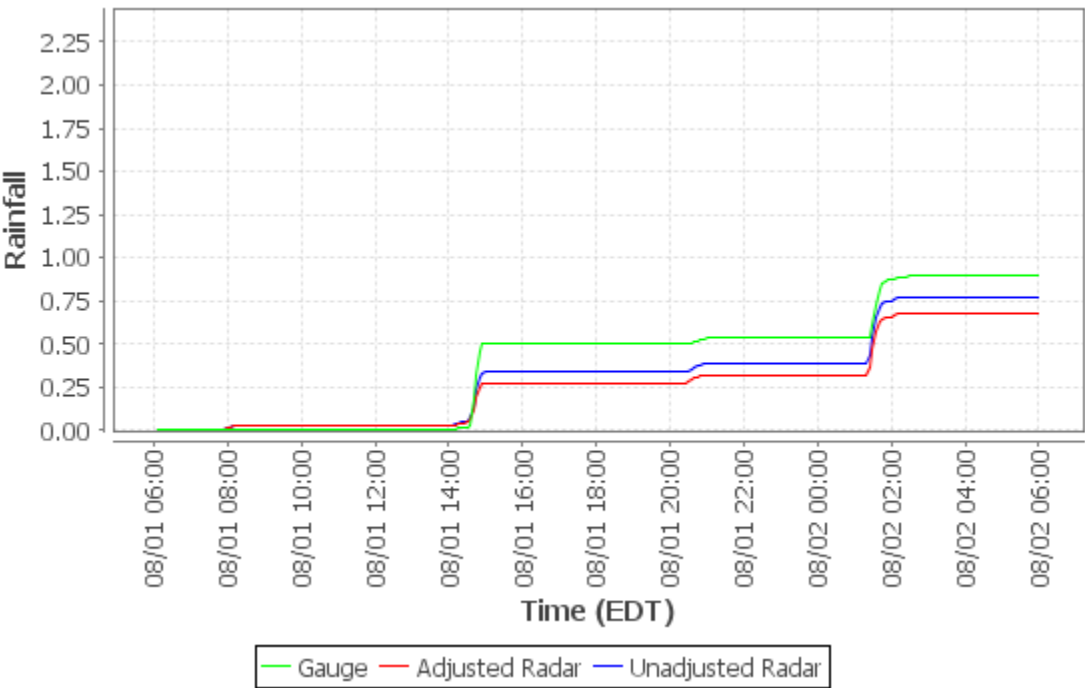




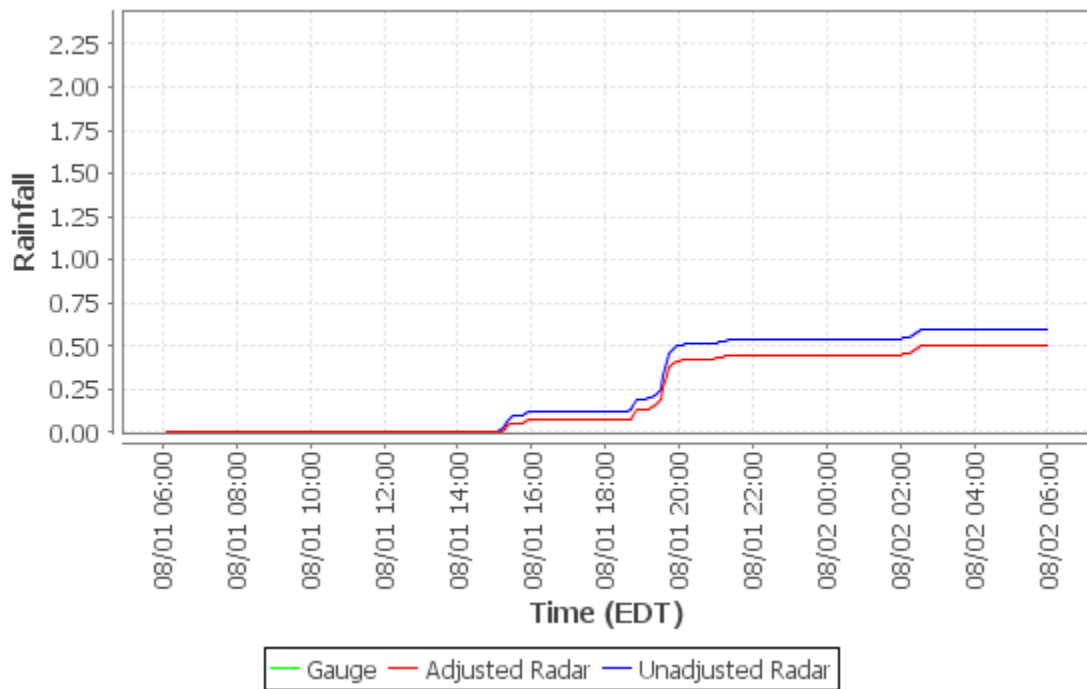
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



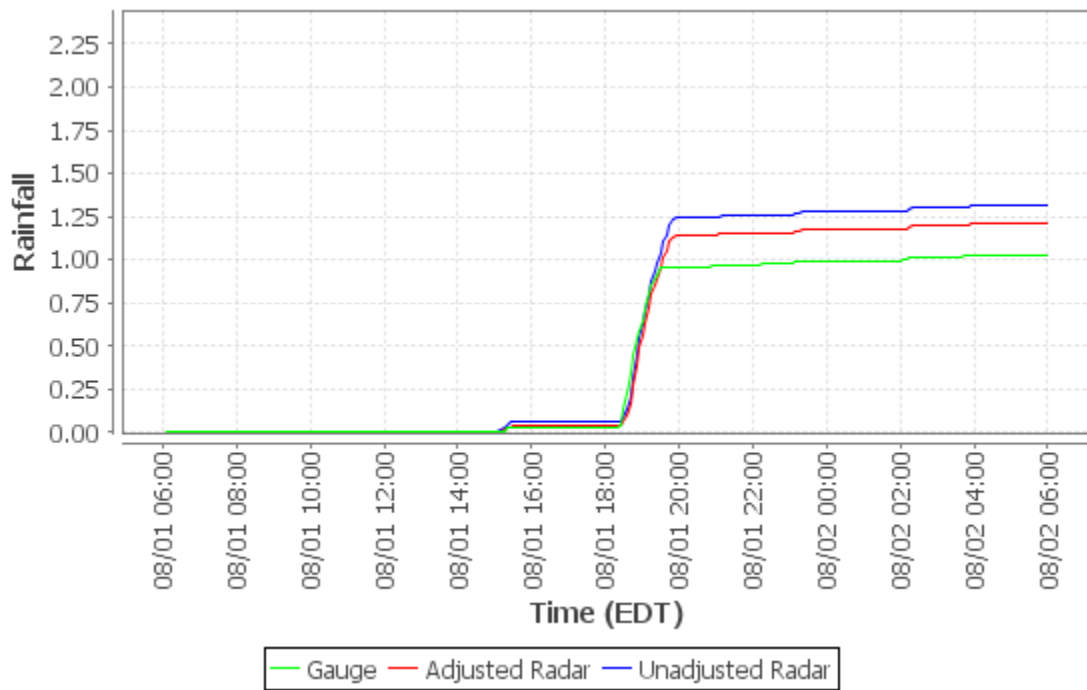
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



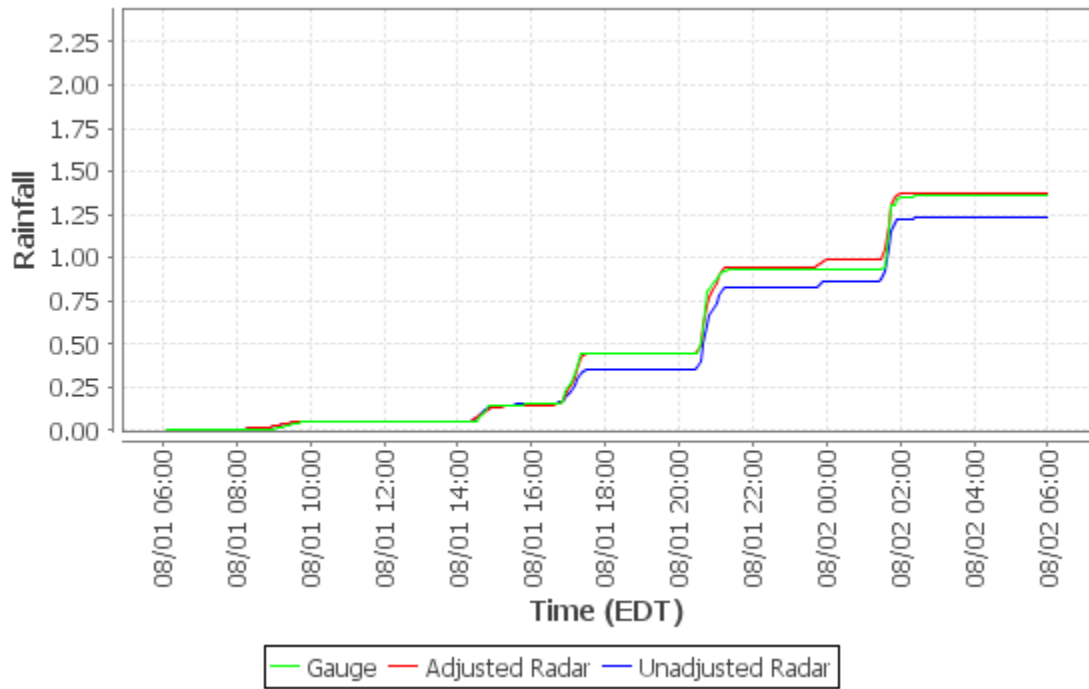
**Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)**



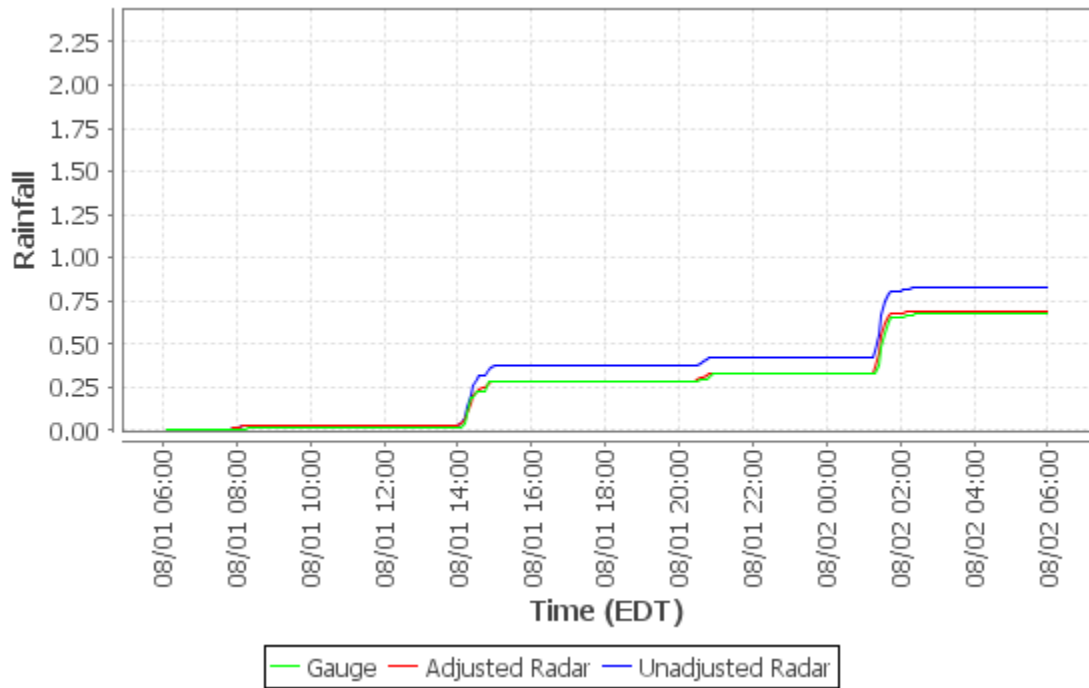
**Cumulative Distribution Plot - Gascola Eq Facility (Loc20)**



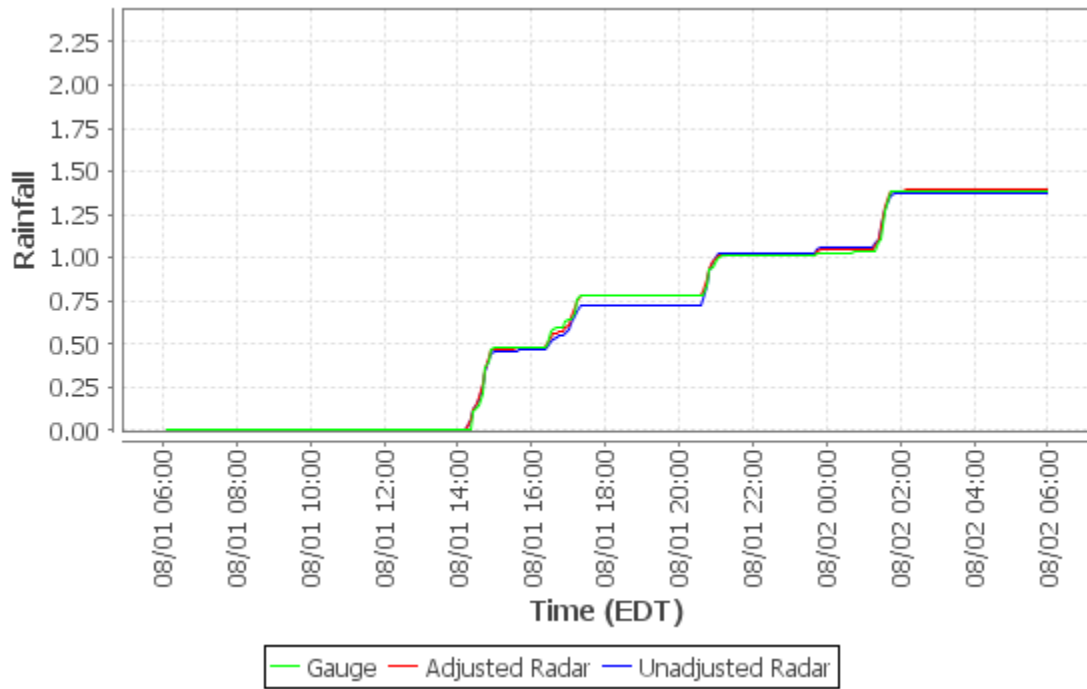
**Cumulative Distribution Plot - Moon TWP (Loc21)**



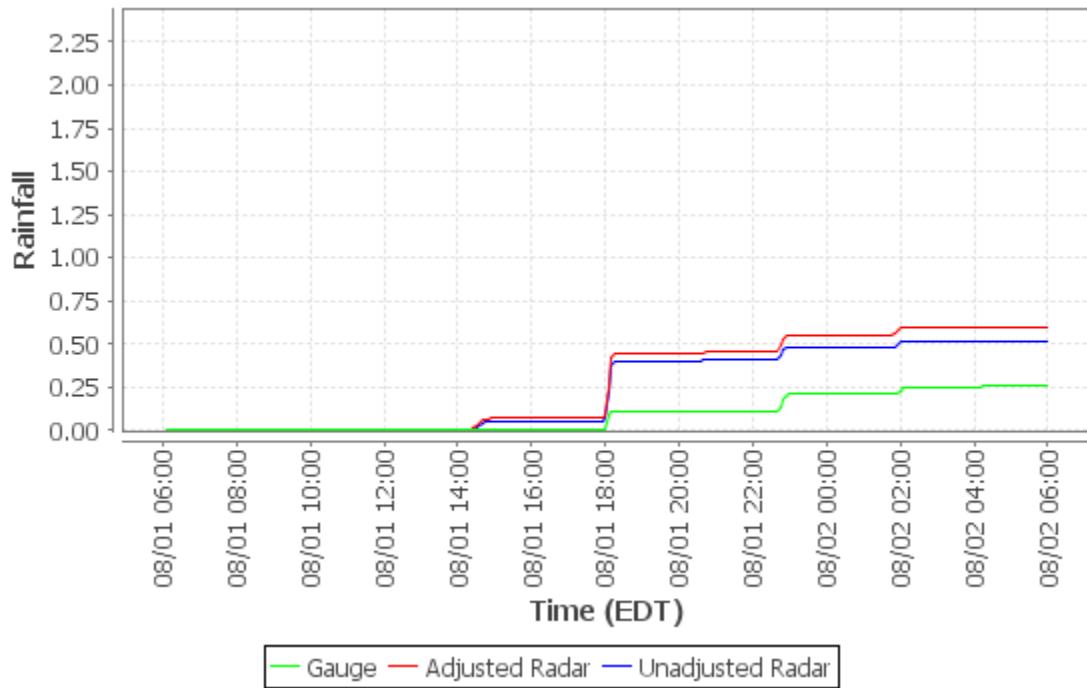
**Cumulative Distribution Plot - North Fayette TWP (Loc22)**



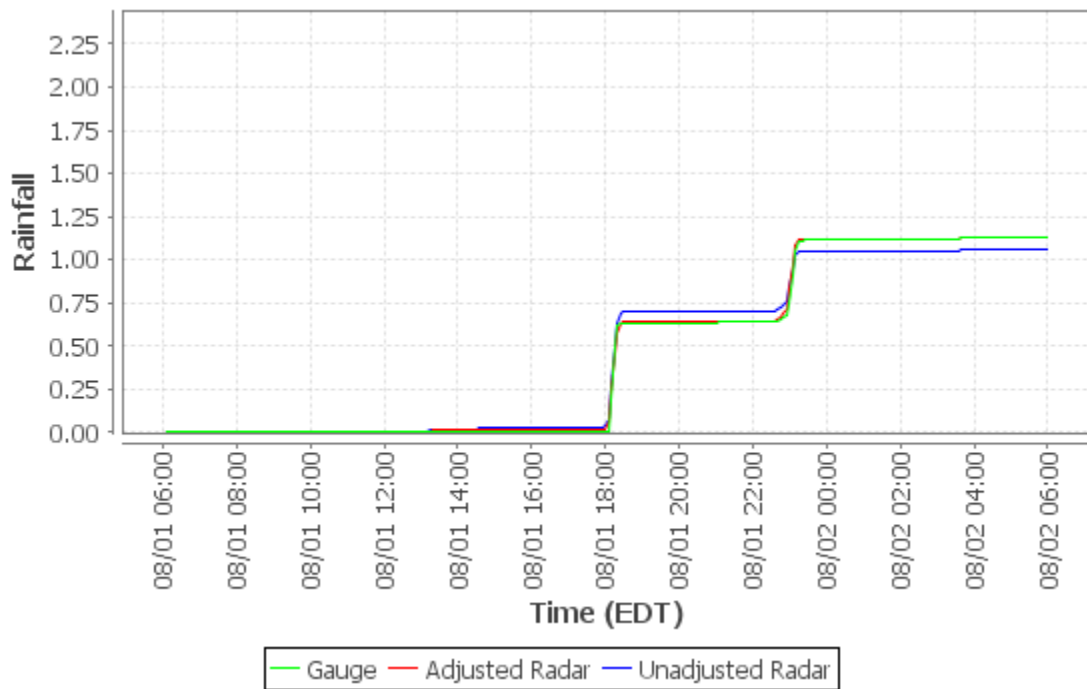
**Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)**



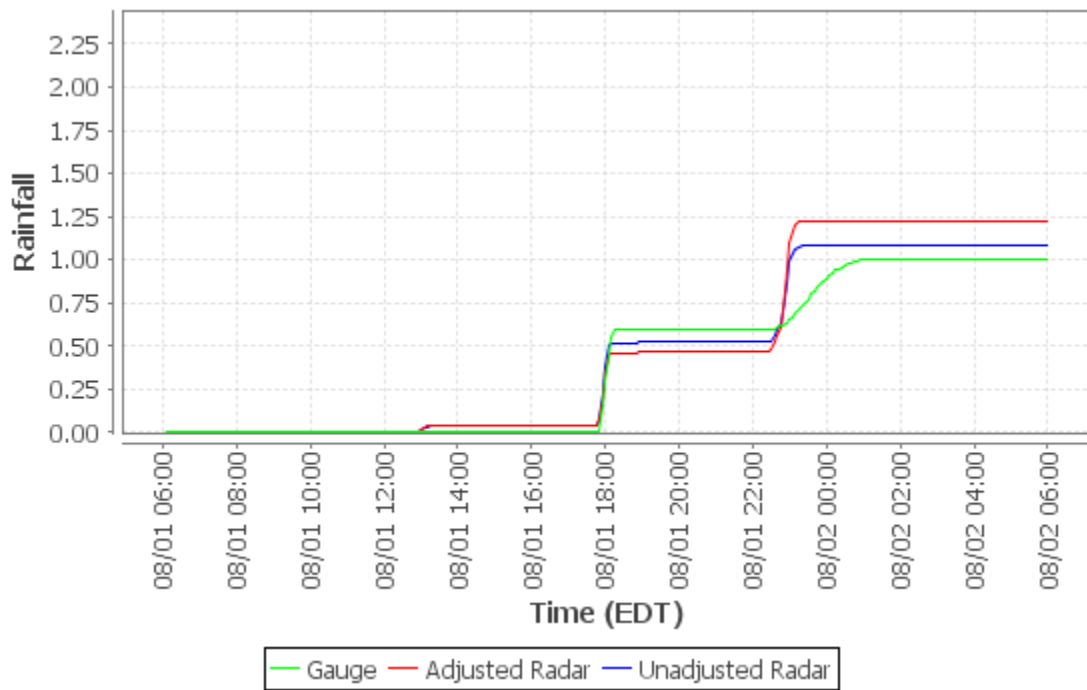
**Cumulative Distribution Plot - Jefferson Hills (Loc24)**



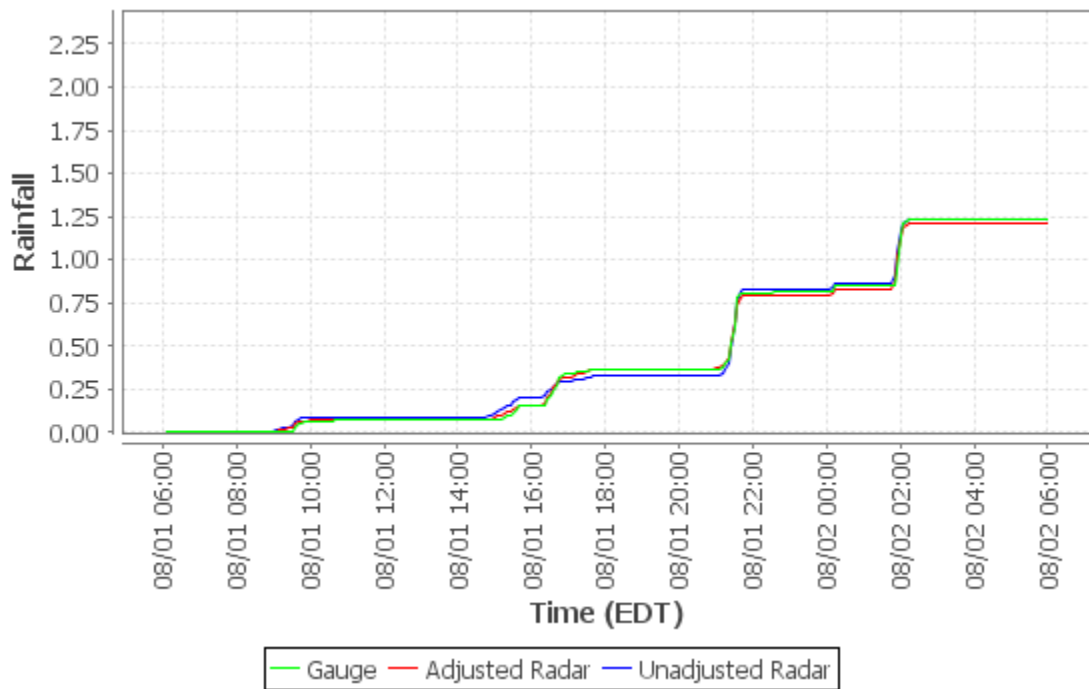
**Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)**



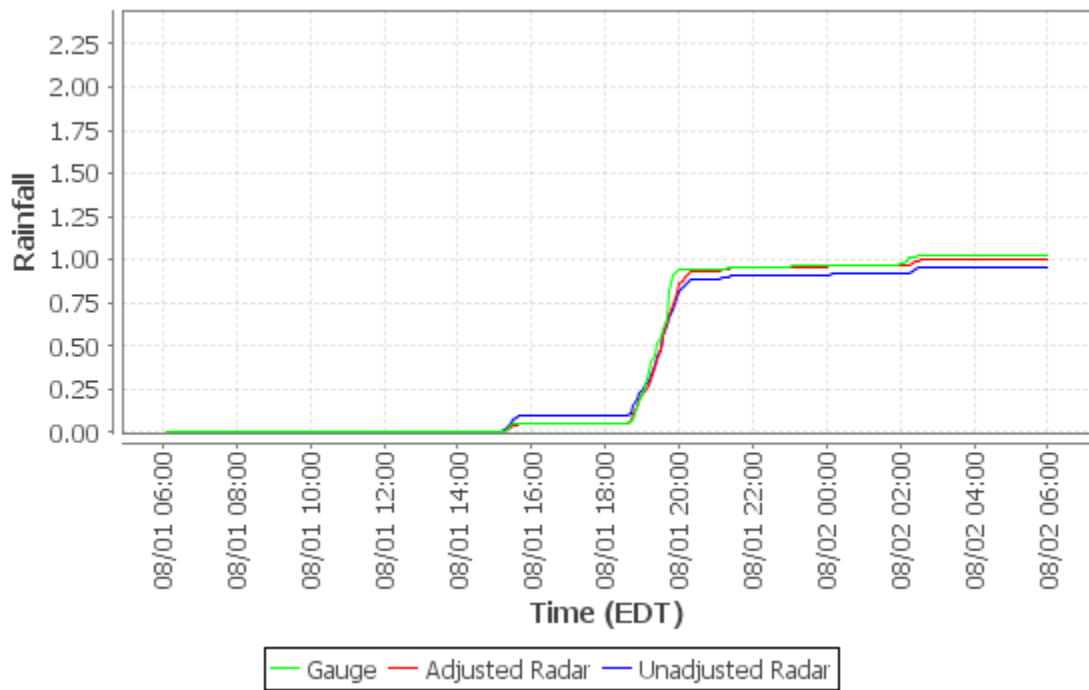
**Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)**



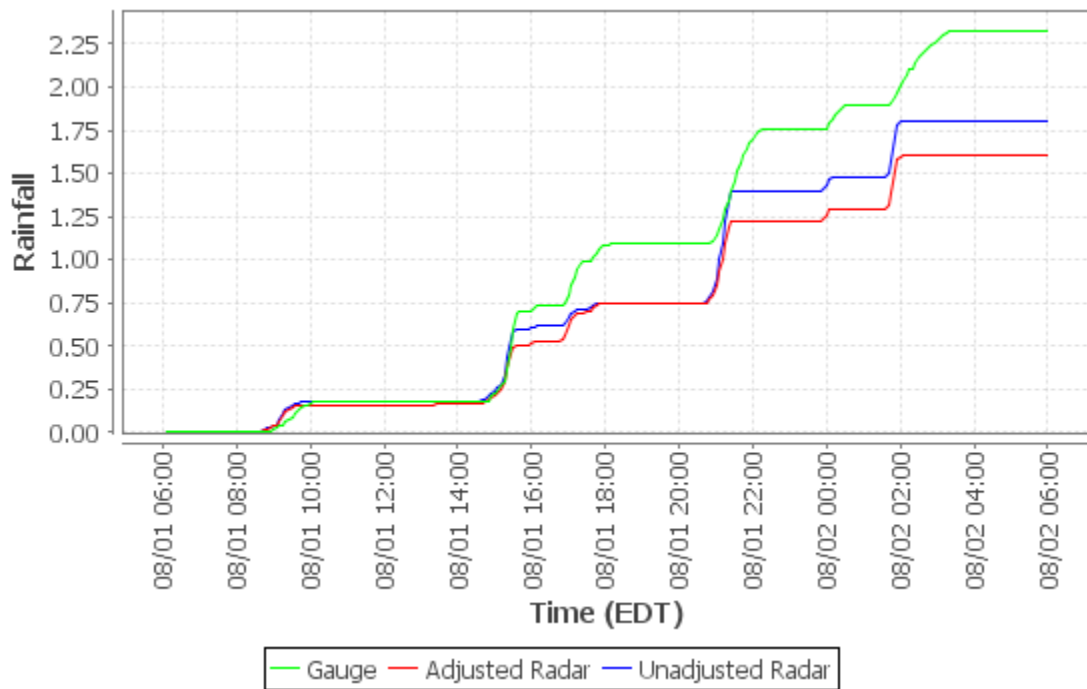
**Cumulative Distribution Plot - Marshall TWP (Loc27)**



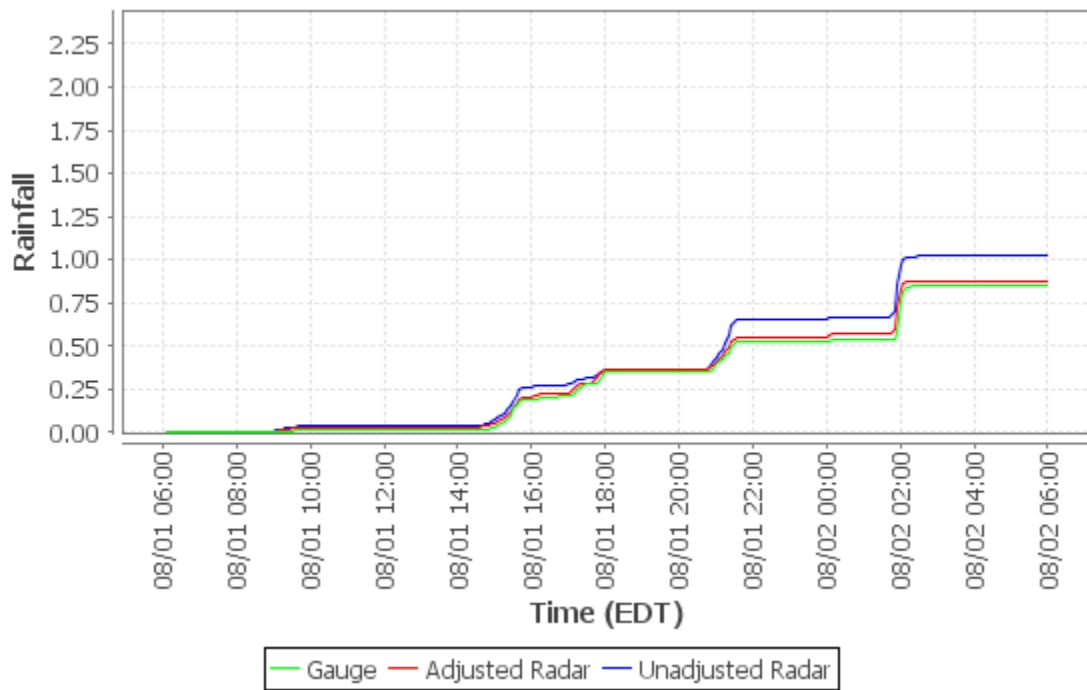
**Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)**



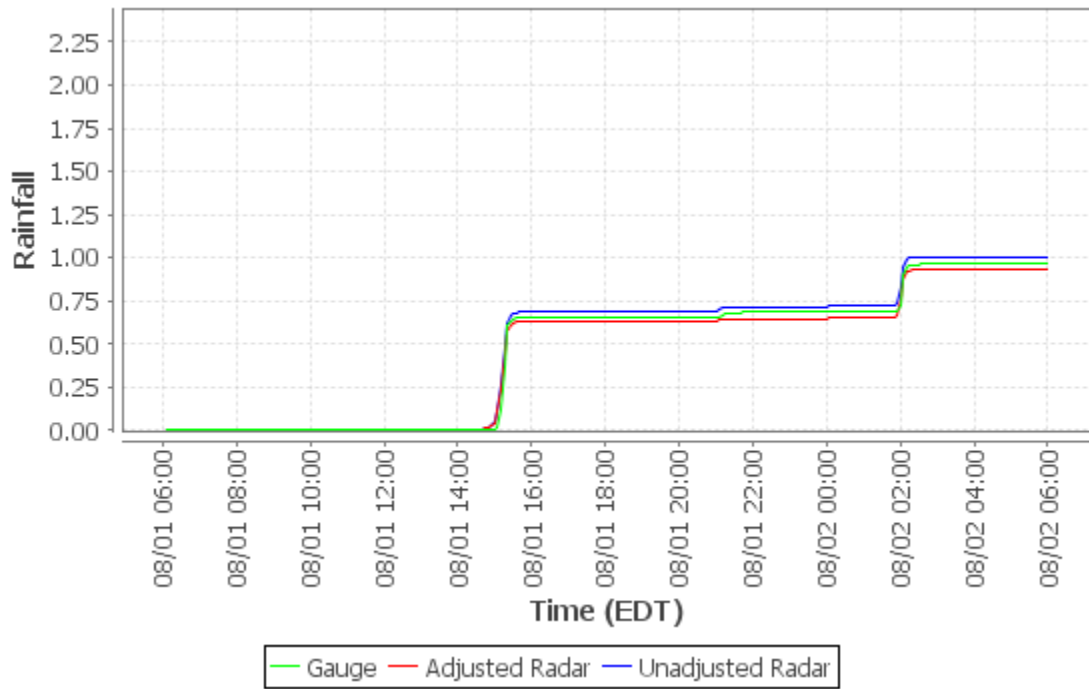
**Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)**



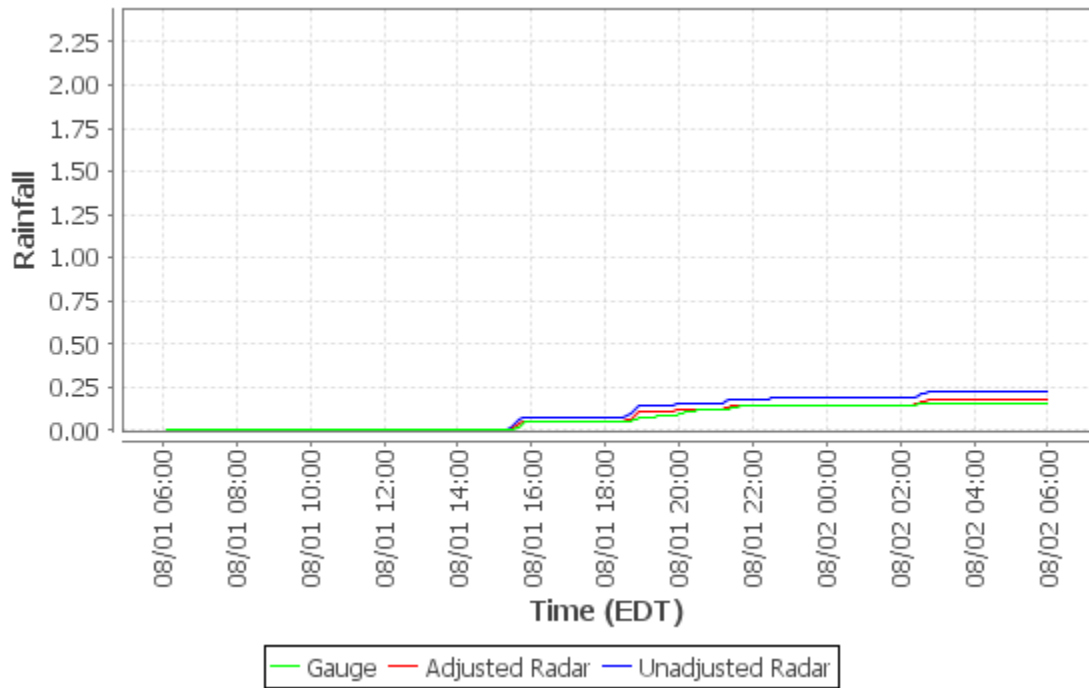
**Cumulative Distribution Plot - McCandless Twn Hall (Loc30)**



**Cumulative Distribution Plot - Hampton Municipal Bldg (Loc31)**

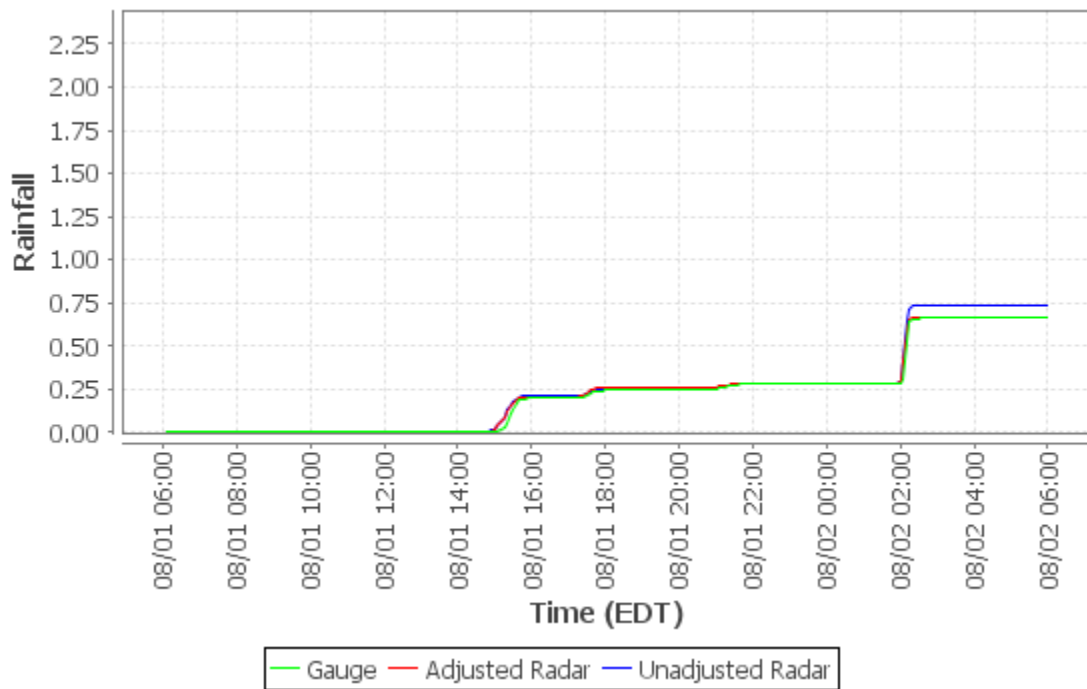


**Cumulative Distribution Plot - Arnold (Loc32)**

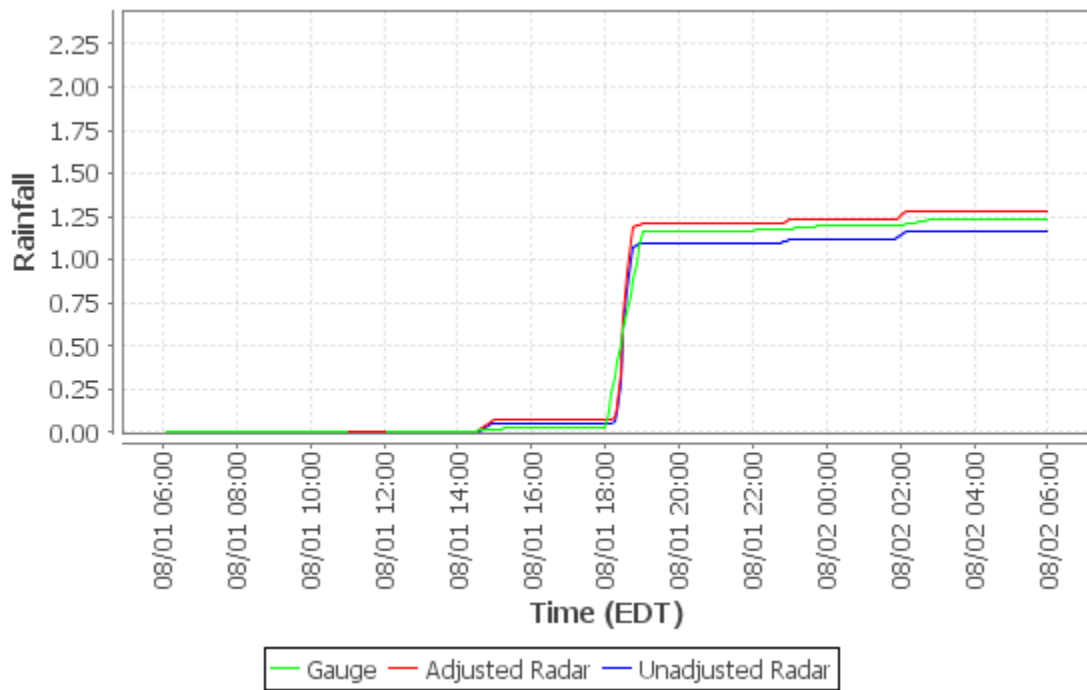




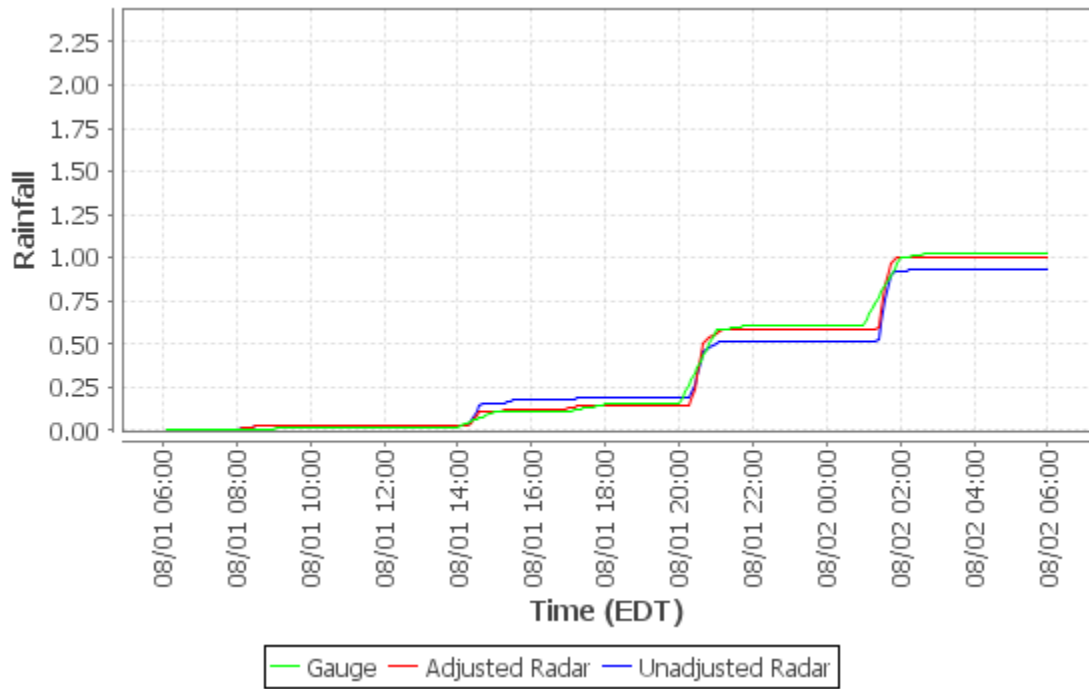
**Cumulative Distribution Plot - Richland TWP (Loc33)**



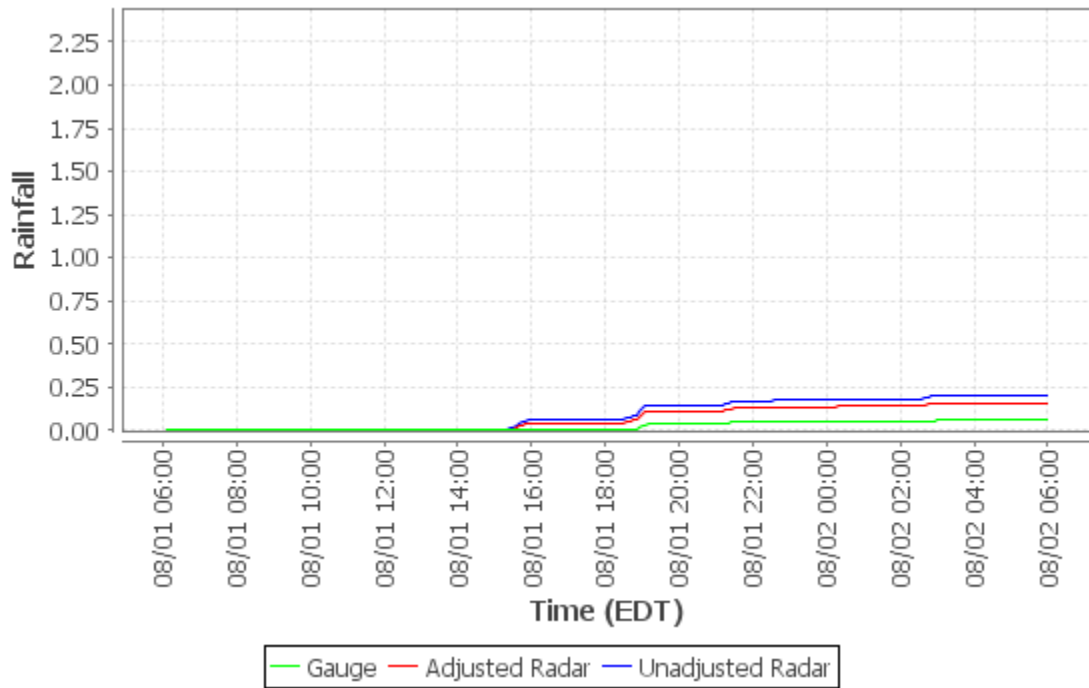
**Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)**



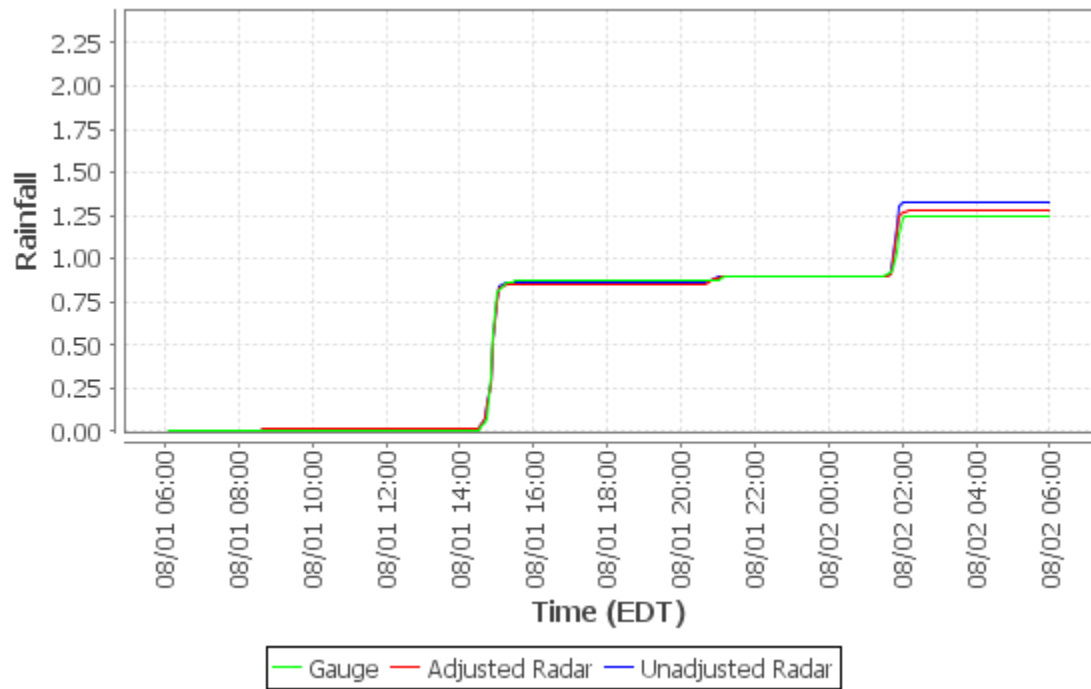
**Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)**



**Cumulative Distribution Plot - Allegheny River at Natrona (03049500)**

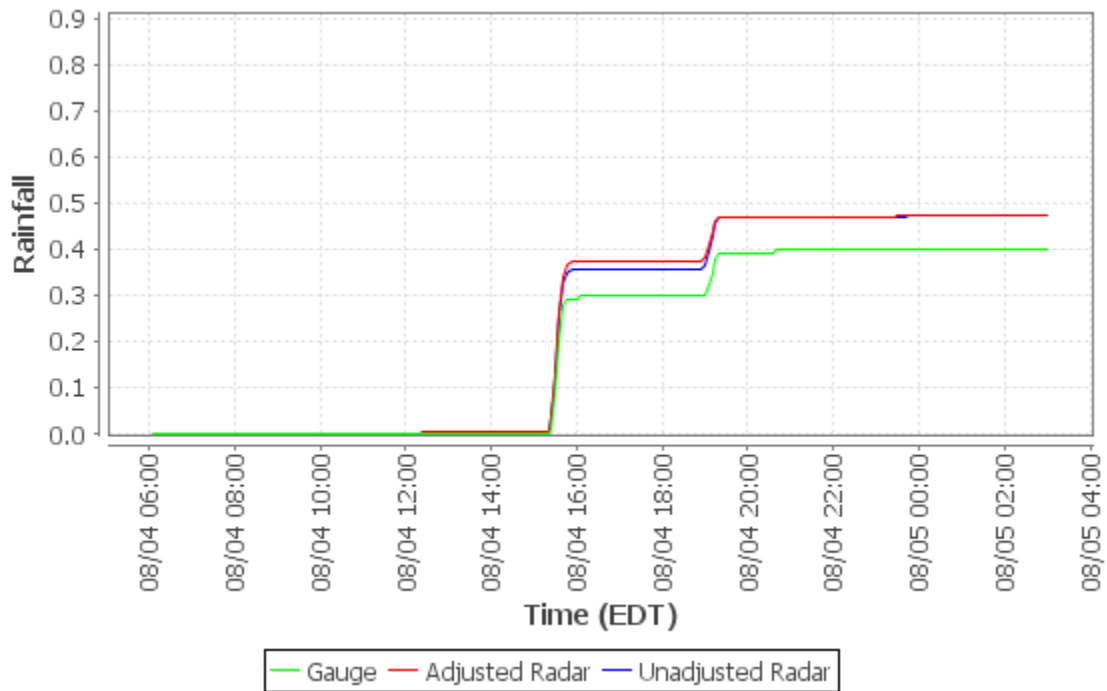


### Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth (03085734)

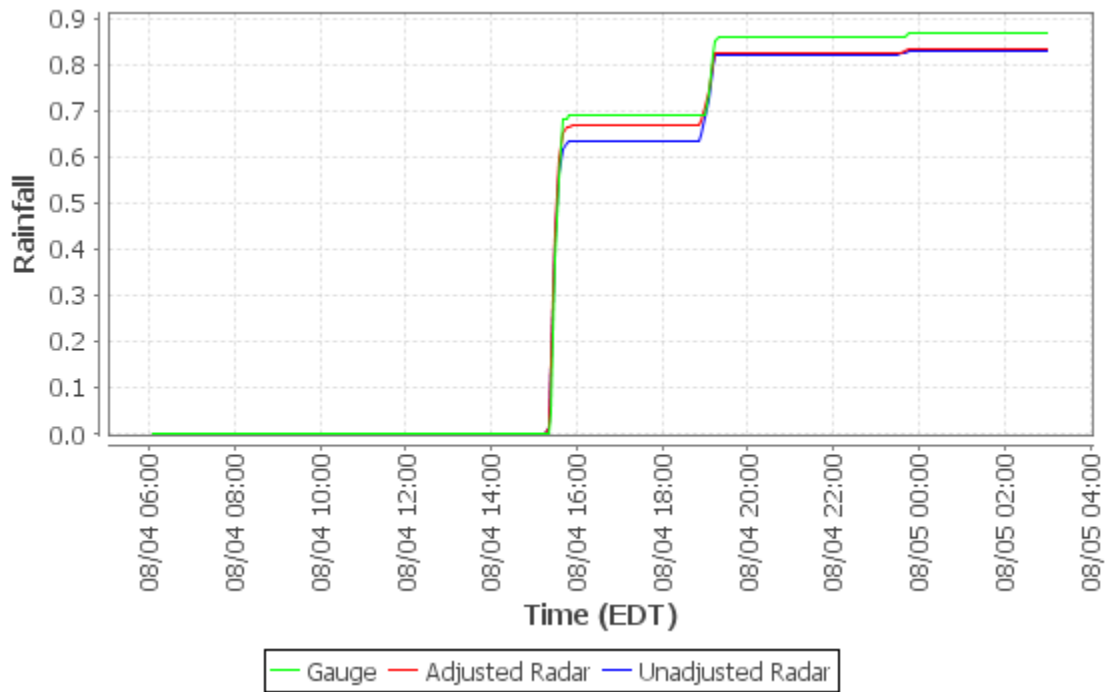


## **Appendix D - Event 2 (2020-08-04) CDPs**

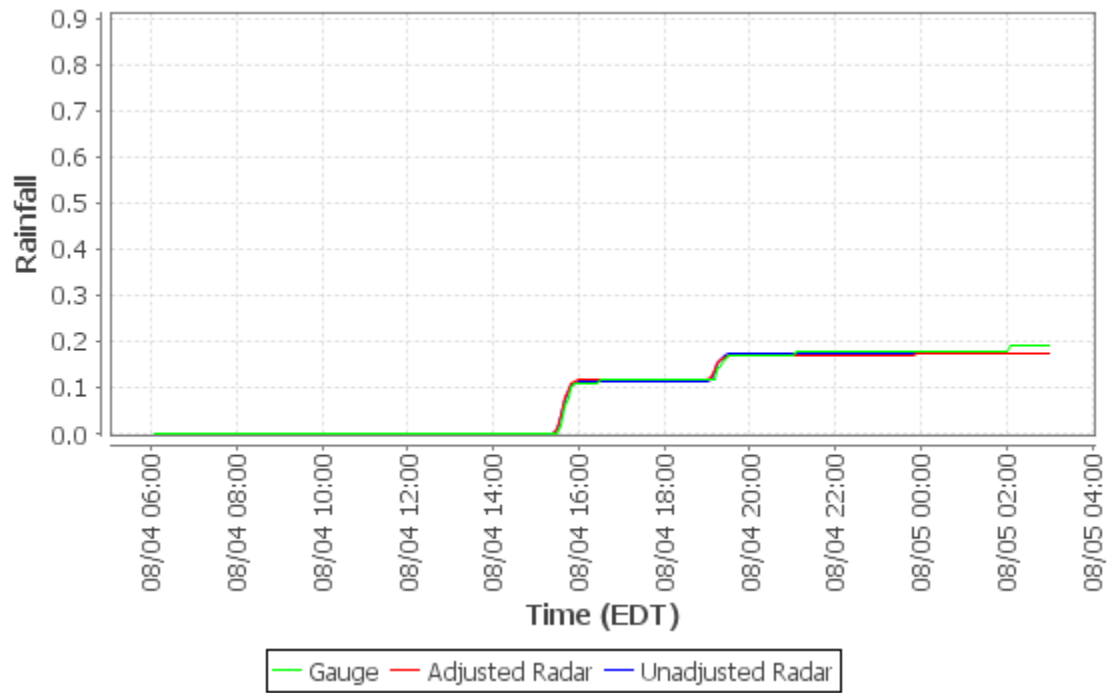
**Cumulative Distribution Plot - PWSA-Montana St. (Loc01)**



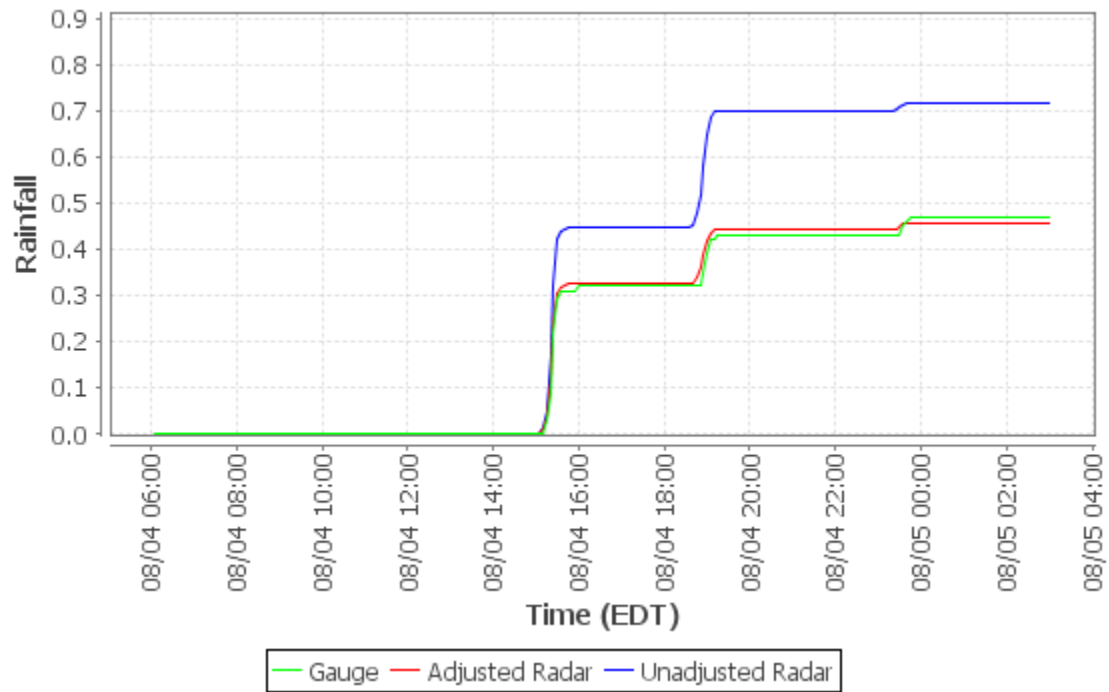
**Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)**



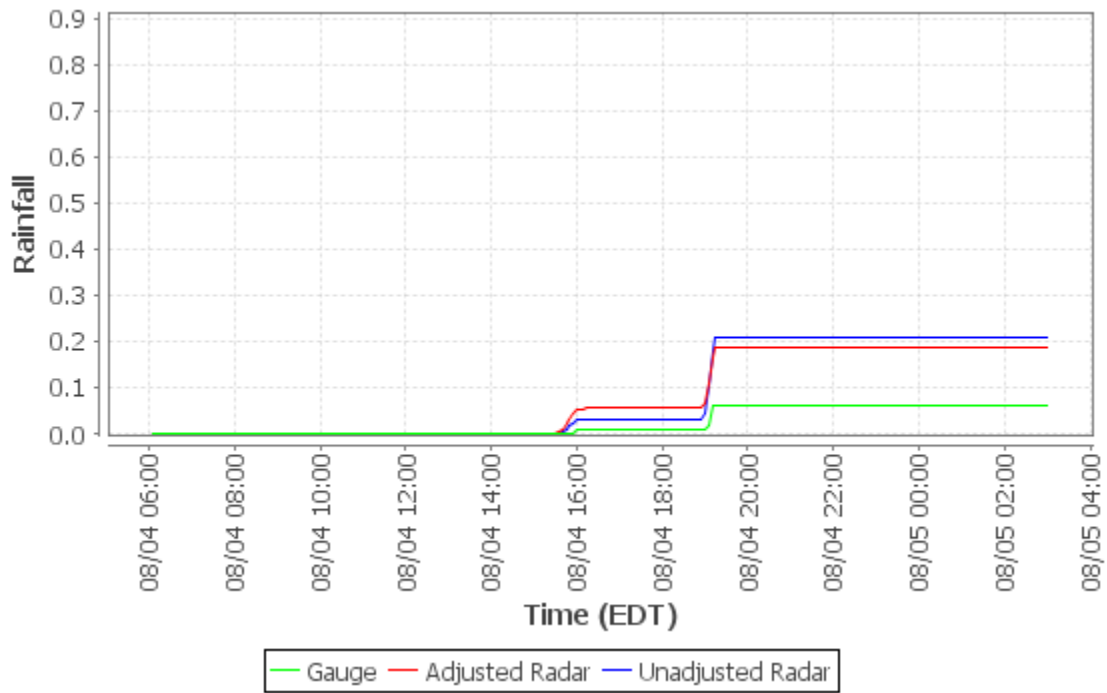
**Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)**



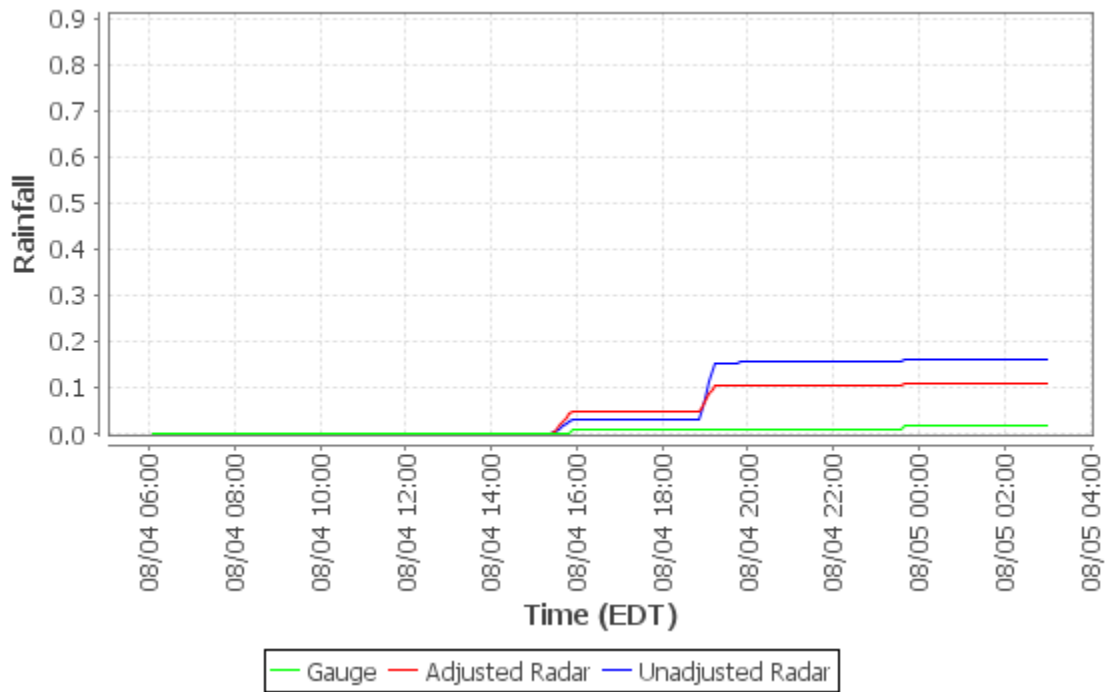
**Cumulative Distribution Plot - Kennedy Twp PS (Loc04)**



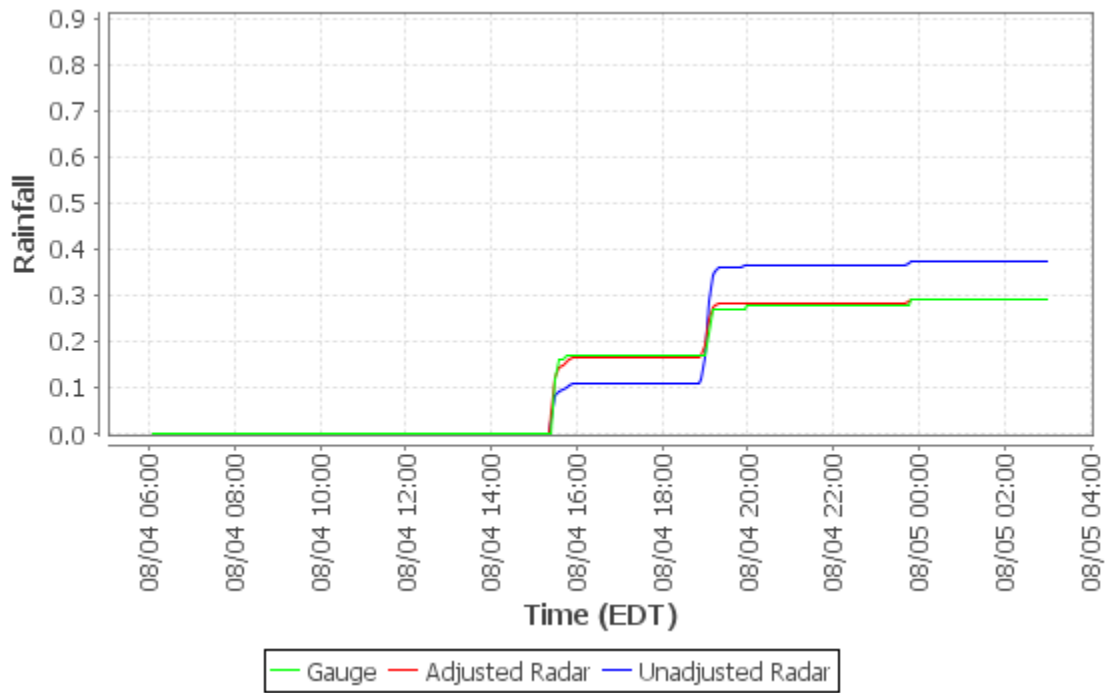
**Cumulative Distribution Plot - Upper St. Clair (Loc05)**



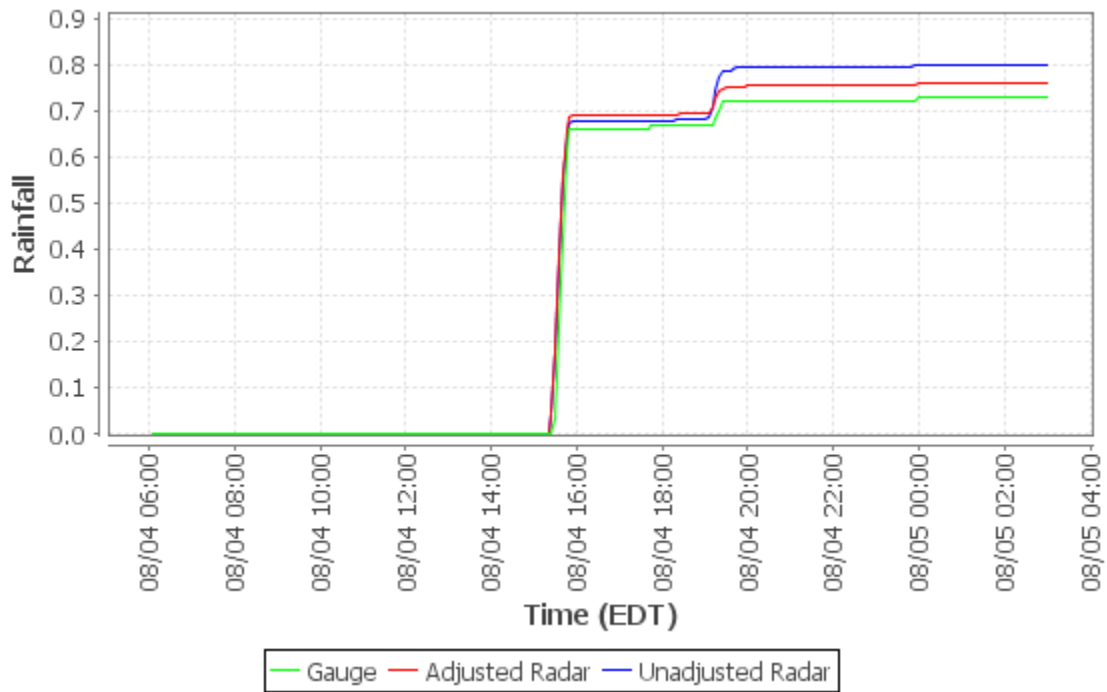
**Cumulative Distribution Plot - Carnegie Transit Time (Loc06)**



**Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)**

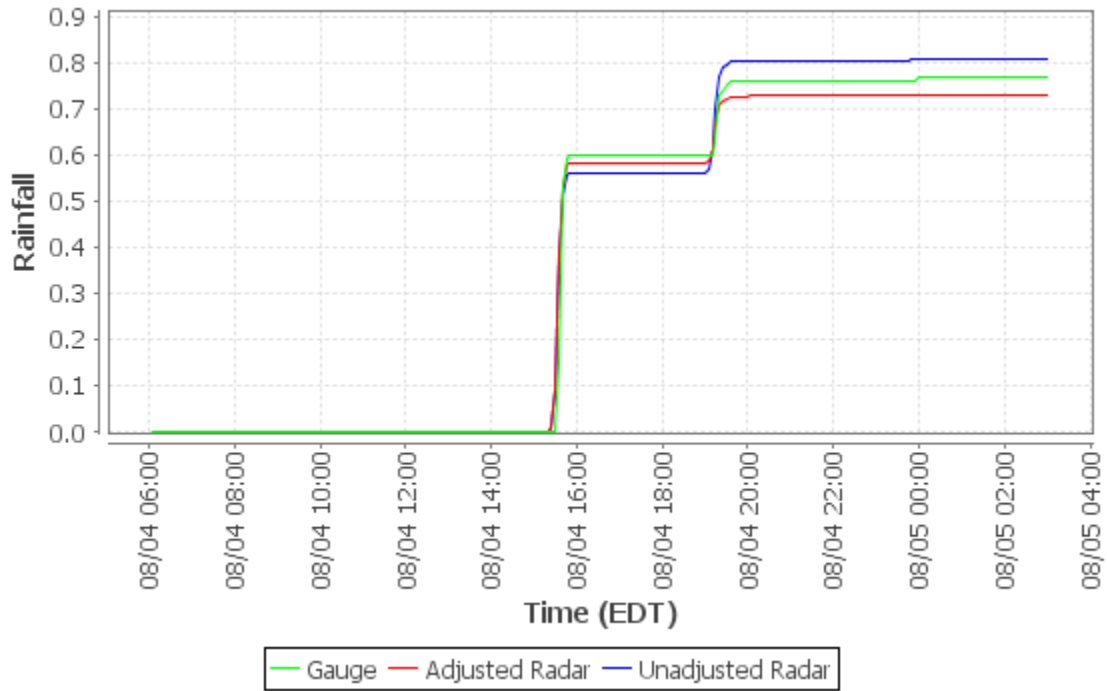


**Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)**

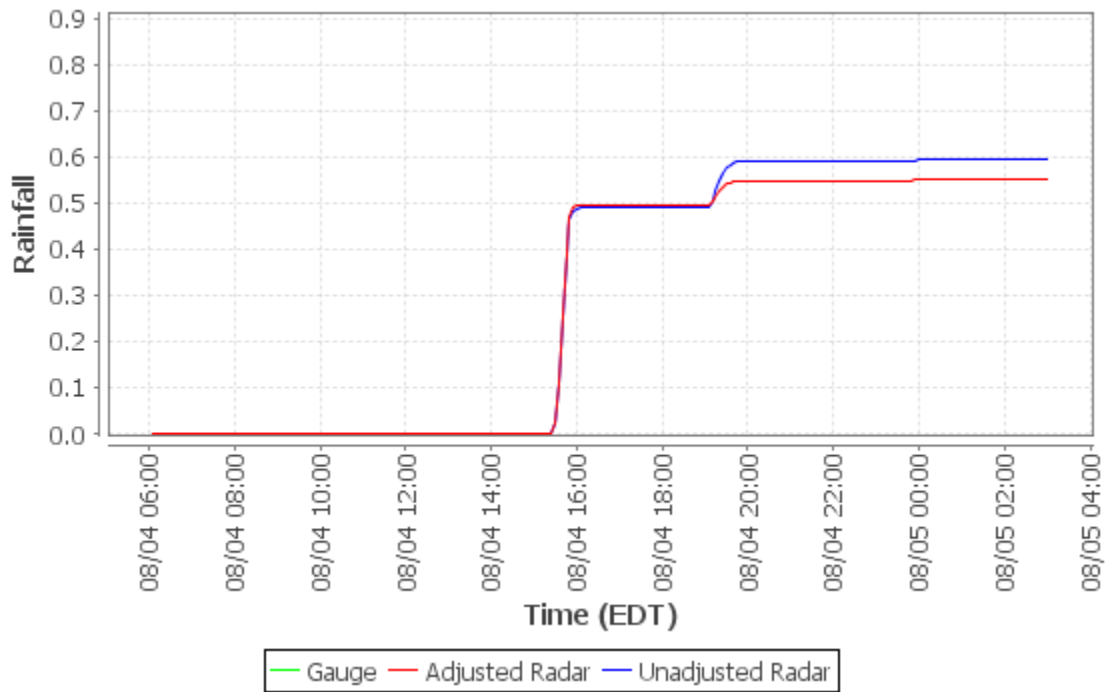




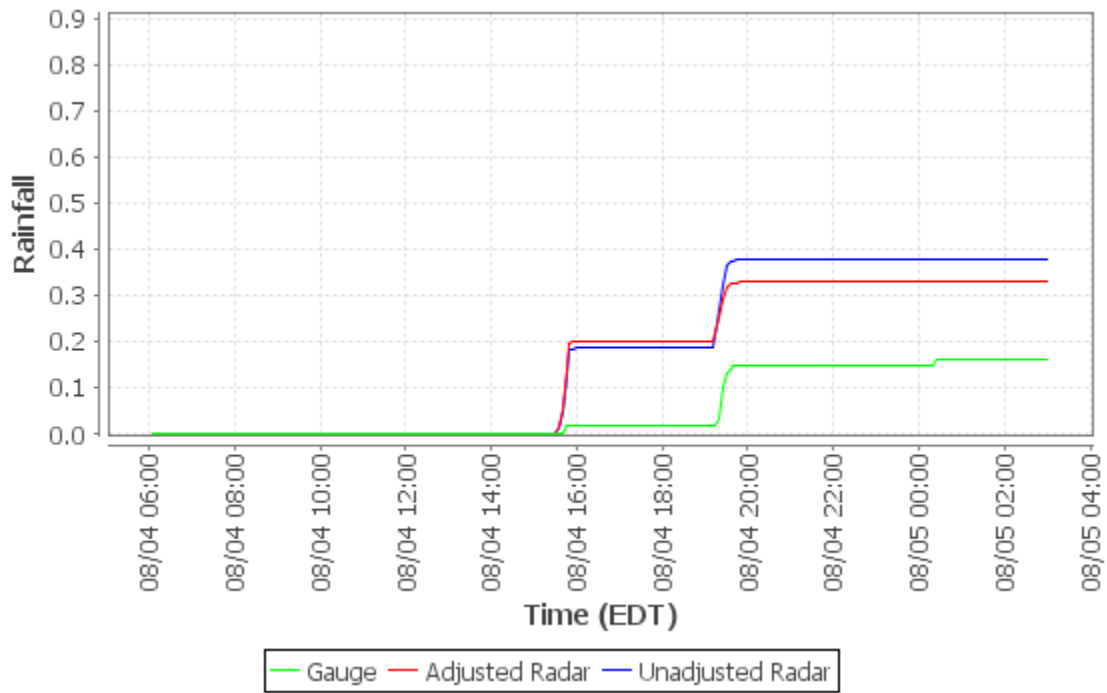
**Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)**



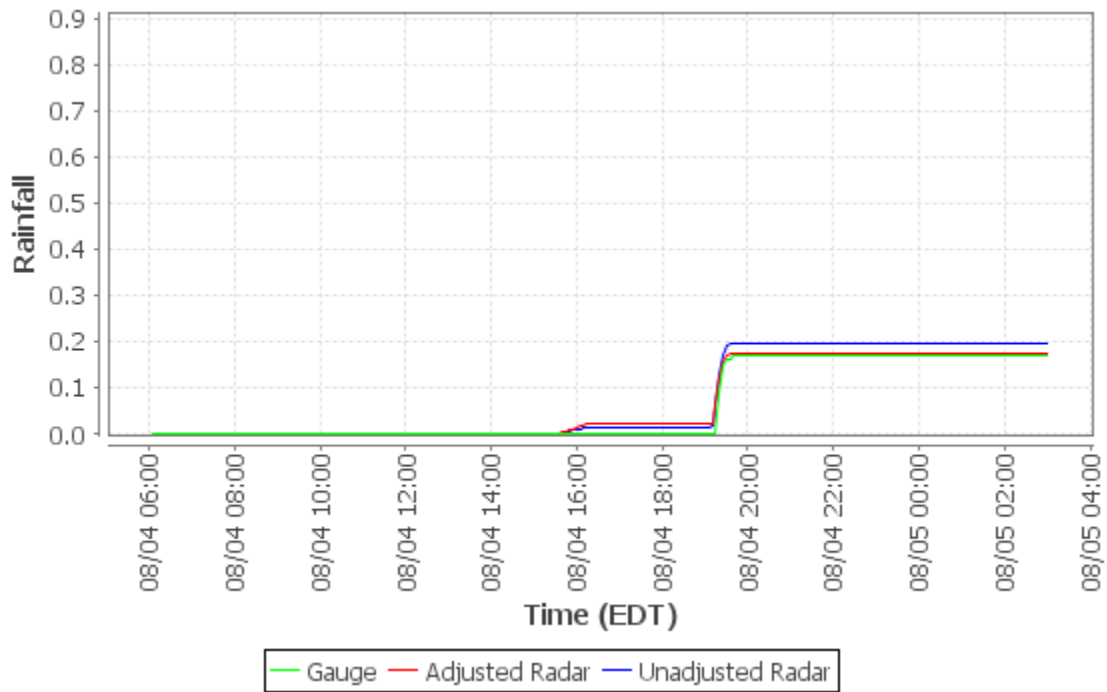
**Cumulative Distribution Plot - PWSA-Highland Park (Loc10)**



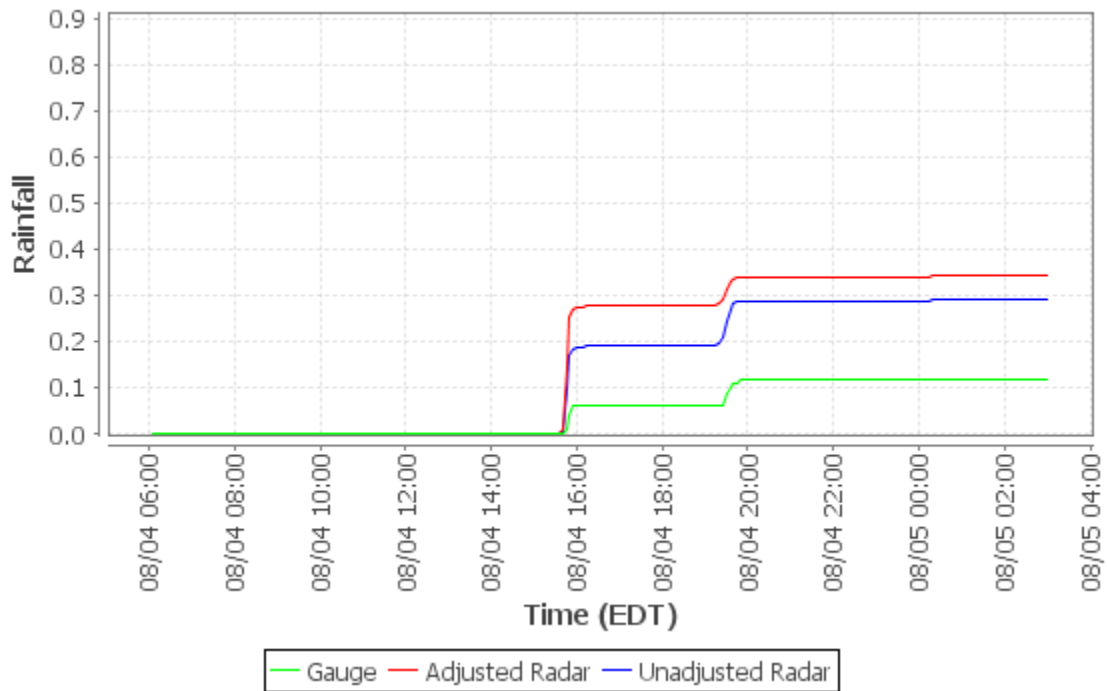
**Cumulative Distribution Plot - M-46 Access Shaft (Loc11)**



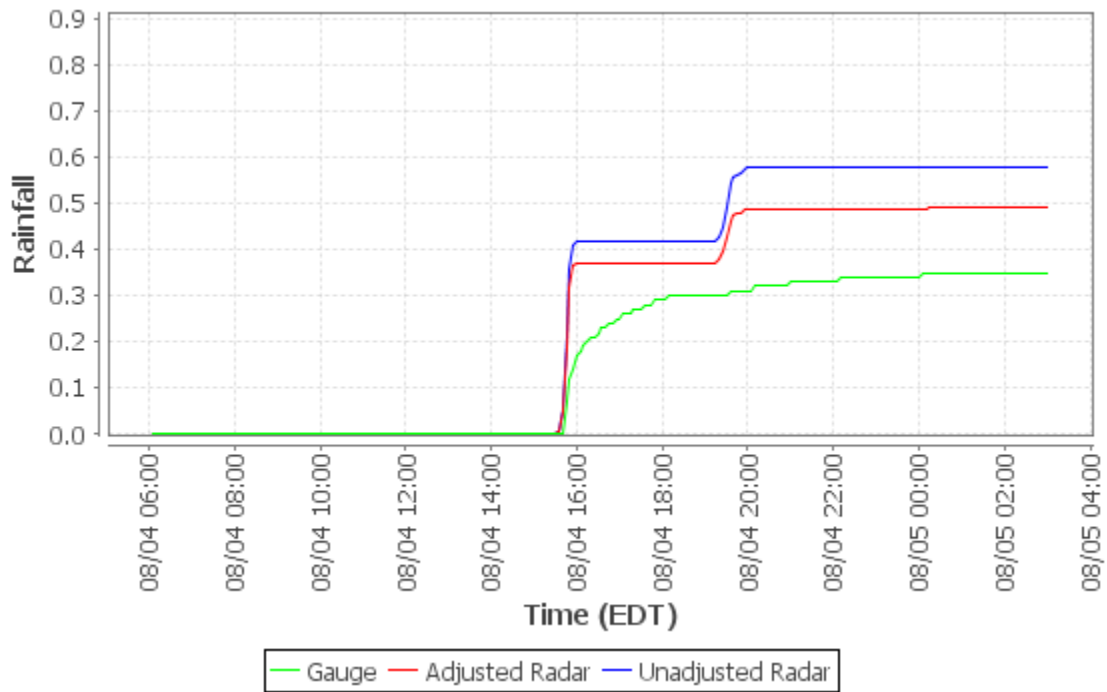
**Cumulative Distribution Plot - Baldwin (Loc12)**



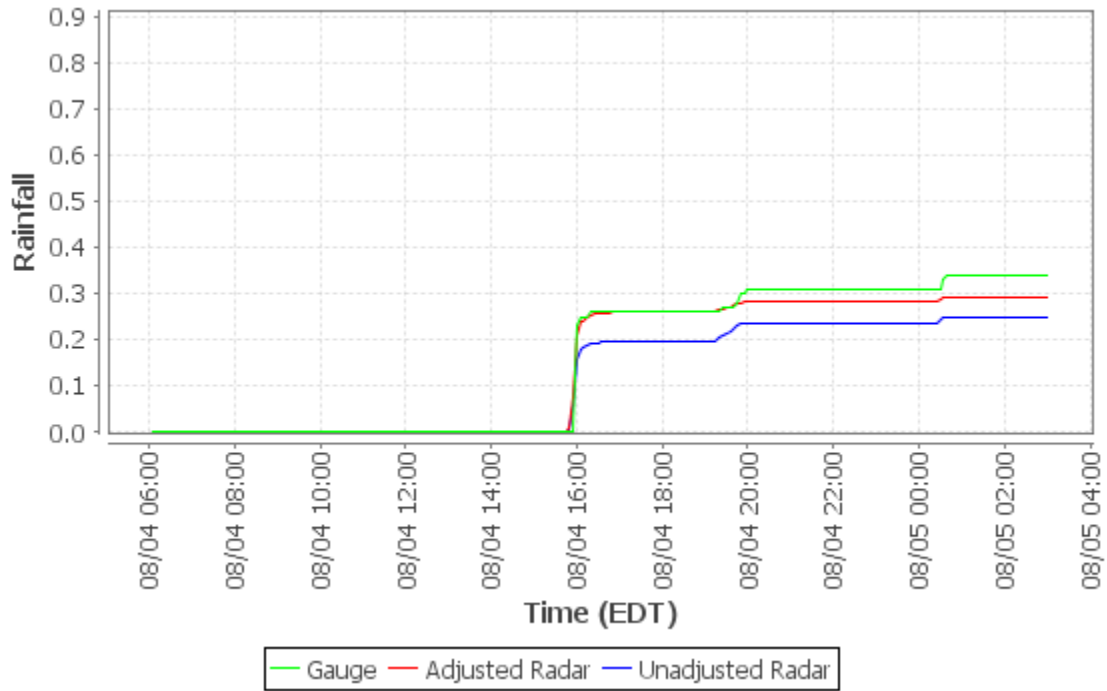
**Cumulative Distribution Plot - M-59 Access Shaft (Loc13)**



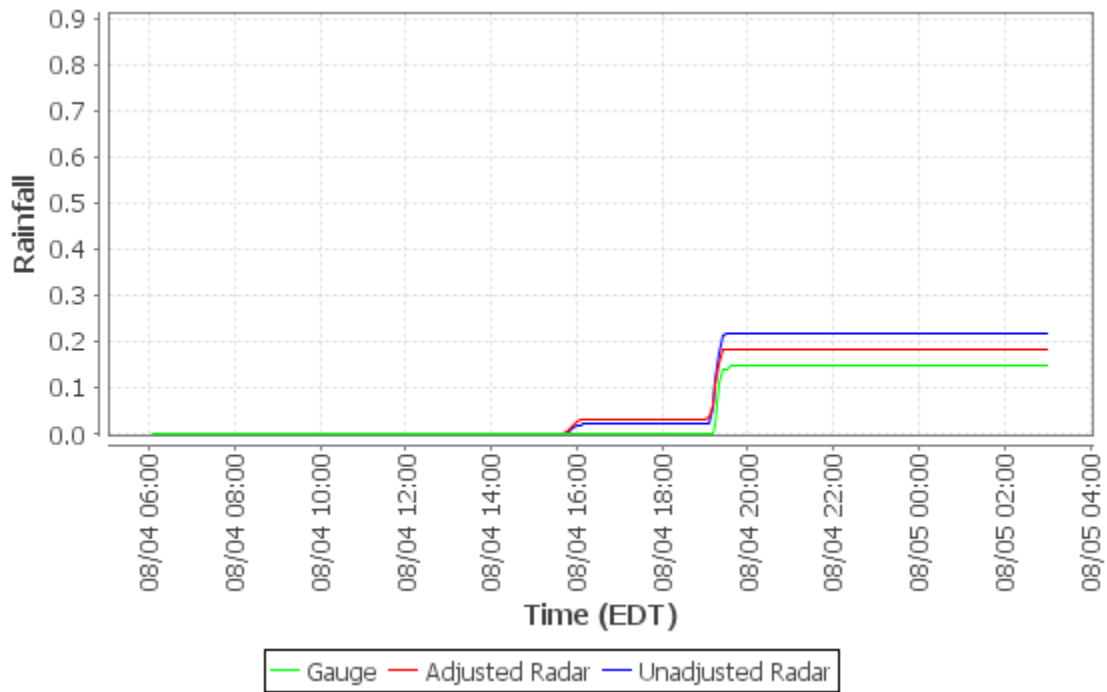
**Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)**



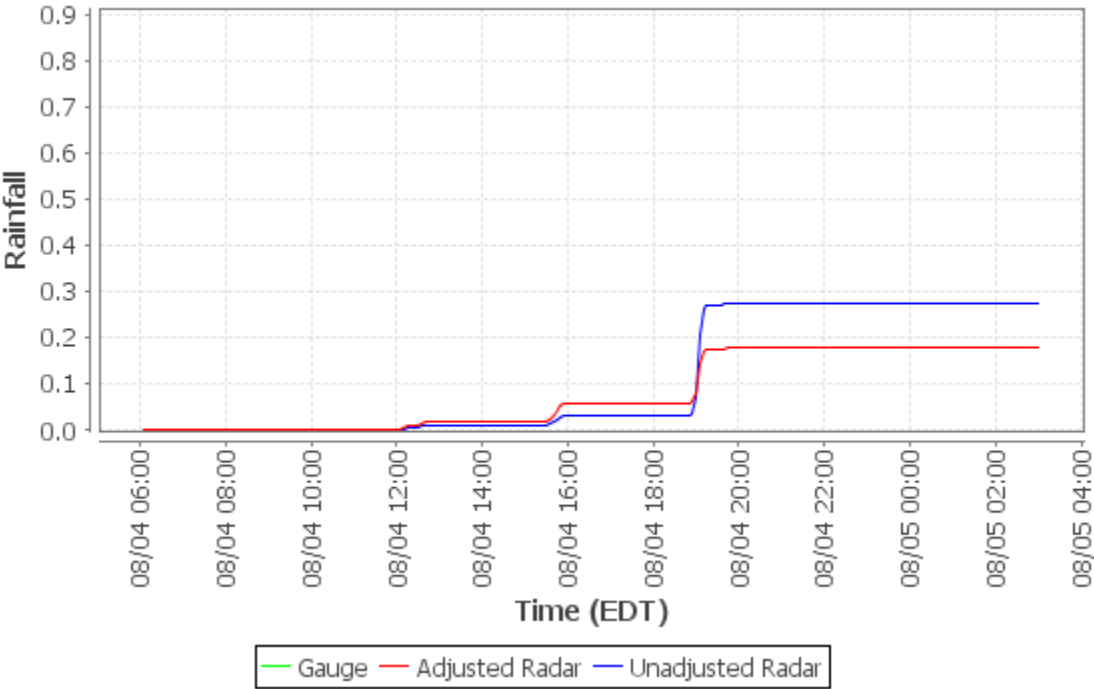
**Cumulative Distribution Plot - Trafford Maint Bldg (Loc15)**



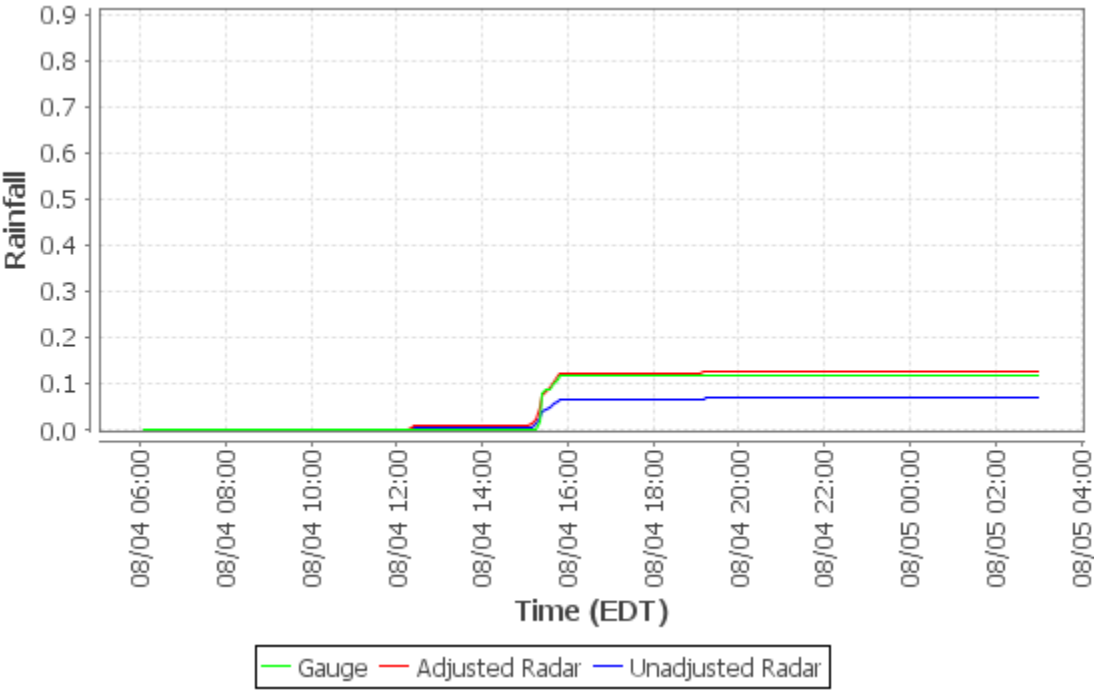
**Cumulative Distribution Plot - Castle Shannon (Loc16)**



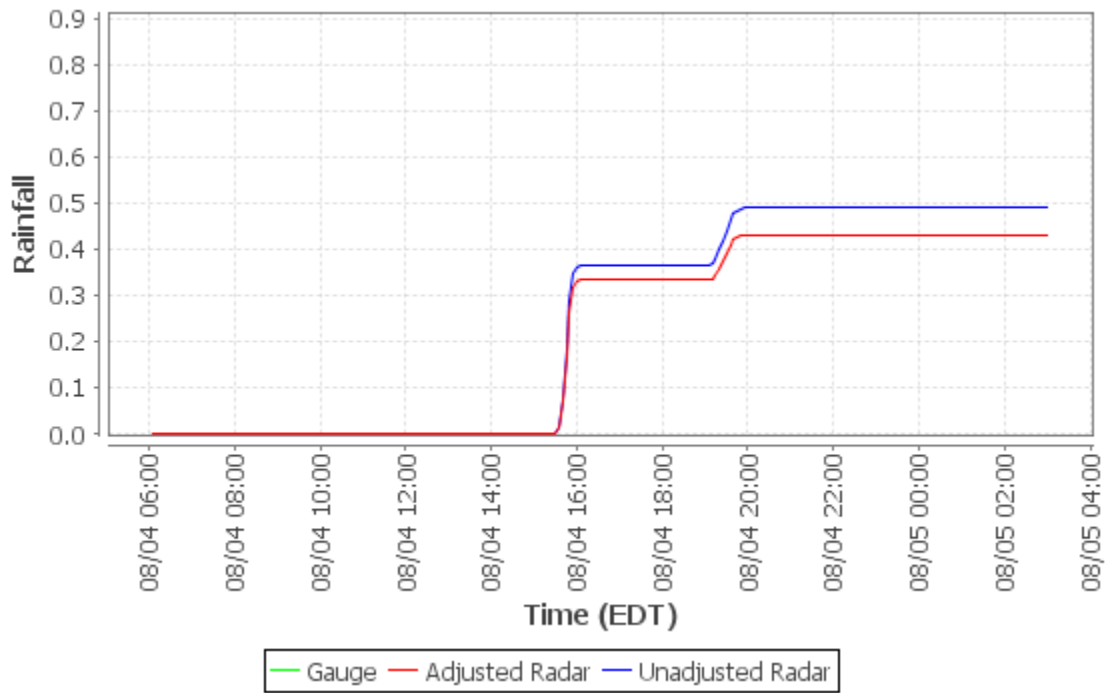
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



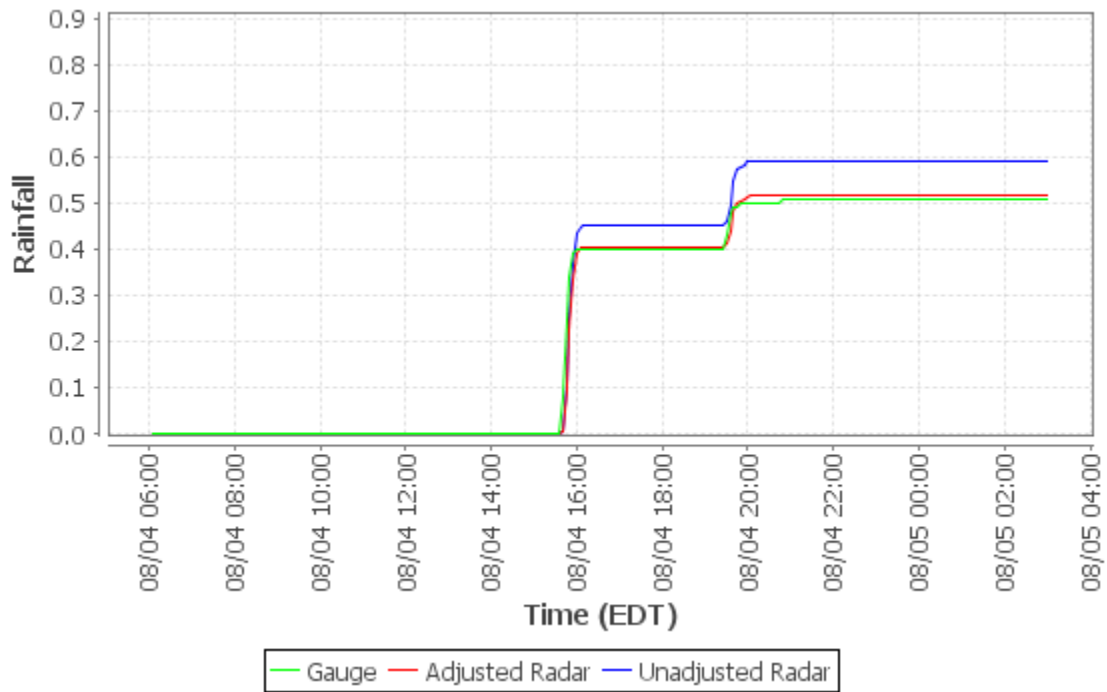
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



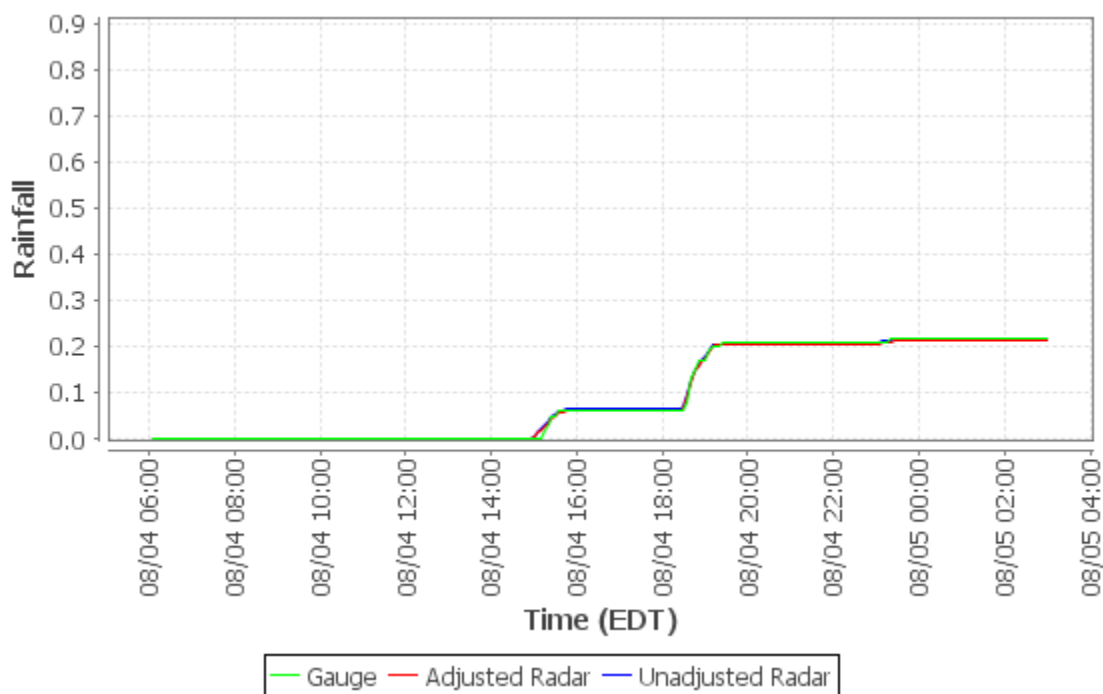
**Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)**



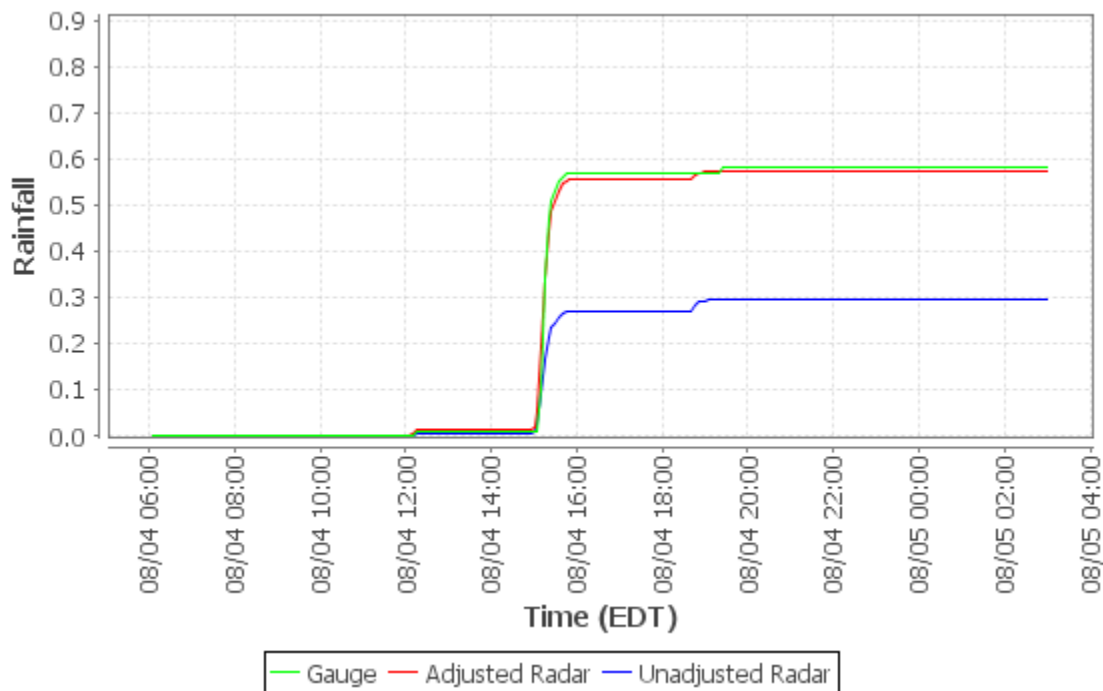
**Cumulative Distribution Plot - Gascola Eq Facility (Loc20)**



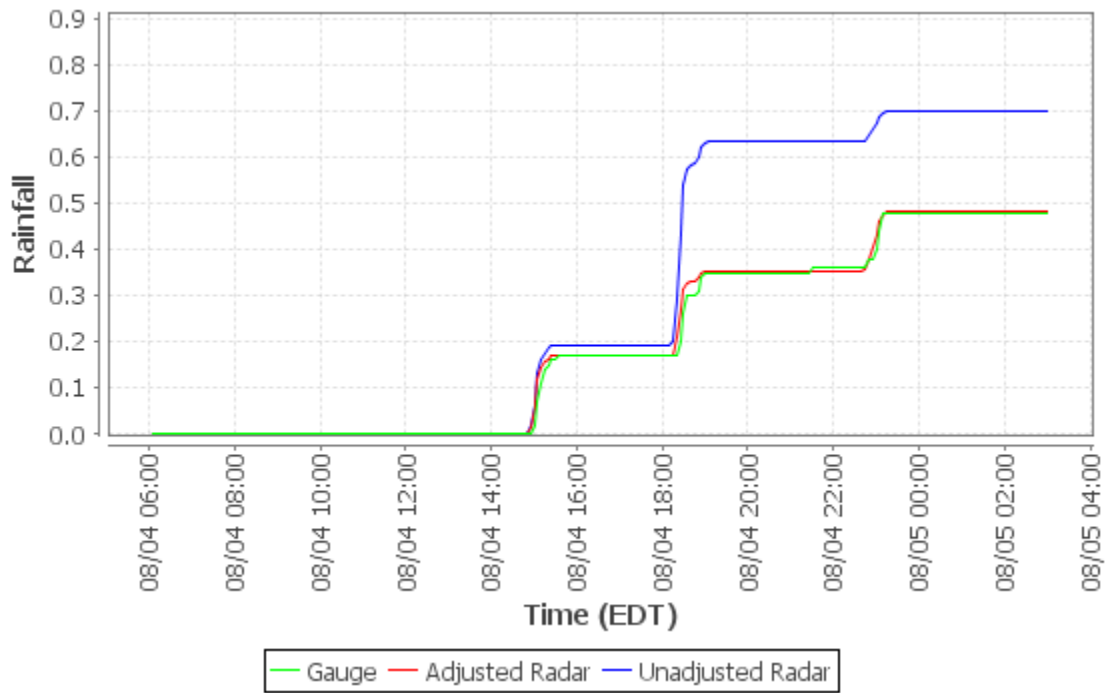
**Cumulative Distribution Plot - Moon TWP (Loc21)**



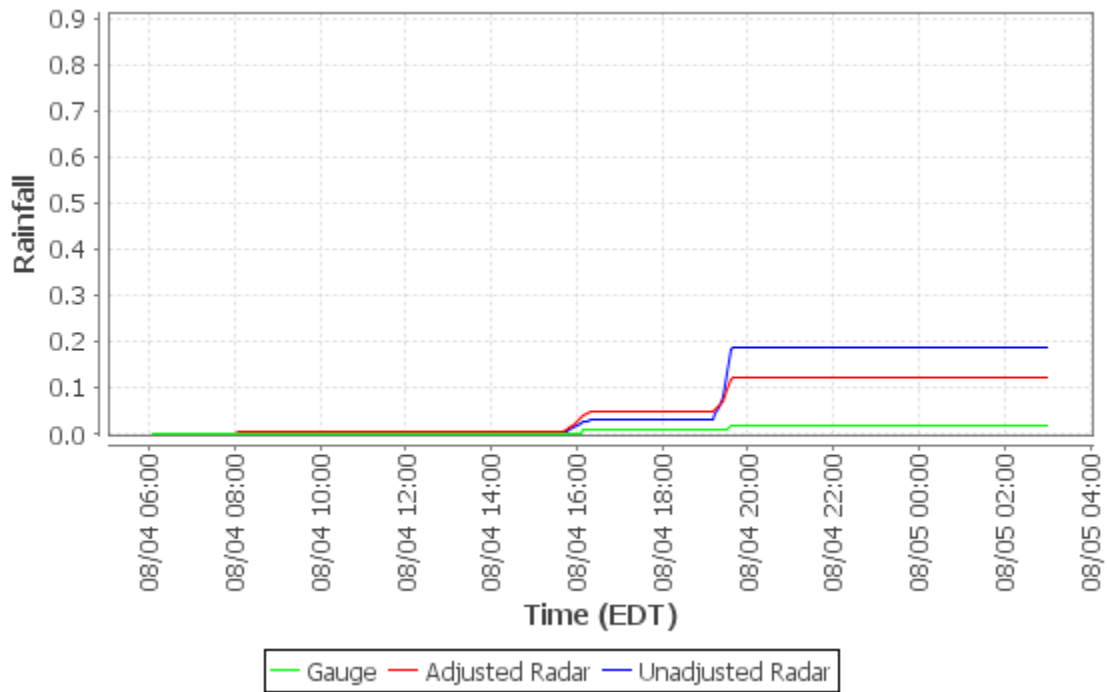
**Cumulative Distribution Plot - North Fayette TWP (Loc22)**



**Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)**

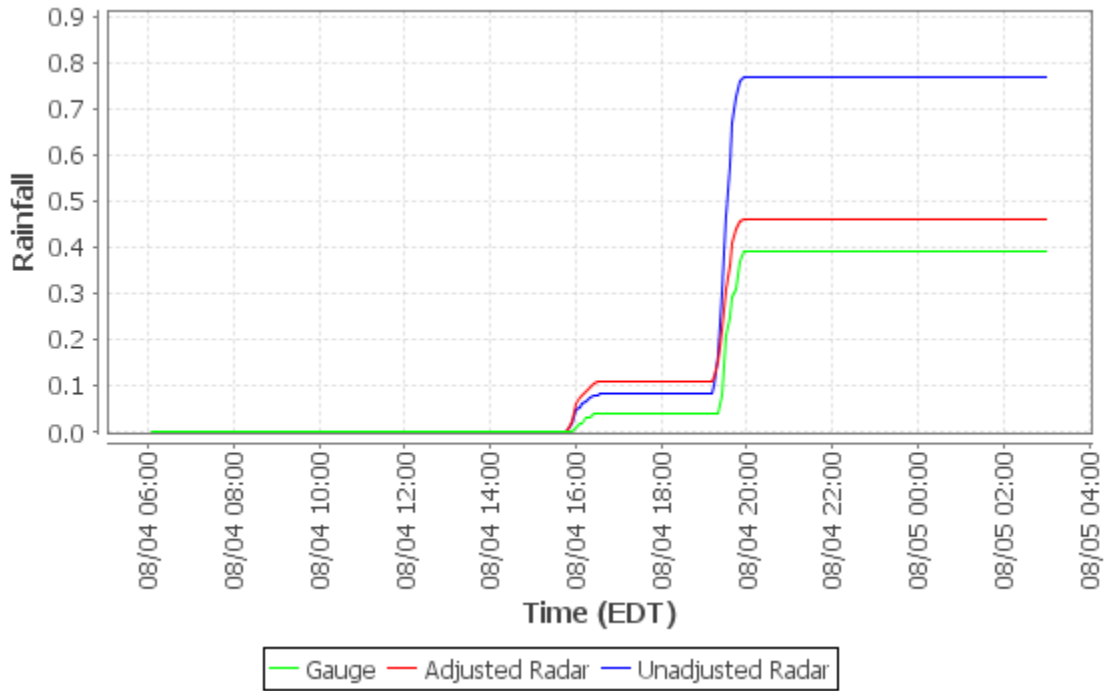


**Cumulative Distribution Plot - Jefferson Hills (Loc24)**

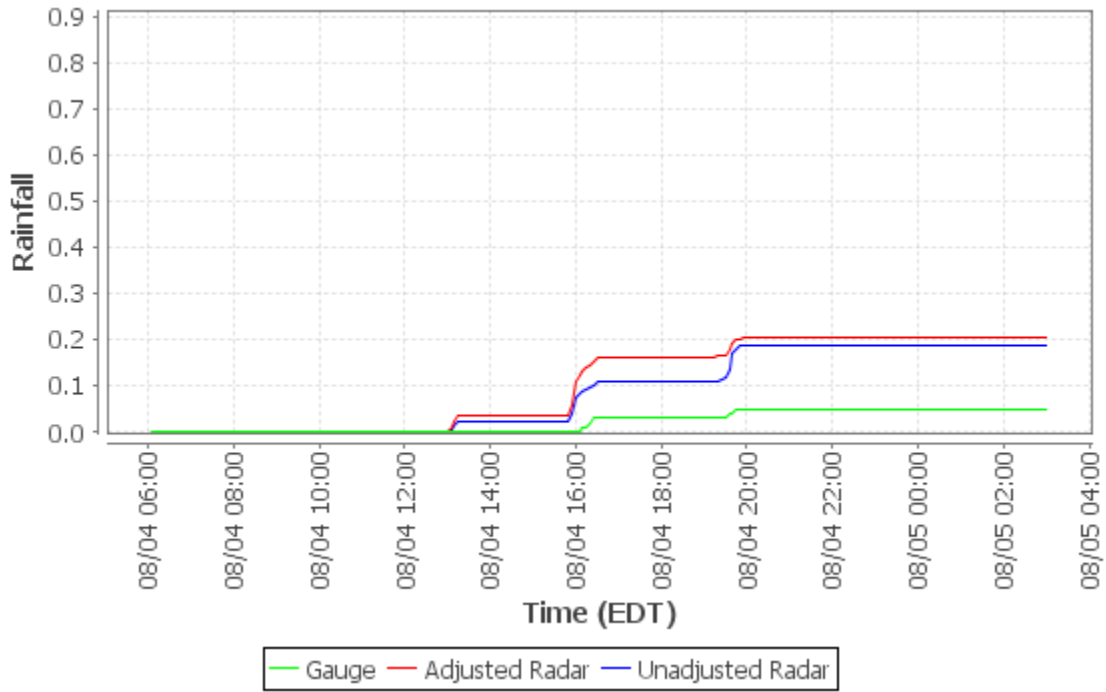




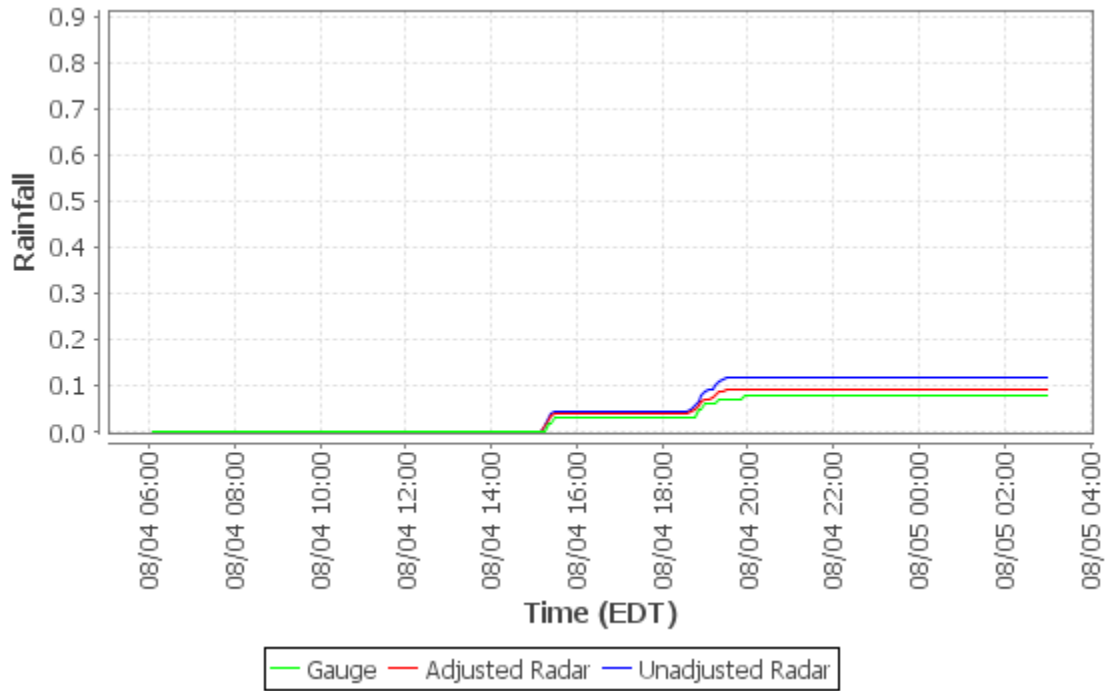
**Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)**



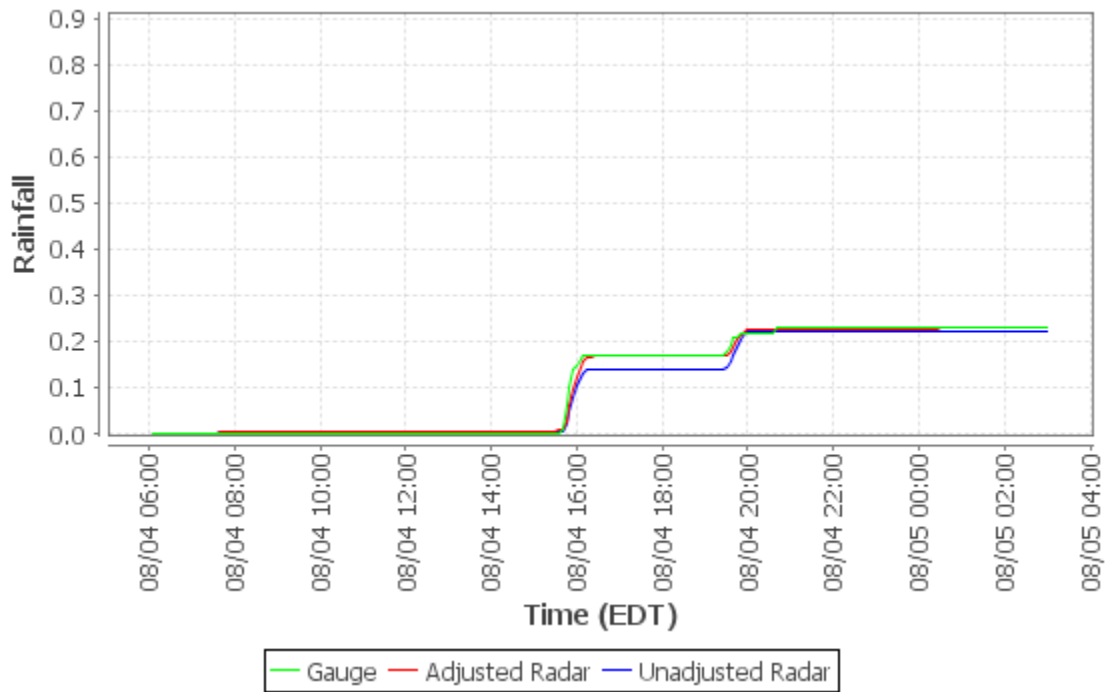
**Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)**



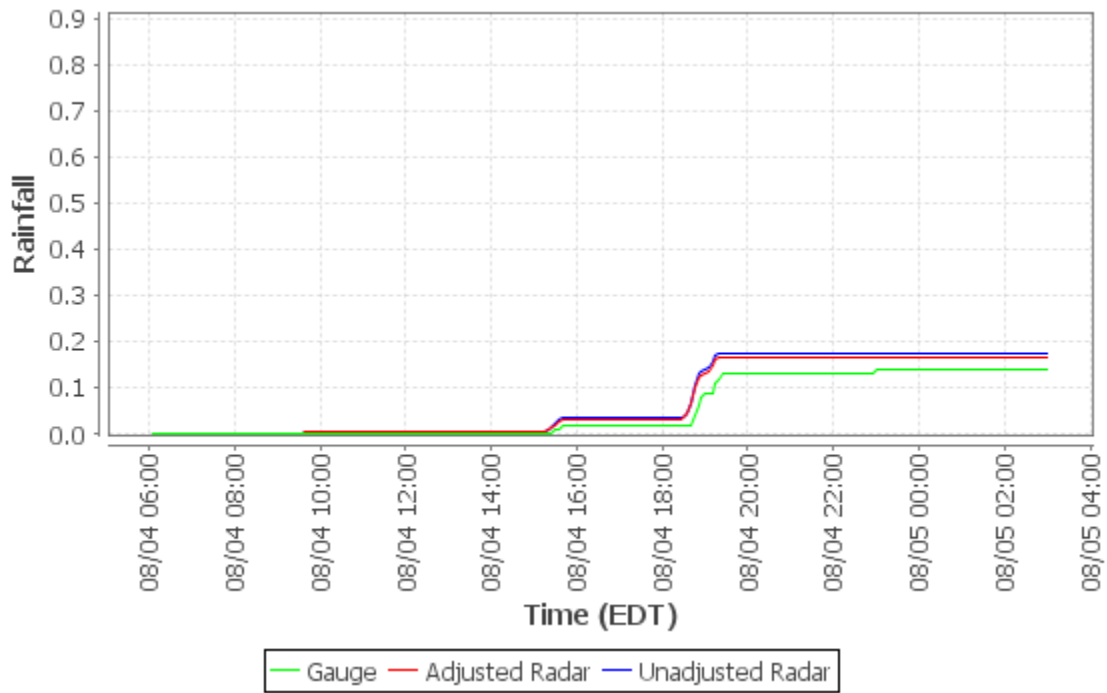
**Cumulative Distribution Plot - Marshall TWP (Loc27)**



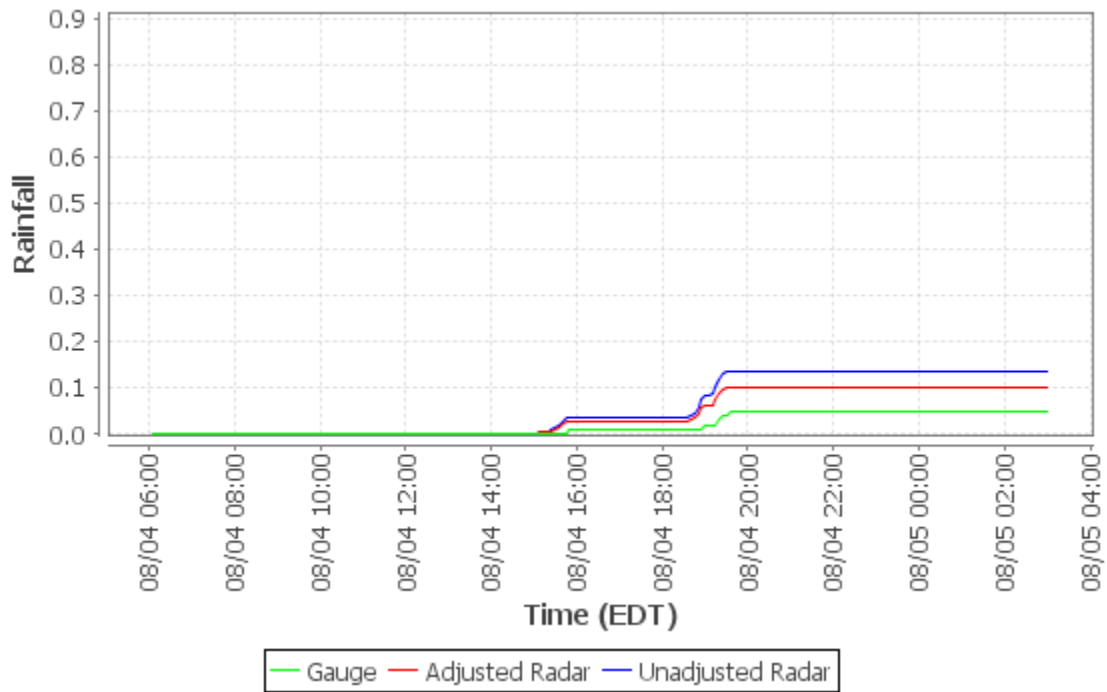
**Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)**



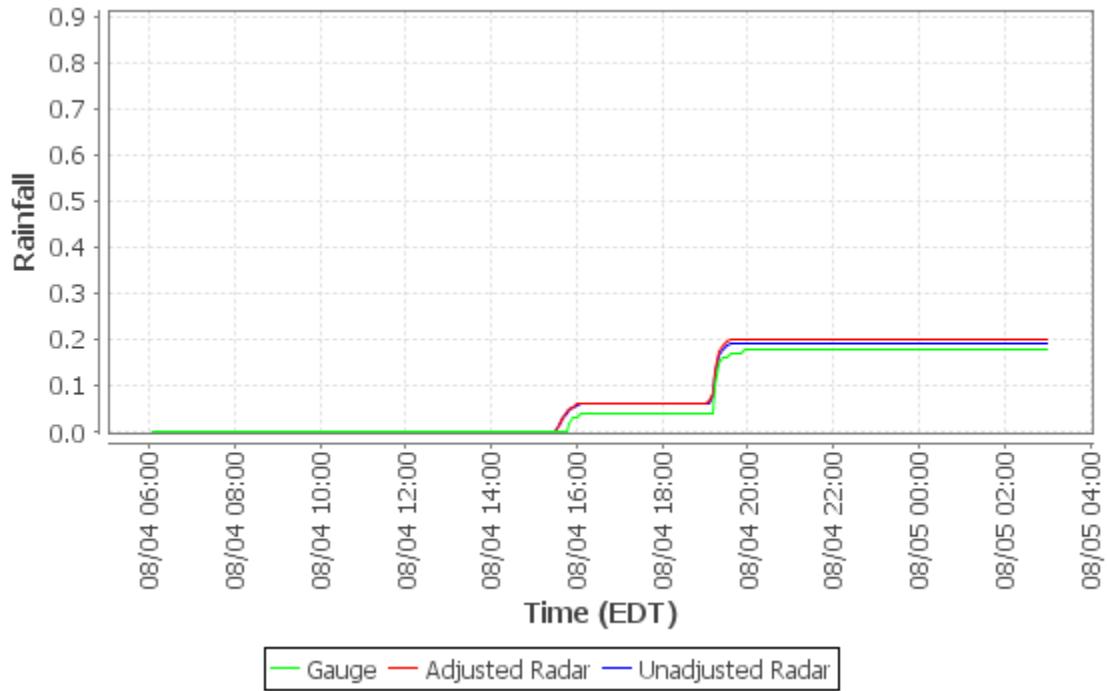
**Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)**



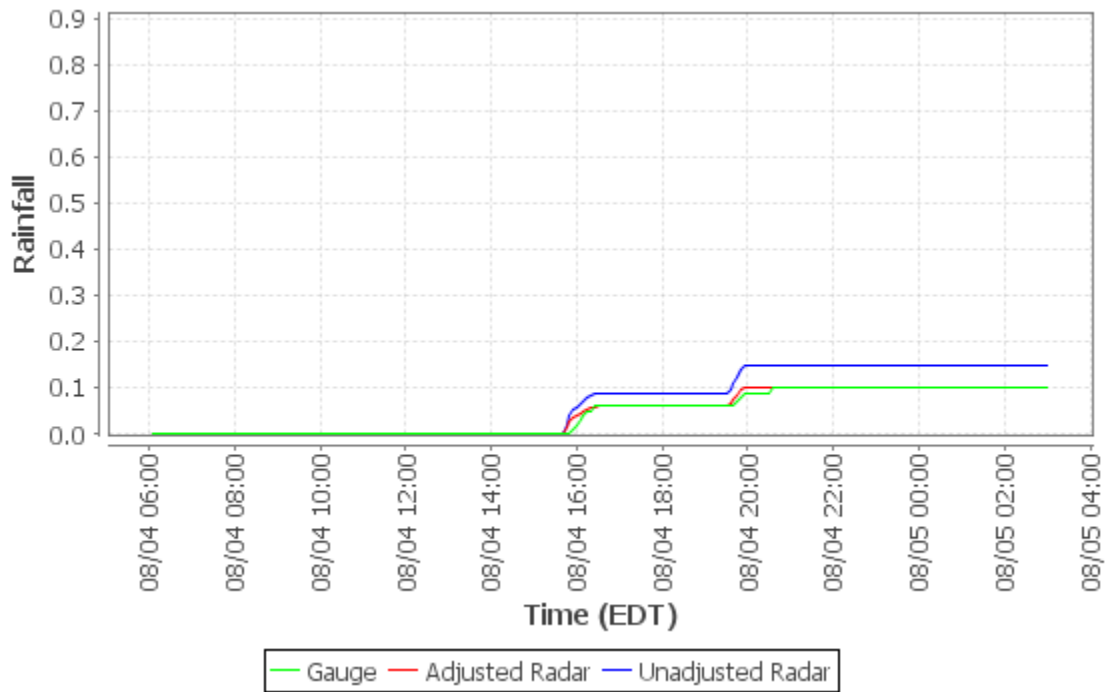
**Cumulative Distribution Plot - McCandless Twn Hall (Loc30)**



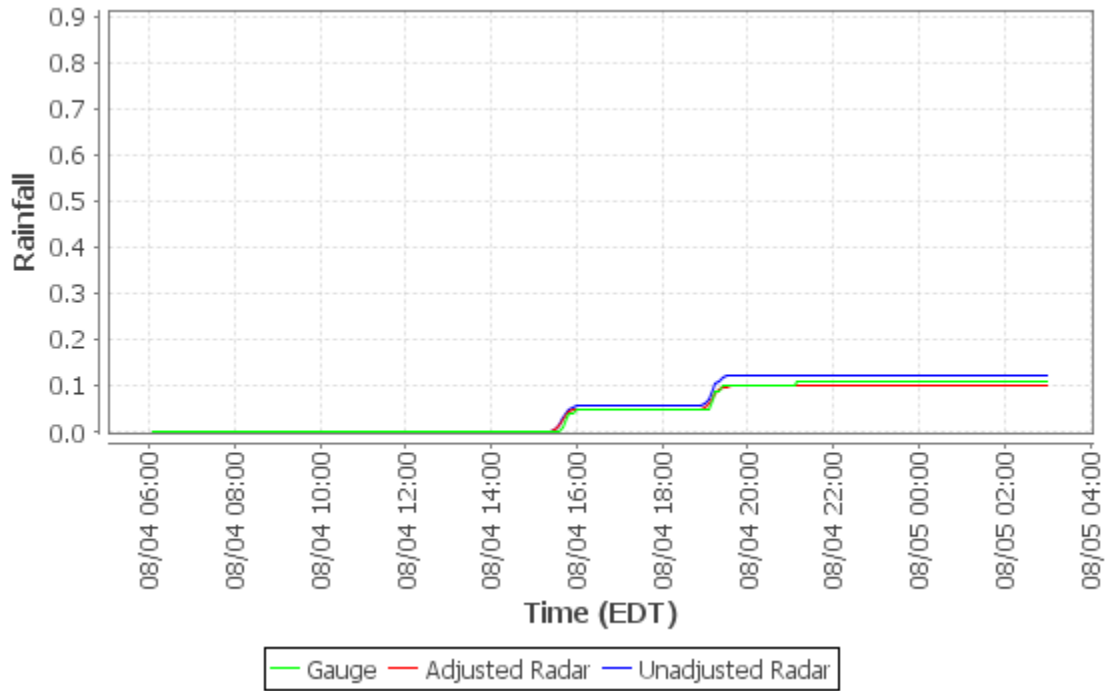
**Cumulative Distribution Plot - Hampton Municipal Bldg (Loc31)**



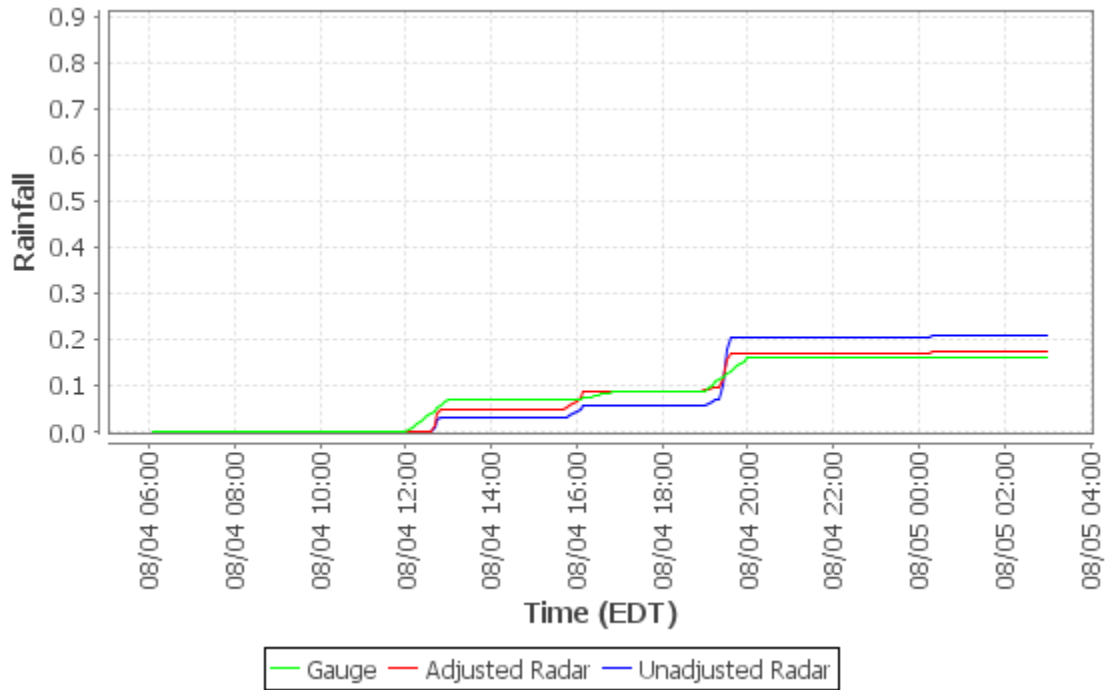
**Cumulative Distribution Plot - Arnold (Loc32)**



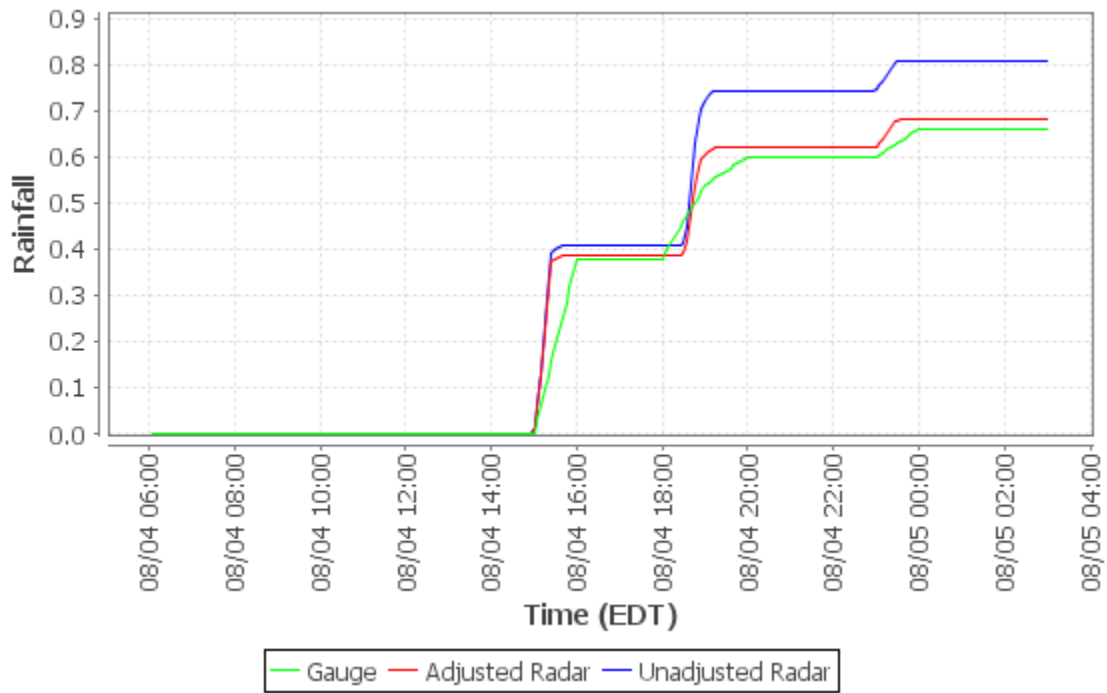
**Cumulative Distribution Plot - Richland TWP (Loc33)**



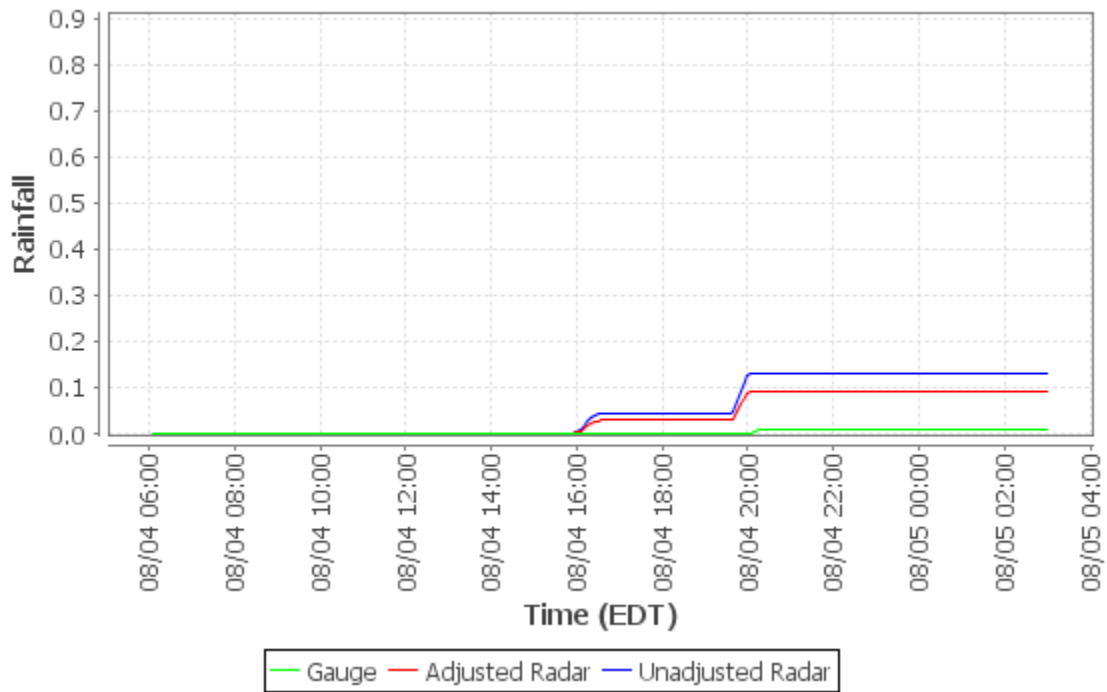
**Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)**



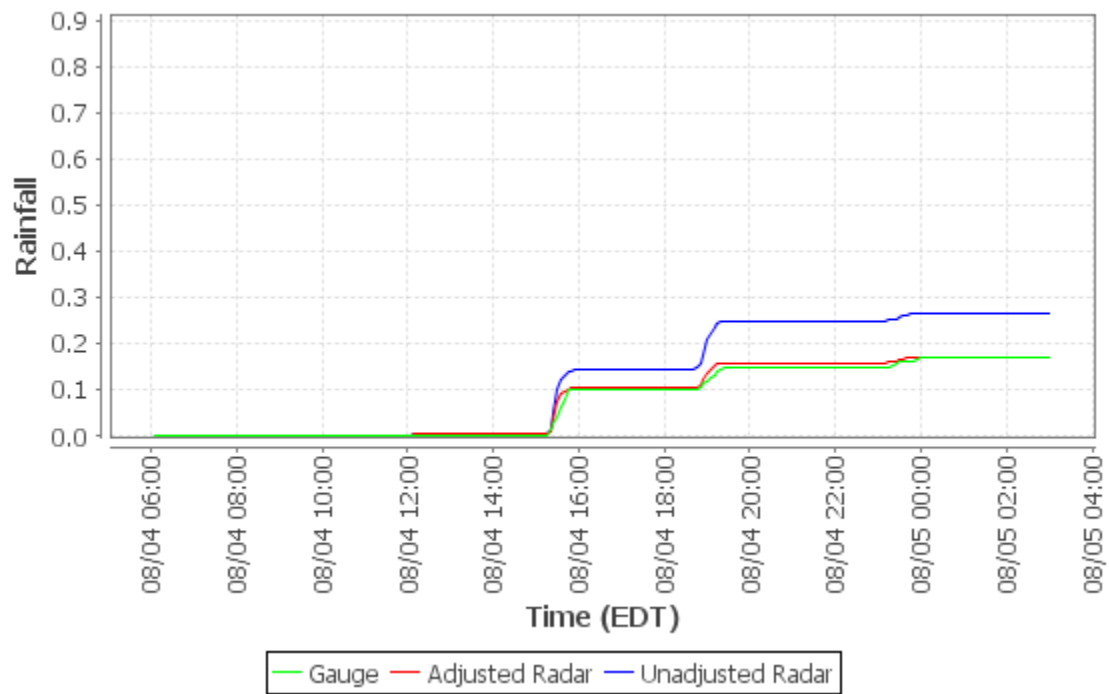
**Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)**



**Cumulative Distribution Plot - Allegheny River at Natrona (03049500)**



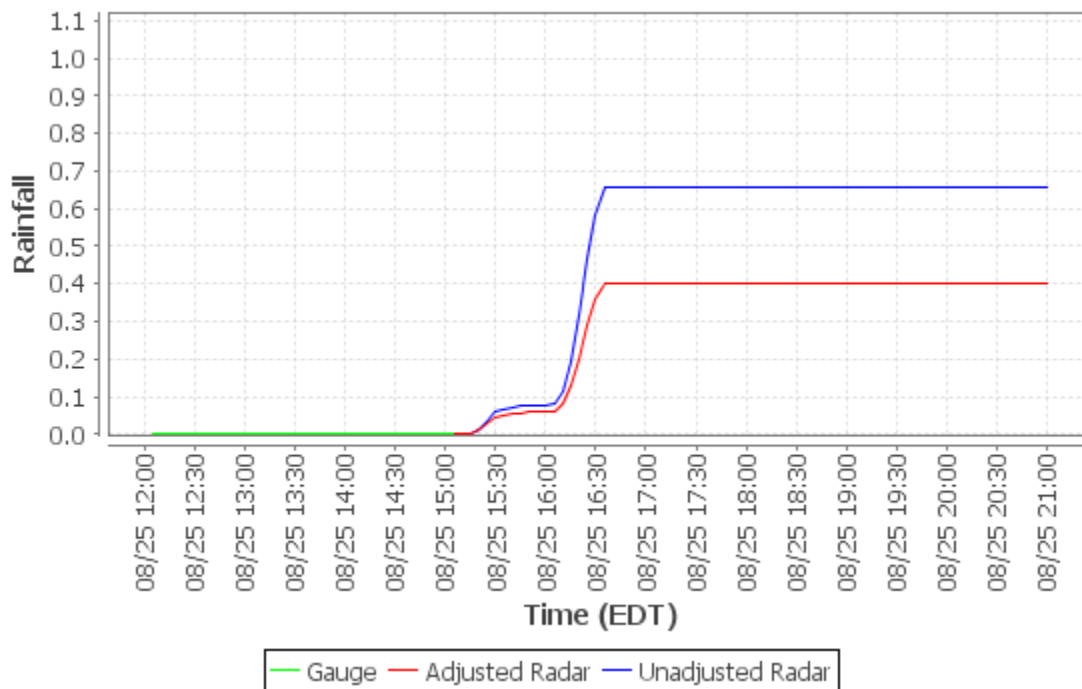
**Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth  
(03085734)**



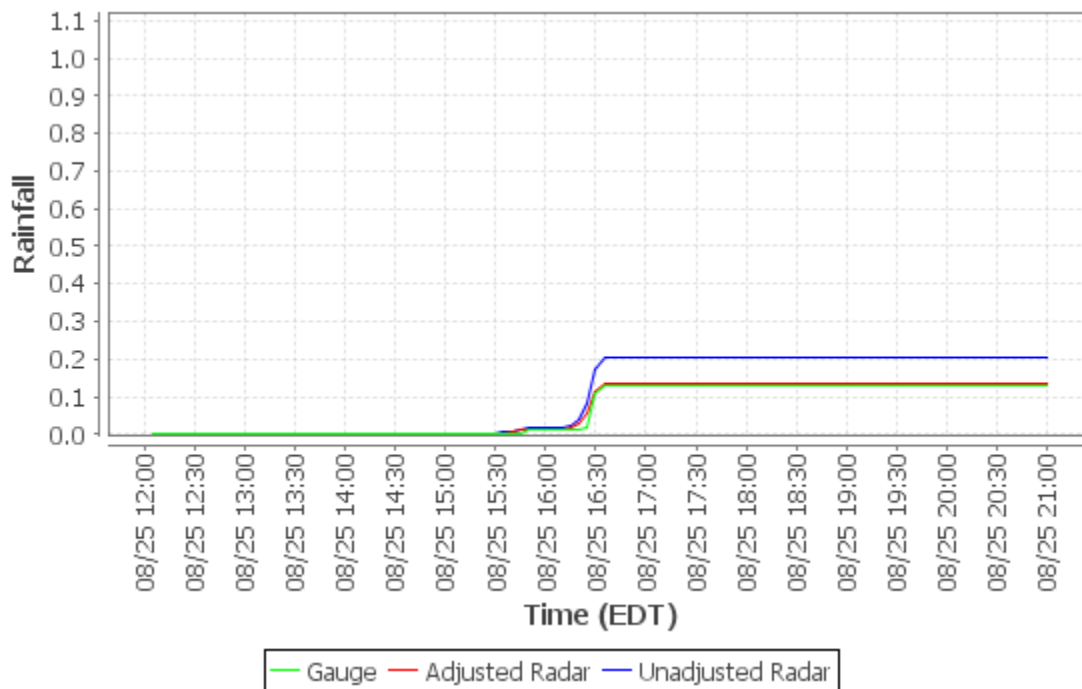
## **Appendix E - Event 3 (2020-08-25) CDPs**



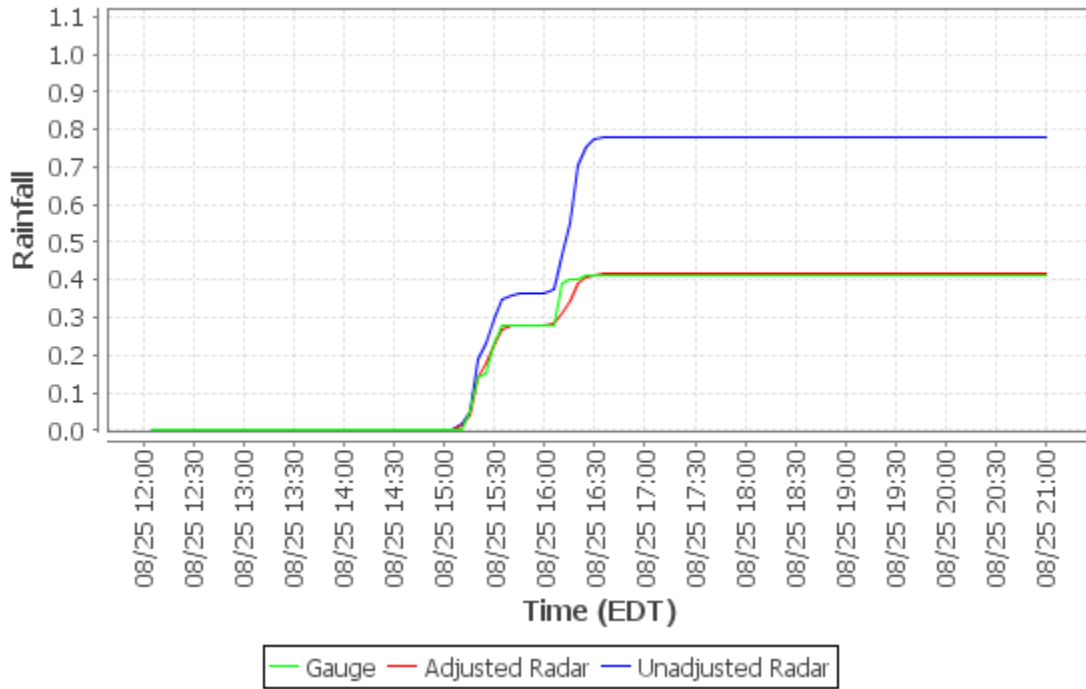
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



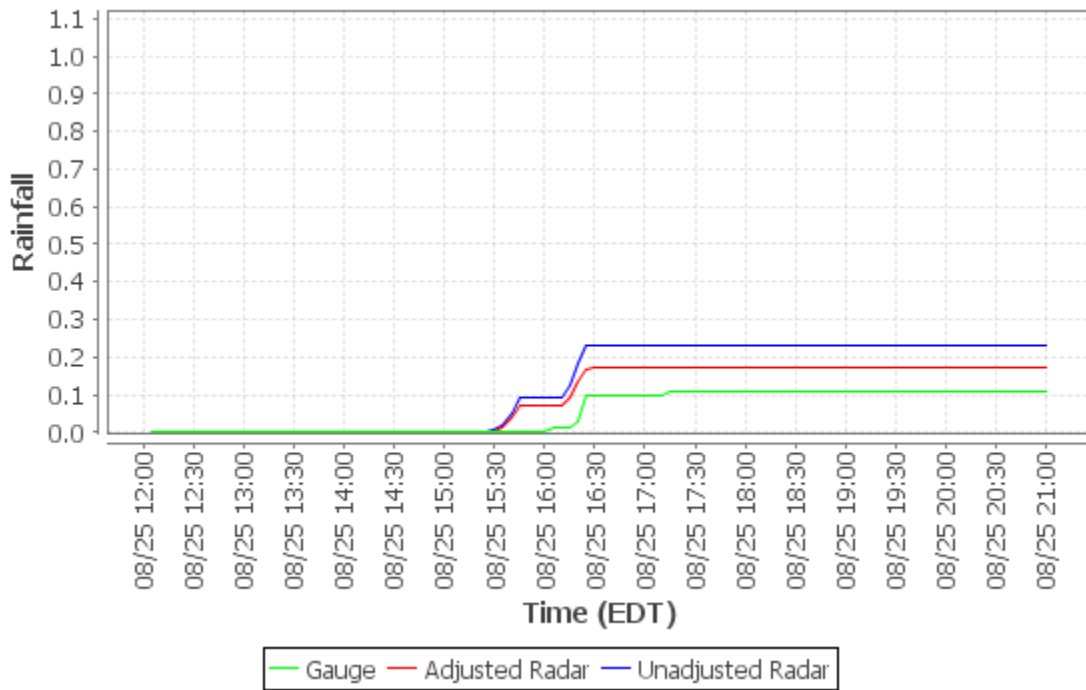
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



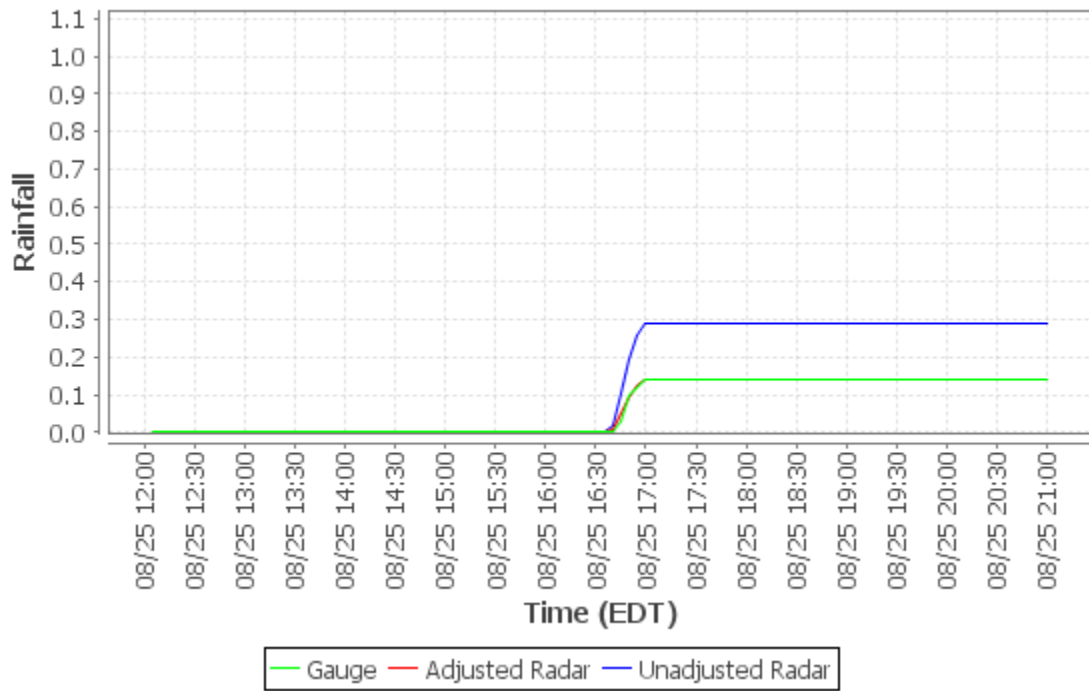
**Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)**



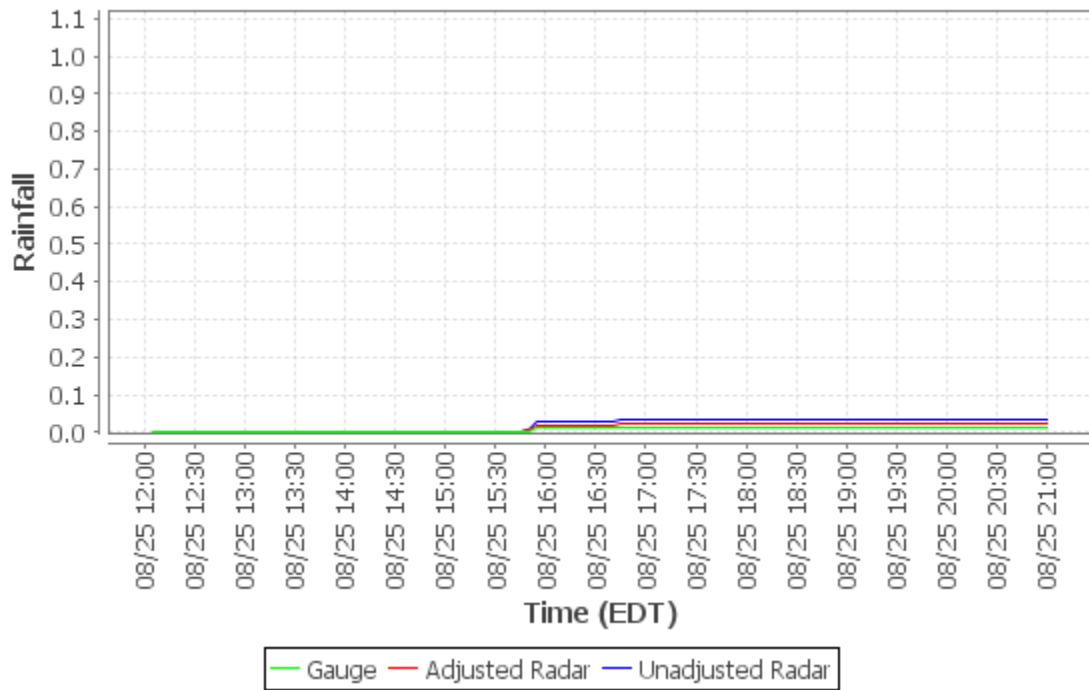
**Cumulative Distribution Plot - Kennedy Twp PS (Loc04)**



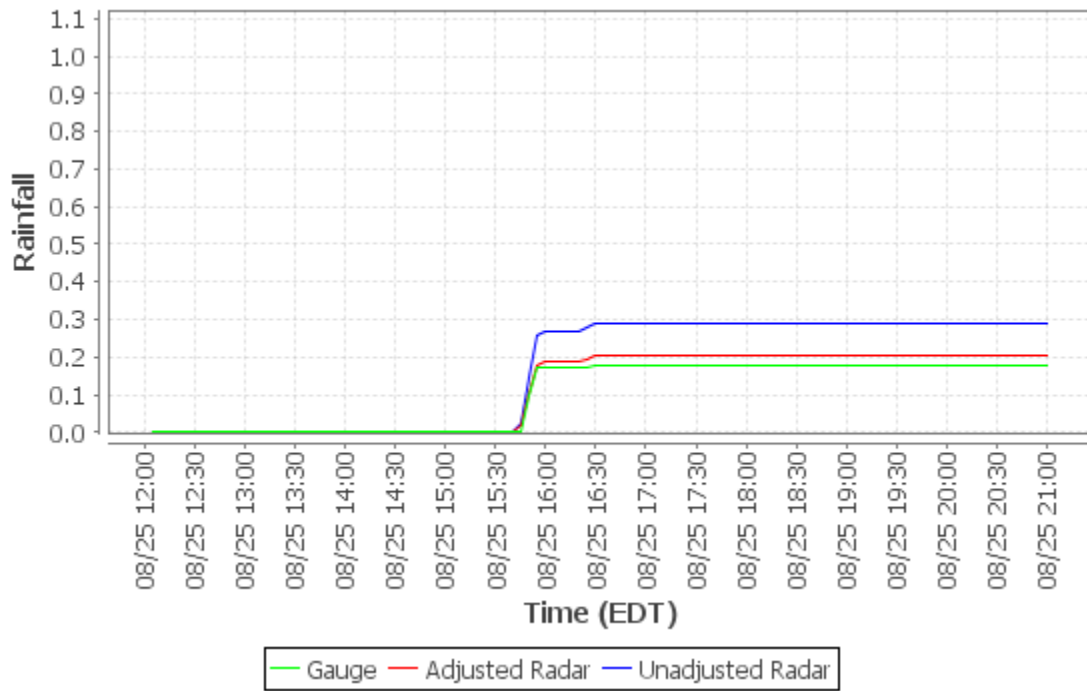
**Cumulative Distribution Plot - Upper St. Clair (Loc05)**



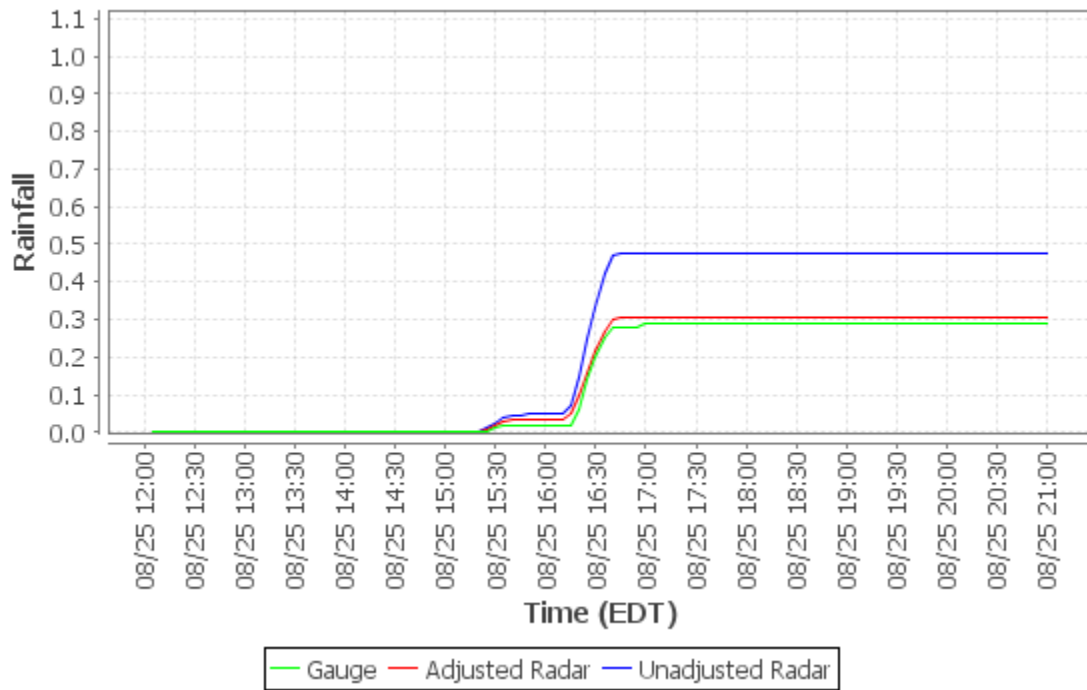
**Cumulative Distribution Plot - Carnegie Transit Time (Loc06)**



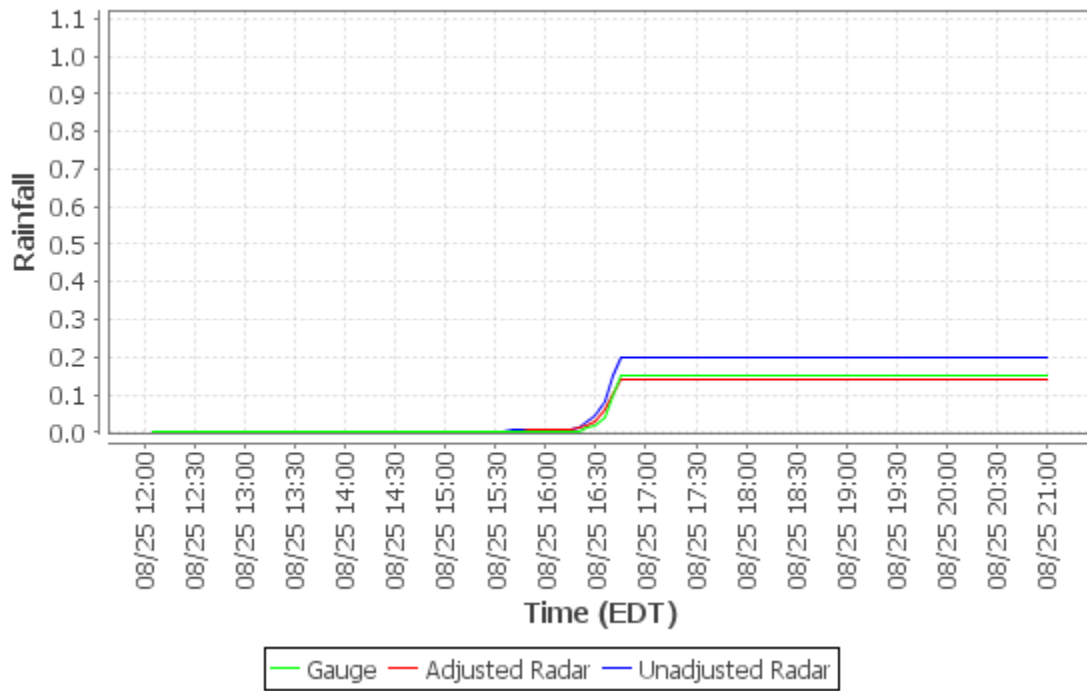
**Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)**



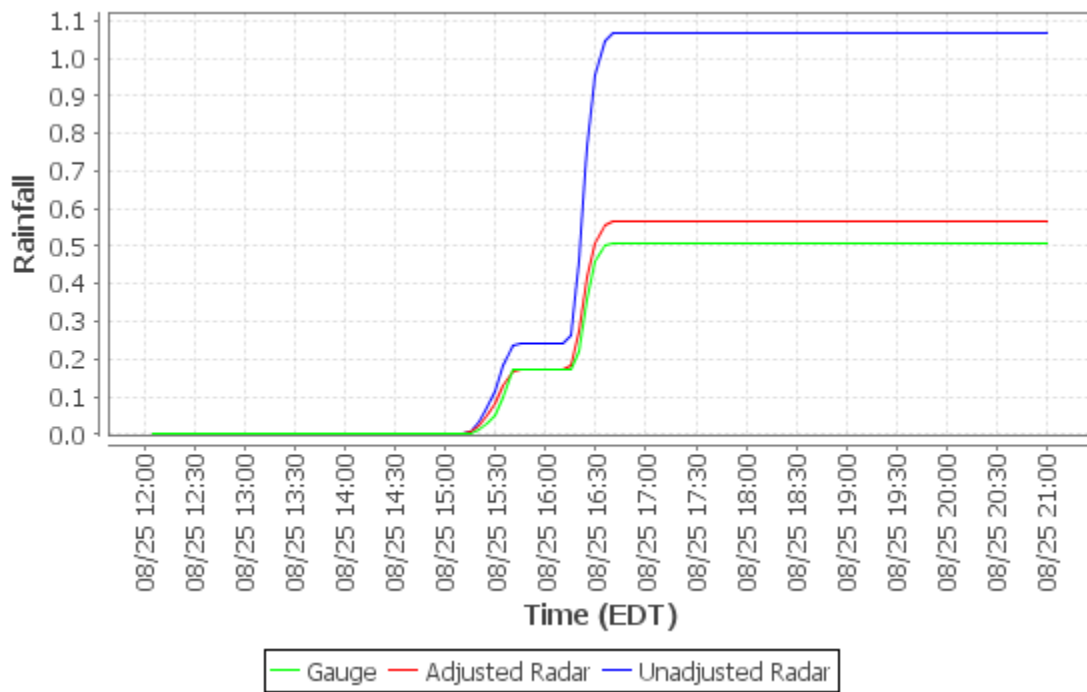
**Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)**



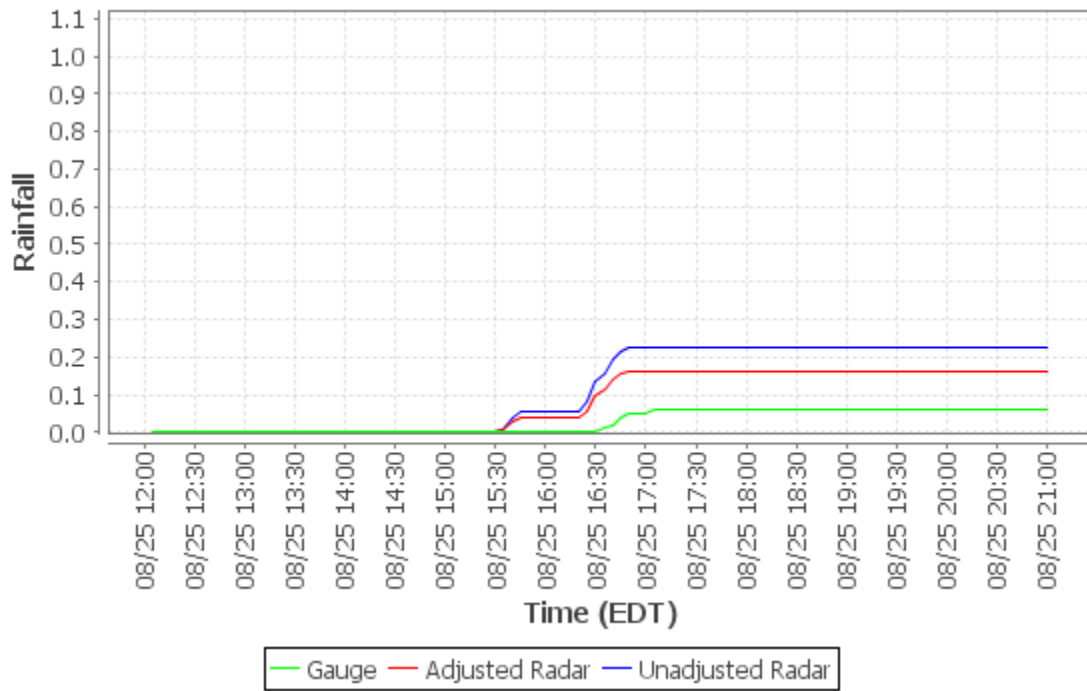
**Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)**



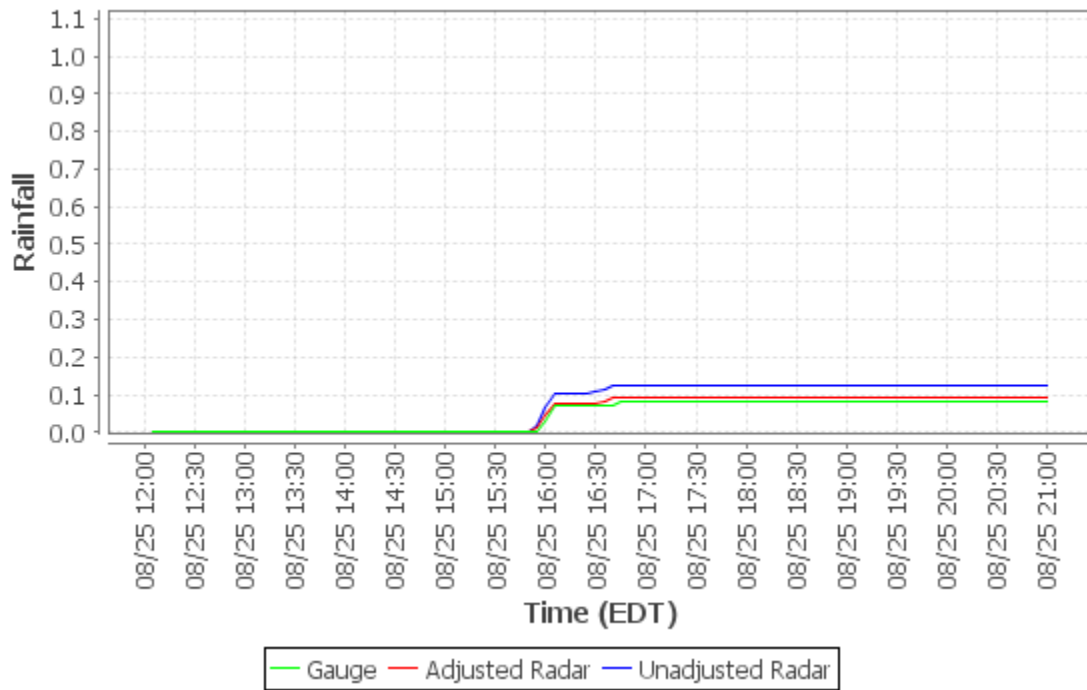
**Cumulative Distribution Plot - PWSA-Highland Park (Loc10)**



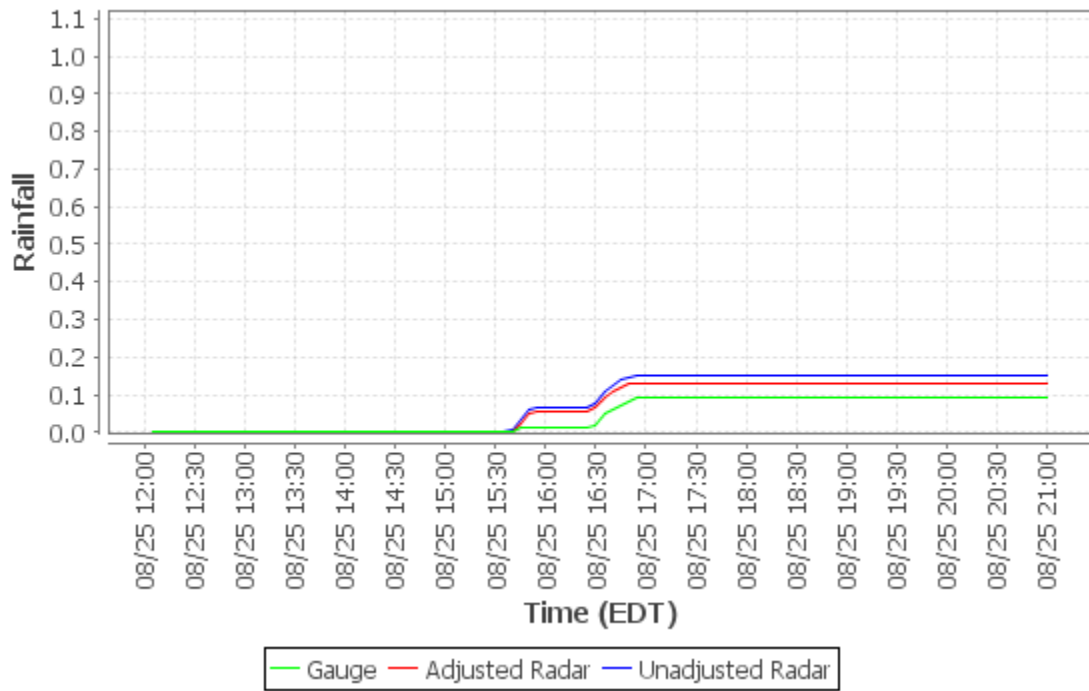
**Cumulative Distribution Plot - M-46 Access Shaft (Loc11)**



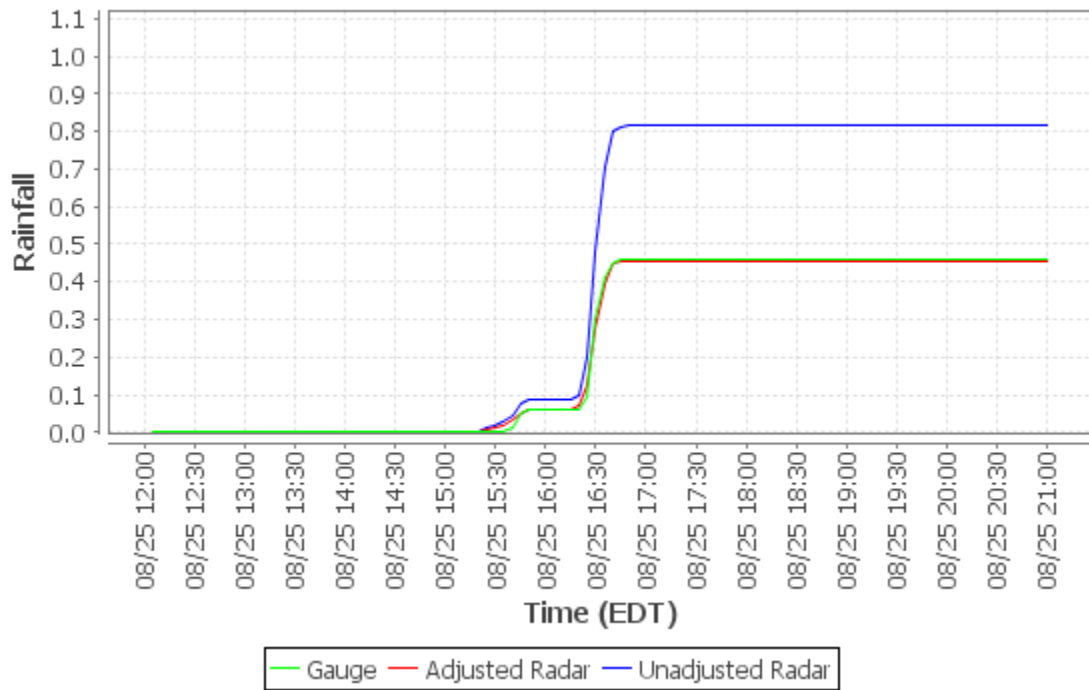
**Cumulative Distribution Plot - Baldwin (Loc12)**



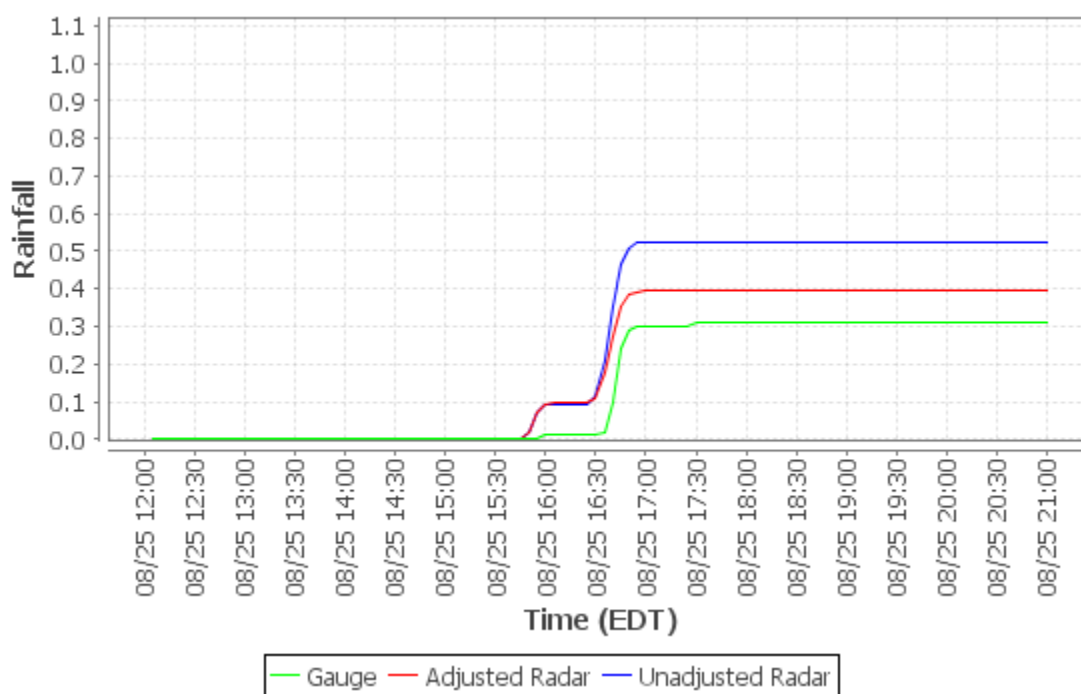
**Cumulative Distribution Plot - M-59 Access Shaft (Loc13)**



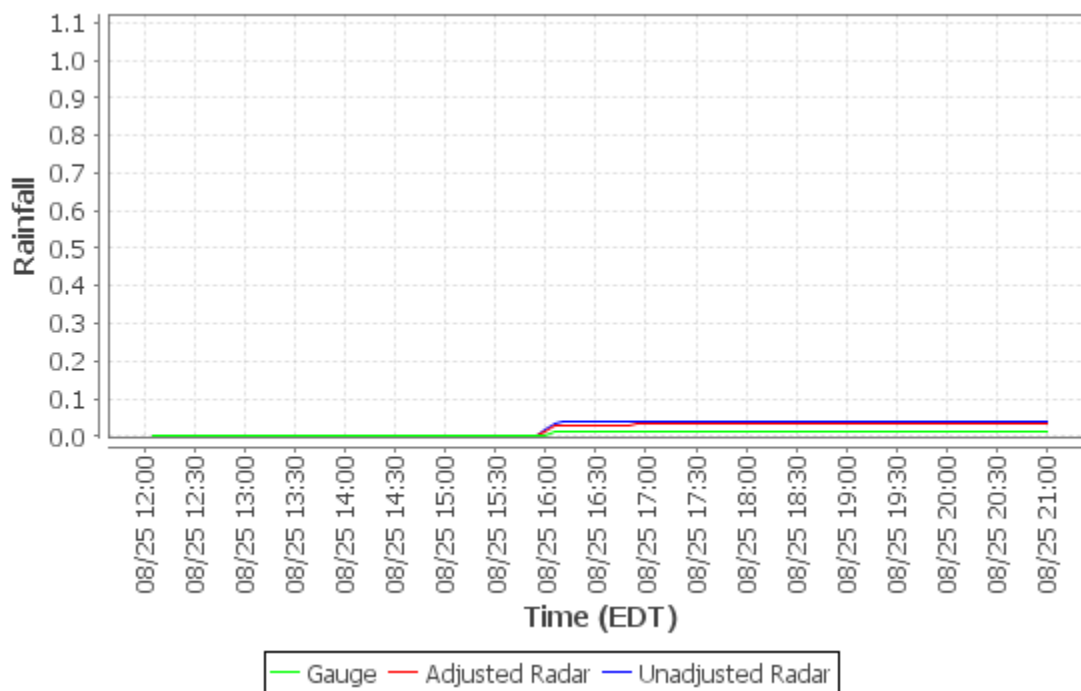
**Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)**



**Cumulative Distribution Plot - Trafford Maint Bldg (Loc15)**

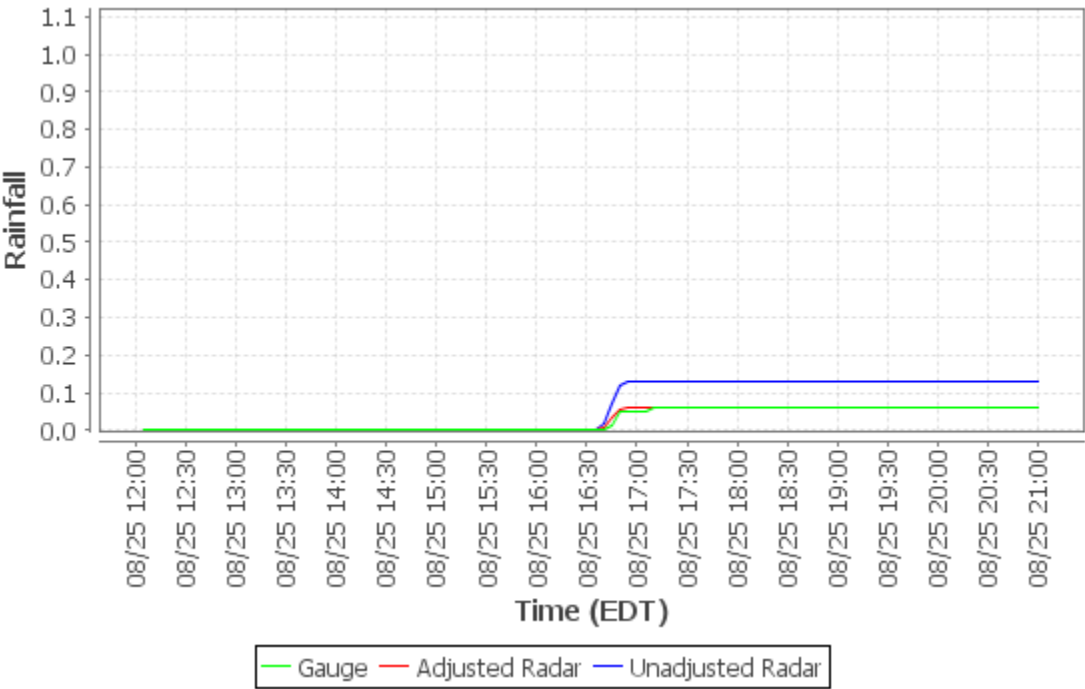


**Cumulative Distribution Plot - Castle Shannon (Loc16)**

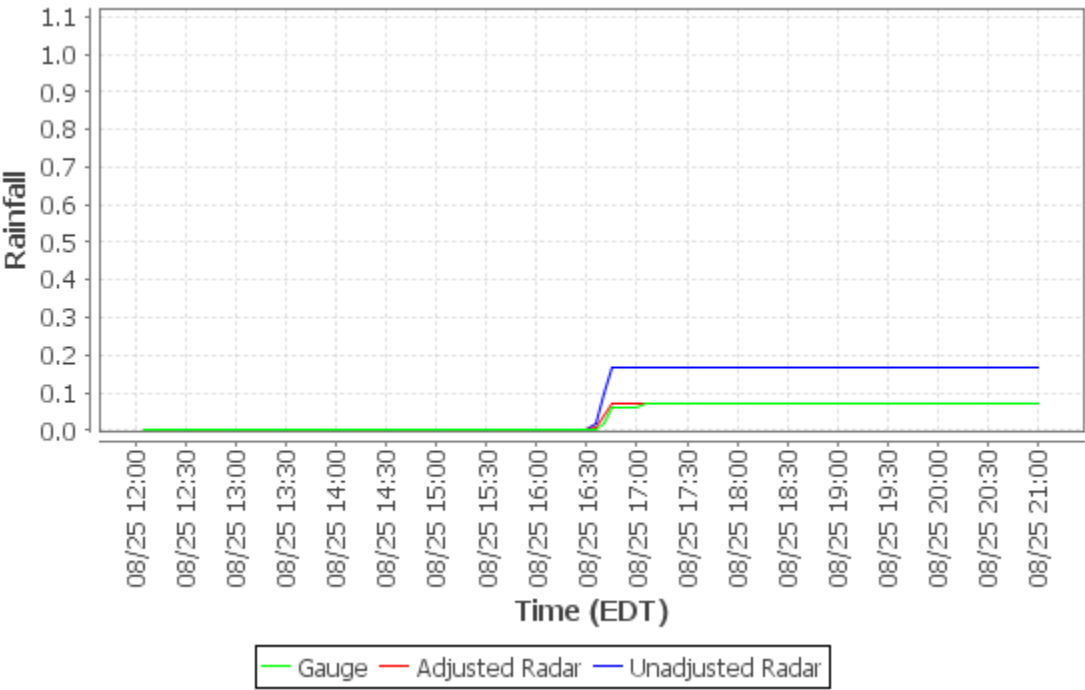




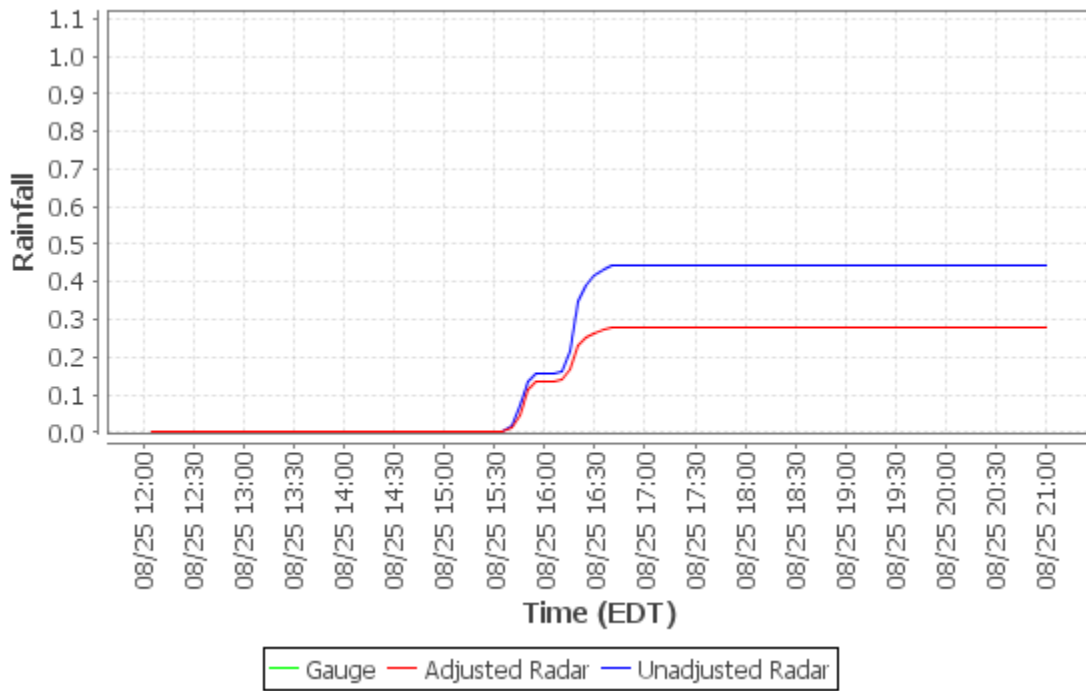
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



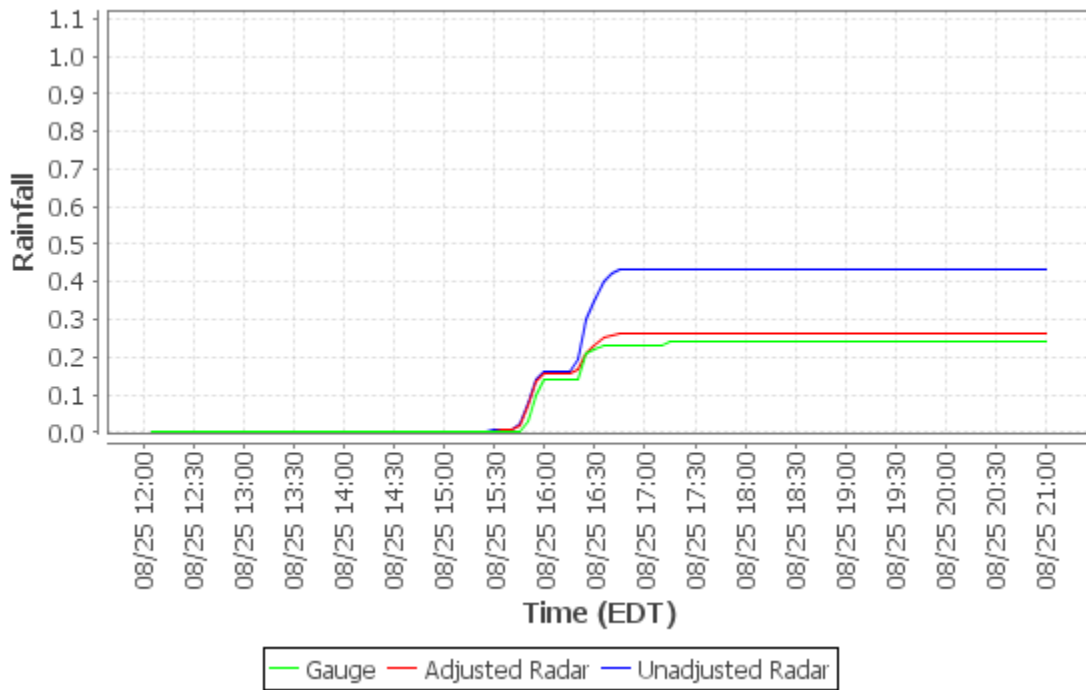
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



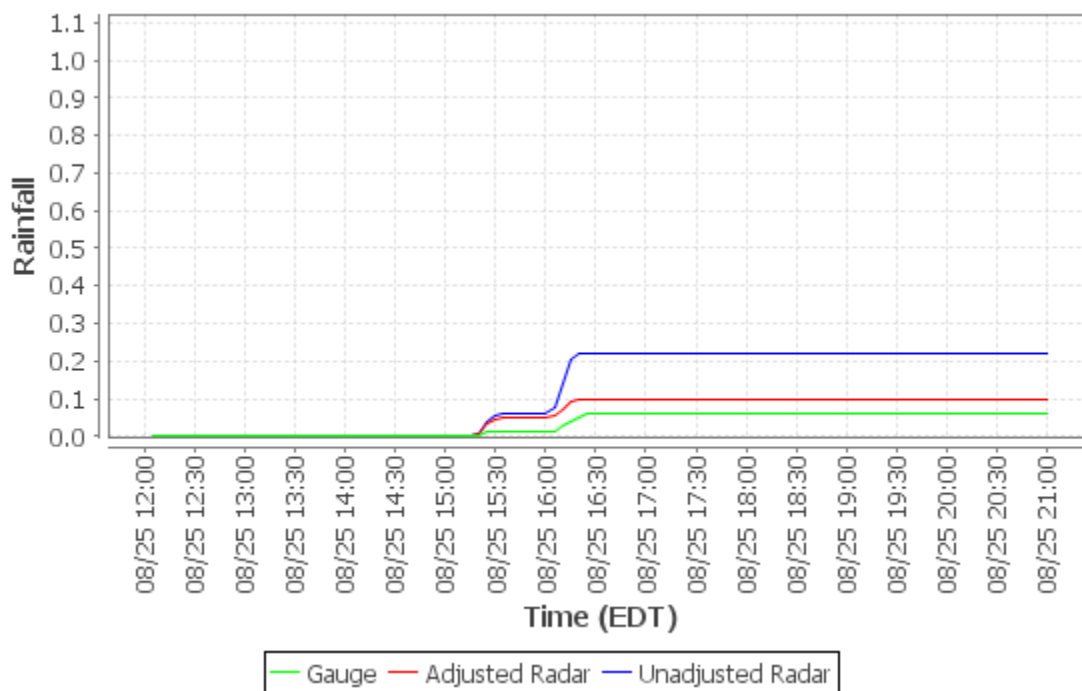
**Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)**



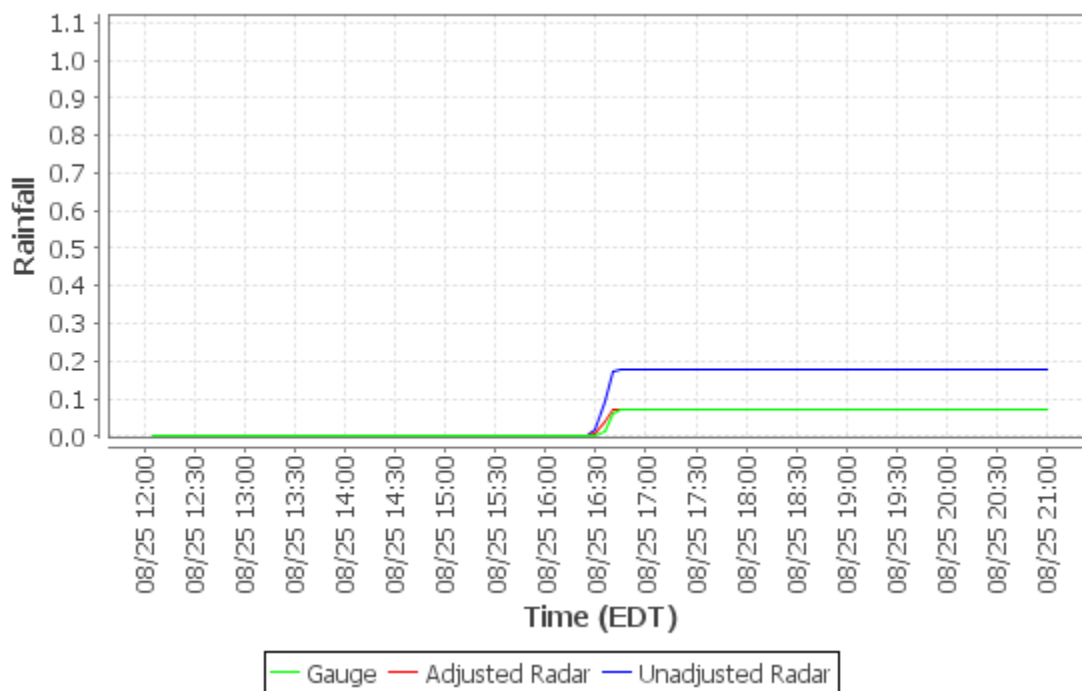
**Cumulative Distribution Plot - Gascola Eq Facility (Loc20)**



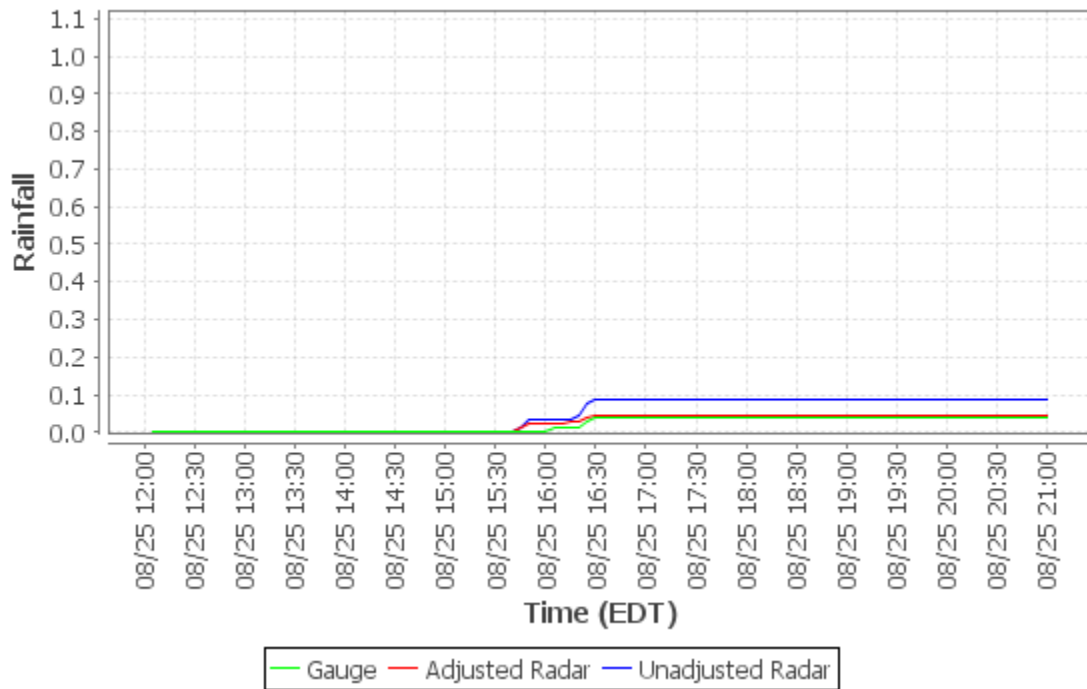
**Cumulative Distribution Plot - Moon TWP (Loc21)**



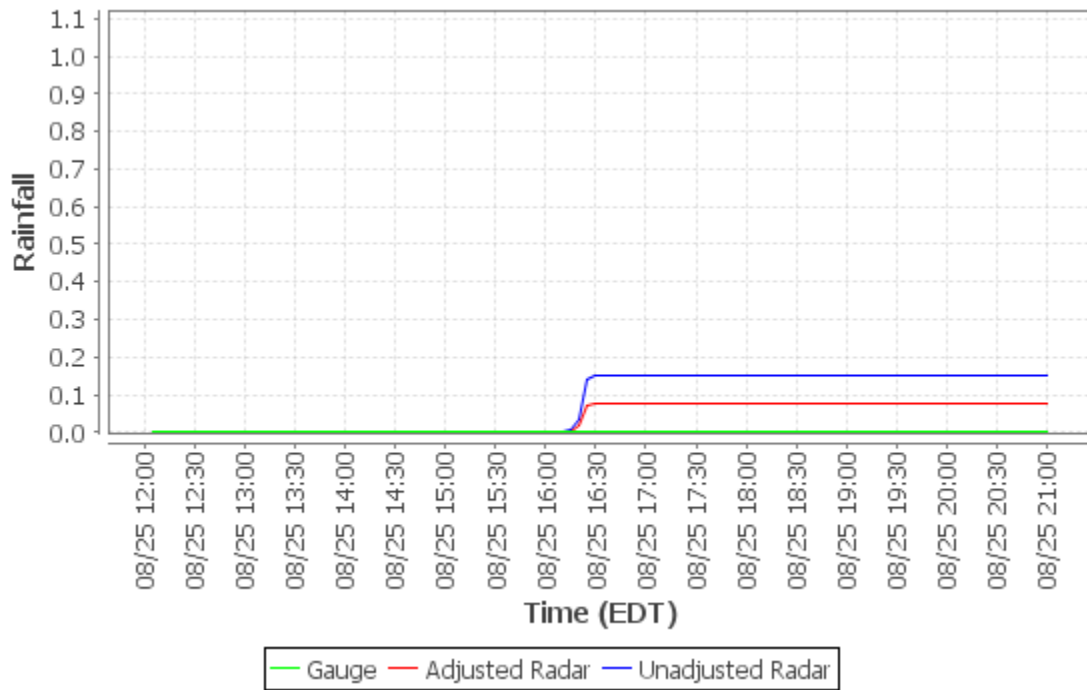
**Cumulative Distribution Plot - North Fayette TWP (Loc22)**



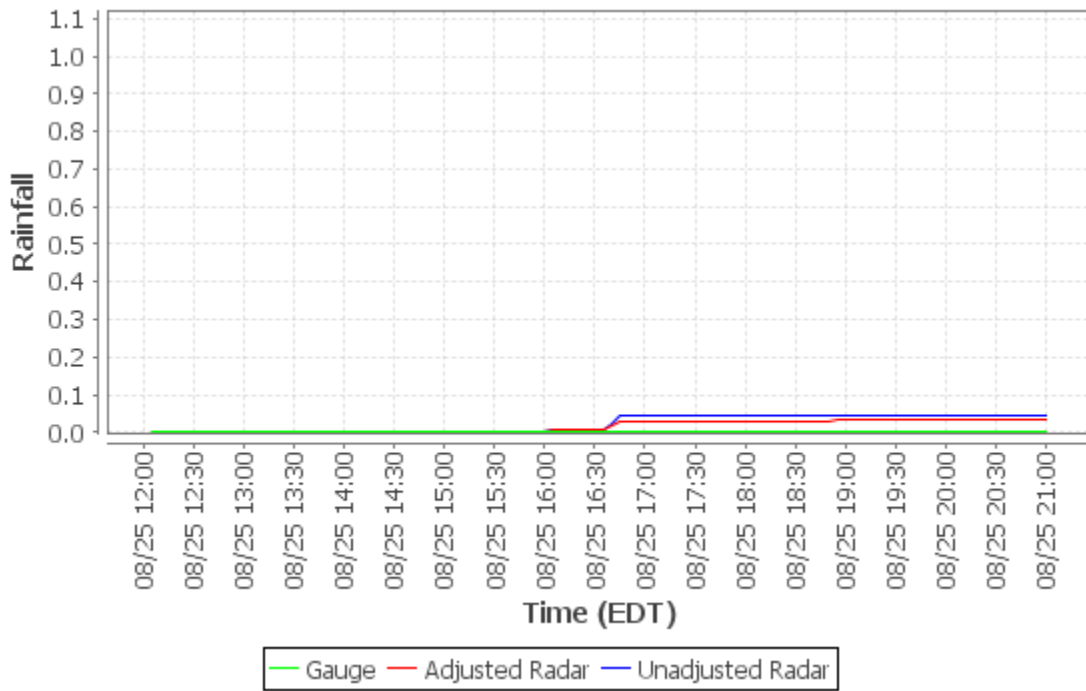
**Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)**



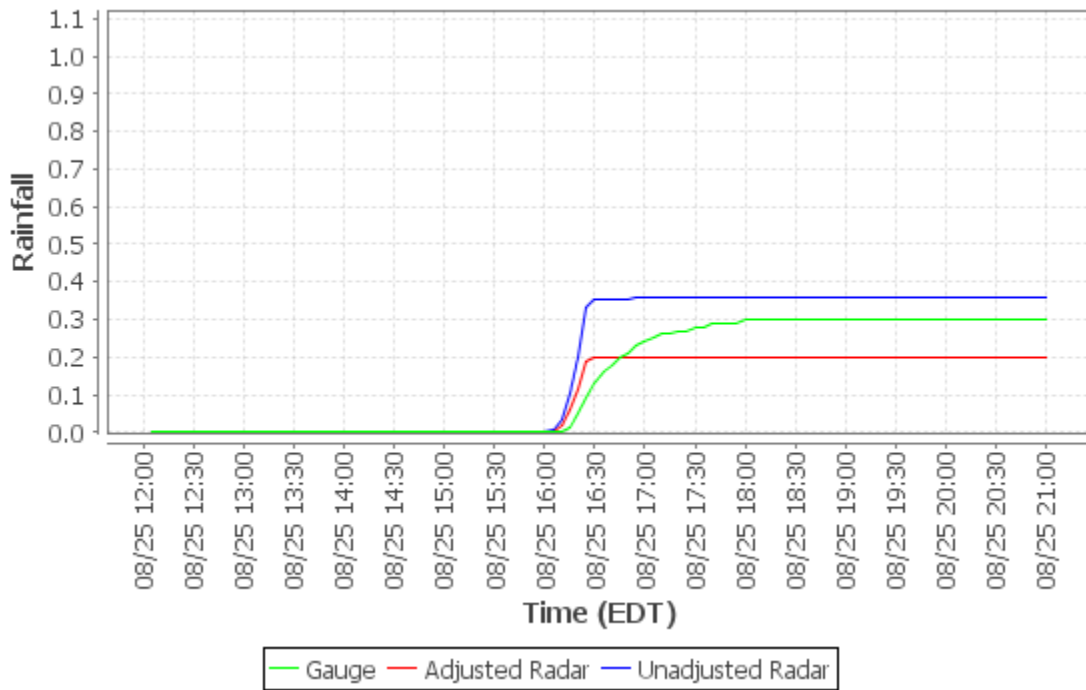
**Cumulative Distribution Plot - Jefferson Hills (Loc24)**



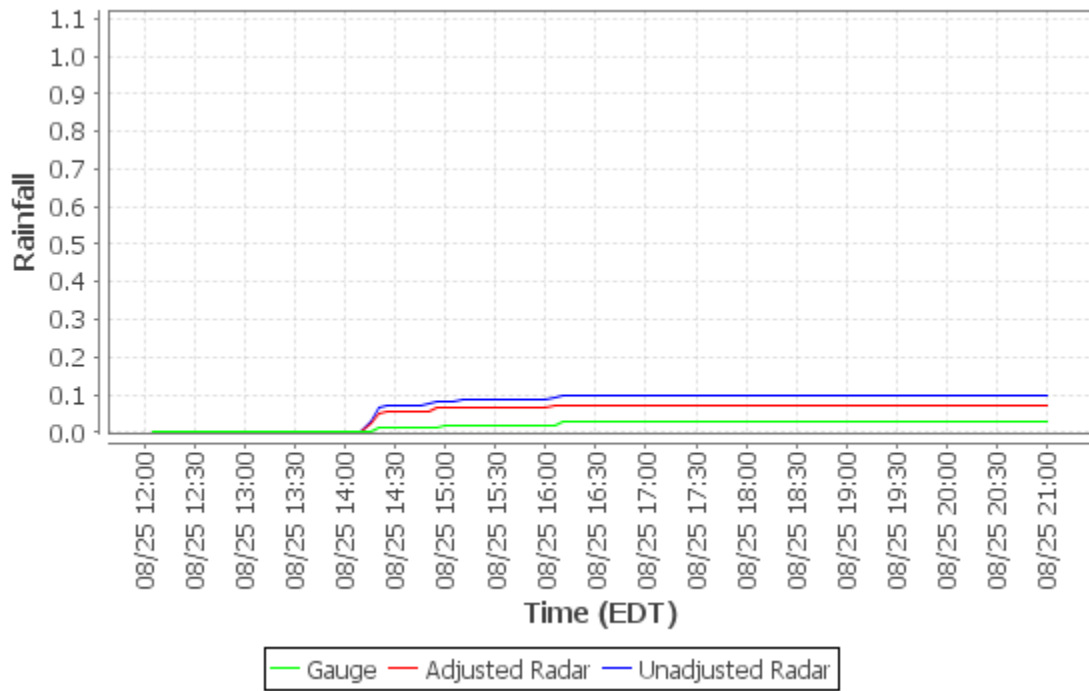
**Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)**



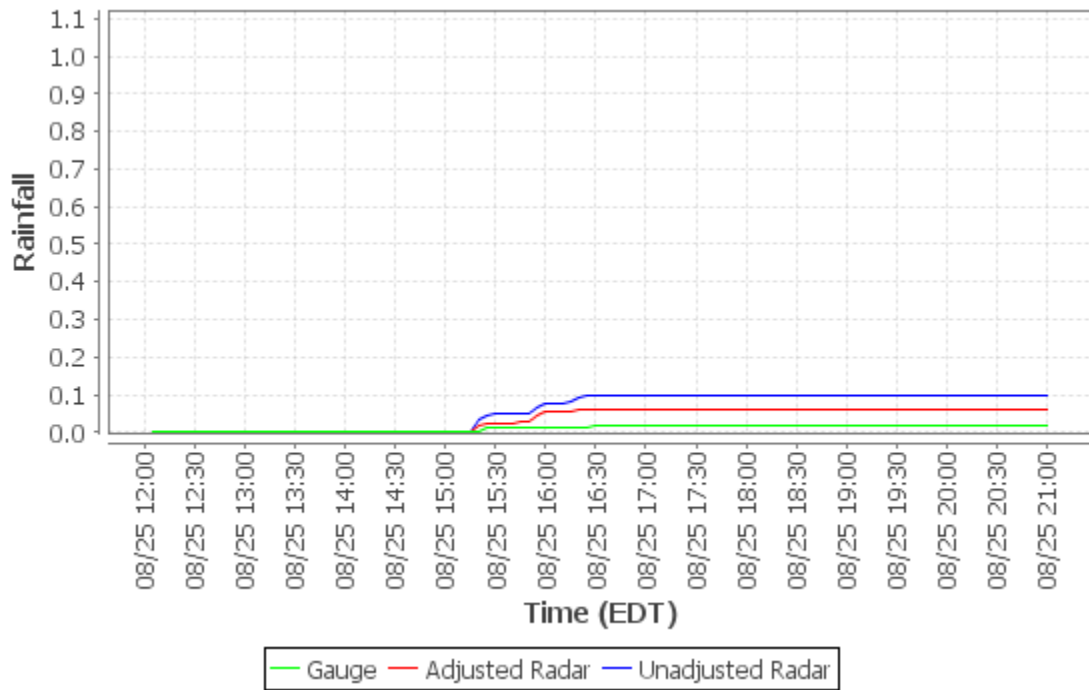
**Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)**



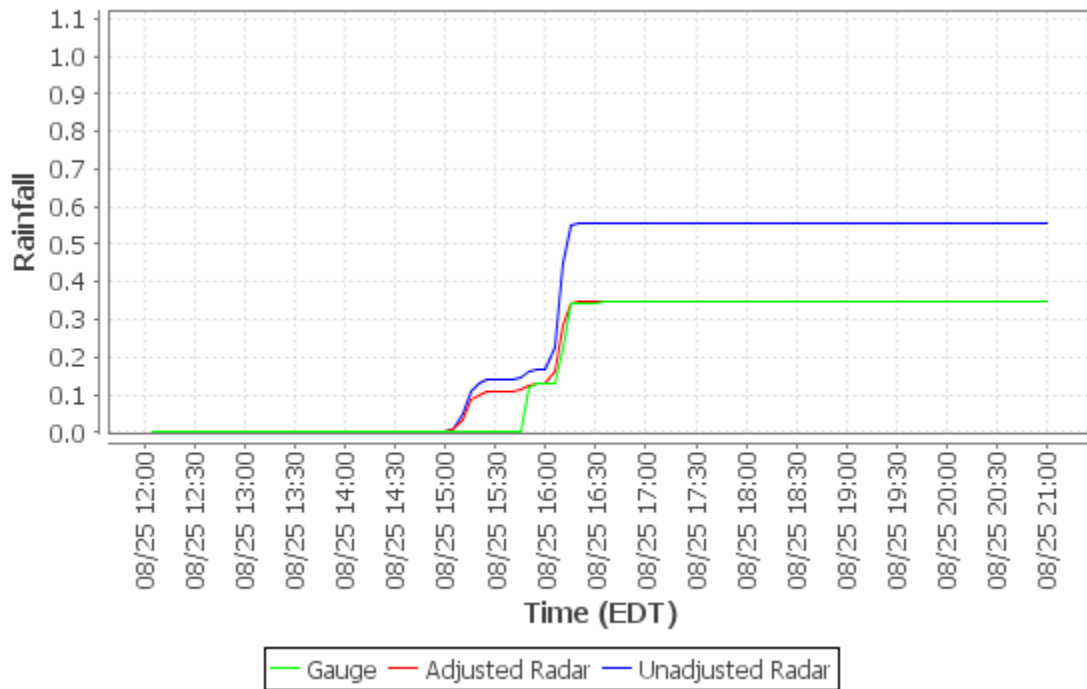
**Cumulative Distribution Plot - Marshall TWP (Loc27)**



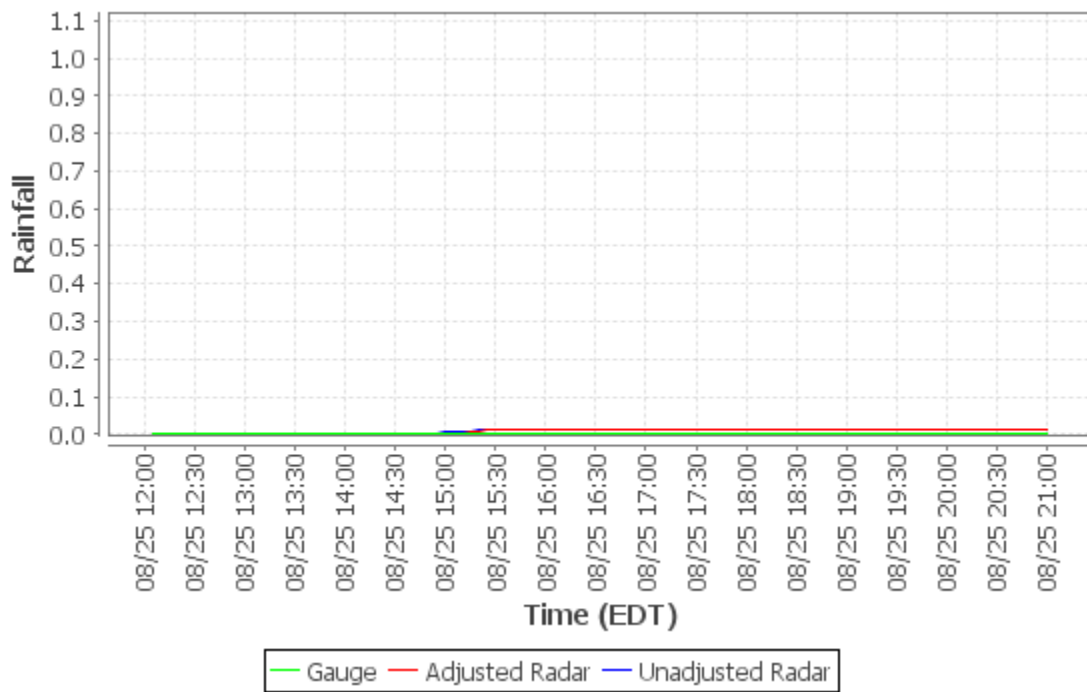
**Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)**



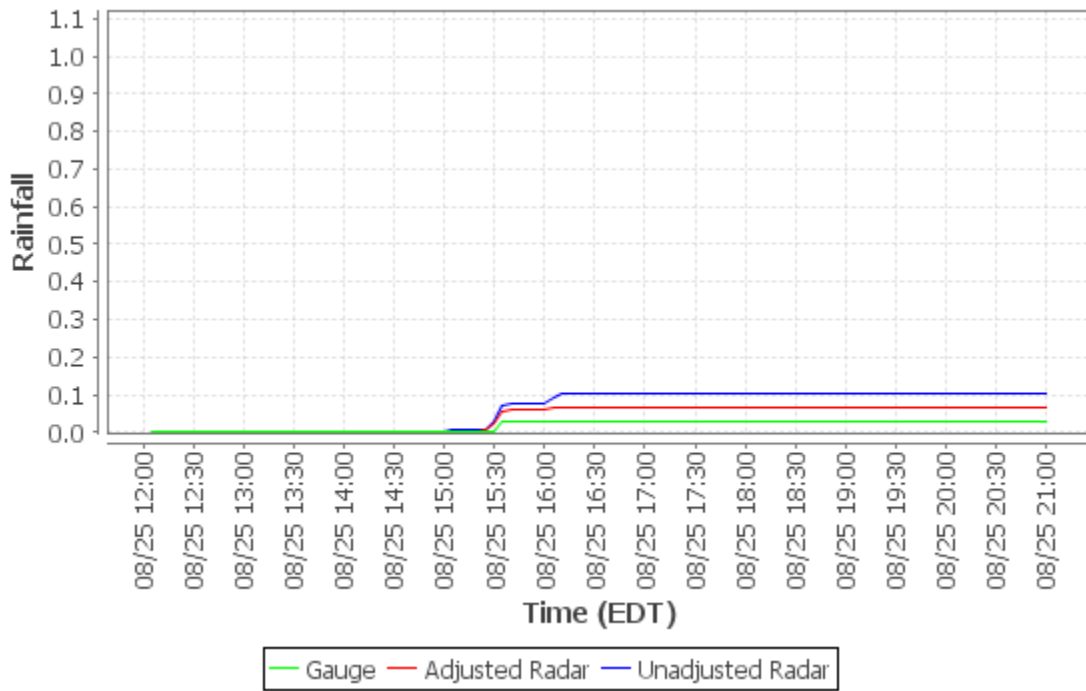
**Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)**



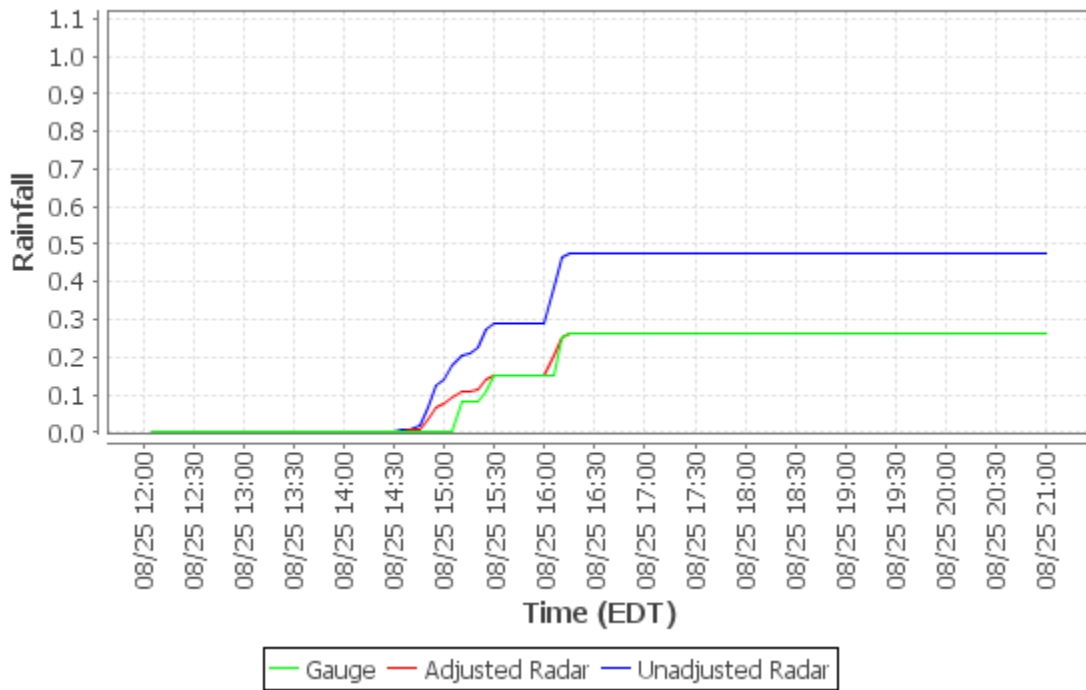
**Cumulative Distribution Plot - McCandless Twn Hall (Loc30)**



**Cumulative Distribution Plot - Hampton Municipal Bldg (Loc31)**

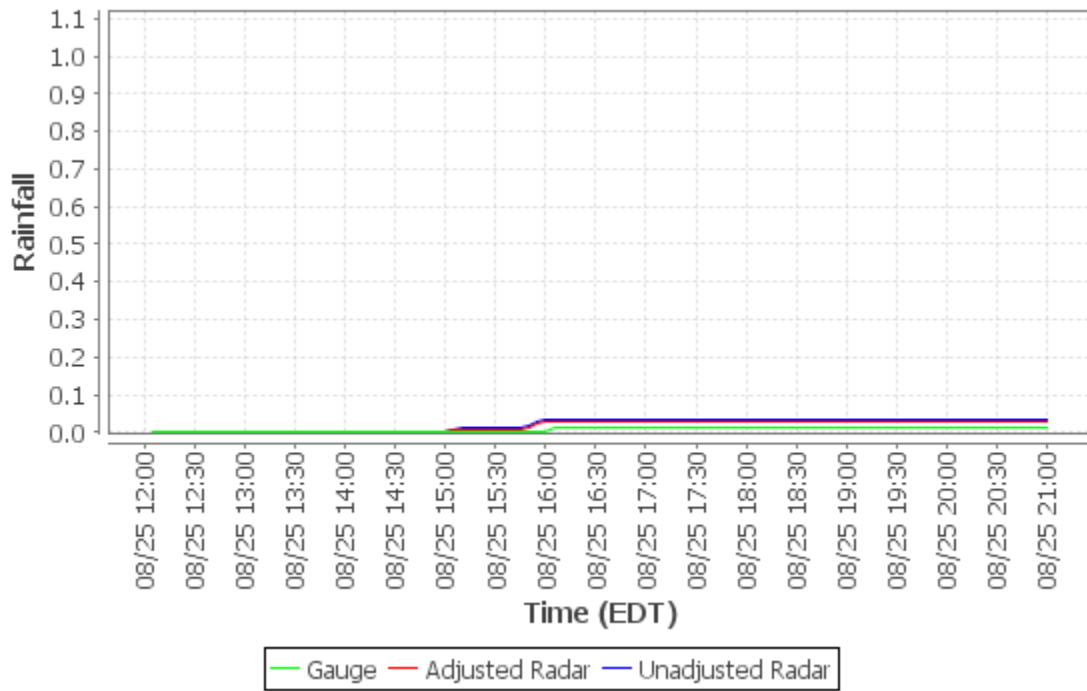


**Cumulative Distribution Plot - Arnold (Loc32)**

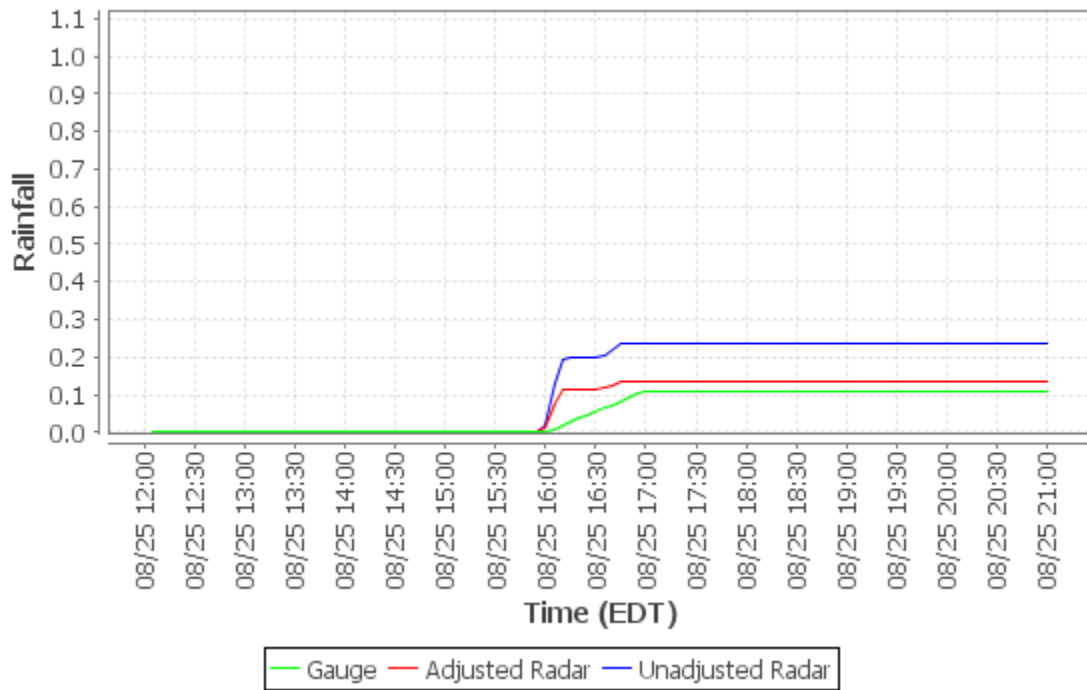




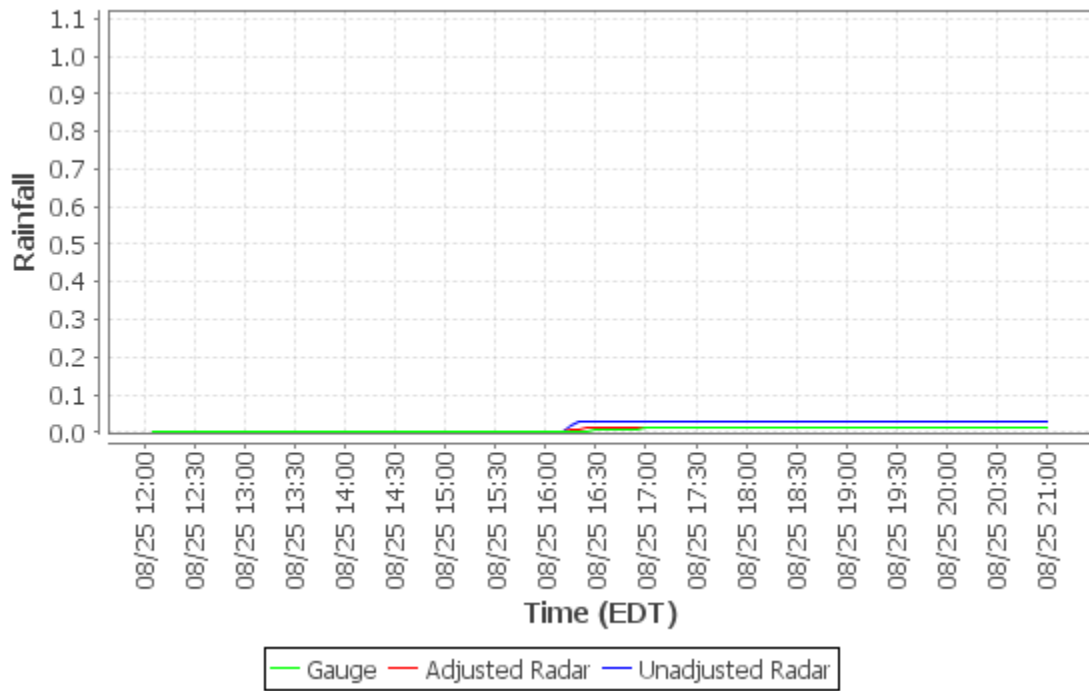
**Cumulative Distribution Plot - Richland TWP (Loc33)**



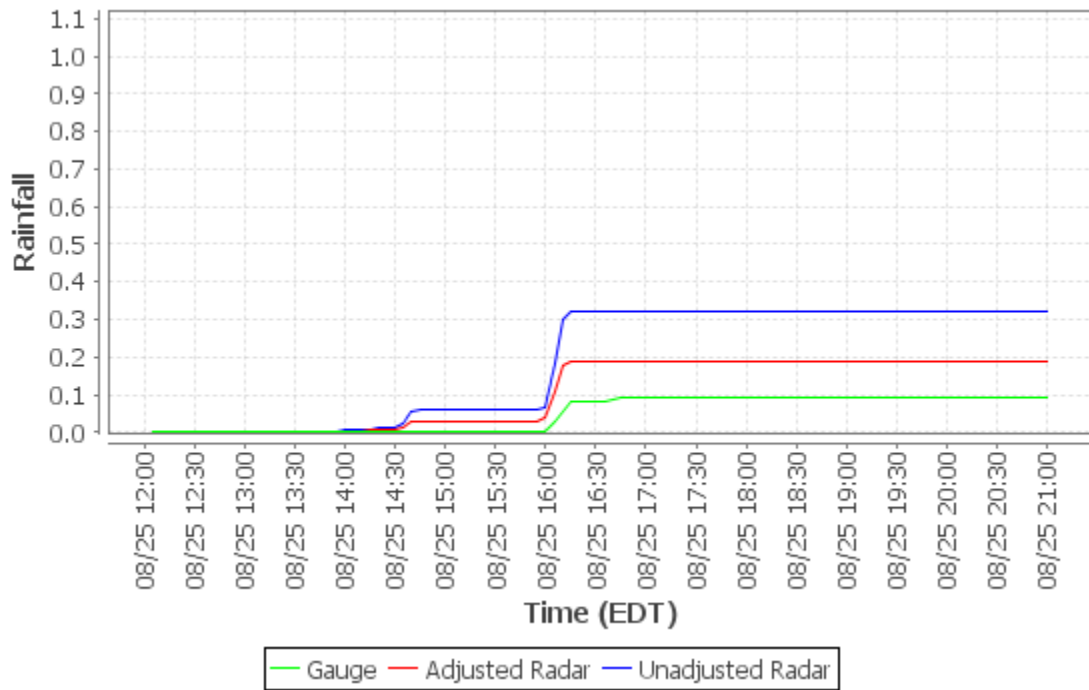
**Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)**



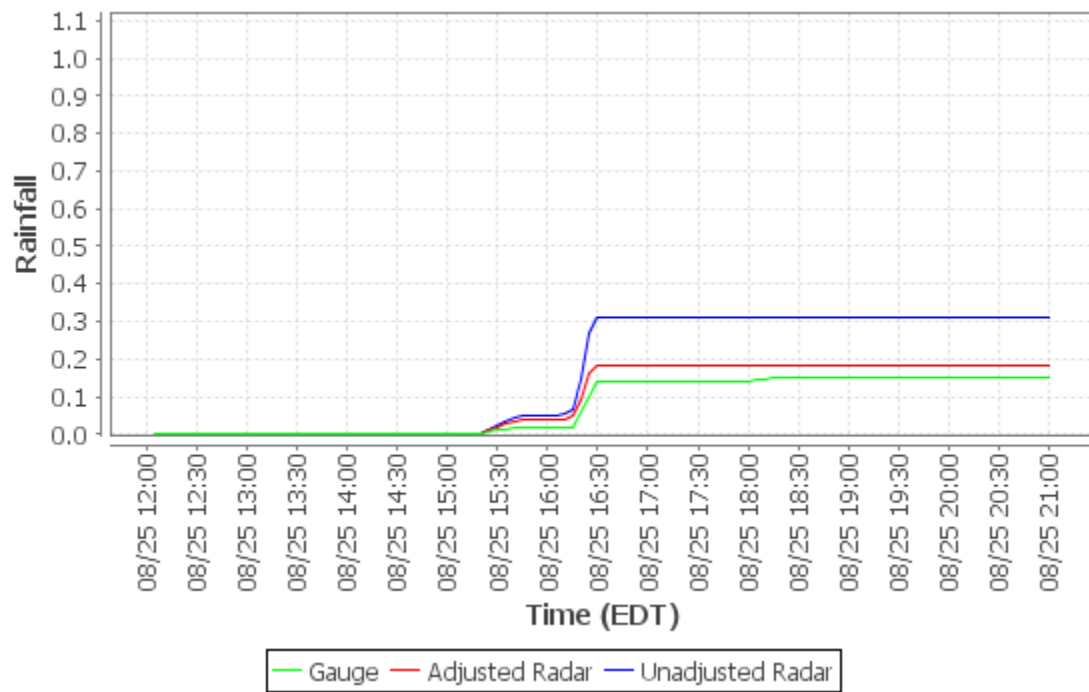
**Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)**



**Cumulative Distribution Plot - Allegheny River at Natrona (03049500)**

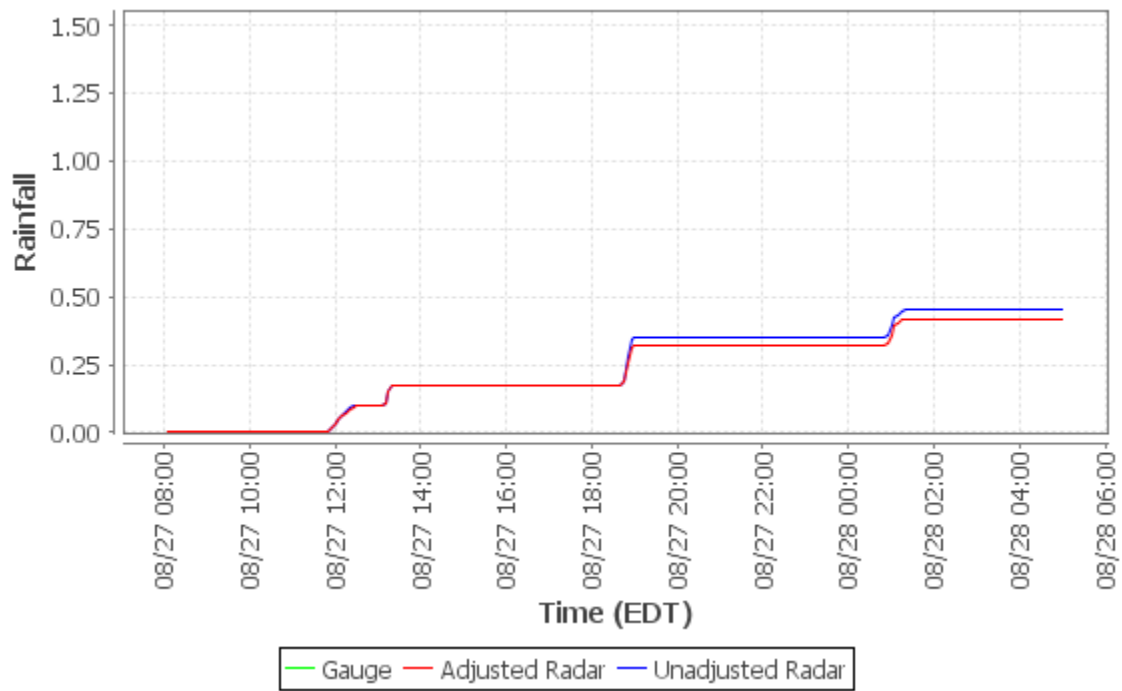


**Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth  
(03085734)**

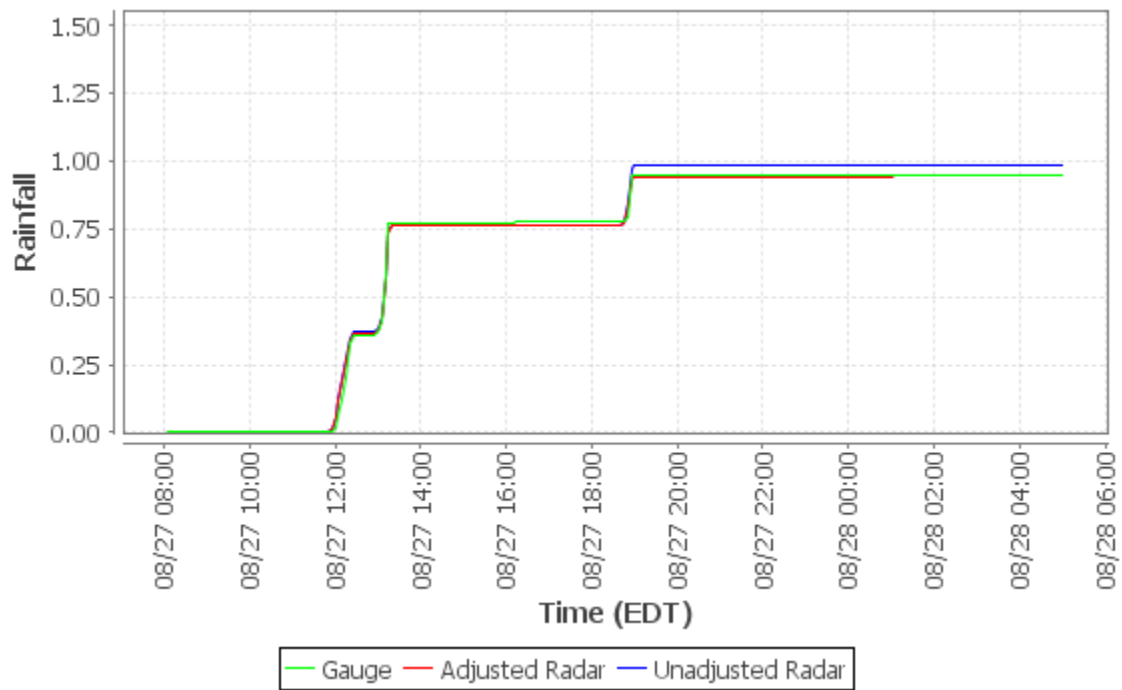


## **Appendix F - Event 4 (2020-08-27) CDPs**

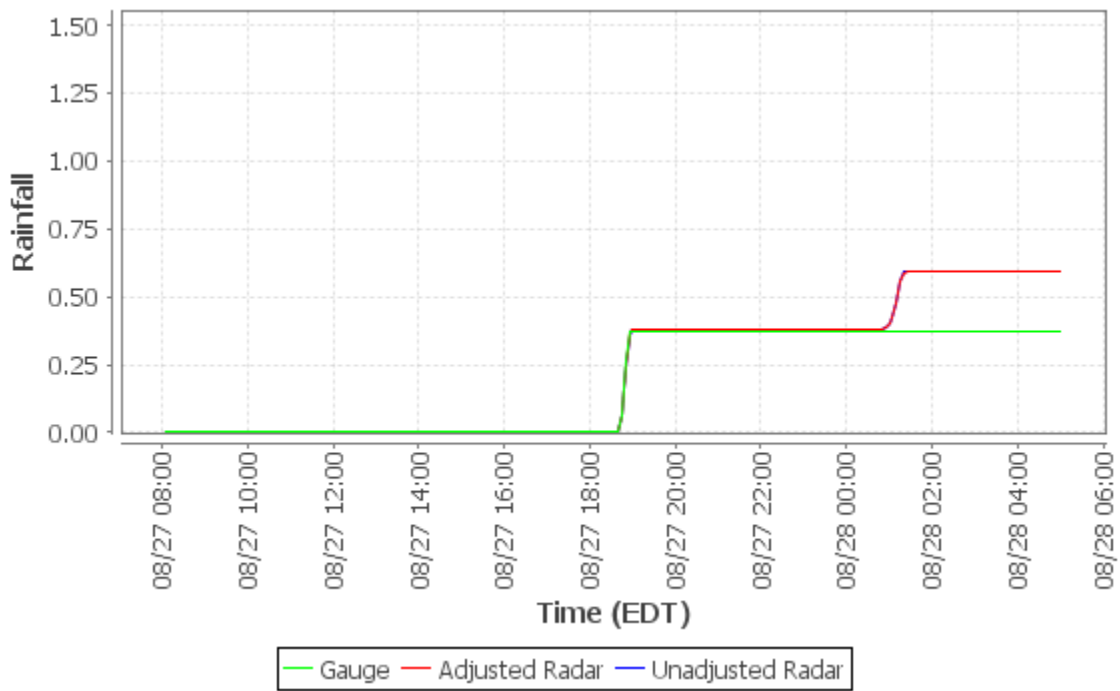
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



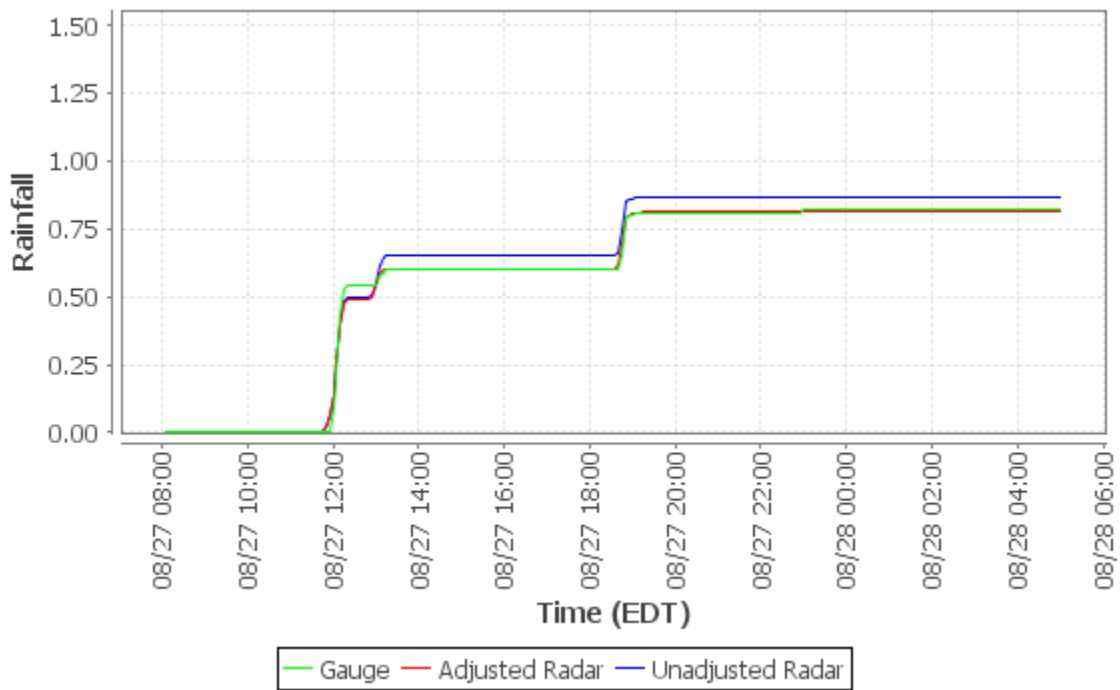
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



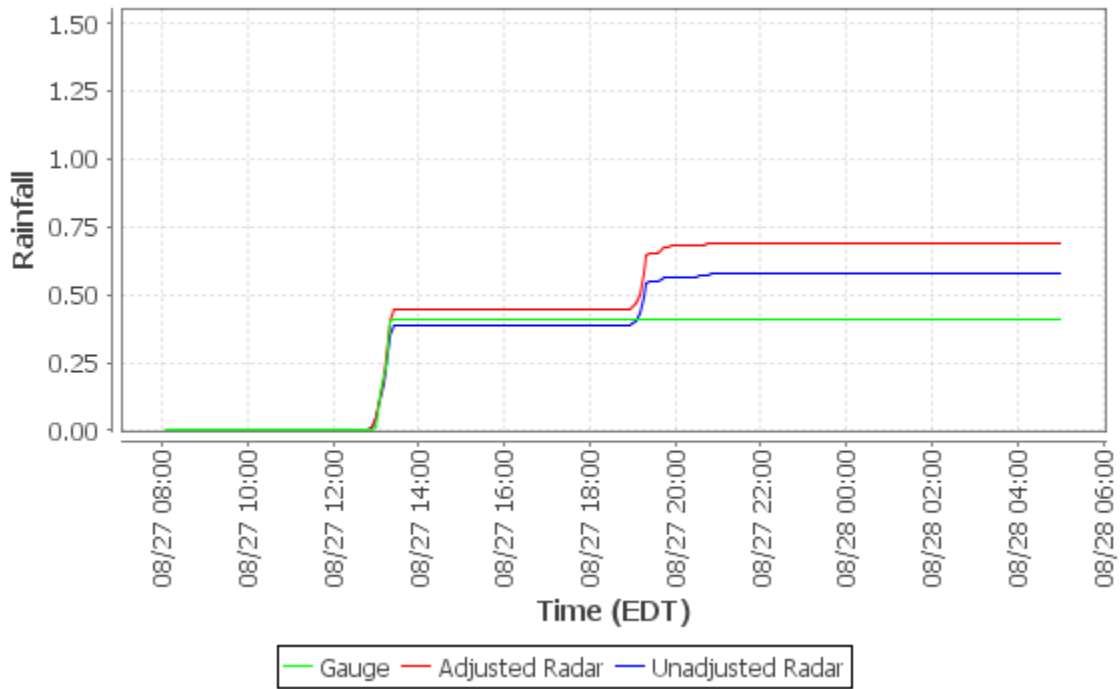
**Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)**



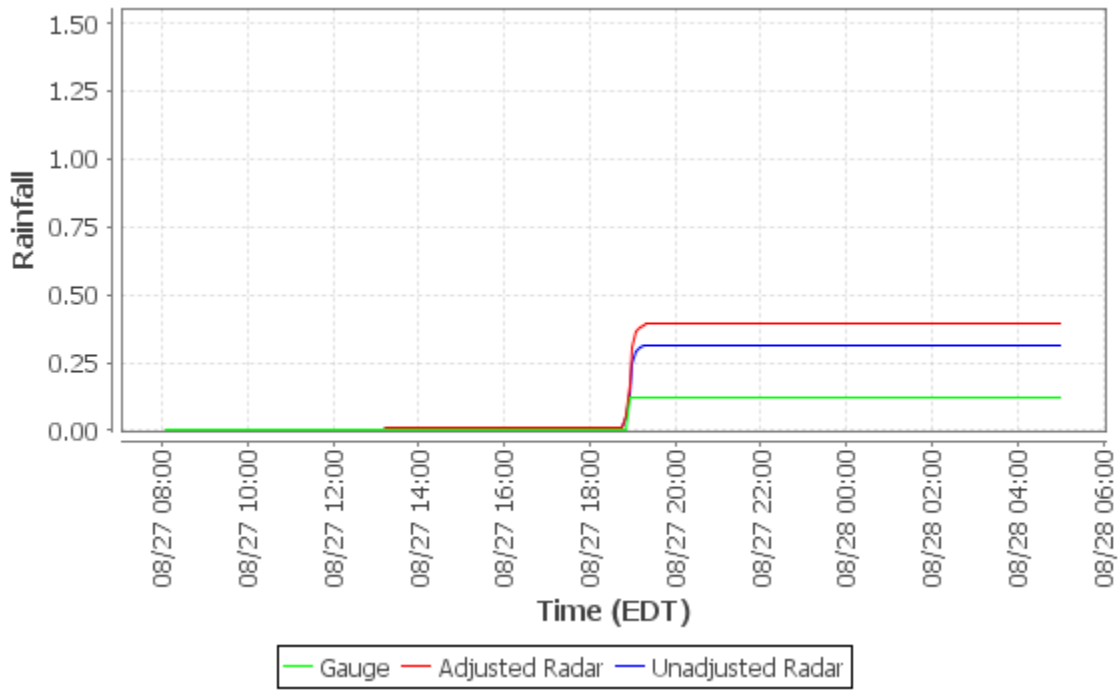
**Cumulative Distribution Plot - Kennedy Twp PS (Loc04)**



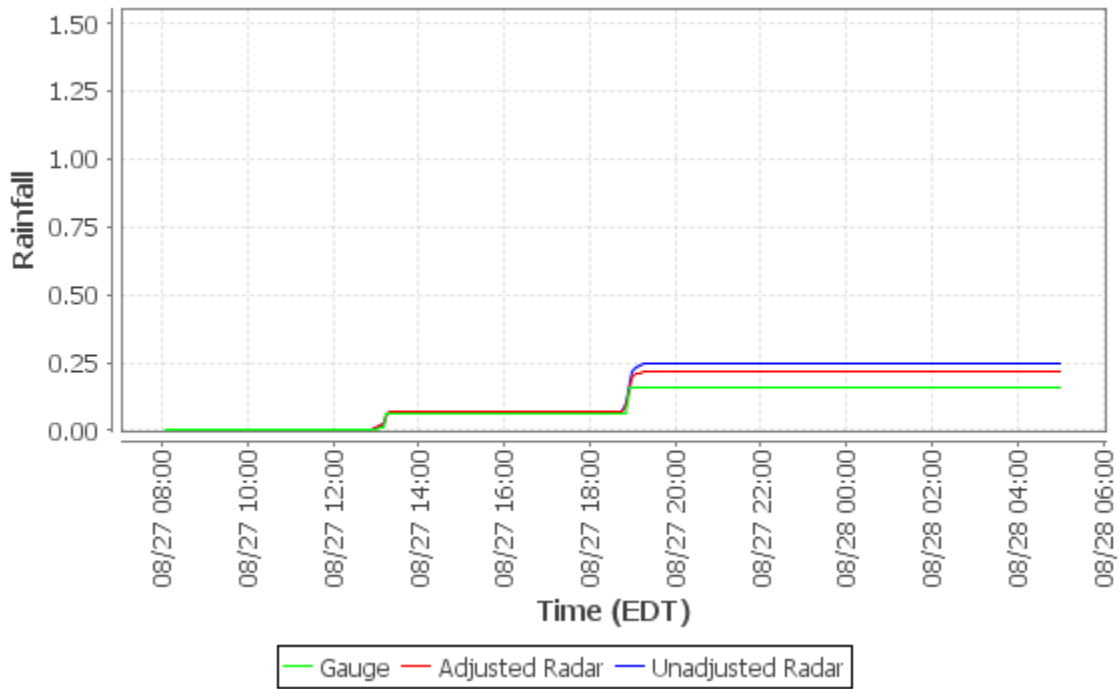
**Cumulative Distribution Plot - Upper St. Clair (Loc05)**



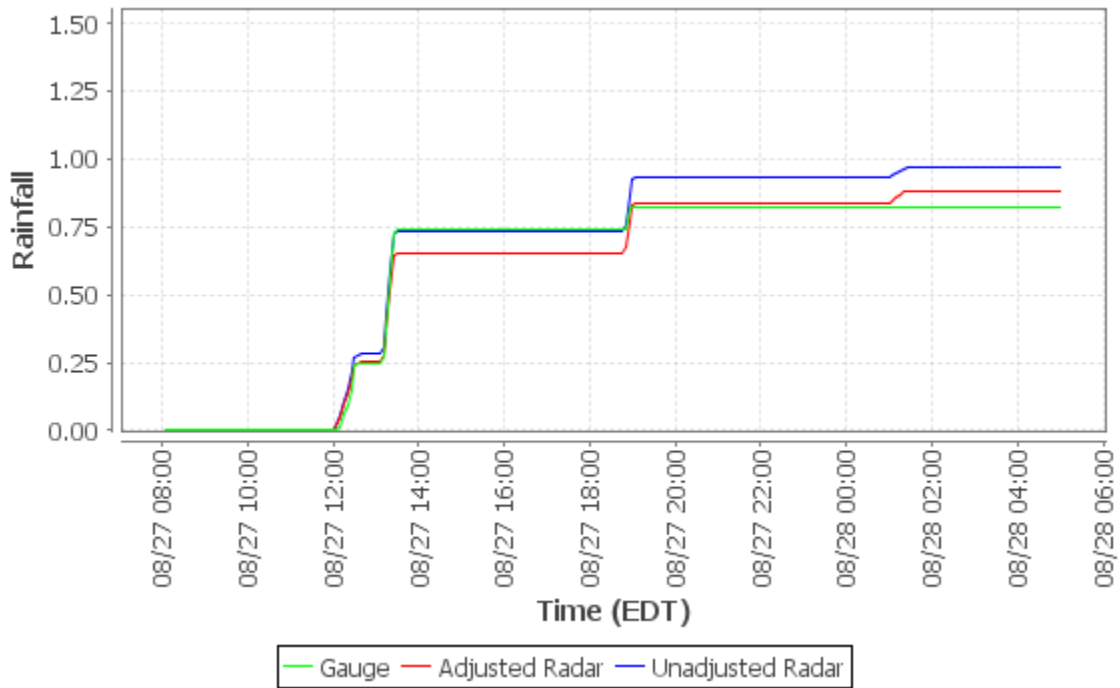
**Cumulative Distribution Plot - Carnegie Transit Time (Loc06)**



**Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)**

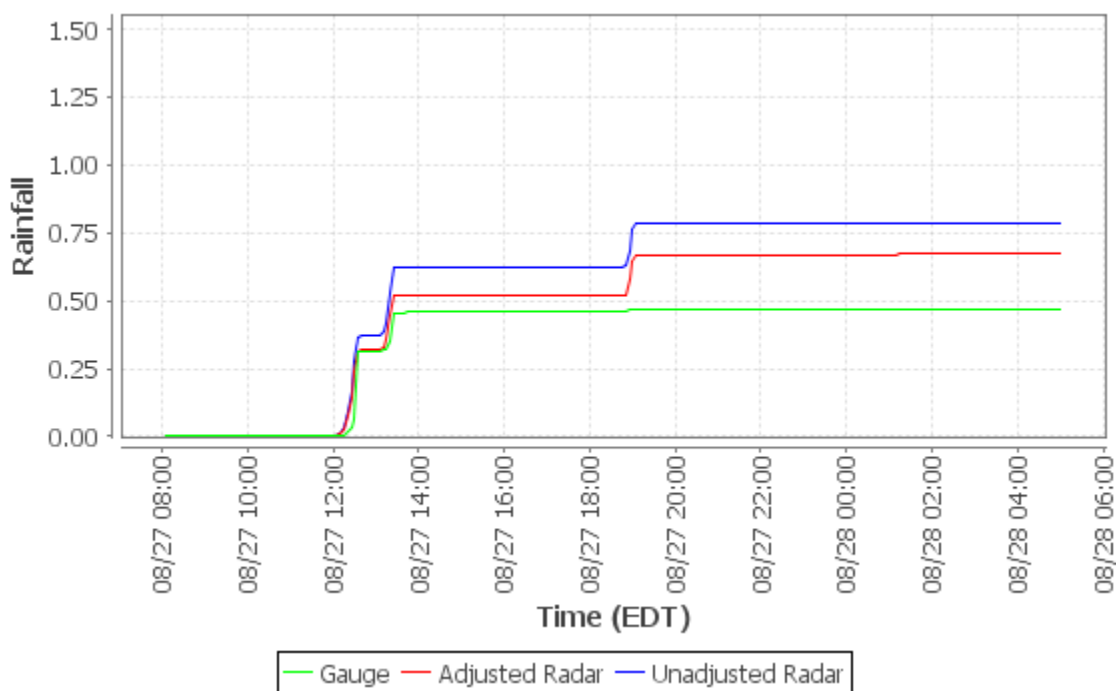


**Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)**

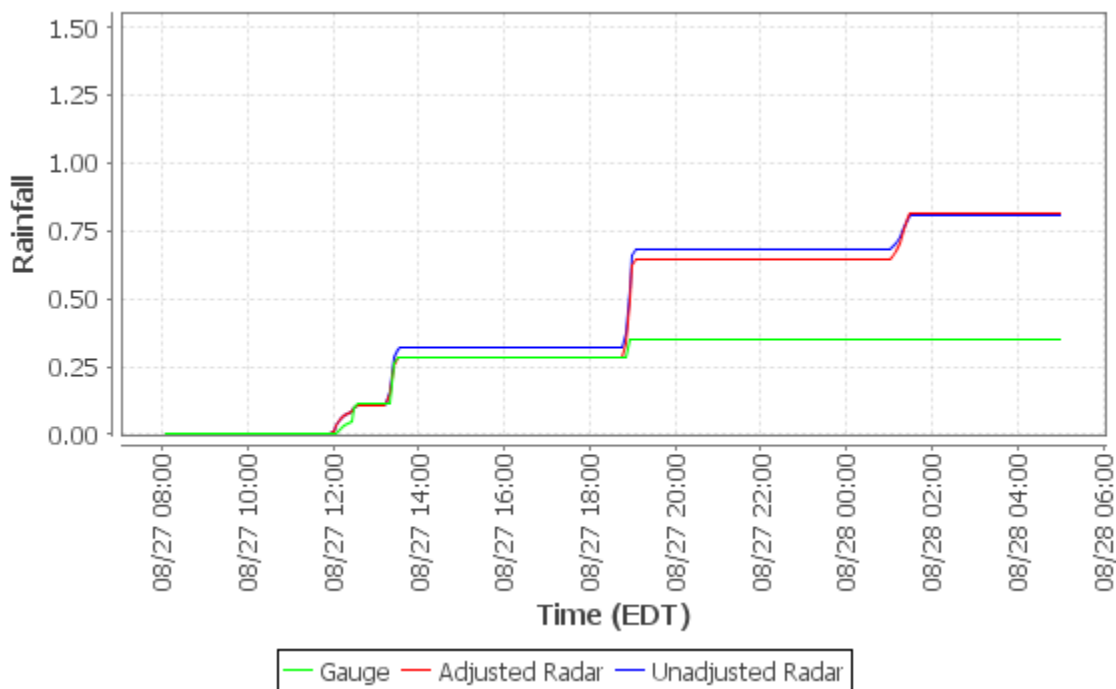




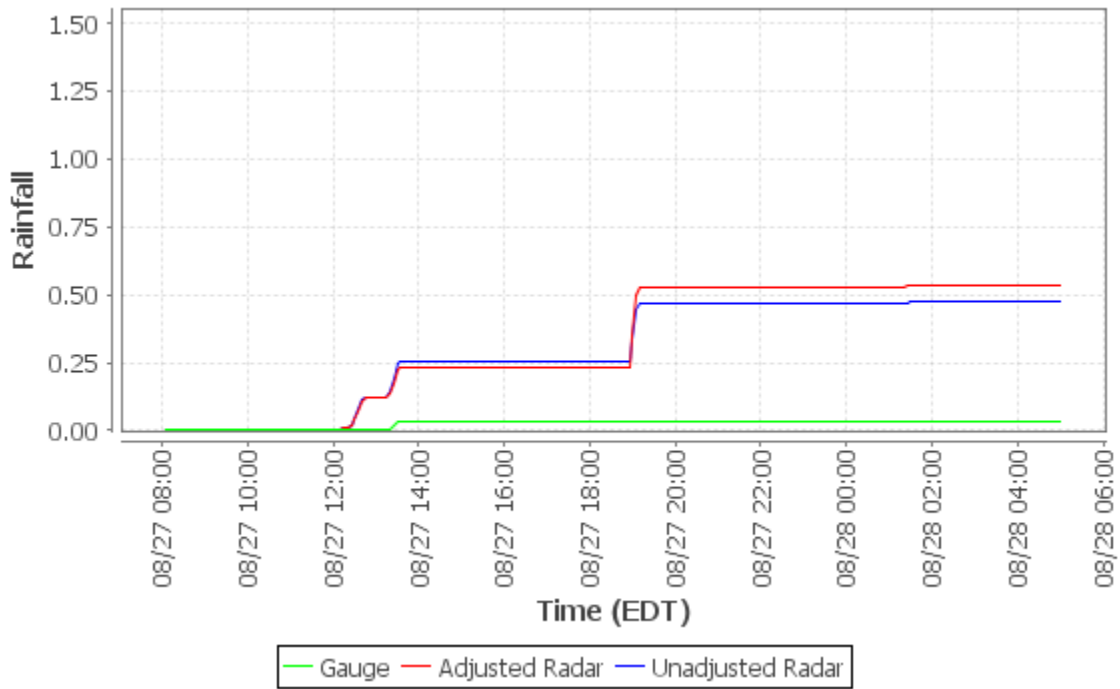
**Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)**



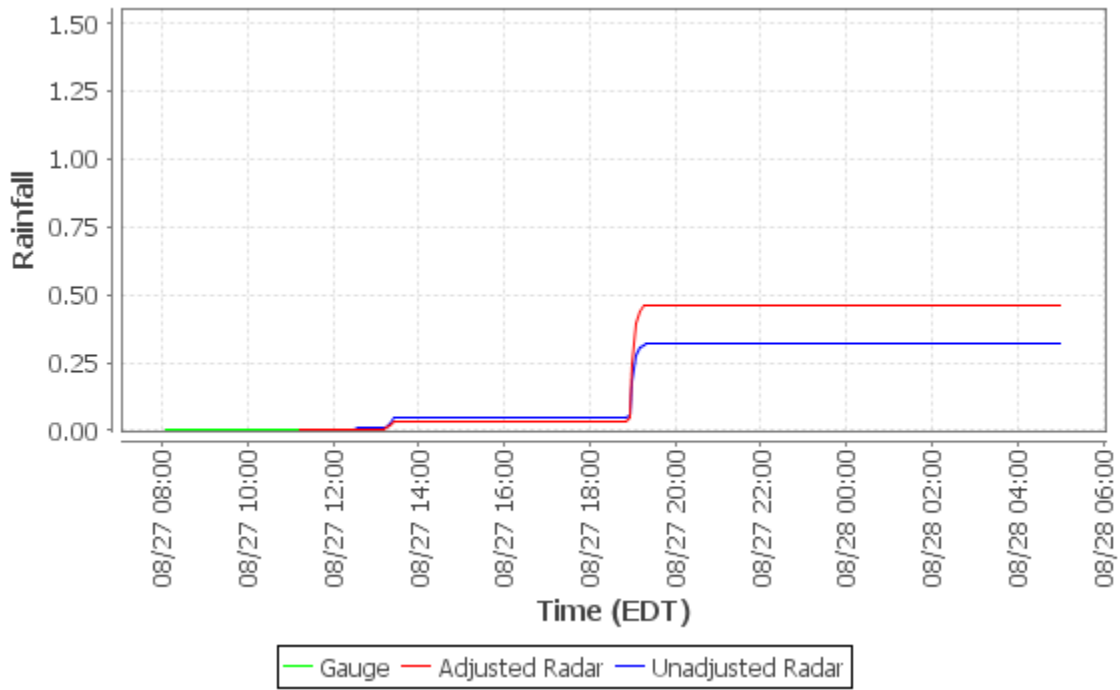
**Cumulative Distribution Plot - PWSA-Highland Park (Loc10)**



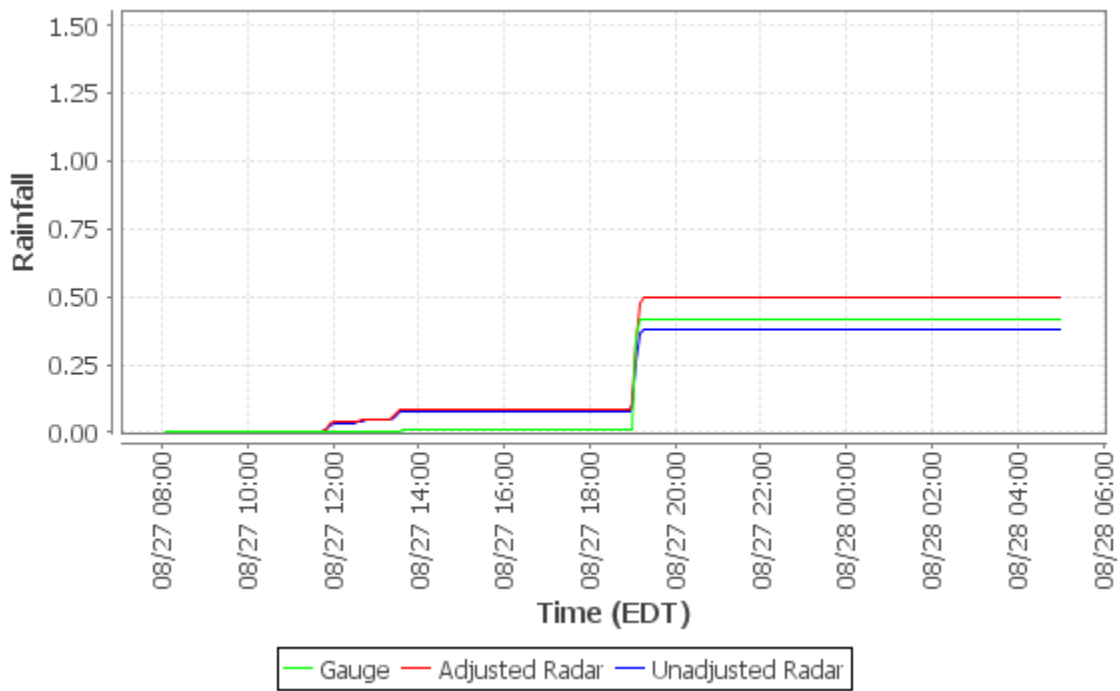
**Cumulative Distribution Plot - M-46 Access Shaft (Loc11)**



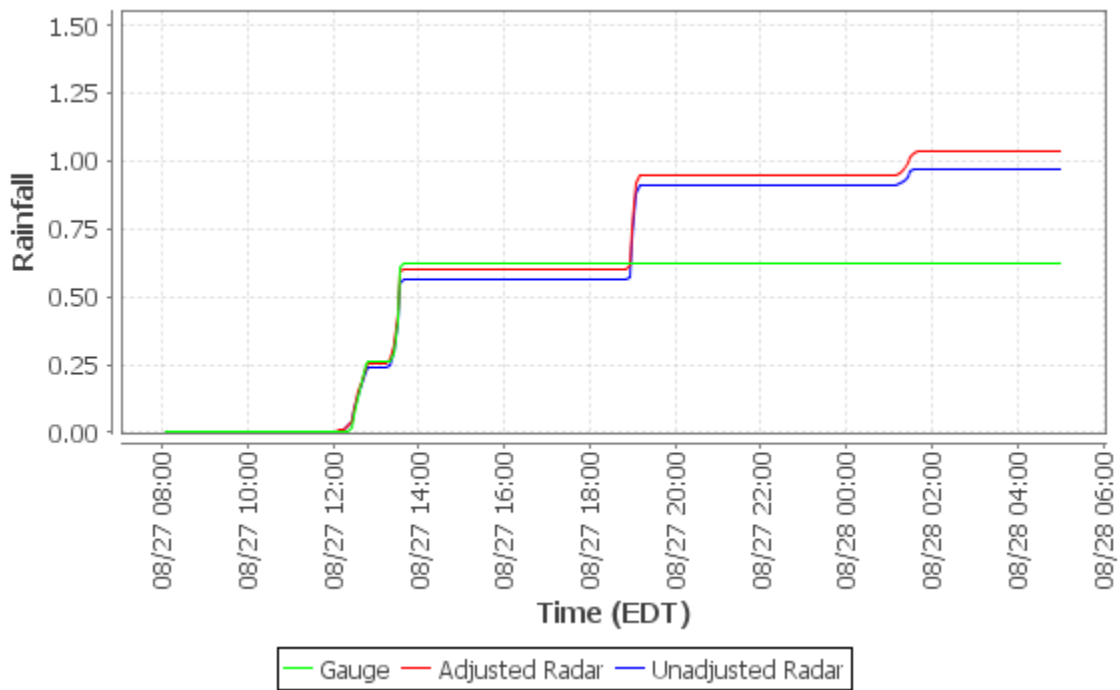
**Cumulative Distribution Plot - Baldwin (Loc12)**



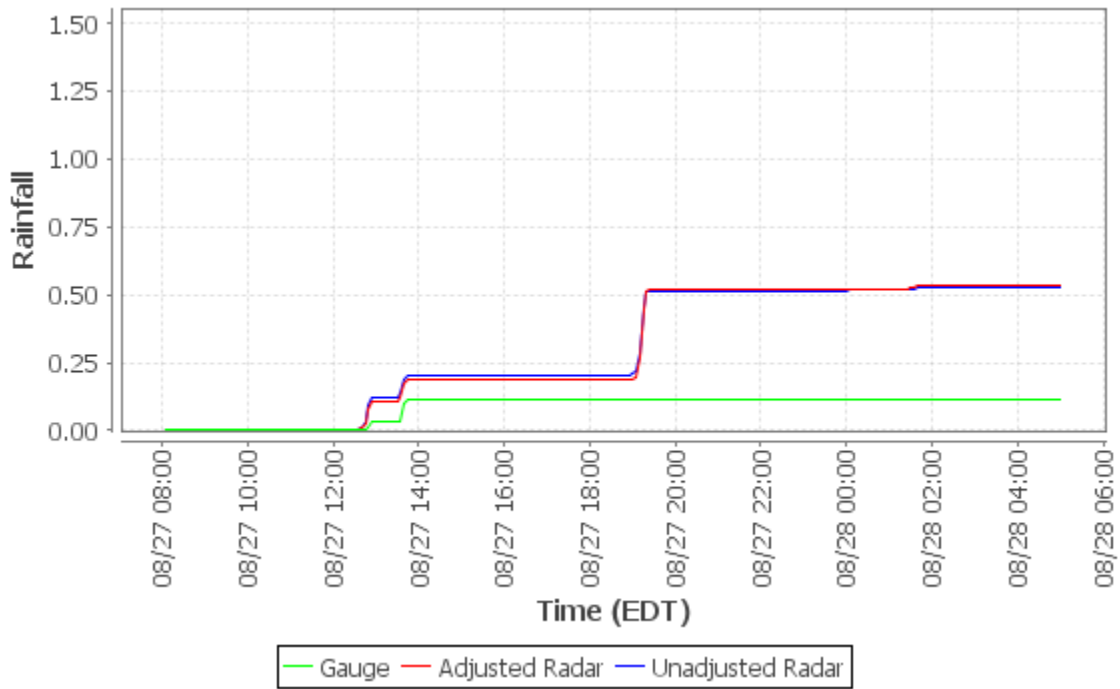
**Cumulative Distribution Plot - M-59 Access Shaft (Loc13)**



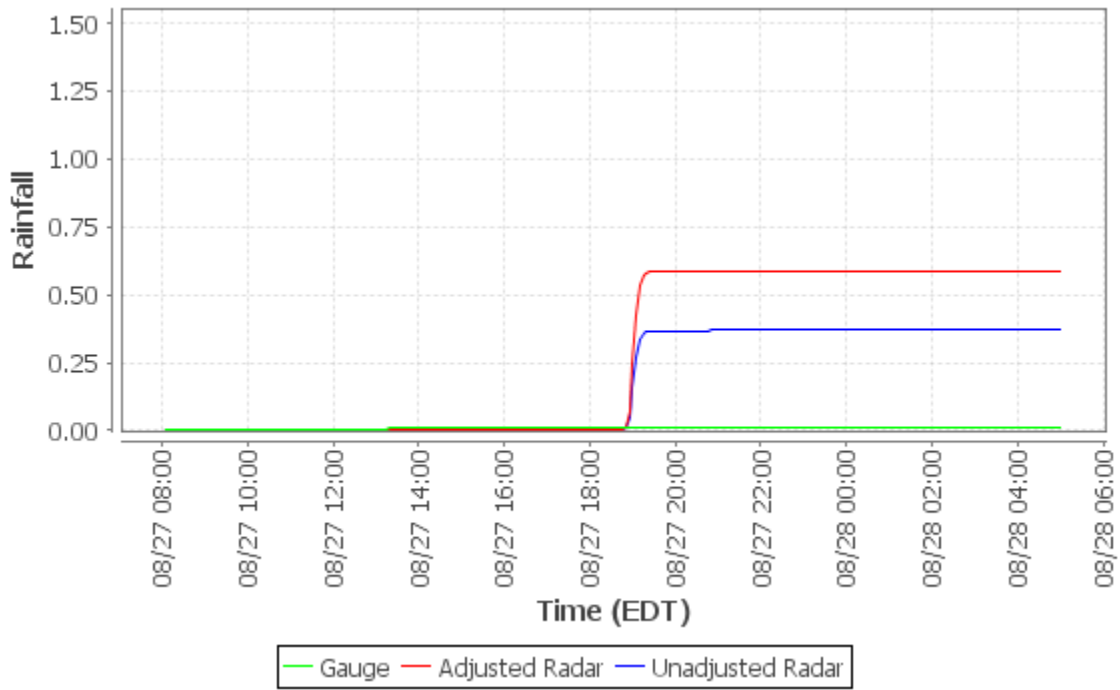
**Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)**



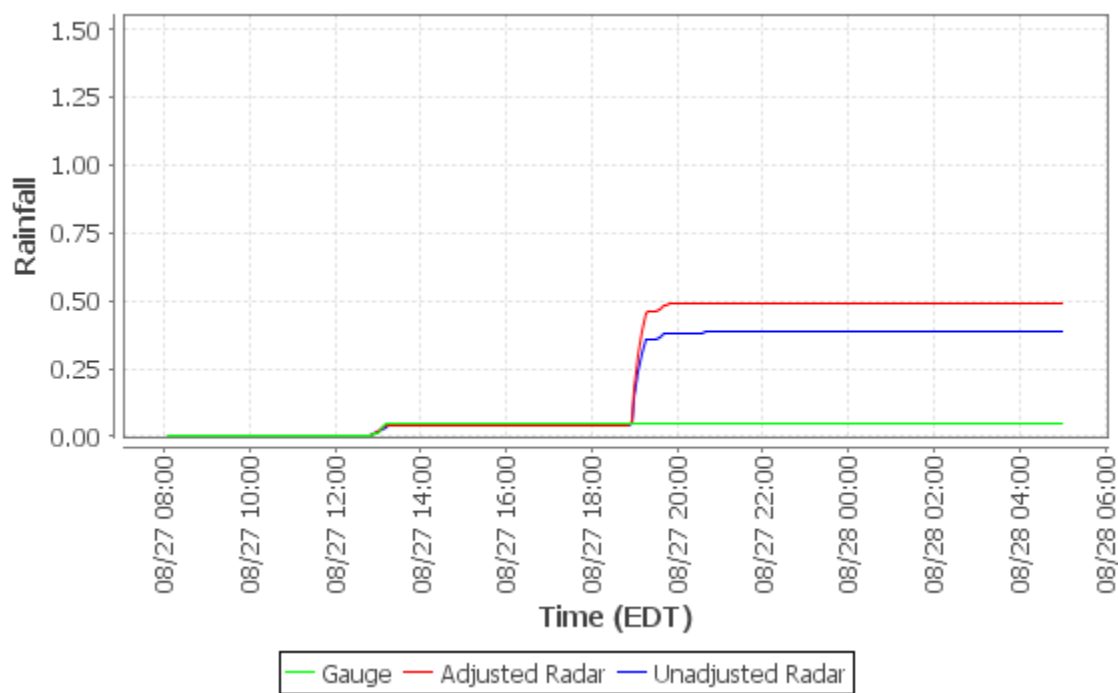
**Cumulative Distribution Plot - Trafford Maint Bldg (Loc15)**



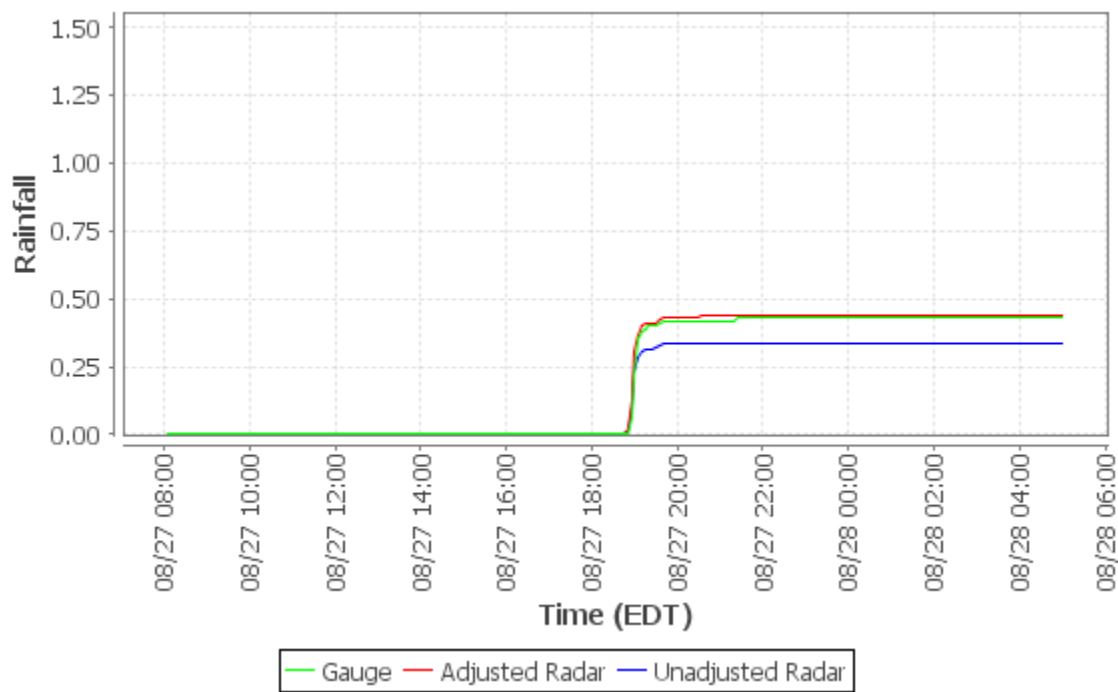
**Cumulative Distribution Plot - Castle Shannon (Loc16)**



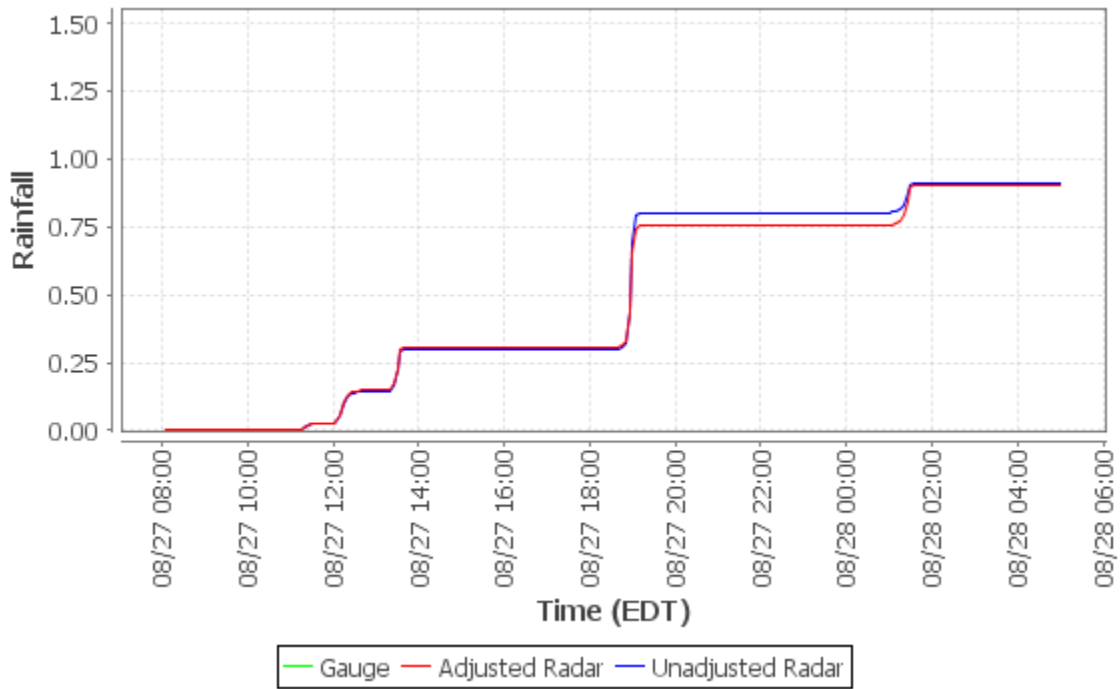
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



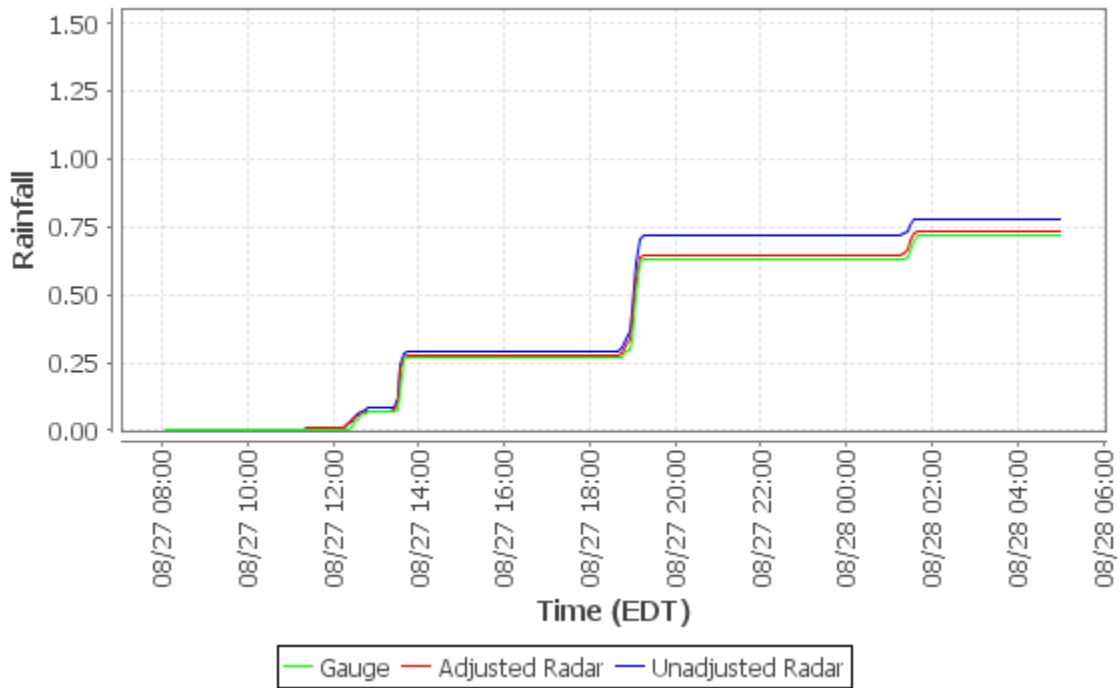
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



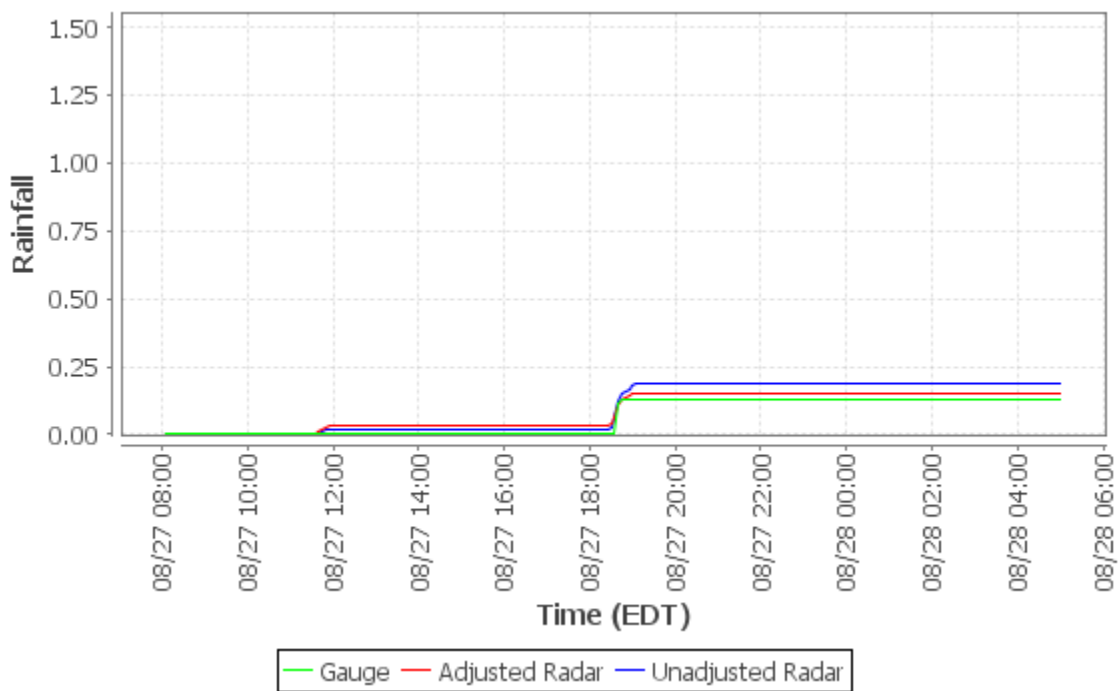
**Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)**



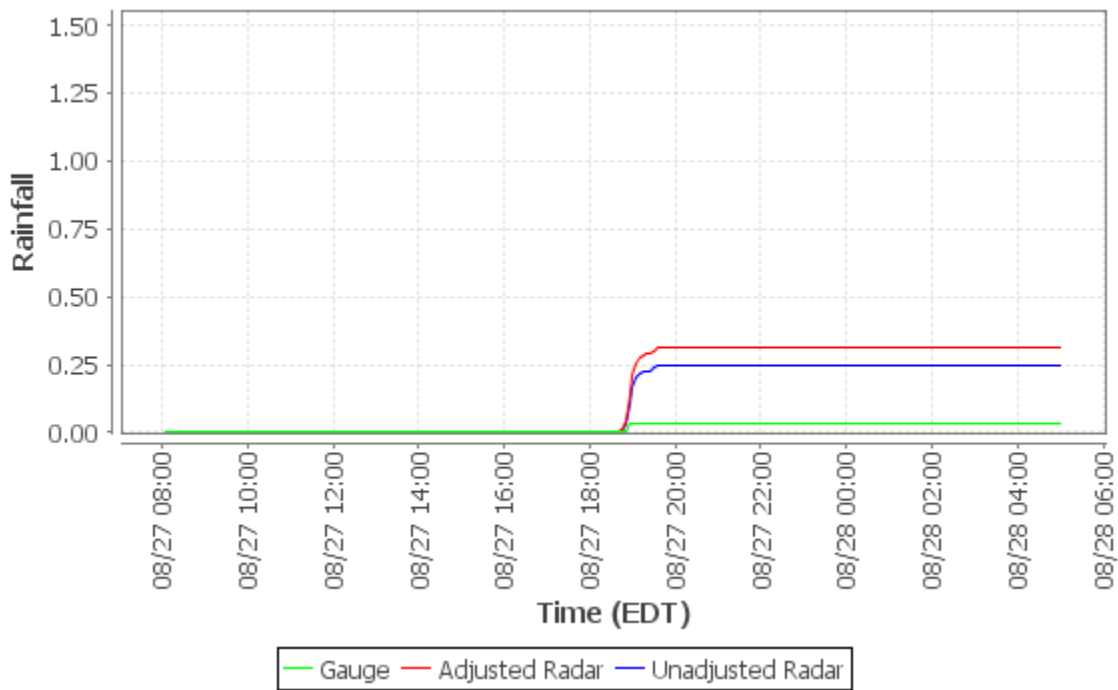
**Cumulative Distribution Plot - Gascola Eq Facility (Loc20)**



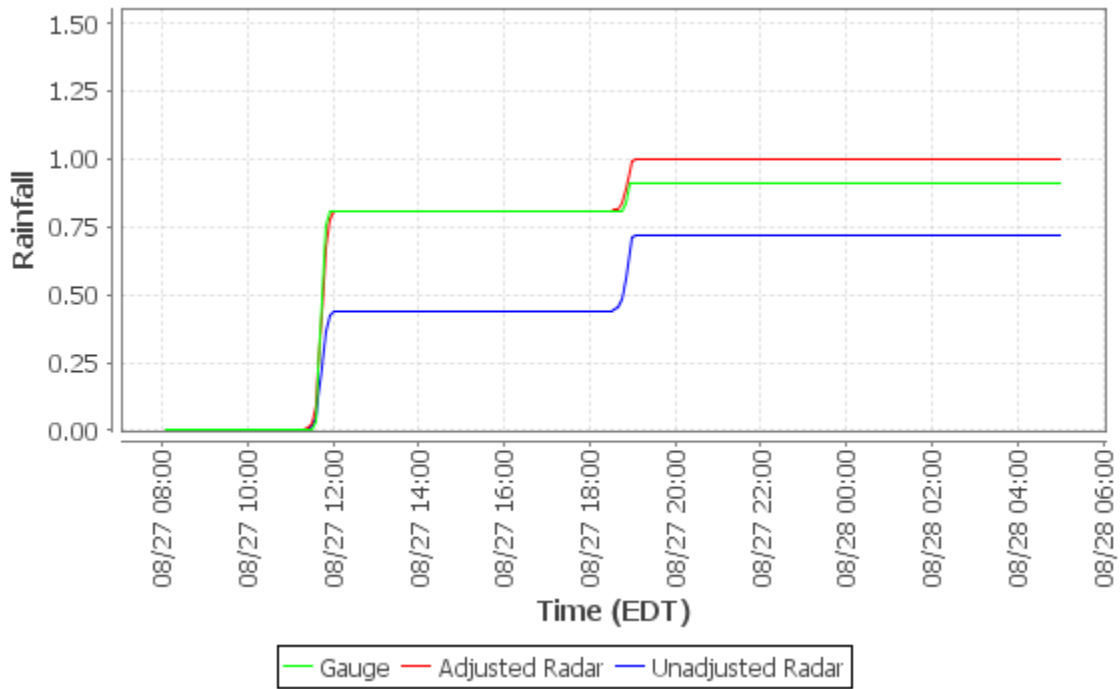
**Cumulative Distribution Plot - Moon TWP (Loc21)**



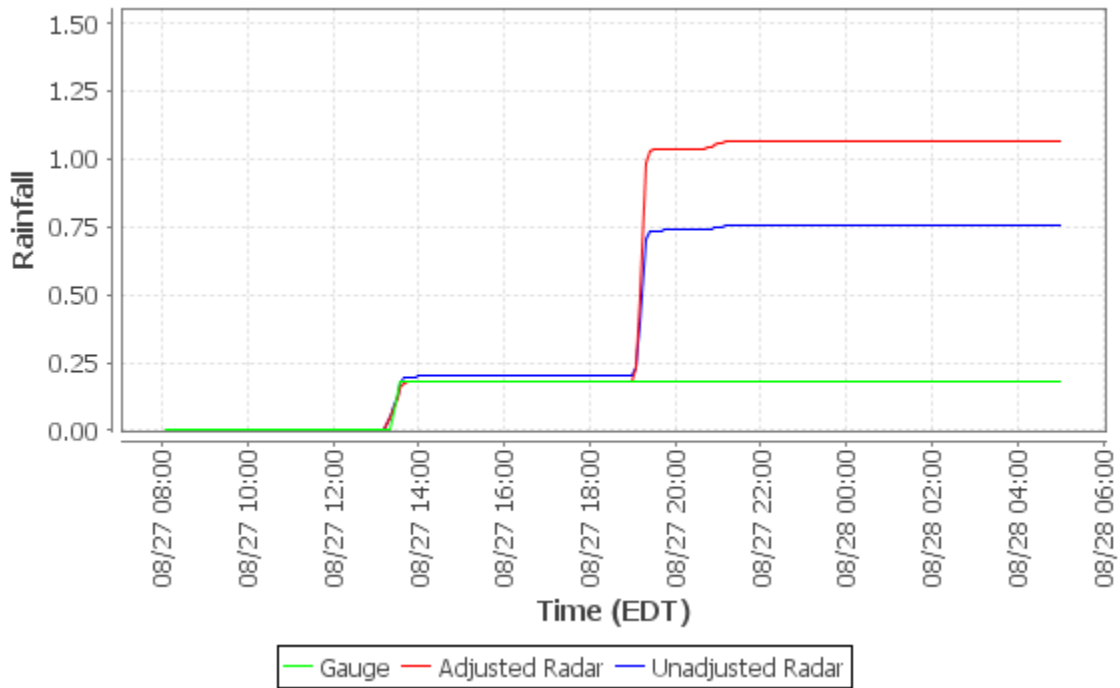
**Cumulative Distribution Plot - North Fayette TWP (Loc22)**



**Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)**

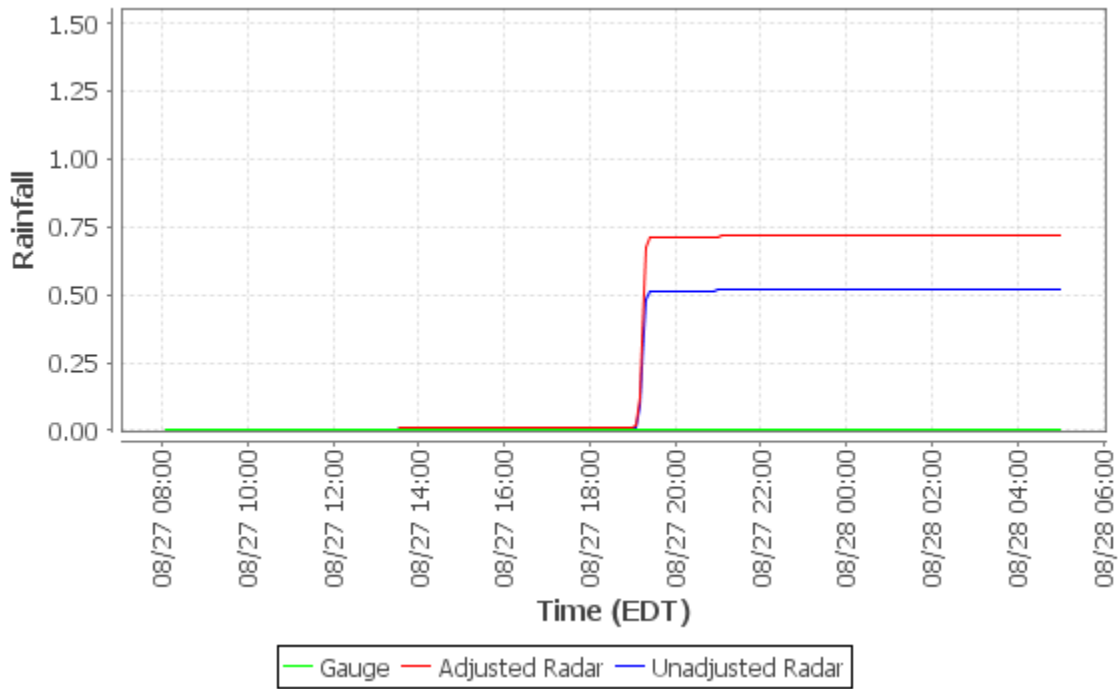


**Cumulative Distribution Plot - Jefferson Hills (Loc24)**

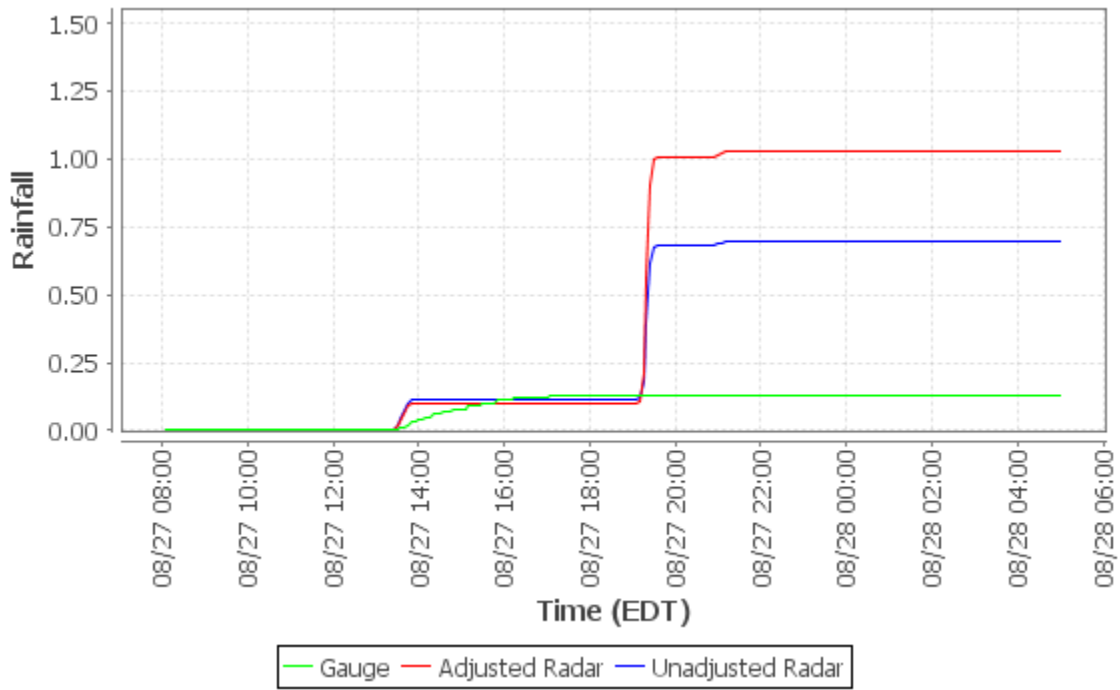




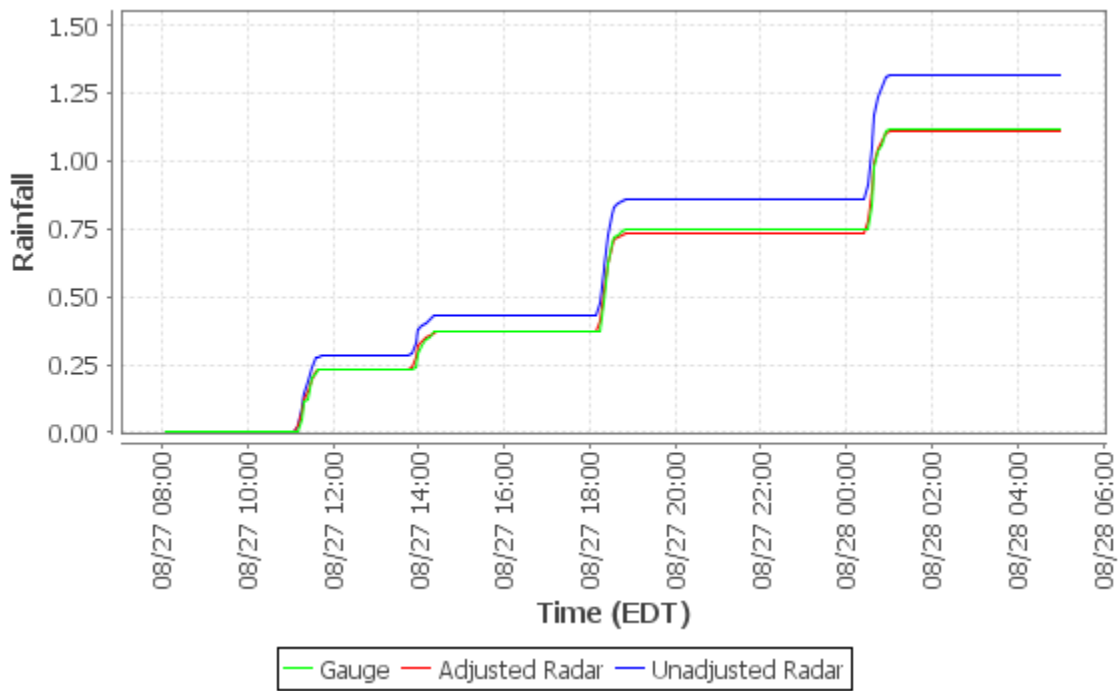
**Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)**



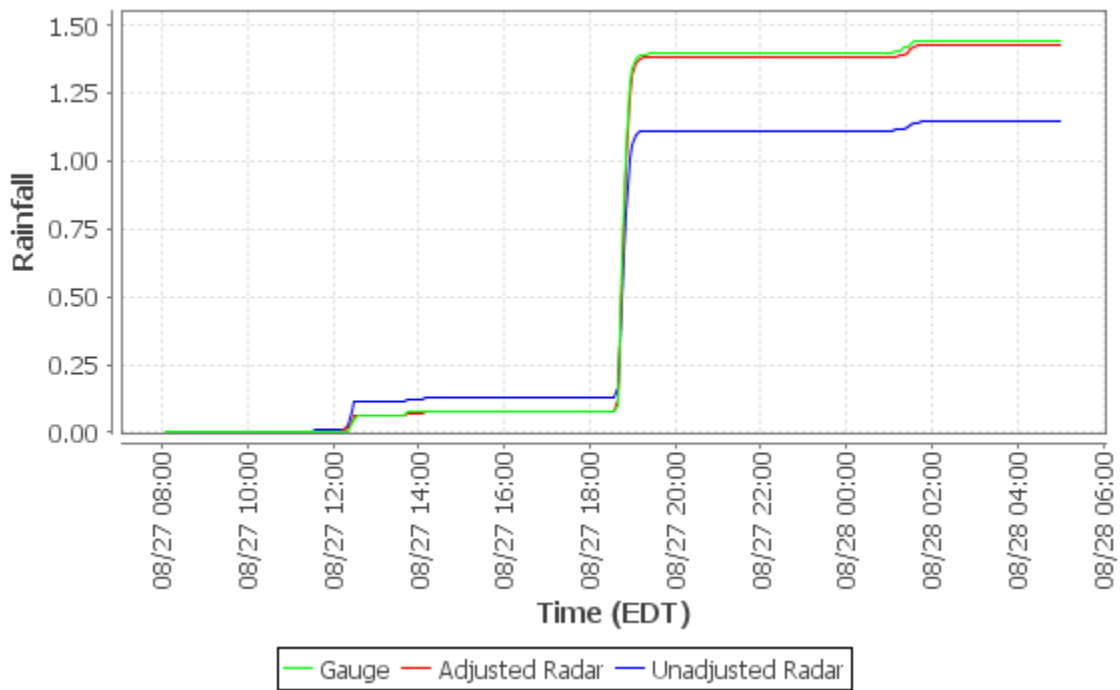
**Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)**



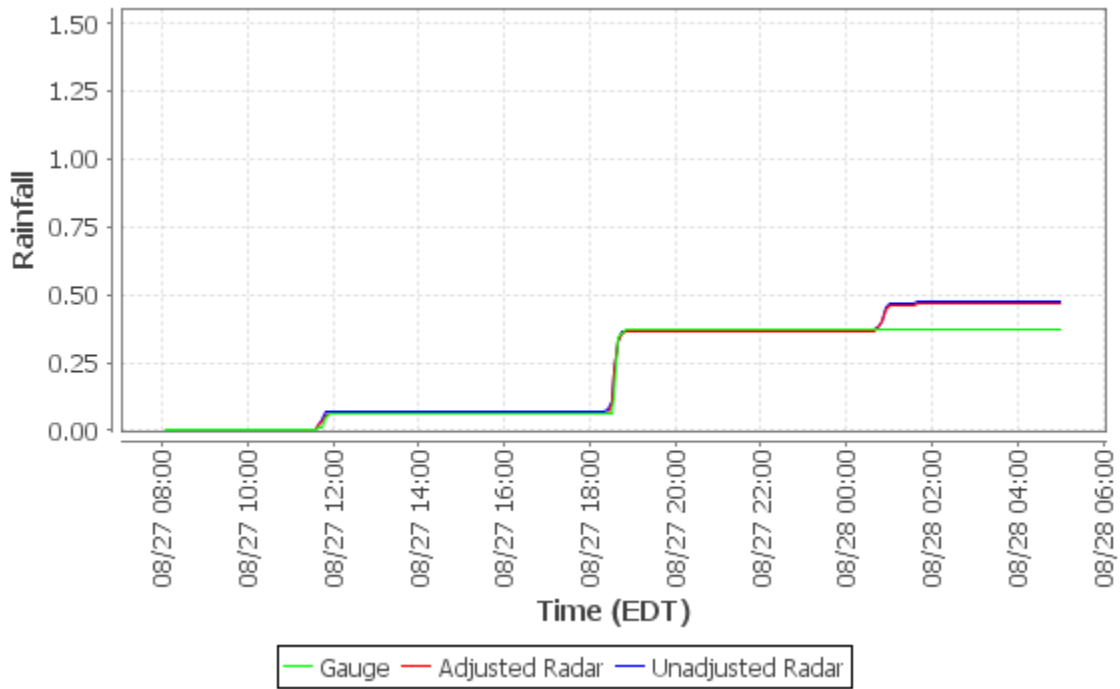
**Cumulative Distribution Plot - Marshall TWP (Loc27)**



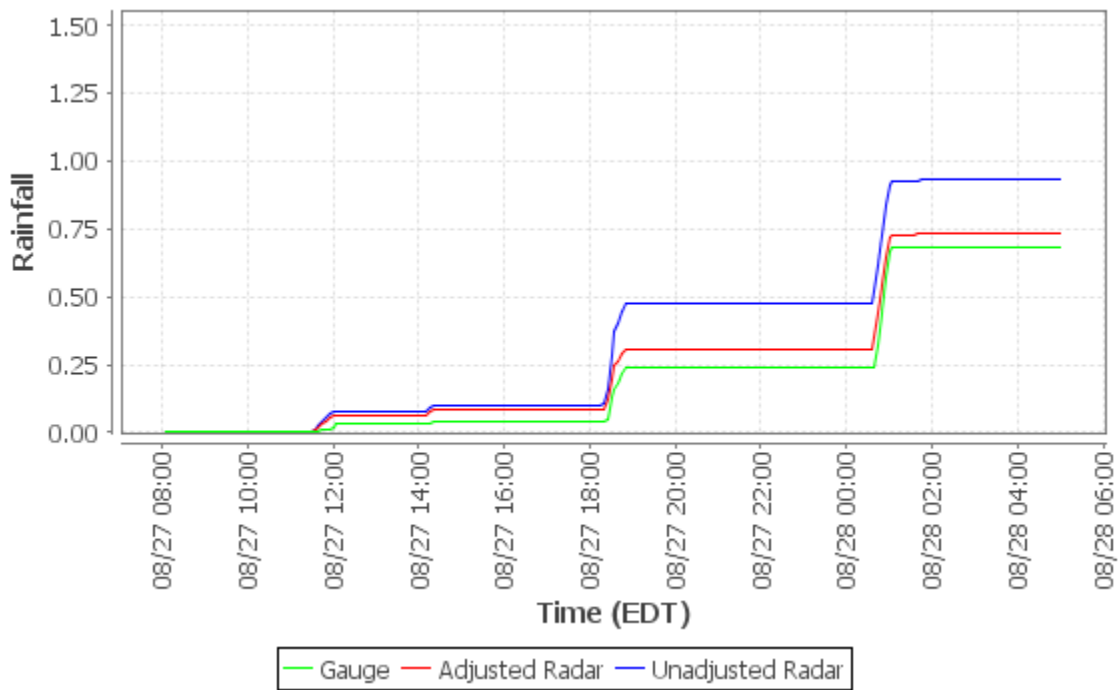
**Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)**



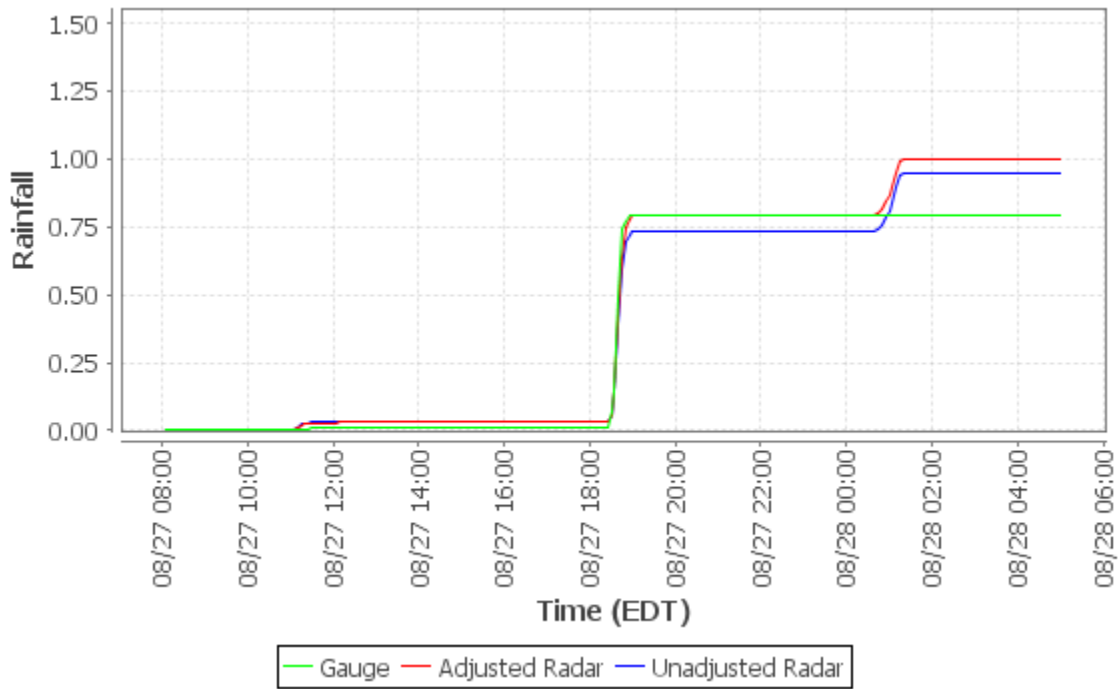
**Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)**



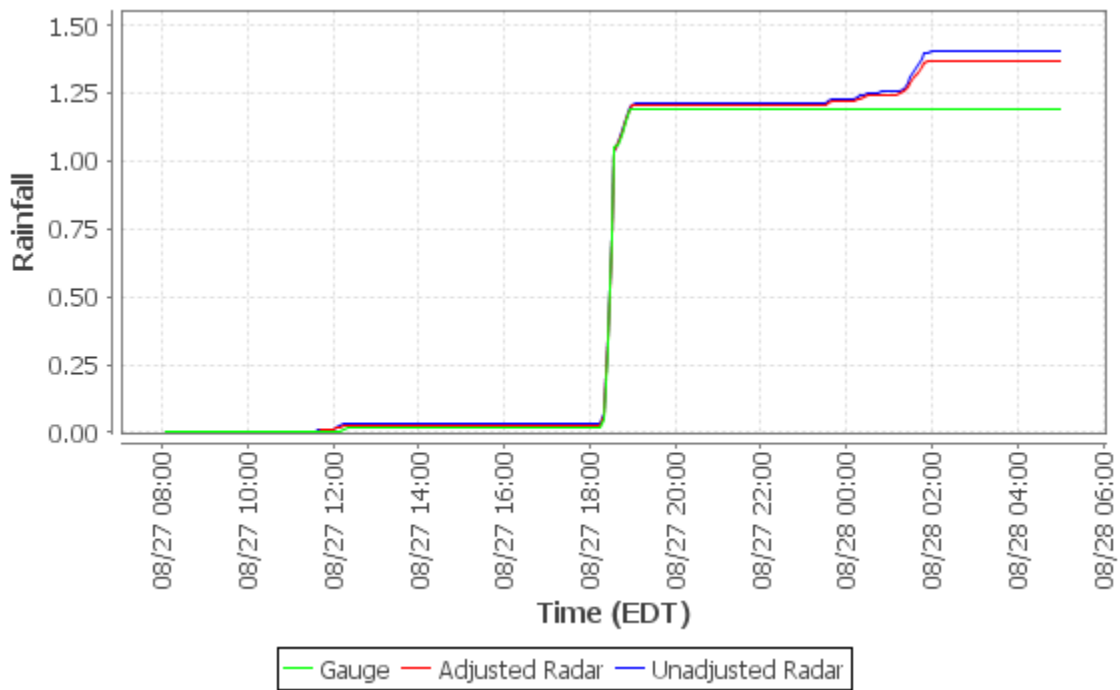
**Cumulative Distribution Plot - McCandless Twn Hall (Loc30)**



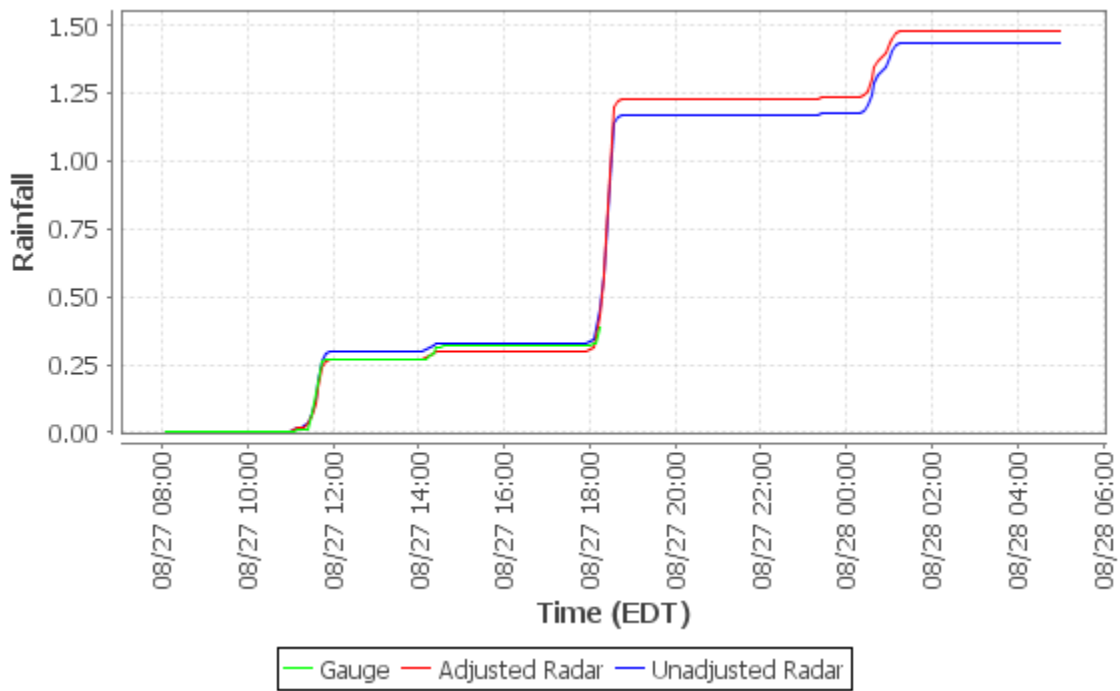
**Cumulative Distribution Plot - Hampton Municipal Bldg (Loc31)**



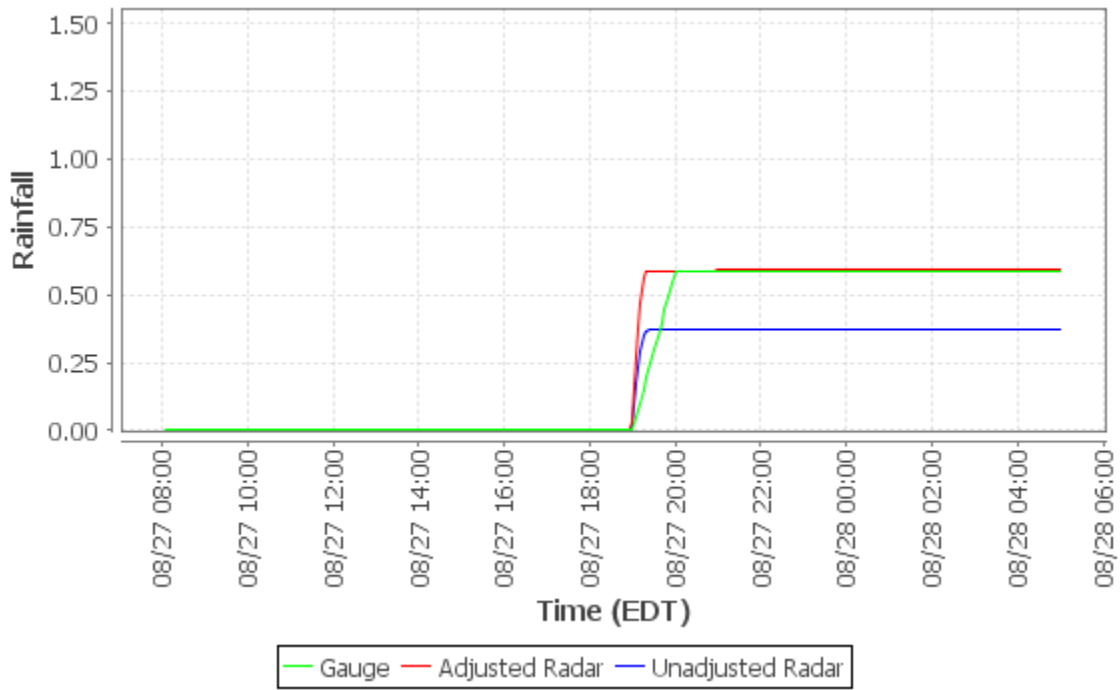
**Cumulative Distribution Plot - Arnold (Loc32)**



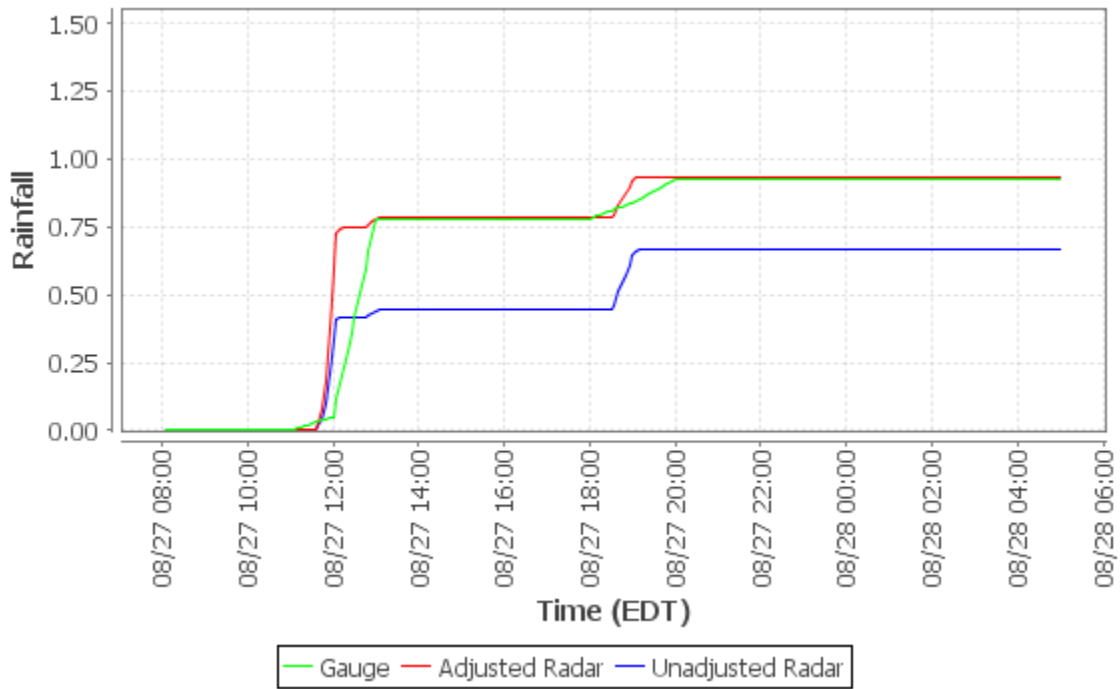
**Cumulative Distribution Plot - Richland TWP (Loc33)**



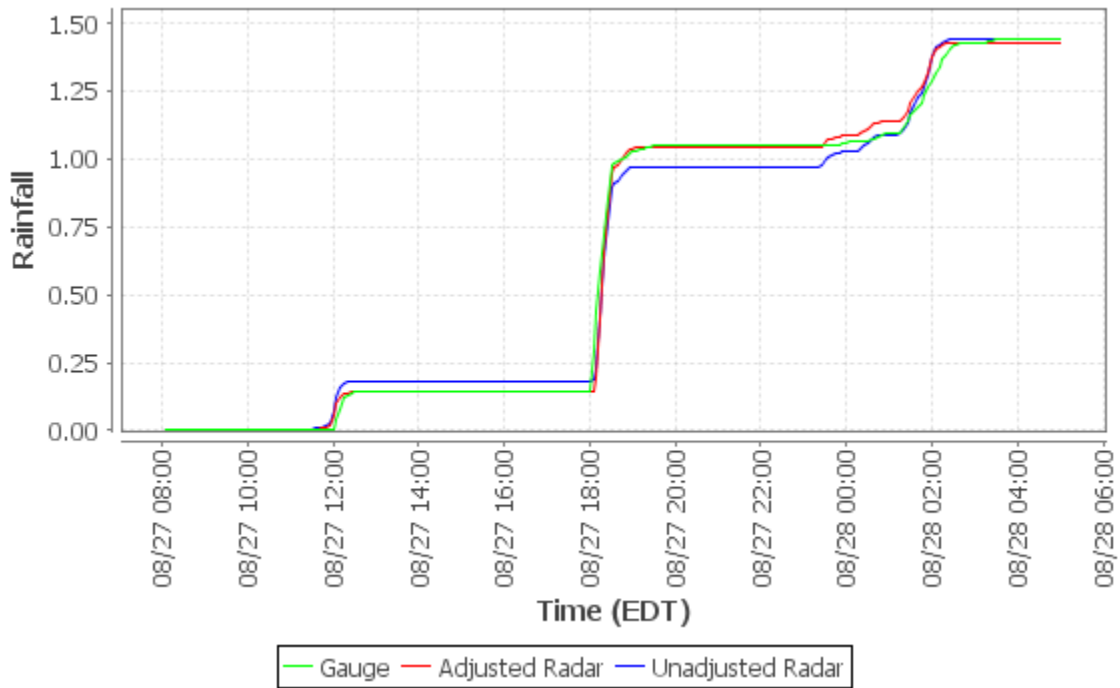
**Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)**



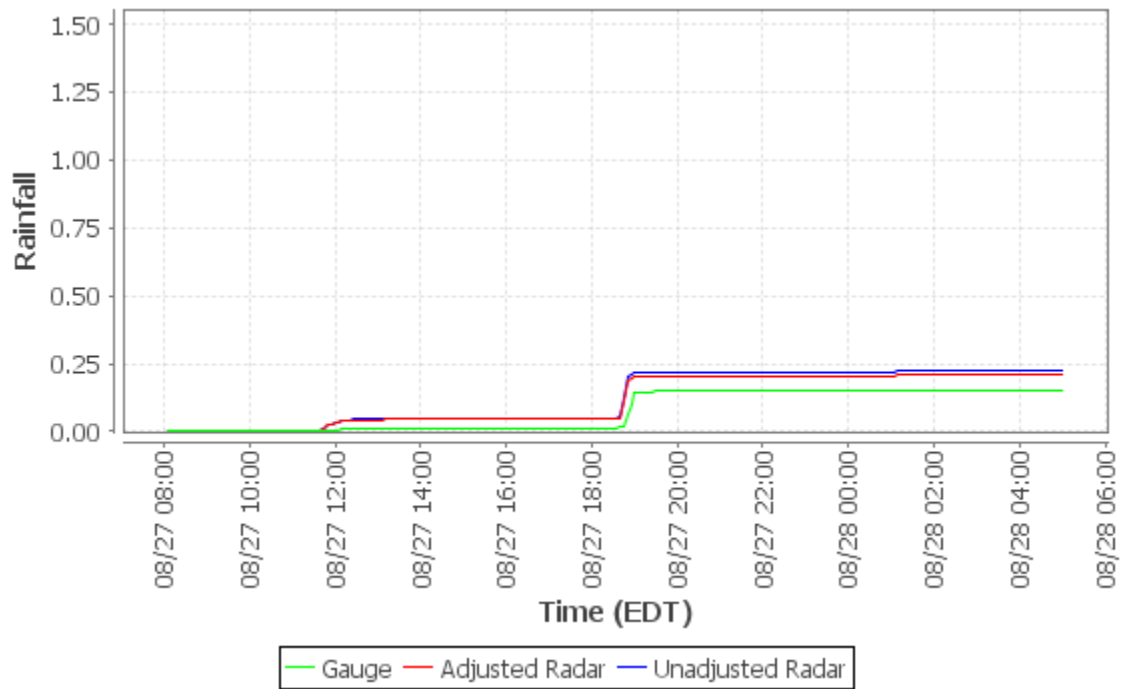
**Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)**



**Cumulative Distribution Plot - Allegheny River at Natrona (03049500)**



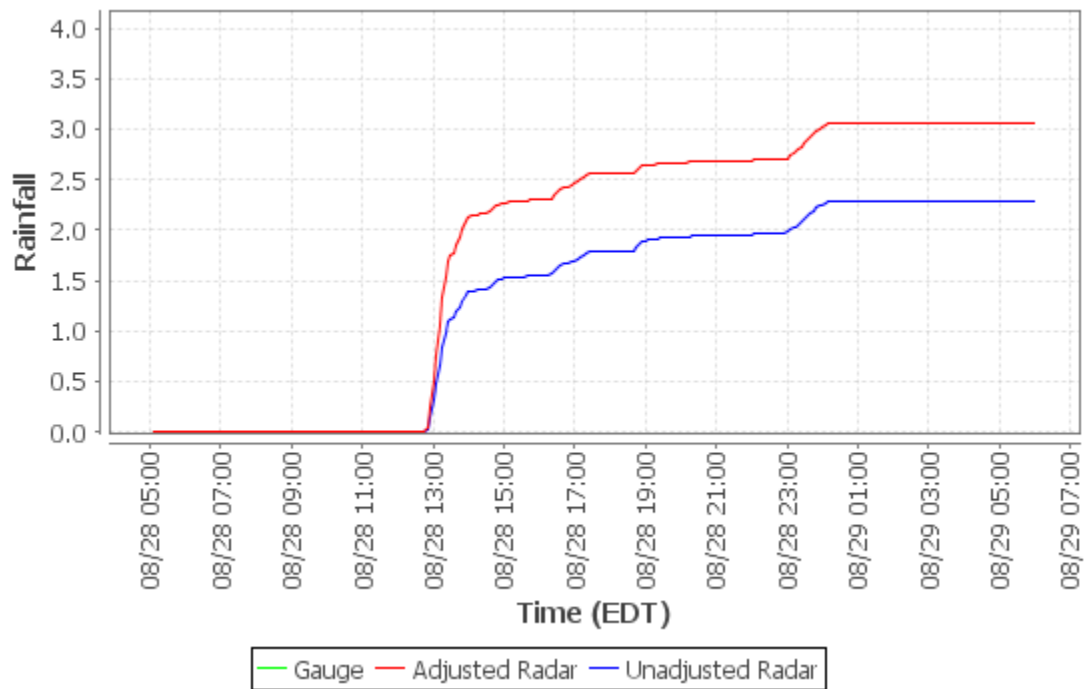
**Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth  
(03085734)**



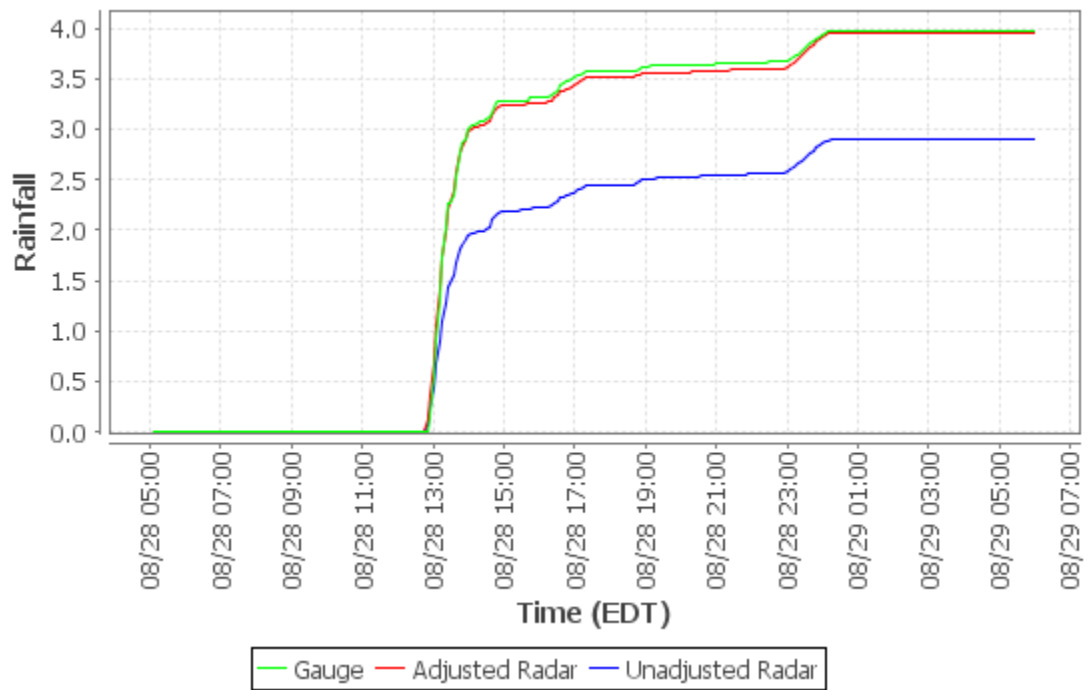
## **Appendix G - Event 5 (2020-08-28) CDPs**



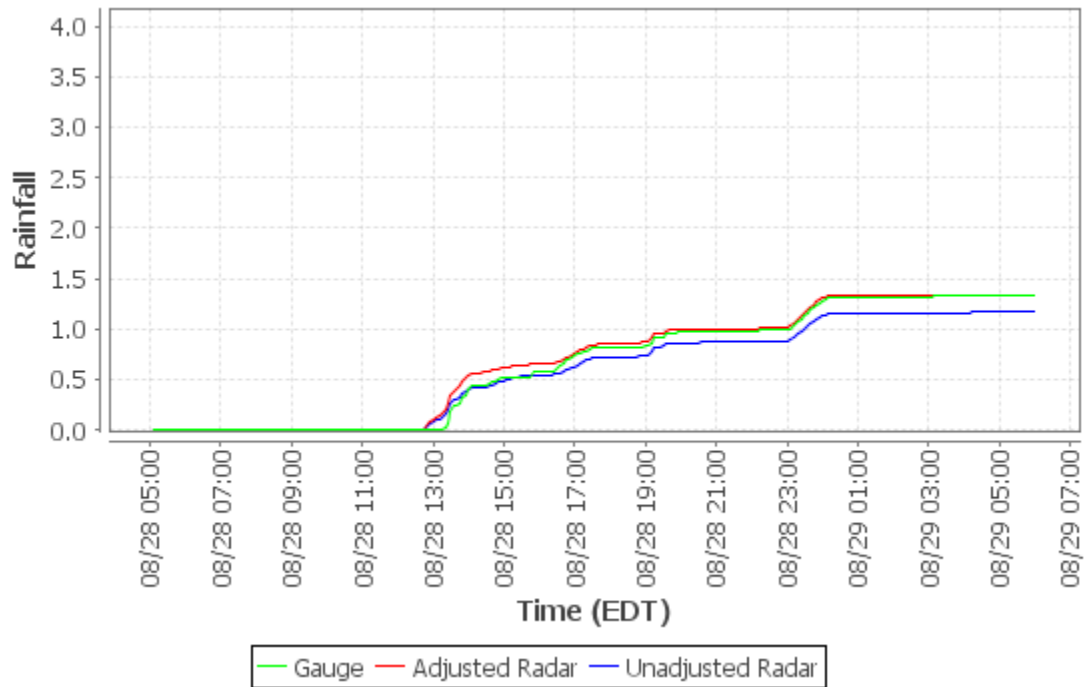
**Cumulative Distribution Plot - PWSA-Montana St. (Loc01)**



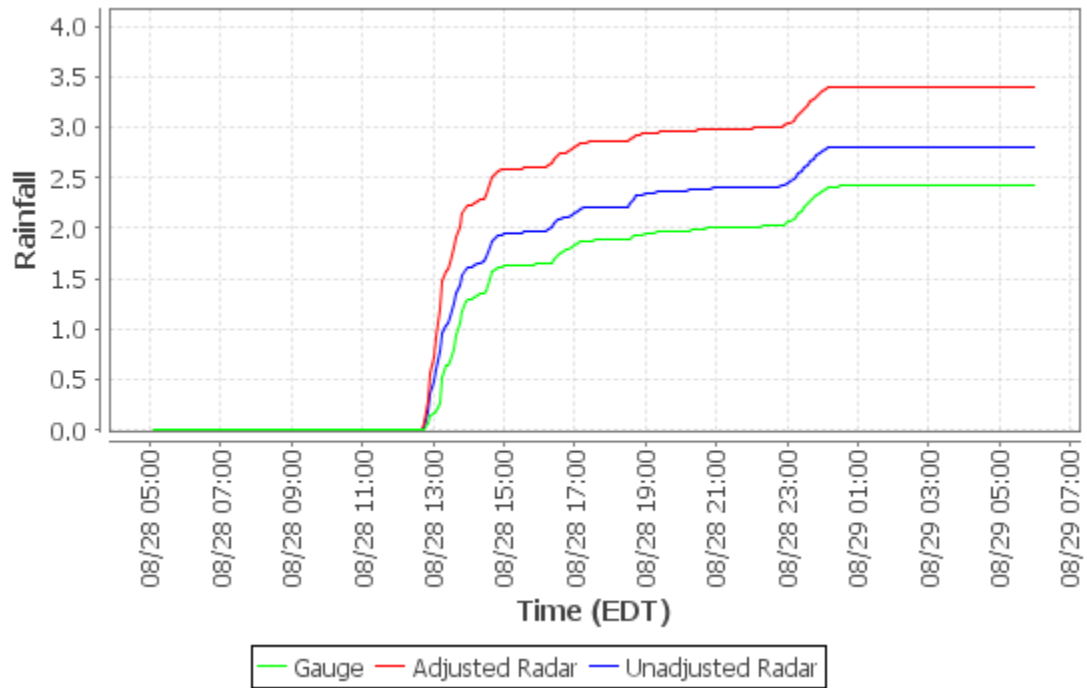
**Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)**



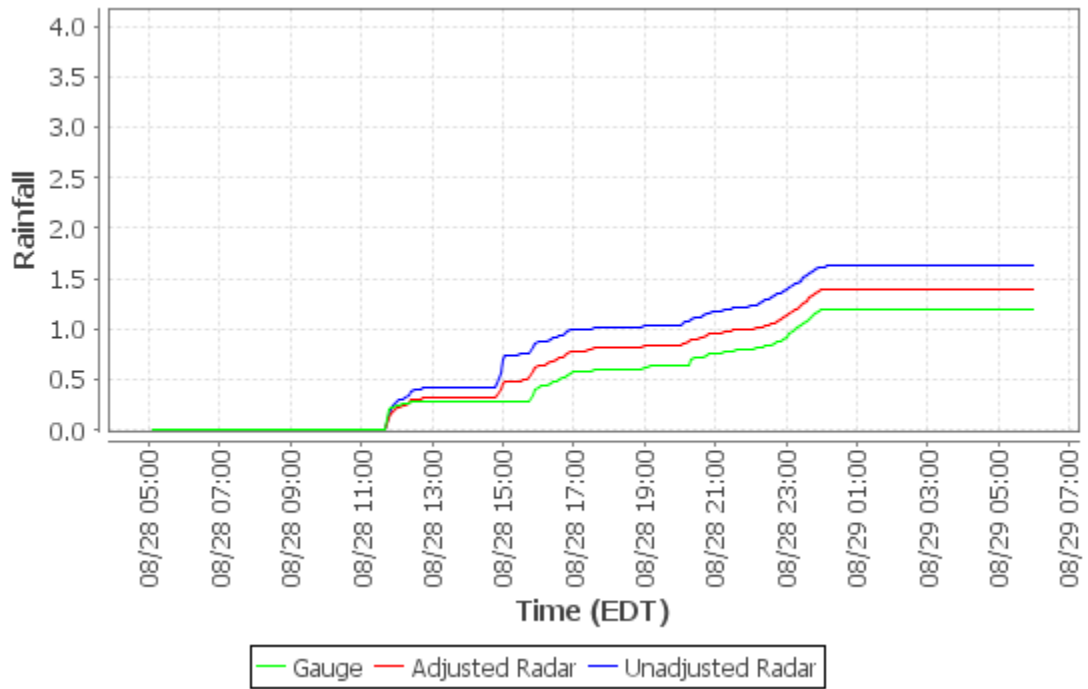
**Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)**



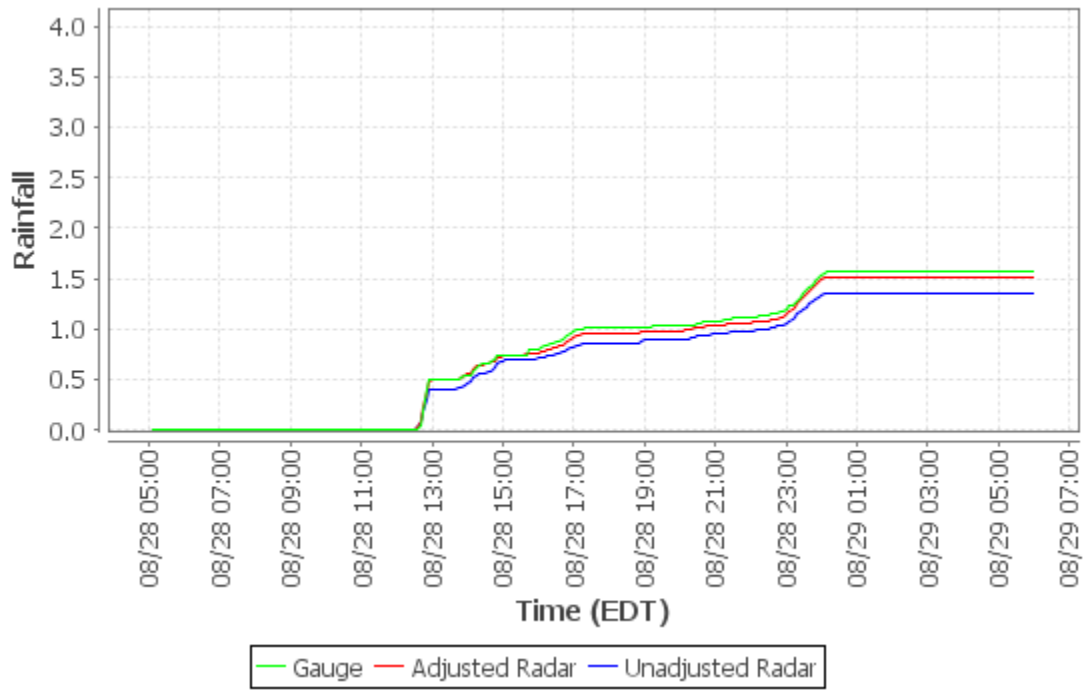
**Cumulative Distribution Plot - Kennedy Twp PS (Loc04)**



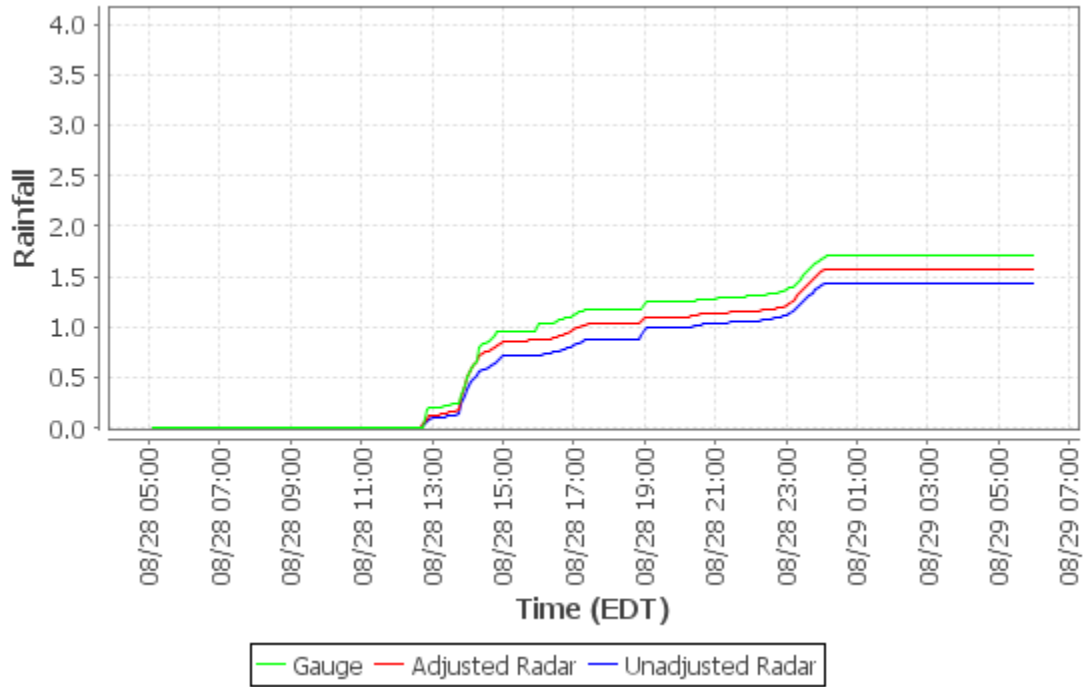
**Cumulative Distribution Plot - Upper St. Clair (Loc05)**



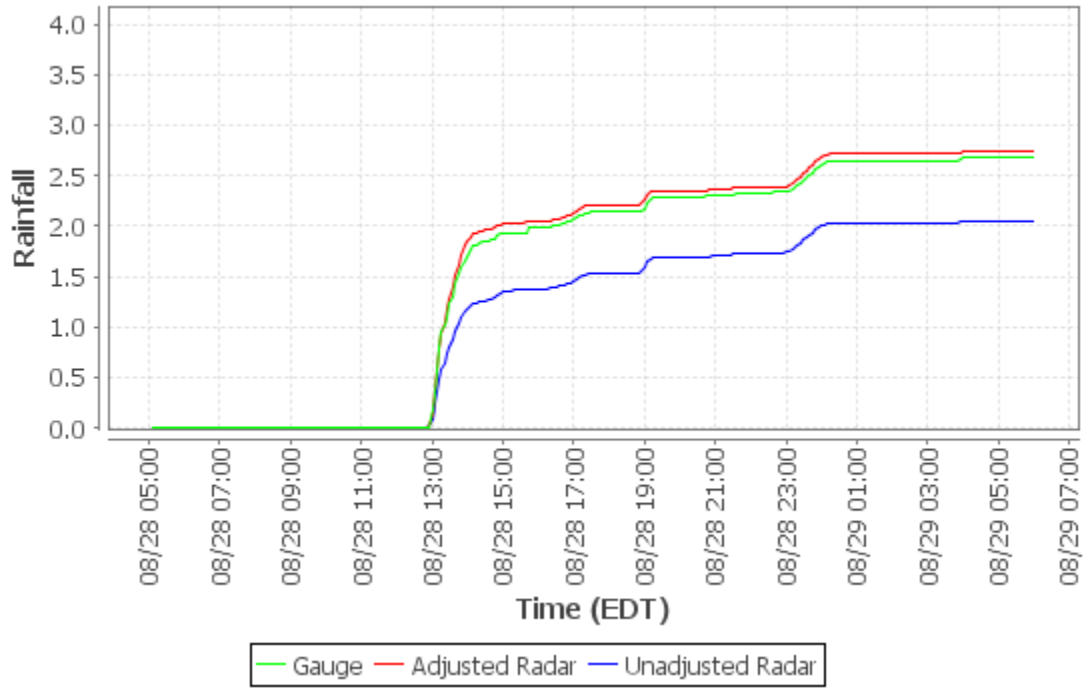
**Cumulative Distribution Plot - Carnegie Transit Time (Loc06)**



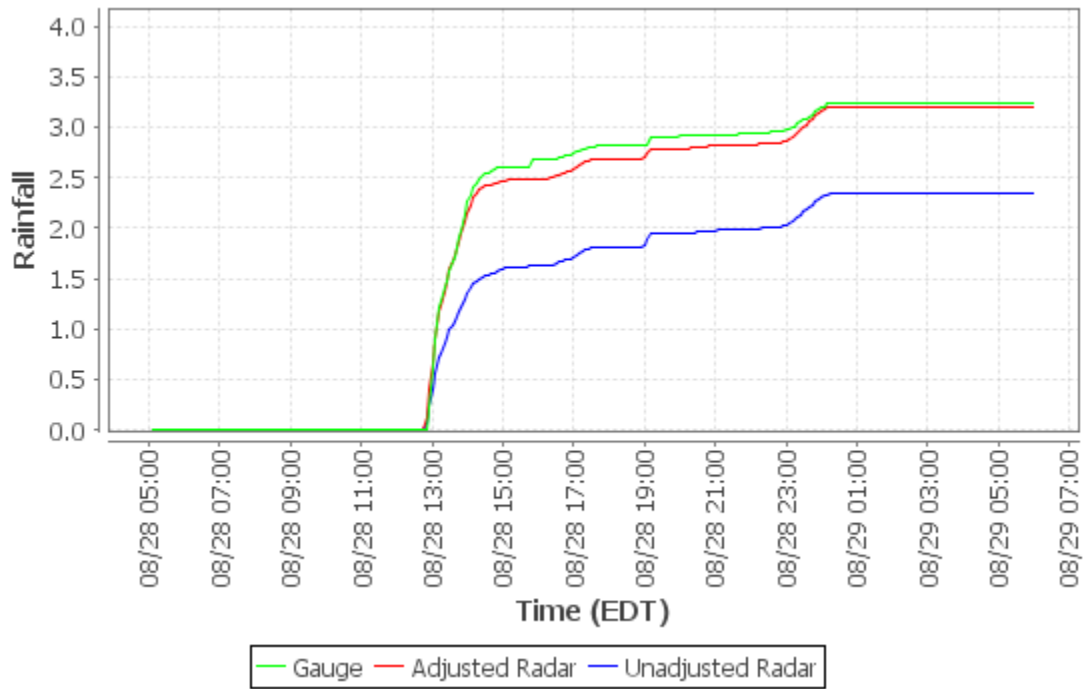
**Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)**



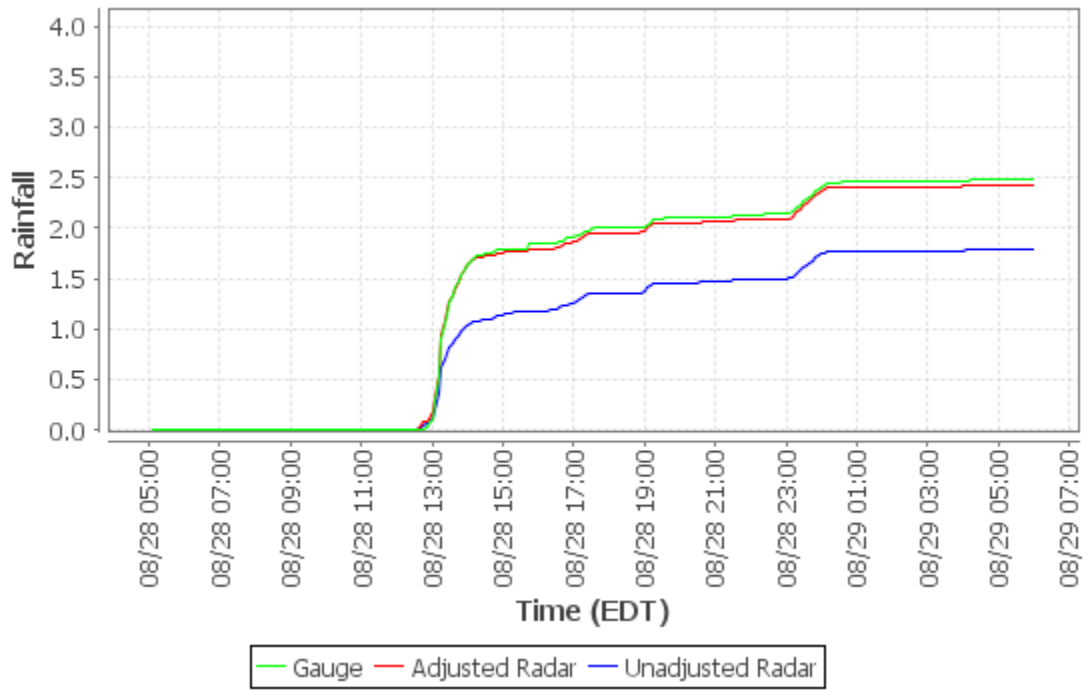
**Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)**



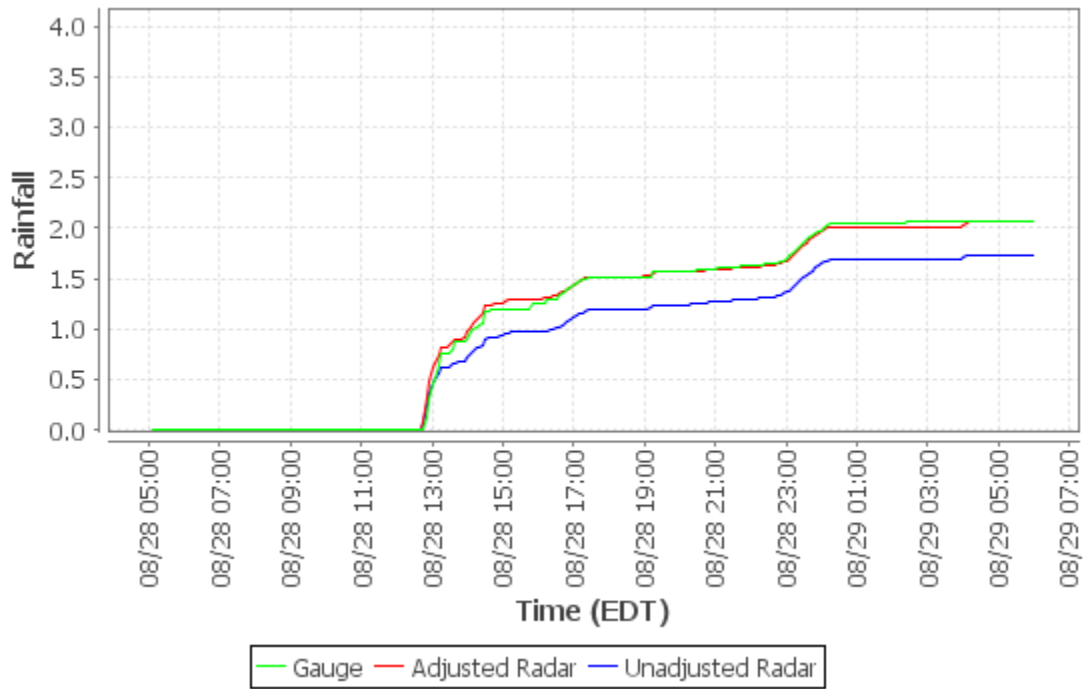
**Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)**



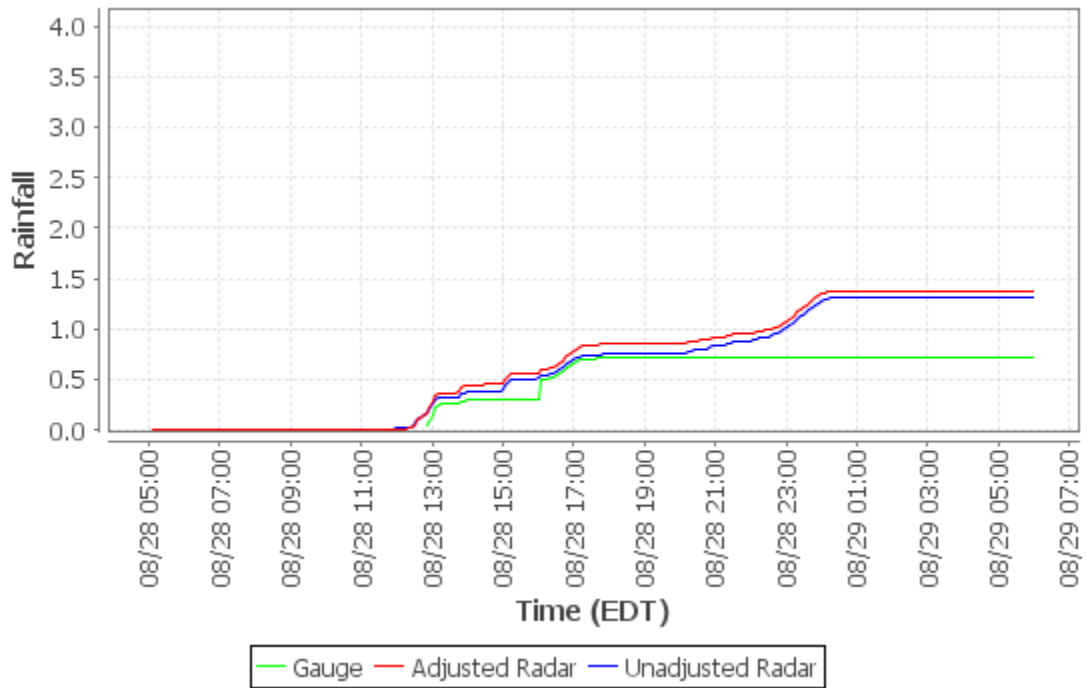
**Cumulative Distribution Plot - PWSA-Highland Park (Loc10)**



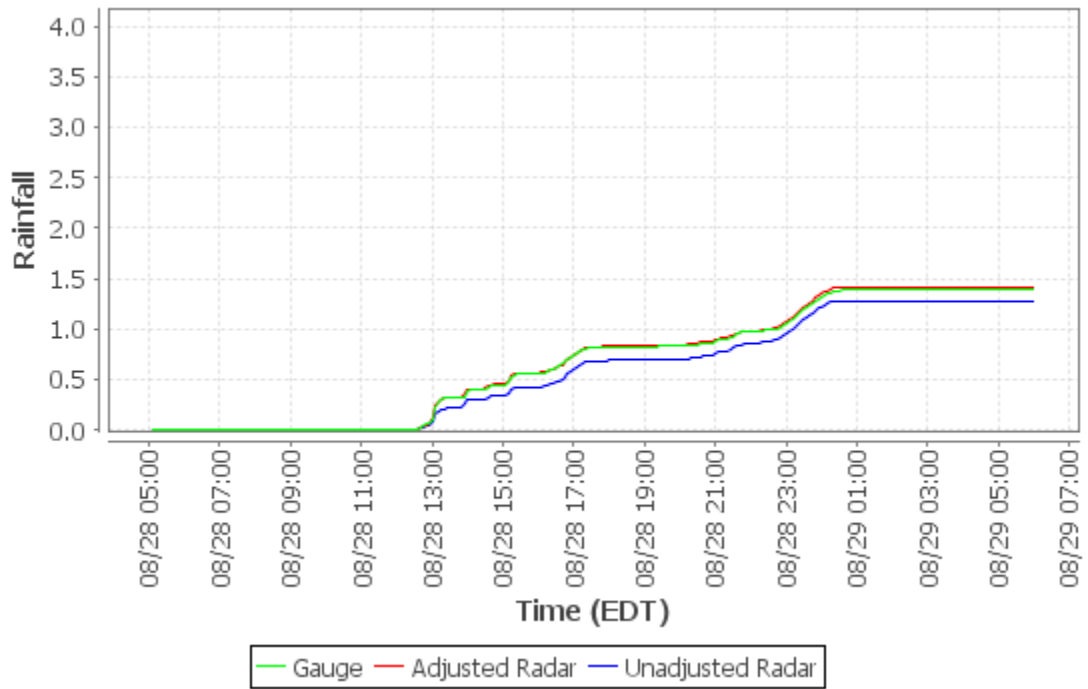
**Cumulative Distribution Plot - M-46 Access Shaft (Loc11)**



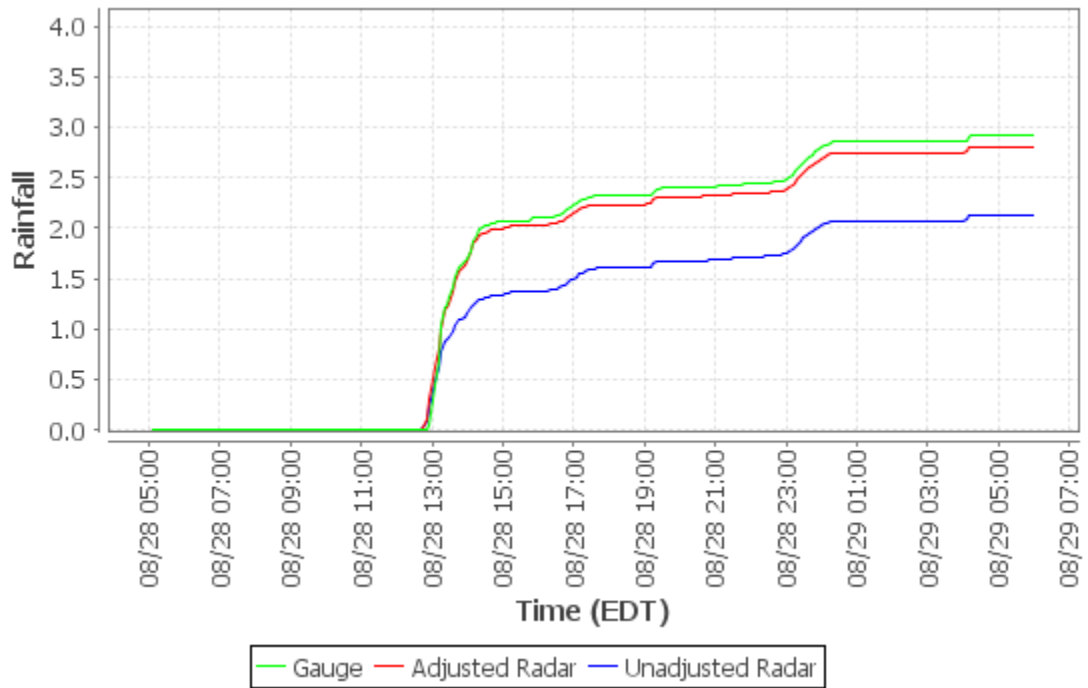
**Cumulative Distribution Plot - Baldwin (Loc12)**



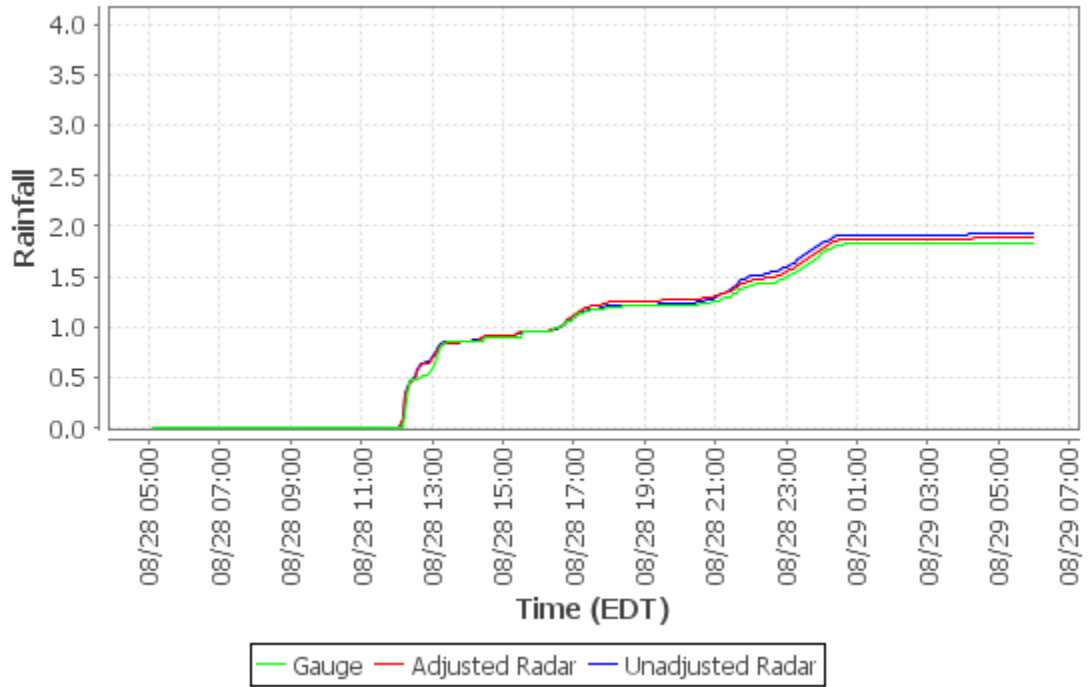
**Cumulative Distribution Plot - M-59 Access Shaft (Loc13)**



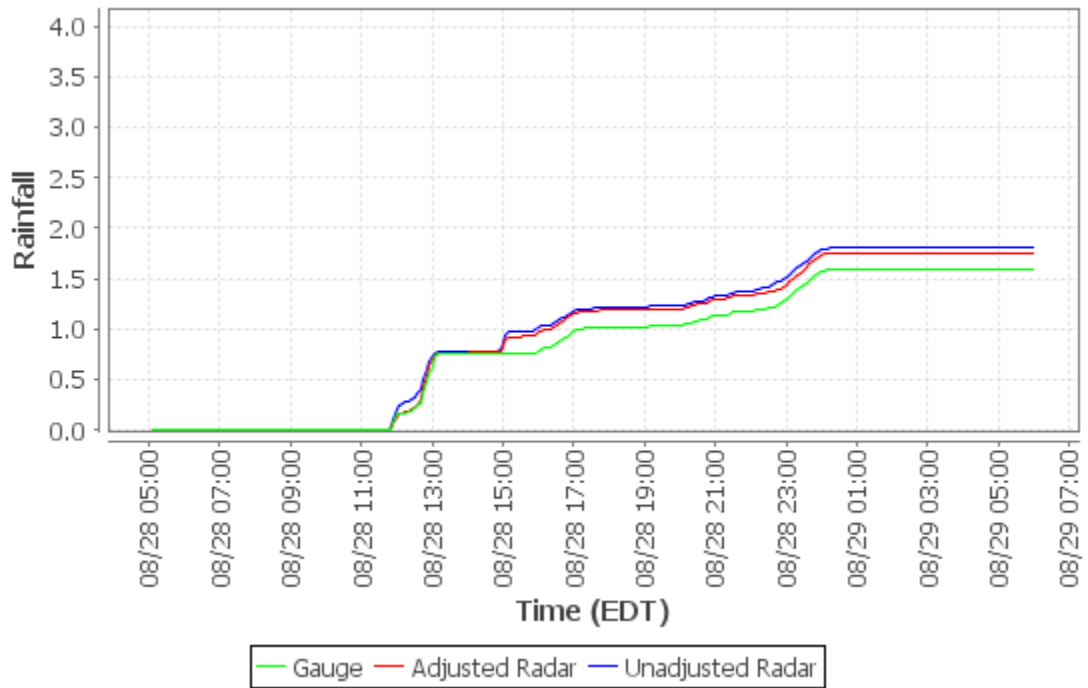
**Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)**



**Cumulative Distribution Plot - Trafford Maint Bldg (Loc15)**

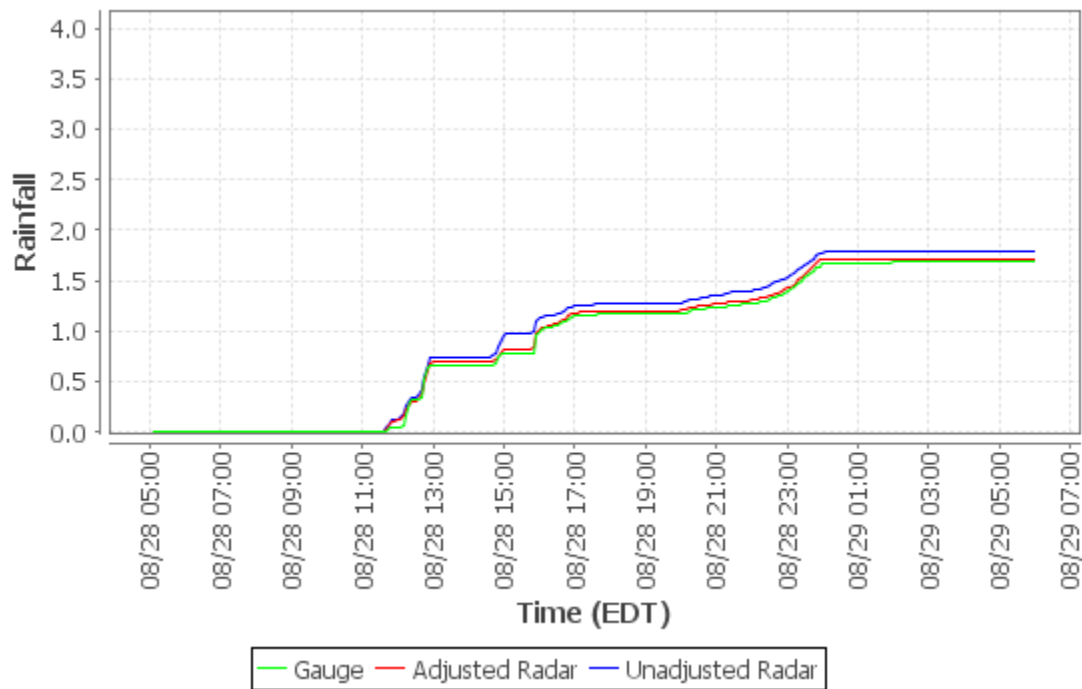


**Cumulative Distribution Plot - Castle Shannon (Loc16)**

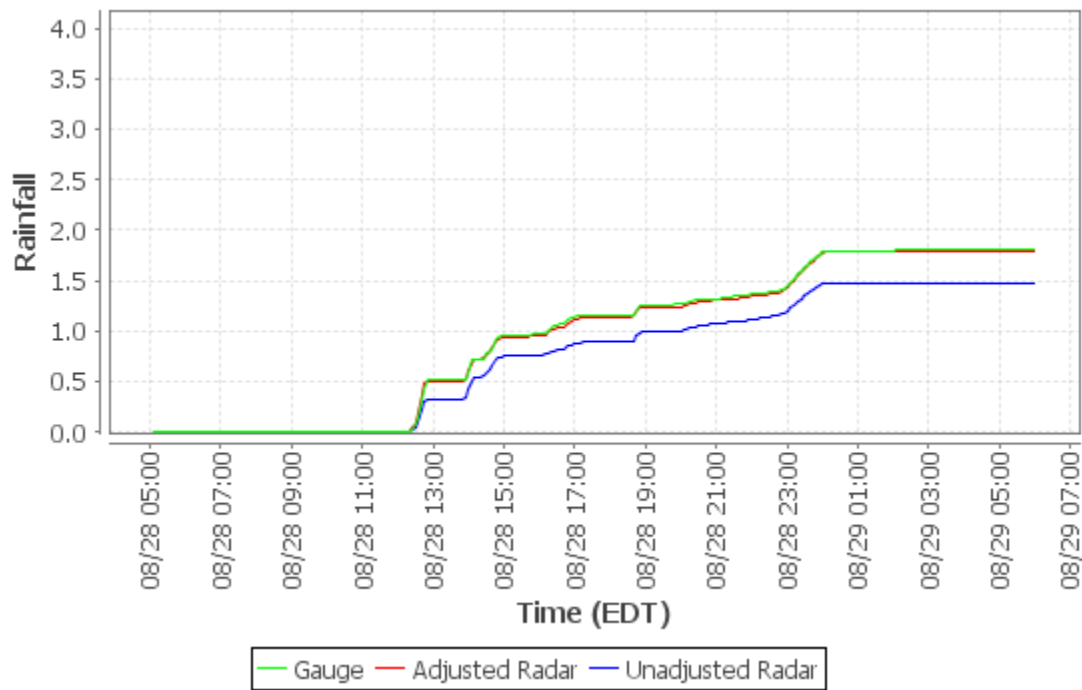




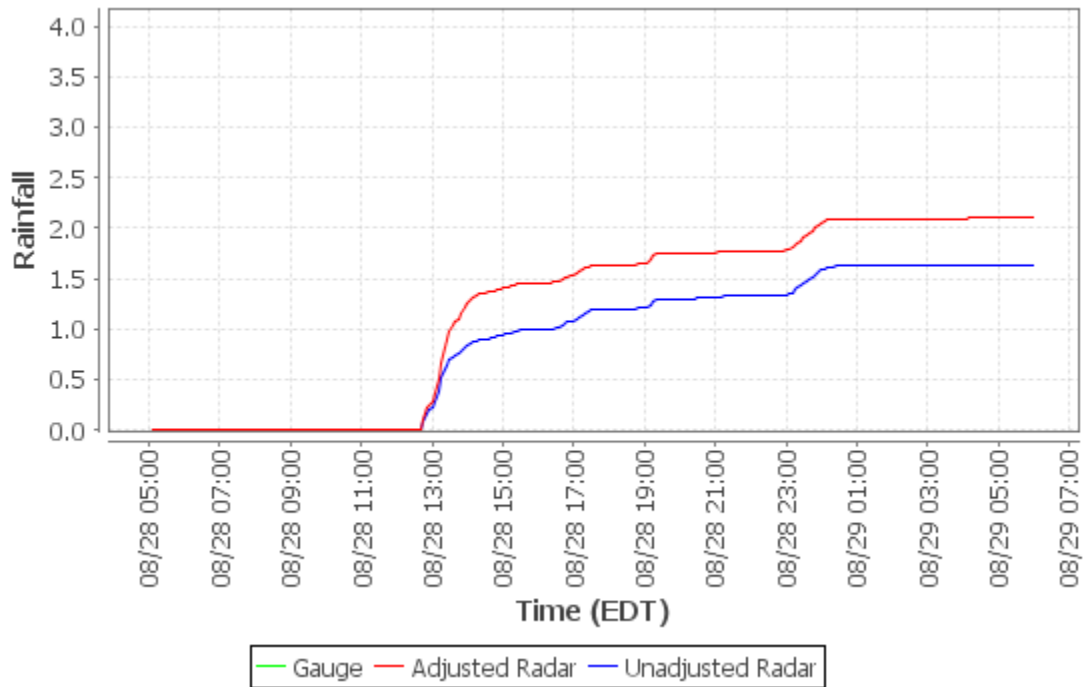
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



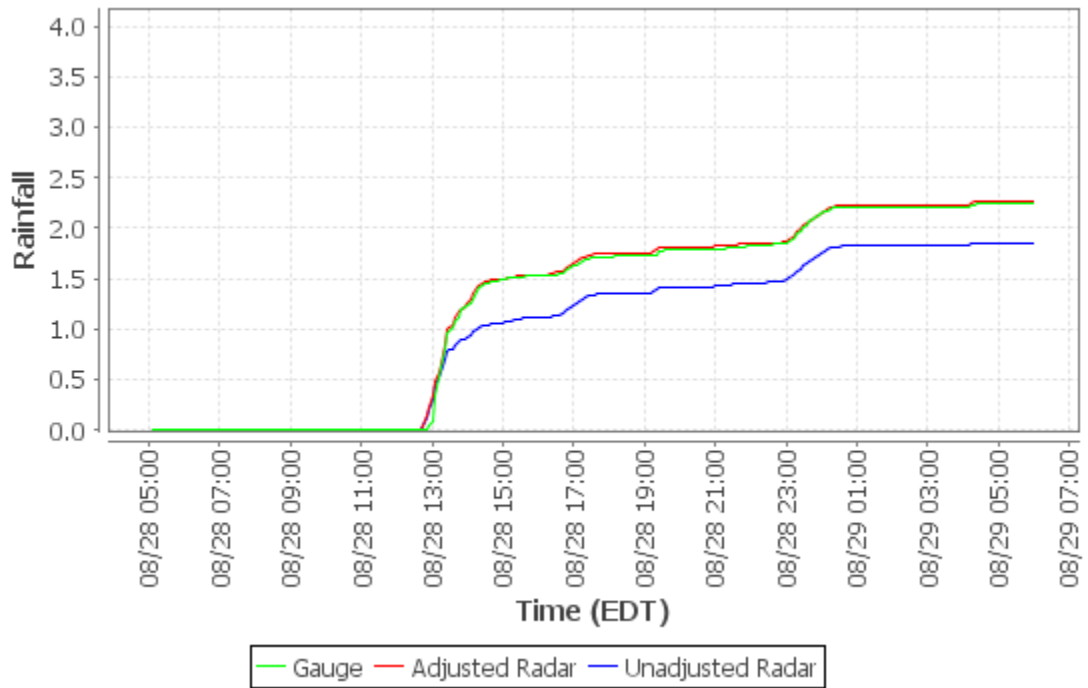
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



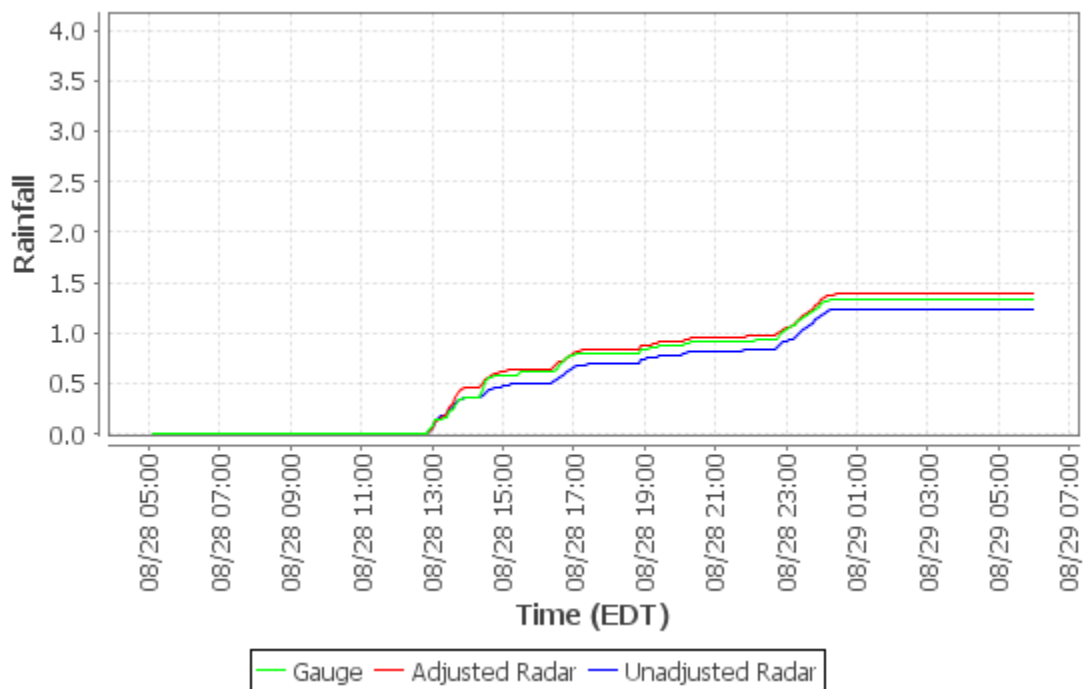
**Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)**



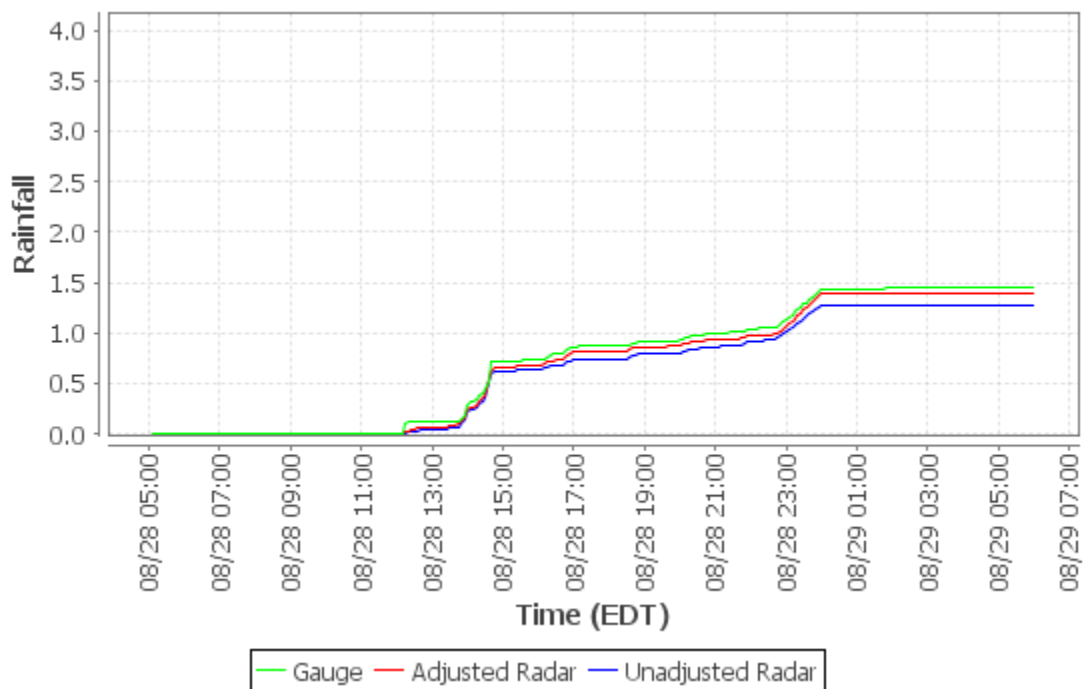
**Cumulative Distribution Plot - Gascola Eq Facility (Loc20)**



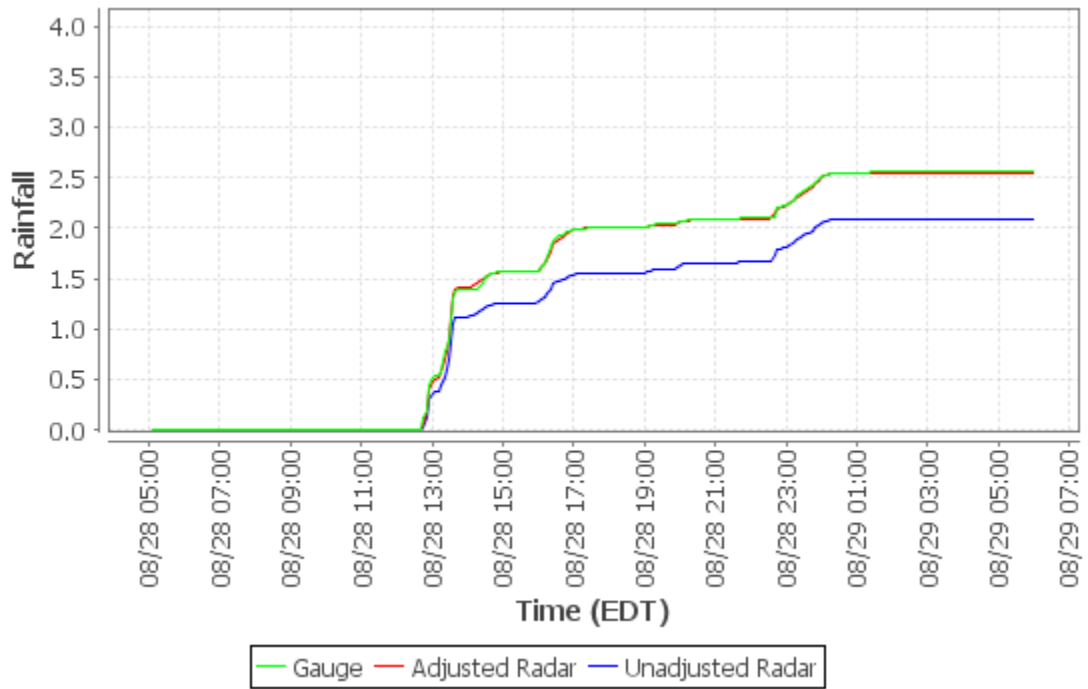
**Cumulative Distribution Plot - Moon TWP (Loc21)**



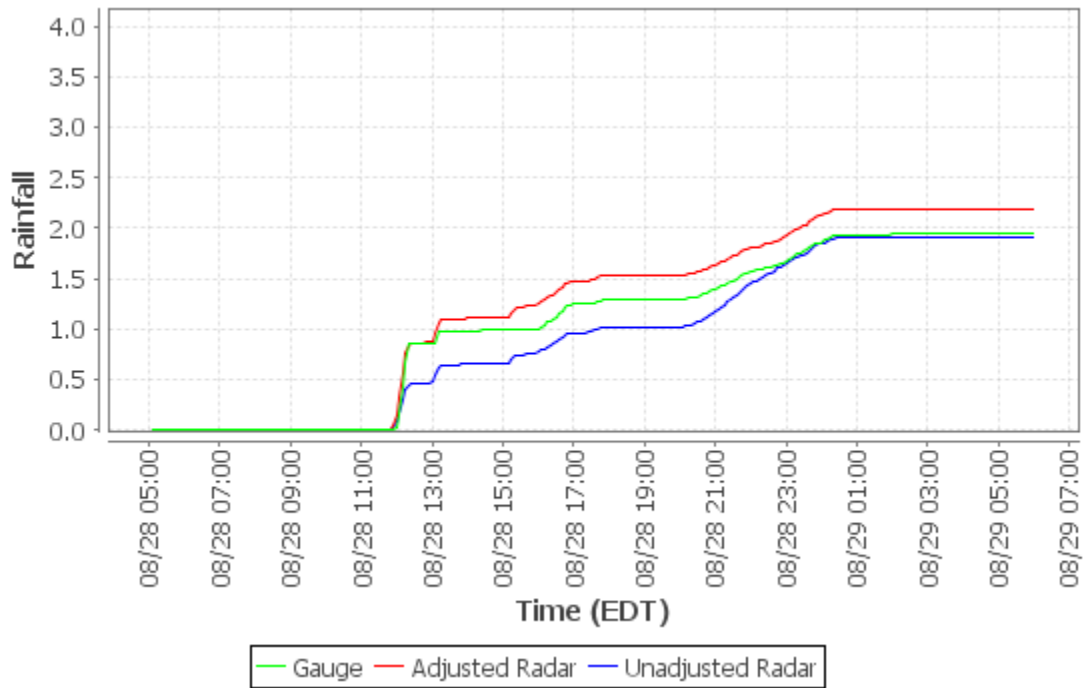
**Cumulative Distribution Plot - North Fayette TWP (Loc22)**



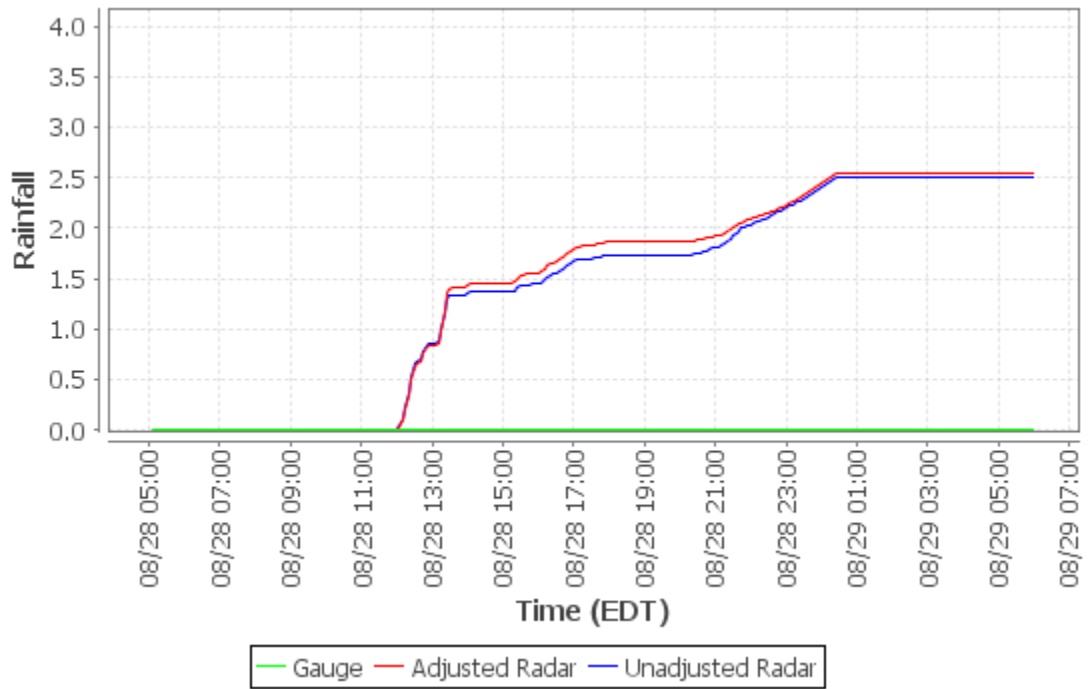
**Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)**



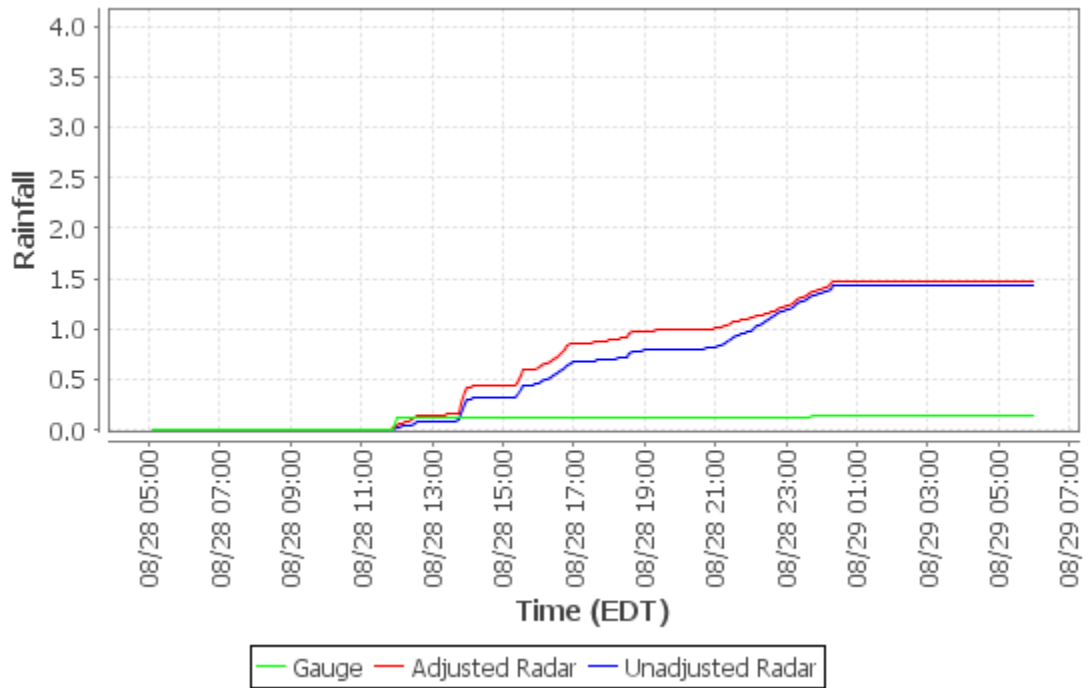
**Cumulative Distribution Plot - Jefferson Hills (Loc24)**



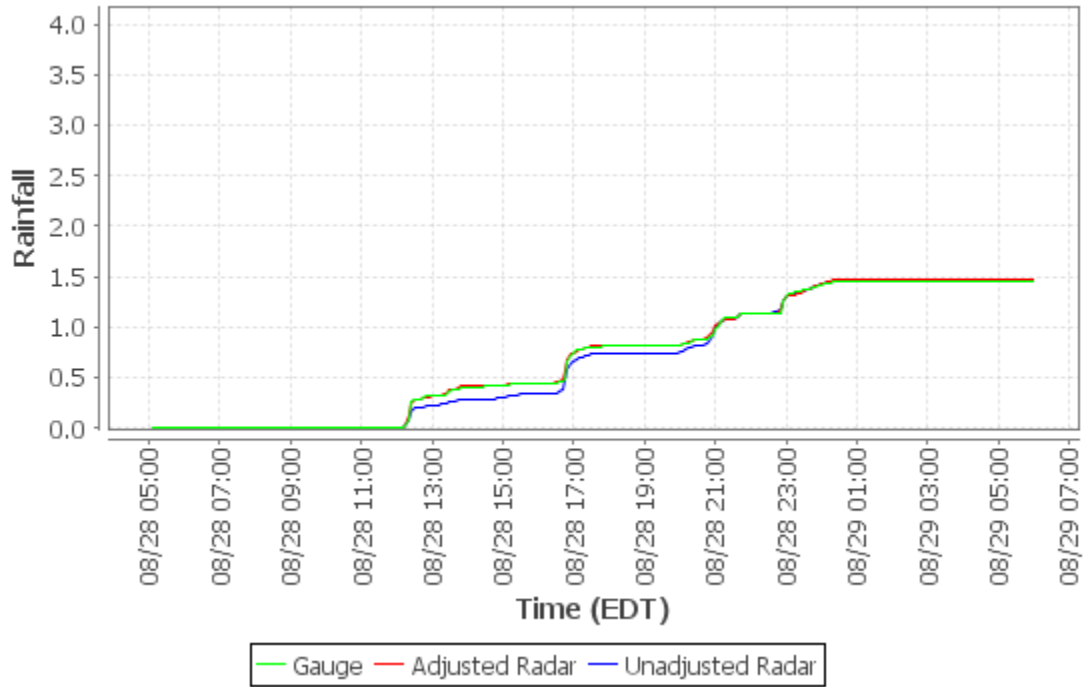
**Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)**



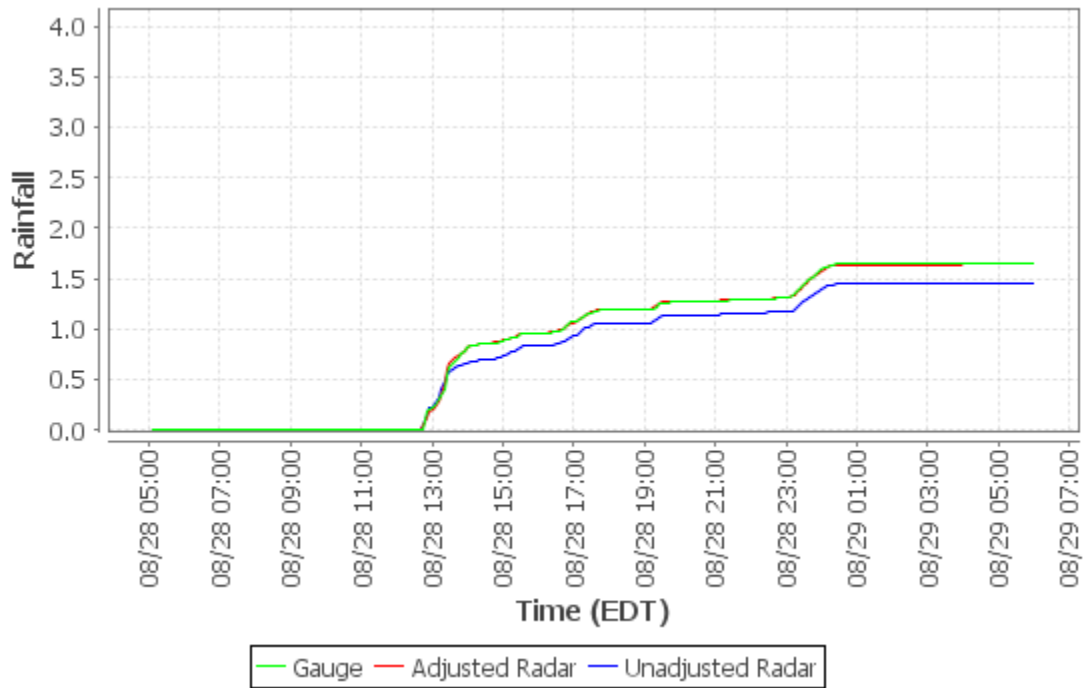
**Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)**



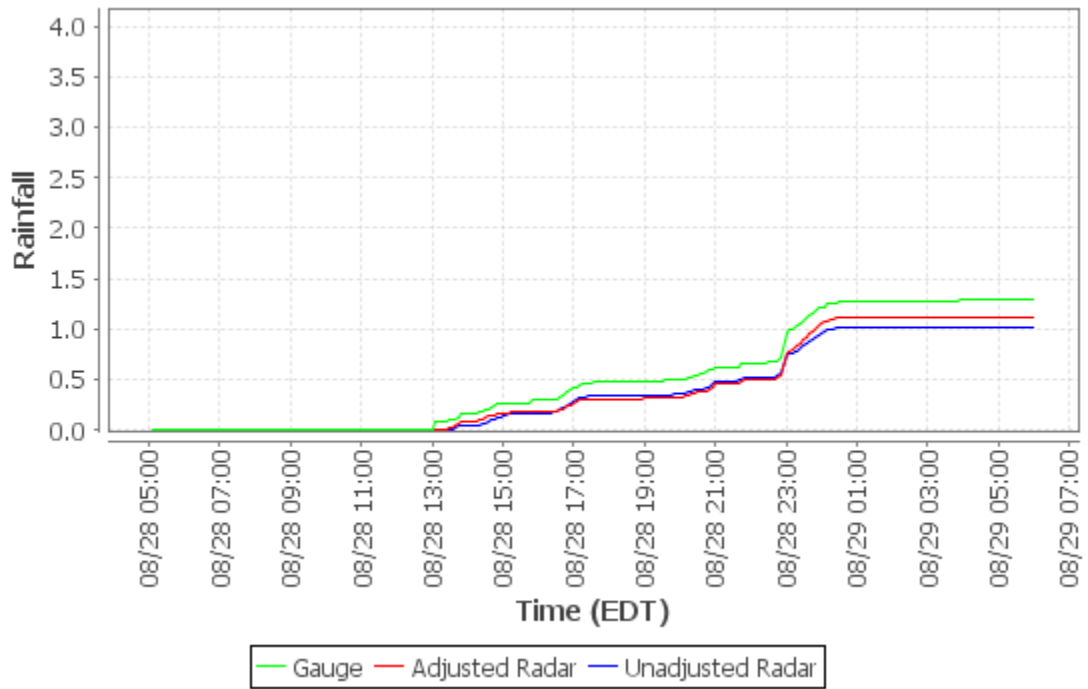
**Cumulative Distribution Plot - Marshall TWP (Loc27)**



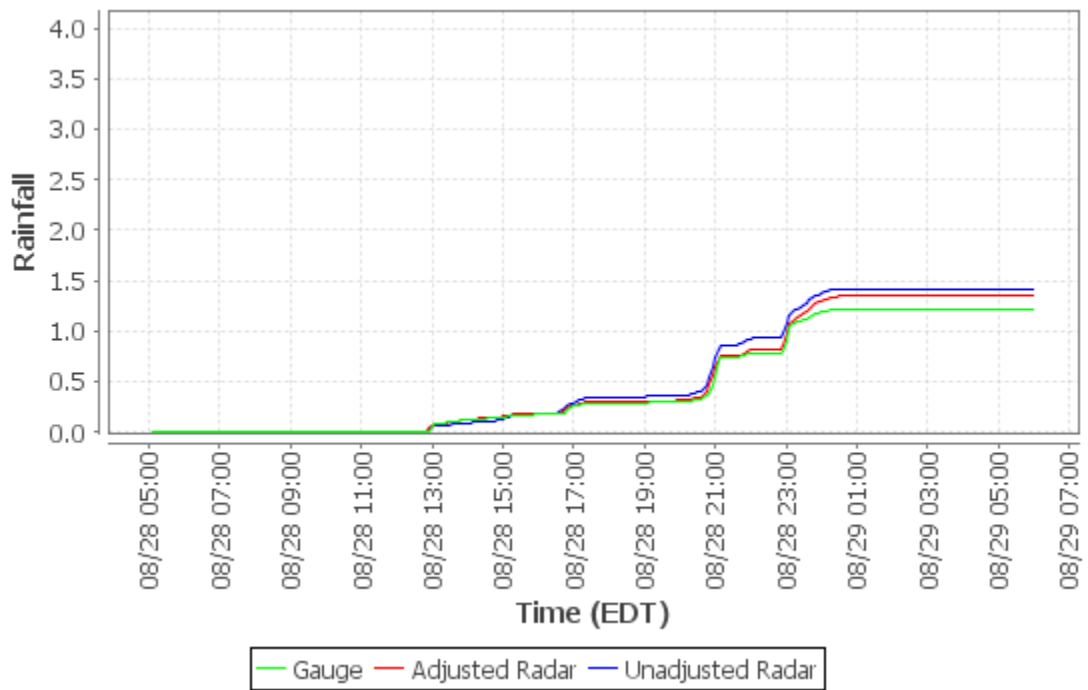
**Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)**



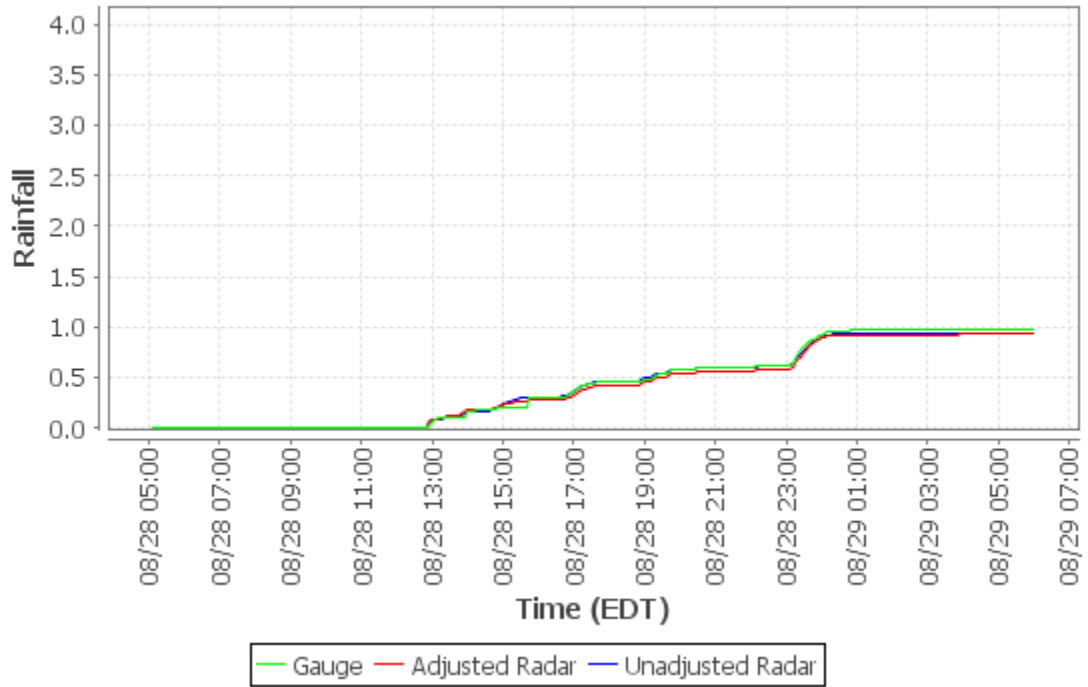
**Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)**



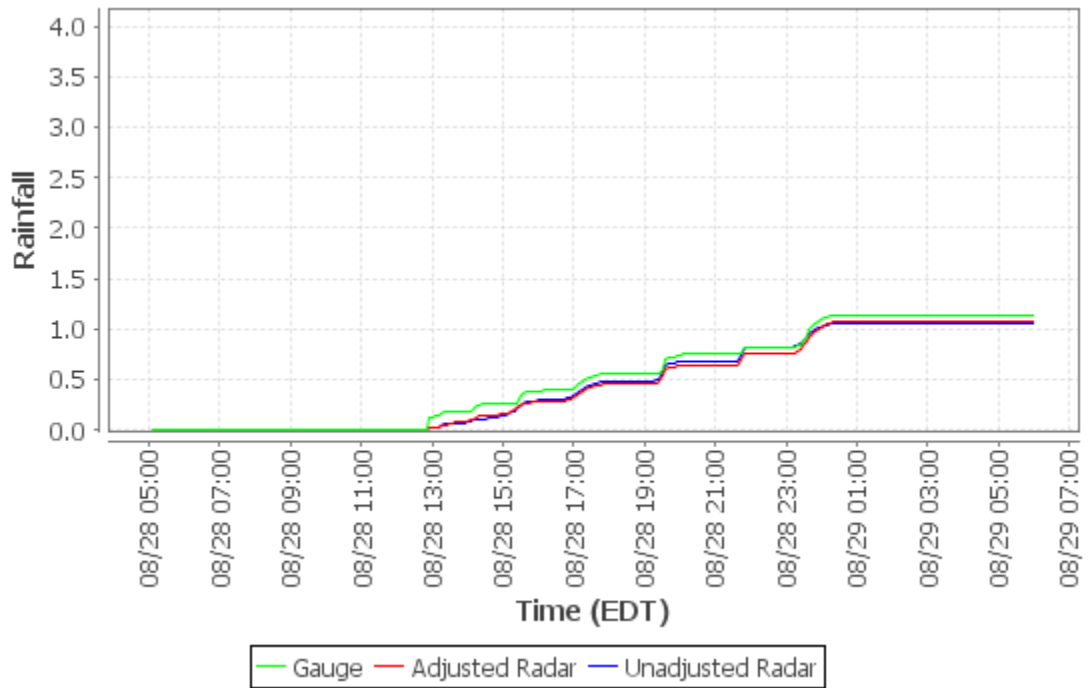
**Cumulative Distribution Plot - McCandless Twn Hall (Loc30)**



**Cumulative Distribution Plot - Hampton Municipal Bldg (Loc31)**

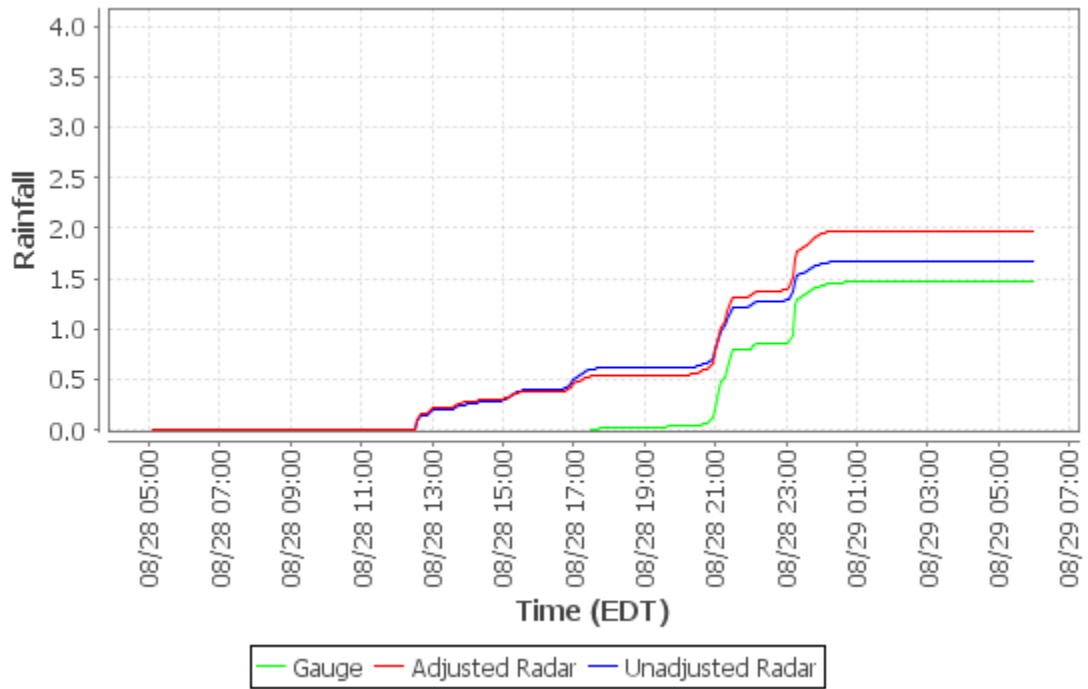


**Cumulative Distribution Plot - Arnold (Loc32)**

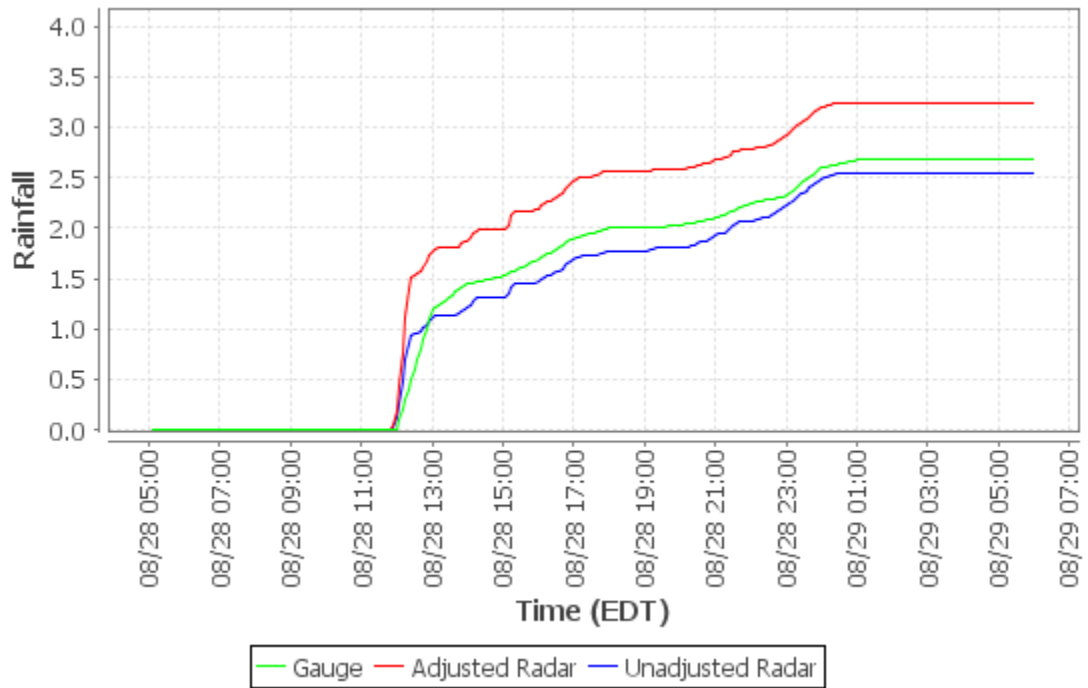




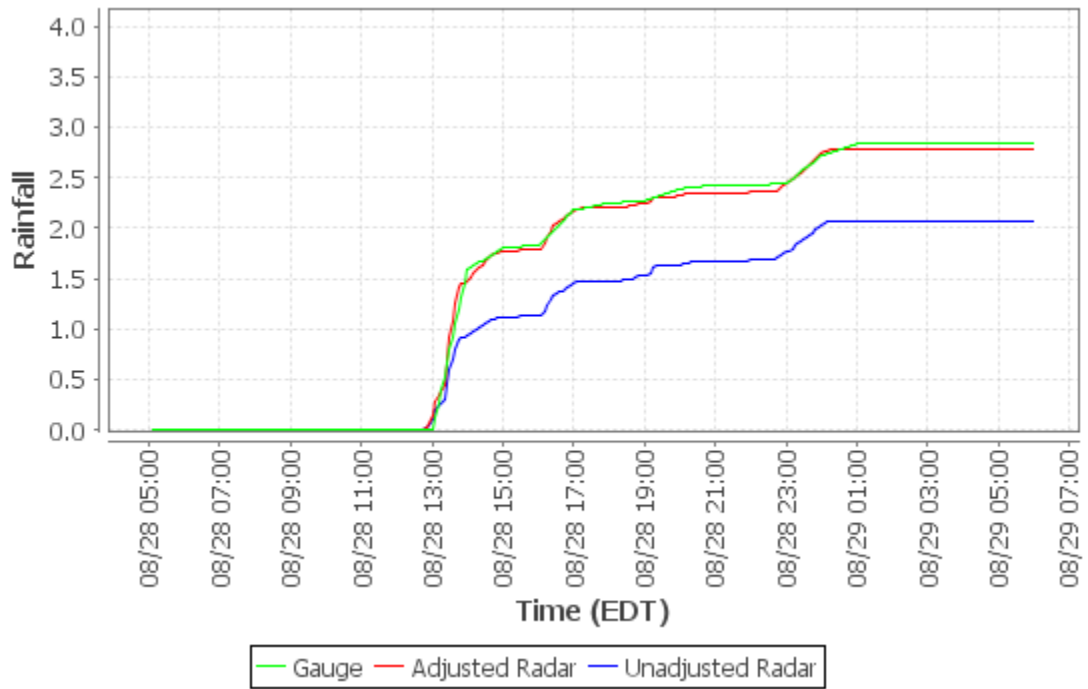
**Cumulative Distribution Plot - Richland TWP (Loc33)**



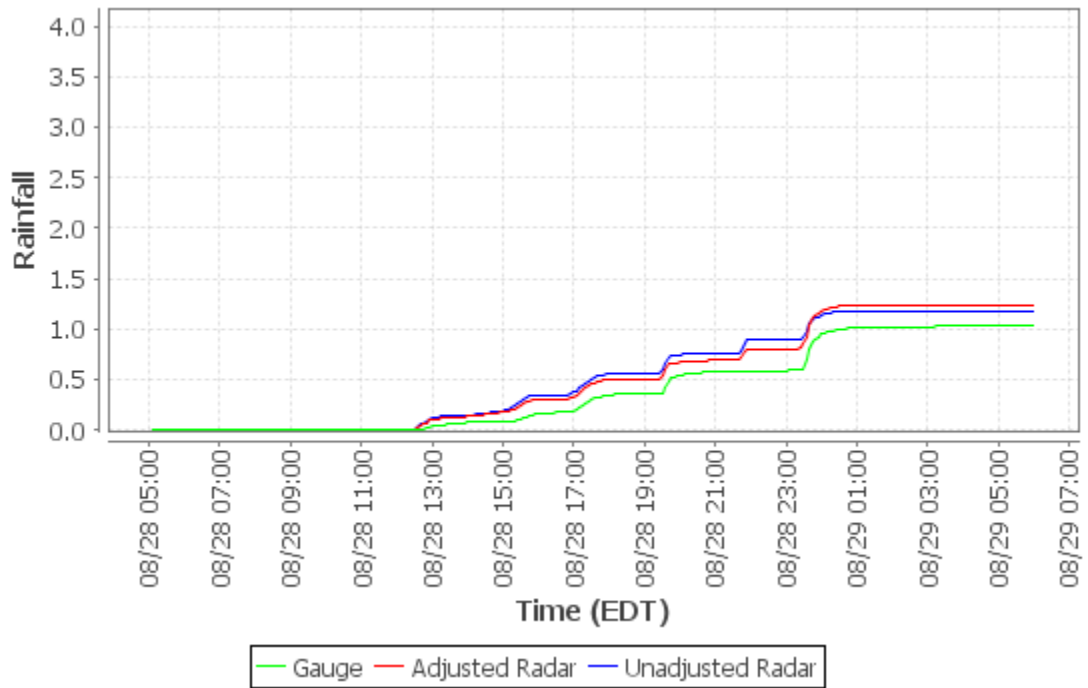
**Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)**



**Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)**



**Cumulative Distribution Plot - Allegheny River at Natrona (03049500)**



**Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth  
(03085734)**

