

# Radar Rainfall Analysis

## May 2019 Summary Report



Prepared for 3 Rivers Wet Weather

June 18, 2019



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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.

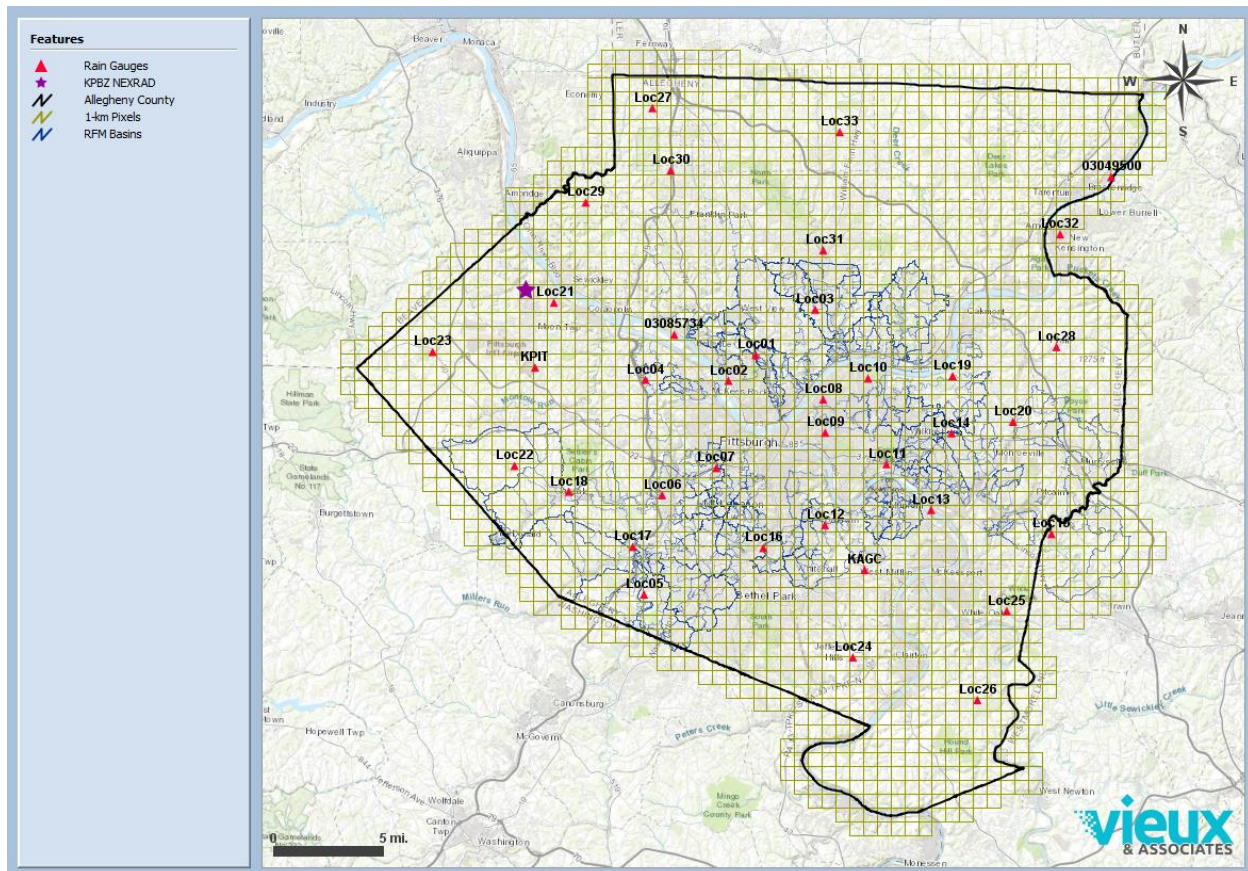
Radar data used in production of GARR is produced by the National Weather Service (NWS) Next Generation Radar (NEXRAD) system. NEXRAD Level II radar data are often referred to as Base Data and contain the full spatial/temporal/data resolution data from the radar. Level II radar data measures reflectivity 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 2019-05-01 00:00 EDT to 2019-06-01 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:

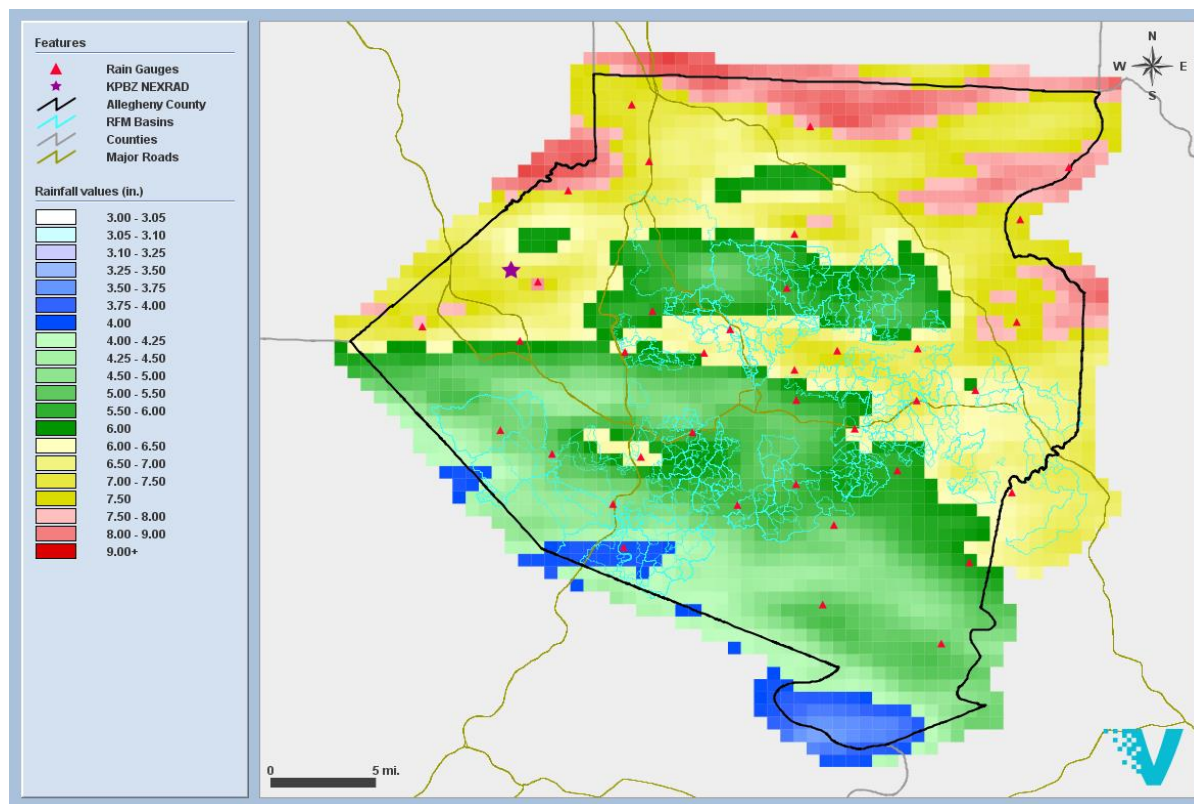
- Individual CSV files are provided for each RFM Basin and RFM Shed.
- The RFM Basin filenames use a "P-" prefix and a "yyyymmG" (i.e. year, month, G) suffix in front and after the RFM Basin ID.
- The RFM Shed filenames use a "P-" prefix and a "yyyymmN" (i.e. year, month, N) suffix in front and after 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 May 2019 are shown in Figure 2. The rainfall amounts for the 2313 1-km<sup>2</sup> pixels range from 3.4 to 8.5 inches with a mean of 6.0 inches. The rainfall amounts for the 440 RFM basins range from 3.9 to 7.0 inches with a mean of 5.7 inches. The rainfall amounts for the 871 RFM sheds range from 3.9 to 7.4 inches with a mean of 5.6 inches.



**Figure 2. GARR Storm Total for May 2019**

GARR was processed continuously at five-minute increments and covers the period from 2019-05-01 00:00 EDT to 2019-06-01 00:00 EDT. Eleven rainfall events were identified as having met the storm definition during May 2019. The GARR statistics for each event are listed in Table 2. Seven of the events were split into multiple sub-event periods to improve gauge-adjustment of the radar, resulting in a total of thirty-five 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 eleven 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 thirty-five event and sub-event periods, the event CAD averaged 3.3%, indicating that the mean GARR agrees with the mean gauge accumulation to within  $\pm 1.6\%$ .

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

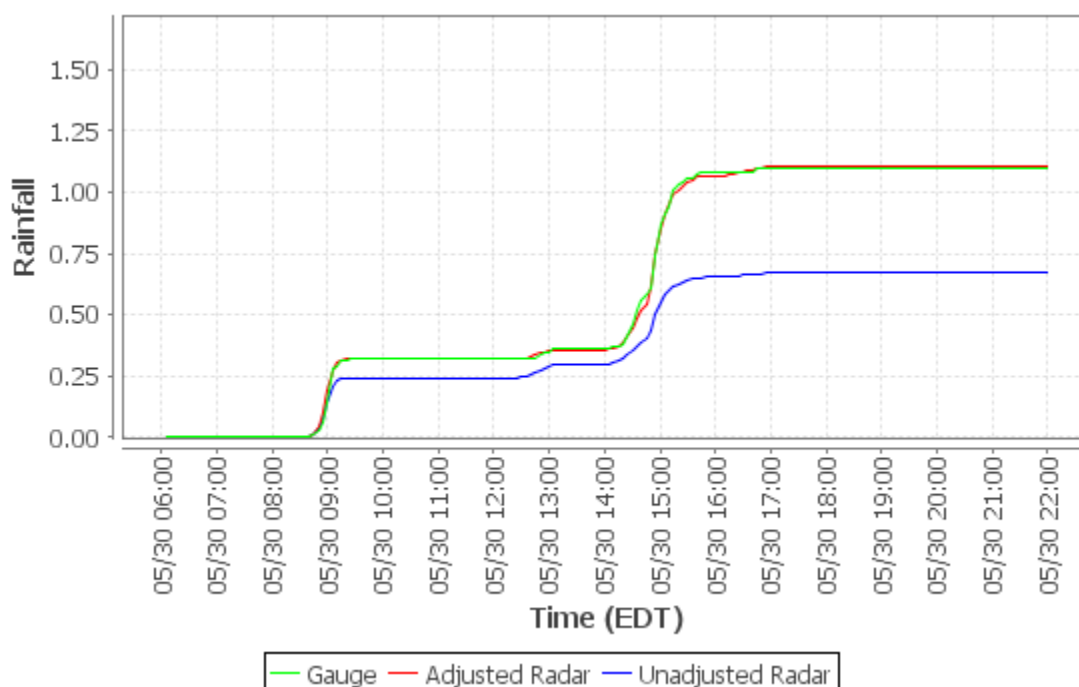
Event #	Source	Event Date	Start Time (EDT)	End Time (EDT)	Gauges Used (37)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
<a href="#">E1</a>	KPBZ LII	2019-05-02	2019-05-02 19:05	2019-05-03 03:00	28	0.211	1.044	10.9	2.6
<a href="#">E2a</a>	KPBZ LII	2019-05-05	2019-05-04 15:05	2019-05-04 22:00	16	0.046	0.981	13.7	3.1
<a href="#">E2b</a>	KPBZ LII	2019-05-05	2019-05-04 22:05	2019-05-05 01:30	27	0.085	1.020	17.7	5.1
<a href="#">E2c</a>	KPBZ LII	2019-05-05	2019-05-05 01:35	2019-05-05 03:00	19	0.060	0.788	29.8	3.7
<a href="#">E2d</a>	Gauge Only	2019-05-05	2019-05-05 03:05	2019-05-05 06:30	31	0.062	---	---	---
<a href="#">E2e</a>	KPBZ LII	2019-05-05	2019-05-05 06:35	2019-05-05 15:00	13	0.068	1.049	22.4	7.4
<a href="#">E3a</a>	KPBZ LII	2019-05-10	2019-05-09 12:05	2019-05-09 23:20	23	0.129	0.855	37.6	3.1
<a href="#">E3b</a>	KPBZ LII	2019-05-10	2019-05-09 23:25	2019-05-10 00:05	23	0.139	1.045	9.3	1.3
<a href="#">E3c</a>	KPBZ LII	2019-05-10	2019-05-10 00:10	2019-05-10 02:30	32	0.139	0.948	16.2	3.0
<a href="#">E3d</a>	KPBZ LII	2019-05-10	2019-05-10 02:35	2019-05-10 11:55	26	0.093	0.992	24.5	6.9
<a href="#">E3e</a>	KPBZ LII	2019-05-10	2019-05-10 12:00	2019-05-10 18:00	6	0.032	0.576	65.3	3.5
<a href="#">E4a</a>	KPBZ LII	2019-05-12	2019-05-11 14:05	2019-05-12 03:00	34	0.255	1.429	31.0	2.1
<a href="#">E4b</a>	KPBZ LII	2019-05-12	2019-05-12 03:05	2019-05-12 04:50	34	0.126	0.593	66.0	2.7
<a href="#">E4c</a>	KPBZ LII	2019-05-12	2019-05-12 04:55	2019-05-12 09:00	18	0.236	4.411	76.8	2.9
<a href="#">E4d</a>	Gauge Only	2019-05-12	2019-05-12 09:05	2019-05-12 17:00	31	0.033	---	---	---
<a href="#">E5a</a>	KPBZ LII	2019-05-17	2019-05-17 14:05	2019-05-18 00:00	30	0.222	1.075	21.3	2.6
<a href="#">E5b</a>	KPBZ LII	2019-05-17	2019-05-18 00:05	2019-05-18 01:05	13	0.048	0.883	17.1	3.9

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	2019-05-17	2019-05-18 01:10	2019-05-18 13:00	16	0.062	1.168	27.5	6.7
<a href="#">E6</a>	KPBZ LII	2019-05-23	2019-05-23 18:05	2019-05-24 02:00	18	0.102	0.748	50.6	6.4
<a href="#">E7</a>	KPBZ LII	2019-05-26	2019-05-26 07:05	2019-05-26 15:00	19	0.117	0.739	41.1	1.4
<a href="#">E8</a>	KPBZ LII	2019-05-28 AM	2019-05-28 00:05	2019-05-28 11:00	24	0.294	1.111	10.9	2.3
<a href="#">E9a</a>	KPBZ LII	2019-05-28 PM	2019-05-28 11:05	2019-05-28 20:10	5	0.161	0.529	85.3	0.8
<a href="#">E9b</a>	KPBZ LII	2019-05-28 PM	2019-05-28 20:15	2019-05-28 21:30	5	0.088	0.670	84.1	2.2
<a href="#">E9c</a>	KPBZ LII	2019-05-28 PM	2019-05-28 21:35	2019-05-29 00:20	20	0.411	0.977	18.1	2.6
<a href="#">E9d</a>	KPBZ LII	2019-05-28 PM	2019-05-29 00:25	2019-05-29 09:00	22	0.400	1.179	19.7	2.9
<a href="#">E10a</a>	KPBZ LII	2019-05-29	2019-05-29 09:05	2019-05-29 15:20	21	0.473	1.018	16.3	2.1
<a href="#">E10b</a>	KPBZ LII	2019-05-29	2019-05-29 15:25	2019-05-29 16:00	9	0.077	0.814	19.4	2.2
<a href="#">E10c</a>	KPBZ LII	2019-05-29	2019-05-29 16:05	2019-05-29 17:25	15	0.070	0.881	31.9	5.0
<a href="#">E10d</a>	KPBZ LII	2019-05-29	2019-05-29 17:30	2019-05-29 21:30	23	0.328	1.111	15.5	2.1
<a href="#">E10e</a>	KPBZ LII	2019-05-29	2019-05-29 21:35	2019-05-30 06:00	5	0.044	1.420	28.0	1.0
<a href="#">E11a</a>	KPBZ LII	2019-05-30	2019-05-30 06:05	2019-05-30 12:00	27	0.199	1.254	19.7	2.7
<a href="#">E11b</a>	KPBZ LII	2019-05-30	2019-05-30 12:05	2019-05-30 14:15	5	0.045	1.111	22.0	1.4
<a href="#">E11c</a>	KPBZ LII	2019-05-30	2019-05-30 14:20	2019-05-30 15:05	9	0.152	1.684	38.8	4.9
<a href="#">E11d</a>	KPBZ LII	2019-05-30	2019-05-30 15:10	2019-05-30 17:00	25	0.120	1.204	24.2	5.7
<a href="#">E11e</a>	KPBZ LII	2019-05-30	2019-05-30 17:05	2019-05-30 22:00	5	0.028	1.245	50.8	1.8

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 - M. CDPs are useful for visualizing rain gauge performance. Figure 3 shows the rainfall accumulation at the Hampton Municipal Bldg (Loc31) gauge during the 2019-05-30 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**

<b>Reason</b>	<b>Explanation</b>
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

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

<b>Reason</b>	<b>Explanation</b>
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: 2019-05-02

The analysis period was from 2019-05-02 19:00 EDT to 2019-05-03 03:00 EDT.

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. Table 6 summarizes 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,  $\text{Diff}^*$  (in) is the difference in inches between the gauge and 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. Figure 4 shows the scatter plot of the RG pairs. Those gauges not used to adjust the radar are shown in red. Figure 5 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 - 0.7 inches with a mean of 0.2 inches. The GARR amounts for the 440 RFM basins range from 0.1 - 0.6 inches with a mean of 0.3 inches. The GARR amounts for the 871 RFM sheds range from 0.1 - 0.8 inches with a mean of 0.3 inches. Table 7 shows the Depth Duration Frequency (DDF) maximum values for the 1-km<sup>2</sup> pixels.

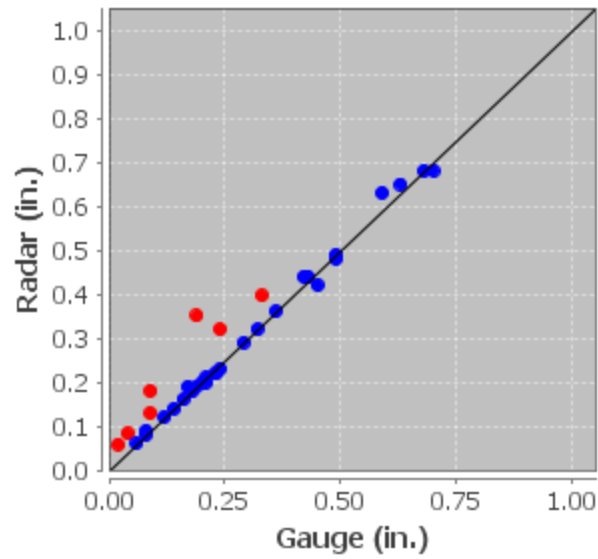
**Table 5. GARR Statistics for Event 1**

Event #	Radar	Event Date	Start Time (EDT)	End Time (EDT)	Gauges Used (37)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E1	KPBZ LII	2019-05-02	2019-05-02 19:05	2019-05-03 03:00	28	0.211	1.044	10.9	2.6

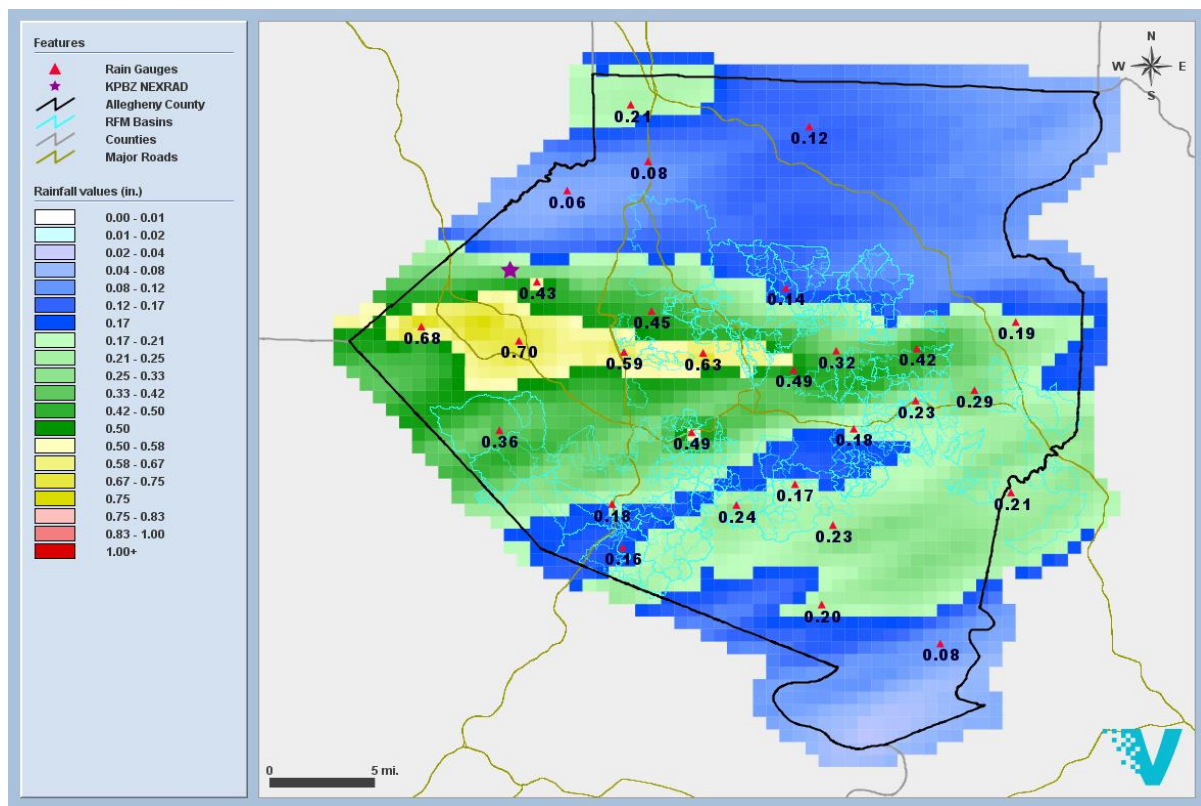
**Table 6. Summary of Individual RG Pairs for Event 1**

Gauge ID	Name	$G_i$ (in)	$R_i$ (in)	$R_i^*$ (in)	$\text{Diff}^*$ (in)	$\text{Diff}^*$ (%)	Flag
<a href="#">Loc30</a>	McCandless Twn Hall	0.08	0.10	0.09	-0.01	-12.5	
<a href="#">Loc12</a>	Baldwin	0.17	0.20	0.19	-0.02	-11.8	
<a href="#">Loc04</a>	Kennedy Twp PS	0.59	0.62	0.63	-0.04	-6.8	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.42	0.44	0.44	-0.02	-4.8	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.63	0.67	0.65	-0.02	-3.2	
<a href="#">Loc21</a>	Moon TWP	0.43	0.43	0.44	-0.01	-2.3	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.14	0.15	0.14	0.00	0.0	
<a href="#">Loc05</a>	Upper St. Clair	0.16	0.15	0.16	0.00	0.0	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.49	0.48	0.49	0.00	0.0	
<a href="#">Loc10</a>	PWSA-Highland Park	0.32	0.31	0.32	0.00	0.0	
<a href="#">Loc11</a>	M-46 Access Shaft	0.18	0.15	0.18	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.21	0.17	0.21	0.00	0.0	
<a href="#">Loc17</a>	Chartiers Pump Station	0.18	0.17	0.18	0.00	0.0	
<a href="#">Loc20</a>	Gascola Eq Facility	0.29	0.27	0.29	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.36	0.34	0.36	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.68	0.72	0.68	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="#">Loc24</a>	Jefferson Hills	0.20	0.21	0.20	0.00	0.0	
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.08	0.07	0.08	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.19	0.19	0.19	0.00	0.0	
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.06	0.06	0.06	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.12	0.14	0.12	0.00	0.0	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.49	0.45	0.48	0.01	2.0	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.70	0.54	0.68	0.02	2.9	
<a href="#">Loc16</a>	Castle Shannon	0.24	0.23	0.23	0.01	4.2	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.23	0.18	0.22	0.01	4.3	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.23	0.20	0.22	0.01	4.3	
<a href="#">Loc27</a>	Marshall TWP	0.21	0.17	0.20	0.01	4.8	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.45	0.35	0.42	0.03	6.7	
<a href="#">03049500</a>	Allegheny River at Natrona	0.02	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	0.33	---	---	---	---	U
<a href="#">Loc06</a>	Carnegie Transit Time	0.24	---	---	---	---	U
<a href="#">Loc09</a>	Univ of Pittsburgh	0.19	---	---	---	---	U
<a href="#">Loc13</a>	M-59 Access Shaft	0.09	---	---	---	---	U
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc25</a>	White Oak Public Works Bldg	ND	---	---	---	---	ND
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.09	---	---	---	---	OAD
<a href="#">Loc32</a>	Arnold	0.04	---	---	---	---	MSTT



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



**Figure 5. GARR Storm Total for Event 1**

**Table 7. Depth Duration Frequency Analyses for Event 1**

<b>Duration</b>	<b>Depth (in)</b>	<b>Pixel</b>	<b>Time (EDT)</b>	<b>Frequency</b>
15 minutes	0.514	121132	2019-05-02 20:45	<1 yr.
30 minutes	0.640	126132	2019-05-02 21:00	<1 yr.
1 hour	0.711	126132	2019-05-02 21:25	<1 yr.
2 hour	0.746	126132	2019-05-02 21:50	<1 yr.
3 hour	0.746	126132	2019-05-02 22:00	<1 yr.
6 hour	0.746	126132	2019-05-03 01:00	<1 yr.

## **Event 2: 2019-05-05**

The analysis period was from 2019-05-04 15:00 EDT to 2019-05-05 15:00 EDT. The event was then split into five sub-event periods at 2019-05-04 22:00 EDT, 2019-05-05 01:30 EDT, 2019-05-05 03:00 EDT and 2019-05-05 06:30 EDT to improve gauge adjustment of the radar. Gauge Only was used during Event 2d since all radar sources were either unavailable or provided insufficient rainfall information.

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 8 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Tables 9 - 13 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 6 - 9 show the scatter plots of the gauge-adjusted RG pairs. Those gauges not used to adjust the radar are shown in red. Figure 10 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 - 0.6 inches with a mean of 0.3 inches. The GARR amounts for the 440 RFM basins range from 0.1 - 0.6 inches with a mean of 0.4 inches. The GARR amounts for the 871 RFM sheds range from 0.1 - 0.6 inches with a mean of 0.4 inches. Table 14 shows the Depth Duration Frequency (DDF) maximum values for the 1-km<sup>2</sup> pixels.

**Table 8. 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	2019-05-05	2019-05-04 15:05	2019-05-04 22:00	16	0.046	0.981	13.7	3.1
E2b	KPBZ LII	2019-05-05	2019-05-04 22:05	2019-05-05 01:30	27	0.085	1.020	17.7	5.1
E2c	KPBZ LII	2019-05-05	2019-05-05 01:35	2019-05-05 03:00	19	0.060	0.788	29.8	3.7
E2d	Gauge Only	2019-05-05	2019-05-05 03:05	2019-05-05 06:30	31	0.062	---	---	---
E2e	KPBZ LII	2019-05-05	2019-05-05 06:35	2019-05-05 15:00	13	0.068	1.049	22.4	7.4

**Table 9. Summary of Individual RG Pairs for Event 2a**

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	0.06	0.08	0.07	-0.01	-16.7	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.06	0.09	0.07	-0.01	-16.7	
<a href="#">Loc01</a>	PWSA-Montana St.	0.10	0.09	0.10	0.00	0.0	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.11	0.10	0.11	0.00	0.0	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.07	0.06	0.07	0.00	0.0	
<a href="#">Loc04</a>	Kennedy Twp PS	0.06	0.06	0.06	0.00	0.0	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.07	0.06	0.07	0.00	0.0	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.07	0.08	0.07	0.00	0.0	
<a href="#">Loc11</a>	M-46 Access Shaft	0.06	0.08	0.06	0.00	0.0	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.07	0.07	0.07	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.09	0.09	0.09	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.08	0.07	0.08	0.00	0.0	
<a href="#">Loc27</a>	Marshall TWP	0.14	0.13	0.14	0.00	0.0	
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.15	0.14	0.15	0.00	0.0	
<a href="#">Loc30</a>	McCandless Twn Hall	0.10	0.12	0.10	0.00	0.0	
<a href="#">Loc10</a>	PWSA-Highland Park	0.08	0.07	0.07	0.01	12.5	
<a href="#">03049500</a>	Allegheny River at Natrona	0.04	---	---	---	---	MSTT
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.03	---	---	---	---	MSTT
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.02	---	---	---	---	MSTT
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.05	---	---	---	---	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="#">Loc05</a>	Upper St. Clair	0.04	---	---	---	---	MSTT
<a href="#">Loc06</a>	Carnegie Transit Time	0.04	---	---	---	---	MSTT
<a href="#">Loc12</a>	Baldwin	0.05	---	---	---	---	MSTT
<a href="#">Loc13</a>	M-59 Access Shaft	0.02	---	---	---	---	MSTT
<a href="#">Loc15</a>	Trafford Maint Bldg	0.02	---	---	---	---	MSTT
<a href="#">Loc16</a>	Castle Shannon	0.06	---	---	---	---	MSTT
<a href="#">Loc17</a>	Chartiers Pump Station	0.06	---	---	---	---	MSTT
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc20</a>	Gascola Eq Facility	0.04	---	---	---	---	MSTT
<a href="#">Loc21</a>	Moon TWP	0.07	---	---	---	---	MSTT
<a href="#">Loc24</a>	Jefferson Hills	0.02	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	ND	---	---	---	---	ND
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.01	---	---	---	---	MSTT
<a href="#">Loc28</a>	Plum Municipal Bldg	0.03	---	---	---	---	MSTT
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.06	---	---	---	---	MSTT
<a href="#">Loc32</a>	Arnold	0.03	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	0.08	---	---	---	---	MSTT

**Table 10. 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="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.06	0.06	0.07	-0.01	-16.7	
<a href="#">Loc01</a>	PWSA-Montana St.	0.12	0.13	0.14	-0.02	-16.7	
<a href="#">Loc13</a>	M-59 Access Shaft	0.10	0.14	0.11	-0.01	-10.0	
<a href="#">Loc05</a>	Upper St. Clair	0.21	0.22	0.23	-0.02	-9.5	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.13	0.16	0.14	-0.01	-7.7	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.14	0.16	0.15	-0.01	-7.1	
<a href="#">03049500</a>	Allegheny River at Natrona	0.11	0.11	0.11	0.00	0.0	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.14	0.20	0.14	0.00	0.0	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.09	0.05	0.09	0.00	0.0	
<a href="#">Loc06</a>	Carnegie Transit Time	0.13	0.11	0.13	0.00	0.0	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.14	0.14	0.14	0.00	0.0	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.13	0.12	0.13	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.17	0.18	0.17	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="#">Loc20</a>	Gascola Eq Facility	0.08	0.08	0.08	0.00	0.0	
<a href="#">Loc24</a>	Jefferson Hills	0.12	0.16	0.12	0.00	0.0	
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.05	0.06	0.05	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.13	0.12	0.13	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.13	0.09	0.13	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.06	0.06	0.06	0.00	0.0	
<a href="#">Loc12</a>	Baldwin	0.17	0.18	0.16	0.01	5.9	
<a href="#">Loc10</a>	PWSA-Highland Park	0.15	0.12	0.14	0.01	6.7	
<a href="#">Loc11</a>	M-46 Access Shaft	0.15	0.15	0.14	0.01	6.7	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.13	0.11	0.12	0.01	7.7	
<a href="#">Loc17</a>	Chartiers Pump Station	0.13	0.09	0.12	0.01	7.7	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.12	0.11	0.11	0.01	8.3	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.11	0.07	0.10	0.01	9.1	
<a href="#">Loc04</a>	Kennedy Twp PS	0.10	0.06	0.09	0.01	10.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.06	---	---	---	---	MSTT
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc21</a>	Moon TWP	0.08	---	---	---	---	MSTT
<a href="#">Loc22</a>	North Fayette TWP	0.09	---	---	---	---	MSTT
<a href="#">Loc23</a>	Clinton Munic Bldg	0.08	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	ND	---	---	---	---	ND
<a href="#">Loc27</a>	Marshall TWP	0.04	---	---	---	---	MSTT
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.04	---	---	---	---	MSTT
<a href="#">Loc30</a>	McCandless Twn Hall	0.04	---	---	---	---	MSTT
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.12	---	---	---	---	OMFB

**Table 11. Summary of Individual RG Pairs for Event 2c**

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	0.08	0.12	0.09	-0.01	-12.5	
<a href="#">Loc11</a>	M-46 Access Shaft	0.13	0.20	0.14	-0.01	-7.7	
<a href="#">Loc06</a>	Carnegie Transit Time	0.17	0.22	0.18	-0.01	-5.9	
<a href="#">03049500</a>	Allegheny River at Natrona	0.11	0.11	0.11	0.00	0.0	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.12	0.13	0.12	0.00	0.0	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.17	0.22	0.17	0.00	0.0	
<a href="#">Loc12</a>	Baldwin	0.11	0.11	0.11	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="#">Loc14</a>	Churchill Munic Bldg	0.20	0.28	0.20	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.08	0.12	0.08	0.00	0.0	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.12	0.17	0.12	0.00	0.0	
<a href="#">Loc20</a>	Gascola Eq Facility	0.12	0.19	0.12	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.08	0.07	0.08	0.00	0.0	
<a href="#">Loc24</a>	Jefferson Hills	0.12	0.13	0.12	0.00	0.0	
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.09	0.13	0.09	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.13	0.20	0.13	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.10	0.14	0.10	0.00	0.0	
<a href="#">Loc10</a>	PWSA-Highland Park	0.13	0.13	0.12	0.01	7.7	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.12	0.15	0.11	0.01	8.3	
<a href="#">Loc17</a>	Chartiers Pump Station	0.10	0.09	0.09	0.01	10.0	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.04	---	---	---	---	MSTT
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.04	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	0.06	---	---	---	---	MSTT
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.05	---	---	---	---	MSTT
<a href="#">Loc03</a>	Shaler Munic Bldg	0.05	---	---	---	---	MSTT
<a href="#">Loc04</a>	Kennedy Twp PS	0.05	---	---	---	---	MSTT
<a href="#">Loc05</a>	Upper St. Clair	0.06	---	---	---	---	MSTT
<a href="#">Loc13</a>	M-59 Access Shaft	0.06	---	---	---	---	OAD
<a href="#">Loc16</a>	Castle Shannon	0.06	---	---	---	---	MSTT
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc21</a>	Moon TWP	0.03	---	---	---	---	MSTT
<a href="#">Loc23</a>	Clinton Munic Bldg	0.05	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	ND	---	---	---	---	ND
<a href="#">Loc27</a>	Marshall TWP	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	0.05	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	0.02	---	---	---	---	MSTT

**Table 12. Summary of Individual RG Pairs for Event 2d**

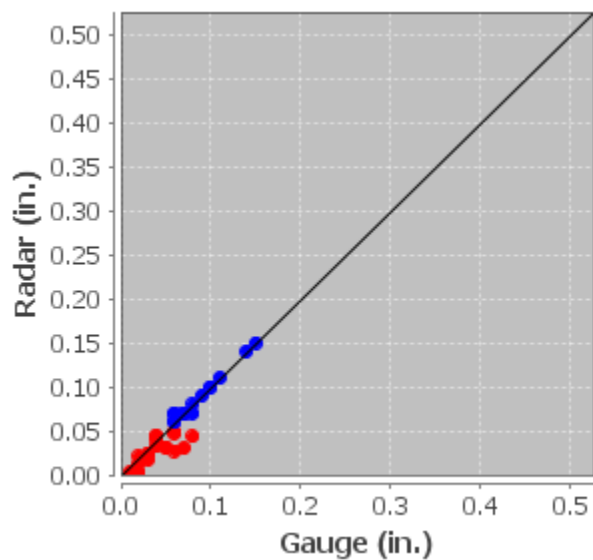
<b>Gauge ID</b>	<b>Name</b>	<b>G<sub>i</sub> (in)</b>	<b>R<sub>i</sub> (in)</b>	<b>R<sub>i</sub>* (in)</b>	<b>Diff* (in)</b>	<b>Diff* (%)</b>	<b>Flag</b>
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.00	---	---	---	---	
<a href="#">Loc01</a>	PWSA-Montana St.	0.01	---	---	---	---	
<a href="#">Loc04</a>	Kennedy Twp PS	0.01	---	---	---	---	
<a href="#">Loc21</a>	Moon TWP	0.01	---	---	---	---	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.01	---	---	---	---	
<a href="#">Loc30</a>	McCandless Twn Hall	0.01	---	---	---	---	
<a href="#">Loc33</a>	Richland TWP	0.01	---	---	---	---	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.02	---	---	---	---	
<a href="#">Loc05</a>	Upper St. Clair	0.02	---	---	---	---	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.02	---	---	---	---	
<a href="#">Loc12</a>	Baldwin	0.02	---	---	---	---	
<a href="#">Loc13</a>	M-59 Access Shaft	0.02	---	---	---	---	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.02	---	---	---	---	
<a href="#">Loc22</a>	North Fayette TWP	0.02	---	---	---	---	
<a href="#">Loc24</a>	Jefferson Hills	0.02	---	---	---	---	
<a href="#">Loc27</a>	Marshall TWP	0.02	---	---	---	---	
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.02	---	---	---	---	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.03	---	---	---	---	
<a href="#">Loc06</a>	Carnegie Transit Time	0.03	---	---	---	---	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.03	---	---	---	---	
<a href="#">Loc17</a>	Chartiers Pump Station	0.03	---	---	---	---	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.03	---	---	---	---	
<a href="#">Loc20</a>	Gascola Eq Facility	0.03	---	---	---	---	
<a href="#">Loc32</a>	Arnold	0.03	---	---	---	---	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.04	---	---	---	---	
<a href="#">Loc10</a>	PWSA-Highland Park	0.04	---	---	---	---	
<a href="#">Loc16</a>	Castle Shannon	0.04	---	---	---	---	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.05	---	---	---	---	
<a href="#">Loc11</a>	M-46 Access Shaft	0.05	---	---	---	---	
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.05	---	---	---	---	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.05	---	---	---	---	
<a href="#">03049500</a>	Allegheny River at Natrona	0.02	---	---	---	---	T
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.02	---	---	---	---	T
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.02	---	---	---	---	T
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.01	---	---	---	---	T

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	ND	---	---	---	---	ND
<a href="#">Loc25</a>	White Oak Public Works Bldg	ND	---	---	---	---	ND

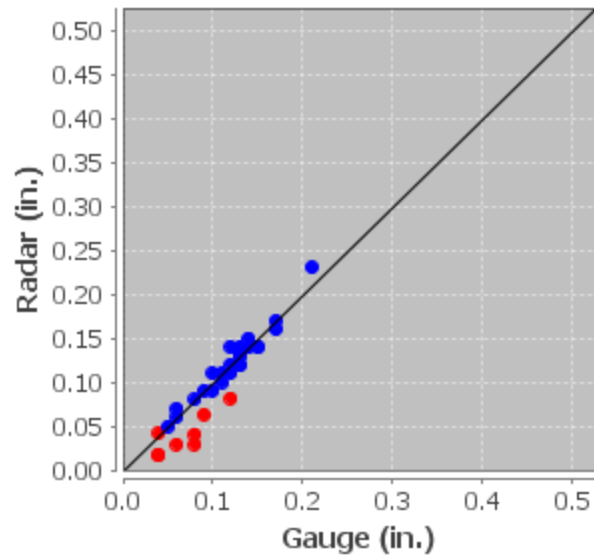
**Table 13. Summary of Individual RG Pairs for Event 2e**

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	0.17	0.15	0.20	-0.03	-17.6	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.06	0.08	0.07	-0.01	-16.7	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.07	0.07	0.08	-0.01	-14.3	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.09	0.10	0.09	0.00	0.0	
<a href="#">Loc10</a>	PWSA-Highland Park	0.14	0.12	0.14	0.00	0.0	
<a href="#">Loc11</a>	M-46 Access Shaft	0.08	0.06	0.08	0.00	0.0	
<a href="#">Loc12</a>	Baldwin	0.05	0.06	0.05	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.20	0.23	0.20	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.06	0.07	0.06	0.00	0.0	
<a href="#">Loc20</a>	Gascola Eq Facility	0.07	0.05	0.07	0.00	0.0	
<a href="#">Loc24</a>	Jefferson Hills	0.11	0.17	0.11	0.00	0.0	
<a href="#">Loc01</a>	PWSA-Montana St.	0.19	0.12	0.17	0.02	10.5	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.15	0.09	0.13	0.02	13.3	
<a href="#">03049500</a>	Allegheny River at Natrona	0.05	---	---	---	---	MSTT
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.06	---	---	---	---	MSTT
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.00	---	---	---	---	MSTT
<a href="#">Loc03</a>	Shaler Munic Bldg	0.06	---	---	---	---	MSTT
<a href="#">Loc04</a>	Kennedy Twp PS	0.05	---	---	---	---	MSTT
<a href="#">Loc05</a>	Upper St. Clair	0.04	---	---	---	---	MSTT
<a href="#">Loc06</a>	Carnegie Transit Time	0.03	---	---	---	---	MSTT
<a href="#">Loc07</a>	Greentree Munic Bldg	0.06	---	---	---	---	MSTT
<a href="#">Loc13</a>	M-59 Access Shaft	0.04	---	---	---	---	MSTT
<a href="#">Loc17</a>	Chartiers Pump Station	0.03	---	---	---	---	MSTT
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.04	---	---	---	---	MSTT
<a href="#">Loc21</a>	Moon TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc22</a>	North Fayette TWP	0.04	---	---	---	---	MSTT
<a href="#">Loc23</a>	Clinton Munic Bldg	0.01	---	---	---	---	MSTT

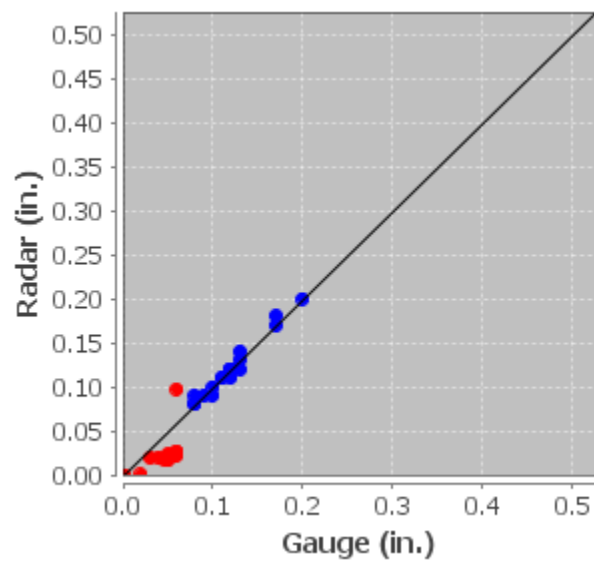
Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc25</a>	White Oak Public Works Bldg	ND	---	---	---	---	ND
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.21	---	---	---	---	OAD
<a href="#">Loc27</a>	Marshall TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc28</a>	Plum Municipal Bldg	0.05	---	---	---	---	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	0.09	---	---	---	---	MSTT
<a href="#">Loc32</a>	Arnold	0.04	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	0.03	---	---	---	---	MSTT



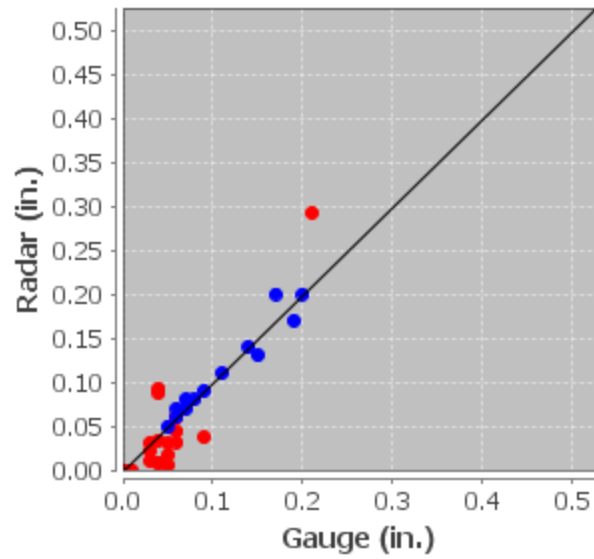
**Figure 6. Scatter Plot of RG Pairs for Event 2a**



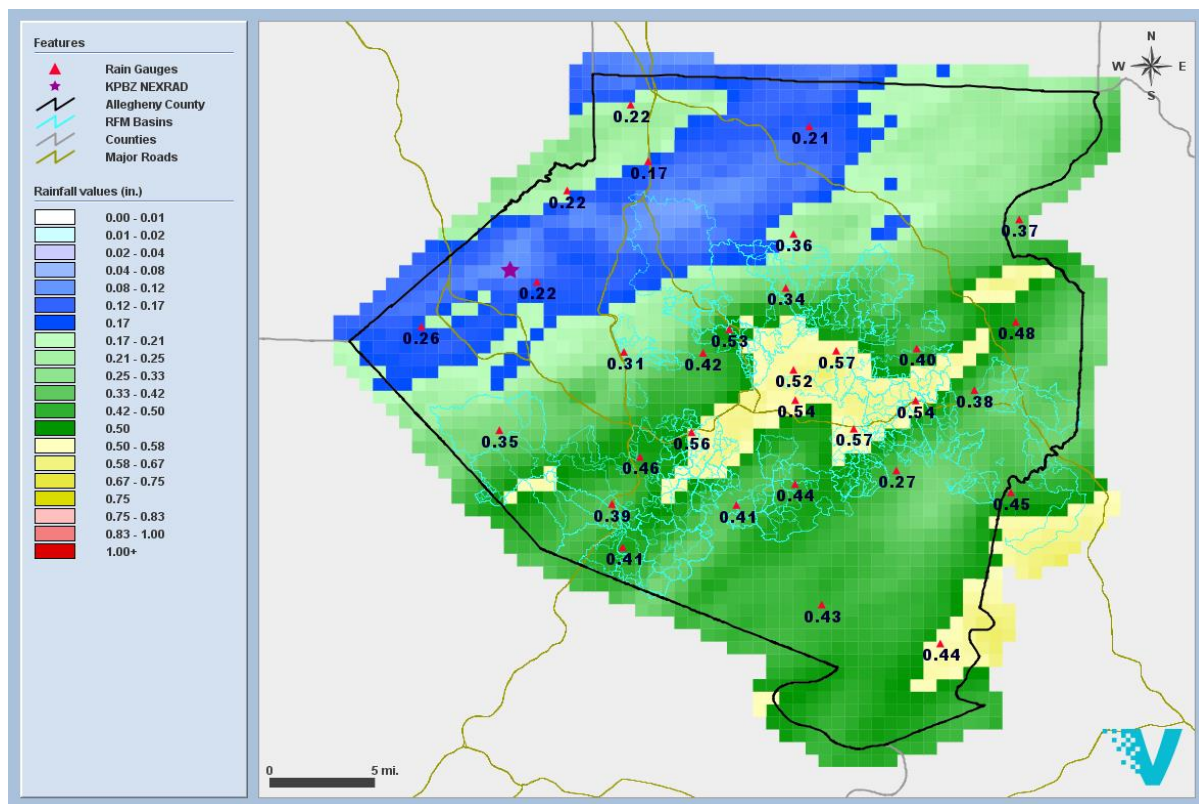
**Figure 7. Scatter Plot of RG Pairs for Event 2b**



**Figure 8. Scatter Plot of RG Pairs for Event 2c**



**Figure 9. Scatter Plot of RG Pairs for Event 2e**



**Figure 10. GARR Storm Total for Event 2**

**Table 14. Depth Duration Frequency Analyses for Event 2**

<b>Duration</b>	<b>Depth (in)</b>	<b>Pixel</b>	<b>Time (EDT)</b>	<b>Frequency</b>
15 minutes	0.097	149135	2019-05-05 11:15	<1 yr.
30 minutes	0.164	161130	2019-05-05 02:45	<1 yr.
1 hour	0.274	165129	2019-05-05 03:20	<1 yr.
2 hour	0.351	165129	2019-05-05 03:50	<1 yr.
3 hour	0.430	165129	2019-05-05 03:25	<1 yr.
6 hour	0.526	165129	2019-05-05 05:00	<1 yr.
12 hour	0.597	165157	2019-05-05 13:15	<1 yr.
24 hour	0.630	170151	2019-05-05 15:00	<1 yr.

**Event 3: 2019-05-10**

The analysis period was from 2019-05-09 12:00 EDT to 2019-05-10 18:00 EDT. The event was then split into five sub-event periods at 2019-05-09 23:20 EDT, 2019-05-10 00:05 EDT, 2019-05-10 02:30 EDT and 2019-05-10 11:55 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 15 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Tables 16 - 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 11 - 15 show the scatter plots of the gauge-adjusted RG pairs. Those gauges not used to adjust the radar are shown in red. Figure 16 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 0.3 - 1.2 inches with a mean of 0.5 inches. The GARR amounts for the 440 RFM basins range from 0.3 - 0.9 inches with a mean of 0.5 inches. The GARR amounts for the 871 RFM sheds range from 0.3 - 0.9 inches with a mean of 0.5 inches. Table 21 shows the Depth Duration Frequency (DDF) maximum values for the 1-km<sup>2</sup> pixels.

**Table 15. 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	2019-05-10	2019-05-09 12:05	2019-05-09 23:20	23	0.129	0.855	37.6	3.1
E3b	KPBZ LII	2019-05-10	2019-05-09 23:25	2019-05-10 00:05	23	0.139	1.045	9.3	1.3
E3c	KPBZ LII	2019-05-10	2019-05-10 00:10	2019-05-10 02:30	32	0.139	0.948	16.2	3.0
E3d	KPBZ LII	2019-05-10	2019-05-10 02:35	2019-05-10 11:55	26	0.093	0.992	24.5	6.9
E3e	KPBZ LII	2019-05-10	2019-05-10 12:00	2019-05-10 18:00	6	0.032	0.576	65.3	3.5

**Table 16. 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	0.13	0.23	0.15	-0.02	-15.4	
<a href="#">Loc06</a>	Carnegie Transit Time	0.11	0.13	0.12	-0.01	-9.1	
<a href="#">Loc20</a>	Gascola Eq Facility	0.11	0.14	0.12	-0.01	-9.1	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.22	0.29	0.23	-0.01	-4.5	
<a href="#">03049500</a>	Allegheny River at Natrona	0.07	0.17	0.07	0.00	0.0	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.14	0.16	0.14	0.00	0.0	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.05	0.13	0.05	0.00	0.0	
<a href="#">Loc04</a>	Kennedy Twp PS	0.05	0.10	0.05	0.00	0.0	
<a href="#">Loc05</a>	Upper St. Clair	0.18	0.17	0.18	0.00	0.0	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.18	0.21	0.18	0.00	0.0	
<a href="#">Loc10</a>	PWSA-Highland Park	0.12	0.13	0.12	0.00	0.0	
<a href="#">Loc13</a>	M-59 Access Shaft	0.17	0.14	0.17	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.27	0.32	0.27	0.00	0.0	
<a href="#">Loc17</a>	Chartiers Pump Station	0.16	0.16	0.16	0.00	0.0	
<a href="#">Loc24</a>	Jefferson Hills	0.22	0.26	0.22	0.00	0.0	
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.16	0.12	0.16	0.00	0.0	
<a href="#">Loc27</a>	Marshall TWP	0.11	0.10	0.11	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.16	0.13	0.16	0.00	0.0	
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.13	0.19	0.13	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.09	0.17	0.09	0.00	0.0	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.20	0.18	0.19	0.01	5.0	



Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.18	0.18	0.17	0.01	5.6	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.32	0.33	0.30	0.02	6.3	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.03	---	---	---	---	MSTT
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.04	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	0.03	---	---	---	---	MSTT
<a href="#">Loc08</a>	AC Health Dept Bldg	0.23	---	---	---	---	O
<a href="#">Loc11</a>	M-46 Access Shaft	0.14	---	---	---	---	S
<a href="#">Loc12</a>	Baldwin	0.33	---	---	---	---	O
<a href="#">Loc15</a>	Trafford Maint Bldg	0.02	---	---	---	---	MSTT
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc21</a>	Moon TWP	0.02	---	---	---	---	MSTT
<a href="#">Loc22</a>	North Fayette TWP	0.03	---	---	---	---	MSTT
<a href="#">Loc23</a>	Clinton Munic Bldg	0.03	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	ND	---	---	---	---	ND
<a href="#">Loc30</a>	McCandless Twn Hall	0.01	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	0.03	---	---	---	---	MSTT

**Table 17. 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="#">Loc20</a>	Gascola Eq Facility	0.17	0.19	0.18	-0.01	-5.9	
<a href="#">Loc11</a>	M-46 Access Shaft	0.21	0.22	0.22	-0.01	-4.8	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.24	0.24	0.25	-0.01	-4.2	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.27	0.28	0.28	-0.01	-3.7	
<a href="#">03049500</a>	Allegheny River at Natrona	0.28	0.25	0.28	0.00	0.0	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.17	0.16	0.17	0.00	0.0	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.08	0.08	0.08	0.00	0.0	
<a href="#">Loc04</a>	Kennedy Twp PS	0.06	0.08	0.06	0.00	0.0	
<a href="#">Loc05</a>	Upper St. Clair	0.05	0.05	0.05	0.00	0.0	
<a href="#">Loc06</a>	Carnegie Transit Time	0.11	0.10	0.11	0.00	0.0	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.08	0.07	0.08	0.00	0.0	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.20	0.19	0.20	0.00	0.0	
<a href="#">Loc10</a>	PWSA-Highland Park	0.29	0.28	0.29	0.00	0.0	
<a href="#">Loc13</a>	M-59 Access Shaft	0.20	0.19	0.20	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="#">Loc15</a>	Trafford Maint Bldg	0.20	0.21	0.20	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.15	0.13	0.15	0.00	0.0	
<a href="#">Loc17</a>	Chartiers Pump Station	0.08	0.08	0.08	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.15	0.13	0.15	0.00	0.0	
<a href="#">Loc24</a>	Jefferson Hills	0.14	0.11	0.14	0.00	0.0	
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.26	0.30	0.26	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.30	0.23	0.30	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.33	0.30	0.33	0.00	0.0	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.30	0.27	0.28	0.02	6.7	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.04	---	---	---	---	MSTT
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.03	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	0.03	---	---	---	---	MSTT
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.03	---	---	---	---	MSTT
<a href="#">Loc12</a>	Baldwin	0.04	---	---	---	---	S
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc21</a>	Moon TWP	0.04	---	---	---	---	MSTT
<a href="#">Loc23</a>	Clinton Munic Bldg	0.03	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	ND	---	---	---	---	ND
<a href="#">Loc27</a>	Marshall TWP	0.03	---	---	---	---	MSTT
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.01	---	---	---	---	MSTT
<a href="#">Loc30</a>	McCandless Twn Hall	0.03	---	---	---	---	MSTT
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.04	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	0.04	---	---	---	---	MSTT

**Table 18. 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="#">Loc07</a>	Greentree Munic Bldg	0.08	0.08	0.09	-0.01	-12.5	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.10	0.11	0.11	-0.01	-10.0	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.14	0.16	0.15	-0.01	-7.1	
<a href="#">Loc21</a>	Moon TWP	0.14	0.19	0.15	-0.01	-7.1	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.15	0.22	0.16	-0.01	-6.7	
<a href="#">Loc30</a>	McCandless Twn Hall	0.15	0.21	0.16	-0.01	-6.7	

<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="#">Loc01</a>	PWSA-Montana St.	0.17	0.22	0.18	-0.01	-5.9	
<a href="#">03049500</a>	Allegheny River at Natrona	0.31	0.32	0.31	0.00	0.0	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.17	0.21	0.17	0.00	0.0	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.11	0.11	0.11	0.00	0.0	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.09	0.09	0.09	0.00	0.0	
<a href="#">Loc11</a>	M-46 Access Shaft	0.11	0.10	0.11	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.11	0.07	0.11	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.06	0.06	0.06	0.00	0.0	
<a href="#">Loc20</a>	Gascola Eq Facility	0.15	0.17	0.15	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.11	0.11	0.11	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.14	0.16	0.14	0.00	0.0	
<a href="#">Loc24</a>	Jefferson Hills	0.11	0.09	0.11	0.00	0.0	
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.09	0.06	0.09	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.26	0.24	0.26	0.00	0.0	
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.15	0.18	0.15	0.00	0.0	
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.17	0.21	0.17	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.26	0.23	0.26	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.17	0.18	0.17	0.00	0.0	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.20	0.24	0.19	0.01	5.0	
<a href="#">Loc04</a>	Kennedy Twp PS	0.20	0.22	0.19	0.01	5.0	
<a href="#">Loc27</a>	Marshall TWP	0.19	0.19	0.18	0.01	5.3	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.17	0.16	0.16	0.01	5.9	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.15	0.14	0.14	0.01	6.7	
<a href="#">Loc10</a>	PWSA-Highland Park	0.13	0.12	0.12	0.01	7.7	
<a href="#">Loc06</a>	Carnegie Transit Time	0.12	0.08	0.11	0.01	8.3	
<a href="#">Loc12</a>	Baldwin	0.10	0.08	0.09	0.01	10.0	
<a href="#">Loc05</a>	Upper St. Clair	0.05	---	---	---	---	MSTT
<a href="#">Loc13</a>	M-59 Access Shaft	0.01	---	---	---	---	S
<a href="#">Loc17</a>	Chartiers Pump Station	0.06	---	---	---	---	MSTT
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc25</a>	White Oak Public Works Bldg	ND	---	---	---	---	ND

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

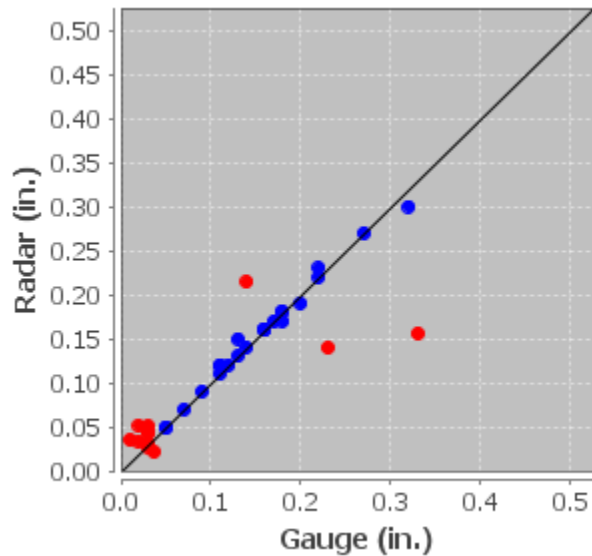
<b>Gauge ID</b>	<b>Name</b>	<b>G<sub>i</sub> (in)</b>	<b>R<sub>i</sub> (in)</b>	<b>R<sub>i</sub>* (in)</b>	<b>Diff* (in)</b>	<b>Diff* (%)</b>	<b>Flag</b>
<a href="#">Loc08</a>	AC Health Dept Bldg	0.06	0.11	0.08	-0.02	-33.3	
<a href="#">Loc11</a>	M-46 Access Shaft	0.05	0.10	0.06	-0.01	-20.0	
<a href="#">Loc17</a>	Chartiers Pump Station	0.06	0.11	0.07	-0.01	-16.7	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.09	0.09	0.10	-0.01	-11.1	
<a href="#">Loc01</a>	PWSA-Montana St.	0.09	0.09	0.10	-0.01	-11.1	
<a href="#">Loc12</a>	Baldwin	0.09	0.12	0.10	-0.01	-11.1	
<a href="#">Loc30</a>	McCandless Twn Hall	0.16	0.15	0.17	-0.01	-6.3	
<a href="#">03049500</a>	Allegheny River at Natrona	0.06	0.06	0.06	0.00	0.0	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.08	0.10	0.08	0.00	0.0	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.10	0.08	0.10	0.00	0.0	
<a href="#">Loc04</a>	Kennedy Twp PS	0.09	0.07	0.09	0.00	0.0	
<a href="#">Loc06</a>	Carnegie Transit Time	0.05	0.05	0.05	0.00	0.0	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.06	0.06	0.06	0.00	0.0	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.07	0.09	0.07	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.16	0.16	0.16	0.00	0.0	
<a href="#">Loc21</a>	Moon TWP	0.11	0.12	0.11	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.07	0.06	0.07	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.13	0.13	0.13	0.00	0.0	
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.18	0.16	0.18	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.14	0.13	0.14	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.25	0.20	0.24	0.01	4.0	
<a href="#">Loc27</a>	Marshall TWP	0.22	0.13	0.21	0.01	4.5	
<a href="#">Loc05</a>	Upper St. Clair	0.16	0.20	0.15	0.01	6.3	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.12	0.08	0.11	0.01	8.3	
<a href="#">Loc10</a>	PWSA-Highland Park	0.08	0.07	0.07	0.01	12.5	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.05	0.06	0.04	0.01	20.0	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.09	---	---	---	---	OAD
<a href="#">Loc13</a>	M-59 Access Shaft	0.00	---	---	---	---	Z
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.05	---	---	---	---	MSTT
<a href="#">Loc20</a>	Gascola Eq Facility	0.05	---	---	---	---	MSTT
<a href="#">Loc24</a>	Jefferson Hills	0.02	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	ND	---	---	---	---	ND
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.02	---	---	---	---	MSTT
<a href="#">Loc28</a>	Plum Municipal Bldg	0.04	---	---	---	---	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="#">Loc31</a>	Hampton Municipal Bldg	0.18	---	---	---	---	O
<a href="#">Loc32</a>	Arnold	0.07	---	---	---	---	MSTT

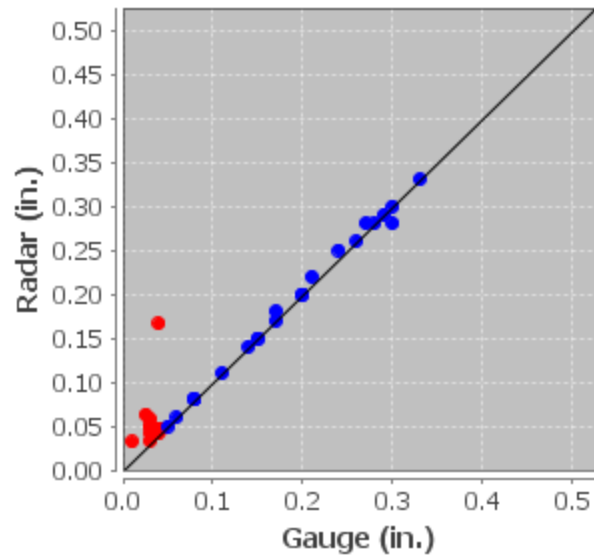
**Table 20. Summary of Individual RG Pairs for Event 3e**

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	0.17	0.40	0.19	-0.02	-11.8	
<a href="#">Loc04</a>	Kennedy Twp PS	0.08	0.08	0.08	0.00	0.0	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.05	0.05	0.05	0.00	0.0	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.14	0.44	0.14	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.06	0.05	0.06	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.34	0.44	0.34	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	0.01	---	---	---	---	MSTT
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.00	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	0.02	---	---	---	---	MSTT
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.02	---	---	---	---	MSTT
<a href="#">Loc03</a>	Shaler Munic Bldg	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="#">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	0.00	---	---	---	---	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	0.01	---	---	---	---	MSTT
<a href="#">Loc17</a>	Chartiers Pump Station	0.00	---	---	---	---	MSTT
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc20</a>	Gascola Eq Facility	0.01	---	---	---	---	MSTT
<a href="#">Loc21</a>	Moon TWP	0.02	---	---	---	---	MSTT
<a href="#">Loc22</a>	North Fayette TWP	0.02	---	---	---	---	MSTT

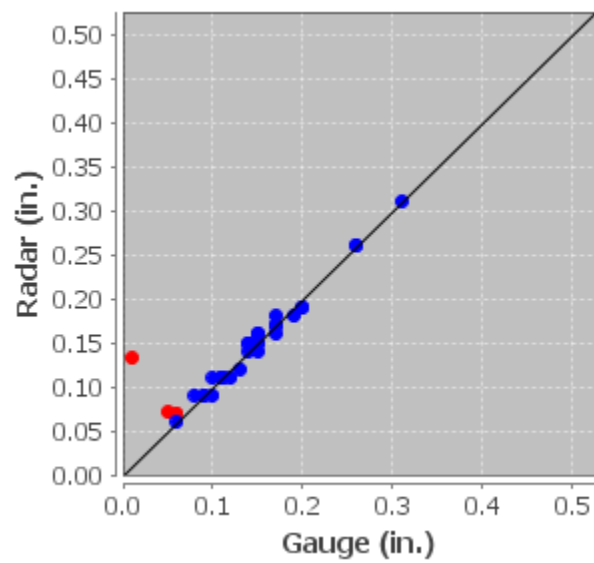
Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc24</a>	Jefferson Hills	0.01	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	ND	---	---	---	---	ND
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc27</a>	Marshall TWP	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	0.01	---	---	---	---	MSTT
<a href="#">Loc32</a>	Arnold	0.00	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	0.00	---	---	---	---	MSTT



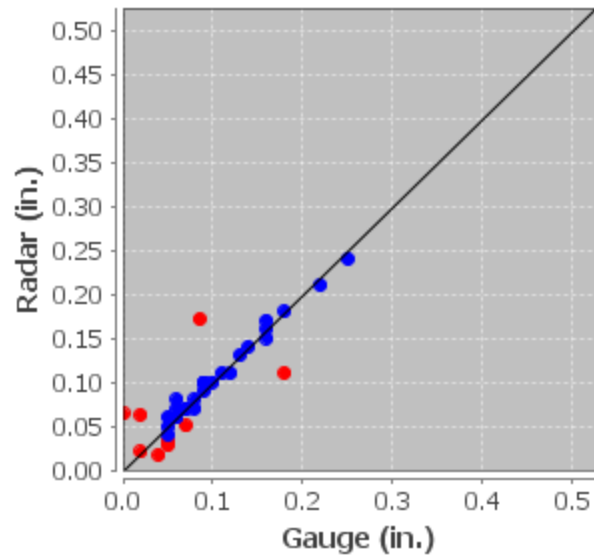
**Figure 11. Scatter Plot of RG Pairs for Event 3a**



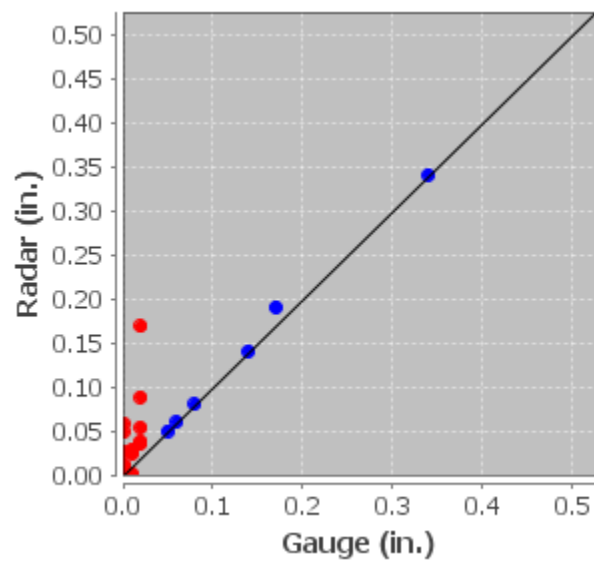
**Figure 12. Scatter Plot of RG Pairs for Event 3b**



**Figure 13. Scatter Plot of RG Pairs for Event 3c**

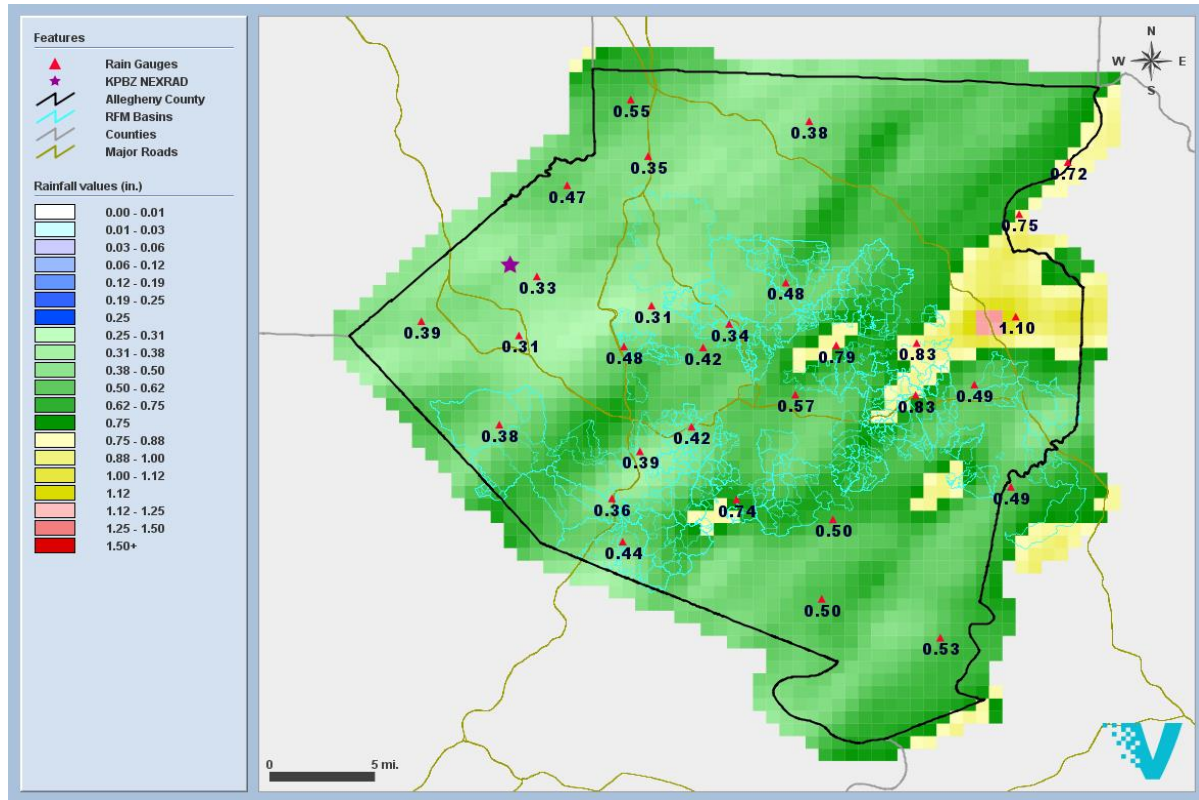


**Figure 14. Scatter Plot of RG Pairs for Event 3d**



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





**Figure 16. GARR Storm Total for Event 3**

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

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	0.353	165132	2019-05-10 13:00	<1 yr.
30 minutes	0.386	165132	2019-05-10 13:10	<1 yr.
1 hour	0.480	165162	2019-05-10 00:30	<1 yr.
2 hour	0.656	165130	2019-05-10 01:15	<1 yr.
3 hour	0.669	165130	2019-05-10 02:10	<1 yr.
6 hour	0.711	165130	2019-05-10 02:10	<1 yr.
12 hour	0.843	170150	2019-05-10 01:50	<1 yr.
24 hour	1.189	165132	2019-05-10 13:10	<1 yr.

## Event 4: 2019-05-12

The analysis period was from 2019-05-11 14:00 EDT to 2019-05-12 17:00 EDT. The event was then split into four sub-event periods at 2019-05-12 03:00 EDT, 2019-05-12 04:50 EDT and 2019-05-12 09:00 EDT to improve gauge adjustment of the radar. Gauge Only was used during Event 4d since all radar sources were either unavailable or provided insufficient rainfall information.

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 17 - 19 show the scatter plots of the gauge-adjusted RG pairs. Those gauges not used to adjust the radar are shown in red. Figure 20 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 0.4 - 1.1 inches with a mean of 0.7 inches. The GARR amounts for the 440 RFM basins range from 0.4 - 0.9 inches with a mean of 0.6 inches. The GARR amounts for the 871 RFM sheds range from 0.4 - 0.9 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	2019-05-12	2019-05-11 14:05	2019-05-12 03:00	34	0.255	1.429	31.0	2.1
E4b	KPBZ LII	2019-05-12	2019-05-12 03:05	2019-05-12 04:50	34	0.126	0.593	66.0	2.7
E4c	KPBZ LII	2019-05-12	2019-05-12 04:55	2019-05-12 09:00	18	0.236	4.411	76.8	2.9
E4d	Gauge Only	2019-05-12	2019-05-12 09:05	2019-05-12 17:00	31	0.033	---	---	---

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

Gauge ID	Name	$G_i$ (in)	$R_i$ (in)	$R_i^*$ (in)	$\text{Diff}^*$ (in)	$\text{Diff}^*$ (%)	Flag
<a href="#">Loc08</a>	AC Health Dept Bldg	0.22	0.16	0.24	-0.02	-9.1	
<a href="#">Loc06</a>	Carnegie Transit Time	0.19	0.14	0.20	-0.01	-5.3	
<a href="#">Loc12</a>	Baldwin	0.20	0.12	0.21	-0.01	-5.0	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.22	0.16	0.23	-0.01	-4.5	
<a href="#">Loc30</a>	McCandless Twn Hall	0.24	0.18	0.25	-0.01	-4.2	
<a href="#">Loc21</a>	Moon TWP	0.27	0.25	0.28	-0.01	-3.7	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.29	0.25	0.30	-0.01	-3.4	

<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	0.33	0.28	0.34	-0.01	-3.0	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.27	0.25	0.27	0.00	0.0	
<a href="#">Loc01</a>	PWSA-Montana St.	0.26	0.23	0.26	0.00	0.0	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.24	0.21	0.24	0.00	0.0	
<a href="#">Loc04</a>	Kennedy Twp PS	0.26	0.25	0.26	0.00	0.0	
<a href="#">Loc05</a>	Upper St. Clair	0.17	0.11	0.17	0.00	0.0	
<a href="#">Loc11</a>	M-46 Access Shaft	0.22	0.14	0.22	0.00	0.0	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.23	0.14	0.23	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.21	0.12	0.21	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.18	0.12	0.18	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.27	0.21	0.27	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.40	0.28	0.40	0.00	0.0	
<a href="#">Loc24</a>	Jefferson Hills	0.19	0.09	0.19	0.00	0.0	
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.19	0.08	0.19	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.27	0.16	0.27	0.00	0.0	
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.31	0.19	0.31	0.00	0.0	
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.31	0.25	0.31	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.38	0.26	0.38	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.30	0.19	0.30	0.00	0.0	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.35	0.26	0.34	0.01	2.9	
<a href="#">Loc27</a>	Marshall TWP	0.35	0.18	0.34	0.01	2.9	
<a href="#">Loc10</a>	PWSA-Highland Park	0.25	0.16	0.24	0.01	4.0	
<a href="#">Loc20</a>	Gascola Eq Facility	0.25	0.14	0.24	0.01	4.0	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.24	0.16	0.23	0.01	4.2	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.24	0.15	0.23	0.01	4.2	
<a href="#">Loc17</a>	Chartiers Pump Station	0.20	0.12	0.19	0.01	5.0	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.18	0.09	0.17	0.01	5.6	
<a href="#">Loc13</a>	M-59 Access Shaft	ND	---	---	---	---	ND
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.10	---	---	---	---	ND

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

<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="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.08	0.14	0.09	-0.01	-12.5	
<a href="#">Loc11</a>	M-46 Access Shaft	0.16	0.38	0.18	-0.02	-12.5	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.11	0.19	0.12	-0.01	-9.1	
<a href="#">Loc05</a>	Upper St. Clair	0.15	0.29	0.16	-0.01	-6.7	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.18	0.39	0.19	-0.01	-5.6	
<a href="#">03049500</a>	Allegheny River at Natrona	0.07	0.11	0.07	0.00	0.0	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.19	0.34	0.19	0.00	0.0	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.09	0.14	0.09	0.00	0.0	
<a href="#">Loc01</a>	PWSA-Montana St.	0.07	0.11	0.07	0.00	0.0	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.08	0.11	0.08	0.00	0.0	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.07	0.12	0.07	0.00	0.0	
<a href="#">Loc04</a>	Kennedy Twp PS	0.08	0.13	0.08	0.00	0.0	
<a href="#">Loc06</a>	Carnegie Transit Time	0.17	0.24	0.17	0.00	0.0	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.16	0.23	0.16	0.00	0.0	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.16	0.26	0.16	0.00	0.0	
<a href="#">Loc12</a>	Baldwin	0.17	0.30	0.17	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.17	0.27	0.17	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.15	0.30	0.15	0.00	0.0	
<a href="#">Loc17</a>	Chartiers Pump Station	0.19	0.31	0.19	0.00	0.0	
<a href="#">Loc20</a>	Gascola Eq Facility	0.16	0.33	0.16	0.00	0.0	
<a href="#">Loc21</a>	Moon TWP	0.07	0.16	0.07	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.08	0.12	0.08	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.09	0.14	0.09	0.00	0.0	
<a href="#">Loc24</a>	Jefferson Hills	0.20	0.37	0.20	0.00	0.0	
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.18	0.32	0.18	0.00	0.0	
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.21	0.34	0.21	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.16	0.25	0.16	0.00	0.0	
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.09	0.14	0.09	0.00	0.0	
<a href="#">Loc30</a>	McCandless Twn Hall	0.08	0.12	0.08	0.00	0.0	
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.09	0.12	0.09	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.09	0.11	0.09	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.11	0.14	0.11	0.00	0.0	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.14	0.21	0.13	0.01	7.1	
<a href="#">Loc10</a>	PWSA-Highland Park	0.13	0.17	0.12	0.01	7.7	
<a href="#">Loc13</a>	M-59 Access Shaft	ND	---	---	---	---	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="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc27</a>	Marshall TWP	0.06	---	---	---	---	OMFB

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

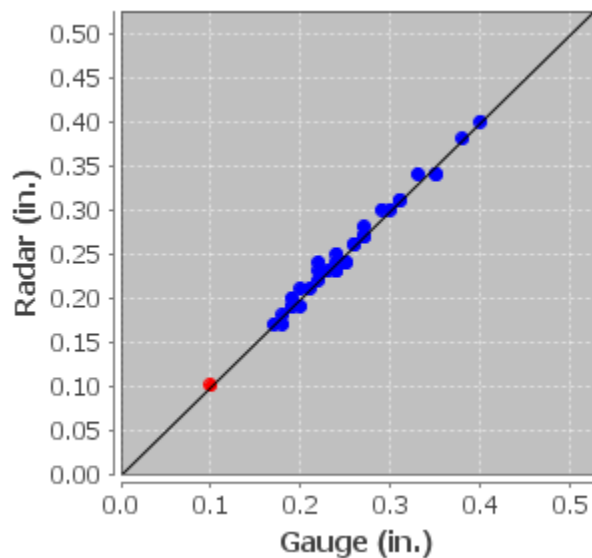
Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc09</a>	Univ of Pittsburgh	0.20	0.06	0.23	-0.03	-15.0	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.21	0.07	0.23	-0.02	-9.5	
<a href="#">Loc20</a>	Gascola Eq Facility	0.33	0.07	0.34	-0.01	-3.0	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.36	0.08	0.37	-0.01	-2.8	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.36	0.07	0.36	0.00	0.0	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.23	0.06	0.23	0.00	0.0	
<a href="#">Loc12</a>	Baldwin	0.34	0.07	0.34	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.44	0.10	0.44	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.28	0.06	0.28	0.00	0.0	
<a href="#">Loc21</a>	Moon TWP	0.25	0.06	0.25	0.00	0.0	
<a href="#">Loc24</a>	Jefferson Hills	0.32	0.07	0.32	0.00	0.0	
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.44	0.11	0.44	0.00	0.0	
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.29	0.10	0.29	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.42	0.07	0.42	0.00	0.0	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.30	0.06	0.29	0.01	3.3	
<a href="#">Loc10</a>	PWSA-Highland Park	0.28	0.06	0.27	0.01	3.6	
<a href="#">Loc06</a>	Carnegie Transit Time	0.27	0.06	0.26	0.01	3.7	
<a href="#">Loc11</a>	M-46 Access Shaft	0.37	0.06	0.34	0.03	8.1	
<a href="#">03049500</a>	Allegheny River at Natrona	0.26	---	---	---	---	MSTT
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.08	---	---	---	---	MSTT
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.15	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	0.17	---	---	---	---	MSTT
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.19	---	---	---	---	MSTT
<a href="#">Loc03</a>	Shaler Munic Bldg	0.16	---	---	---	---	MSTT
<a href="#">Loc04</a>	Kennedy Twp PS	0.09	---	---	---	---	MSTT
<a href="#">Loc05</a>	Upper St. Clair	0.18	---	---	---	---	MSTT
<a href="#">Loc13</a>	M-59 Access Shaft	ND	---	---	---	---	ND
<a href="#">Loc17</a>	Chartiers Pump Station	0.20	---	---	---	---	MSTT

<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="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc22</a>	North Fayette TWP	0.09	---	---	---	---	MSTT
<a href="#">Loc23</a>	Clinton Munic Bldg	0.23	---	---	---	---	MSTT
<a href="#">Loc27</a>	Marshall TWP	0.25	---	---	---	---	MSTT
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.22	---	---	---	---	MSTT
<a href="#">Loc30</a>	McCandless Twn Hall	0.19	---	---	---	---	MSTT
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.13	---	---	---	---	MSTT
<a href="#">Loc32</a>	Arnold	0.33	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	0.26	---	---	---	---	MSTT

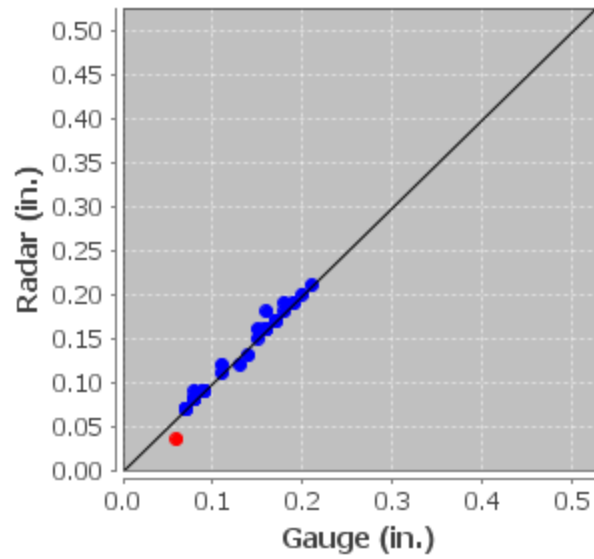
**Table 26. Summary of Individual RG Pairs for Event 4d**

<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="#">Loc01</a>	PWSA-Montana St.	0.00	---	---	---	---	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.00	---	---	---	---	
<a href="#">Loc04</a>	Kennedy Twp PS	0.00	---	---	---	---	
<a href="#">Loc05</a>	Upper St. Clair	0.00	---	---	---	---	
<a href="#">Loc06</a>	Carnegie Transit Time	0.00	---	---	---	---	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.00	---	---	---	---	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.00	---	---	---	---	
<a href="#">Loc10</a>	PWSA-Highland Park	0.00	---	---	---	---	
<a href="#">Loc12</a>	Baldwin	0.00	---	---	---	---	
<a href="#">Loc16</a>	Castle Shannon	0.00	---	---	---	---	
<a href="#">Loc17</a>	Chartiers Pump Station	0.00	---	---	---	---	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.00	---	---	---	---	
<a href="#">Loc21</a>	Moon TWP	0.00	---	---	---	---	
<a href="#">Loc22</a>	North Fayette TWP	0.00	---	---	---	---	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.00	---	---	---	---	
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.00	---	---	---	---	
<a href="#">Loc30</a>	McCandless Twn Hall	0.00	---	---	---	---	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.01	---	---	---	---	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.01	---	---	---	---	
<a href="#">Loc11</a>	M-46 Access Shaft	0.01	---	---	---	---	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.01	---	---	---	---	
<a href="#">Loc20</a>	Gascola Eq Facility	0.01	---	---	---	---	

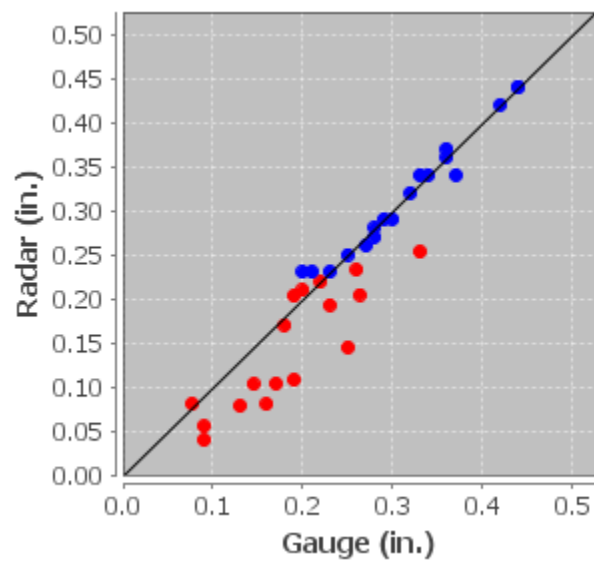
Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc24</a>	Jefferson Hills	0.01	---	---	---	---	
<a href="#">Loc27</a>	Marshall TWP	0.01	---	---	---	---	
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.02	---	---	---	---	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.02	---	---	---	---	
<a href="#">Loc32</a>	Arnold	0.02	---	---	---	---	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.03	---	---	---	---	
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.03	---	---	---	---	
<a href="#">Loc33</a>	Richland TWP	0.03	---	---	---	---	
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.04	---	---	---	---	
<a href="#">03049500</a>	Allegheny River at Natrona	0.03	---	---	---	---	T
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.00	---	---	---	---	T
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.01	---	---	---	---	T
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.00	---	---	---	---	T
<a href="#">Loc13</a>	M-59 Access Shaft	ND	---	---	---	---	ND
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND



**Figure 17. Scatter Plot of RG Pairs for Event 4a**

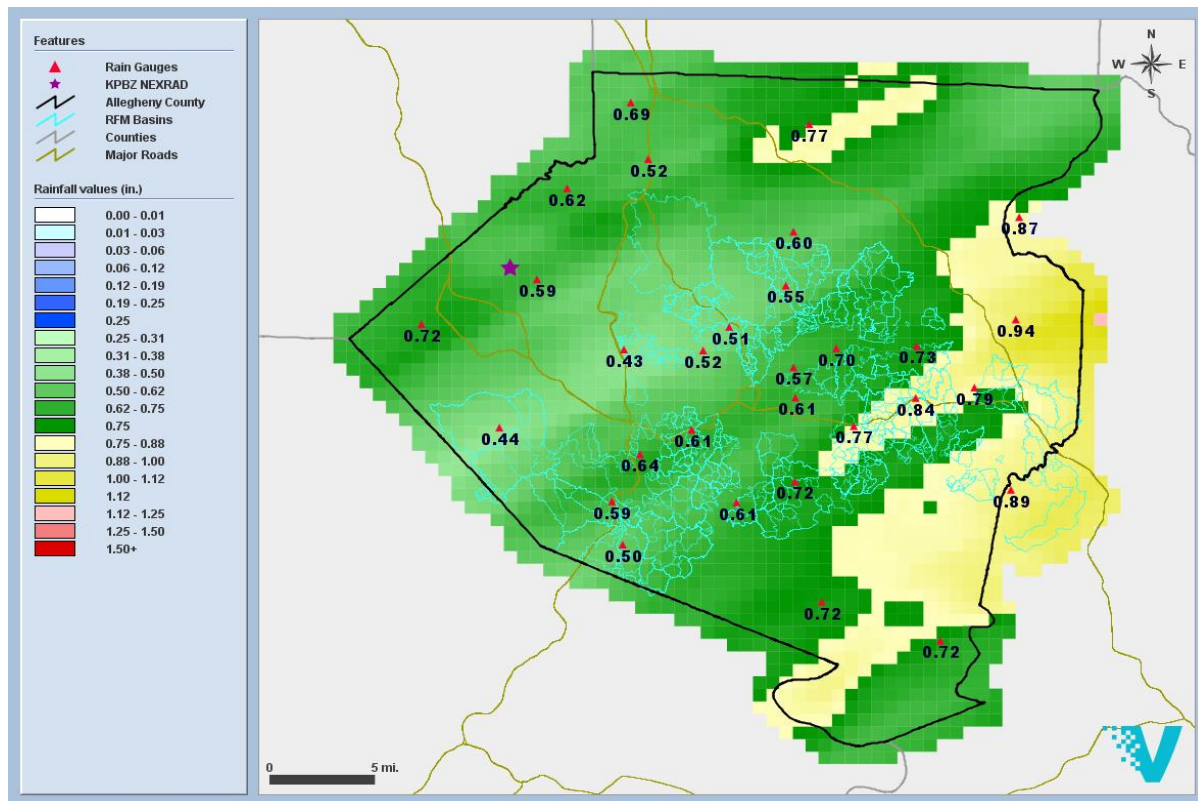


**Figure 18. Scatter Plot of RG Pairs for Event 4b**



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





**Figure 20. GARR Storm Total for Event 4**

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

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	0.203	155112	2019-05-12 07:15	<1 yr.
30 minutes	0.272	155112	2019-05-12 07:25	<1 yr.
1 hour	0.349	152162	2019-05-12 06:50	<1 yr.
2 hour	0.478	152161	2019-05-12 07:40	<1 yr.
3 hour	0.527	152161	2019-05-12 08:40	<1 yr.
6 hour	0.738	173132	2019-05-12 09:30	<1 yr.
12 hour	1.025	173131	2019-05-12 11:30	<1 yr.
24 hour	1.129	173132	2019-05-12 15:10	<1 yr.

## Event 5: 2019-05-17

The analysis period was from 2019-05-17 14:00 EDT to 2019-05-18 13:00 EDT. The event was then split into three sub-event periods at 2019-05-18 00:00 EDT and 2019-05-18 01:05 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 - 31 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 21 - 23 show the scatter plots of the gauge-adjusted RG pairs. Those gauges not used to adjust the radar are shown in red. Figure 24 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 - 1.2 inches with a mean of 0.3 inches. The GARR amounts for the 440 RFM basins range from 0.1 - 0.9 inches with a mean of 0.4 inches. The GARR amounts for the 871 RFM sheds range from 0.1 - 1.0 inches with a mean of 0.4 inches. Table 32 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	2019-05-17	2019-05-17 14:05	2019-05-18 00:00	30	0.222	1.075	21.3	2.6
E5b	KPBZ LII	2019-05-17	2019-05-18 00:05	2019-05-18 01:05	13	0.048	0.883	17.1	3.9
E5c	KPBZ LII	2019-05-17	2019-05-18 01:10	2019-05-18 13:00	16	0.062	1.168	27.5	6.7

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

Gauge ID	Name	$G_i$ (in)	$R_i$ (in)	$R_i^*$ (in)	$\text{Diff}^*$ (in)	$\text{Diff}^*$ (%)	Flag
<a href="#">Loc30</a>	McCandless Twn Hall	0.32	0.36	0.35	-0.03	-9.4	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.12	0.14	0.13	-0.01	-8.3	
<a href="#">Loc06</a>	Carnegie Transit Time	0.72	0.84	0.77	-0.05	-6.9	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.15	0.21	0.16	-0.01	-6.7	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.15	0.16	0.16	-0.01	-6.7	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.18	0.15	0.19	-0.01	-5.6	
<a href="#">Loc24</a>	Jefferson Hills	0.40	0.61	0.41	-0.01	-2.5	
<a href="#">03049500</a>	Allegheny River at Natrona	0.07	0.10	0.07	0.00	0.0	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.18	0.19	0.18	0.00	0.0	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.15	0.17	0.15	0.00	0.0	
<a href="#">Loc01</a>	PWSA-Montana St.	0.16	0.16	0.16	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="#">Loc04</a>	Kennedy Twp PS	0.16	0.16	0.16	0.00	0.0	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.19	0.19	0.19	0.00	0.0	
<a href="#">Loc11</a>	M-46 Access Shaft	0.23	0.24	0.23	0.00	0.0	
<a href="#">Loc12</a>	Baldwin	0.13	0.13	0.13	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.43	0.30	0.43	0.00	0.0	
<a href="#">Loc17</a>	Chartiers Pump Station	0.25	0.18	0.25	0.00	0.0	
<a href="#">Loc20</a>	Gascola Eq Facility	0.11	0.10	0.11	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.80	0.62	0.80	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.06	0.08	0.06	0.00	0.0	
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.58	0.48	0.58	0.00	0.0	
<a href="#">Loc27</a>	Marshall TWP	0.08	0.06	0.08	0.00	0.0	
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.16	0.10	0.16	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.18	0.12	0.18	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.61	0.54	0.60	0.01	1.6	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.26	0.12	0.25	0.01	3.8	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.25	0.24	0.24	0.01	4.0	
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.22	0.13	0.21	0.01	4.5	
<a href="#">Loc10</a>	PWSA-Highland Park	0.37	0.29	0.34	0.03	8.1	
<a href="#">Loc05</a>	Upper St. Clair	0.12	0.07	0.11	0.01	8.3	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.00	---	---	---	---	MSTT
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.00	---	---	---	---	MSTT
<a href="#">Loc13</a>	M-59 Access Shaft	ND	---	---	---	---	ND
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc21</a>	Moon TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.02	---	---	---	---	ND
<a href="#">Loc32</a>	Arnold	0.03	---	---	---	---	MSTT

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

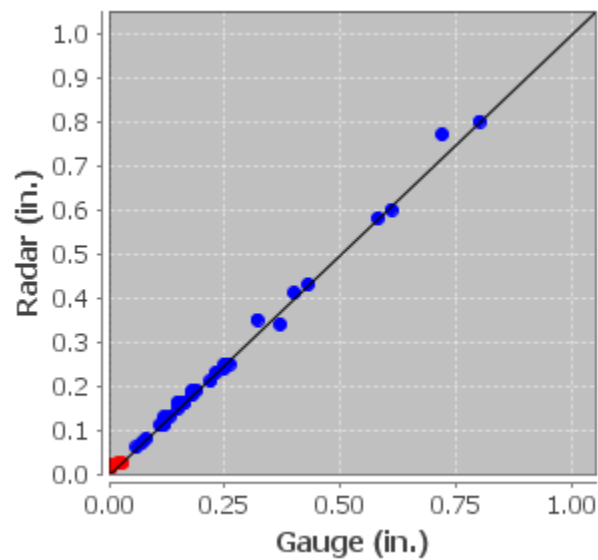
Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc20</a>	Gascola Eq Facility	0.10	0.17	0.11	-0.01	-10.0	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.14	0.20	0.15	-0.01	-7.1	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.23	0.33	0.24	-0.01	-4.3	
<a href="#">Loc10</a>	PWSA-Highland Park	0.23	0.23	0.24	-0.01	-4.3	

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.	0.20	0.22	0.20	0.00	0.0	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.07	0.07	0.07	0.00	0.0	
<a href="#">Loc04</a>	Kennedy Twp PS	0.05	0.05	0.05	0.00	0.0	
<a href="#">Loc11</a>	M-46 Access Shaft	0.05	0.06	0.05	0.00	0.0	
<a href="#">Loc21</a>	Moon TWP	0.14	0.14	0.14	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.13	0.14	0.13	0.00	0.0	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.16	0.14	0.15	0.01	6.3	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.15	0.14	0.14	0.01	6.7	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.11	0.10	0.10	0.01	9.1	
<a href="#">03049500</a>	Allegheny River at Natrona	0.00	---	---	---	---	MSTT
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.00	---	---	---	---	MSTT
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.01	---	---	---	---	MSTT
<a href="#">Loc05</a>	Upper St. Clair	0.04	---	---	---	---	MSTT
<a href="#">Loc06</a>	Carnegie Transit Time	0.00	---	---	---	---	MSTT
<a href="#">Loc07</a>	Greentree Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc09</a>	Univ of Pittsburgh	0.03	---	---	---	---	MSTT
<a href="#">Loc12</a>	Baldwin	0.00	---	---	---	---	MSTT
<a href="#">Loc13</a>	M-59 Access Shaft	ND	---	---	---	---	ND
<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	0.00	---	---	---	---	MSTT
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc22</a>	North Fayette TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc23</a>	Clinton Munic Bldg	0.01	---	---	---	---	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="#">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
<a href="#">Loc32</a>	Arnold	0.00	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	0.00	---	---	---	---	MSTT

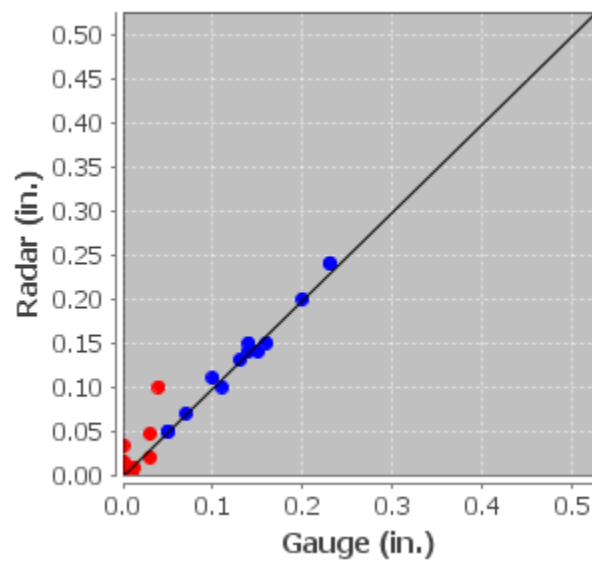
**Table 31. Summary of Individual RG Pairs for Event 5c**

<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="#">Loc11</a>	M-46 Access Shaft	0.09	0.16	0.11	-0.02	-22.2	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.23	0.26	0.28	-0.05	-21.7	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.15	0.18	0.17	-0.02	-13.3	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.21	0.22	0.22	-0.01	-4.8	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.22	0.21	0.23	-0.01	-4.5	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.08	0.05	0.08	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.27	0.20	0.27	0.00	0.0	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.14	0.10	0.14	0.00	0.0	
<a href="#">Loc20</a>	Gascola Eq Facility	0.22	0.14	0.22	0.00	0.0	
<a href="#">Loc21</a>	Moon TWP	0.13	0.12	0.13	0.00	0.0	
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.07	0.08	0.07	0.00	0.0	
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.16	0.06	0.16	0.00	0.0	
<a href="#">Loc10</a>	PWSA-Highland Park	0.19	0.14	0.18	0.01	5.3	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.18	0.12	0.17	0.01	5.6	
<a href="#">Loc04</a>	Kennedy Twp PS	0.09	0.07	0.08	0.01	11.1	
<a href="#">Loc01</a>	PWSA-Montana St.	0.28	0.20	0.24	0.04	14.3	
<a href="#">03049500</a>	Allegheny River at Natrona	0.01	---	---	---	---	MSTT
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.04	---	---	---	---	MSTT
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.05	---	---	---	---	MSTT
<a href="#">Loc05</a>	Upper St. Clair	0.03	---	---	---	---	MSTT
<a href="#">Loc06</a>	Carnegie Transit Time	0.02	---	---	---	---	MSTT
<a href="#">Loc07</a>	Greentree Munic Bldg	0.04	---	---	---	---	MSTT
<a href="#">Loc12</a>	Baldwin	0.04	---	---	---	---	MSTT
<a href="#">Loc13</a>	M-59 Access Shaft	ND	---	---	---	---	ND
<a href="#">Loc16</a>	Castle Shannon	0.03	---	---	---	---	MSTT
<a href="#">Loc17</a>	Chartiers Pump Station	0.03	---	---	---	---	MSTT
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc22</a>	North Fayette TWP	0.03	---	---	---	---	MSTT
<a href="#">Loc23</a>	Clinton Munic Bldg	0.05	---	---	---	---	MSTT
<a href="#">Loc24</a>	Jefferson Hills	0.03	---	---	---	---	MSTT
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.03	---	---	---	---	MSTT
<a href="#">Loc27</a>	Marshall TWP	0.01	---	---	---	---	MSTT
<a href="#">Loc28</a>	Plum Municipal Bldg	0.02	---	---	---	---	MSTT
<a href="#">Loc30</a>	McCandless Twn Hall	0.03	---	---	---	---	MSTT
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.12	---	---	---	---	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	0.01	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	0.00	---	---	---	---	MSTT

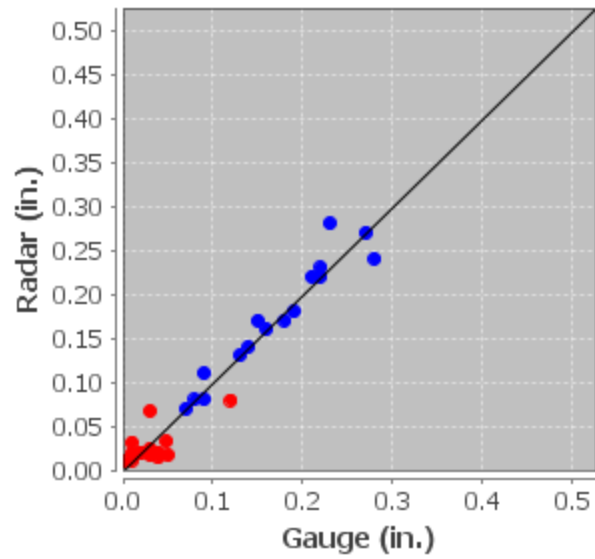


**Figure 21. Scatter Plot of RG Pairs for Event 5a**

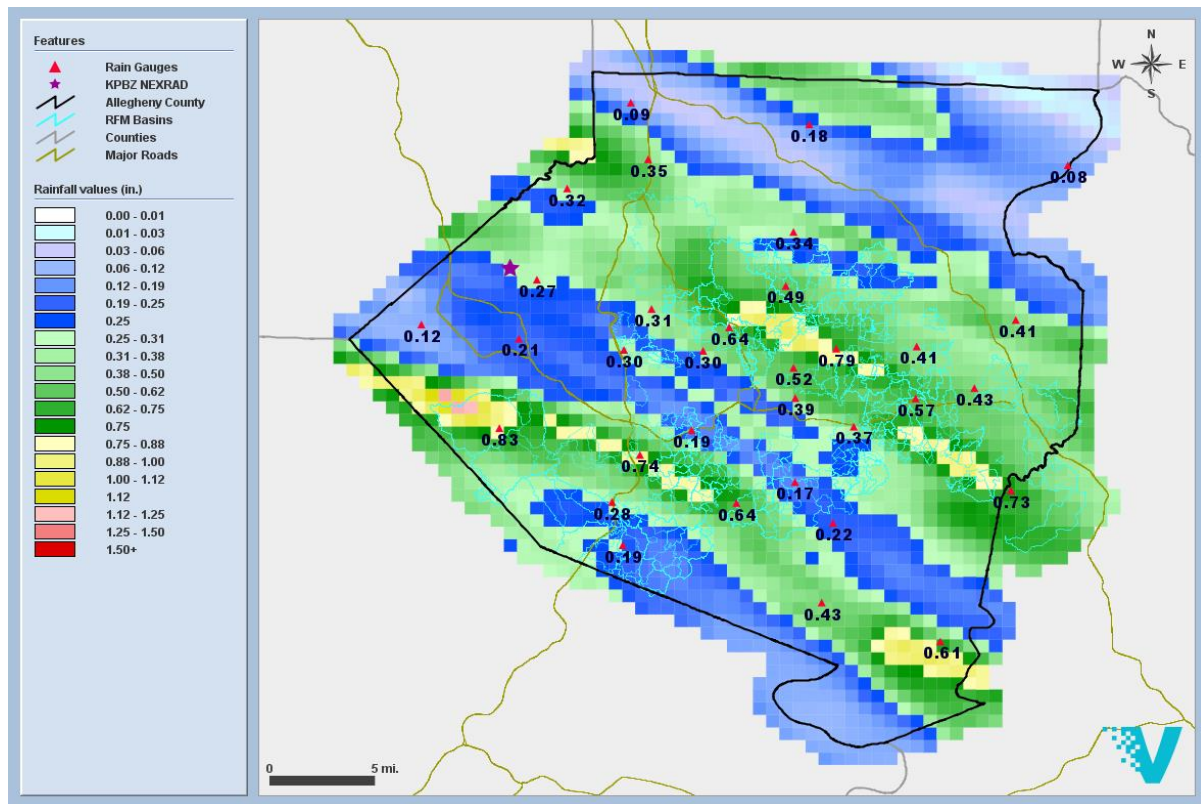


**Figure 22. Scatter Plot of RG Pairs for Event 5b**





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



**Figure 24. GARR Storm Total for Event 5**

**Table 32. Depth Duration Frequency Analyses for Event 5**

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	0.650	123138	2019-05-17 20:05	1 yr.
30 minutes	0.859	160159	2019-05-17 19:15	1 yr.
1 hour	0.909	160159	2019-05-17 19:35	<1 yr.
2 hour	1.151	123138	2019-05-17 20:15	1 yr.
3 hour	1.151	123138	2019-05-17 20:15	<1 yr.
6 hour	1.151	123138	2019-05-17 20:15	<1 yr.
12 hour	1.168	123138	2019-05-18 05:55	<1 yr.

**Event 6: 2019-05-23**

The analysis period was from 2019-05-23 18:00 EDT to 2019-05-24 02:00 EDT.

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 33 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Table 34 summarizes 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,  $\text{Diff}^*$  (in) is the difference in inches between the gauge and 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. Figure 25 shows the scatter plot of the RG pairs. Those gauges not used to adjust the radar are shown in red. Figure 26 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 - 0.6 inches with a mean of 0.1 inches. The GARR amounts for the 440 RFM basins range from 0.0 - 0.6 inches with a mean of 0.2 inches. The GARR amounts for the 871 RFM sheds range from 0.0 - 0.6 inches with a mean of 0.2 inches. Table 35 shows the Depth Duration Frequency (DDF) maximum values for the 1-km<sup>2</sup> pixels.

**Table 33. GARR Statistics for Event 6**

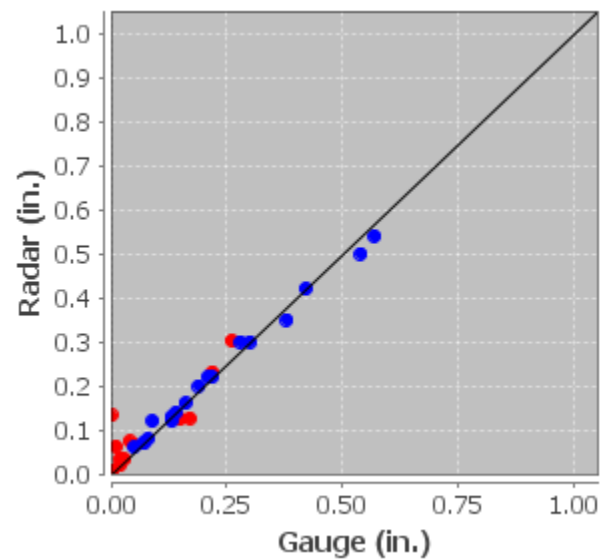
Event #	Radar	Event Date	Start Time (EDT)	End Time (EDT)	Gauges Used (37)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E6	KPBZ LII	2019-05-23	2019-05-23 18:05	2019-05-24 02:00	18	0.102	0.748	50.6	6.4



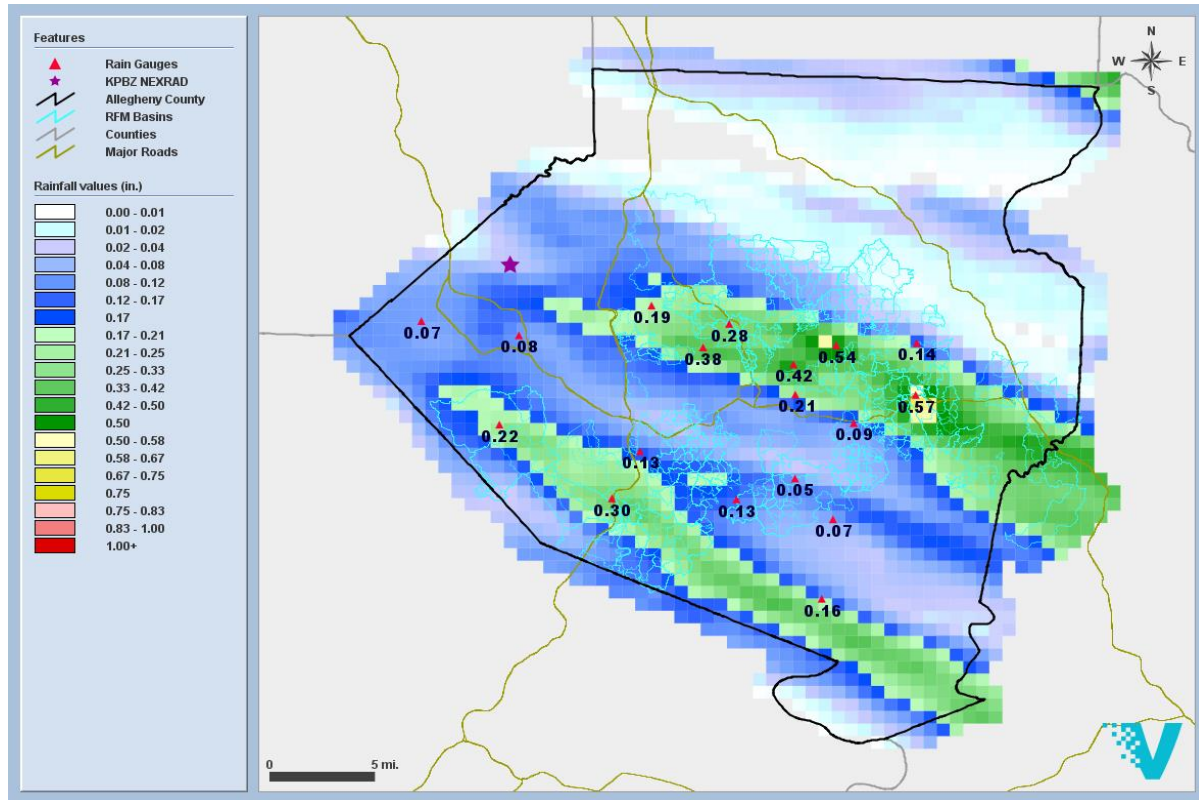
**Table 34. Summary of Individual RG Pairs for Event 6**

<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="#">Loc11</a>	M-46 Access Shaft	0.09	0.28	0.12	-0.03	-33.3	
<a href="#">Loc12</a>	Baldwin	0.05	0.11	0.06	-0.01	-20.0	
<a href="#">Loc01</a>	PWSA-Montana St.	0.28	0.45	0.30	-0.02	-7.1	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.19	0.33	0.20	-0.01	-5.3	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.21	0.35	0.22	-0.01	-4.8	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.07	0.10	0.07	0.00	0.0	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.08	0.10	0.08	0.00	0.0	
<a href="#">Loc06</a>	Carnegie Transit Time	0.13	0.15	0.13	0.00	0.0	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.42	0.60	0.42	0.00	0.0	
<a href="#">Loc17</a>	Chartiers Pump Station	0.30	0.31	0.30	0.00	0.0	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.14	0.17	0.14	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.22	0.23	0.22	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.07	0.18	0.07	0.00	0.0	
<a href="#">Loc24</a>	Jefferson Hills	0.16	0.17	0.16	0.00	0.0	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.57	0.63	0.54	0.03	5.3	
<a href="#">Loc10</a>	PWSA-Highland Park	0.54	0.63	0.50	0.04	7.4	
<a href="#">Loc16</a>	Castle Shannon	0.13	0.12	0.12	0.01	7.7	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.38	0.49	0.35	0.03	7.9	
<a href="#">03049500</a>	Allegheny River at Natrona	0.00	---	---	---	---	MSTT
<a href="#">Loc03</a>	Shaler Munic Bldg	0.05	---	---	---	---	C
<a href="#">Loc04</a>	Kennedy Twp PS	0.15	---	---	---	---	C
<a href="#">Loc05</a>	Upper St. Clair	0.00	---	---	---	---	Z
<a href="#">Loc07</a>	Greentree Munic Bldg	0.02	---	---	---	---	MSTT
<a href="#">Loc13</a>	M-59 Access Shaft	ND	---	---	---	---	ND
<a href="#">Loc15</a>	Trafford Maint Bldg	0.26	---	---	---	---	C
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc20</a>	Gascola Eq Facility	0.22	---	---	---	---	C
<a href="#">Loc21</a>	Moon TWP	0.01	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.17	---	---	---	---	C
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.04	---	---	---	---	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	0.02	---	---	---	---	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	0.03	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	0.00	---	---	---	---	MSTT



**Figure 25. Scatter Plot of RG Pairs for Event 6**



**Figure 26. GARR Storm Total for Event 6**

**Table 35. Depth Duration Frequency Analyses for Event 6**

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	0.482	152134	2019-05-23 22:35	<1 yr.
30 minutes	0.620	159139	2019-05-23 22:50	<1 yr.
1 hour	0.623	159139	2019-05-23 22:55	<1 yr.
2 hour	0.623	159139	2019-05-23 22:55	<1 yr.
3 hour	0.623	159139	2019-05-23 22:55	<1 yr.
6 hour	0.623	159139	2019-05-24 00:00	<1 yr.

## Event 7: 2019-05-26

The analysis period was from 2019-05-26 07:00 EDT to 2019-05-26 15:00 EDT.

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 36 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Table 37 summarizes 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,  $\text{Diff}^*$  (in) is the difference in inches between the gauge and 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. Figure 27 shows the scatter plot of the RG pairs. Those gauges not used to adjust the radar are shown in red. Figure 28 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 - 0.5 inches with a mean of 0.1 inches. The GARR amounts for the 440 RFM basins range from 0.0 - 0.3 inches with a mean of 0.1 inches. The GARR amounts for the 871 RFM sheds range from 0.0 - 0.3 inches with a mean of 0.1 inches. Table 38 shows the Depth Duration Frequency (DDF) maximum values for the 1-km<sup>2</sup> pixels.

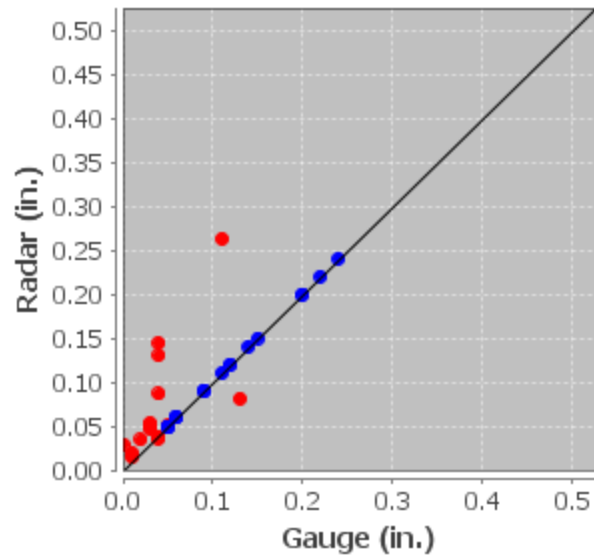
**Table 36. GARR Statistics for Event 7**

Event #	Radar	Event Date	Start Time (EDT)	End Time (EDT)	Gauges Used (37)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E7	KPBZ LII	2019-05-26	2019-05-26 07:05	2019-05-26 15:00	19	0.117	0.739	41.1	1.4

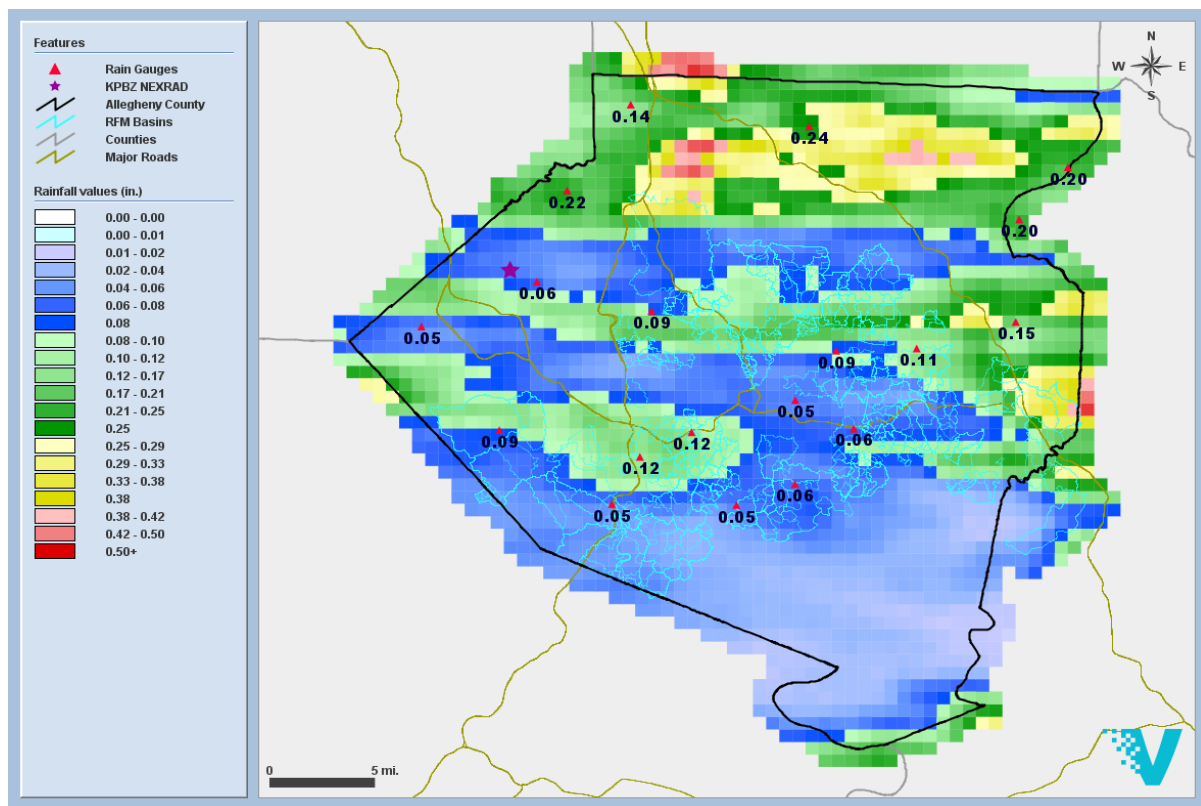
**Table 37. Summary of Individual RG Pairs for Event 7**

Gauge ID	Name	$G_i$ (in)	$R_i$ (in)	$R_i^*$ (in)	$\text{Diff}^*$ (in)	$\text{Diff}^*$ (%)	Flag
<a href="#">03049500</a>	Allegheny River at Natrona	0.20	0.37	0.20	0.00	0.0	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.09	0.14	0.09	0.00	0.0	
<a href="#">Loc06</a>	Carnegie Transit Time	0.12	0.14	0.12	0.00	0.0	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.12	0.12	0.12	0.00	0.0	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.05	0.08	0.05	0.00	0.0	
<a href="#">Loc10</a>	PWSA-Highland Park	0.09	0.13	0.09	0.00	0.0	
<a href="#">Loc11</a>	M-46 Access Shaft	0.06	0.08	0.06	0.00	0.0	
<a href="#">Loc12</a>	Baldwin	0.06	0.07	0.06	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.05	0.08	0.05	0.00	0.0	
<a href="#">Loc17</a>	Chartiers Pump Station	0.05	0.07	0.05	0.00	0.0	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.11	0.20	0.11	0.00	0.0	
<a href="#">Loc21</a>	Moon TWP	0.06	0.10	0.06	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.09	0.13	0.09	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.05	0.06	0.05	0.00	0.0	
<a href="#">Loc27</a>	Marshall TWP	0.14	0.11	0.14	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="#">Loc28</a>	Plum Municipal Bldg	0.15	0.11	0.15	0.00	0.0	
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.22	0.25	0.22	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.20	0.36	0.20	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.24	0.34	0.24	0.00	0.0	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.05	---	---	---	---	MSTT
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.03	---	---	---	---	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	0.13	---	---	---	---	C
<a href="#">Loc04</a>	Kennedy Twp PS	0.03	---	---	---	---	C
<a href="#">Loc05</a>	Upper St. Clair	0.04	---	---	---	---	C
<a href="#">Loc08</a>	AC Health Dept Bldg	0.03	---	---	---	---	MSTT
<a href="#">Loc13</a>	M-59 Access Shaft	ND	---	---	---	---	ND
<a href="#">Loc14</a>	Churchill Munic Bldg	0.04	---	---	---	---	C
<a href="#">Loc15</a>	Trafford Maint Bldg	0.02	---	---	---	---	C
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc20</a>	Gascola Eq Facility	0.04	---	---	---	---	C
<a href="#">Loc24</a>	Jefferson Hills	0.01	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.01	---	---	---	---	MSTT
<a href="#">Loc30</a>	McCandless Twn Hall	0.11	---	---	---	---	C
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.03	---	---	---	---	C



**Figure 27. Scatter Plot of RG Pairs for Event 7**



**Figure 28. GARR Storm Total for Event 7**

**Table 38. Depth Duration Frequency Analyses for Event 7**

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	0.446	172139	2019-05-26 11:10	<1 yr.
30 minutes	0.467	172139	2019-05-26 11:15	<1 yr.
1 hour	0.467	142112	2019-05-26 11:10	<1 yr.
2 hour	0.472	142112	2019-05-26 11:10	<1 yr.
3 hour	0.472	142112	2019-05-26 11:10	<1 yr.
6 hour	0.472	142112	2019-05-26 13:00	<1 yr.

**Event 8: 2019-05-28 AM**

The analysis period was from 2019-05-28 00:00 EDT to 2019-05-28 11:00 EDT.

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 39 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Table 40 summarizes 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, Diff\* (in) is the difference in inches between the gauge and GARR estimate, and 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. Figure 29 shows the scatter plot of the RG pairs. Those gauges not used to adjust the radar are shown in red. Figure 30 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 - 0.6 inches with a mean of 0.3 inches. The GARR amounts for the 440 RFM basins range from 0.2 - 0.4 inches with a mean of 0.3 inches. The GARR amounts for the 871 RFM sheds range from 0.2 - 0.4 inches with a mean of 0.3 inches. Table 41 shows the Depth Duration Frequency (DDF) maximum values for the 1-km<sup>2</sup> pixels.

**Table 39. GARR Statistics for Event 8**

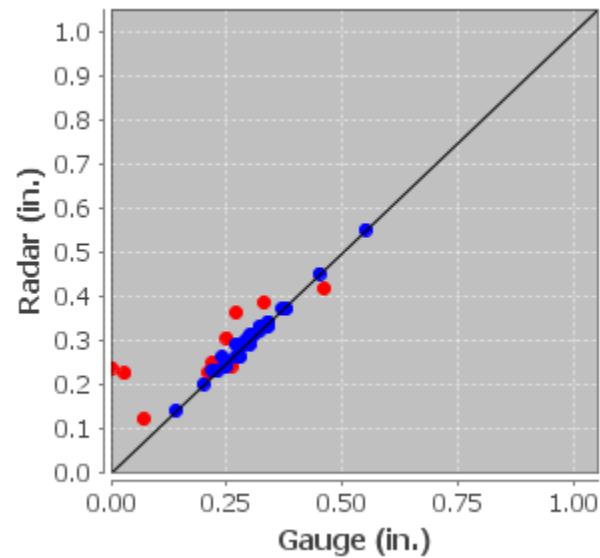
Event #	Radar	Event Date	Start Time (EDT)	End Time (EDT)	Gauges Used (37)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E8	KPBZ LII	2019-05-28 AM	2019-05-28 00:05	2019-05-28 11:00	24	0.294	1.111	10.9	2.3

**Table 40. Summary of Individual RG Pairs for Event 8**

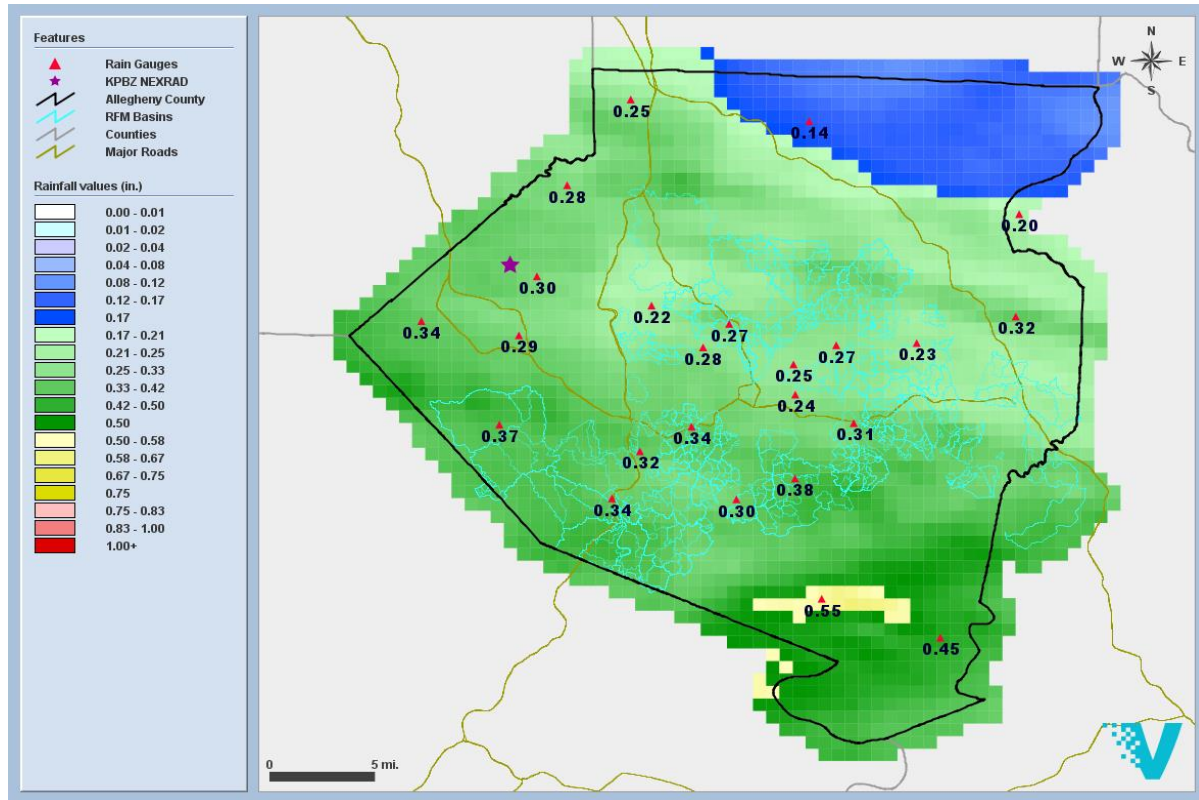
<b>Gauge ID</b>	<b>Name</b>	<b>G<sub>i</sub> (in)</b>	<b>R<sub>i</sub> (in)</b>	<b>R<sub>i</sub>* (in)</b>	<b>Diff* (in)</b>	<b>Diff* (%)</b>	<b>Flag</b>
<a href="#">Loc09</a>	Univ of Pittsburgh	0.24	0.26	0.26	-0.02	-8.3	
<a href="#">Loc01</a>	PWSA-Montana St.	0.27	0.28	0.29	-0.02	-7.4	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.22	0.23	0.23	-0.01	-4.5	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.29	0.26	0.30	-0.01	-3.4	
<a href="#">Loc16</a>	Castle Shannon	0.30	0.30	0.31	-0.01	-3.3	
<a href="#">Loc06</a>	Carnegie Transit Time	0.32	0.32	0.33	-0.01	-3.1	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.34	0.31	0.34	0.00	0.0	
<a href="#">Loc11</a>	M-46 Access Shaft	0.31	0.28	0.31	0.00	0.0	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.23	0.23	0.23	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.37	0.36	0.37	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.34	0.29	0.34	0.00	0.0	
<a href="#">Loc24</a>	Jefferson Hills	0.55	0.43	0.55	0.00	0.0	
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.45	0.35	0.45	0.00	0.0	
<a href="#">Loc27</a>	Marshall TWP	0.25	0.18	0.25	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.32	0.34	0.32	0.00	0.0	
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.28	0.28	0.28	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.20	0.17	0.20	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.14	0.13	0.14	0.00	0.0	
<a href="#">Loc12</a>	Baldwin	0.38	0.32	0.37	0.01	2.6	
<a href="#">Loc17</a>	Chartiers Pump Station	0.34	0.29	0.33	0.01	2.9	
<a href="#">Loc21</a>	Moon TWP	0.30	0.22	0.29	0.01	3.3	
<a href="#">Loc10</a>	PWSA-Highland Park	0.27	0.22	0.26	0.01	3.7	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.25	0.23	0.24	0.01	4.0	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.28	0.23	0.26	0.02	7.1	
<a href="#">03049500</a>	Allegheny River at Natrona	0.07	---	---	---	---	U
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.27	---	---	---	---	U
<a href="#">Loc03</a>	Shaler Munic Bldg	0.22	---	---	---	---	C
<a href="#">Loc04</a>	Kennedy Twp PS	0.26	---	---	---	---	C
<a href="#">Loc05</a>	Upper St. Clair	0.33	---	---	---	---	C
<a href="#">Loc13</a>	M-59 Access Shaft	ND	---	---	---	---	ND
<a href="#">Loc14</a>	Churchill Munic Bldg	0.21	---	---	---	---	C
<a href="#">Loc15</a>	Trafford Maint Bldg	0.30	---	---	---	---	C
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc20</a>	Gascola Eq Facility	0.03	---	---	---	---	C
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.46	---	---	---	---	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="#">Loc30</a>	McCandless Twn Hall	0.25	---	---	---	---	C
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.00	---	---	---	---	C



**Figure 29. Scatter Plot of RG Pairs for Event 8**



**Figure 30. GARR Storm Total for Event 8**

**Table 41. Depth Duration Frequency Analyses for Event 8**

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	0.269	154154	2019-05-28 03:10	<1 yr.
30 minutes	0.340	147162	2019-05-28 03:10	<1 yr.
1 hour	0.454	147162	2019-05-28 03:25	<1 yr.
2 hour	0.527	147162	2019-05-28 03:55	<1 yr.
3 hour	0.527	147162	2019-05-28 03:55	<1 yr.
6 hour	0.594	154155	2019-05-28 06:25	<1 yr.

## Event 9: 2019-05-28 PM

The analysis period was from 2019-05-28 11:00 EDT to 2019-05-29 09:00 EDT. The event was then split into four sub-event periods at 2019-05-28 20:10 EDT, 2019-05-28 21:30 EDT and 2019-05-29 00:20 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 42 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Tables 43 - 46 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 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 31 - 34 show the scatter plots of the gauge-adjusted RG pairs. Those gauges not used to adjust the radar are shown in red. Figure 35 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 - 3.8 inches with a mean of 1.1 inches. The GARR amounts for the 440 RFM basins range from 0.0 - 1.8 inches with a mean of 0.7 inches. The GARR amounts for the 871 RFM sheds range from 0.0 - 1.8 inches with a mean of 0.7 inches. Table 47 shows the Depth Duration Frequency (DDF) maximum values for the 1-km<sup>2</sup> pixels.

**Table 42. GARR Statistics for Event 9**

Event #	Radar	Event Date	Start Time (EDT)	End Time (EDT)	Gauges Used (37)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E9a	KPBZ LII	2019-05-28 PM	2019-05-28 11:05	2019-05-28 20:10	5	0.161	0.529	85.3	0.8
E9b	KPBZ LII	2019-05-28 PM	2019-05-28 20:15	2019-05-28 21:30	5	0.088	0.670	84.1	2.2
E9c	KPBZ LII	2019-05-28 PM	2019-05-28 21:35	2019-05-29 00:20	20	0.411	0.977	18.1	2.6
E9d	KPBZ LII	2019-05-28 PM	2019-05-29 00:25	2019-05-29 09:00	22	0.400	1.179	19.7	2.9

**Table 43. Summary of Individual RG Pairs for Event 9a**

Gauge ID	Name	$G_i$ (in)	$R_i$ (in)	$R_i^*$ (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc32</a>	Arnold	0.39	0.95	0.40	-0.01	-2.6	
<a href="#">Loc27</a>	Marshall TWP	0.44	0.67	0.44	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.12	0.18	0.12	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.90	1.72	0.90	0.00	0.0	
<a href="#">03049500</a>	Allegheny River at Natrona	1.08	2.02	1.06	0.02	1.9	
<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.	0.00	---	---	---	---	MSTT
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.00	---	---	---	---	MSTT
<a href="#">Loc03</a>	Shaler 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="#">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	0.01	---	---	---	---	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	ND	---	---	---	---	ND
<a href="#">Loc14</a>	Churchill Munic Bldg	0.02	---	---	---	---	C
<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	ND	---	---	---	---	ND
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.02	---	---	---	---	MSTT
<a href="#">Loc20</a>	Gascola Eq Facility	0.01	---	---	---	---	C
<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="#">Loc29</a>	Bell Acres Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc30</a>	McCandless Twn Hall	0.01	---	---	---	---	C
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.01	---	---	---	---	C

**Table 44. Summary of Individual RG Pairs for Event 9b**

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	0.07	0.22	0.08	-0.01	-14.3	
<a href="#">Loc27</a>	Marshall TWP	0.50	0.61	0.50	0.00	0.0	
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.13	0.25	0.13	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.41	0.57	0.41	0.00	0.0	
<a href="#">03049500</a>	Allegheny River at Natrona	0.26	0.39	0.25	0.01	3.8	

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<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.	0.01	---	---	---	---	MSTT
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.00	---	---	---	---	MSTT
<a href="#">Loc03</a>	Shaler Munic Bldg	0.02	---	---	---	---	C
<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	0.03	---	---	---	---	MSTT
<a href="#">Loc10</a>	PWSA-Highland Park	0.01	---	---	---	---	MSTT
<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	ND	---	---	---	---	ND
<a href="#">Loc14</a>	Churchill Munic Bldg	0.01	---	---	---	---	C
<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	ND	---	---	---	---	ND
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.00	---	---	---	---	MSTT
<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	0.00	---	---	---	---	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	0.00	---	---	---	---	MSTT
<a href="#">Loc30</a>	McCandless Twn Hall	0.01	---	---	---	---	C
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.00	---	---	---	---	C

**Table 45. Summary of Individual RG Pairs for Event 9c**

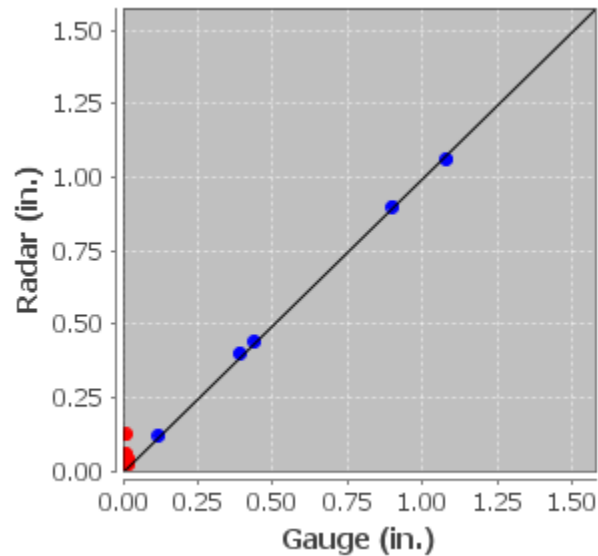
<b>Gauge ID</b>	<b>Name</b>	<b>G<sub>i</sub> (in)</b>	<b>R<sub>i</sub> (in)</b>	<b>R<sub>i</sub>* (in)</b>	<b>Diff* (in)</b>	<b>Diff* (%)</b>	<b>Flag</b>
<a href="#">Loc01</a>	PWSA-Montana St.	0.52	0.71	0.57	-0.05	-9.6	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.22	0.28	0.24	-0.02	-9.1	
<a href="#">Loc11</a>	M-46 Access Shaft	0.39	0.56	0.41	-0.02	-5.1	
<a href="#">Loc04</a>	Kennedy Twp PS	0.57	0.61	0.59	-0.02	-3.5	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.63	0.68	0.65	-0.02	-3.2	
<a href="#">03049500</a>	Allegheny River at Natrona	0.34	0.31	0.34	0.00	0.0	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.41	0.34	0.41	0.00	0.0	
<a href="#">Loc12</a>	Baldwin	0.28	0.34	0.28	0.00	0.0	
<a href="#">Loc17</a>	Chartiers Pump Station	0.07	0.05	0.07	0.00	0.0	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.39	0.51	0.39	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.38	0.30	0.38	0.00	0.0	
<a href="#">Loc27</a>	Marshall TWP	0.68	0.76	0.68	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.25	0.29	0.25	0.00	0.0	
<a href="#">Loc29</a>	Bell Acres Munic Bldg	1.15	0.84	1.15	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.75	0.77	0.75	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.63	0.67	0.63	0.00	0.0	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.70	0.79	0.68	0.02	2.9	
<a href="#">Loc21</a>	Moon TWP	0.66	0.48	0.63	0.03	4.5	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.41	0.40	0.39	0.02	4.9	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.67	0.61	0.63	0.04	6.0	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.02	---	---	---	---	MSTT
<a href="#">Loc03</a>	Shaler Munic Bldg	0.20	---	---	---	---	C
<a href="#">Loc05</a>	Upper St. Clair	0.00	---	---	---	---	MSTT
<a href="#">Loc06</a>	Carnegie Transit Time	0.06	---	---	---	---	U
<a href="#">Loc10</a>	PWSA-Highland Park	0.15	---	---	---	---	C
<a href="#">Loc13</a>	M-59 Access Shaft	ND	---	---	---	---	ND
<a href="#">Loc14</a>	Churchill Munic Bldg	0.00	---	---	---	---	C
<a href="#">Loc15</a>	Trafford Maint Bldg	0.22	---	---	---	---	C
<a href="#">Loc16</a>	Castle Shannon	0.03	---	---	---	---	MSTT
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc20</a>	Gascola Eq Facility	0.00	---	---	---	---	C
<a href="#">Loc22</a>	North Fayette TWP	0.06	---	---	---	---	OAD
<a href="#">Loc24</a>	Jefferson Hills	0.01	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.35	---	---	---	---	C
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	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="#">Loc30</a>	McCandless Twn Hall	0.05	---	---	---	---	C
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.00	---	---	---	---	C

**Table 46. Summary of Individual RG Pairs for Event 9d**

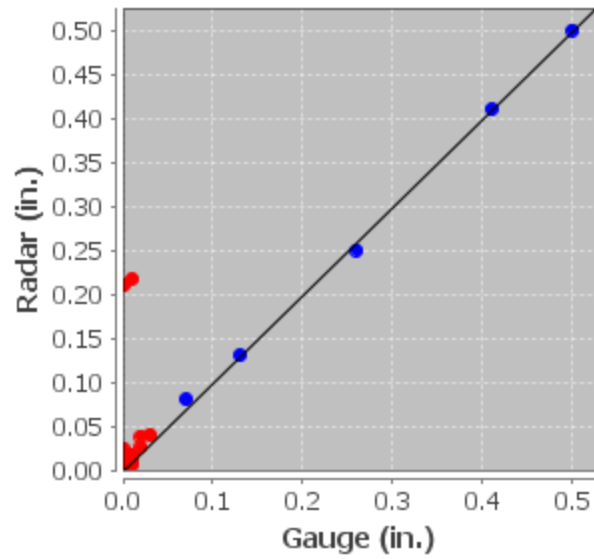
Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc01</a>	PWSA-Montana St.	0.26	0.42	0.31	-0.05	-19.2	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.22	0.23	0.23	-0.01	-4.5	
<a href="#">Loc11</a>	M-46 Access Shaft	0.24	0.28	0.25	-0.01	-4.2	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.27	0.30	0.28	-0.01	-3.7	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.48	0.36	0.49	-0.01	-2.1	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.35	0.32	0.35	0.00	0.0	
<a href="#">Loc12</a>	Baldwin	0.28	0.27	0.28	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.17	0.15	0.17	0.00	0.0	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.61	0.60	0.61	0.00	0.0	
<a href="#">Loc23</a>	Clinton Munic Bldg	0.68	0.52	0.68	0.00	0.0	
<a href="#">Loc24</a>	Jefferson Hills	0.05	0.07	0.05	0.00	0.0	
<a href="#">Loc27</a>	Marshall TWP	0.97	0.72	0.97	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.97	0.54	0.97	0.00	0.0	
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.83	0.54	0.83	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.61	0.48	0.61	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.56	0.53	0.56	0.00	0.0	
<a href="#">Loc04</a>	Kennedy Twp PS	0.41	0.34	0.40	0.01	2.4	
<a href="#">Loc06</a>	Carnegie Transit Time	0.36	0.31	0.35	0.01	2.8	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.33	0.30	0.32	0.01	3.0	
<a href="#">Loc21</a>	Moon TWP	0.31	0.18	0.30	0.01	3.2	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.21	0.21	0.20	0.01	4.8	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.35	0.37	0.32	0.03	8.6	
<a href="#">03049500</a>	Allegheny River at Natrona	0.24	---	---	---	---	U
<a href="#">Loc03</a>	Shaler Munic Bldg	0.20	---	---	---	---	C
<a href="#">Loc05</a>	Upper St. Clair	0.00	---	---	---	---	MSTT
<a href="#">Loc10</a>	PWSA-Highland Park	0.06	---	---	---	---	C
<a href="#">Loc13</a>	M-59 Access Shaft	ND	---	---	---	---	ND
<a href="#">Loc14</a>	Churchill Munic Bldg	0.02	---	---	---	---	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="#">Loc15</a>	Trafford Maint Bldg	0.38	---	---	---	---	C
<a href="#">Loc17</a>	Chartiers Pump Station	0.03	---	---	---	---	MSTT
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc20</a>	Gascola Eq Facility	0.01	---	---	---	---	C
<a href="#">Loc22</a>	North Fayette TWP	0.04	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.43	---	---	---	---	C
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.01	---	---	---	---	MSTT
<a href="#">Loc30</a>	McCandless Twn Hall	0.05	---	---	---	---	C
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.02	---	---	---	---	C

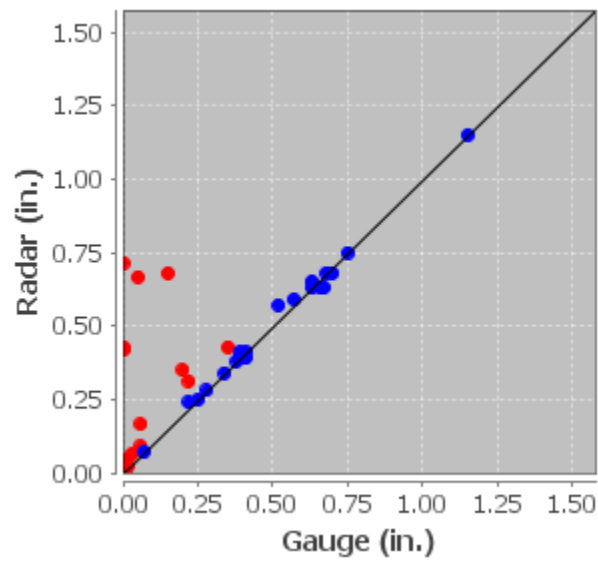


**Figure 31. Scatter Plot of RG Pairs for Event 9a**

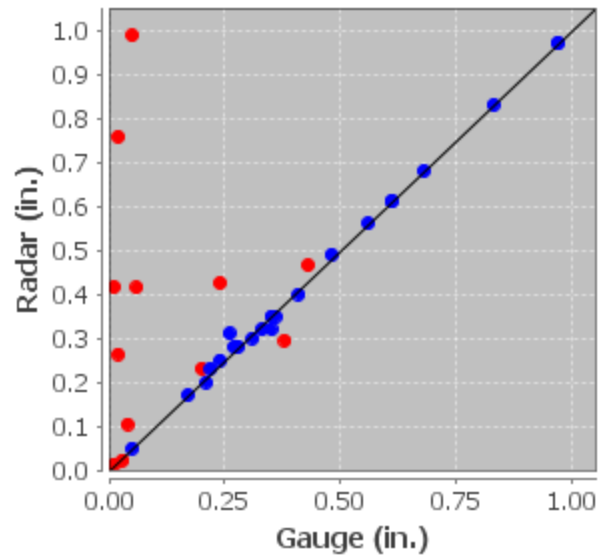




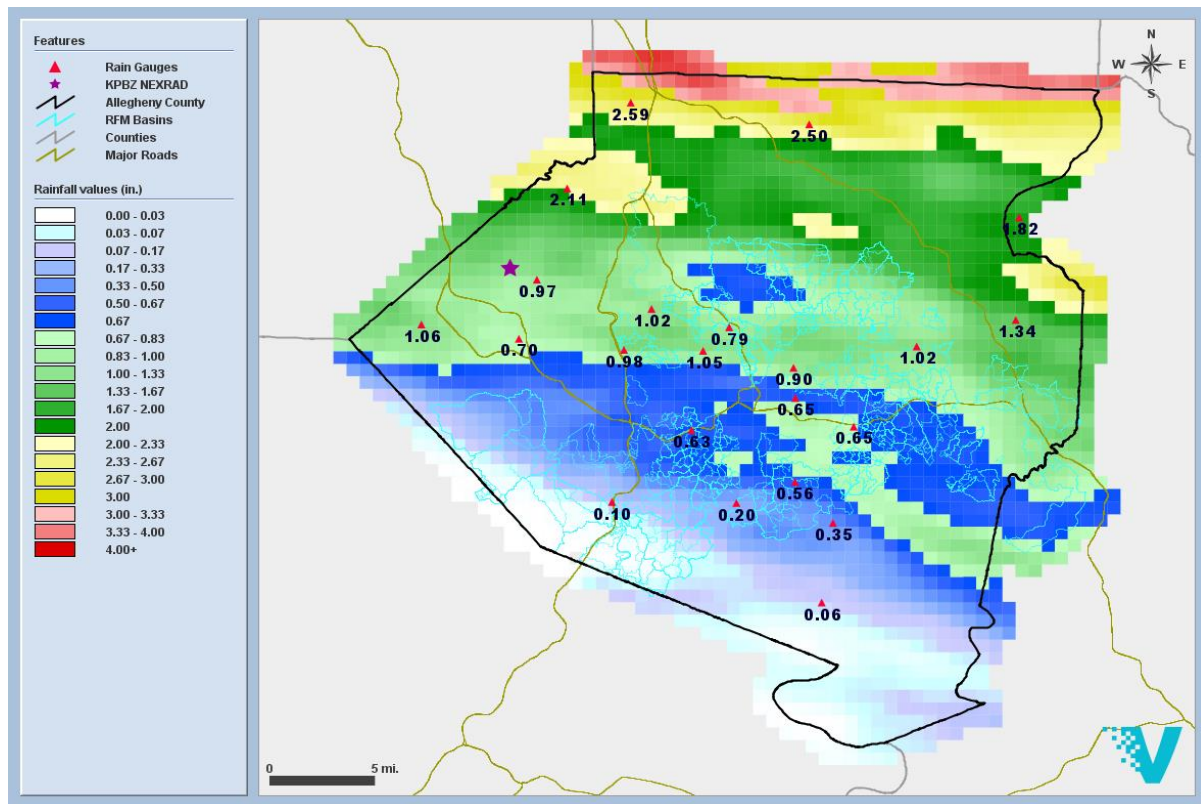
**Figure 32. Scatter Plot of RG Pairs for Event 9b**



**Figure 33. Scatter Plot of RG Pairs for Event 9c**



**Figure 34. Scatter Plot of RG Pairs for Event 9d**



**Figure 35. GARR Storm Total for Event 9**

**Table 47. Depth Duration Frequency Analyses for Event 9**

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	0.766	133113	2019-05-29 00:45	2 yr.
30 minutes	1.160	135112	2019-05-29 00:55	2 yr.
1 hour	1.351	135112	2019-05-29 01:20	2 yr.
2 hour	1.519	153113	2019-05-28 22:30	2 yr.
3 hour	1.685	159114	2019-05-28 22:30	2 yr.
6 hour	2.869	174113	2019-05-28 22:40	10 yr.
12 hour	3.772	139111	2019-05-29 01:35	25 yr.

**Event 10: 2019-05-29**

The analysis period was from 2019-05-29 09:00 EDT to 2019-05-30 06:00 EDT. The event was then split into five sub-event periods at 2019-05-29 15:20 EDT, 2019-05-29 16:00 EDT, 2019-05-29 17:25 EDT and 2019-05-29 21:30 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 48 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Tables 49 - 53 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 36 - 40 show the scatter plots of the gauge-adjusted RG pairs. Those gauges not used to adjust the radar are shown in red. Figure 41 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 0.2 - 2.0 inches with a mean of 1.0 inches. The GARR amounts for the 440 RFM basins range from 0.3 - 1.8 inches with a mean of 1.1 inches. The GARR amounts for the 871 RFM sheds range from 0.3 - 1.9 inches with a mean of 1.2 inches. Table 54 shows the Depth Duration Frequency (DDF) maximum values for the 1-km<sup>2</sup> pixels.

**Table 48. GARR Statistics for Event 10**

Event #	Radar	Event Date	Start Time (EDT)	End Time (EDT)	Gauges Used (37)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E10a	KPBZ LII	2019-05-29	2019-05-29 09:05	2019-05-29 15:20	21	0.473	1.018	16.3	2.1
E10b	KPBZ LII	2019-05-29	2019-05-29 15:25	2019-05-29 16:00	9	0.077	0.814	19.4	2.2

Event #	Radar	Event Date	Start Time (EDT)	End Time (EDT)	Gauges Used (37)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E10c	KPBZ LII	2019-05-29	2019-05-29 16:05	2019-05-29 17:25	15	0.070	0.881	31.9	5.0
E10d	KPBZ LII	2019-05-29	2019-05-29 17:30	2019-05-29 21:30	23	0.328	1.111	15.5	2.1
E10e	KPBZ LII	2019-05-29	2019-05-29 21:35	2019-05-30 06:00	5	0.044	1.420	28.0	1.0

**Table 49. Summary of Individual RG Pairs for Event 10a**

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.	0.25	0.24	0.28	-0.03	-12.0	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.36	0.35	0.38	-0.02	-5.6	
<a href="#">Loc12</a>	Baldwin	0.52	0.79	0.54	-0.02	-3.8	
<a href="#">Loc06</a>	Carnegie Transit Time	0.31	0.31	0.32	-0.01	-3.2	
<a href="#">Loc32</a>	Arnold	0.47	0.40	0.48	-0.01	-2.1	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.23	0.19	0.23	0.00	0.0	
<a href="#">Loc04</a>	Kennedy Twp PS	0.29	0.27	0.29	0.00	0.0	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.21	0.19	0.21	0.00	0.0	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.15	0.13	0.15	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.85	0.97	0.85	0.00	0.0	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.28	0.37	0.28	0.00	0.0	
<a href="#">Loc21</a>	Moon TWP	0.90	0.71	0.90	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.18	0.27	0.18	0.00	0.0	
<a href="#">Loc24</a>	Jefferson Hills	0.40	0.40	0.40	0.00	0.0	
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.56	0.54	0.56	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.68	0.65	0.68	0.00	0.0	
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.49	0.46	0.49	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	1.17	1.08	1.17	0.00	0.0	
<a href="#">03049500</a>	Allegheny River at Natrona	0.76	0.54	0.75	0.01	1.3	
<a href="#">Loc16</a>	Castle Shannon	0.43	0.52	0.42	0.01	2.3	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.21	0.14	0.18	0.03	14.3	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.37	---	---	---	---	U
<a href="#">Loc03</a>	Shaler Munic Bldg	0.05	---	---	---	---	C
<a href="#">Loc05</a>	Upper St. Clair	0.06	---	---	---	---	C
<a href="#">Loc08</a>	AC Health Dept Bldg	0.06	---	---	---	---	OAD

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	0.02	---	---	---	---	C
<a href="#">Loc11</a>	M-46 Access Shaft	0.37	---	---	---	---	O
<a href="#">Loc13</a>	M-59 Access Shaft	ND	---	---	---	---	ND
<a href="#">Loc14</a>	Churchill Munic Bldg	0.21	---	---	---	---	C
<a href="#">Loc17</a>	Chartiers Pump Station	0.47	---	---	---	---	O
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc20</a>	Gascola Eq Facility	0.00	---	---	---	---	C
<a href="#">Loc23</a>	Clinton Munic Bldg	0.74	---	---	---	---	C
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.41	---	---	---	---	C
<a href="#">Loc27</a>	Marshall TWP	0.89	---	---	---	---	C
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.82	---	---	---	---	C
<a href="#">Loc30</a>	McCandless Twn Hall	0.79	---	---	---	---	C

**Table 50. Summary of Individual RG Pairs for Event 10b**

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc06</a>	Carnegie Transit Time	0.05	0.08	0.06	-0.01	-20.0	
<a href="#">Loc11</a>	M-46 Access Shaft	0.09	0.09	0.09	0.00	0.0	
<a href="#">Loc12</a>	Baldwin	0.07	0.08	0.07	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.08	0.08	0.08	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.08	0.09	0.08	0.00	0.0	
<a href="#">Loc24</a>	Jefferson Hills	0.66	0.85	0.66	0.00	0.0	
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.09	0.11	0.09	0.00	0.0	
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.57	0.73	0.57	0.00	0.0	
<a href="#">Loc17</a>	Chartiers Pump Station	0.13	0.13	0.12	0.01	7.7	
<a href="#">03049500</a>	Allegheny River at Natrona	0.01	---	---	---	---	MSTT
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.00	---	---	---	---	MSTT
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.23	---	---	---	---	O
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.00	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	0.02	---	---	---	---	MSTT
<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	0.03	---	---	---	---	MSTT
<a href="#">Loc05</a>	Upper St. Clair	0.07	---	---	---	---	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="#">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	0.00	---	---	---	---	MSTT
<a href="#">Loc13</a>	M-59 Access Shaft	ND	---	---	---	---	ND
<a href="#">Loc14</a>	Churchill Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc15</a>	Trafford Maint Bldg	0.03	---	---	---	---	MSTT
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.00	---	---	---	---	MSTT
<a href="#">Loc20</a>	Gascola Eq Facility	0.00	---	---	---	---	MSTT
<a href="#">Loc21</a>	Moon TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc23</a>	Clinton Munic 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	0.00	---	---	---	---	MSTT
<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	0.01	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	0.00	---	---	---	---	MSTT

**Table 51. Summary of Individual RG Pairs for Event 10c**

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	0.05	0.08	0.06	-0.01	-20.0	
<a href="#">Loc12</a>	Baldwin	0.11	0.19	0.13	-0.02	-18.2	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.09	0.21	0.10	-0.01	-11.1	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.06	0.08	0.06	0.00	0.0	
<a href="#">Loc06</a>	Carnegie Transit Time	0.40	0.37	0.40	0.00	0.0	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.31	0.30	0.31	0.00	0.0	
<a href="#">Loc11</a>	M-46 Access Shaft	0.06	0.09	0.06	0.00	0.0	
<a href="#">Loc17</a>	Chartiers Pump Station	0.20	0.20	0.20	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.36	0.36	0.36	0.00	0.0	
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.05	0.05	0.05	0.00	0.0	
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.08	0.10	0.08	0.00	0.0	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.17	0.16	0.16	0.01	5.9	

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	0.17	0.17	0.16	0.01	5.9	
<a href="#">Loc16</a>	Castle Shannon	0.16	0.17	0.15	0.01	6.3	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.08	0.14	0.07	0.01	12.5	
<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="#">Loc01</a>	PWSA-Montana St.	0.02	---	---	---	---	MSTT
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.04	---	---	---	---	MSTT
<a href="#">Loc03</a>	Shaler Munic Bldg	0.01	---	---	---	---	C
<a href="#">Loc04</a>	Kennedy Twp PS	0.05	---	---	---	---	OAD
<a href="#">Loc05</a>	Upper St. Clair	0.20	---	---	---	---	C
<a href="#">Loc10</a>	PWSA-Highland Park	0.01	---	---	---	---	C
<a href="#">Loc13</a>	M-59 Access Shaft	ND	---	---	---	---	ND
<a href="#">Loc15</a>	Trafford Maint Bldg	0.07	---	---	---	---	MSTT
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc20</a>	Gascola Eq Facility	0.00	---	---	---	---	MSTT
<a href="#">Loc21</a>	Moon TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc23</a>	Clinton Munic Bldg	0.01	---	---	---	---	C
<a href="#">Loc24</a>	Jefferson Hills	0.02	---	---	---	---	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	0.00	---	---	---	---	MSTT
<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 52. Summary of Individual RG Pairs for Event 10d**

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc16</a>	Castle Shannon	0.21	0.29	0.23	-0.02	-9.5	
<a href="#">Loc06</a>	Carnegie Transit Time	0.32	0.33	0.34	-0.02	-6.3	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.41	0.43	0.43	-0.02	-4.9	
<a href="#">03049500</a>	Allegheny River at Natrona	0.27	0.46	0.28	-0.01	-3.7	
<a href="#">Loc21</a>	Moon TWP	0.90	0.69	0.91	-0.01	-1.1	

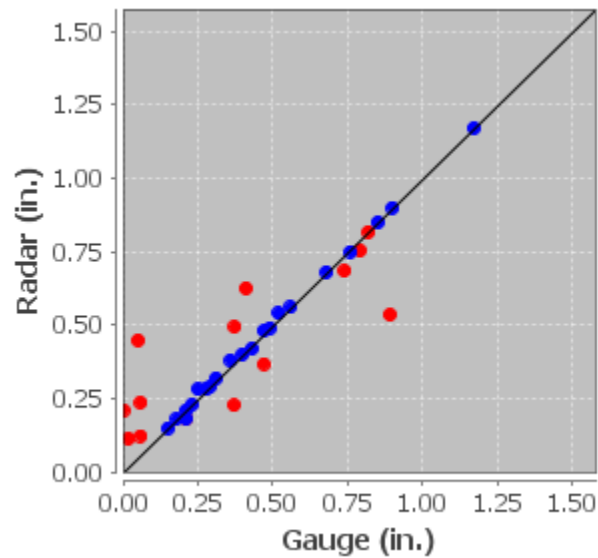
<b>Gauge ID</b>	<b>Name</b>	<b>G<sub>i</sub> (in)</b>	<b>R<sub>i</sub> (in)</b>	<b>R<sub>i</sub>* (in)</b>	<b>Diff* (in)</b>	<b>Diff* (%)</b>	<b>Flag</b>
<a href="#">Loc08</a>	AC Health Dept Bldg	1.03	0.95	1.04	-0.01	-1.0	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.76	0.68	0.76	0.00	0.0	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.35	0.33	0.35	0.00	0.0	
<a href="#">Loc04</a>	Kennedy Twp PS	1.15	1.04	1.15	0.00	0.0	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.87	0.79	0.87	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.78	0.69	0.78	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.19	0.19	0.19	0.00	0.0	
<a href="#">Loc24</a>	Jefferson Hills	0.07	0.06	0.07	0.00	0.0	
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.24	0.23	0.24	0.00	0.0	
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.10	0.07	0.10	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.20	0.19	0.20	0.00	0.0	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	1.37	1.18	1.36	0.01	0.7	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	1.06	0.72	1.04	0.02	1.9	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.40	0.38	0.39	0.01	2.5	
<a href="#">Loc12</a>	Baldwin	0.54	0.48	0.52	0.02	3.7	
<a href="#">Loc14</a>	Churchill Munic Bldg	1.07	0.90	1.03	0.04	3.7	
<a href="#">Loc32</a>	Arnold	0.24	0.25	0.23	0.01	4.2	
<a href="#">Loc17</a>	Chartiers Pump Station	0.23	0.17	0.22	0.01	4.3	
<a href="#">Loc01</a>	PWSA-Montana St.	0.62	---	---	---	---	U
<a href="#">Loc03</a>	Shaler Munic Bldg	0.02	---	---	---	---	C
<a href="#">Loc05</a>	Upper St. Clair	0.25	---	---	---	---	C
<a href="#">Loc10</a>	PWSA-Highland Park	0.96	---	---	---	---	C
<a href="#">Loc11</a>	M-46 Access Shaft	0.78	---	---	---	---	C
<a href="#">Loc13</a>	M-59 Access Shaft	ND	---	---	---	---	ND
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc20</a>	Gascola Eq Facility	0.00	---	---	---	---	C
<a href="#">Loc23</a>	Clinton Munic Bldg	0.89	---	---	---	---	C
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.04	---	---	---	---	MSTT
<a href="#">Loc27</a>	Marshall TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc28</a>	Plum Municipal Bldg	0.08	---	---	---	---	OAD
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.06	---	---	---	---	C
<a href="#">Loc30</a>	McCandless Twn Hall	0.03	---	---	---	---	MSTT



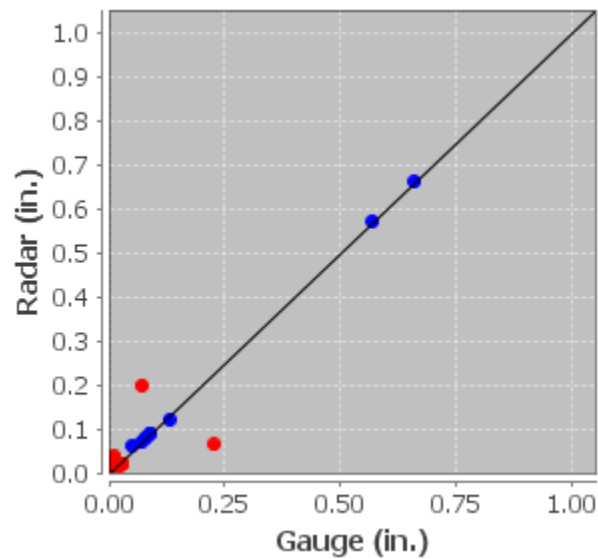
**Table 53. Summary of Individual RG Pairs for Event 10e**

<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	0.10	0.05	0.10	0.00	0.0	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.31	0.17	0.31	0.00	0.0	
<a href="#">Loc12</a>	Baldwin	0.08	0.06	0.08	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.17	0.15	0.17	0.00	0.0	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.19	0.16	0.19	0.00	0.0	
<a href="#">03049500</a>	Allegheny River at Natrona	0.01	---	---	---	---	MSTT
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.05	---	---	---	---	MSTT
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.04	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	0.01	---	---	---	---	MSTT
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.00	---	---	---	---	MSTT
<a href="#">Loc03</a>	Shaler Munic Bldg	0.03	---	---	---	---	C
<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	0.18	---	---	---	---	U
<a href="#">Loc08</a>	AC Health Dept Bldg	0.01	---	---	---	---	MSTT
<a href="#">Loc09</a>	Univ of Pittsburgh	0.05	---	---	---	---	MSTT
<a href="#">Loc10</a>	PWSA-Highland Park	0.15	---	---	---	---	C
<a href="#">Loc11</a>	M-46 Access Shaft	0.08	---	---	---	---	C
<a href="#">Loc13</a>	M-59 Access Shaft	ND	---	---	---	---	ND
<a href="#">Loc14</a>	Churchill Munic Bldg	0.01	---	---	---	---	MSTT
<a href="#">Loc15</a>	Trafford Maint Bldg	0.01	---	---	---	---	MSTT
<a href="#">Loc17</a>	Chartiers Pump Station	0.03	---	---	---	---	MSTT
<a href="#">Loc18</a>	Oakdale Pump Station	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	0.01	---	---	---	---	MSTT
<a href="#">Loc23</a>	Clinton Munic Bldg	0.12	---	---	---	---	C
<a href="#">Loc24</a>	Jefferson Hills	0.00	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.04	---	---	---	---	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	0.02	---	---	---	---	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

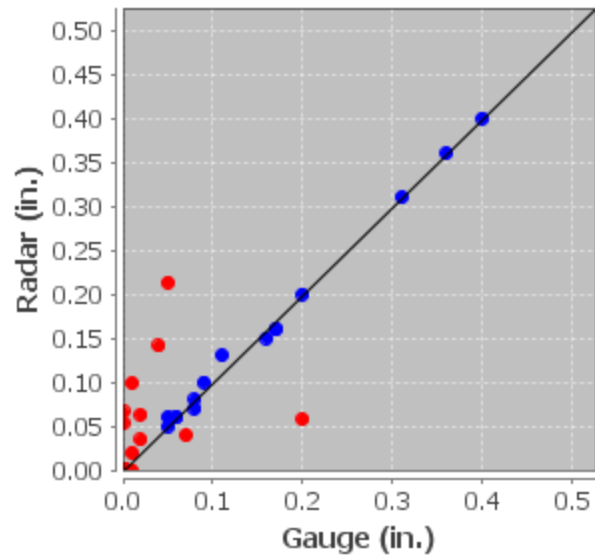
Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc32</a>	Arnold	0.02	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	0.04	---	---	---	---	MSTT



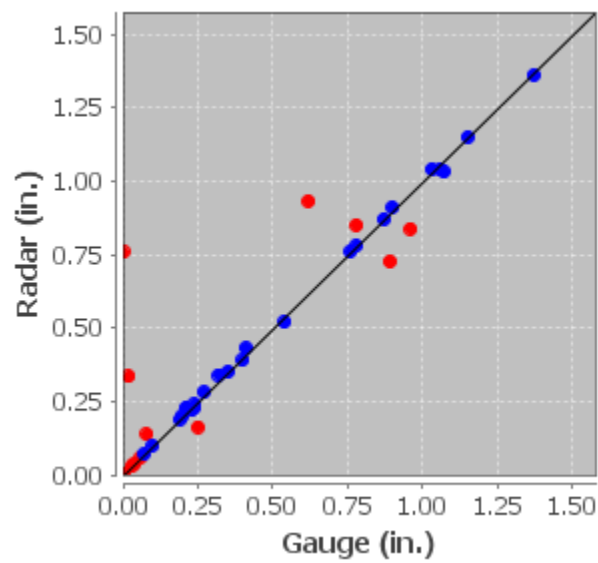
**Figure 36. Scatter Plot of RG Pairs for Event 10a**



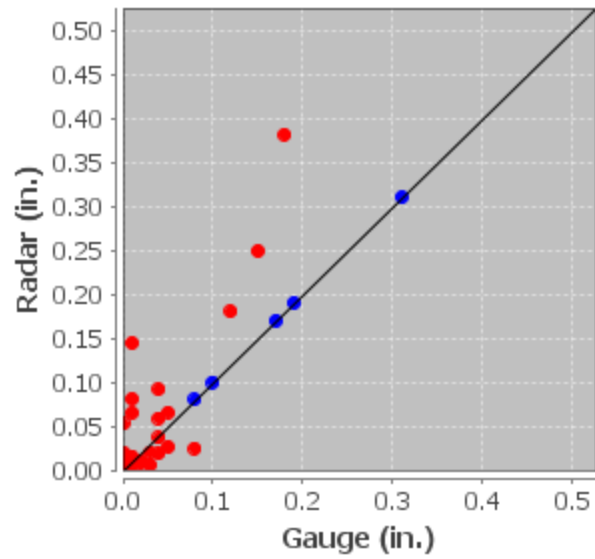
**Figure 37. Scatter Plot of RG Pairs for Event 10b**



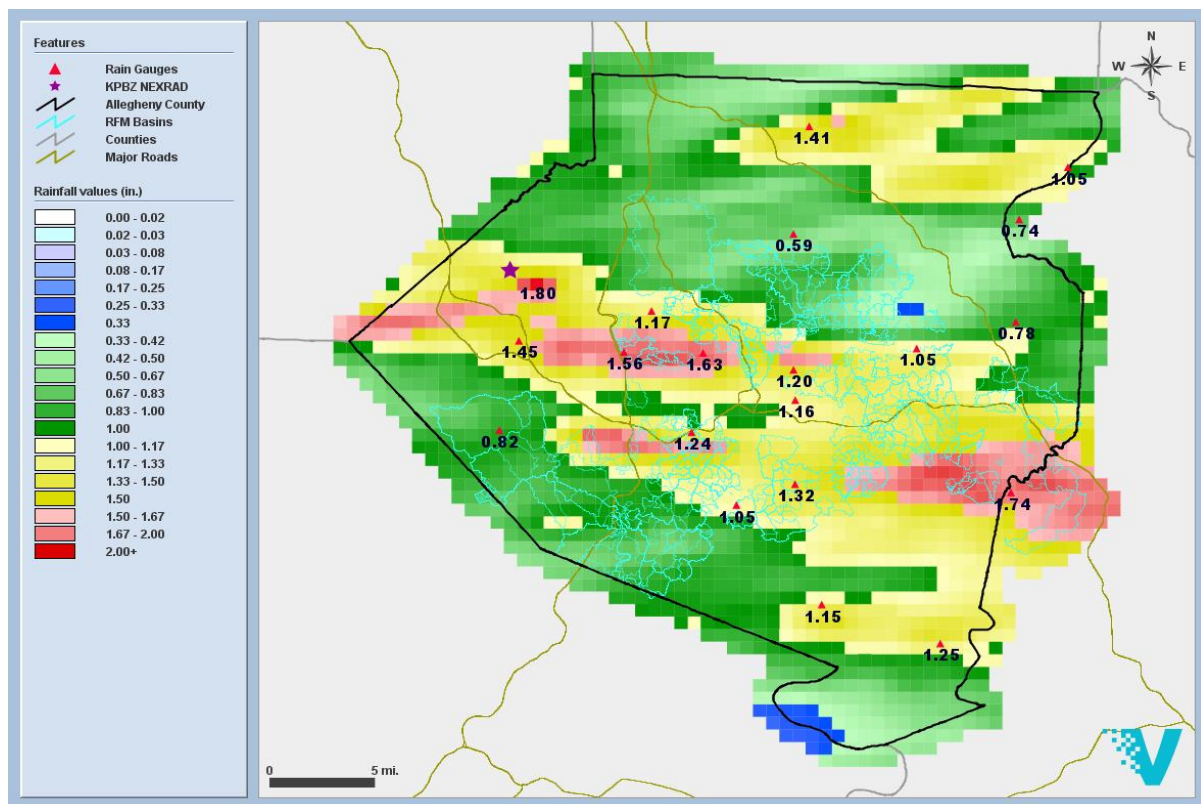
**Figure 38. Scatter Plot of RG Pairs for Event 10c**



**Figure 39. Scatter Plot of RG Pairs for Event 10d**



**Figure 40. Scatter Plot of RG Pairs for Event 10e**



**Figure 41. GARR Storm Total for Event 10**

**Table 54. Depth Duration Frequency Analyses for Event 10**

Duration	Depth (in)	Pixel	Time (EDT)	Frequency
15 minutes	0.821	130129	2019-05-29 18:05	2 yr.
30 minutes	1.060	165114	2019-05-29 14:15	2 yr.
1 hour	1.291	163114	2019-05-29 14:30	2 yr.
2 hour	1.536	140135	2019-05-29 18:55	2 yr.
3 hour	1.579	140135	2019-05-29 19:00	2 yr.
6 hour	1.961	130129	2019-05-29 18:55	2 yr.
12 hour	1.967	130129	2019-05-30 01:20	1 yr.

**Event 11: 2019-05-30**

The analysis period was from 2019-05-30 06:00 EDT to 2019-05-30 22:00 EDT. The event was then split into five sub-event periods at 2019-05-30 12:00 EDT, 2019-05-30 14:15 EDT, 2019-05-30 15:05 EDT and 2019-05-30 17:00 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 55 shows the mean bias and average depth of the event along with the AD and CAD, respectively. Tables 56 - 60 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  $Diff^*$  (%) 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 42 - 46 show the scatter plots of the gauge-adjusted RG pairs. Those gauges not used to adjust the radar are shown in red. Figure 47 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 - 1.8 inches with a mean of 0.5 inches. The GARR amounts for the 440 RFM basins range from 0.2 - 1.3 inches with a mean of 0.4 inches. The GARR amounts for the 871 RFM sheds range from 0.2 - 1.3 inches with a mean of 0.4 inches. Table 61 shows the Depth Duration Frequency (DDF) maximum values for the 1-km<sup>2</sup> pixels.

**Table 55. GARR Statistics for Event 11**

Event #	Radar	Event Date	Start Time (EDT)	End Time (EDT)	Gauges Used (37)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E11a	KPBZ LII	2019-05-30	2019-05-30 06:05	2019-05-30 12:00	27	0.199	1.254	19.7	2.7
E11b	KPBZ LII	2019-05-30	2019-05-30 12:05	2019-05-30 14:15	5	0.045	1.111	22.0	1.4

Event #	Radar	Event Date	Start Time (EDT)	End Time (EDT)	Gauges Used (37)	Avg. Depth (in)	Bias	AD (%)	CAD (%)
E11c	KPBZ LII	2019-05-30	2019-05-30 14:20	2019-05-30 15:05	9	0.152	1.684	38.8	4.9
E11d	KPBZ LII	2019-05-30	2019-05-30 15:10	2019-05-30 17:00	25	0.120	1.204	24.2	5.7
E11e	KPBZ LII	2019-05-30	2019-05-30 17:05	2019-05-30 22:00	5	0.028	1.245	50.8	1.8

**Table 56. Summary of Individual RG Pairs for Event 11a**

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	0.08	0.11	0.10	-0.02	-25.0	
<a href="#">Loc01</a>	PWSA-Montana St.	0.16	0.19	0.17	-0.01	-6.3	
<a href="#">03049500</a>	Allegheny River at Natrona	0.30	0.26	0.30	0.00	0.0	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.13	0.11	0.13	0.00	0.0	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.11	0.09	0.11	0.00	0.0	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.20	0.10	0.20	0.00	0.0	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.11	0.12	0.11	0.00	0.0	
<a href="#">Loc04</a>	Kennedy Twp PS	0.13	0.12	0.13	0.00	0.0	
<a href="#">Loc06</a>	Carnegie Transit Time	0.13	0.10	0.13	0.00	0.0	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.11	0.09	0.11	0.00	0.0	
<a href="#">Loc11</a>	M-46 Access Shaft	0.10	0.10	0.10	0.00	0.0	
<a href="#">Loc12</a>	Baldwin	0.08	0.08	0.08	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.11	0.10	0.11	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.09	0.08	0.09	0.00	0.0	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.11	0.12	0.11	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.08	0.06	0.08	0.00	0.0	
<a href="#">Loc24</a>	Jefferson Hills	0.19	0.12	0.19	0.00	0.0	
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.13	0.11	0.13	0.00	0.0	
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.24	0.18	0.24	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.11	0.10	0.11	0.00	0.0	
<a href="#">Loc30</a>	McCandless Twn Hall	0.58	0.27	0.58	0.00	0.0	
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.32	0.24	0.32	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.32	0.30	0.32	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.19	0.10	0.19	0.00	0.0	
<a href="#">Loc17</a>	Chartiers Pump Station	0.17	0.11	0.16	0.01	5.9	

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	0.12	0.11	0.11	0.01	8.3	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.11	0.11	0.10	0.01	9.1	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.05	---	---	---	---	C
<a href="#">Loc05</a>	Upper St. Clair	0.12	---	---	---	---	C
<a href="#">Loc10</a>	PWSA-Highland Park	0.09	---	---	---	---	C
<a href="#">Loc13</a>	M-59 Access Shaft	ND	---	---	---	---	ND
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc20</a>	Gascola Eq Facility	0.00	---	---	---	---	C
<a href="#">Loc21</a>	Moon TWP	0.60	---	---	---	---	O
<a href="#">Loc23</a>	Clinton Munic Bldg	0.29	---	---	---	---	C
<a href="#">Loc27</a>	Marshall TWP	0.20	---	---	---	---	C
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.45	---	---	---	---	C

**Table 57. Summary of Individual RG Pairs for Event 11b**

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	0.13	0.14	0.14	-0.01	-7.7	
<a href="#">03049500</a>	Allegheny River at Natrona	0.23	0.18	0.23	0.00	0.0	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.07	0.06	0.07	0.00	0.0	
<a href="#">Loc21</a>	Moon TWP	0.12	0.09	0.12	0.00	0.0	
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.05	0.07	0.05	0.00	0.0	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.08	---	---	---	---	MSTT
<a href="#">Loc01</a>	PWSA-Montana St.	0.01	---	---	---	---	MSTT
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.02	---	---	---	---	MSTT
<a href="#">Loc03</a>	Shaler Munic Bldg	0.03	---	---	---	---	C
<a href="#">Loc04</a>	Kennedy Twp PS	0.04	---	---	---	---	MSTT
<a href="#">Loc05</a>	Upper St. Clair	0.03	---	---	---	---	C
<a href="#">Loc06</a>	Carnegie Transit Time	0.00	---	---	---	---	MSTT
<a href="#">Loc07</a>	Greentree Munic Bldg	0.02	---	---	---	---	MSTT
<a href="#">Loc08</a>	AC Health Dept Bldg	0.02	---	---	---	---	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	0.03	---	---	---	---	MSTT
<a href="#">Loc12</a>	Baldwin	0.04	---	---	---	---	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	ND	---	---	---	---	ND
<a href="#">Loc14</a>	Churchill Munic Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc15</a>	Trafford Maint Bldg	0.02	---	---	---	---	MSTT
<a href="#">Loc16</a>	Castle Shannon	0.02	---	---	---	---	MSTT
<a href="#">Loc17</a>	Chartiers Pump Station	0.00	---	---	---	---	MSTT
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.01	---	---	---	---	MSTT
<a href="#">Loc20</a>	Gascola Eq Facility	0.00	---	---	---	---	MSTT
<a href="#">Loc22</a>	North Fayette TWP	0.01	---	---	---	---	MSTT
<a href="#">Loc23</a>	Clinton Munic Bldg	0.06	---	---	---	---	C
<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	0.05	---	---	---	---	C
<a href="#">Loc28</a>	Plum Municipal Bldg	0.03	---	---	---	---	MSTT
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.01	---	---	---	---	C
<a href="#">Loc30</a>	McCandless Twn Hall	0.03	---	---	---	---	MSTT
<a href="#">Loc32</a>	Arnold	0.03	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	0.02	---	---	---	---	MSTT

**Table 58. Summary of Individual RG Pairs for Event 11c**

Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc04</a>	Kennedy Twp PS	0.08	0.09	0.10	-0.02	-25.0	
<a href="#">Loc01</a>	PWSA-Montana St.	0.21	0.23	0.22	-0.01	-4.8	
<a href="#">Loc21</a>	Moon TWP	0.71	0.41	0.73	-0.02	-2.8	
<a href="#">Loc30</a>	McCandless Twn Hall	0.30	0.15	0.30	0.00	0.0	
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.54	0.27	0.54	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.14	0.08	0.14	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.21	0.13	0.21	0.00	0.0	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.41	0.19	0.40	0.01	2.4	
<a href="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.49	0.29	0.44	0.05	10.2	
<a href="#">03049500</a>	Allegheny River at Natrona	0.05	---	---	---	---	U
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	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="#">Loc02</a>	ALCOSAN WWTP Lab	0.02	---	---	---	---	MSTT
<a href="#">Loc03</a>	Shaler Munic Bldg	1.37	---	---	---	---	O
<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	0.00	---	---	---	---	MSTT
<a href="#">Loc11</a>	M-46 Access Shaft	0.00	---	---	---	---	MSTT
<a href="#">Loc12</a>	Baldwin	0.01	---	---	---	---	MSTT
<a href="#">Loc13</a>	M-59 Access Shaft	ND	---	---	---	---	ND
<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	0.01	---	---	---	---	MSTT
<a href="#">Loc17</a>	Chartiers Pump Station	0.00	---	---	---	---	MSTT
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.02	---	---	---	---	MSTT
<a href="#">Loc20</a>	Gascola Eq Facility	0.00	---	---	---	---	MSTT
<a href="#">Loc22</a>	North Fayette TWP	0.00	---	---	---	---	MSTT
<a href="#">Loc23</a>	Clinton Munic Bldg	0.15	---	---	---	---	C
<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	0.17	---	---	---	---	C
<a href="#">Loc28</a>	Plum Municipal Bldg	0.01	---	---	---	---	MSTT
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.08	---	---	---	---	C

**Table 59. Summary of Individual RG Pairs for Event 11d**

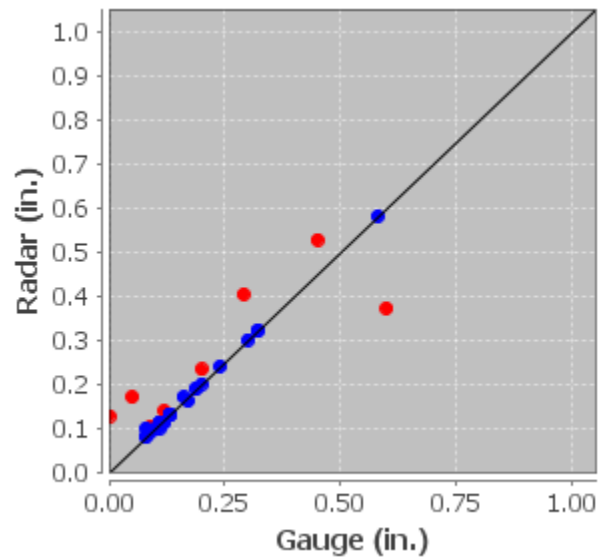
Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc01</a>	PWSA-Montana St.	0.06	0.10	0.09	-0.03	-50.0	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.07	0.09	0.08	-0.01	-14.3	
<a href="#">Loc12</a>	Baldwin	0.08	0.09	0.09	-0.01	-12.5	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.09	0.11	0.10	-0.01	-11.1	

<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="#">03085734</a>	Ohio River at Emsworth Dam Lower Pool at Emsworth	0.08	0.07	0.08	0.00	0.0	
<a href="#">KAGC</a>	Pittsburgh Allegheny Cty	0.08	0.08	0.08	0.00	0.0	
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	0.11	0.07	0.11	0.00	0.0	
<a href="#">Loc04</a>	Kennedy Twp PS	0.09	0.08	0.09	0.00	0.0	
<a href="#">Loc06</a>	Carnegie Transit Time	0.09	0.09	0.09	0.00	0.0	
<a href="#">Loc07</a>	Greentree Munic Bldg	0.09	0.09	0.09	0.00	0.0	
<a href="#">Loc11</a>	M-46 Access Shaft	0.08	0.09	0.08	0.00	0.0	
<a href="#">Loc15</a>	Trafford Maint Bldg	0.06	0.06	0.06	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.12	0.11	0.12	0.00	0.0	
<a href="#">Loc17</a>	Chartiers Pump Station	0.12	0.10	0.12	0.00	0.0	
<a href="#">Loc21</a>	Moon TWP	0.13	0.07	0.13	0.00	0.0	
<a href="#">Loc22</a>	North Fayette TWP	0.07	0.05	0.07	0.00	0.0	
<a href="#">Loc28</a>	Plum Municipal Bldg	0.38	0.44	0.38	0.00	0.0	
<a href="#">Loc30</a>	McCandless Twn Hall	0.07	0.06	0.07	0.00	0.0	
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.19	0.09	0.19	0.00	0.0	
<a href="#">Loc32</a>	Arnold	0.34	0.17	0.34	0.00	0.0	
<a href="#">Loc33</a>	Richland TWP	0.13	0.07	0.13	0.00	0.0	
<a href="#">Loc03</a>	Shaler Munic Bldg	0.19	0.08	0.18	0.01	5.3	
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.30	0.25	0.28	0.02	6.7	
<a href="#">Loc08</a>	AC Health Dept Bldg	0.11	0.10	0.10	0.01	9.1	
<a href="#">Loc02</a>	ALCOSAN WWTP Lab	0.09	0.08	0.08	0.01	11.1	
<a href="#">03049500</a>	Allegheny River at Natrona	0.21	---	---	---	---	U
<a href="#">Loc05</a>	Upper St. Clair	0.07	---	---	---	---	C
<a href="#">Loc10</a>	PWSA-Highland Park	0.00	---	---	---	---	C
<a href="#">Loc13</a>	M-59 Access Shaft	ND	---	---	---	---	ND
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc20</a>	Gascola Eq Facility	0.00	---	---	---	---	C
<a href="#">Loc23</a>	Clinton Munic Bldg	0.29	---	---	---	---	C
<a href="#">Loc24</a>	Jefferson Hills	0.02	---	---	---	---	MSTT
<a href="#">Loc25</a>	White Oak Public Works Bldg	0.03	---	---	---	---	MSTT
<a href="#">Loc26</a>	Elizabeth TWP Municipal Bldg	0.02	---	---	---	---	MSTT
<a href="#">Loc27</a>	Marshall TWP	0.05	---	---	---	---	C
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.17	---	---	---	---	C

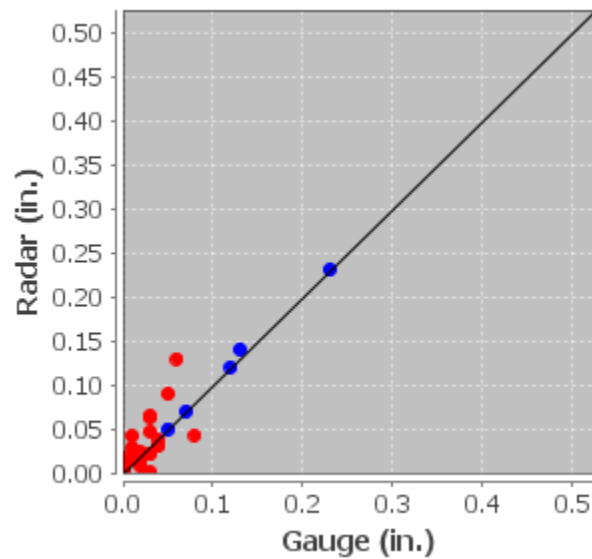
**Table 60. Summary of Individual RG Pairs for Event 11e**

<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="#">Loc07</a>	Greentree Munic Bldg	0.08	0.12	0.09	-0.01	-12.5	
<a href="#">Loc09</a>	Univ of Pittsburgh	0.05	0.07	0.05	0.00	0.0	
<a href="#">Loc14</a>	Churchill Munic Bldg	0.06	0.09	0.06	0.00	0.0	
<a href="#">Loc16</a>	Castle Shannon	0.17	0.07	0.17	0.00	0.0	
<a href="#">Loc17</a>	Chartiers Pump Station	0.18	0.09	0.18	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	0.05	---	---	---	---	MSTT
<a href="#">KPIT</a>	Greater Pittsburgh Int'l	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	0.00	---	---	---	---	MSTT
<a href="#">Loc04</a>	Kennedy Twp PS	0.00	---	---	---	---	MSTT
<a href="#">Loc05</a>	Upper St. Clair	0.06	---	---	---	---	C
<a href="#">Loc06</a>	Carnegie Transit Time	0.23	---	---	---	---	C
<a href="#">Loc08</a>	AC Health Dept Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc10</a>	PWSA-Highland Park	0.00	---	---	---	---	MSTT
<a href="#">Loc11</a>	M-46 Access Shaft	0.17	---	---	---	---	C
<a href="#">Loc12</a>	Baldwin	0.08	---	---	---	---	MSTT
<a href="#">Loc13</a>	M-59 Access Shaft	ND	---	---	---	---	ND
<a href="#">Loc15</a>	Trafford Maint Bldg	0.01	---	---	---	---	MSTT
<a href="#">Loc18</a>	Oakdale Pump Station	ND	---	---	---	---	ND
<a href="#">Loc19</a>	Sandy Creek Eq Facility	0.01	---	---	---	---	MSTT
<a href="#">Loc20</a>	Gascola Eq Facility	0.00	---	---	---	---	C
<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	0.24	---	---	---	---	C
<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	0.01	---	---	---	---	C
<a href="#">Loc28</a>	Plum Municipal Bldg	0.00	---	---	---	---	MSTT
<a href="#">Loc29</a>	Bell Acres Munic Bldg	0.15	---	---	---	---	C
<a href="#">Loc30</a>	McCandless Twn Hall	0.00	---	---	---	---	MSTT
<a href="#">Loc31</a>	Hampton Municipal Bldg	0.00	---	---	---	---	MSTT

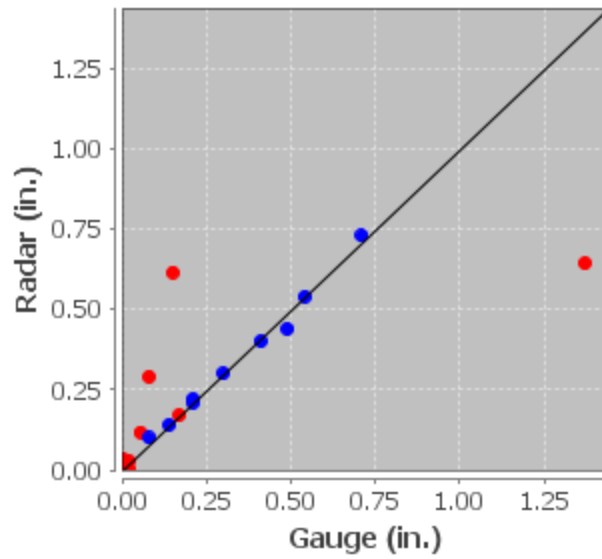
Gauge ID	Name	G <sub>i</sub> (in)	R <sub>i</sub> (in)	R <sub>i</sub> * (in)	Diff* (in)	Diff* (%)	Flag
<a href="#">Loc32</a>	Arnold	0.00	---	---	---	---	MSTT
<a href="#">Loc33</a>	Richland TWP	0.00	---	---	---	---	MSTT



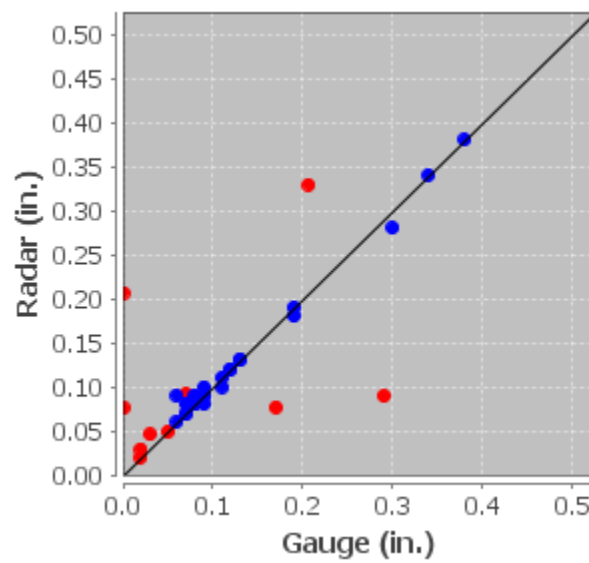
**Figure 42. Scatter Plot of RG Pairs for Event 11a**



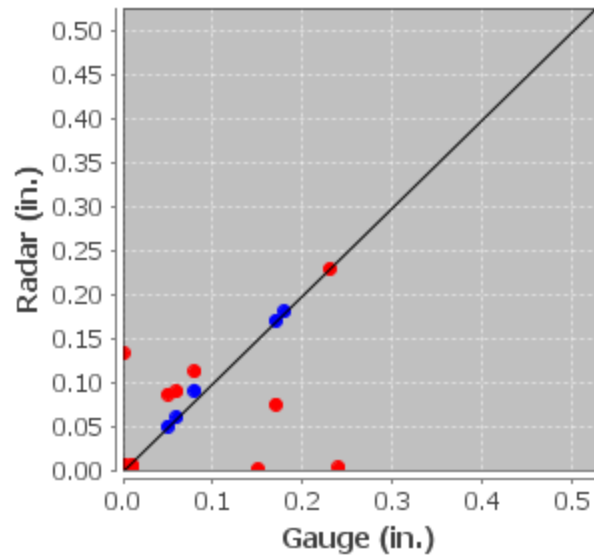
**Figure 43. Scatter Plot of RG Pairs for Event 11b**



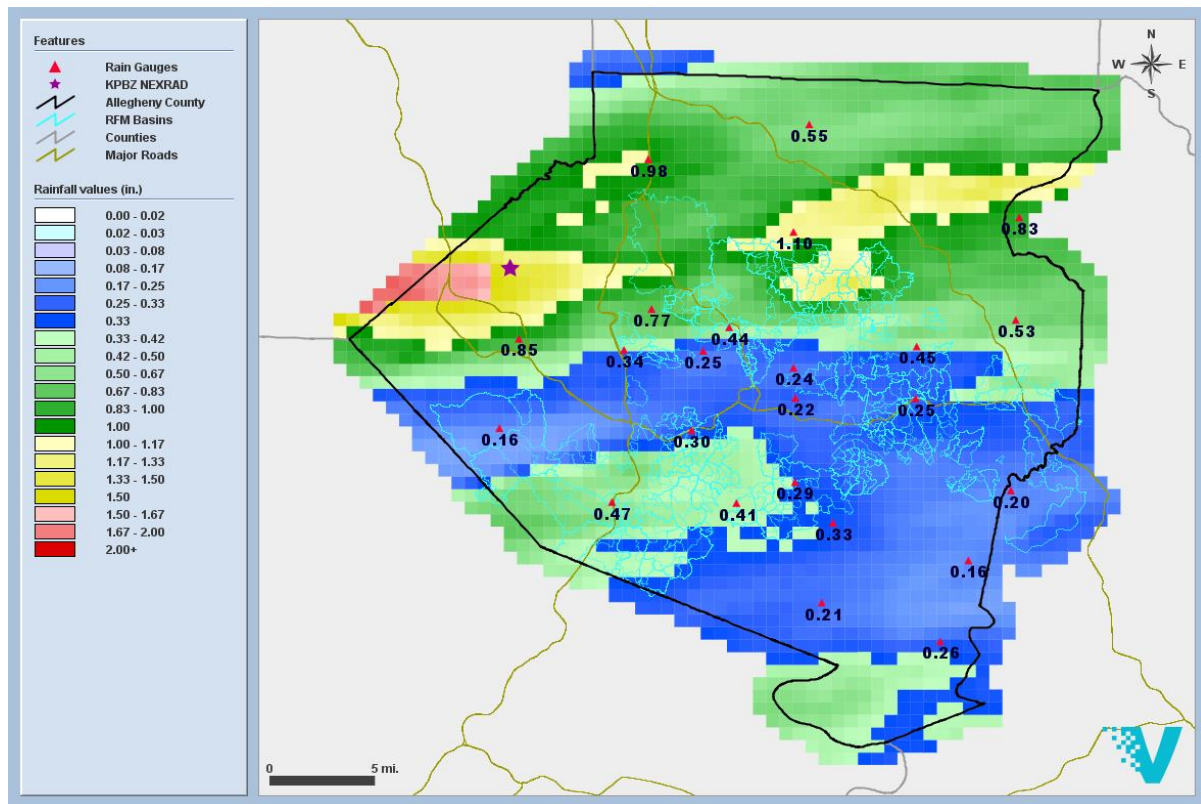
**Figure 44. Scatter Plot of RG Pairs for Event 11c**



**Figure 45. Scatter Plot of RG Pairs for Event 11d**



**Figure 46. Scatter Plot of RG Pairs for Event 11e**



**Figure 47. GARR Storm Total for Event 11**

**Table 61. Depth Duration Frequency Analyses for Event 11**

<b>Duration</b>	<b>Depth (in)</b>	<b>Pixel</b>	<b>Time (EDT)</b>	<b>Frequency</b>
15 minutes	0.534	157121	2019-05-30 09:10	<1 yr.
30 minutes	0.711	117131	2019-05-30 08:45	<1 yr.
1 hour	1.020	119129	2019-05-30 15:05	1 yr.
2 hour	1.129	119129	2019-05-30 15:35	1 yr.
3 hour	1.142	119129	2019-05-30 16:40	<1 yr.
6 hour	1.151	119129	2019-05-30 16:40	<1 yr.
12 hour	1.754	117131	2019-05-30 18:00	1 yr.

## Appendices



[Appendix A](#) - Gauge Performance Exclusion Table  
[Appendix B](#) - Gauge Statistical Criteria Exclusion Table  
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[Appendix M](#) - Event 11 (2019-05-30) 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="#">E1</a>	<a href="#">E2a</a>	<a href="#">E2b</a>	<a href="#">E2c</a>	<a href="#">E2d</a>
Event Date	2019-05-02	2019-05-05	2019-05-05	2019-05-05	2019-05-05
Start Time (EDT)	2019-05-02 19:05	2019-05-04 15:05	2019-05-04 22:05	2019-05-05 01:35	2019-05-05 03:05
End Time (EDT)	2019-05-03 03:00	2019-05-04 22:00	2019-05-05 01:30	2019-05-05 03:00	2019-05-05 06:30
Loc01	U				
Loc02					
Loc03					
Loc04					
Loc05					
Loc06	U				
Loc07					
Loc08					
Loc09	U				
Loc10					
Loc11					
Loc12					
Loc13	U				
Loc14					
Loc15					
Loc16					
Loc17					
Loc18	ND	ND	ND	ND	ND
Loc19					
Loc20					
Loc21					
Loc22					
Loc23					
Loc24					
Loc25	ND	ND	ND	ND	ND

Event #	<a href="#"><u>E1</u></a>	<a href="#"><u>E2a</u></a>	<a href="#"><u>E2b</u></a>	<a href="#"><u>E2c</u></a>	<a href="#"><u>E2d</u></a>
Event Date	2019-05-02	2019-05-05	2019-05-05	2019-05-05	2019-05-05
Start Time (EDT)	2019-05-02 19:05	2019-05-04 15:05	2019-05-04 22:05	2019-05-05 01:35	2019-05-05 03:05
End Time (EDT)	2019-05-03 03:00	2019-05-04 22:00	2019-05-05 01:30	2019-05-05 03:00	2019-05-05 06:30
Loc26					
Loc27					
Loc28					
Loc29					
Loc30					
Loc31					
Loc32					
Loc33					
KAGC					T
KPIT					T
03049500					T
03085734					T

Event #	<a href="#">E2e</a>	<a href="#">E3a</a>	<a href="#">E3b</a>	<a href="#">E3c</a>	<a href="#">E3d</a>
Event Date	2019-05-05	2019-05-10	2019-05-10	2019-05-10	2019-05-10
Start Time (EDT)	2019-05-05 06:35	2019-05-09 12:05	2019-05-09 23:25	2019-05-10 00:10	2019-05-10 02:35
End Time (EDT)	2019-05-05 15:00	2019-05-09 23:20	2019-05-10 00:05	2019-05-10 02:30	2019-05-10 11:55
Loc01					
Loc02					
Loc03					
Loc04					
Loc05					
Loc06					
Loc07					
Loc08		O			
Loc09					
Loc10					
Loc11		S			
Loc12		O	S		
Loc13				S	Z
Loc14					
Loc15					
Loc16					
Loc17					
Loc18	ND	ND	ND	ND	ND
Loc19					
Loc20					
Loc21					
Loc22					
Loc23					

<b>Event #</b>	<b><a href="#">E2e</a></b>	<b><a href="#">E3a</a></b>	<b><a href="#">E3b</a></b>	<b><a href="#">E3c</a></b>	<b><a href="#">E3d</a></b>
<b>Event Date</b>	<b>2019-05-05</b>	<b>2019-05-10</b>	<b>2019-05-10</b>	<b>2019-05-10</b>	<b>2019-05-10</b>
<b>Start Time (EDT)</b>	2019-05-05 06:35	2019-05-09 12:05	2019-05-09 23:25	2019-05-10 00:10	2019-05-10 02:35
<b>End Time (EDT)</b>	2019-05-05 15:00	2019-05-09 23:20	2019-05-10 00:05	2019-05-10 02:30	2019-05-10 11:55
Loc24					
Loc25	ND	ND	ND	ND	ND
Loc26					
Loc27					
Loc28					
Loc29					
Loc30					
Loc31					O
Loc32					
Loc33					
KAGC					
KPIT					
03049500					
03085734					

Event #	<a href="#">E3e</a>	<a href="#">E4a</a>	<a href="#">E4b</a>	<a href="#">E4c</a>	<a href="#">E4d</a>
Event Date	2019-05-10	2019-05-12	2019-05-12	2019-05-12	2019-05-12
Start Time (EDT)	2019-05-10 12:00	2019-05-11 14:05	2019-05-12 03:05	2019-05-12 04:55	2019-05-12 09:05
End Time (EDT)	2019-05-10 18:00	2019-05-12 03:00	2019-05-12 04:50	2019-05-12 09:00	2019-05-12 17:00
Loc01					
Loc02					
Loc03					
Loc04					
Loc05					
Loc06					
Loc07					
Loc08					
Loc09					
Loc10					
Loc11					
Loc12					
Loc13		ND	ND	ND	ND
Loc14					
Loc15					
Loc16					
Loc17					
Loc18	ND	ND	ND	ND	ND
Loc19					
Loc20					
Loc21					
Loc22					
Loc23					

Event #	<a href="#">E3e</a>	<a href="#">E4a</a>	<a href="#">E4b</a>	<a href="#">E4c</a>	<a href="#">E4d</a>
Event Date	2019-05-10	2019-05-12	2019-05-12	2019-05-12	2019-05-12
Start Time (EDT)	2019-05-10 12:00	2019-05-11 14:05	2019-05-12 03:05	2019-05-12 04:55	2019-05-12 09:05
End Time (EDT)	2019-05-10 18:00	2019-05-12 03:00	2019-05-12 04:50	2019-05-12 09:00	2019-05-12 17:00
Loc24					
Loc25	ND	ND			
Loc26					
Loc27					
Loc28					
Loc29					
Loc30					
Loc31					
Loc32					
Loc33					
KAGC					T
KPIT					T
03049500					T
03085734					T



Event #	<a href="#">E5a</a>	<a href="#">E5b</a>	<a href="#">E5c</a>	<a href="#">E6</a>	<a href="#">E7</a>
Event Date	2019-05-17	2019-05-17	2019-05-17	2019-05-23	2019-05-26
Start Time (EDT)	2019-05-17 14:05	2019-05-18 00:05	2019-05-18 01:10	2019-05-23 18:05	2019-05-26 07:05
End Time (EDT)	2019-05-18 00:00	2019-05-18 01:05	2019-05-18 13:00	2019-05-24 02:00	2019-05-26 15:00
Loc01					
Loc02					
Loc03				C	C
Loc04				C	C
Loc05				Z	C
Loc06					
Loc07					
Loc08					
Loc09					
Loc10					
Loc11					
Loc12					
Loc13	ND	ND	ND	ND	ND
Loc14					C
Loc15				C	C
Loc16					
Loc17					
Loc18	ND	ND	ND	ND	ND
Loc19					
Loc20				C	C
Loc21					
Loc22					
Loc23					

Event #	<a href="#">E5a</a>	<a href="#">E5b</a>	<a href="#">E5c</a>	<a href="#">E6</a>	<a href="#">E7</a>
Event Date	2019-05-17	2019-05-17	2019-05-17	2019-05-23	2019-05-26
Start Time (EDT)	2019-05-17 14:05	2019-05-18 00:05	2019-05-18 01:10	2019-05-23 18:05	2019-05-26 07:05
End Time (EDT)	2019-05-18 00:00	2019-05-18 01:05	2019-05-18 13:00	2019-05-24 02:00	2019-05-26 15:00
Loc24					
Loc25	ND			C	
Loc26					
Loc27					
Loc28					
Loc29					
Loc30					C
Loc31					C
Loc32					
Loc33					
KAGC					
KPIT					
03049500					
03085734					

Event #	<a href="#">E8</a>	<a href="#">E9a</a>	<a href="#">E9b</a>	<a href="#">E9c</a>	<a href="#">E9d</a>
Event Date	2019-05-28 AM	2019-05-28 PM	2019-05-28 PM	2019-05-28 PM	2019-05-28 PM
Start Time (EDT)	2019-05-28 00:05	2019-05-28 11:05	2019-05-28 20:15	2019-05-28 21:35	2019-05-29 00:25
End Time (EDT)	2019-05-28 11:00	2019-05-28 20:10	2019-05-28 21:30	2019-05-29 00:20	2019-05-29 09:00
Loc01					
Loc02					
Loc03	C		C	C	C
Loc04	C				
Loc05	C				
Loc06				U	
Loc07					
Loc08					
Loc09					
Loc10				C	C
Loc11					
Loc12					
Loc13	ND	ND	ND	ND	ND
Loc14	C	C	C	C	C
Loc15	C			C	C
Loc16					
Loc17					
Loc18	ND	ND	ND	ND	ND
Loc19					
Loc20	C	C		C	C
Loc21					
Loc22					
Loc23					

Event #	<a href="#">E8</a>	<a href="#">E9a</a>	<a href="#">E9b</a>	<a href="#">E9c</a>	<a href="#">E9d</a>
Event Date	2019-05-28 AM	2019-05-28 PM	2019-05-28 PM	2019-05-28 PM	2019-05-28 PM
Start Time (EDT)	2019-05-28 00:05	2019-05-28 11:05	2019-05-28 20:15	2019-05-28 21:35	2019-05-29 00:25
End Time (EDT)	2019-05-28 11:00	2019-05-28 20:10	2019-05-28 21:30	2019-05-29 00:20	2019-05-29 09:00
Loc24					
Loc25	C			C	C
Loc26					
Loc27					
Loc28					
Loc29					
Loc30	C	C	C	C	C
Loc31	C	C	C	C	C
Loc32					
Loc33					
KAGC	U				
KPIT					
03049500	U				U
03085734					

Event #	<a href="#">E10a</a>	<a href="#">E10b</a>	<a href="#">E10c</a>	<a href="#">E10d</a>	<a href="#">E10e</a>
Event Date	2019-05-29	2019-05-29	2019-05-29	2019-05-29	2019-05-29
Start Time (EDT)	2019-05-29 09:05	2019-05-29 15:25	2019-05-29 16:05	2019-05-29 17:30	2019-05-29 21:35
End Time (EDT)	2019-05-29 15:20	2019-05-29 16:00	2019-05-29 17:25	2019-05-29 21:30	2019-05-30 06:00
Loc01				U	
Loc02					
Loc03	C		C	C	C
Loc04					
Loc05	C	C	C	C	
Loc06					U
Loc07					
Loc08					
Loc09					
Loc10	C		C	C	C
Loc11	O			C	C
Loc12					
Loc13	ND	ND	ND	ND	ND
Loc14	C				
Loc15					
Loc16					
Loc17	O				
Loc18	ND	ND	ND	ND	ND
Loc19					
Loc20	C			C	
Loc21					
Loc22					
Loc23	C		C	C	C

Event #	<a href="#">E10a</a>	<a href="#">E10b</a>	<a href="#">E10c</a>	<a href="#">E10d</a>	<a href="#">E10e</a>
Event Date	2019-05-29	2019-05-29	2019-05-29	2019-05-29	2019-05-29
Start Time (EDT)	2019-05-29 09:05	2019-05-29 15:25	2019-05-29 16:05	2019-05-29 17:30	2019-05-29 21:35
End Time (EDT)	2019-05-29 15:20	2019-05-29 16:00	2019-05-29 17:25	2019-05-29 21:30	2019-05-30 06:00
Loc24					
Loc25	C				
Loc26					
Loc27	C				
Loc28					
Loc29	C			C	
Loc30	C				
Loc31					
Loc32					
Loc33					
KAGC	U	O			
KPIT					
03049500					
03085734					

Event #	<a href="#">E11a</a>	<a href="#">E11b</a>	<a href="#">E11c</a>	<a href="#">E11d</a>	<a href="#">E11e</a>
Event Date	2019-05-30	2019-05-30	2019-05-30	2019-05-30	2019-05-30
Start Time (EDT)	2019-05-30 06:05	2019-05-30 12:05	2019-05-30 14:20	2019-05-30 15:10	2019-05-30 17:05
End Time (EDT)	2019-05-30 12:00	2019-05-30 14:15	2019-05-30 15:05	2019-05-30 17:00	2019-05-30 22:00
Loc01					
Loc02					
Loc03	C	C	O		
Loc04					
Loc05	C	C		C	C
Loc06					C
Loc07					
Loc08					
Loc09					
Loc10	C			C	
Loc11					C
Loc12					
Loc13	ND	ND	ND	ND	ND
Loc14					
Loc15					
Loc16					
Loc17					
Loc18	ND	ND	ND	ND	ND
Loc19					
Loc20	C			C	C
Loc21	O				
Loc22					
Loc23	C	C	C	C	C

Event #	<a href="#">E11a</a>	<a href="#">E11b</a>	<a href="#">E11c</a>	<a href="#">E11d</a>	<a href="#">E11e</a>
Event Date	2019-05-30	2019-05-30	2019-05-30	2019-05-30	2019-05-30
Start Time (EDT)	2019-05-30 06:05	2019-05-30 12:05	2019-05-30 14:20	2019-05-30 15:10	2019-05-30 17:05
End Time (EDT)	2019-05-30 12:00	2019-05-30 14:15	2019-05-30 15:05	2019-05-30 17:00	2019-05-30 22:00
Loc24					
Loc25					
Loc26					
Loc27	C	C	C	C	C
Loc28					
Loc29	C	C	C	C	C
Loc30					
Loc31					
Loc32					
Loc33					
KAGC					
KPIT					
03049500			U	U	
03085734					



### 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="#">E1</a>	<a href="#">E2a</a>	<a href="#">E2b</a>	<a href="#">E2c</a>	<a href="#">E2e</a>
Event Date	2019-05-02	2019-05-05	2019-05-05	2019-05-05	2019-05-05
Start Time (EDT)	2019-05-02 19:05	2019-05-04 15:05	2019-05-04 22:05	2019-05-05 01:35	2019-05-05 06:35
End Time (EDT)	2019-05-03 03:00	2019-05-04 22:00	2019-05-05 01:30	2019-05-05 03:00	2019-05-05 15:00
Source	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII
Loc01				MSTT	
Loc02				MSTT	
Loc03				MSTT	MSTT
Loc04				MSTT	MSTT
Loc05		MSTT		MSTT	MSTT
Loc06		MSTT			MSTT
Loc07					MSTT
Loc08					
Loc09					
Loc10					
Loc11					
Loc12		MSTT			
Loc13		MSTT		OAD	MSTT
Loc14					
Loc15		MSTT	MSTT		
Loc16		MSTT		MSTT	
Loc17		MSTT			MSTT
Loc18					
Loc19					MSTT
Loc20		MSTT			
Loc21		MSTT	MSTT	MSTT	MSTT
Loc22			MSTT		MSTT
Loc23			MSTT	MSTT	MSTT
Loc24		MSTT			

<b>Event #</b>	<b><u>E1</u></b>	<b><u>E2a</u></b>	<b><u>E2b</u></b>	<b><u>E2c</u></b>	<b><u>E2e</u></b>
<b>Event Date</b>	<b>2019-05-02</b>	<b>2019-05-05</b>	<b>2019-05-05</b>	<b>2019-05-05</b>	<b>2019-05-05</b>
<b>Start Time (EDT)</b>	2019-05-02 19:05	2019-05-04 15:05	2019-05-04 22:05	2019-05-05 01:35	2019-05-05 06:35
<b>End Time (EDT)</b>	2019-05-03 03:00	2019-05-04 22:00	2019-05-05 01:30	2019-05-05 03:00	2019-05-05 15:00
<b>Source</b>	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII
Loc25					
Loc26		MSTT			OAD
Loc27			MSTT	MSTT	MSTT
Loc28		MSTT			MSTT
Loc29			MSTT	MSTT	MSTT
Loc30			MSTT	MSTT	MSTT
Loc31	OAD	MSTT	OMFB	MSTT	MSTT
Loc32	MSTT	MSTT			MSTT
Loc33		MSTT		MSTT	MSTT
KAGC		MSTT			
KPIT		MSTT		MSTT	MSTT
03049500	MSTT	MSTT			MSTT
03085734		MSTT		MSTT	MSTT

Event #	<a href="#">E3a</a>	<a href="#">E3b</a>	<a href="#">E3c</a>	<a href="#">E3d</a>	<a href="#">E3e</a>
Event Date	2019-05-10	2019-05-10	2019-05-10	2019-05-10	2019-05-10
Start Time (EDT)	2019-05-09 12:05	2019-05-09 23:25	2019-05-10 00:10	2019-05-10 02:35	2019-05-10 12:00
End Time (EDT)	2019-05-09 23:20	2019-05-10 00:05	2019-05-10 02:30	2019-05-10 11:55	2019-05-10 18:00
Source	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII
Loc01	MSTT	MSTT			MSTT
Loc02		MSTT			MSTT
Loc03					MSTT
Loc04					
Loc05			MSTT		MSTT
Loc06					MSTT
Loc07					MSTT
Loc08					MSTT
Loc09					
Loc10					
Loc11					MSTT
Loc12					MSTT
Loc13					MSTT
Loc14					MSTT
Loc15	MSTT				MSTT
Loc16					MSTT
Loc17			MSTT		MSTT
Loc18					
Loc19				MSTT	
Loc20				MSTT	MSTT
Loc21	MSTT	MSTT			MSTT
Loc22	MSTT				MSTT

Event #	<a href="#">E3a</a>	<a href="#">E3b</a>	<a href="#">E3c</a>	<a href="#">E3d</a>	<a href="#">E3e</a>
Event Date	2019-05-10	2019-05-10	2019-05-10	2019-05-10	2019-05-10
Start Time (EDT)	2019-05-09 12:05	2019-05-09 23:25	2019-05-10 00:10	2019-05-10 02:35	2019-05-10 12:00
End Time (EDT)	2019-05-09 23:20	2019-05-10 00:05	2019-05-10 02:30	2019-05-10 11:55	2019-05-10 18:00
Source	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII
Loc23	MSTT	MSTT			
Loc24				MSTT	MSTT
Loc25					
Loc26				MSTT	MSTT
Loc27		MSTT			MSTT
Loc28				MSTT	
Loc29		MSTT			MSTT
Loc30	MSTT	MSTT			MSTT
Loc31		MSTT			MSTT
Loc32				MSTT	MSTT
Loc33	MSTT	MSTT			MSTT
KAGC				OAD	MSTT
KPIT	MSTT	MSTT			MSTT
03049500					MSTT
03085734	MSTT	MSTT			MSTT

Event #	<a href="#">E4a</a>	<a href="#">E4b</a>	<a href="#">E4c</a>	<a href="#">E5a</a>	<a href="#">E5b</a>
Event Date	2019-05-12	2019-05-12	2019-05-12	2019-05-17	2019-05-17
Start Time (EDT)	2019-05-11 14:05	2019-05-12 03:05	2019-05-12 04:55	2019-05-17 14:05	2019-05-18 00:05
End Time (EDT)	2019-05-12 03:00	2019-05-12 04:50	2019-05-12 09:00	2019-05-18 00:00	2019-05-18 01:05
Source	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII
Loc01			MSTT		
Loc02			MSTT	MSTT	
Loc03			MSTT		
Loc04			MSTT		
Loc05			MSTT		MSTT
Loc06					MSTT
Loc07					MSTT
Loc08					
Loc09					MSTT
Loc10					
Loc11					
Loc12					MSTT
Loc13					
Loc14					
Loc15					MSTT
Loc16					MSTT
Loc17			MSTT		MSTT
Loc18					
Loc19					
Loc20					
Loc21				MSTT	
Loc22			MSTT		MSTT

<b>Event #</b>	<b><a href="#">E4a</a></b>	<b><a href="#">E4b</a></b>	<b><a href="#">E4c</a></b>	<b><a href="#">E5a</a></b>	<b><a href="#">E5b</a></b>
<b>Event Date</b>	<b>2019-05-12</b>	<b>2019-05-12</b>	<b>2019-05-12</b>	<b>2019-05-17</b>	<b>2019-05-17</b>
<b>Start Time (EDT)</b>	2019-05-11 14:05	2019-05-12 03:05	2019-05-12 04:55	2019-05-17 14:05	2019-05-18 00:05
<b>End Time (EDT)</b>	2019-05-12 03:00	2019-05-12 04:50	2019-05-12 09:00	2019-05-18 00:00	2019-05-18 01:05
<b>Source</b>	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII
Loc23			MSTT		MSTT
Loc24					MSTT
Loc25					MSTT
Loc26					MSTT
Loc27		OMFB	MSTT		MSTT
Loc28					
Loc29			MSTT		MSTT
Loc30			MSTT		MSTT
Loc31			MSTT		MSTT
Loc32			MSTT	MSTT	MSTT
Loc33			MSTT		MSTT
KAGC					MSTT
KPIT			MSTT		MSTT
03049500			MSTT		MSTT
03085734			MSTT	MSTT	

Event #	<a href="#">E5c</a>	<a href="#">E6</a>	<a href="#">E7</a>	<a href="#">E8</a>	<a href="#">E9a</a>
Event Date	2019-05-17	2019-05-23	2019-05-26	2019-05-28 AM	2019-05-28 PM
Start Time (EDT)	2019-05-18 01:10	2019-05-23 18:05	2019-05-26 07:05	2019-05-28 00:05	2019-05-28 11:05
End Time (EDT)	2019-05-18 13:00	2019-05-24 02:00	2019-05-26 15:00	2019-05-28 11:00	2019-05-28 20:10
Source	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII
Loc01			MSTT		MSTT
Loc02			MSTT		MSTT
Loc03					MSTT
Loc04					MSTT
Loc05	MSTT				MSTT
Loc06	MSTT				MSTT
Loc07	MSTT	MSTT			MSTT
Loc08			MSTT		MSTT
Loc09					MSTT
Loc10					MSTT
Loc11					MSTT
Loc12	MSTT				MSTT
Loc13					
Loc14					
Loc15					MSTT
Loc16	MSTT				MSTT
Loc17	MSTT				MSTT
Loc18					
Loc19					MSTT
Loc20					
Loc21		MSTT			MSTT
Loc22	MSTT				MSTT



<b>Event #</b>	<b><a href="#">E5c</a></b>	<b><a href="#">E6</a></b>	<b><a href="#">E7</a></b>	<b><a href="#">E8</a></b>	<b><a href="#">E9a</a></b>
<b>Event Date</b>	<b>2019-05-17</b>	<b>2019-05-23</b>	<b>2019-05-26</b>	<b>2019-05-28 AM</b>	<b>2019-05-28 PM</b>
<b>Start Time (EDT)</b>	2019-05-18 01:10	2019-05-23 18:05	2019-05-26 07:05	2019-05-28 00:05	2019-05-28 11:05
<b>End Time (EDT)</b>	2019-05-18 13:00	2019-05-24 02:00	2019-05-26 15:00	2019-05-28 11:00	2019-05-28 20:10
<b>Source</b>	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII
Loc23	MSTT				MSTT
Loc24	MSTT		MSTT		MSTT
Loc25			MSTT		MSTT
Loc26	MSTT	MSTT	MSTT		MSTT
Loc27	MSTT	MSTT			
Loc28	MSTT	MSTT			
Loc29		MSTT			MSTT
Loc30	MSTT	MSTT			
Loc31	MSTT	MSTT			
Loc32	MSTT	MSTT			
Loc33	MSTT	MSTT			
KAGC	MSTT		MSTT		MSTT
KPIT	MSTT		MSTT		MSTT
03049500	MSTT	MSTT			
03085734					MSTT

Event #	<a href="#">E9b</a>	<a href="#">E9c</a>	<a href="#">E9d</a>	<a href="#">E10a</a>	<a href="#">E10b</a>
Event Date	2019-05-28 PM	2019-05-28 PM	2019-05-28 PM	2019-05-29	2019-05-29
Start Time (EDT)	2019-05-28 20:15	2019-05-28 21:35	2019-05-29 00:25	2019-05-29 09:05	2019-05-29 15:25
End Time (EDT)	2019-05-28 21:30	2019-05-29 00:20	2019-05-29 09:00	2019-05-29 15:20	2019-05-29 16:00
Source	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII
Loc01	MSTT				MSTT
Loc02	MSTT				MSTT
Loc03					MSTT
Loc04	MSTT				MSTT
Loc05	MSTT	MSTT	MSTT		
Loc06	MSTT				
Loc07	MSTT				MSTT
Loc08	MSTT			OAD	MSTT
Loc09	MSTT				MSTT
Loc10	MSTT				MSTT
Loc11	MSTT				
Loc12	MSTT				
Loc13					
Loc14					MSTT
Loc15	MSTT				MSTT
Loc16	MSTT	MSTT			
Loc17	MSTT		MSTT		
Loc18					
Loc19	MSTT				MSTT
Loc20	MSTT				MSTT
Loc21	MSTT				MSTT
Loc22	MSTT	OAD	MSTT		

<b>Event #</b>	<b><a href="#">E9b</a></b>	<b><a href="#">E9c</a></b>	<b><a href="#">E9d</a></b>	<b><a href="#">E10a</a></b>	<b><a href="#">E10b</a></b>
<b>Event Date</b>	<b>2019-05-28 PM</b>	<b>2019-05-28 PM</b>	<b>2019-05-28 PM</b>	<b>2019-05-29</b>	<b>2019-05-29</b>
<b>Start Time (EDT)</b>	2019-05-28 20:15	2019-05-28 21:35	2019-05-29 00:25	2019-05-29 09:05	2019-05-29 15:25
<b>End Time (EDT)</b>	2019-05-28 21:30	2019-05-29 00:20	2019-05-29 09:00	2019-05-29 15:20	2019-05-29 16:00
<b>Source</b>	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII
Loc23	MSTT				MSTT
Loc24	MSTT	MSTT			
Loc25	MSTT				
Loc26	MSTT	MSTT	MSTT		
Loc27					MSTT
Loc28	MSTT				MSTT
Loc29					MSTT
Loc30					MSTT
Loc31					MSTT
Loc32					MSTT
Loc33					MSTT
KAGC	MSTT	MSTT			
KPIT	MSTT				MSTT
03049500					MSTT
03085734	MSTT				MSTT

<b>Event #</b>	<b><u>E10c</u></b>	<b><u>E10d</u></b>	<b><u>E10e</u></b>	<b><u>E11a</u></b>	<b><u>E11b</u></b>
<b>Event Date</b>	<b>2019-05-29</b>	<b>2019-05-29</b>	<b>2019-05-29</b>	<b>2019-05-30</b>	<b>2019-05-30</b>
<b>Start Time (EDT)</b>	2019-05-29 16:05	2019-05-29 17:30	2019-05-29 21:35	2019-05-30 06:05	2019-05-30 12:05
<b>End Time (EDT)</b>	2019-05-29 17:25	2019-05-29 21:30	2019-05-30 06:00	2019-05-30 12:00	2019-05-30 14:15
<b>Source</b>	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII
Loc01	MSTT		MSTT		MSTT
Loc02	MSTT		MSTT		MSTT
Loc03					
Loc04	OAD		MSTT		MSTT
Loc05			MSTT		
Loc06					MSTT
Loc07					MSTT
Loc08			MSTT		MSTT
Loc09			MSTT		MSTT
Loc10					MSTT
Loc11					MSTT
Loc12					MSTT
Loc13					
Loc14			MSTT		MSTT
Loc15	MSTT		MSTT		MSTT
Loc16					MSTT
Loc17			MSTT		MSTT
Loc18					
Loc19					MSTT
Loc20	MSTT		MSTT		MSTT
Loc21	MSTT		MSTT		
Loc22			MSTT		MSTT

<b>Event #</b>	<b><a href="#">E10c</a></b>	<b><a href="#">E10d</a></b>	<b><a href="#">E10e</a></b>	<b><a href="#">E11a</a></b>	<b><a href="#">E11b</a></b>
<b>Event Date</b>	<b>2019-05-29</b>	<b>2019-05-29</b>	<b>2019-05-29</b>	<b>2019-05-30</b>	<b>2019-05-30</b>
<b>Start Time (EDT)</b>	2019-05-29 16:05	2019-05-29 17:30	2019-05-29 21:35	2019-05-30 06:05	2019-05-30 12:05
<b>End Time (EDT)</b>	2019-05-29 17:25	2019-05-29 21:30	2019-05-30 06:00	2019-05-30 12:00	2019-05-30 14:15
<b>Source</b>	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII	KPBZ LII
Loc23					
Loc24	MSTT		MSTT		MSTT
Loc25			MSTT		MSTT
Loc26		MSTT	MSTT		MSTT
Loc27	MSTT	MSTT	MSTT		
Loc28	MSTT	OAD	MSTT		MSTT
Loc29	MSTT		MSTT		
Loc30	MSTT	MSTT	MSTT		MSTT
Loc31	MSTT		MSTT		
Loc32	MSTT		MSTT		MSTT
Loc33	MSTT		MSTT		MSTT
KAGC			MSTT		MSTT
KPIT					
03049500	MSTT		MSTT		
03085734	MSTT		MSTT		

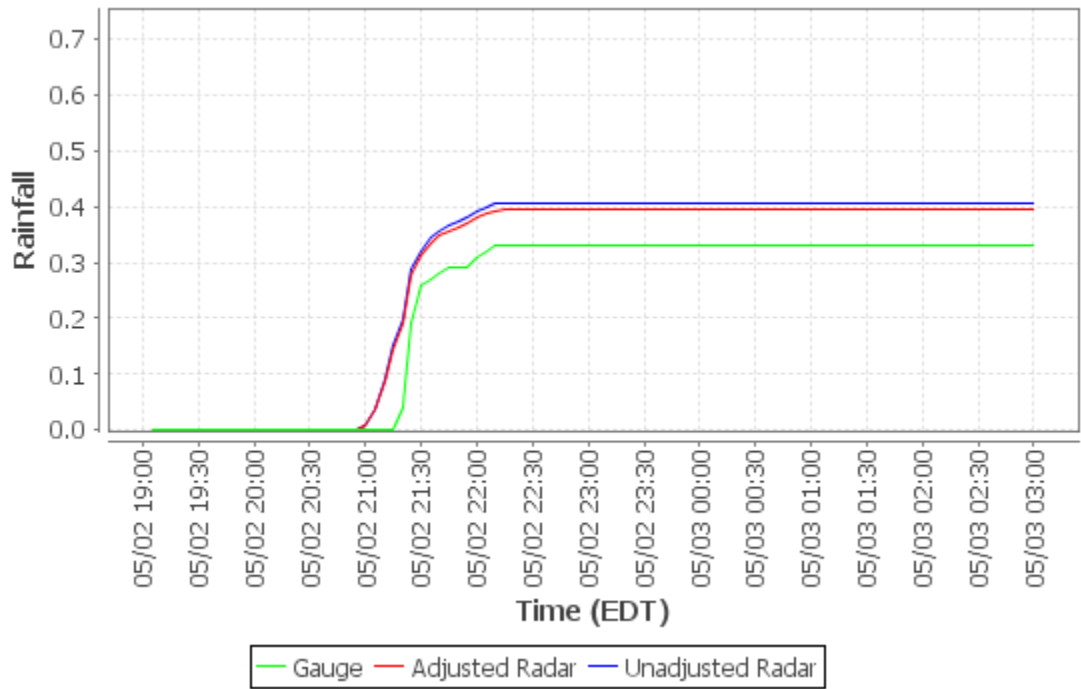
<b>Event #</b>	<b><a href="#">E11c</a></b>	<b><a href="#">E11d</a></b>	<b><a href="#">E11e</a></b>
<b>Event Date</b>	<b>2019-05-30</b>	<b>2019-05-30</b>	<b>2019-05-30</b>
<b>Start Time (EDT)</b>	2019-05-30 14:20	2019-05-30 15:10	2019-05-30 17:05
<b>End Time (EDT)</b>	2019-05-30 15:05	2019-05-30 17:00	2019-05-30 22:00
<b>Source</b>	KPBZ LII	KPBZ LII	KPBZ LII
Loc01			MSTT
Loc02	MSTT		MSTT
Loc03			MSTT
Loc04			MSTT
Loc05	MSTT		
Loc06	MSTT		
Loc07	MSTT		
Loc08	MSTT		MSTT
Loc09	MSTT		
Loc10	MSTT		MSTT
Loc11	MSTT		
Loc12	MSTT		MSTT
Loc13			
Loc14	MSTT		
Loc15	MSTT		MSTT
Loc16	MSTT		
Loc17	MSTT		
Loc18			
Loc19	MSTT		MSTT
Loc20	MSTT		
Loc21			MSTT
Loc22	MSTT		MSTT
Loc23			
Loc24	MSTT	MSTT	MSTT

<b>Event #</b>	<b><a href="#">E11c</a></b>	<b><a href="#">E11d</a></b>	<b><a href="#">E11e</a></b>
<b>Event Date</b>	<b>2019-05-30</b>	<b>2019-05-30</b>	<b>2019-05-30</b>
<b>Start Time (EDT)</b>	2019-05-30 14:20	2019-05-30 15:10	2019-05-30 17:05
<b>End Time (EDT)</b>	2019-05-30 15:05	2019-05-30 17:00	2019-05-30 22:00
<b>Source</b>	KPBZ LII	KPBZ LII	KPBZ LII
Loc25	MSTT	MSTT	MSTT
Loc26	MSTT	MSTT	MSTT
Loc27			
Loc28	MSTT		MSTT
Loc29			
Loc30			MSTT
Loc31			MSTT
Loc32			MSTT
Loc33			MSTT
KAGC	MSTT		MSTT
KPIT			MSTT
03049500			MSTT
03085734			MSTT

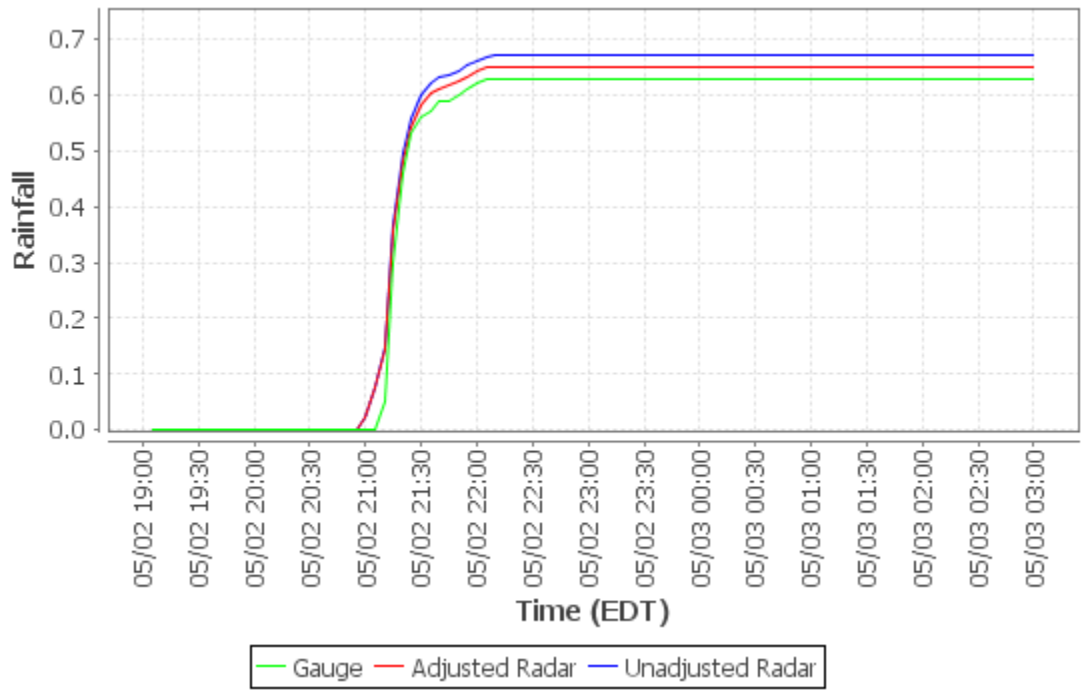
## **Appendix C - Event 1 (2019-05-02) CDPs**



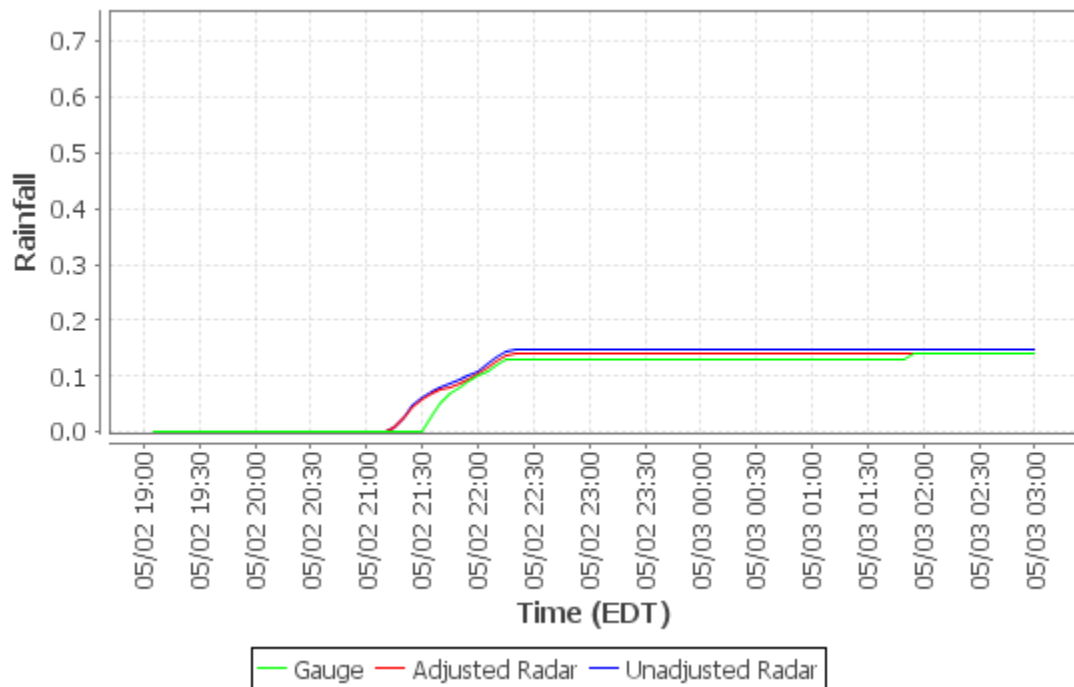
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



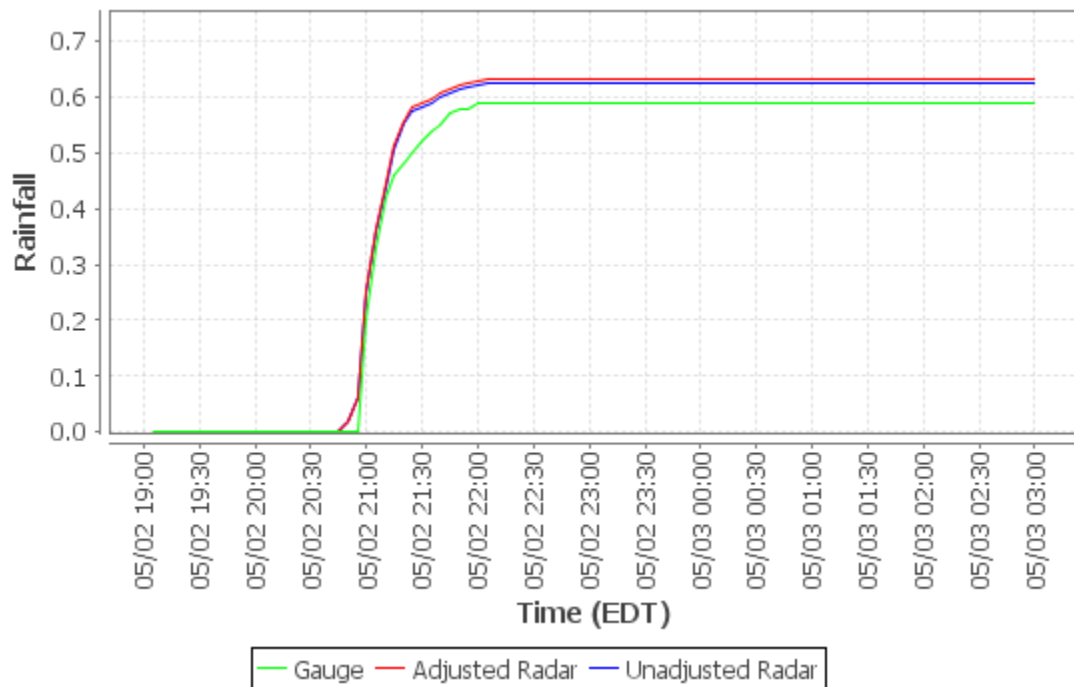
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



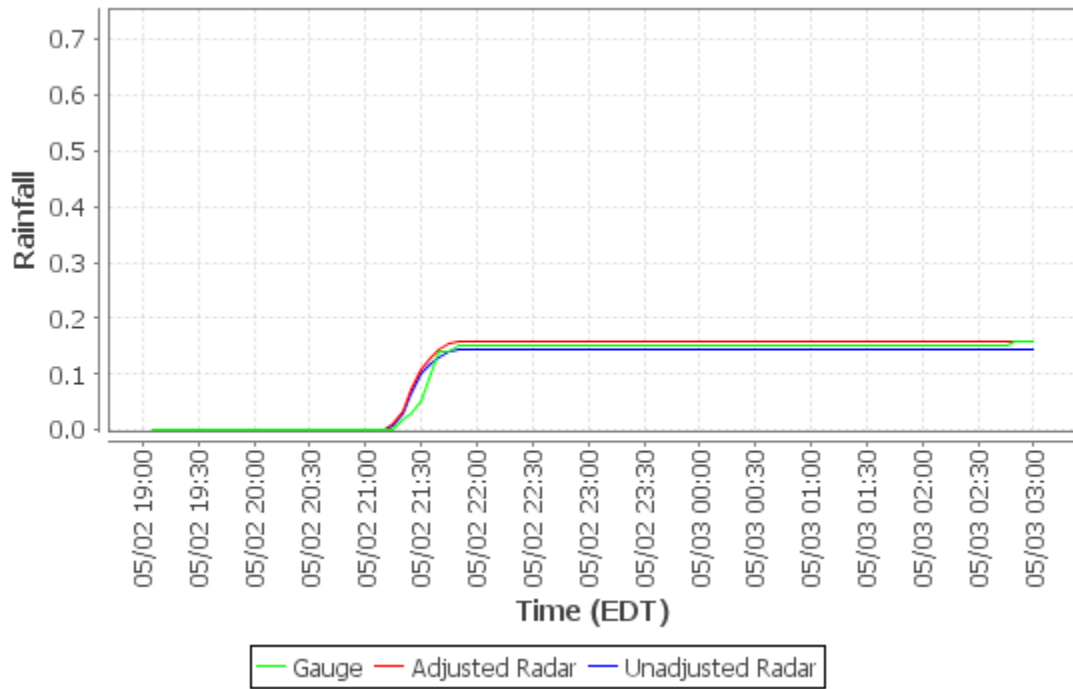
**Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)**



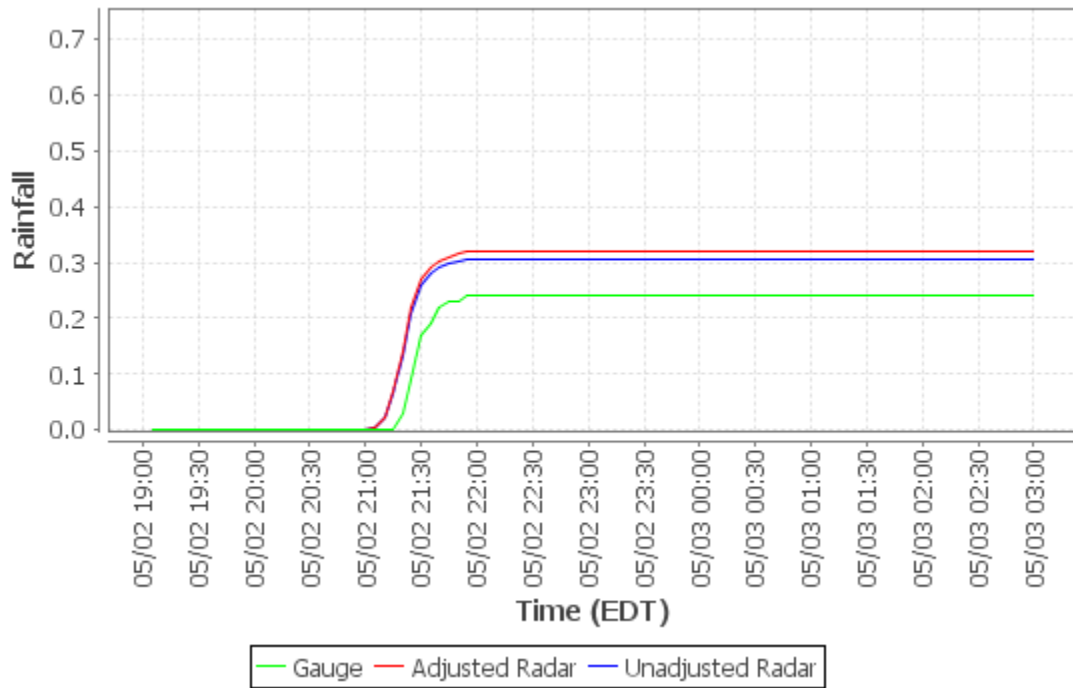
**Cumulative Distribution Plot - Kennedy Twp PS (Loc04)**



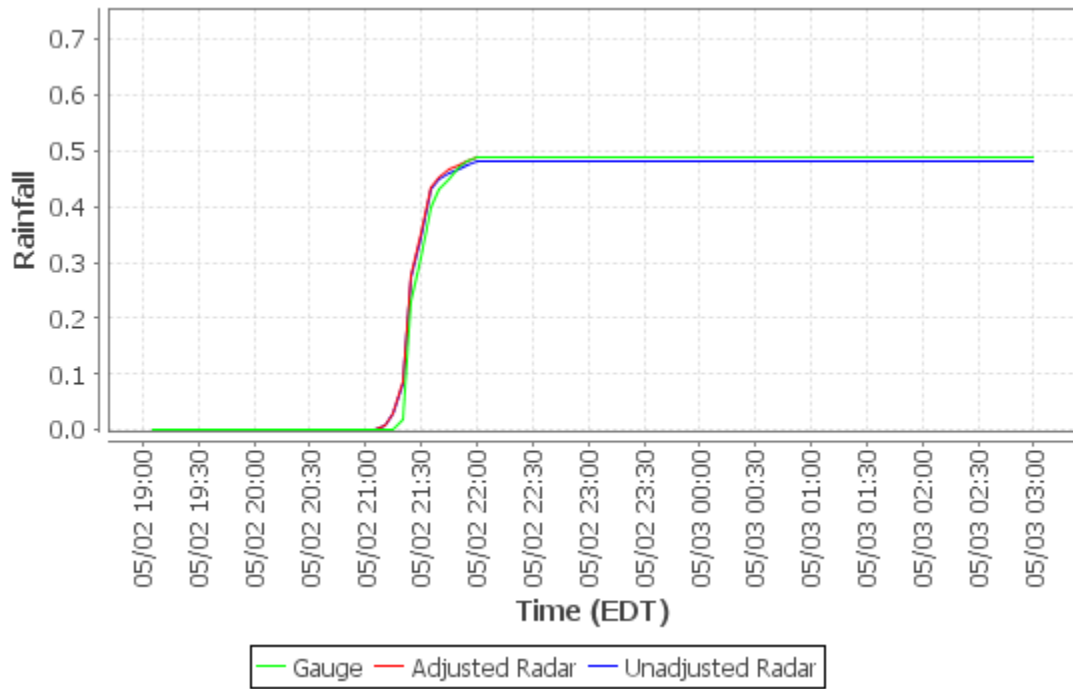
**Cumulative Distribution Plot - Upper St. Clair (Loc05)**



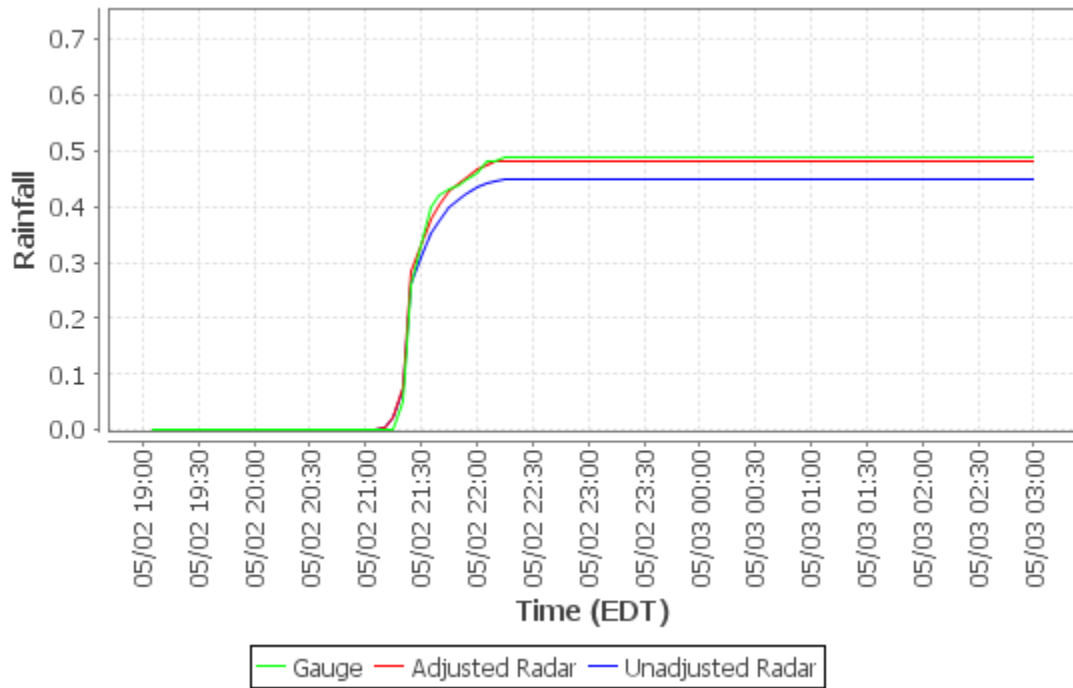
**Cumulative Distribution Plot - Carnegie Transit Time (Loc06)**



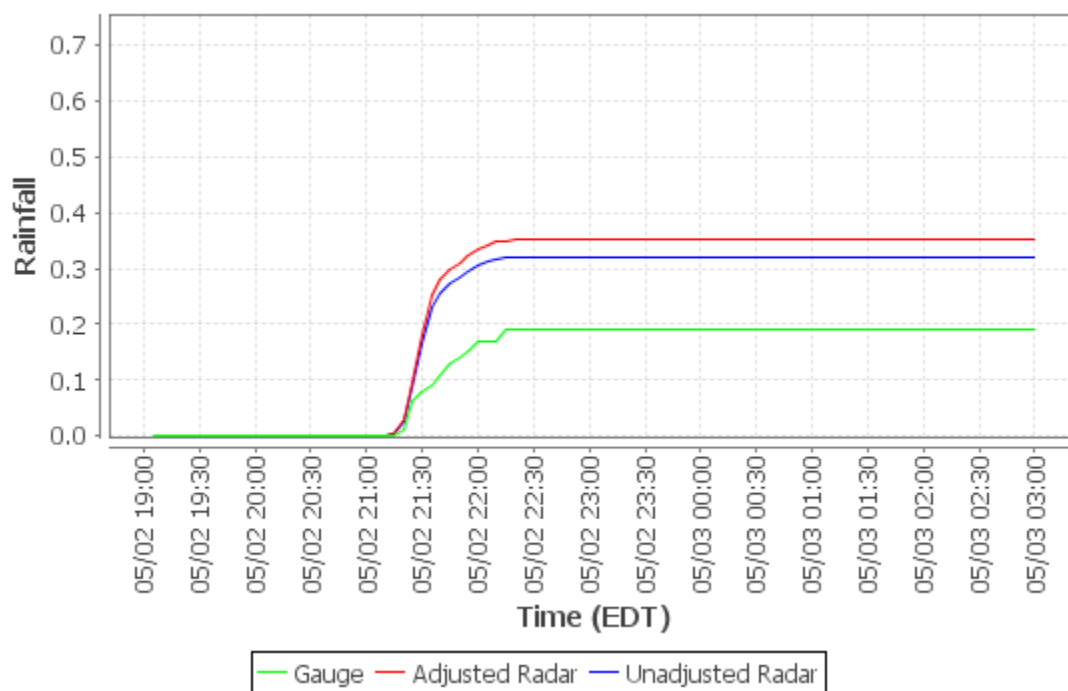
**Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)**



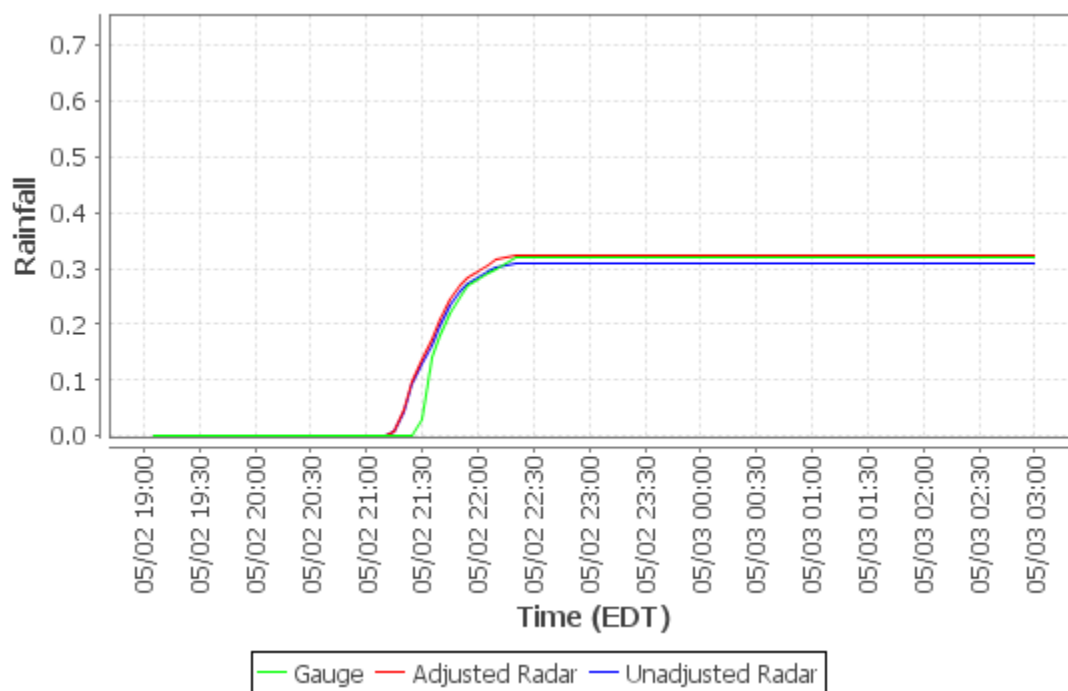
**Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)**



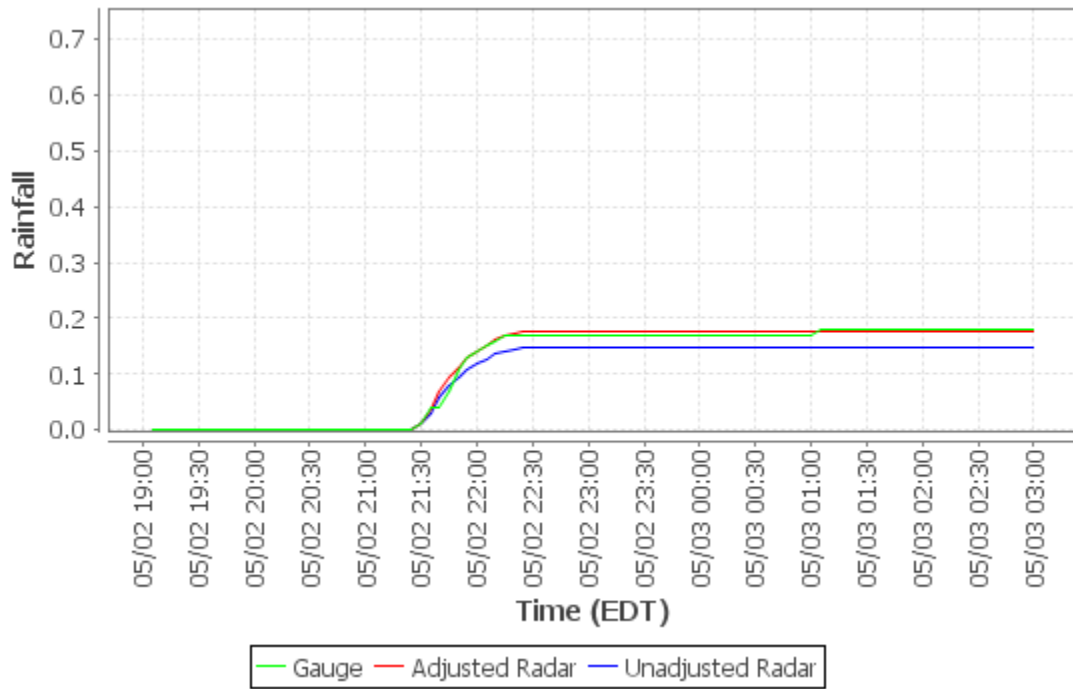
**Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)**



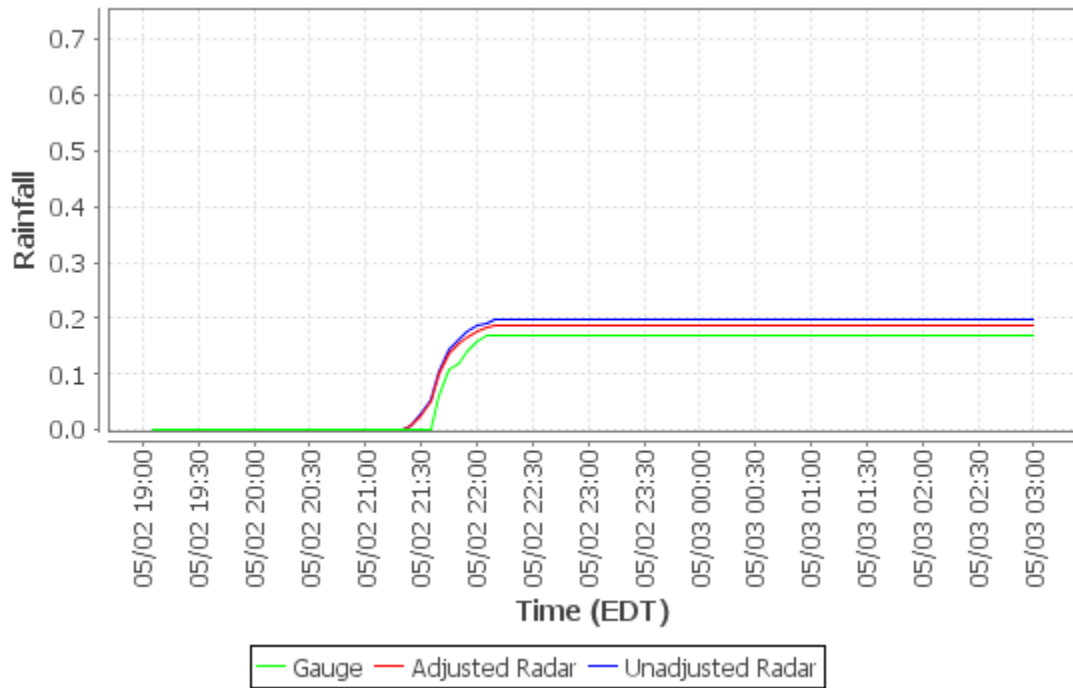
**Cumulative Distribution Plot - PWSA-Highland Park (Loc10)**



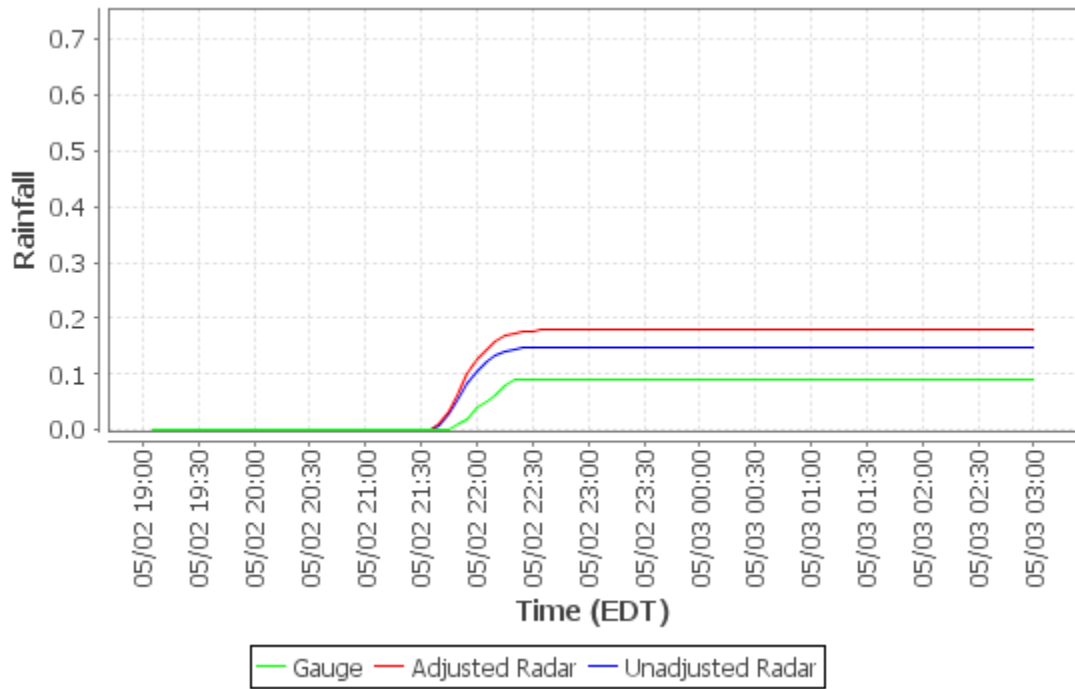
**Cumulative Distribution Plot - M-46 Access Shaft (Loc11)**



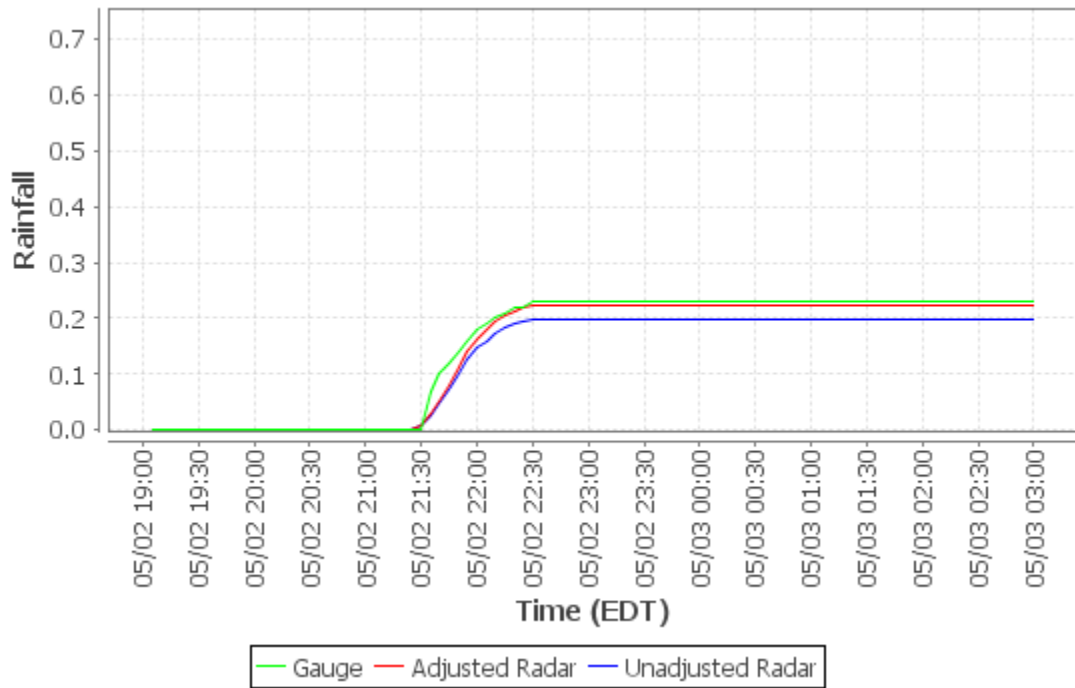
**Cumulative Distribution Plot - Baldwin (Loc12)**



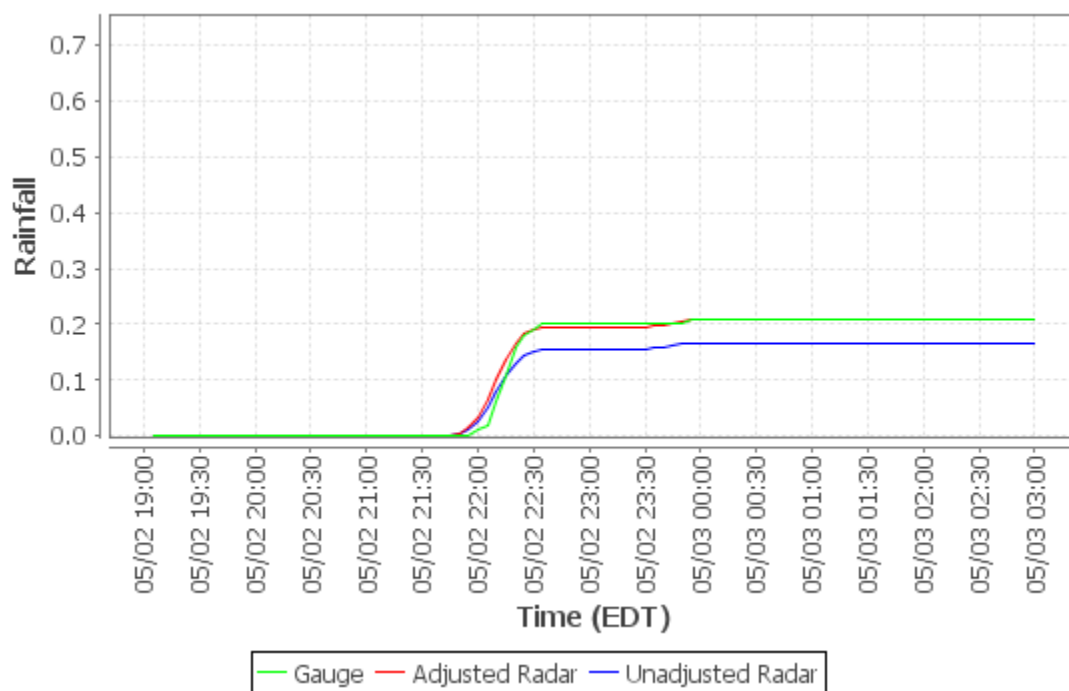
**Cumulative Distribution Plot - M-59 Access Shaft (Loc13)**



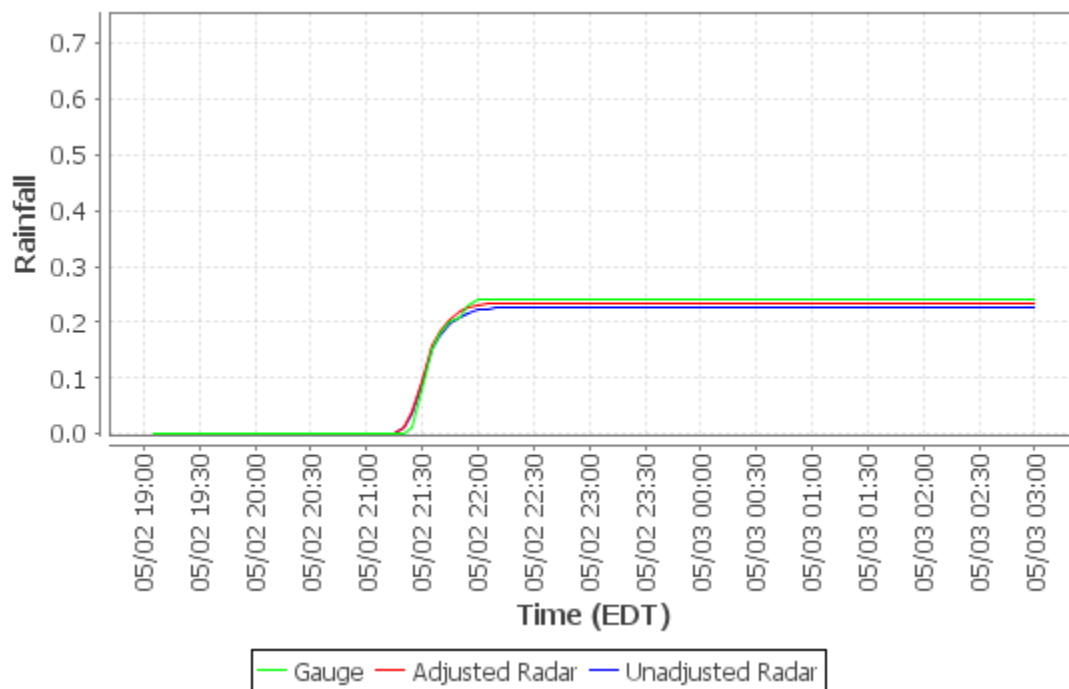
**Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)**



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

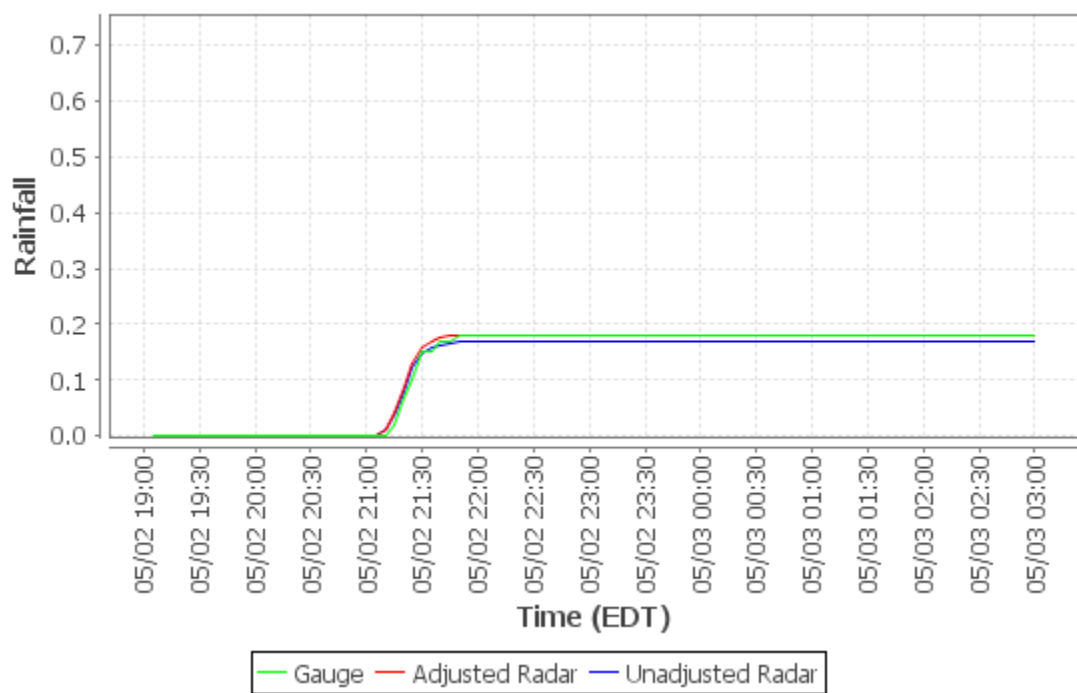


**Cumulative Distribution Plot - Castle Shannon (Loc16)**

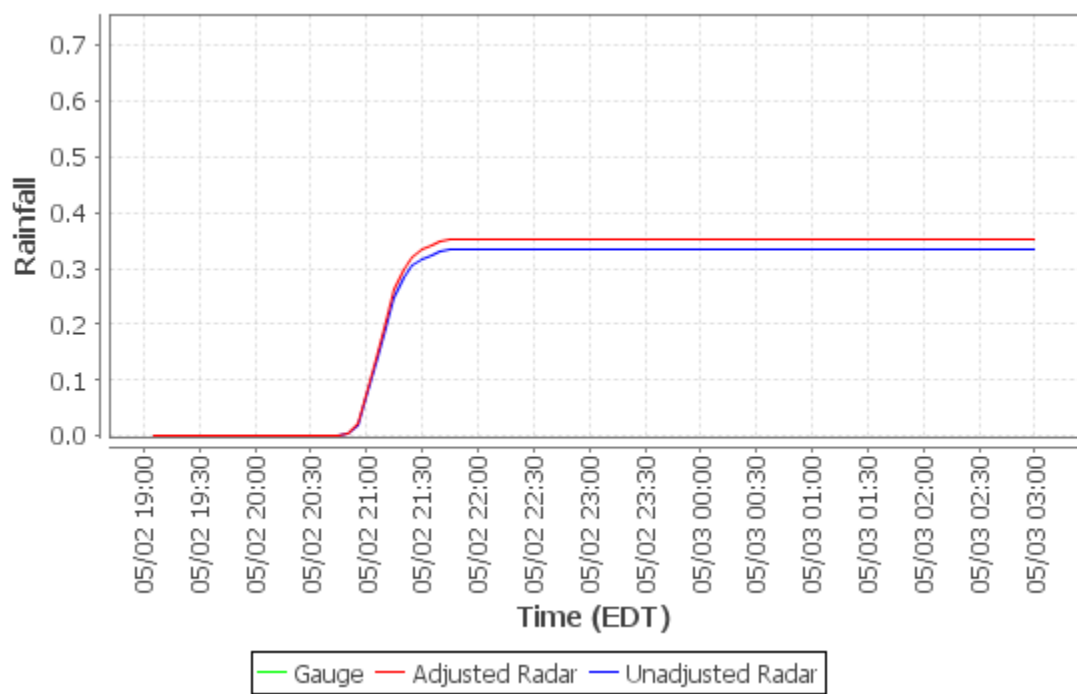




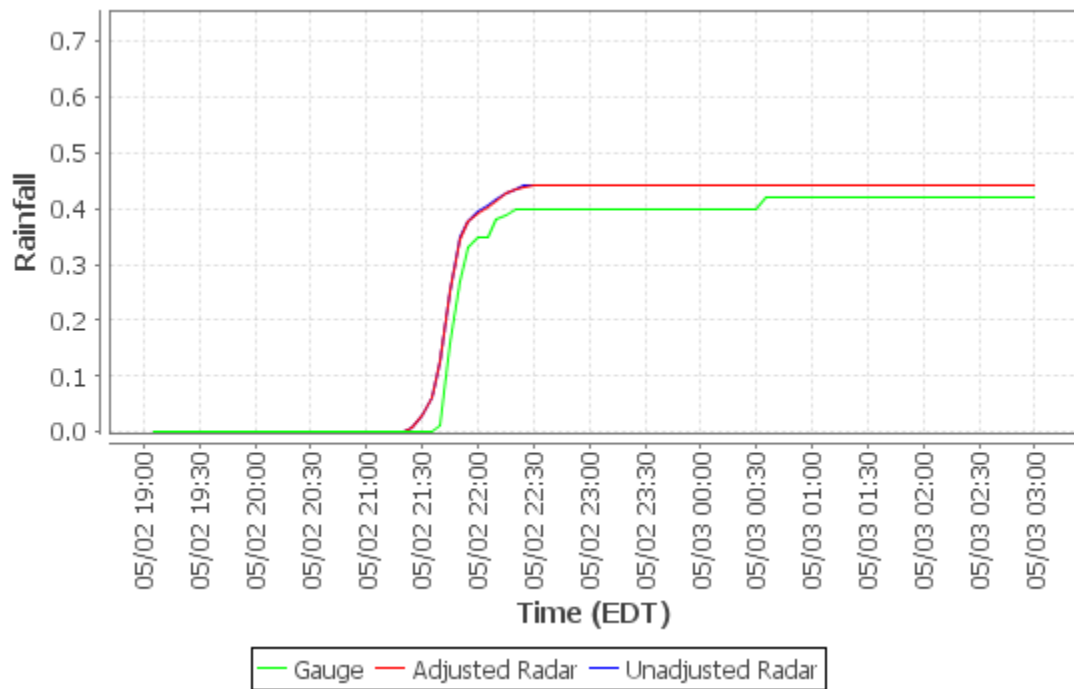
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



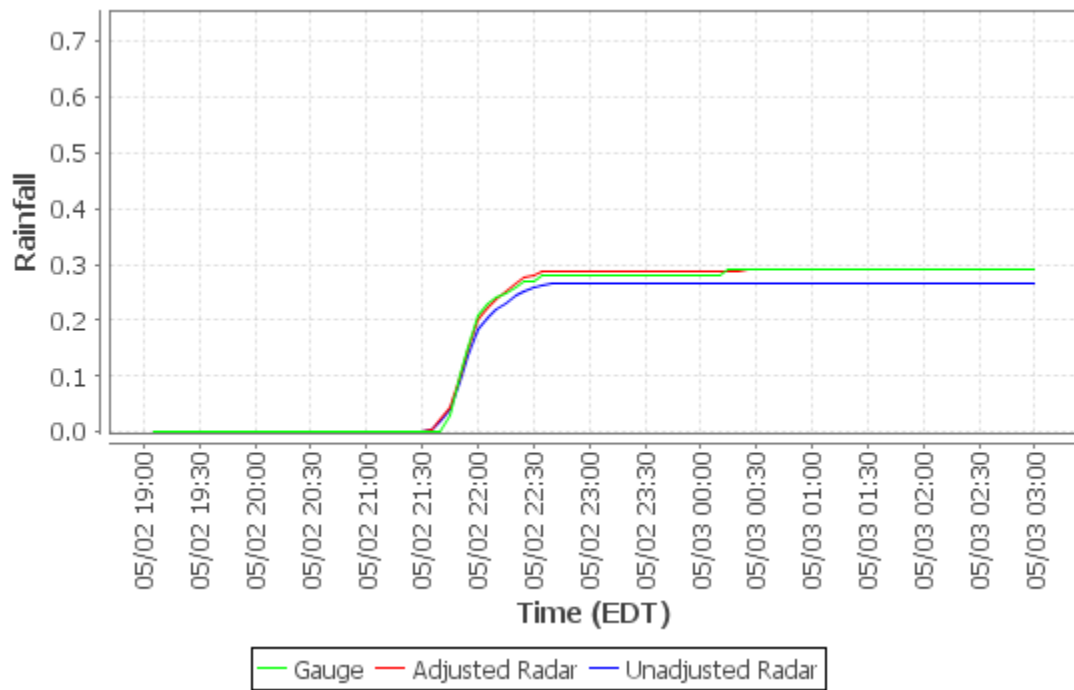
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



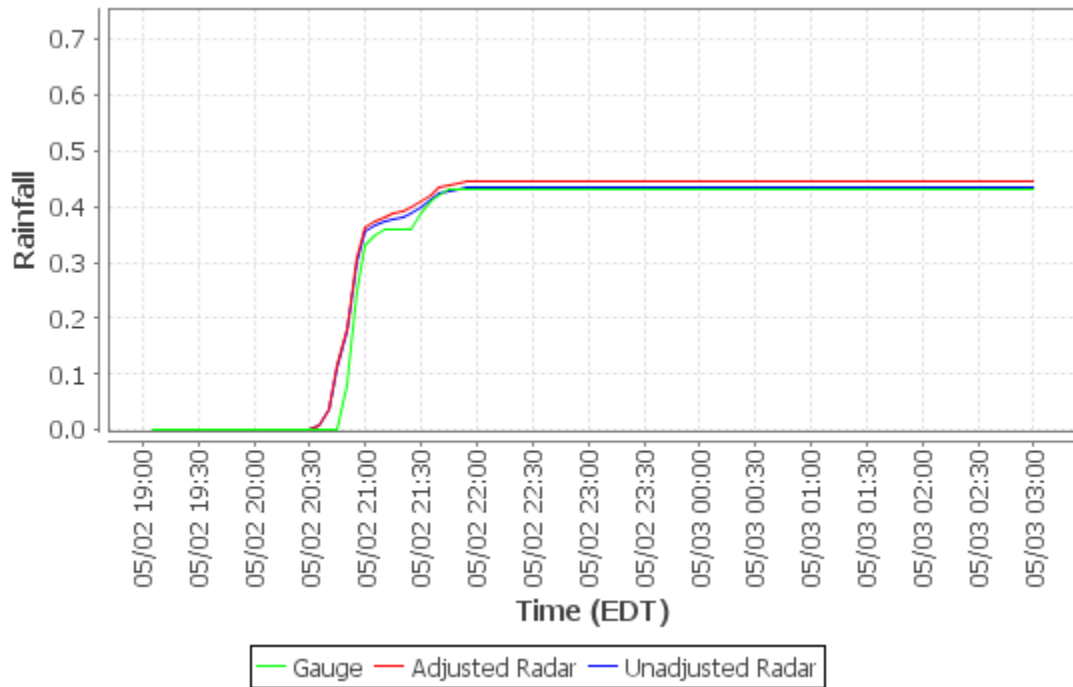
**Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)**



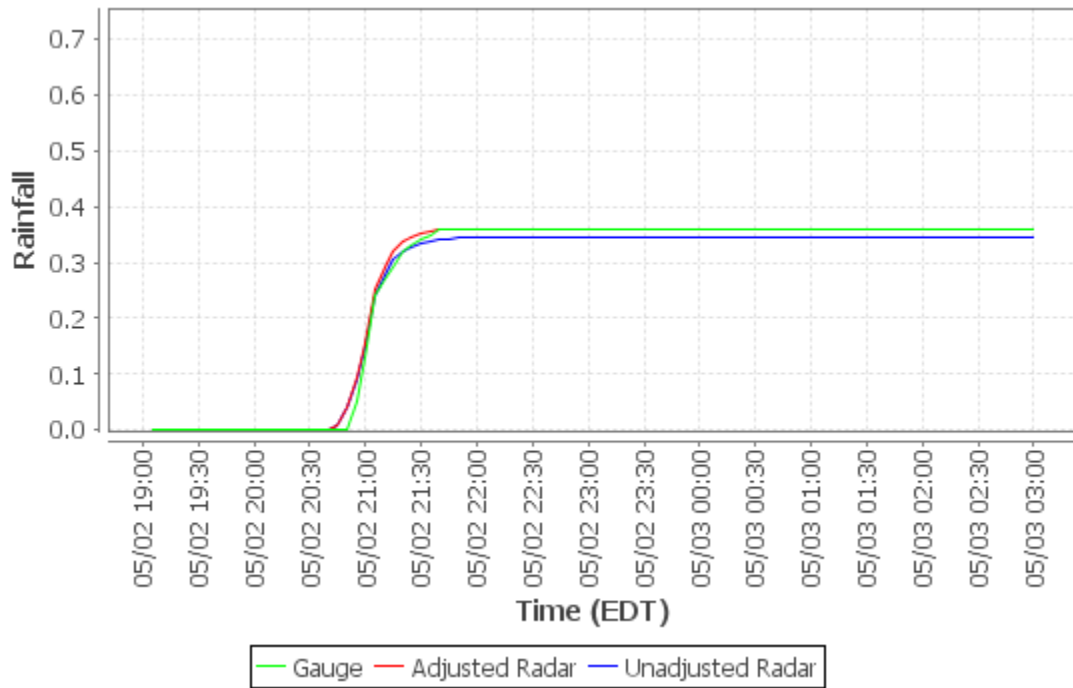
**Cumulative Distribution Plot - Gascola Eq Facility (Loc20)**



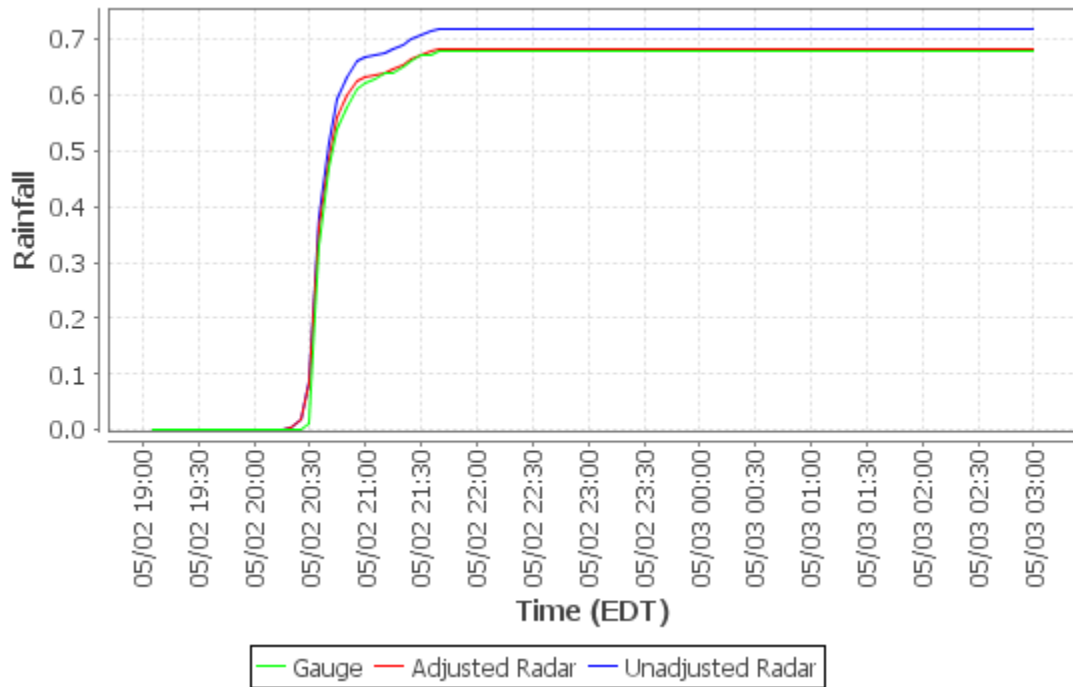
**Cumulative Distribution Plot - Moon TWP (Loc21)**



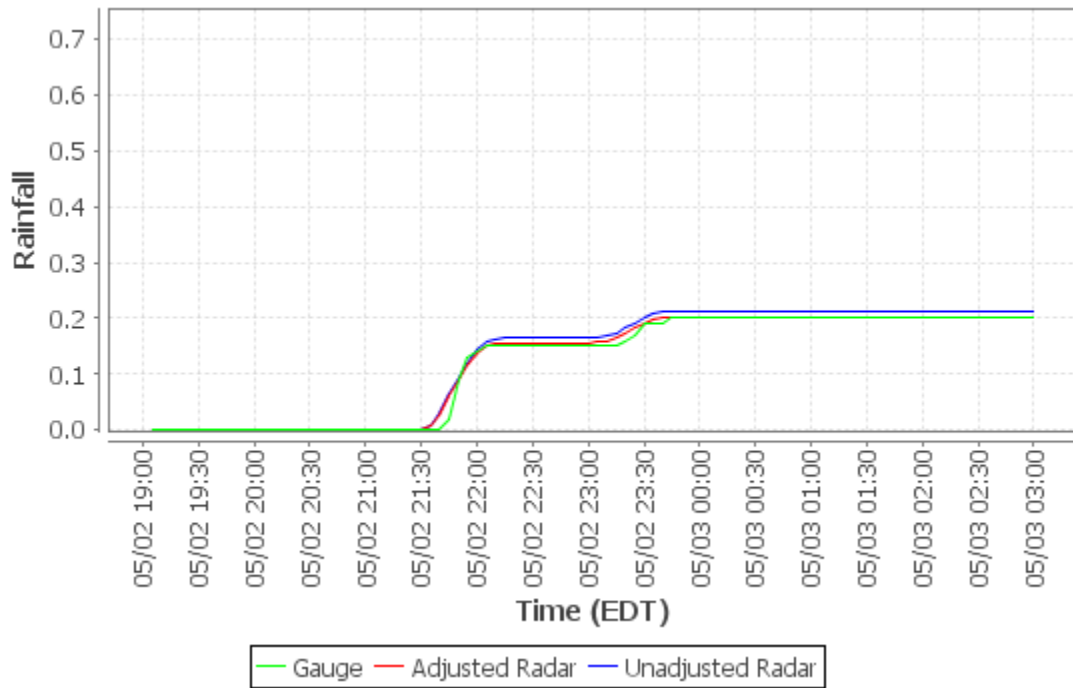
**Cumulative Distribution Plot - North Fayette TWP (Loc22)**



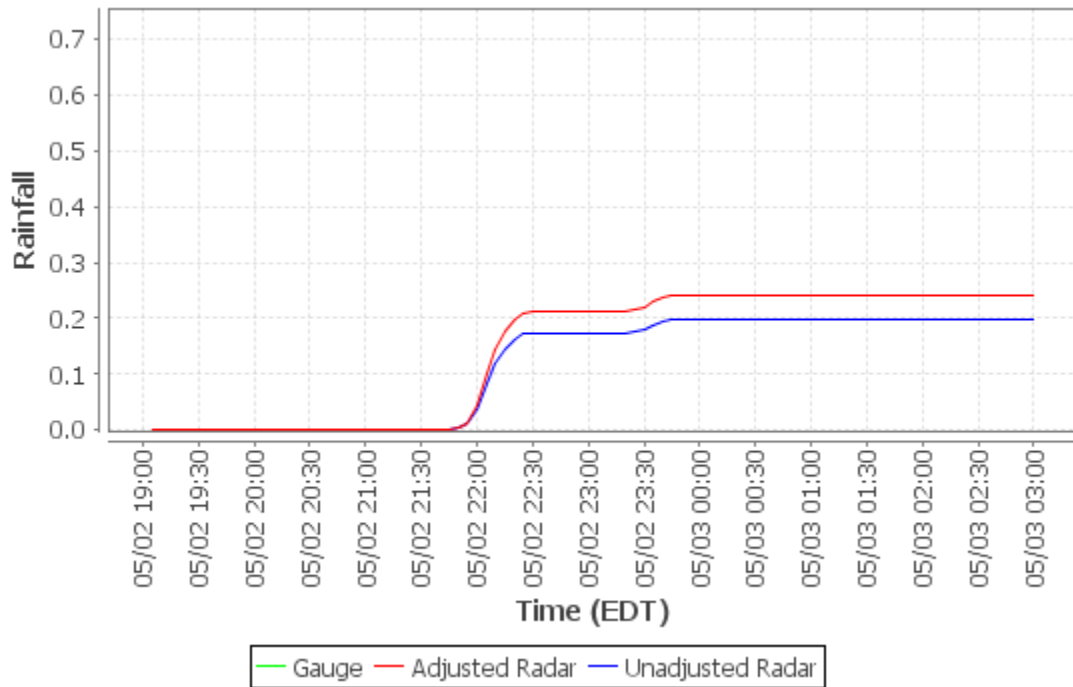
**Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)**



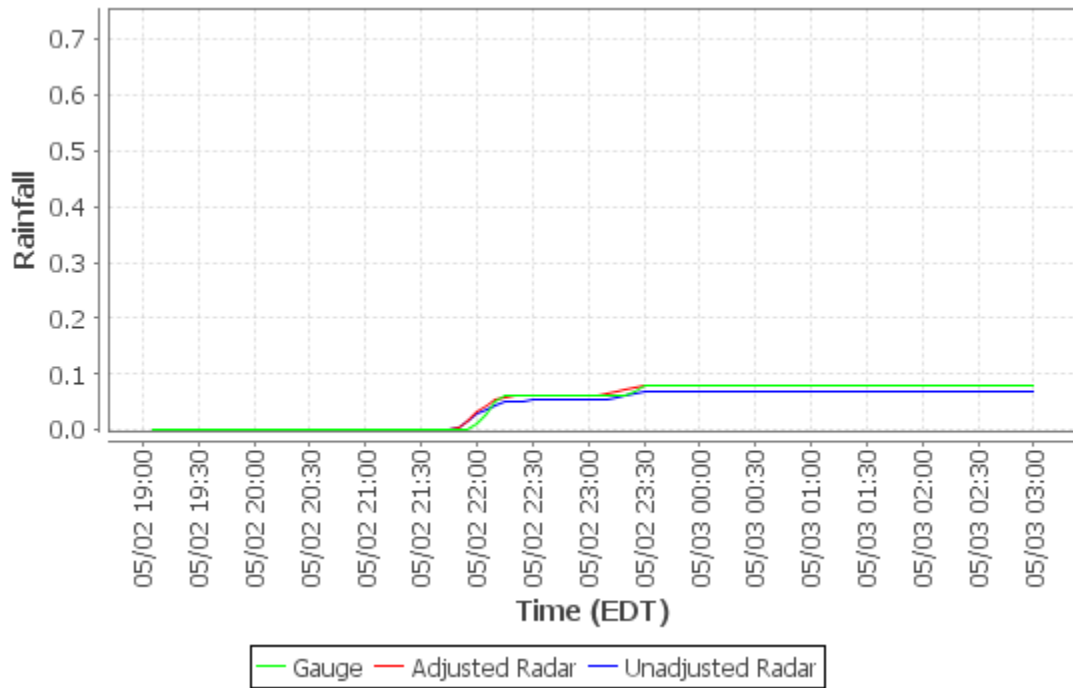
**Cumulative Distribution Plot - Jefferson Hills (Loc24)**



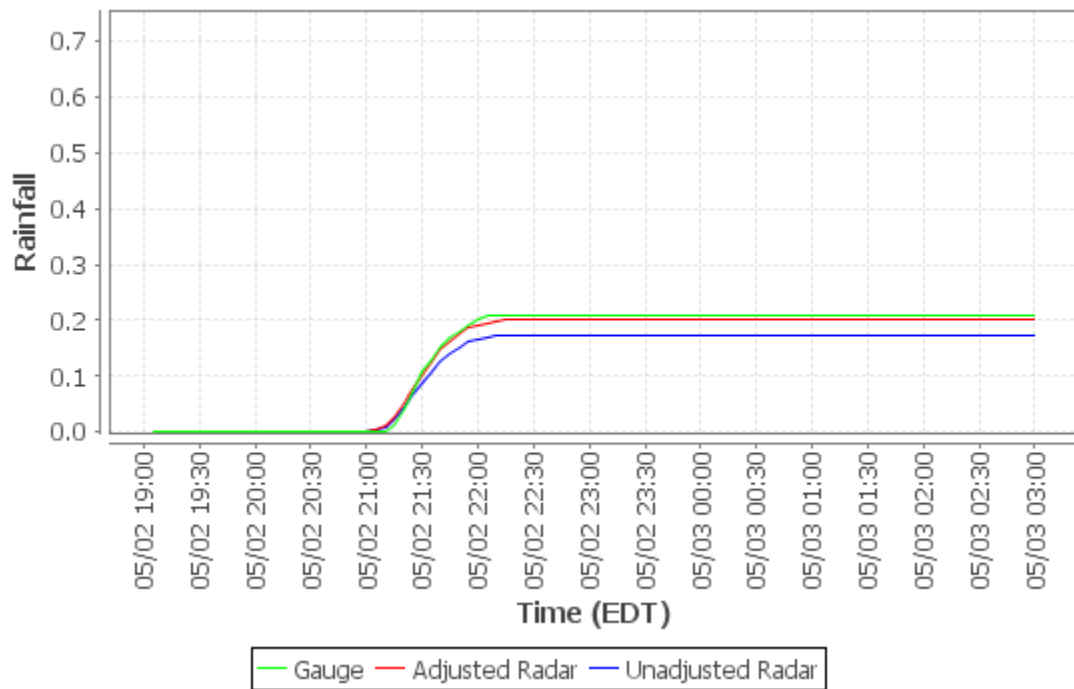
**Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)**



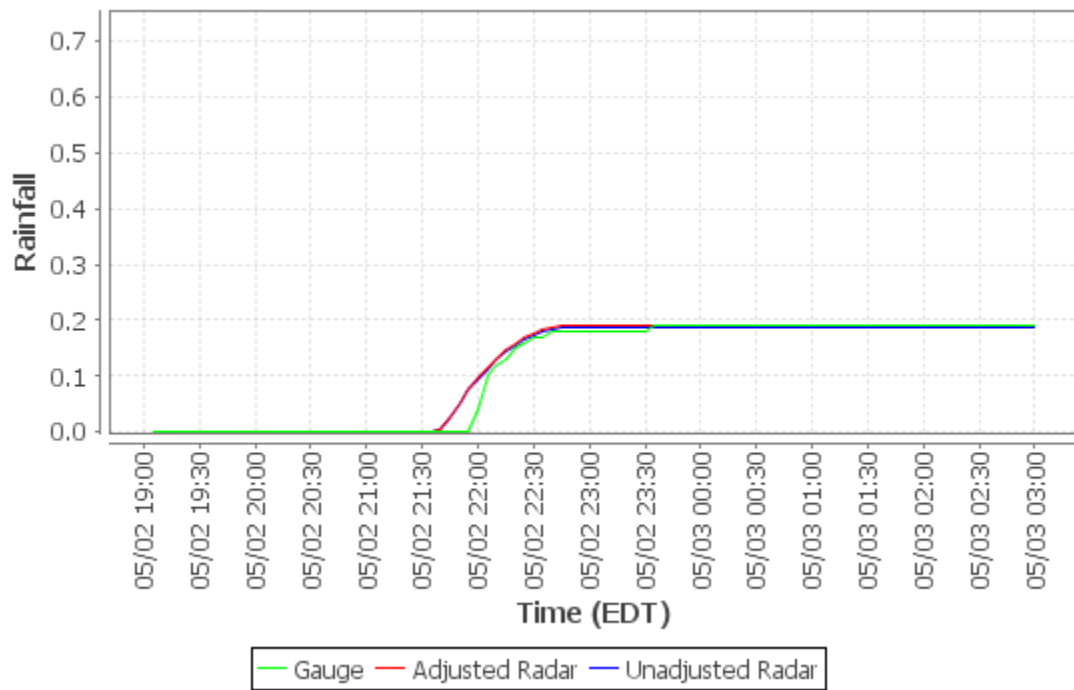
**Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)**



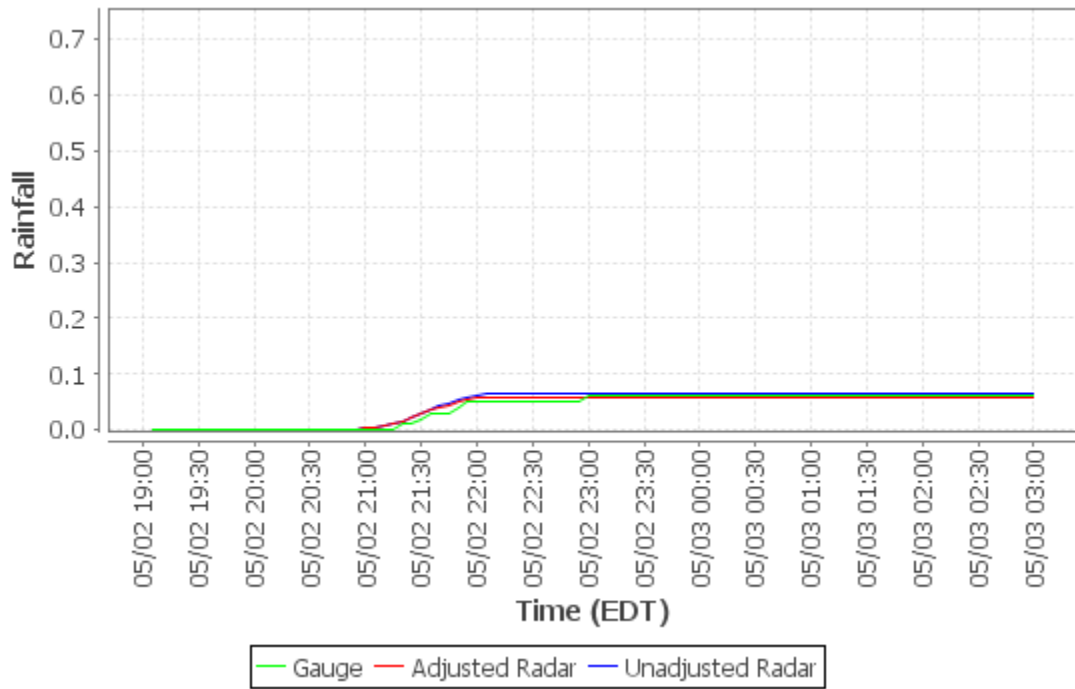
**Cumulative Distribution Plot - Marshall TWP (Loc27)**



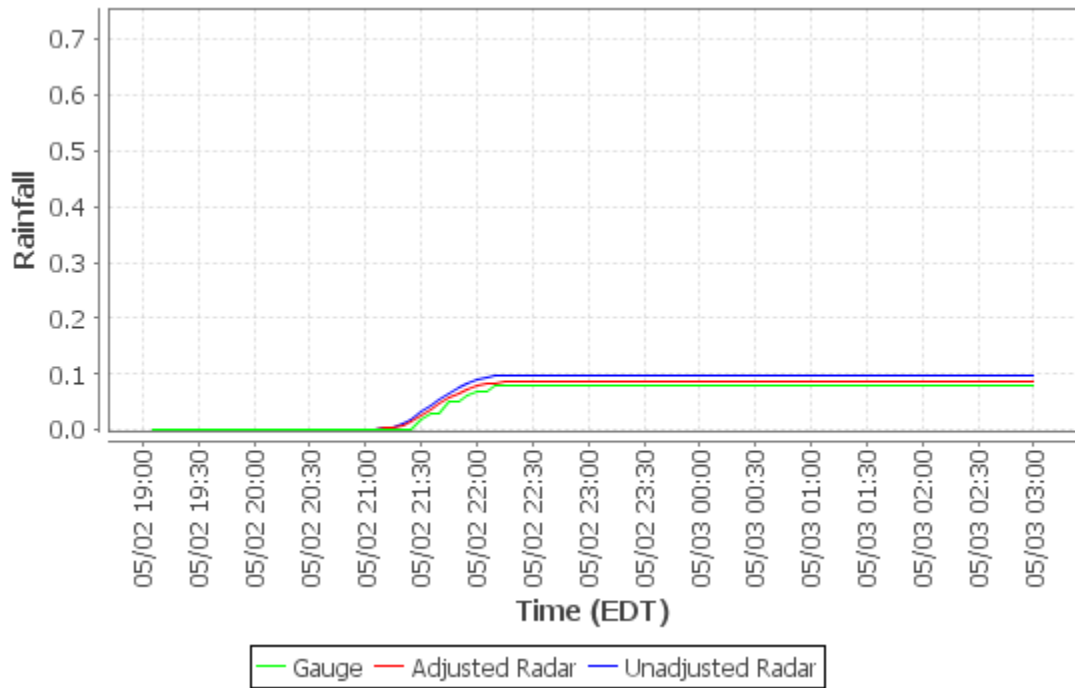
**Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)**



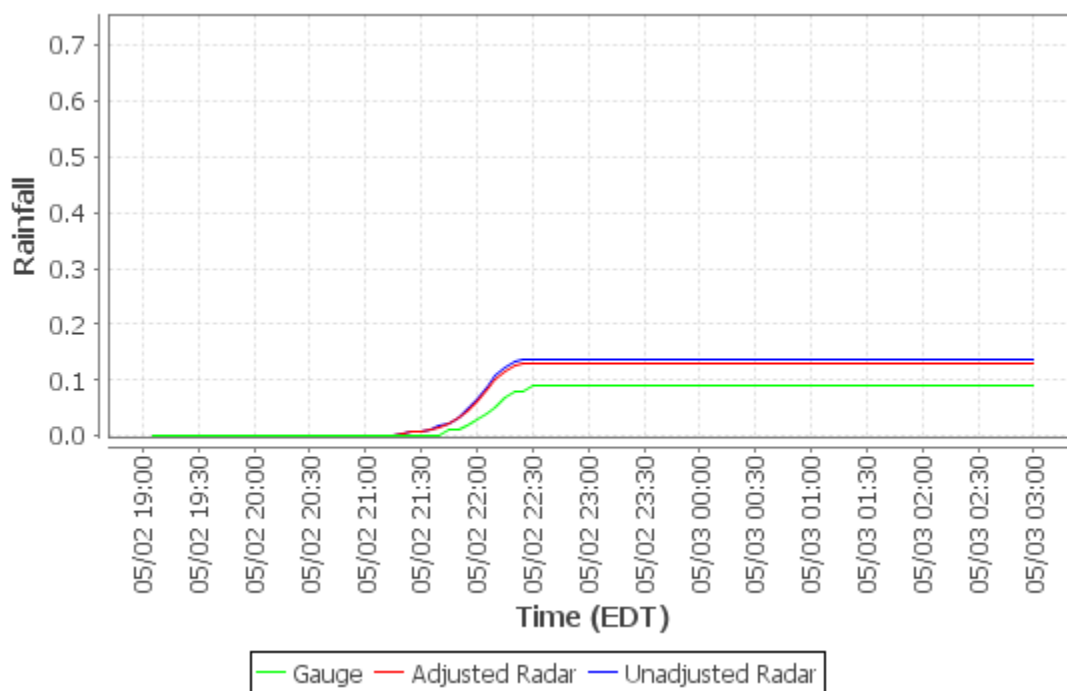
**Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)**



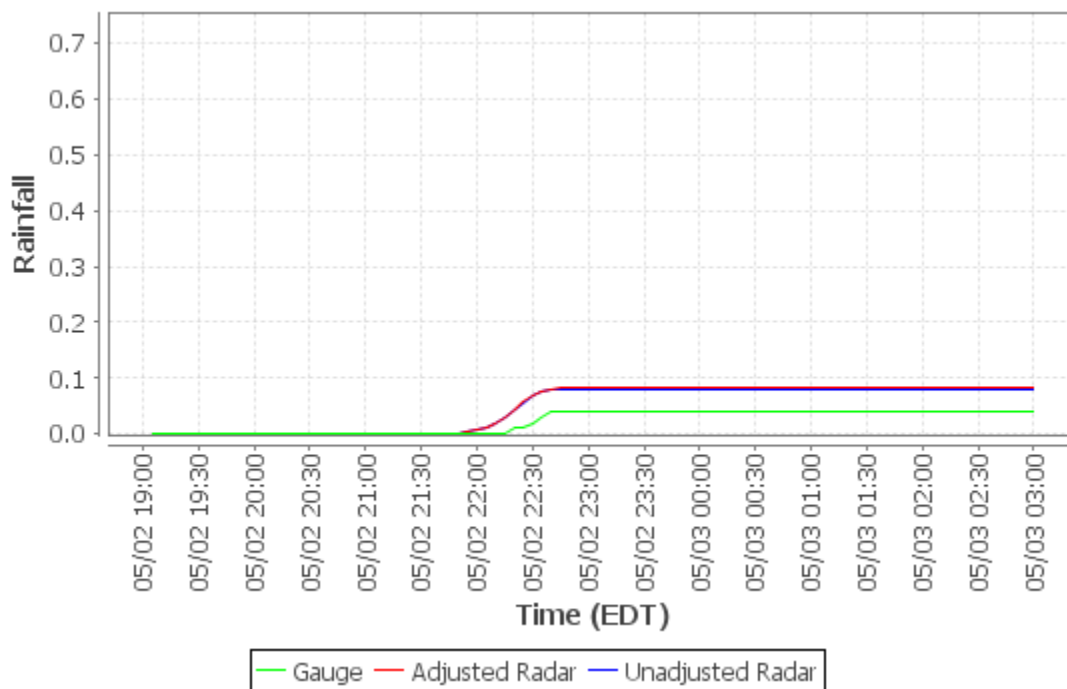
**Cumulative Distribution Plot - McCandless Twm Hall (Loc30)**



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

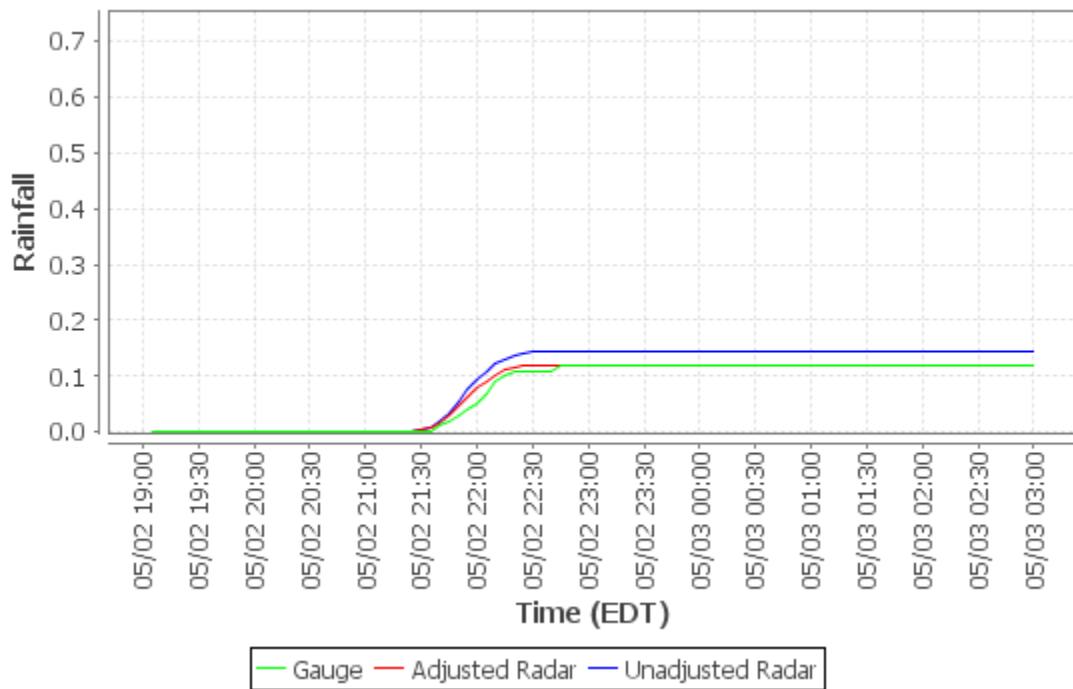


**Cumulative Distribution Plot - Arnold (Loc32)**

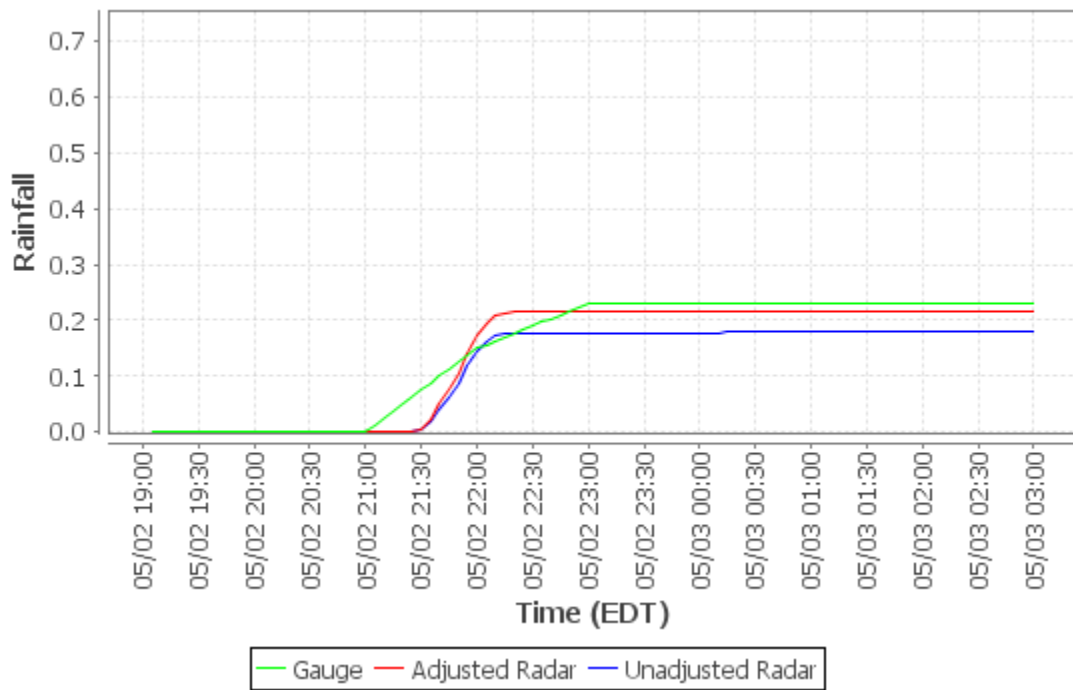




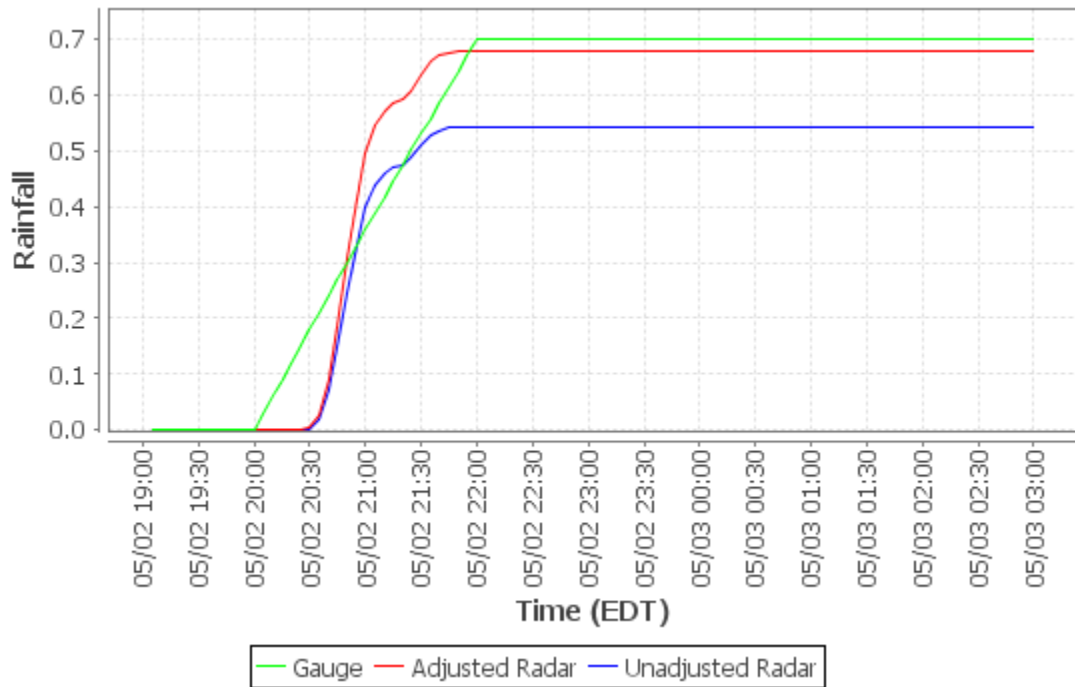
**Cumulative Distribution Plot - Richland TWP (Loc33)**



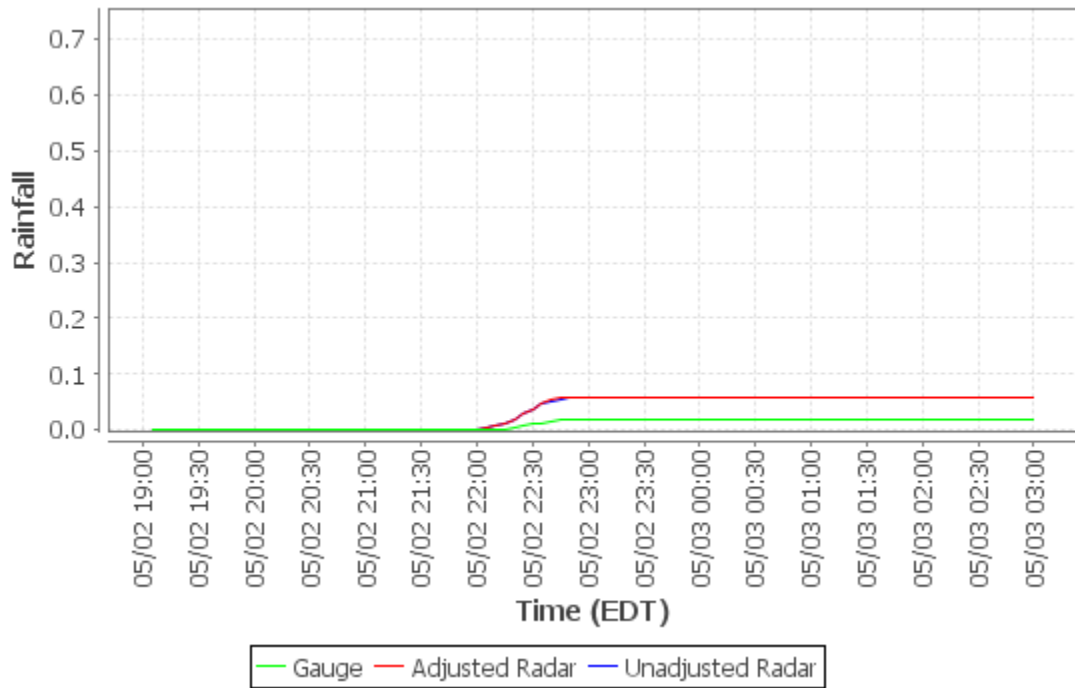
**Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)**



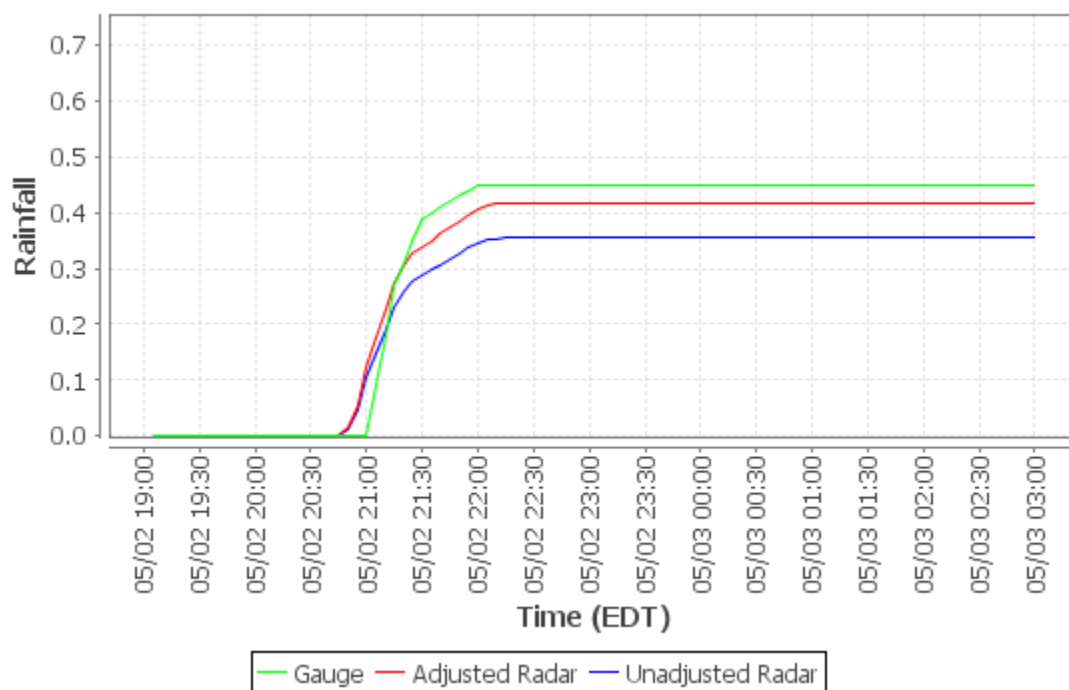
**Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)**



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

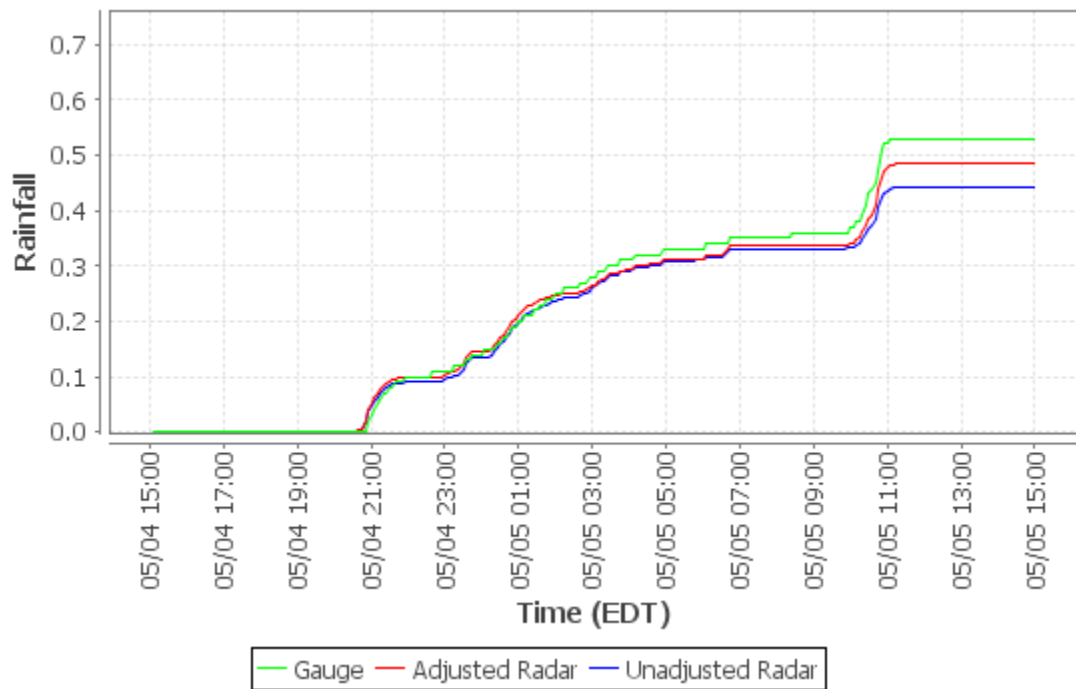


### Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth (03085734)

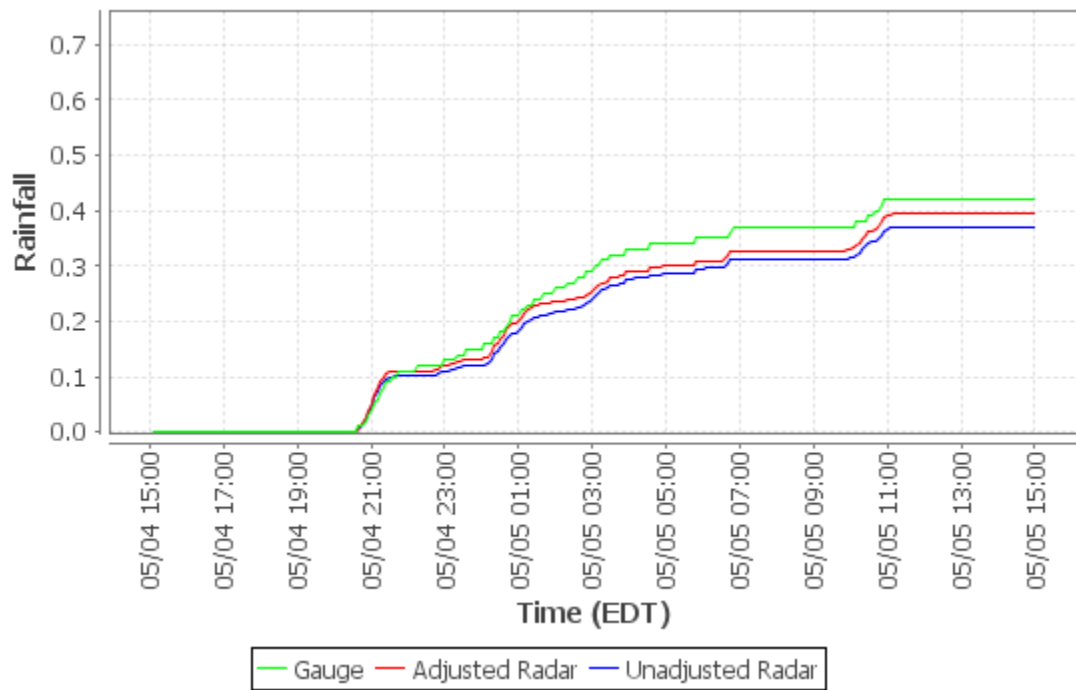


## **Appendix D - Event 2 (2019-05-05) CDPs**

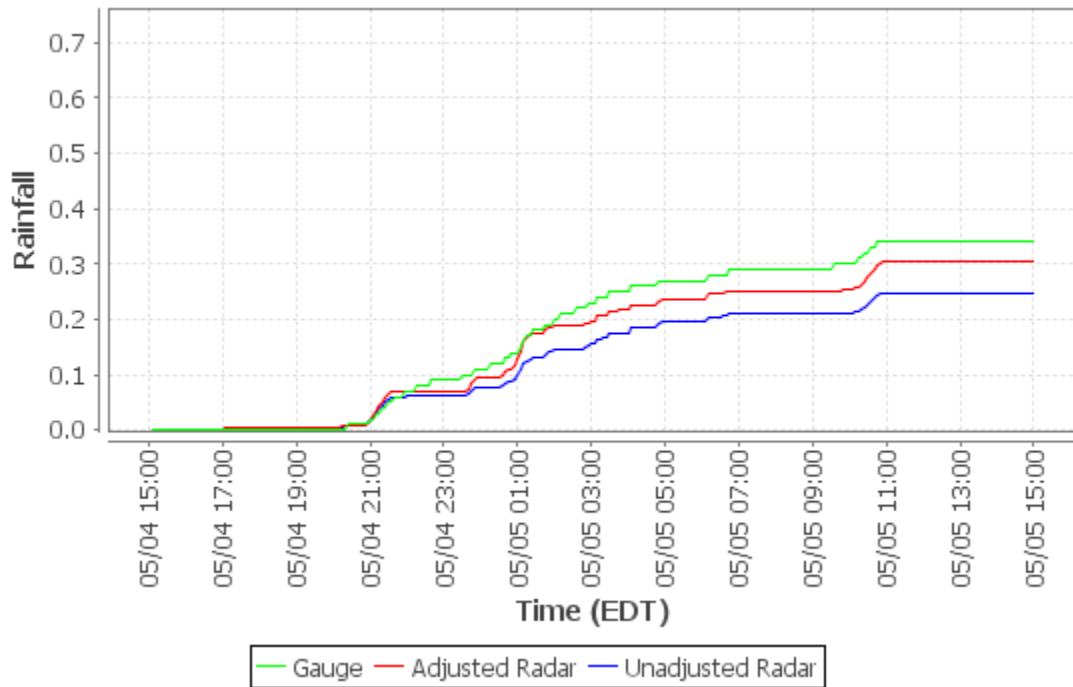
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



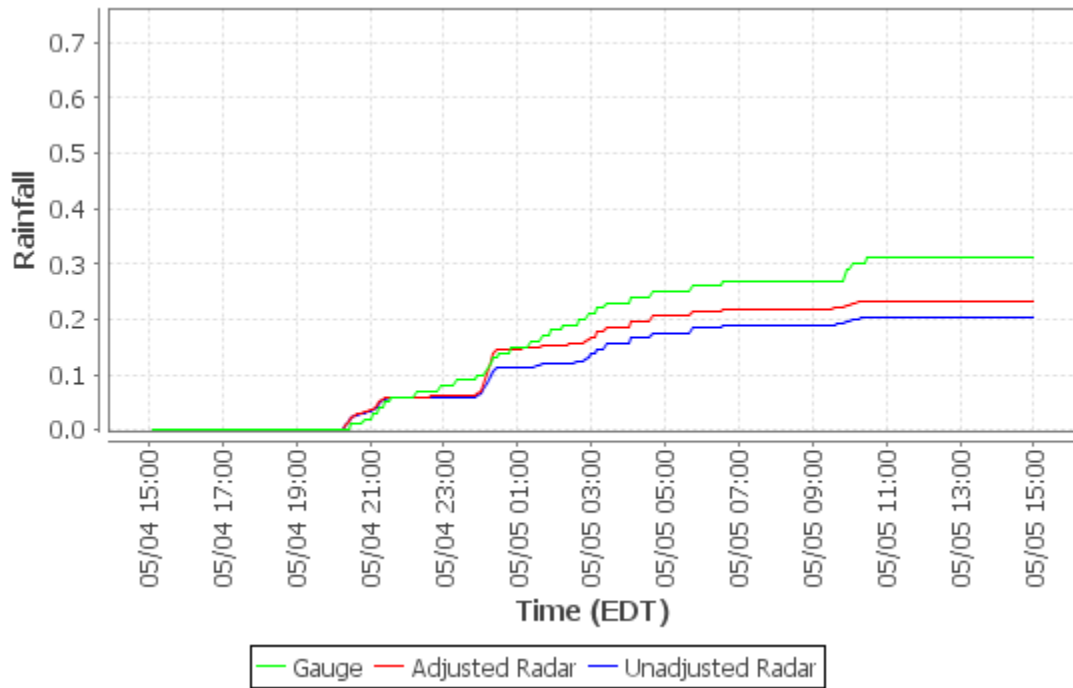
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



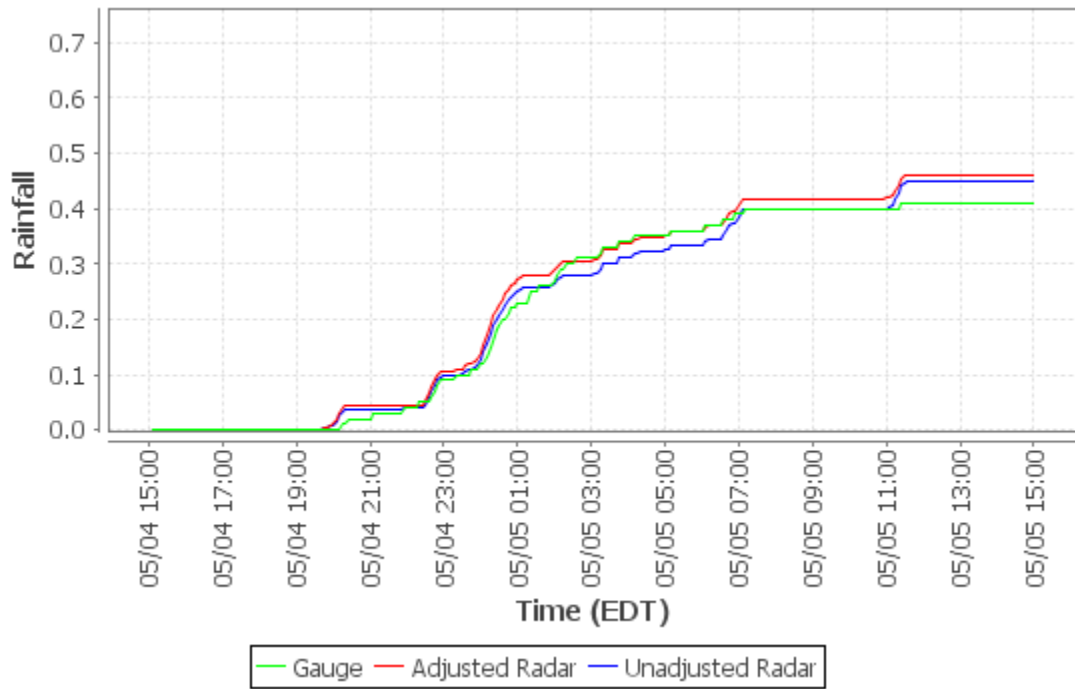
**Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)**



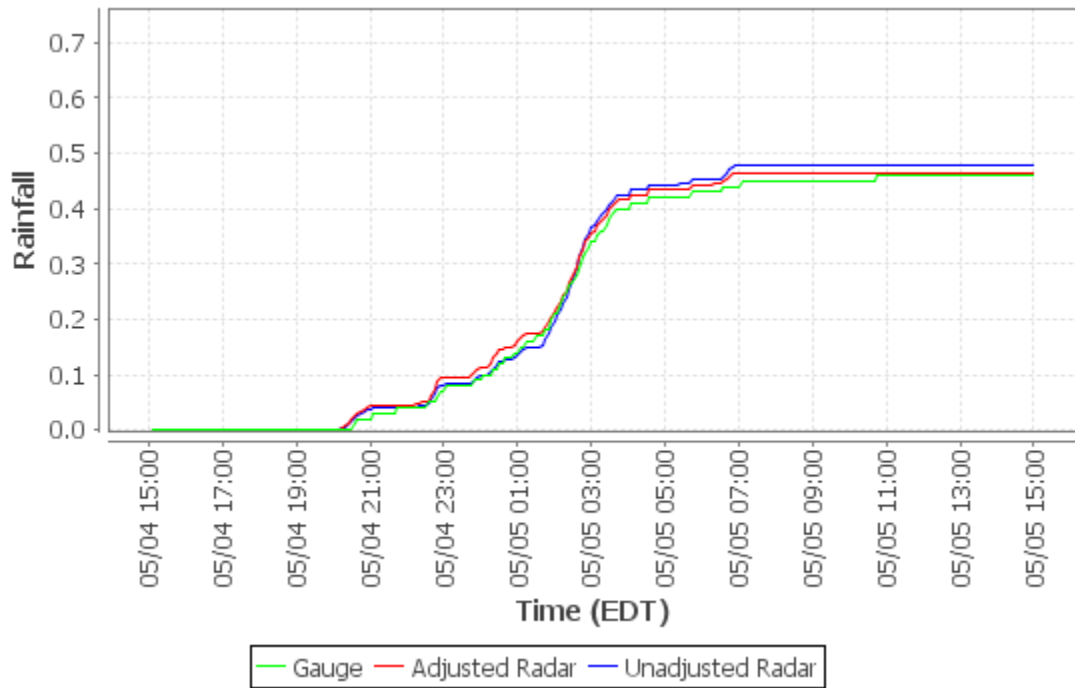
**Cumulative Distribution Plot - Kennedy Twp PS (Loc04)**



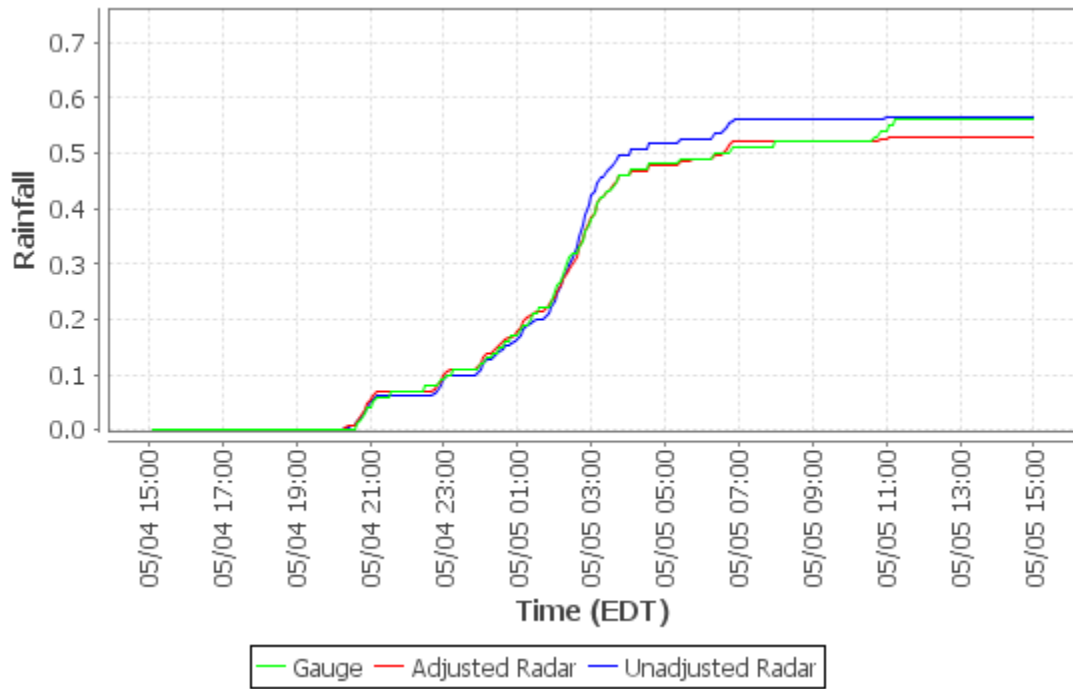
**Cumulative Distribution Plot - Upper St. Clair (Loc05)**



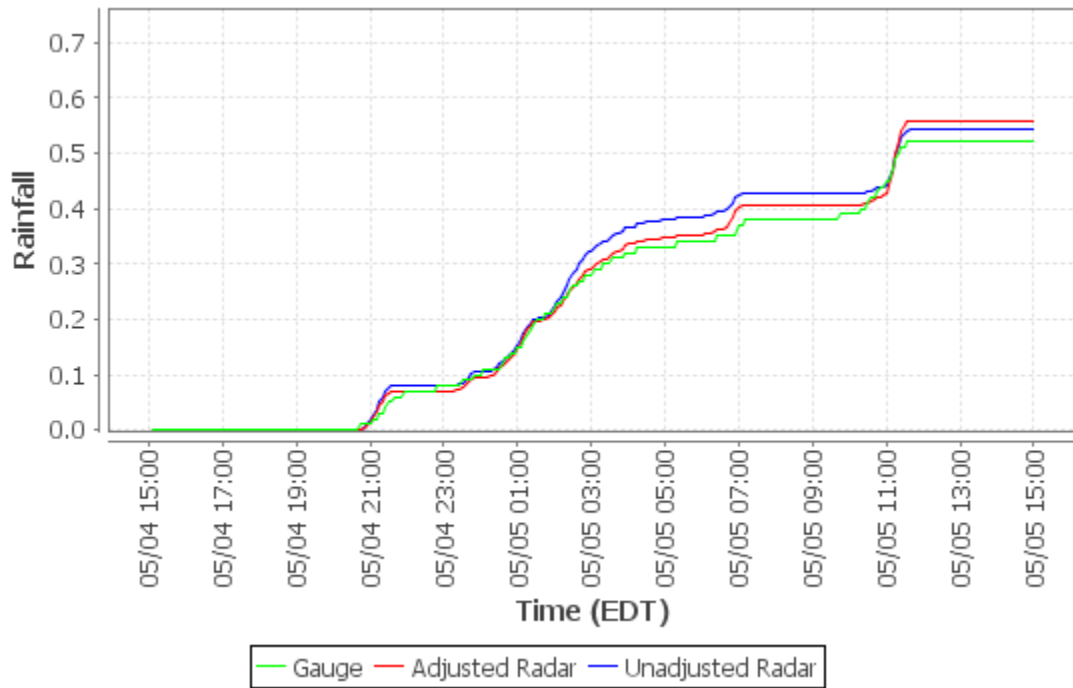
**Cumulative Distribution Plot - Carnegie Transit Time (Loc06)**



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

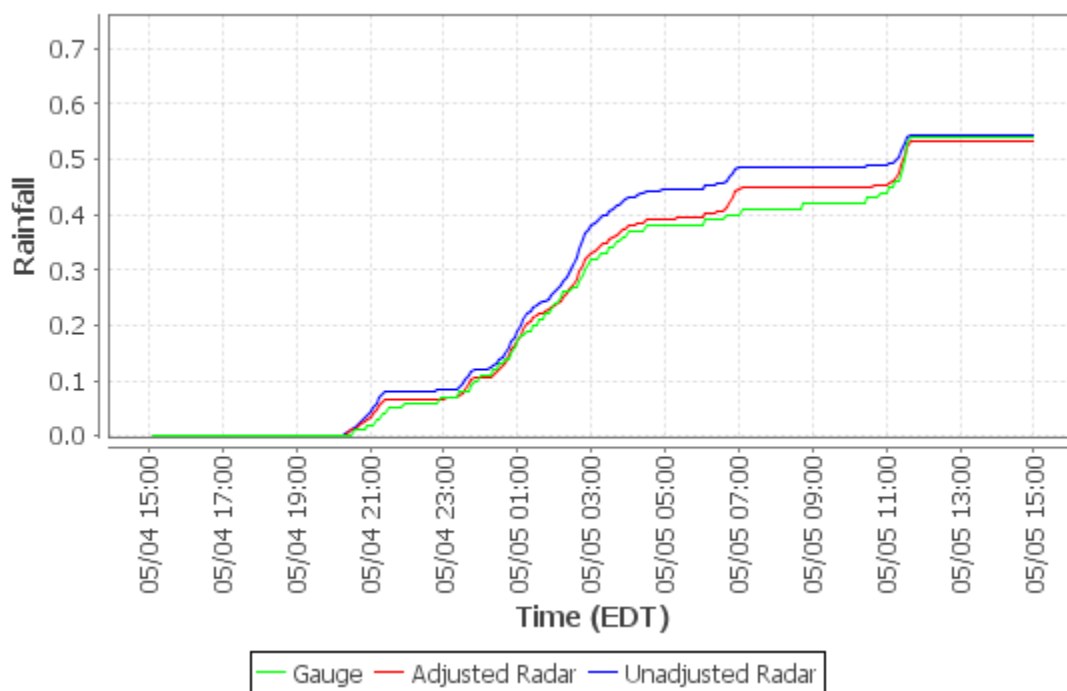


**Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)**

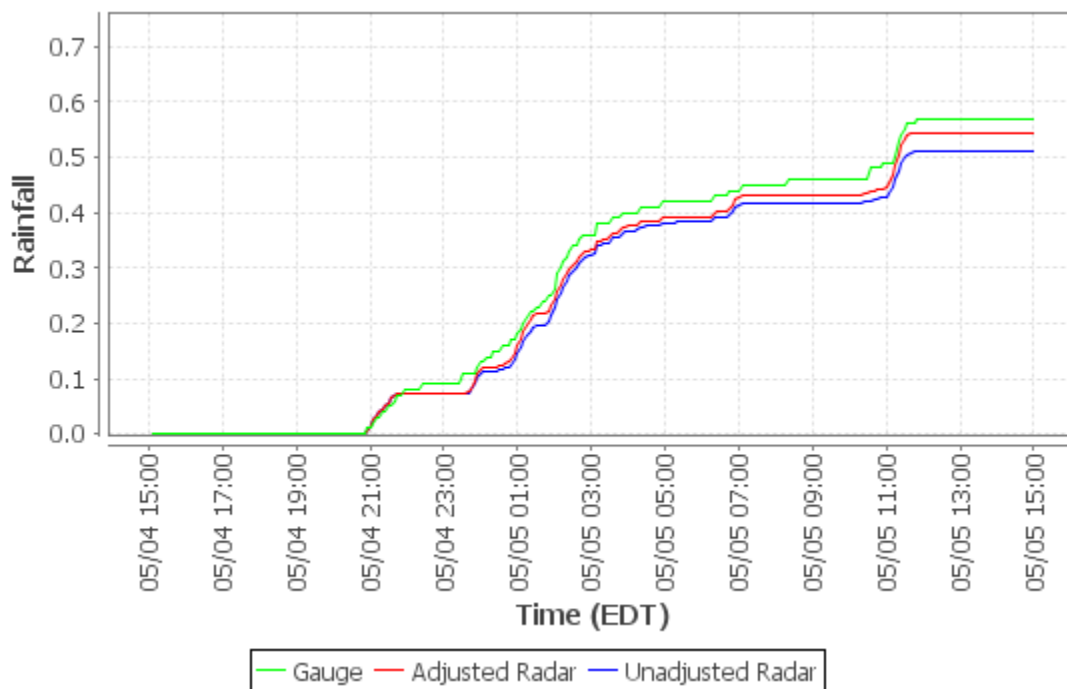




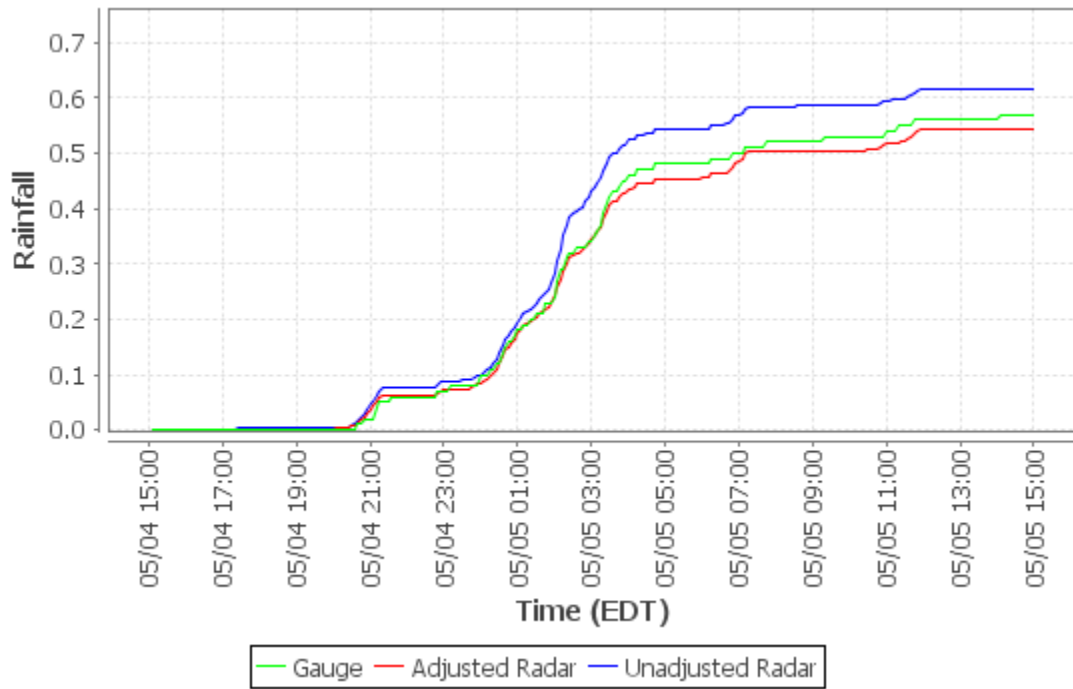
Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)



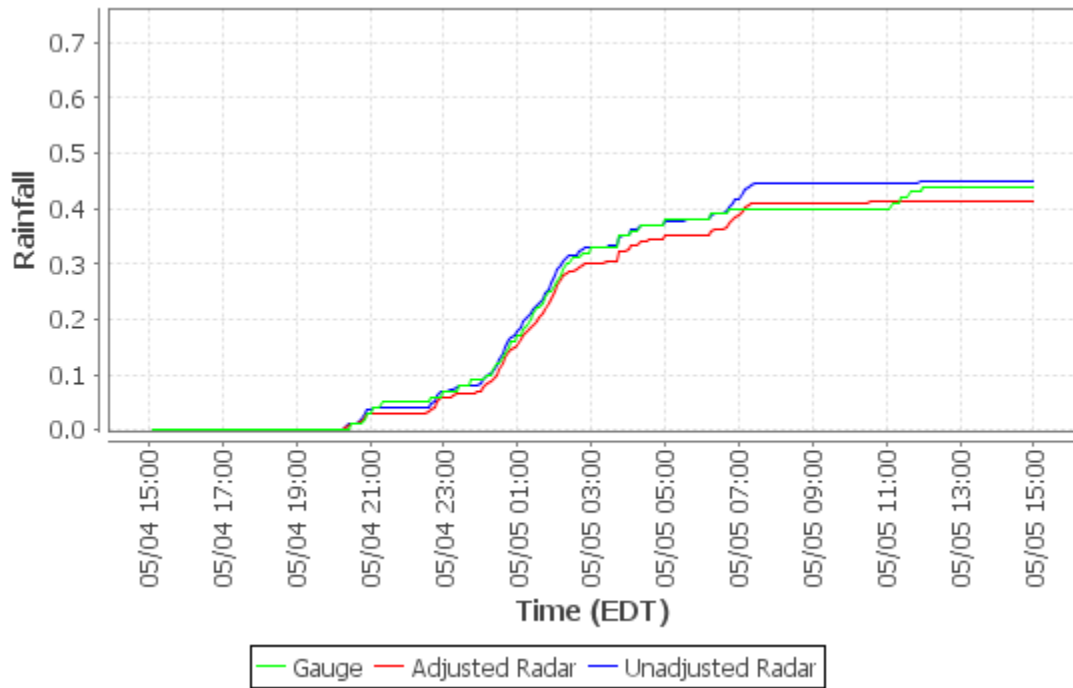
Cumulative Distribution Plot - PWSA-Highland Park (Loc10)



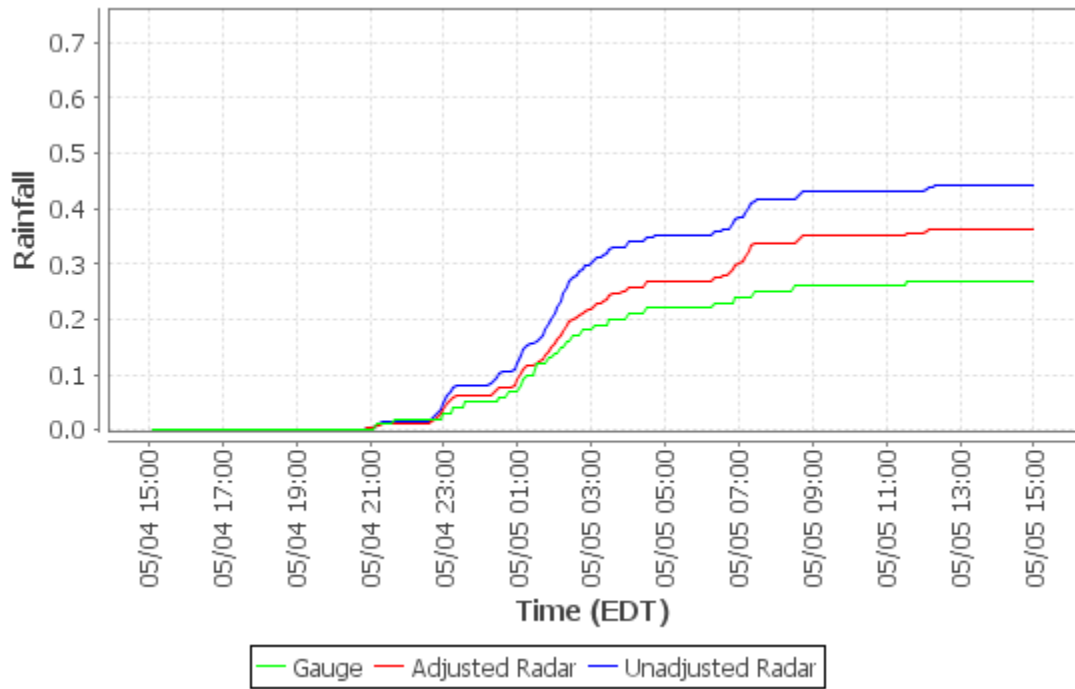
**Cumulative Distribution Plot - M-46 Access Shaft (Loc11)**



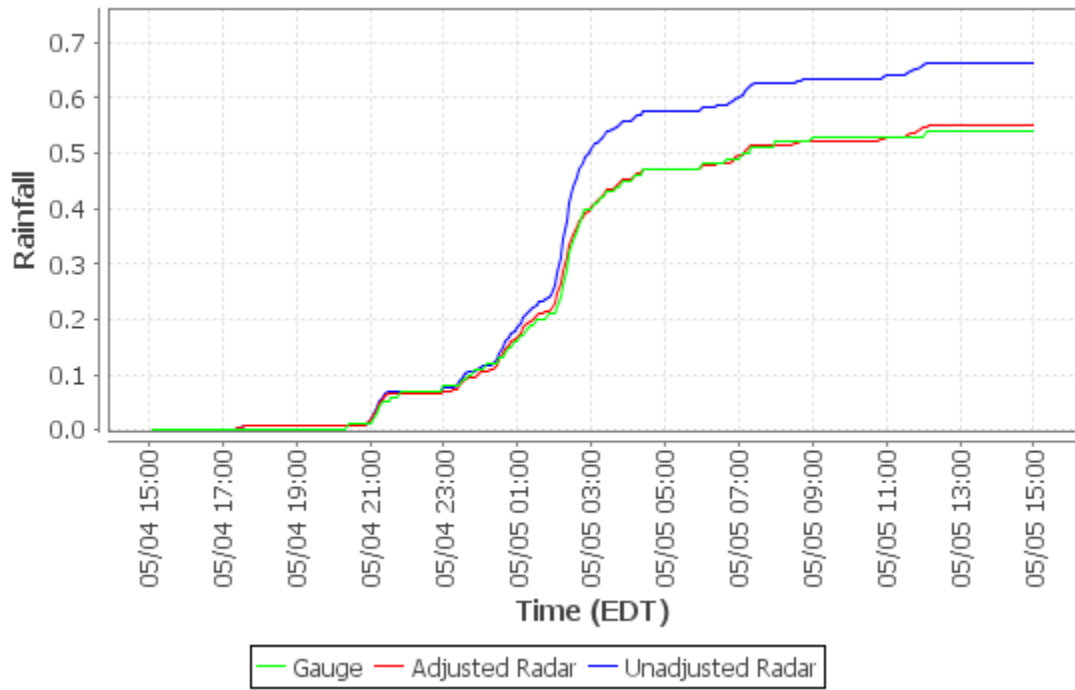
**Cumulative Distribution Plot - Baldwin (Loc12)**



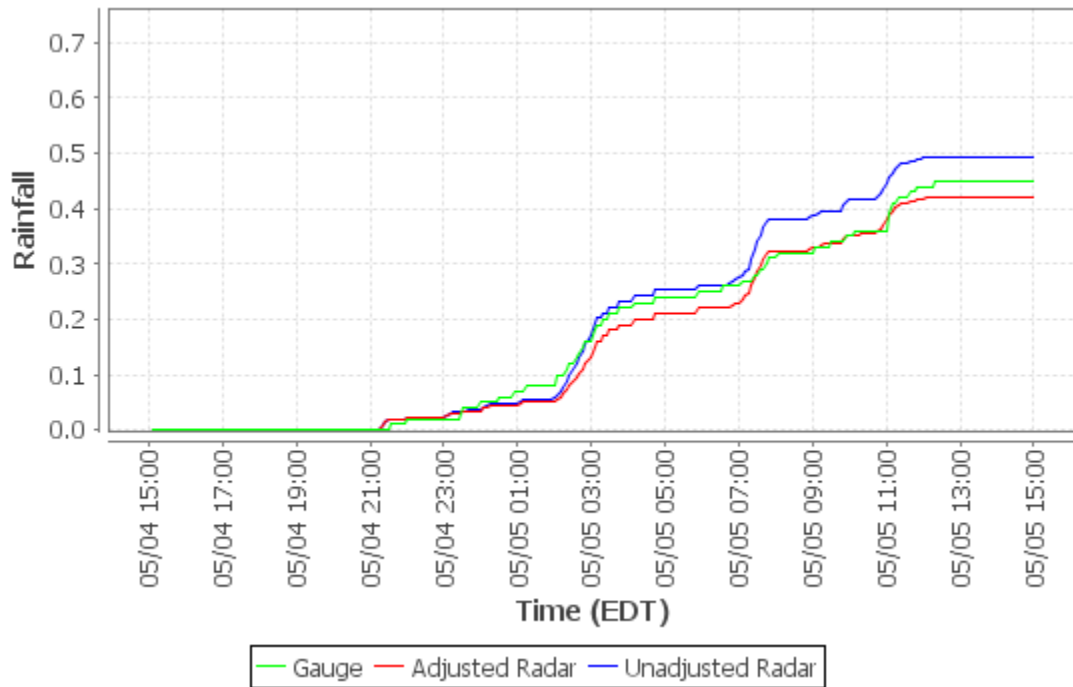
**Cumulative Distribution Plot - M-59 Access Shaft (Loc13)**



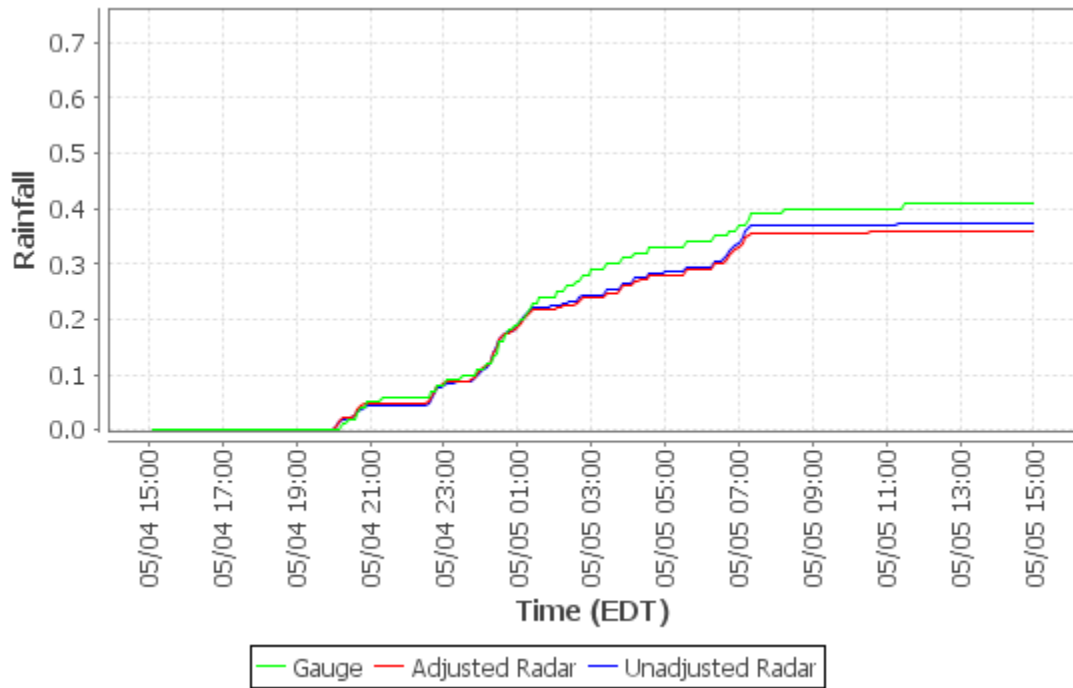
**Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)**



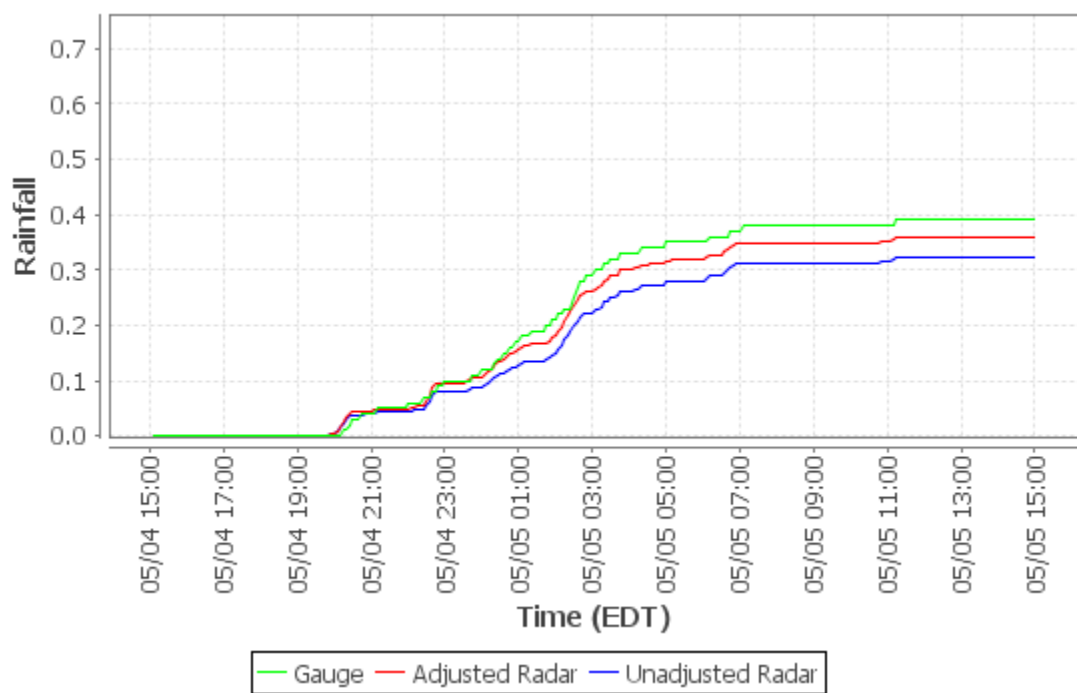
**Cumulative Distribution Plot - Trafford Maint Bldg (Loc15)**



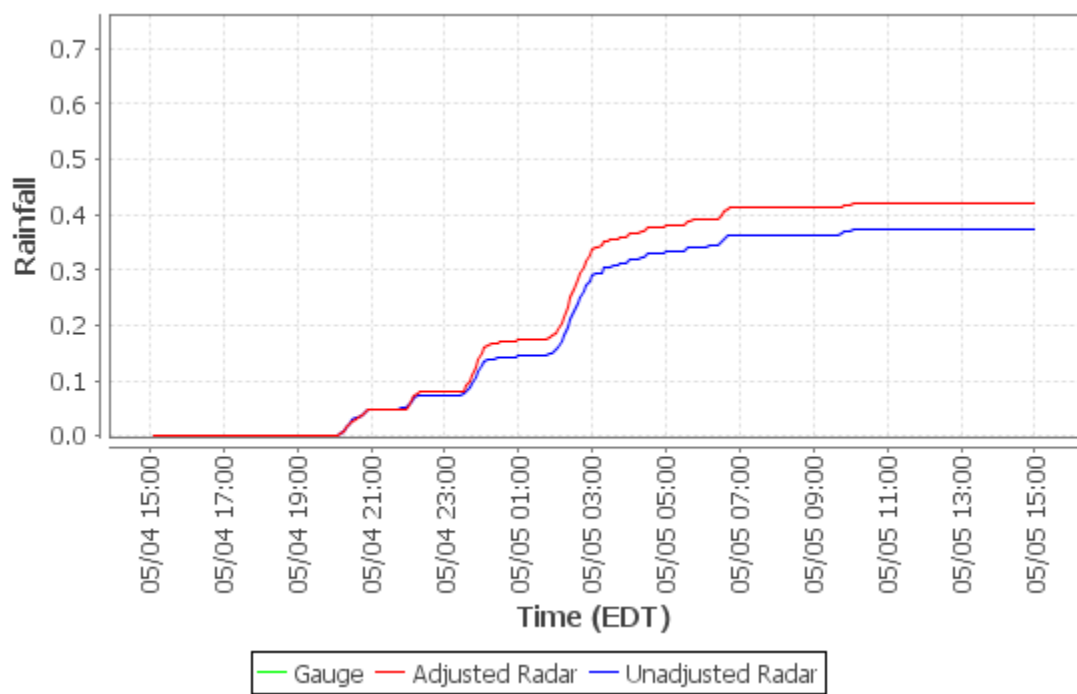
**Cumulative Distribution Plot - Castle Shannon (Loc16)**



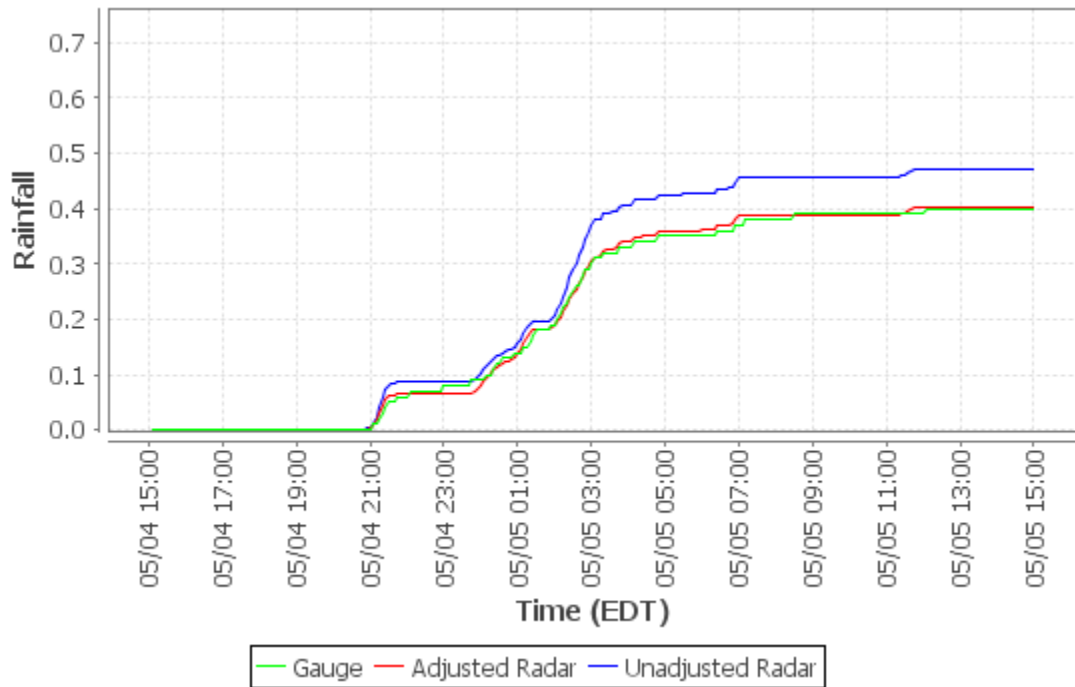
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



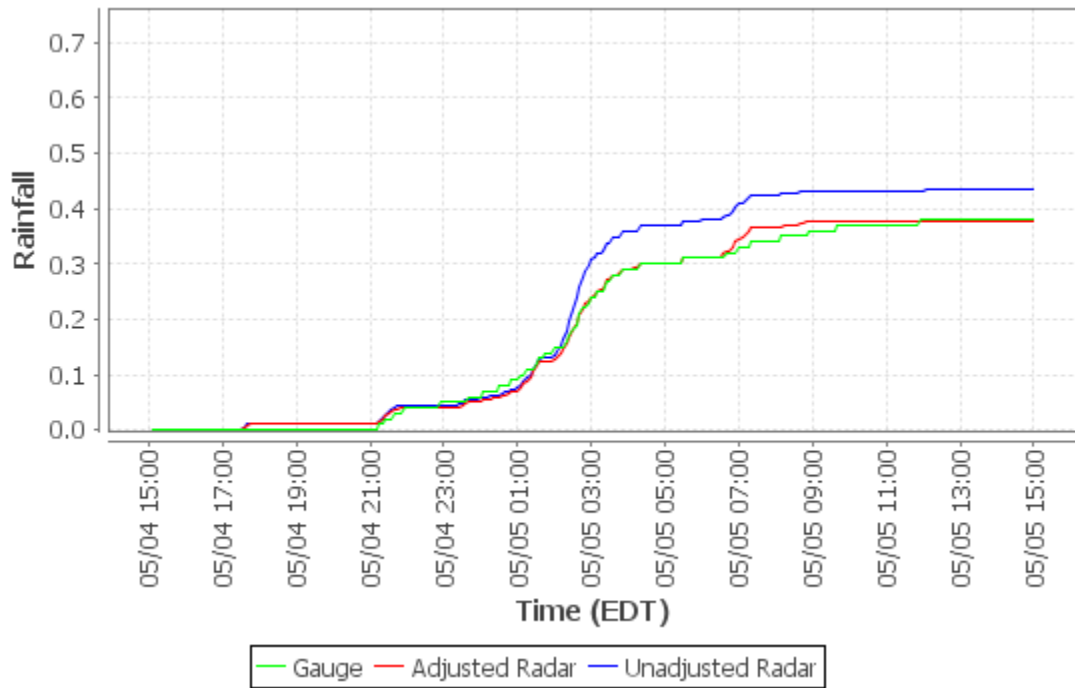
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



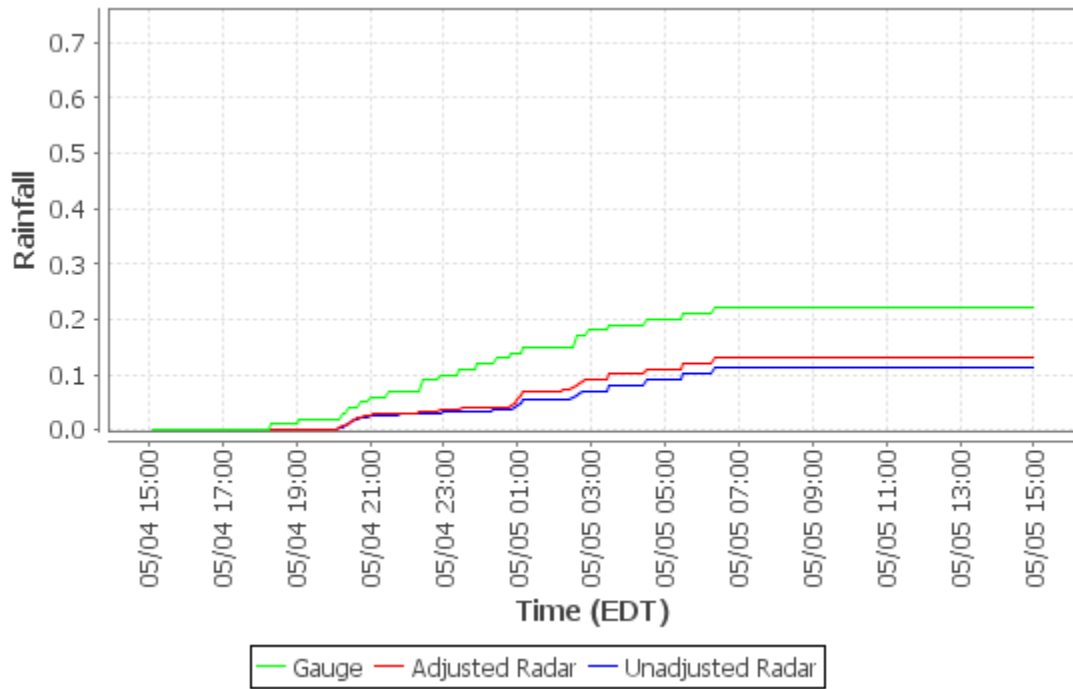
**Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)**



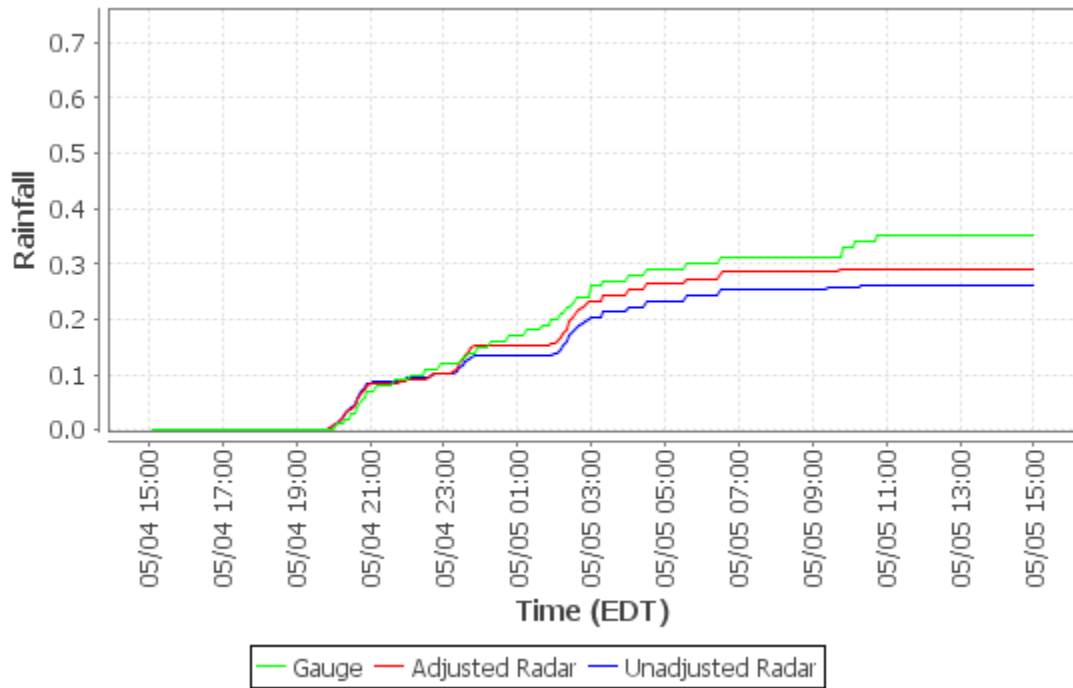
**Cumulative Distribution Plot - Gascola Eq Facility (Loc20)**



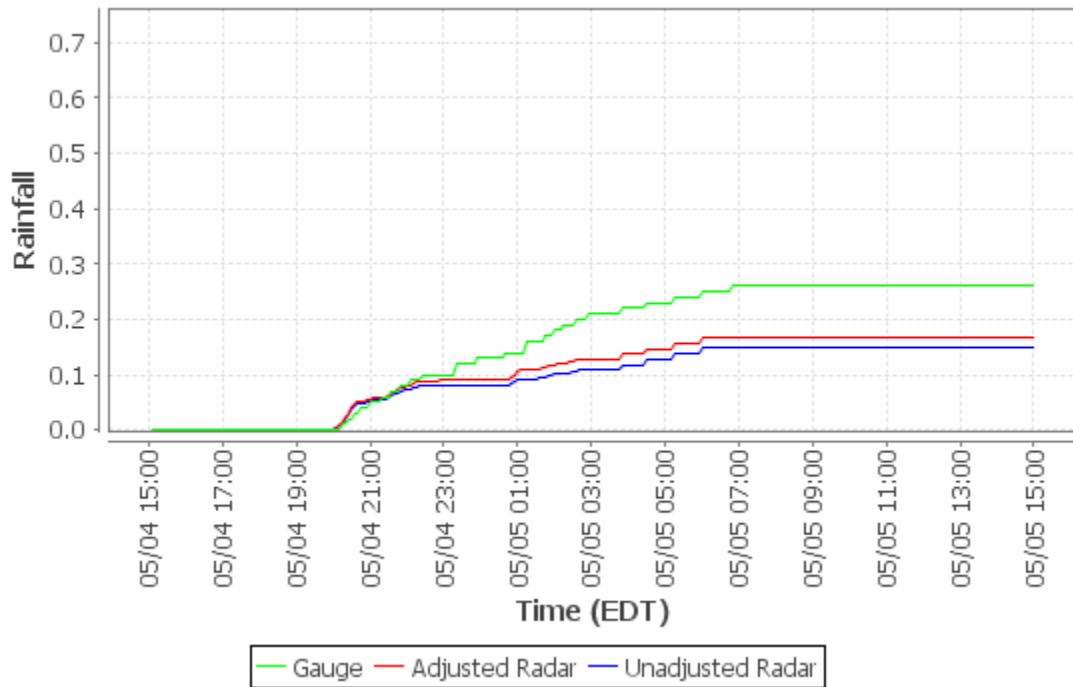
**Cumulative Distribution Plot - Moon TWP (Loc21)**



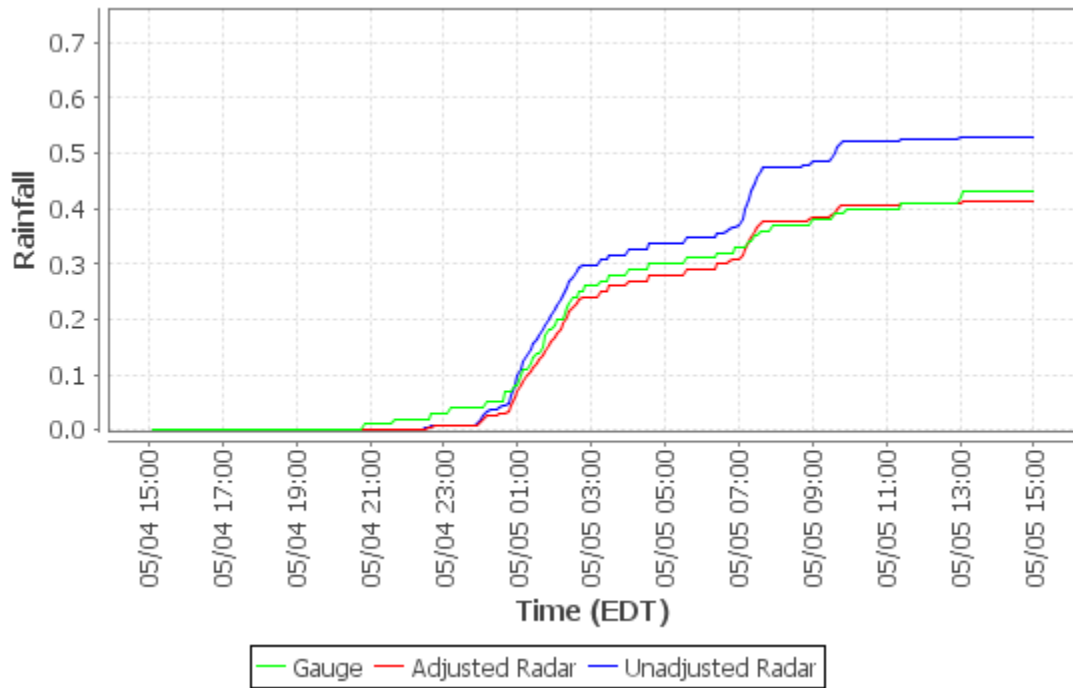
**Cumulative Distribution Plot - North Fayette TWP (Loc22)**



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

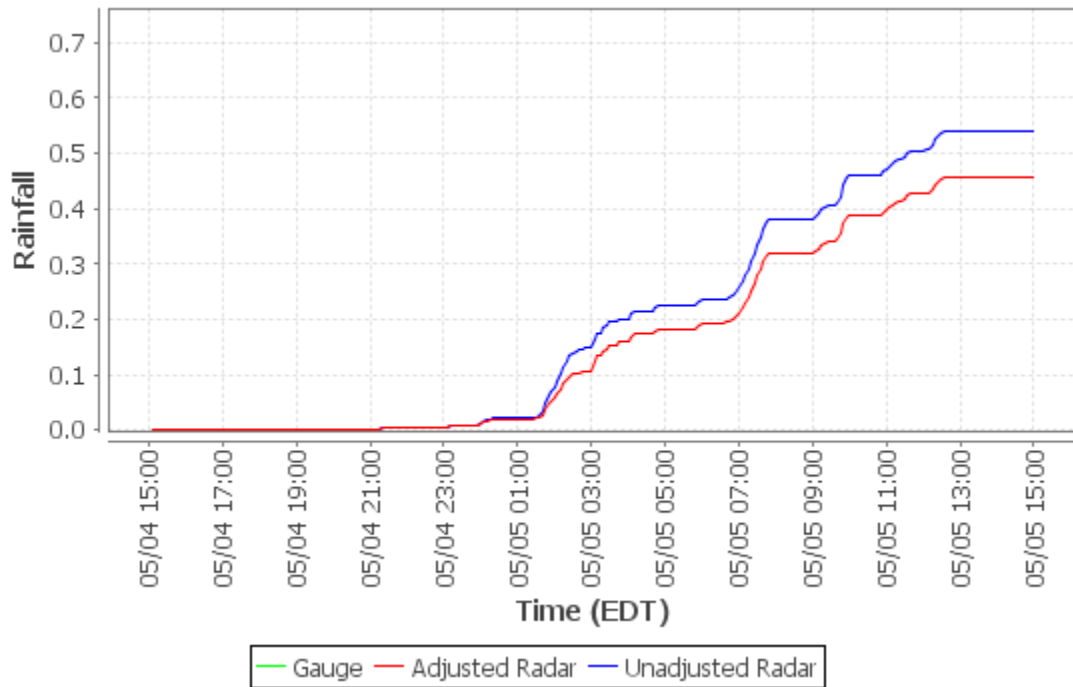


**Cumulative Distribution Plot - Jefferson Hills (Loc24)**

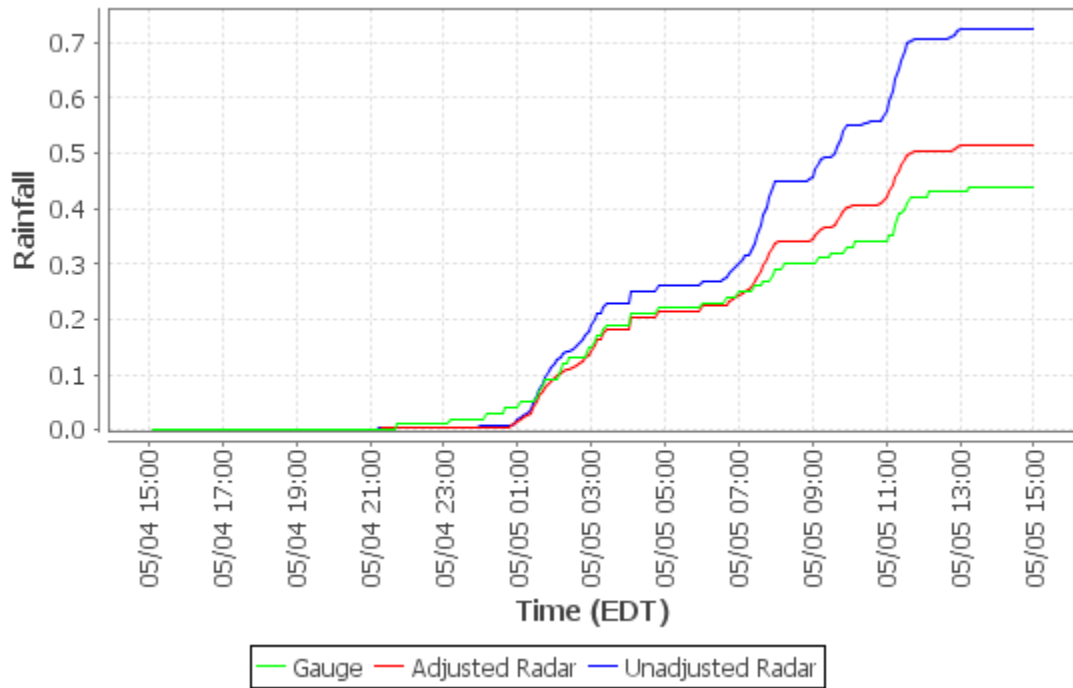




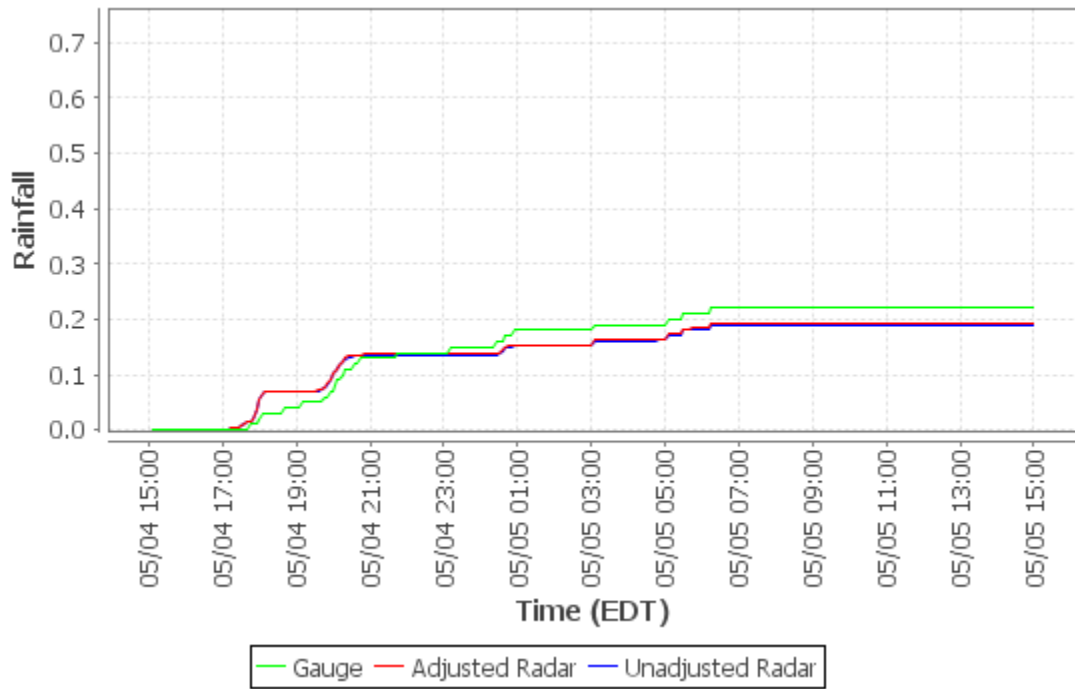
**Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)**



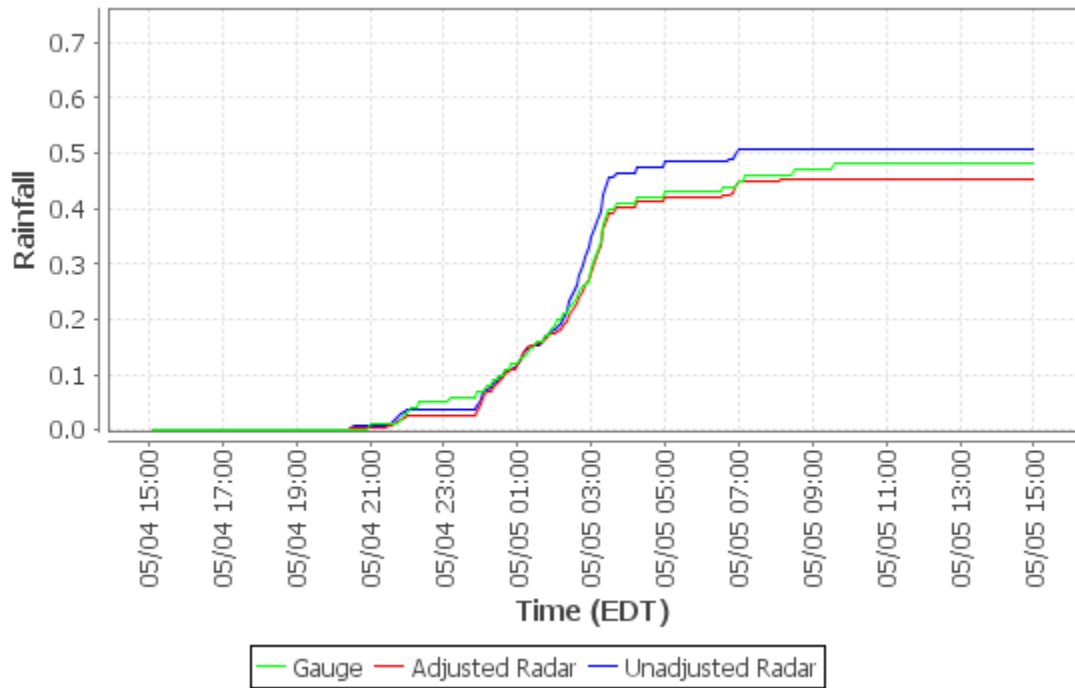
**Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)**



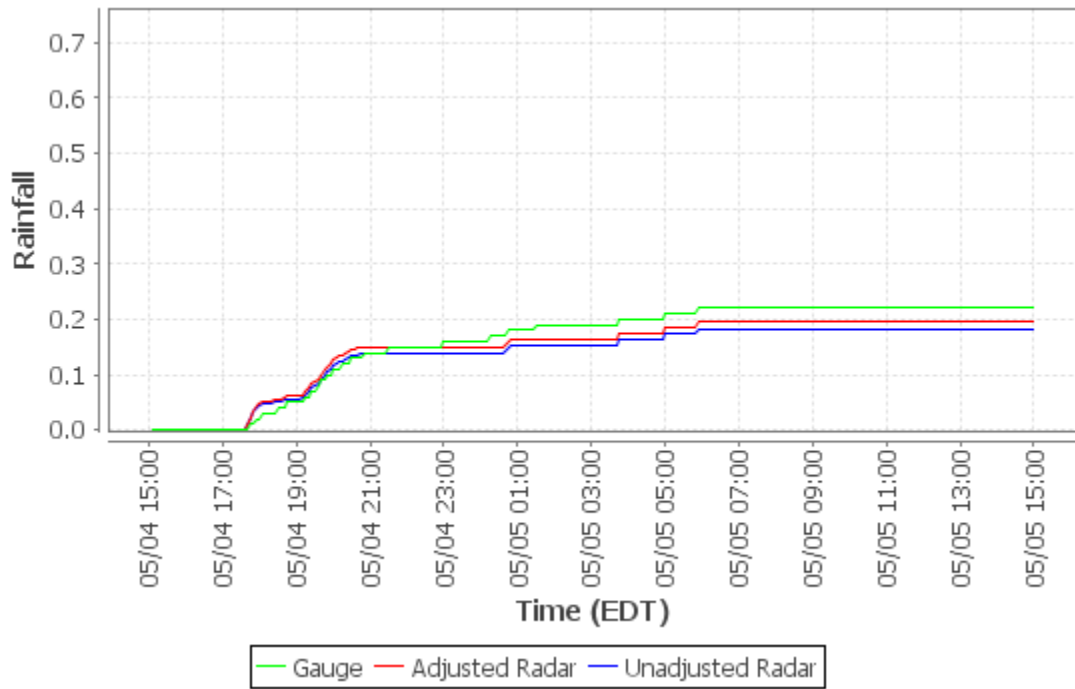
**Cumulative Distribution Plot - Marshall TWP (Loc27)**



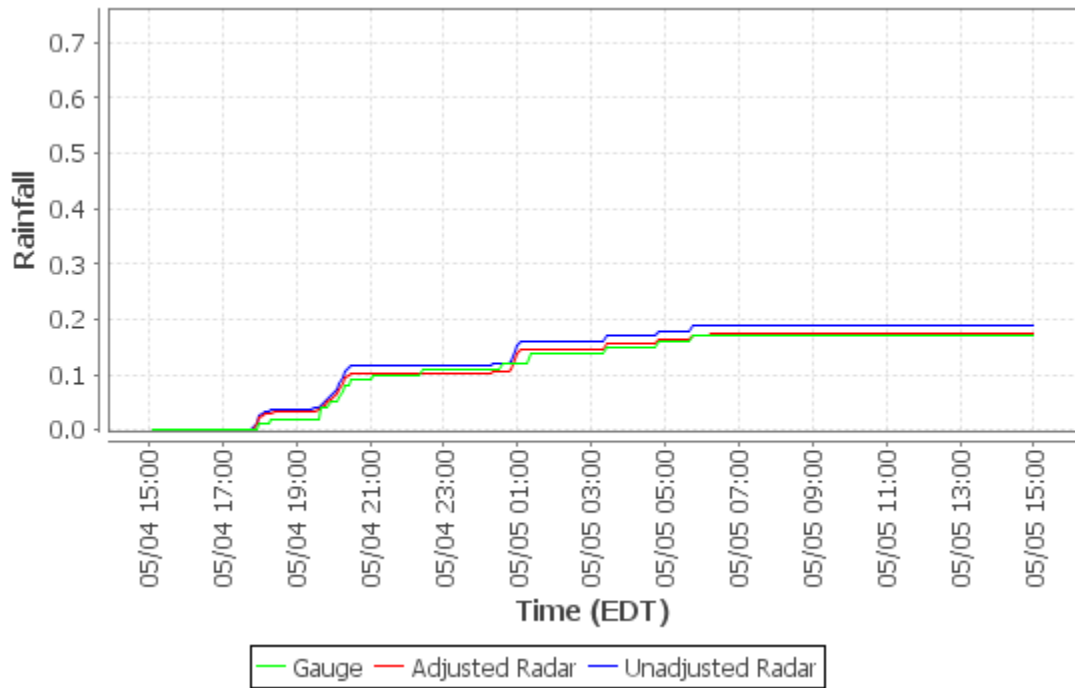
**Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)**



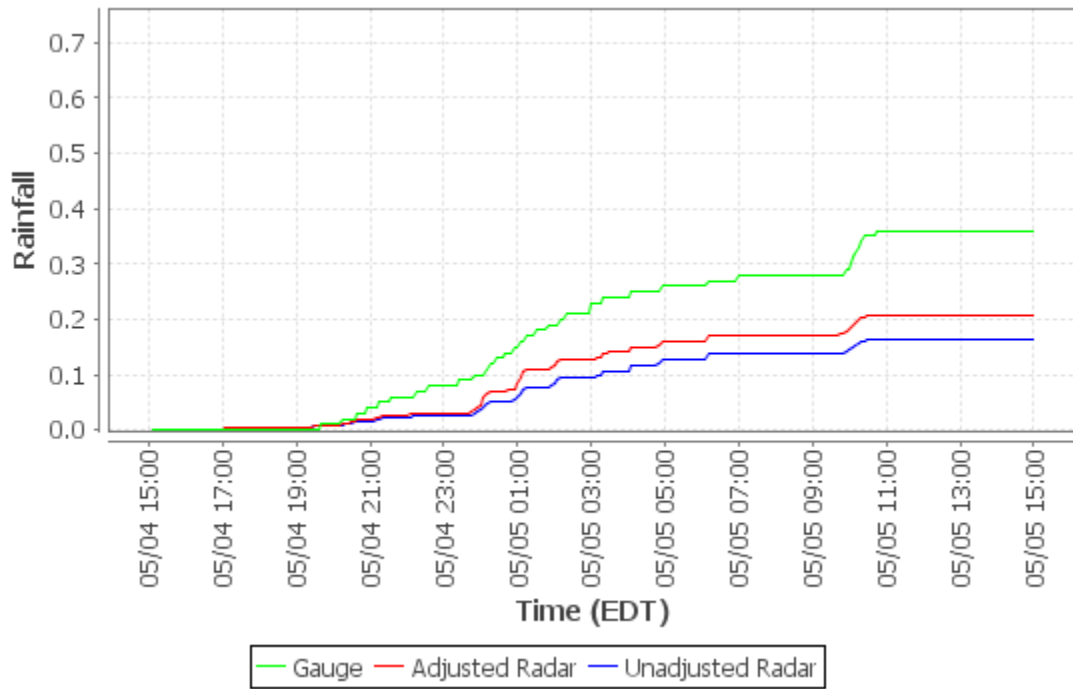
**Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)**



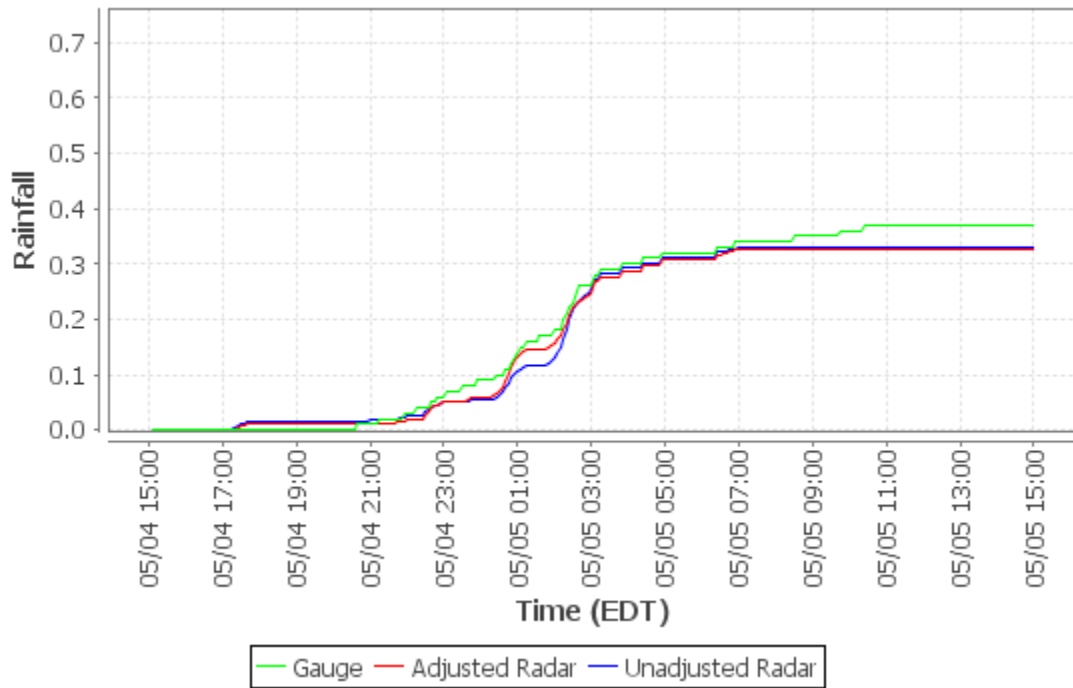
**Cumulative Distribution Plot - McCandless Twn Hall (Loc30)**



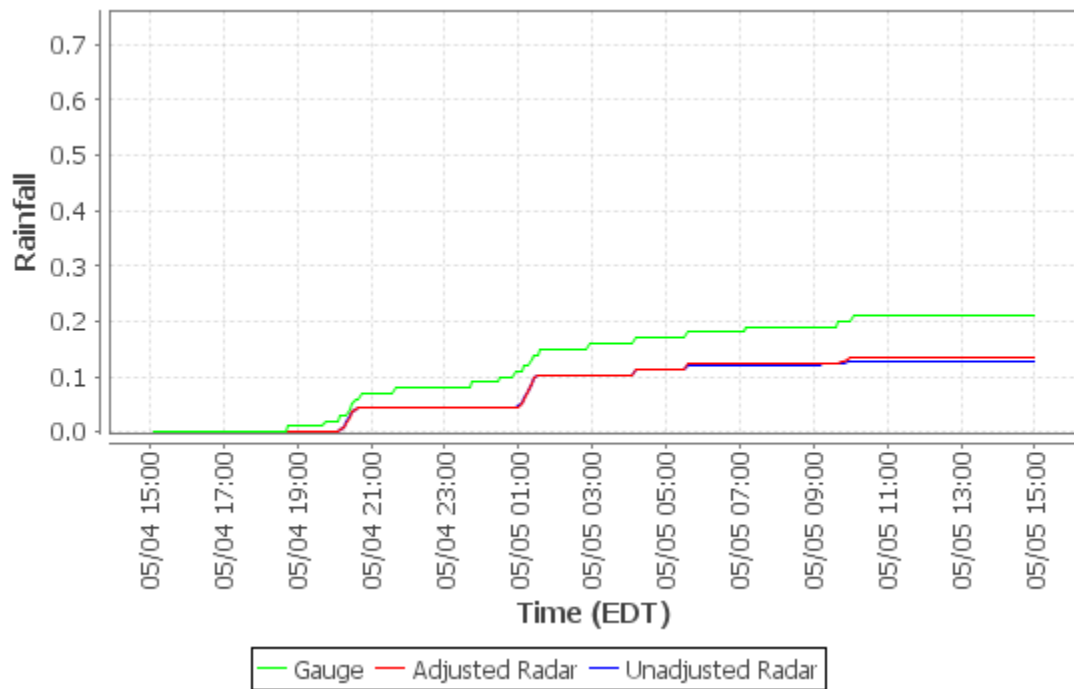
**Cumulative Distribution Plot - Hampton Municipal Bldg (Loc31)**



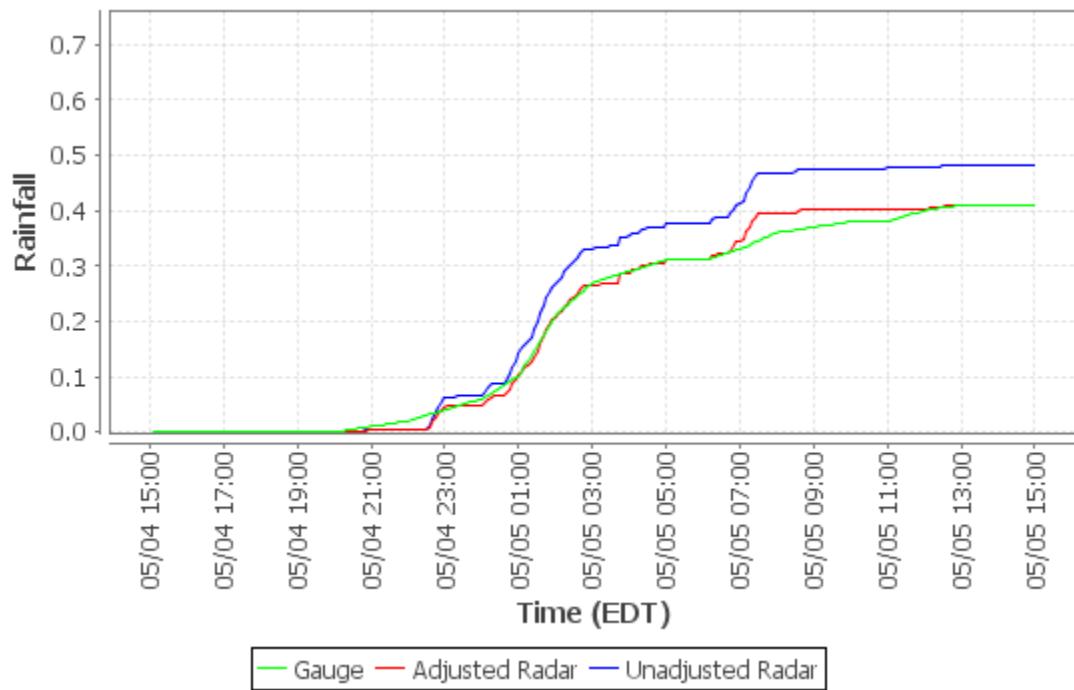
**Cumulative Distribution Plot - Arnold (Loc32)**



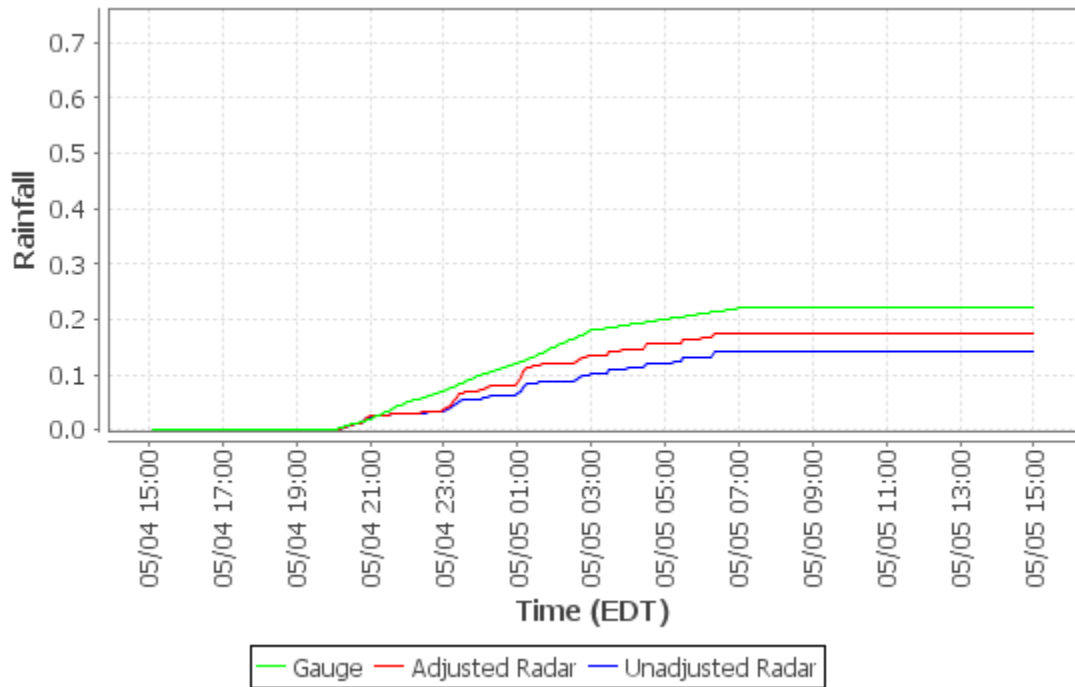
**Cumulative Distribution Plot - Richland TWP (Loc33)**



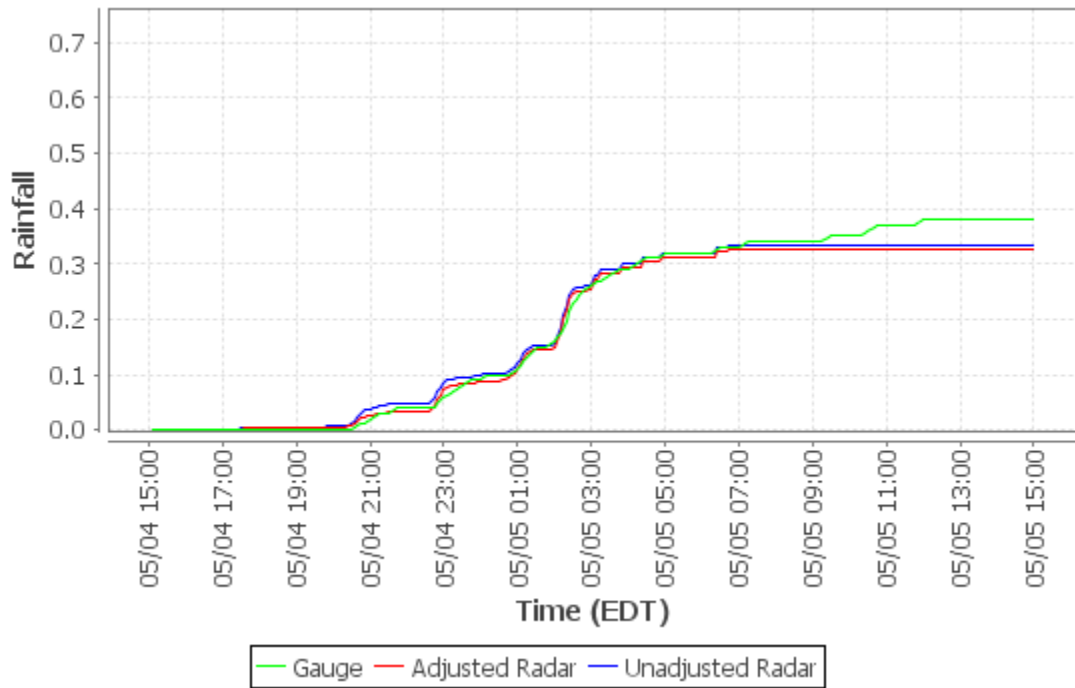
**Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)**



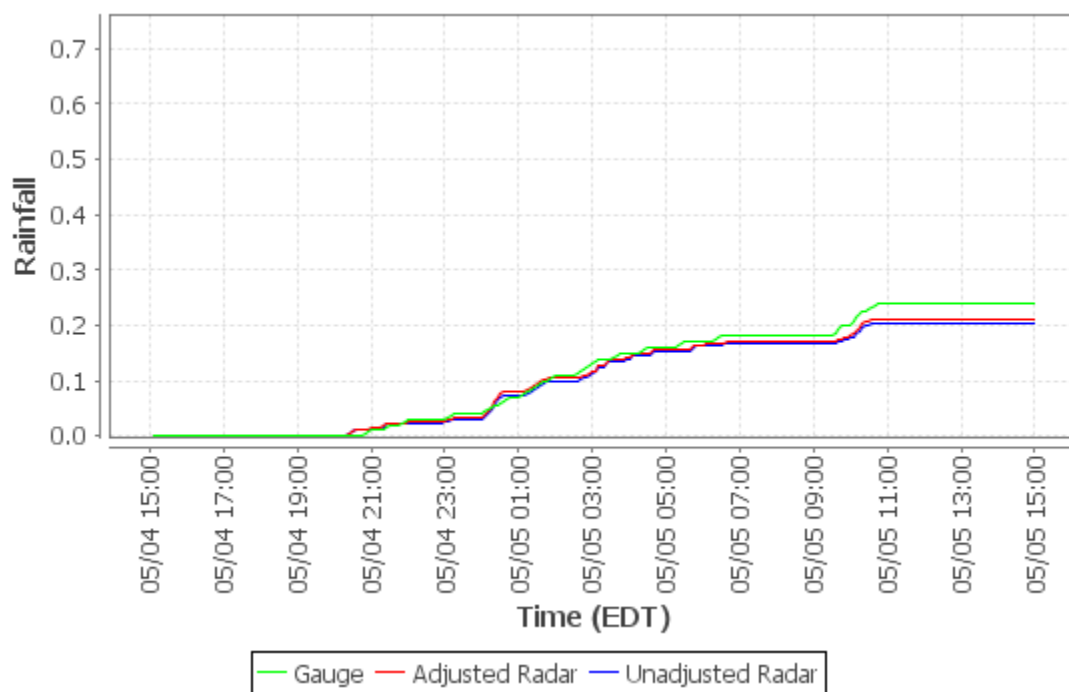
**Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)**



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



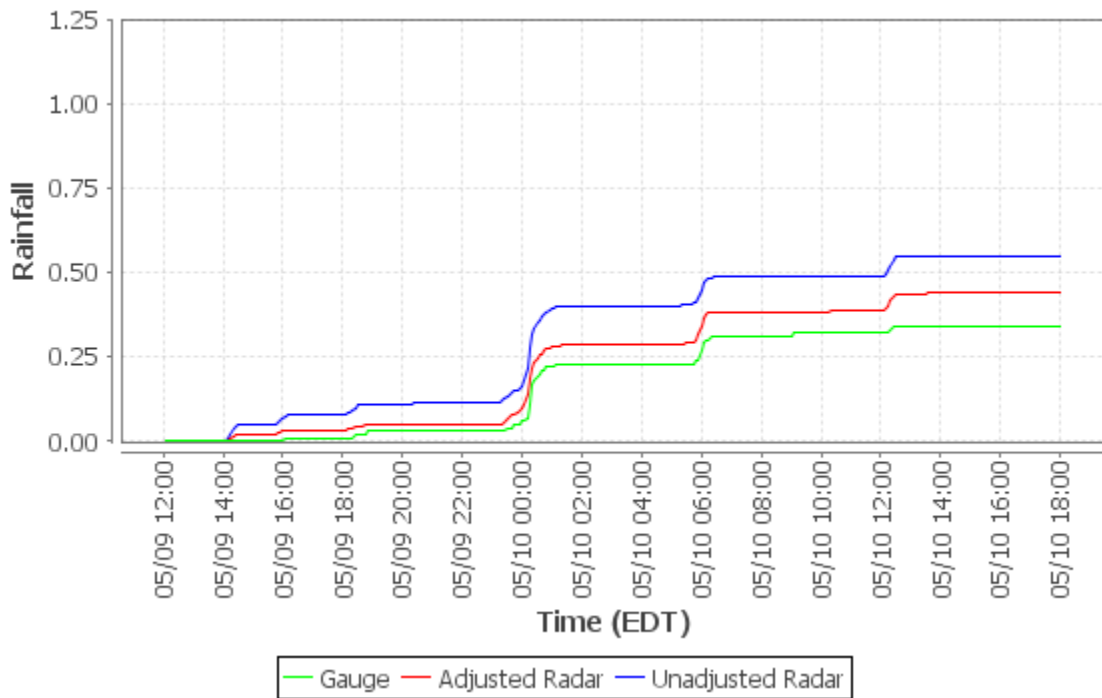
### Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth (03085734)



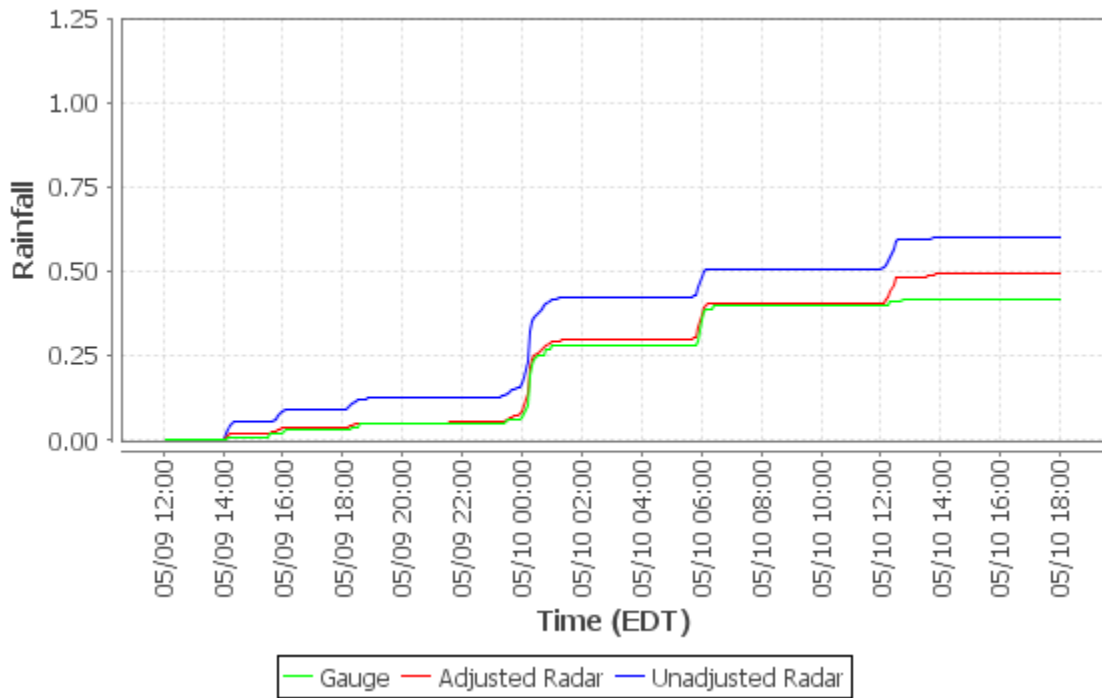
## **Appendix E - Event 3 (2019-05-10) CDPs**



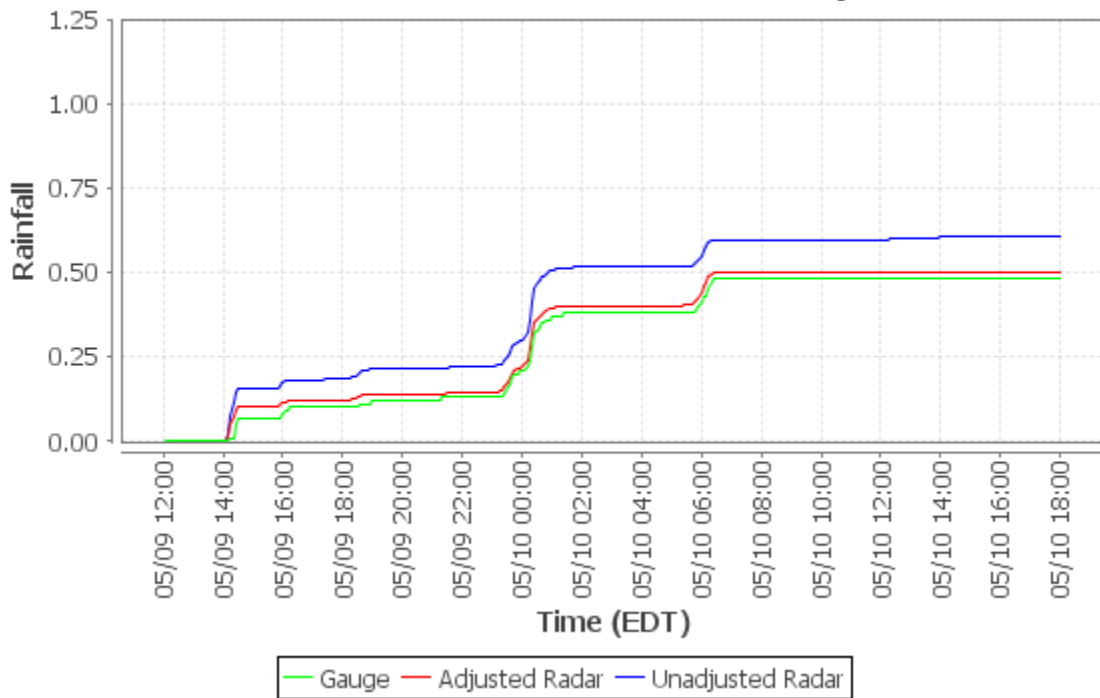
**Cumulative Distribution Plot - PWSA-Montana St. (Loc01)**



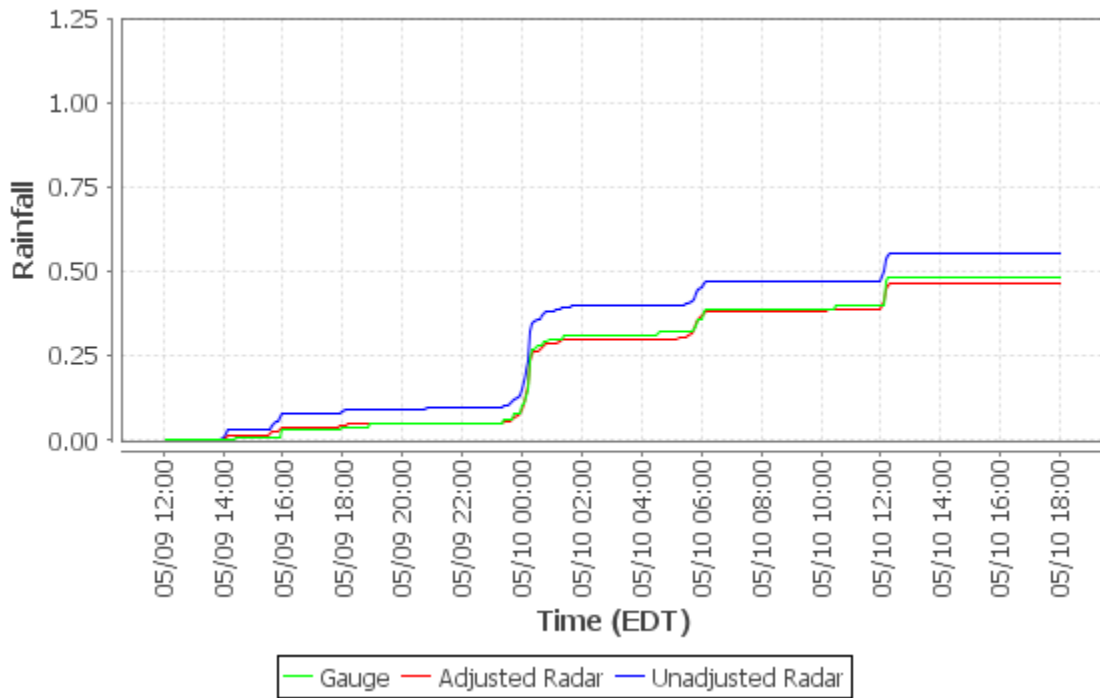
**Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)**



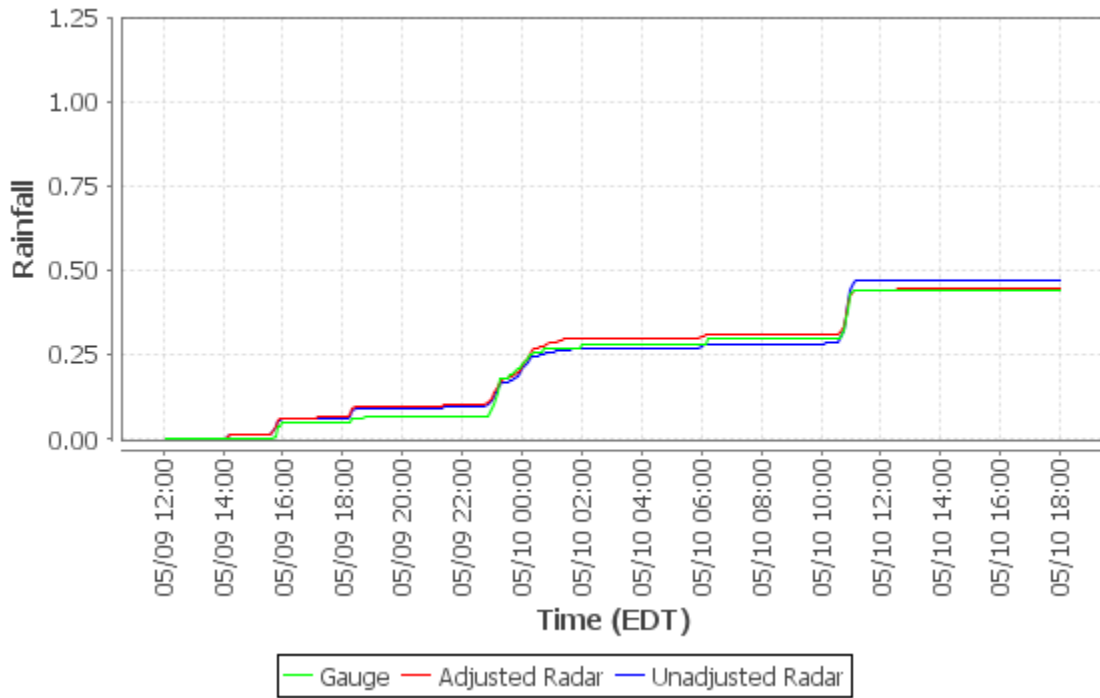
**Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)**



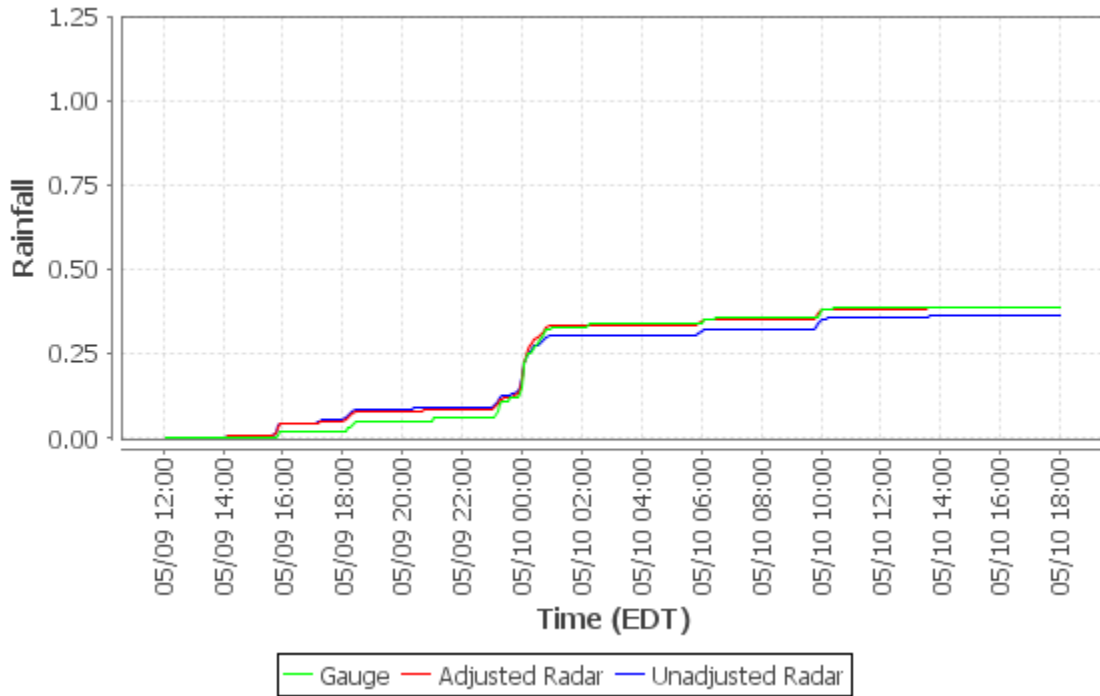
**Cumulative Distribution Plot - Kennedy Twp PS (Loc04)**



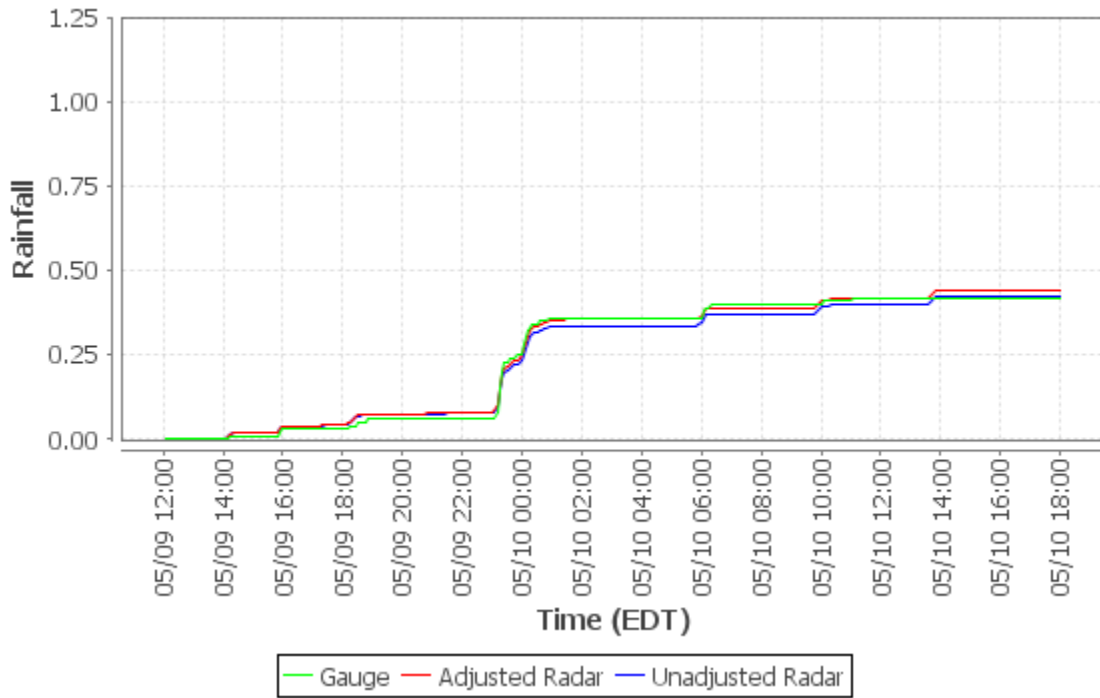
**Cumulative Distribution Plot - Upper St. Clair (Loc05)**



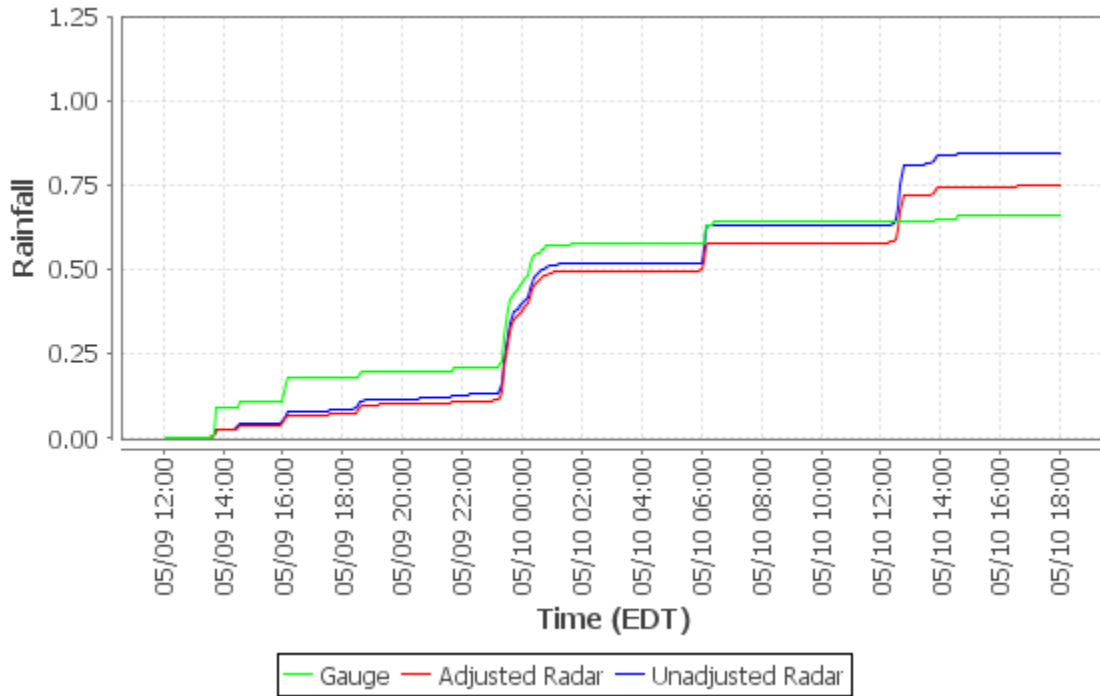
**Cumulative Distribution Plot - Carnegie Transit Time (Loc06)**



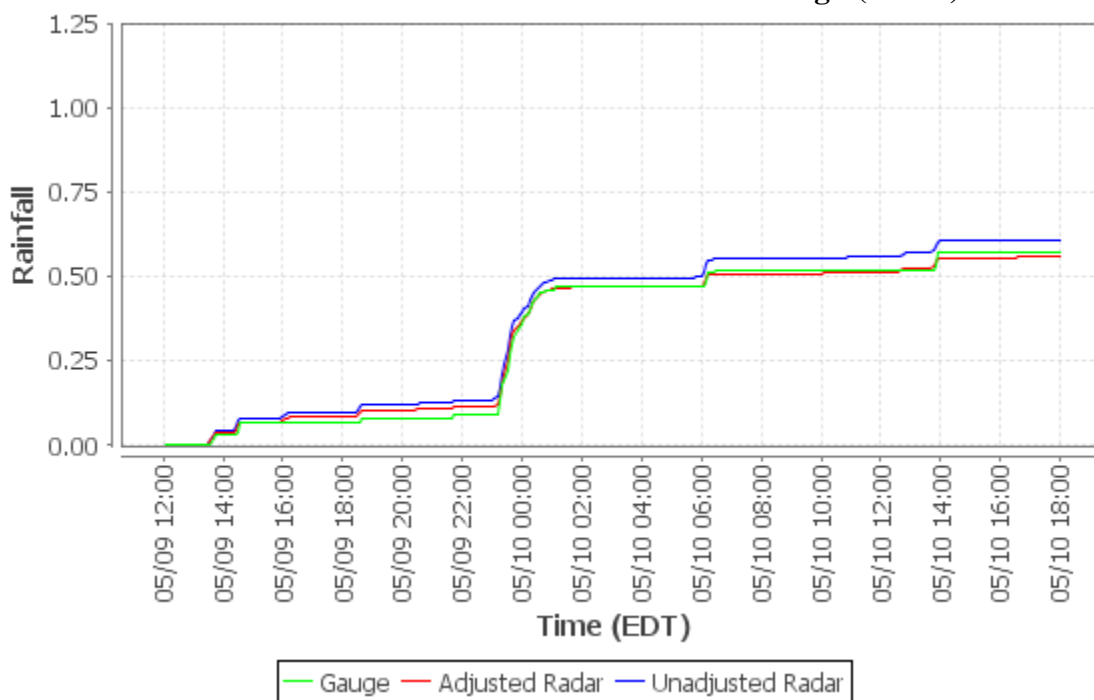
**Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)**



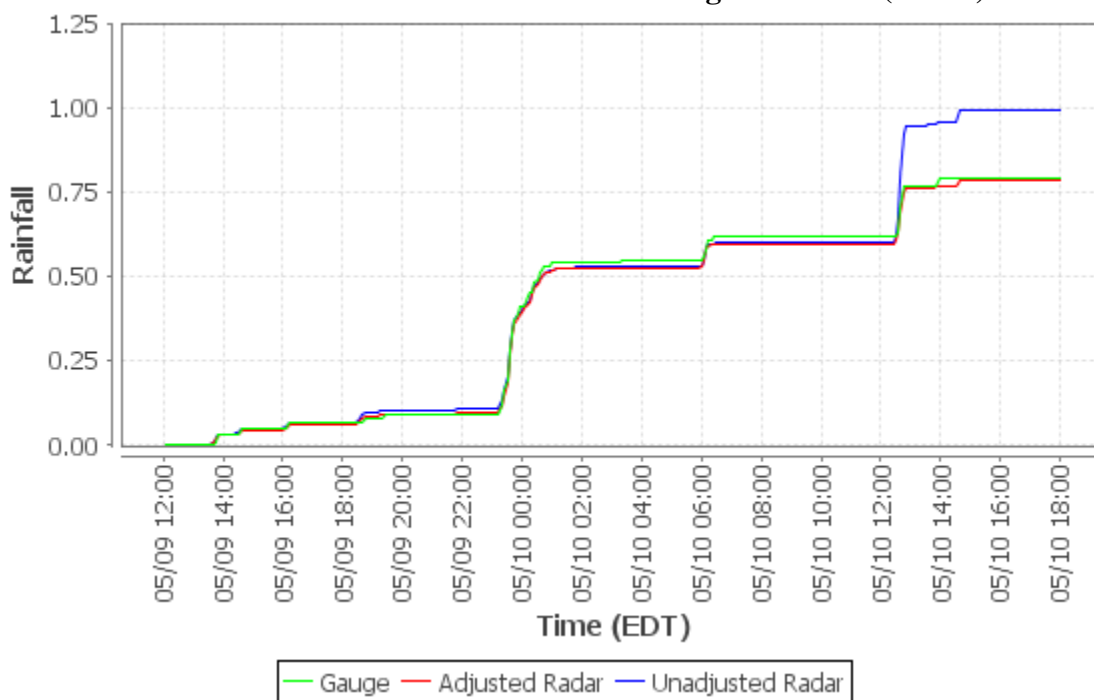
**Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)**



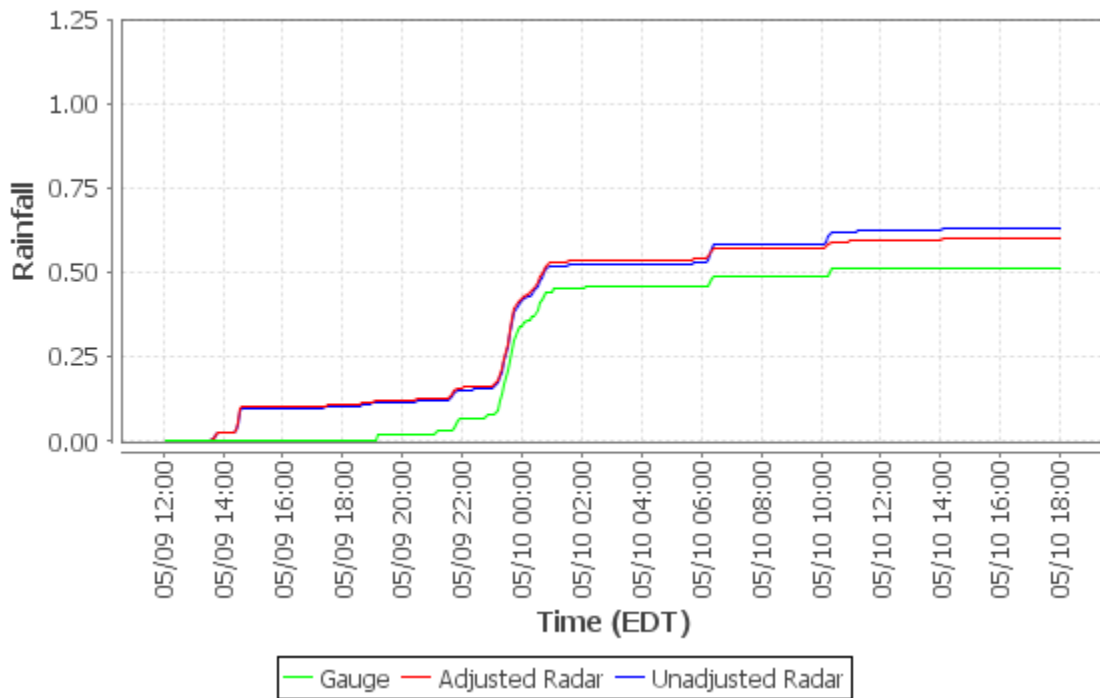
**Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)**



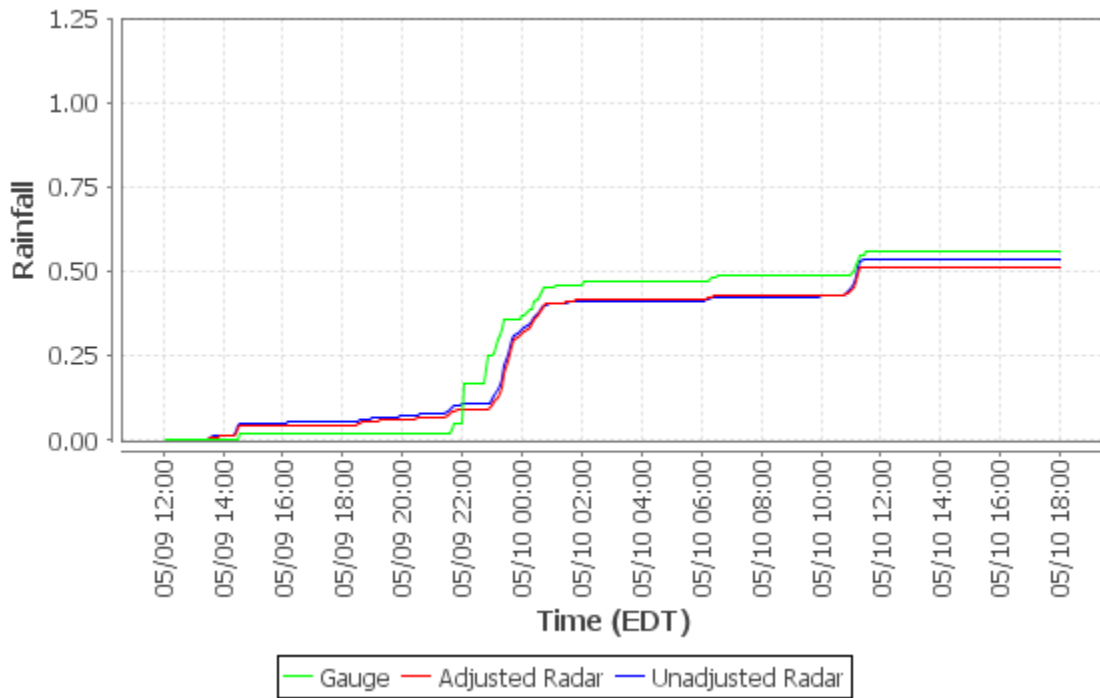
**Cumulative Distribution Plot - PWSA-Highland Park (Loc10)**



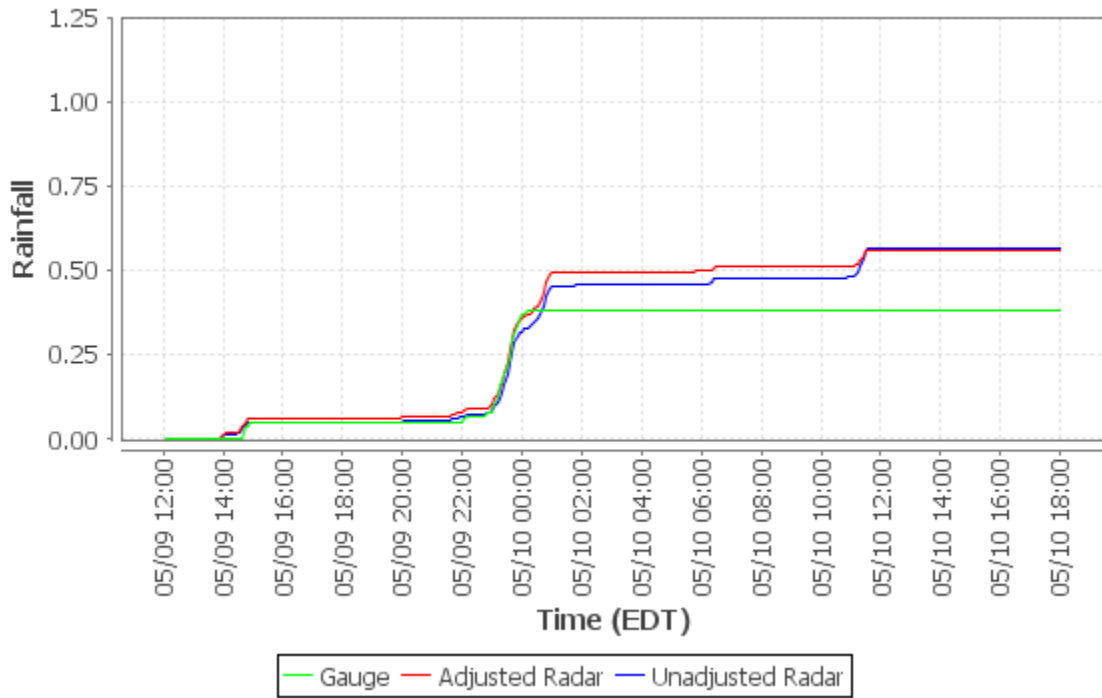
**Cumulative Distribution Plot - M-46 Access Shaft (Loc11)**



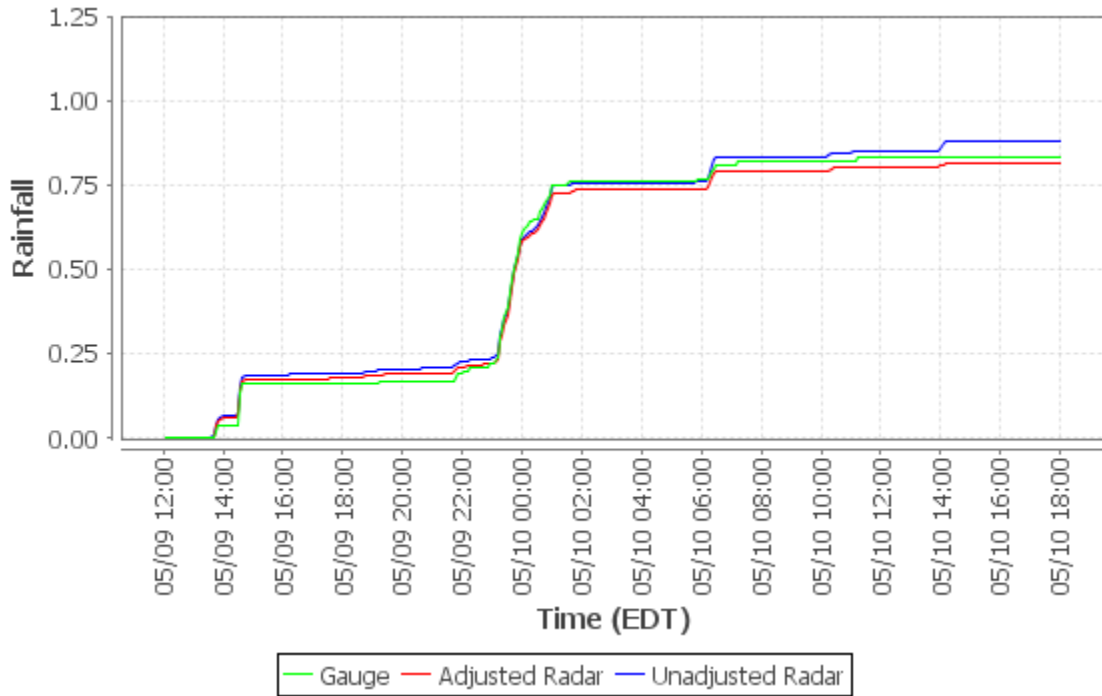
**Cumulative Distribution Plot - Baldwin (Loc12)**



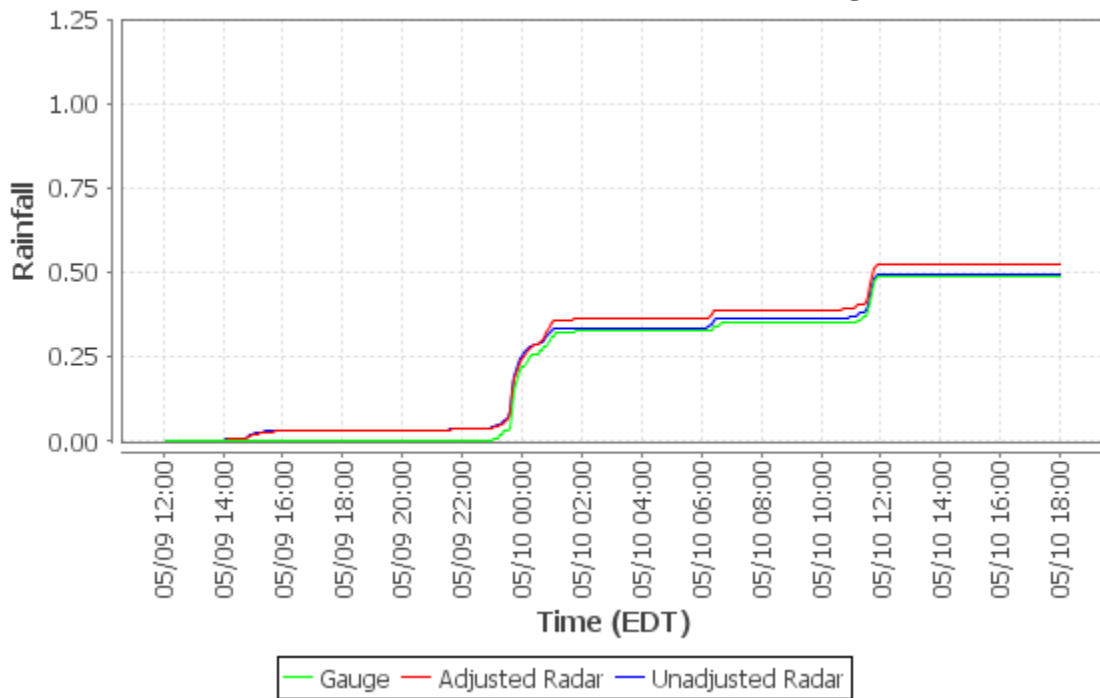
**Cumulative Distribution Plot - M-59 Access Shaft (Loc13)**



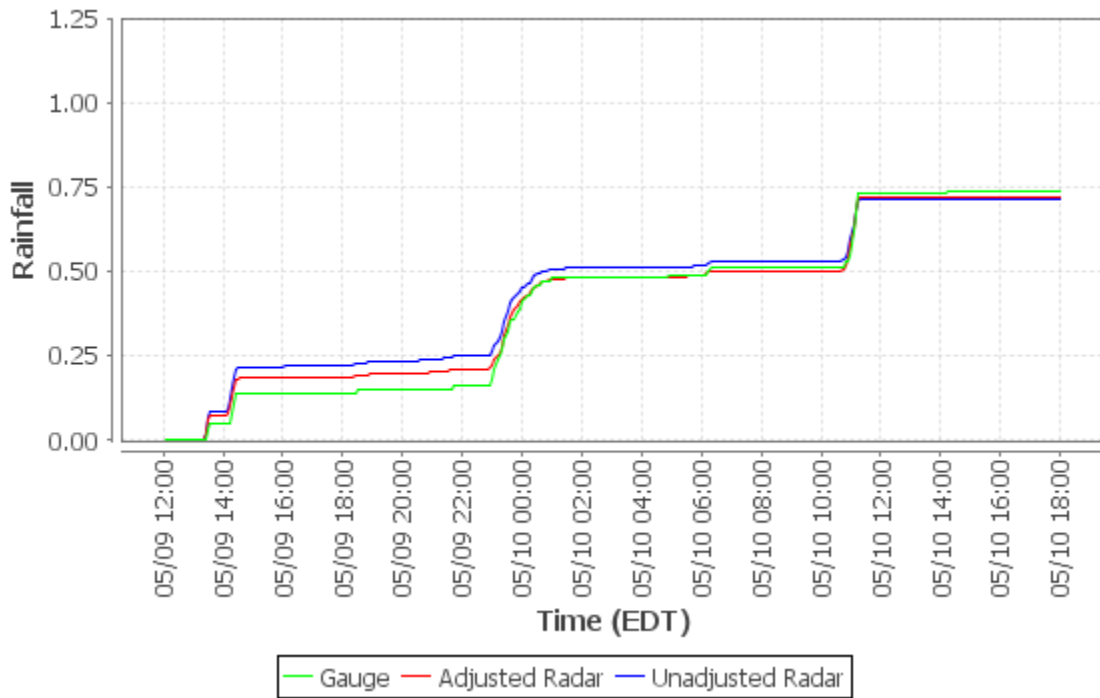
**Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)**



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

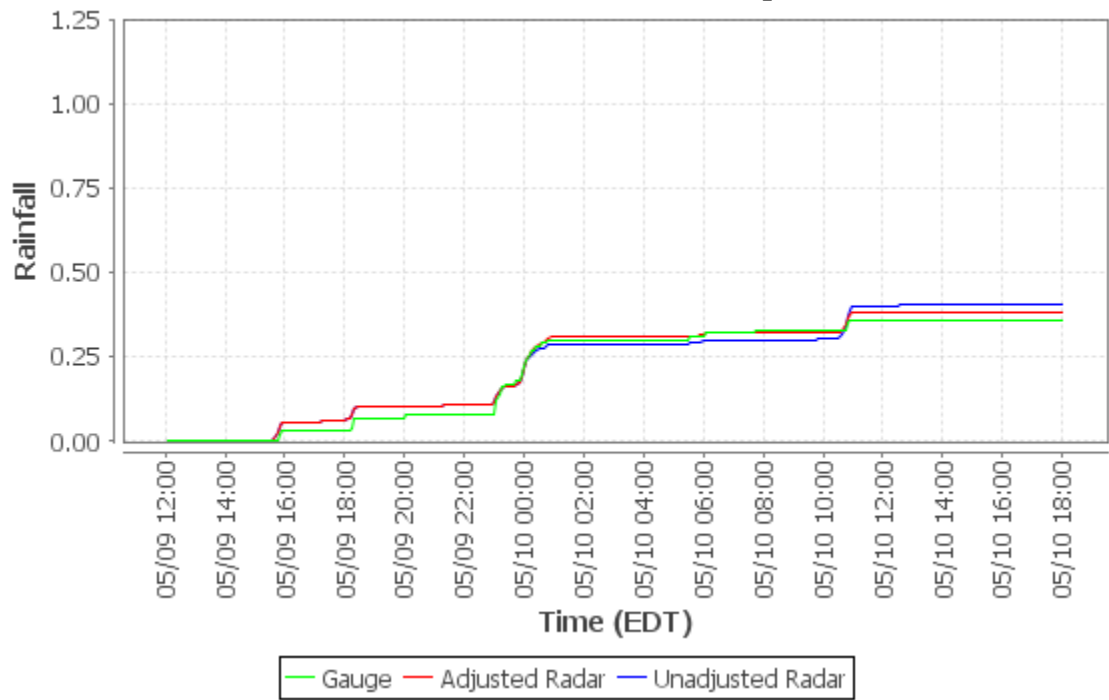


**Cumulative Distribution Plot - Castle Shannon (Loc16)**

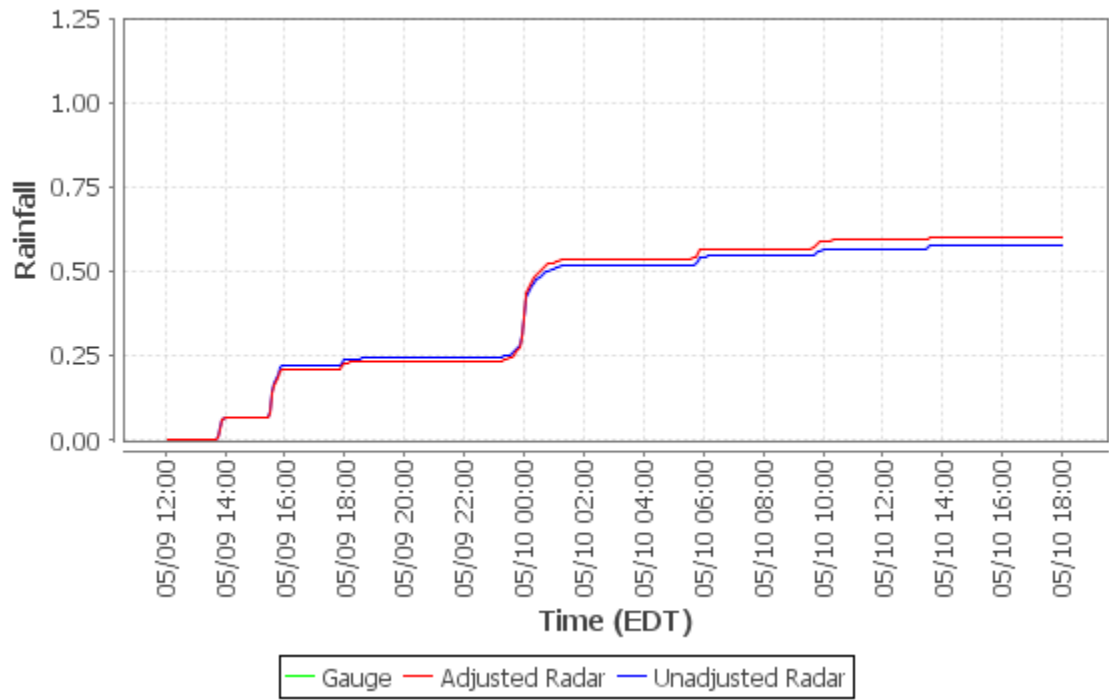




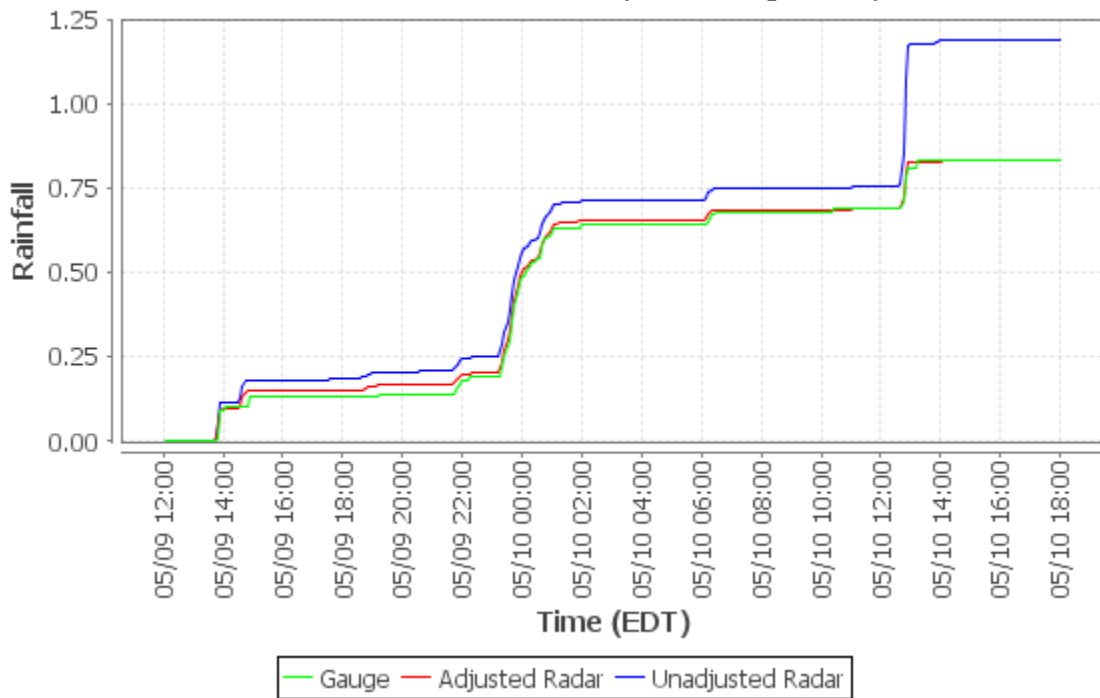
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



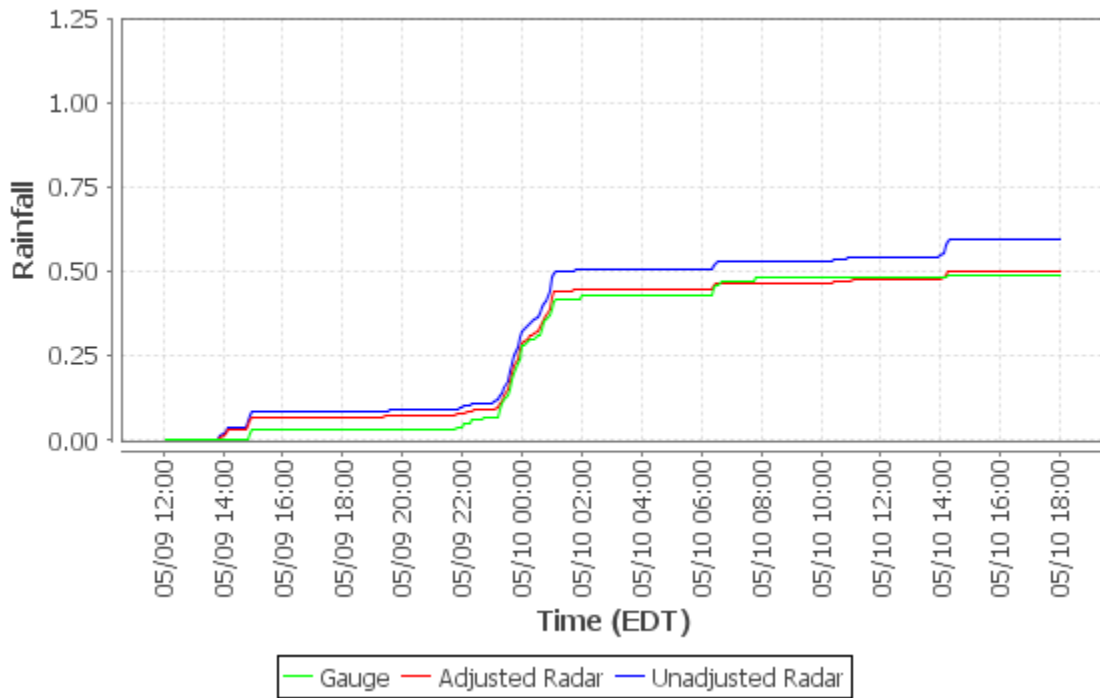
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



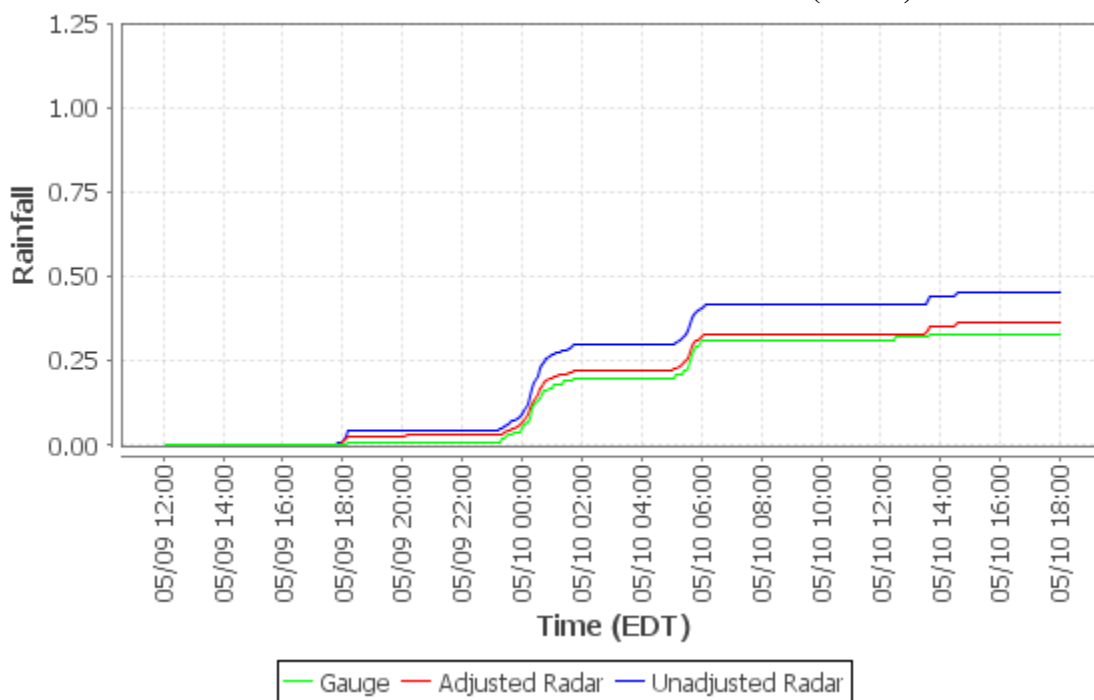
**Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)**



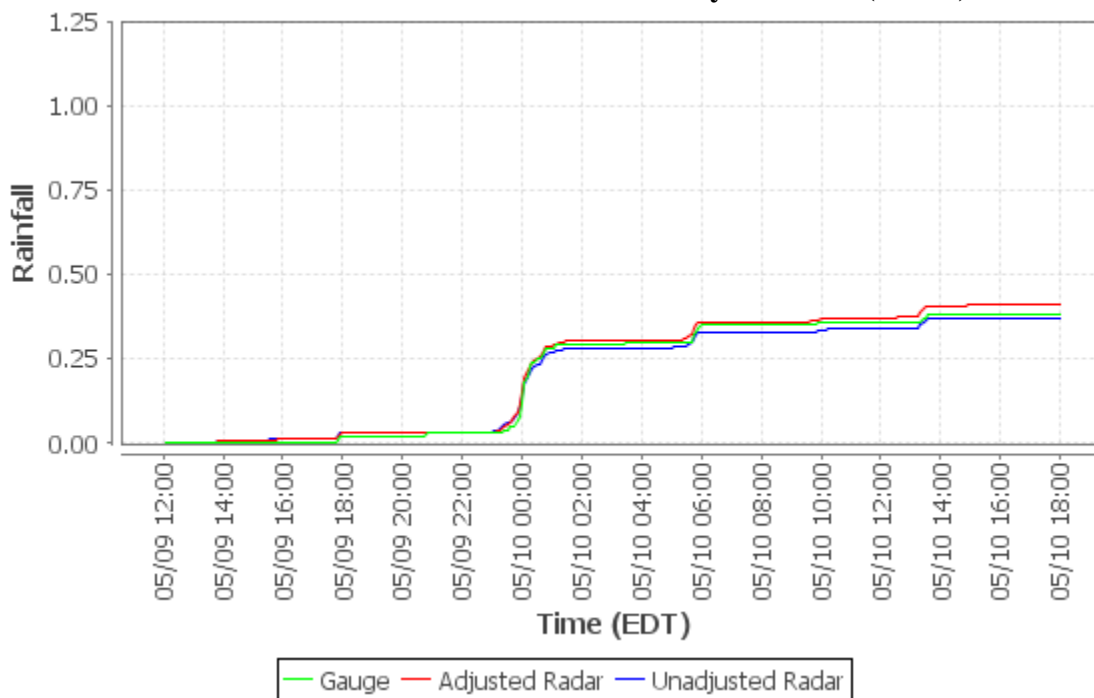
**Cumulative Distribution Plot - Gascola Eq Facility (Loc20)**



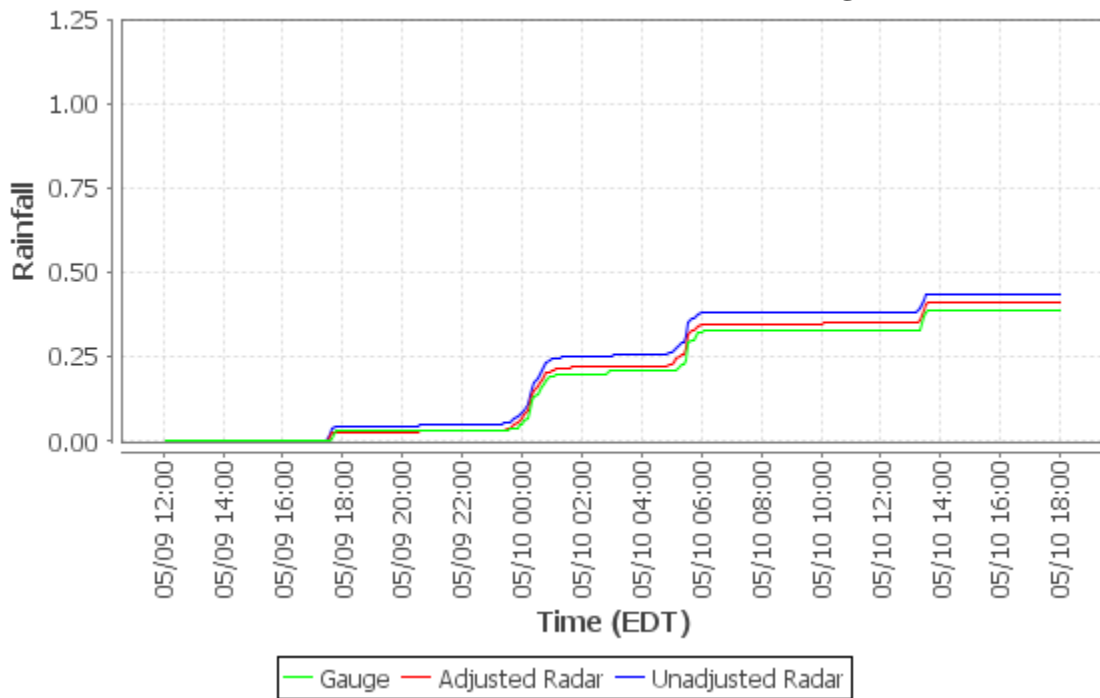
**Cumulative Distribution Plot - Moon TWP (Loc21)**



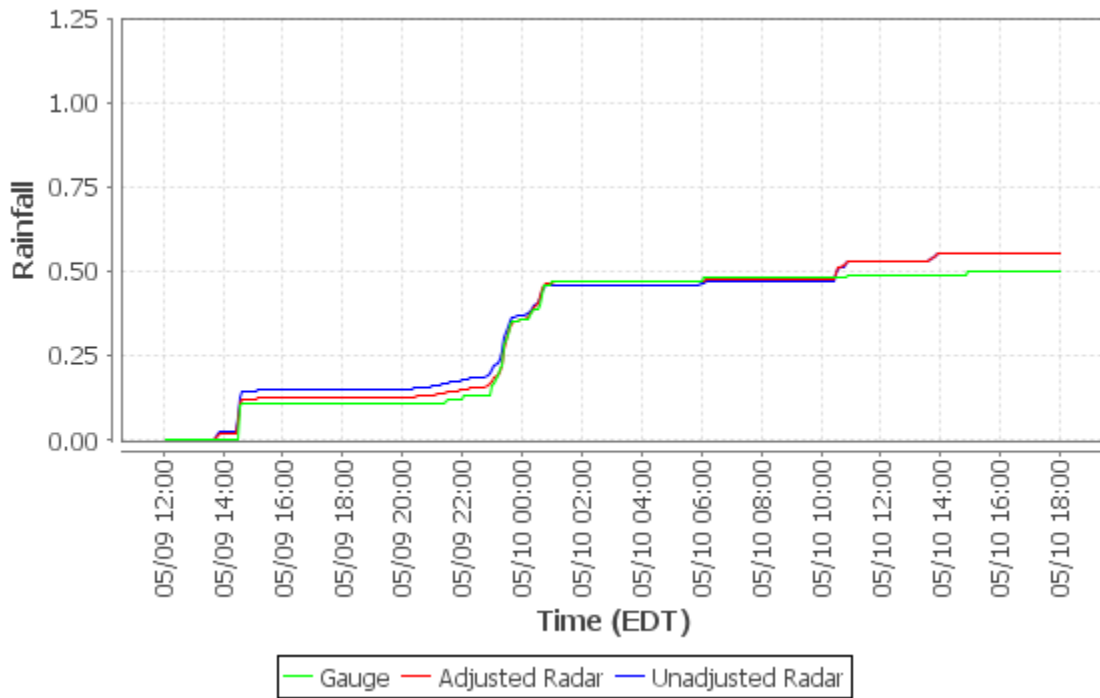
**Cumulative Distribution Plot - North Fayette TWP (Loc22)**



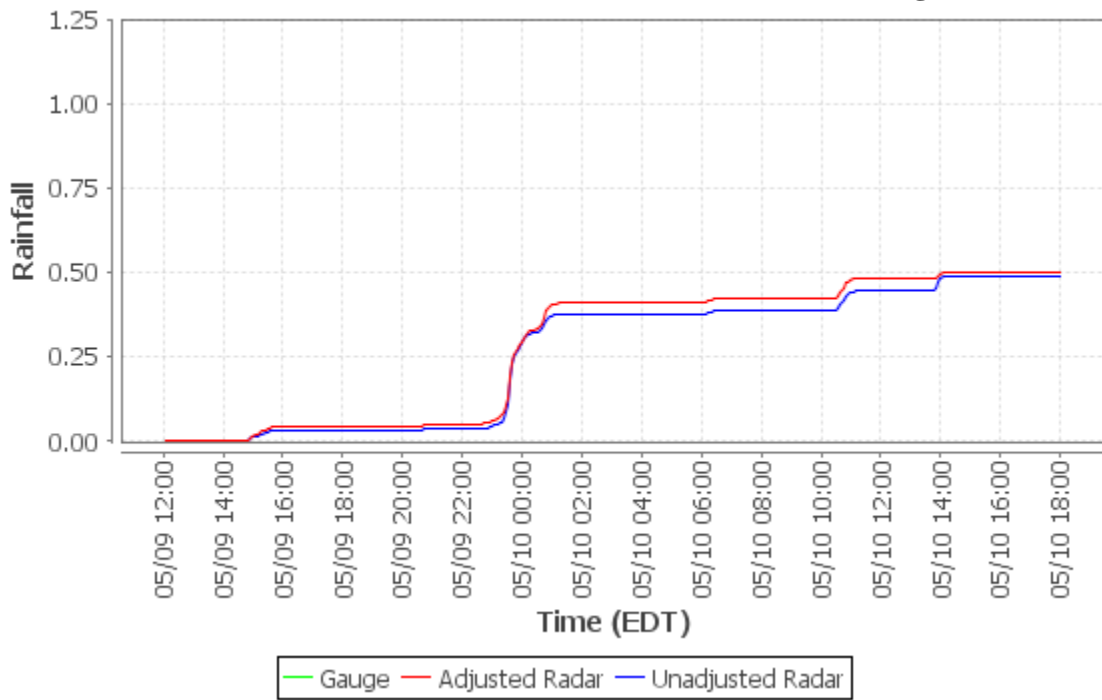
**Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)**



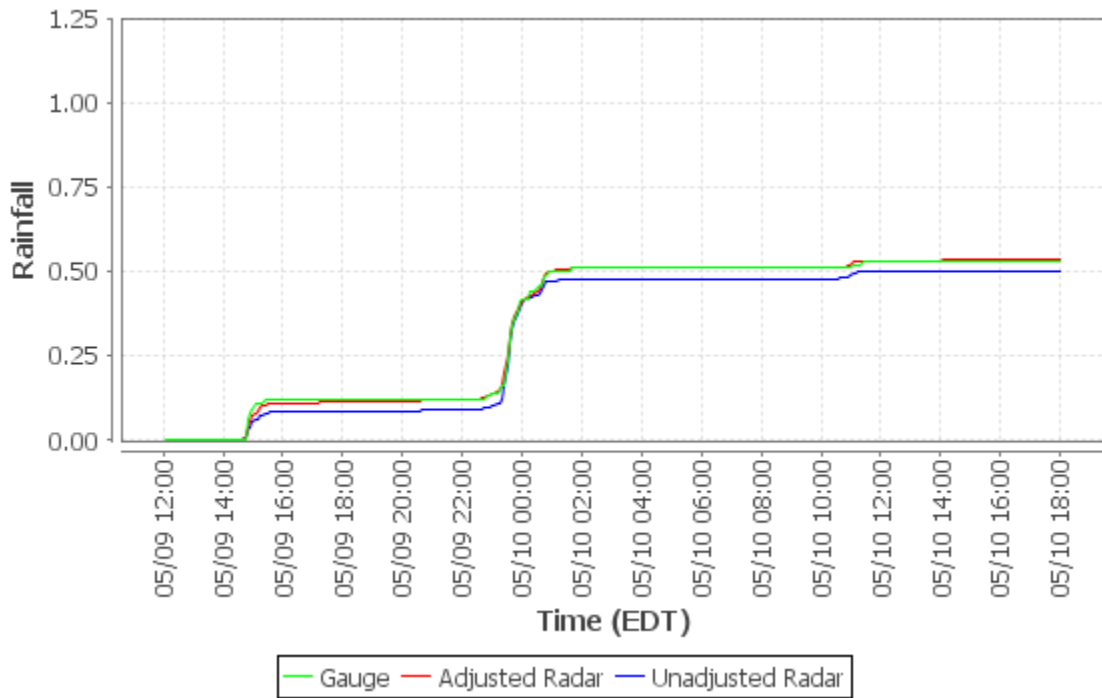
**Cumulative Distribution Plot - Jefferson Hills (Loc24)**



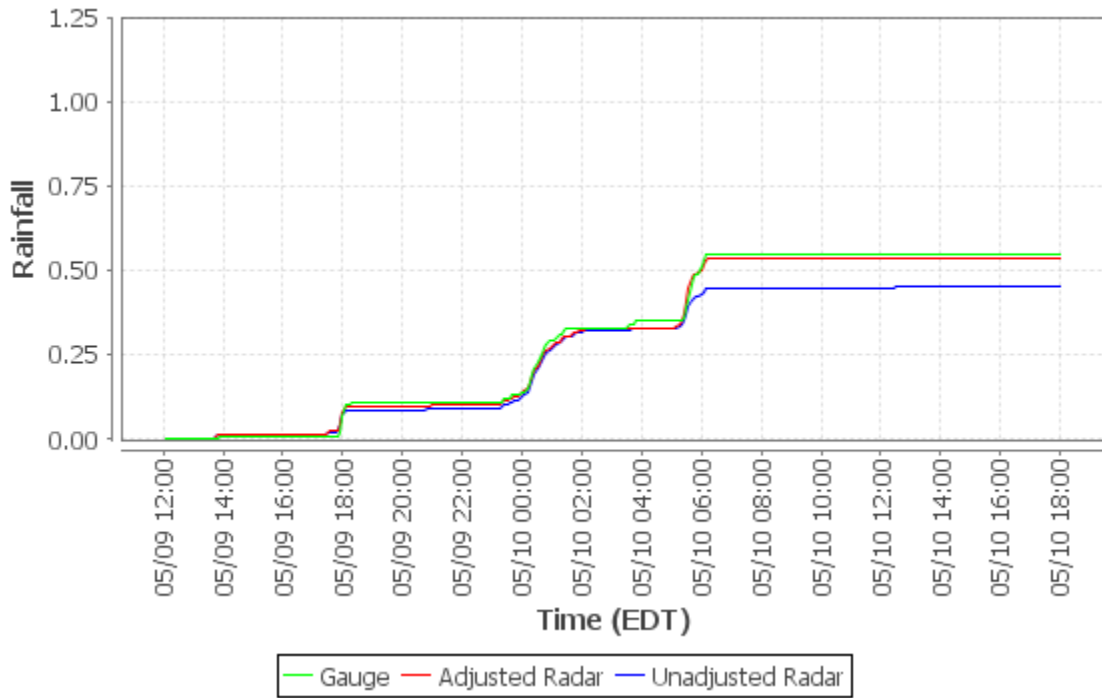
**Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)**



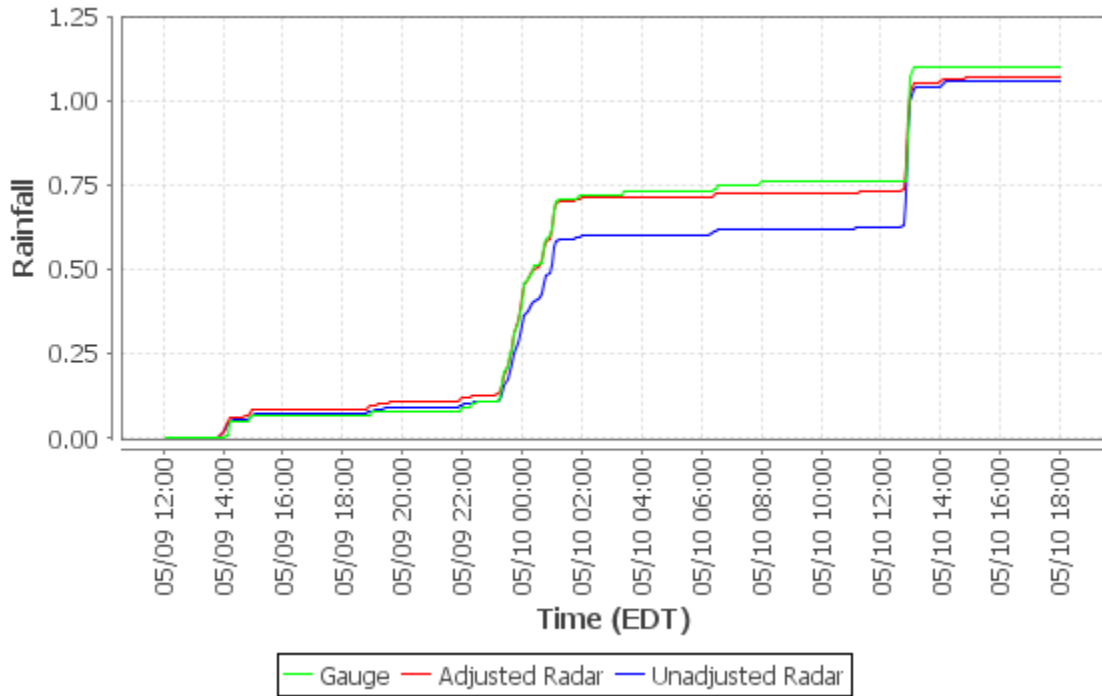
**Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)**



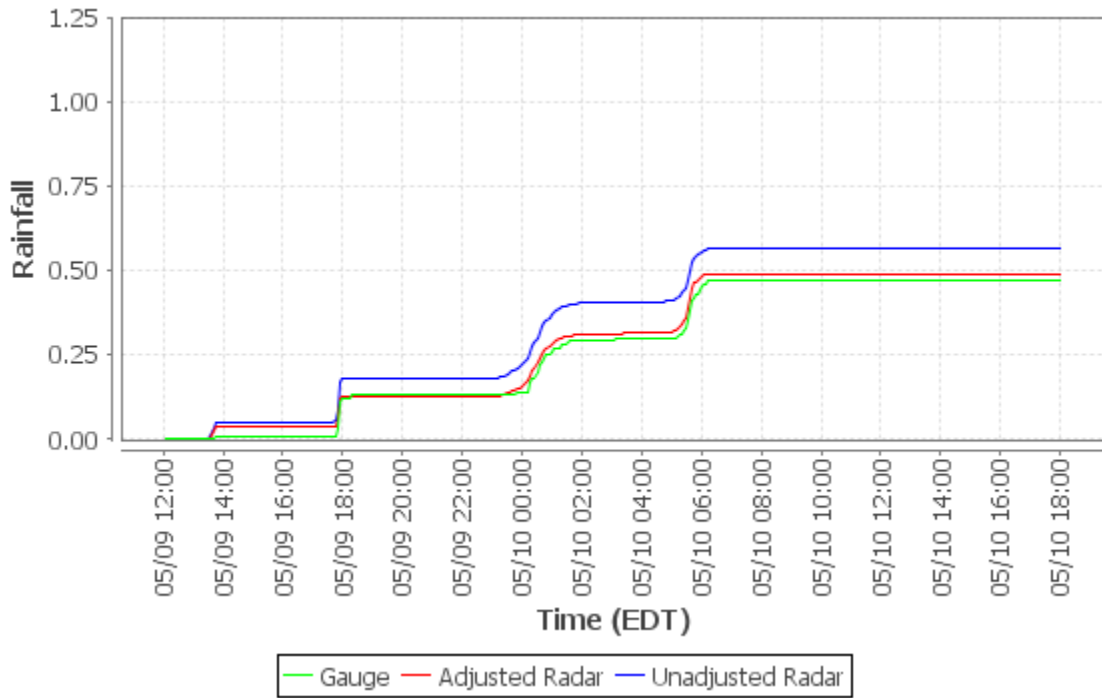
**Cumulative Distribution Plot - Marshall TWP (Loc27)**



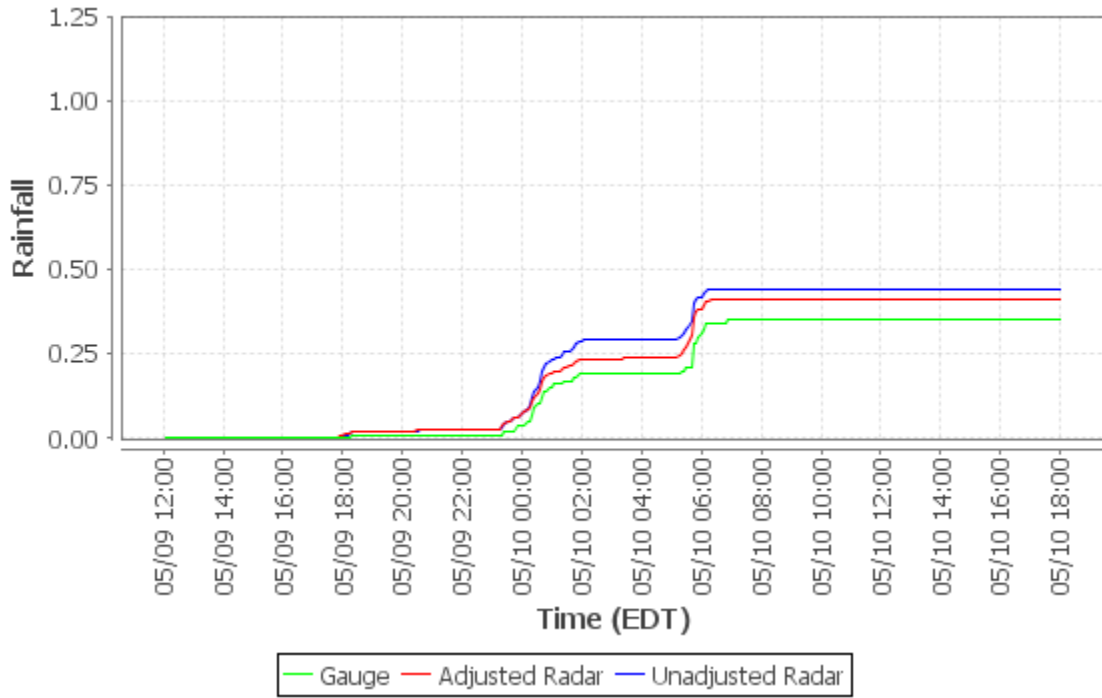
**Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)**



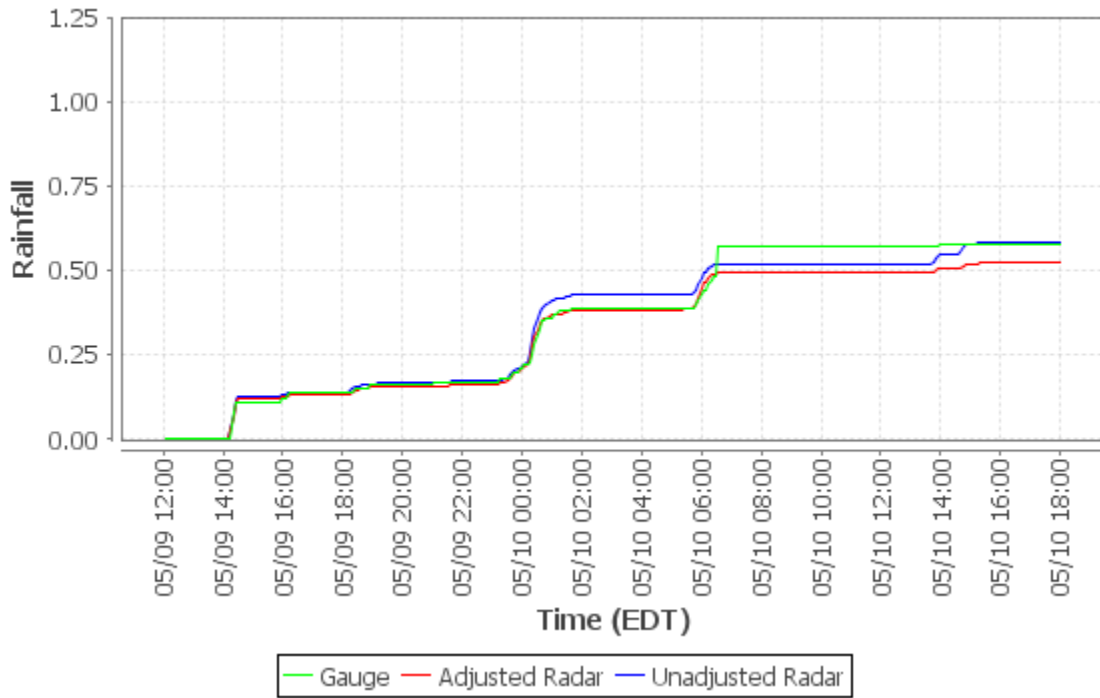
**Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)**



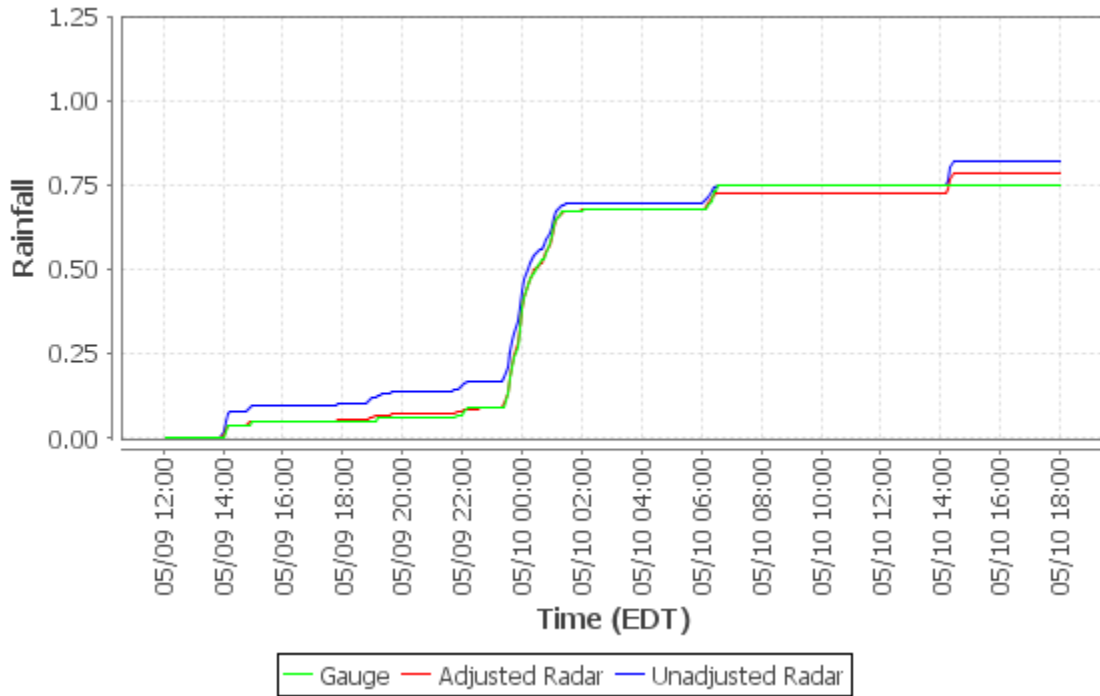
**Cumulative Distribution Plot - McCandless Twn Hall (Loc30)**



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

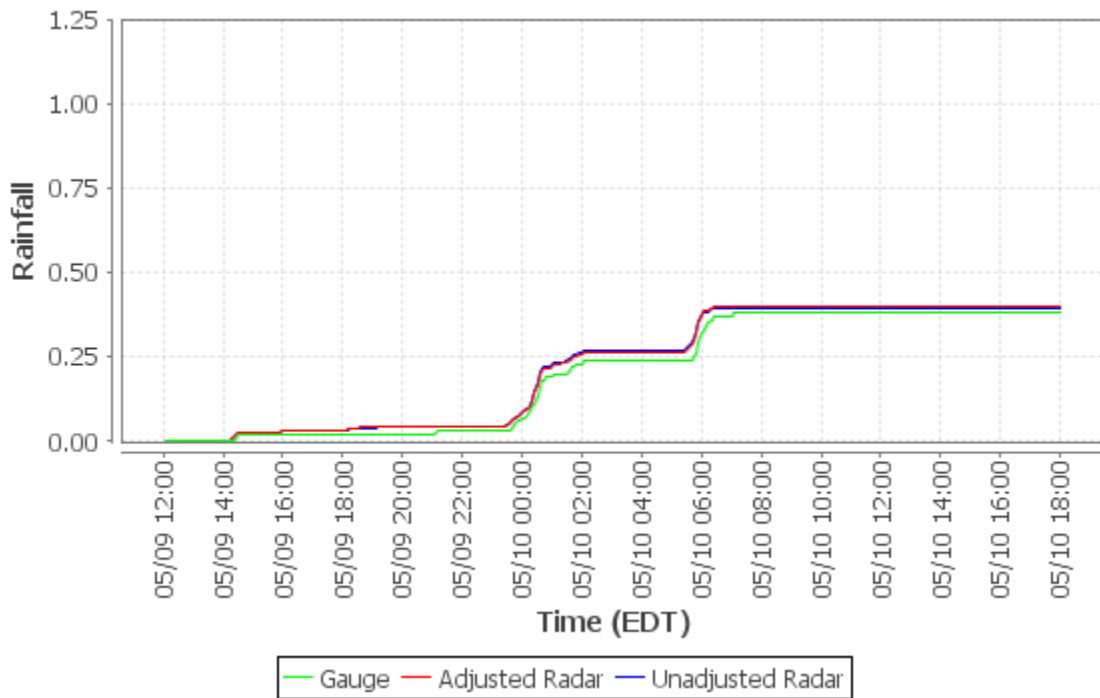


**Cumulative Distribution Plot - Arnold (Loc32)**

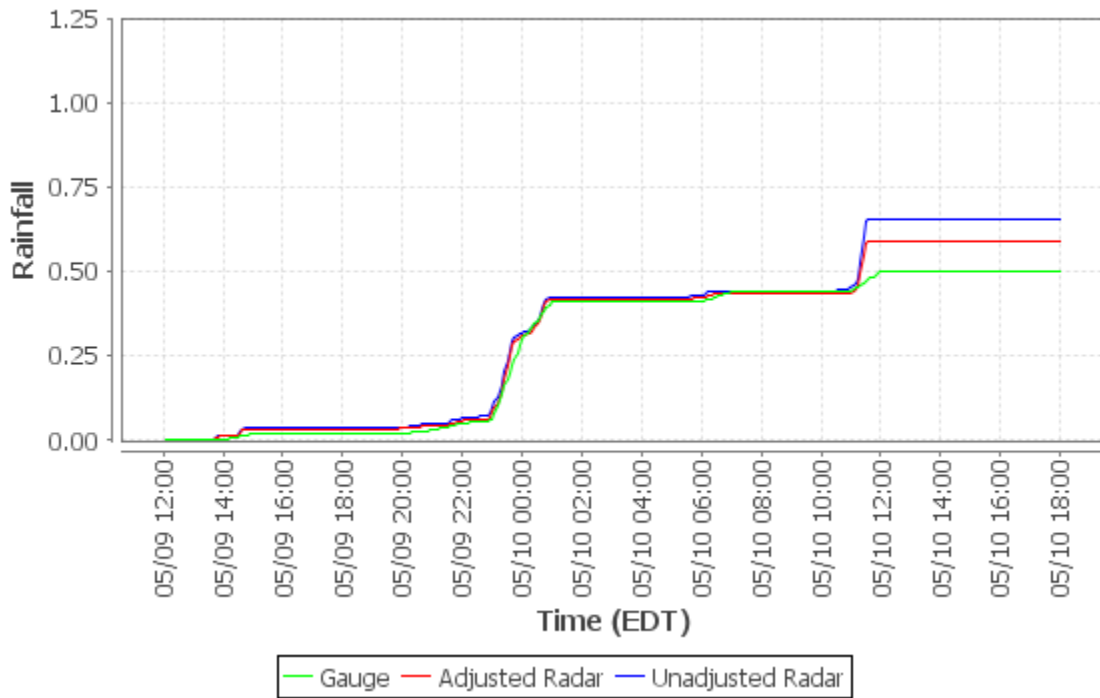




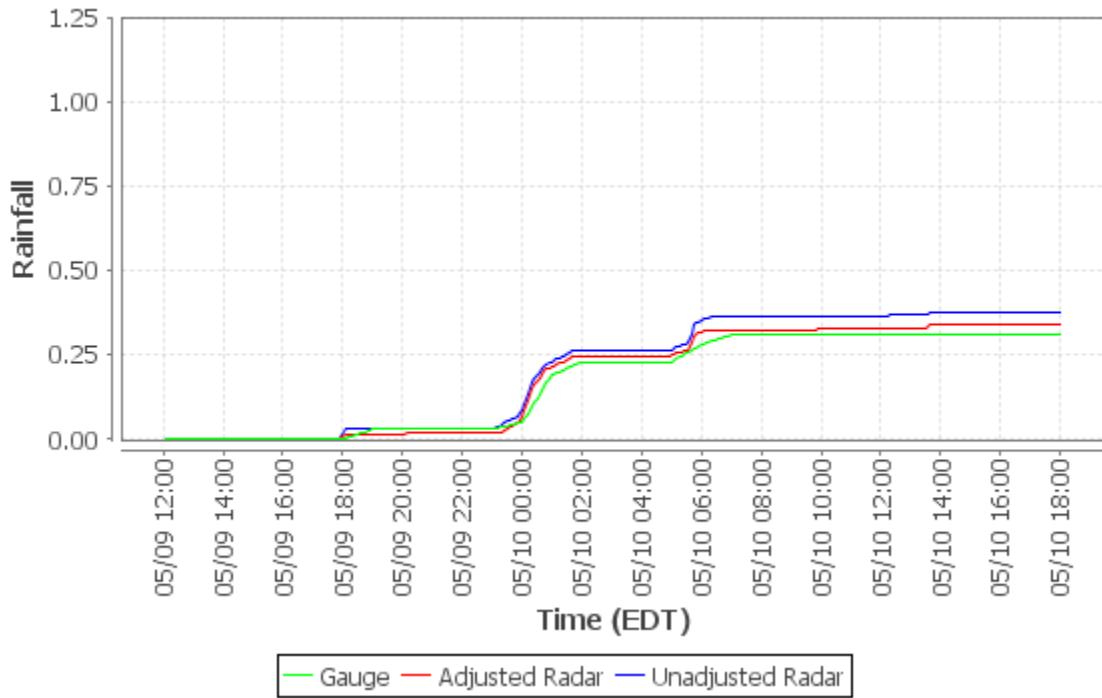
**Cumulative Distribution Plot - Richland TWP (Loc33)**



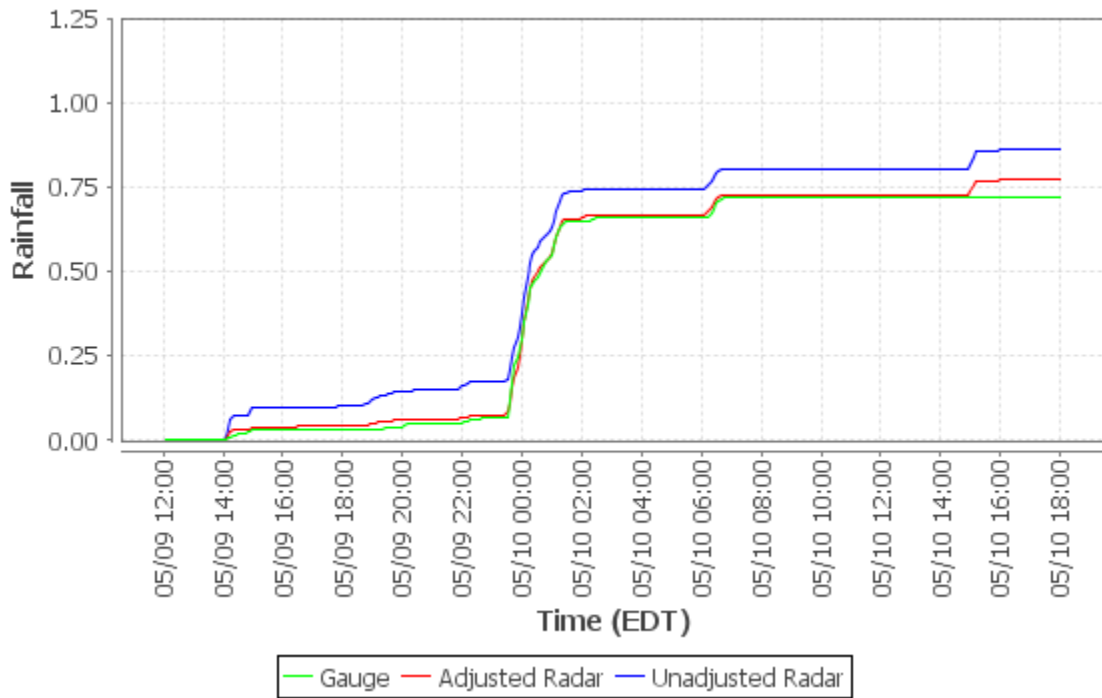
**Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)**



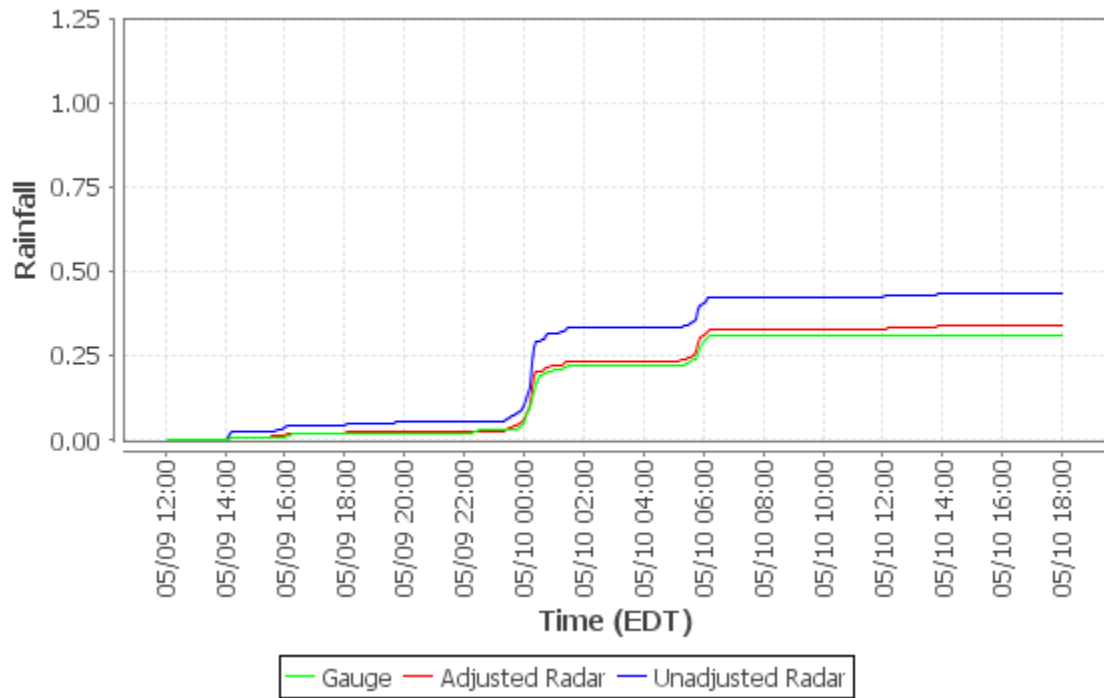
**Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)**



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

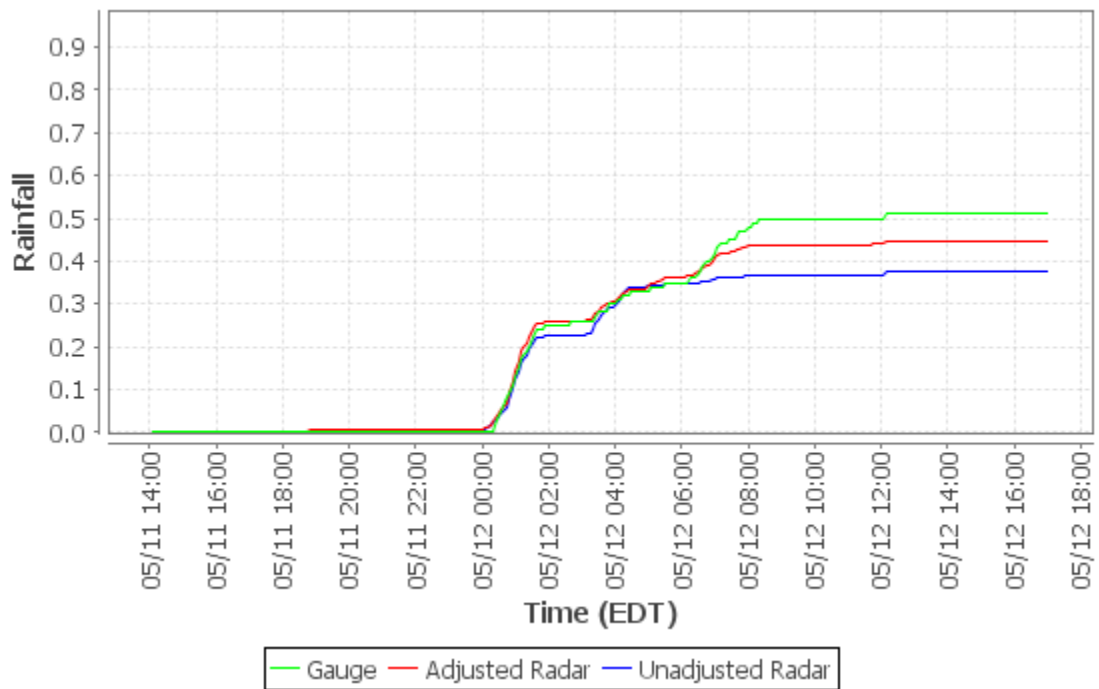


**Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth  
(03085734)**

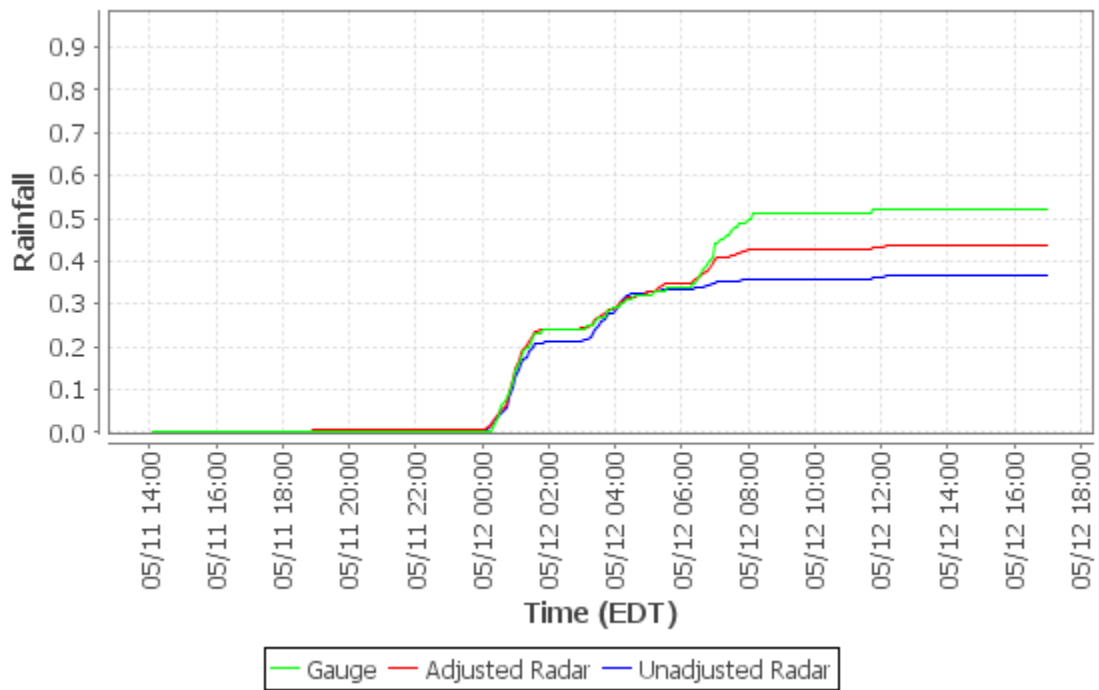


## **Appendix F - Event 4 (2019-05-12) CDPs**

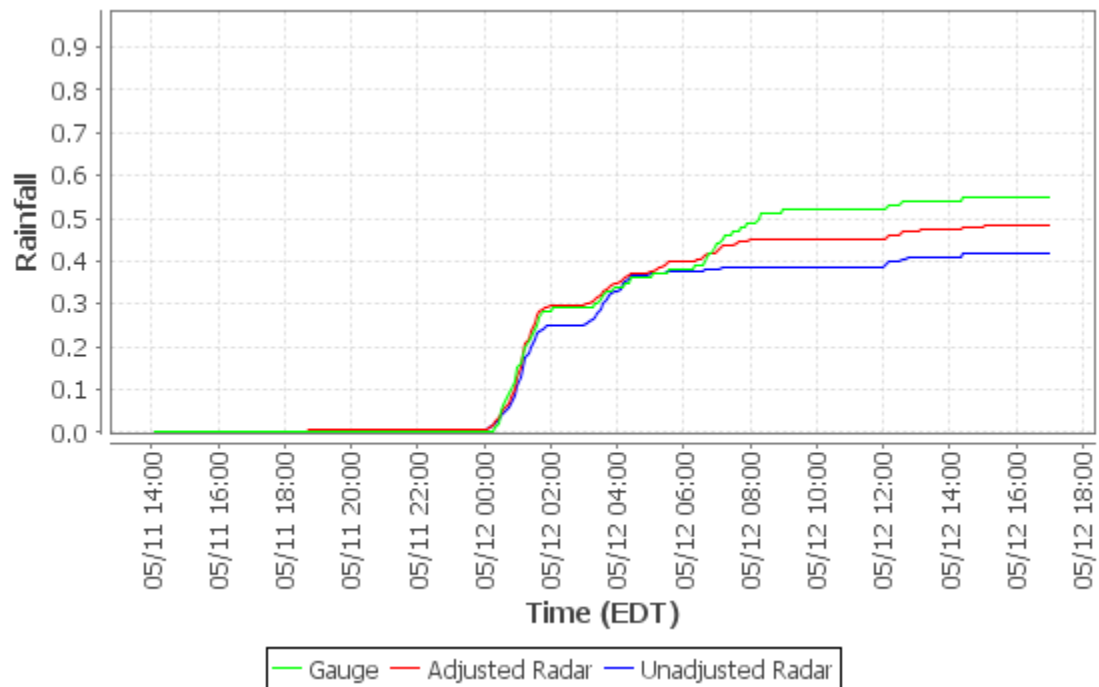
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



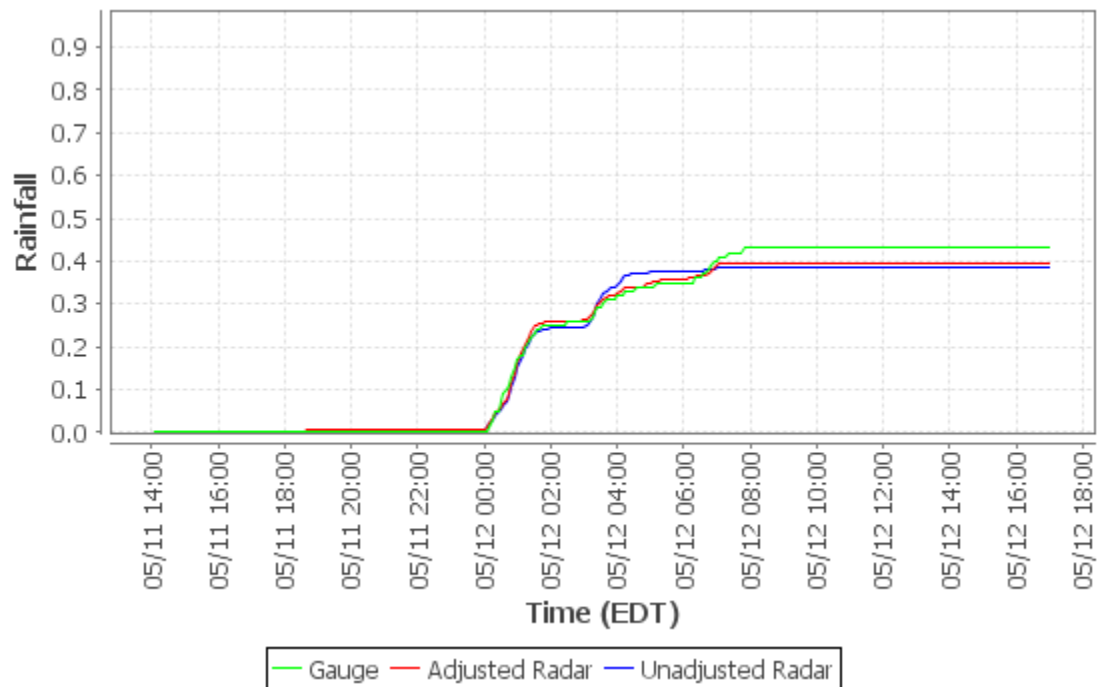
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



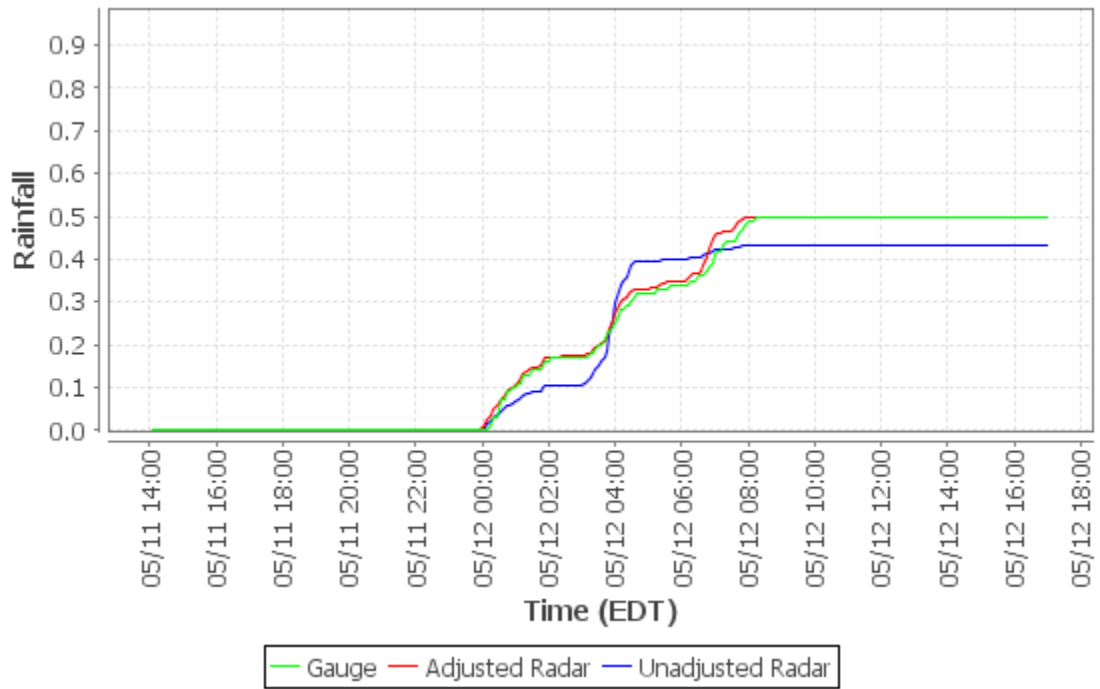
**Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)**



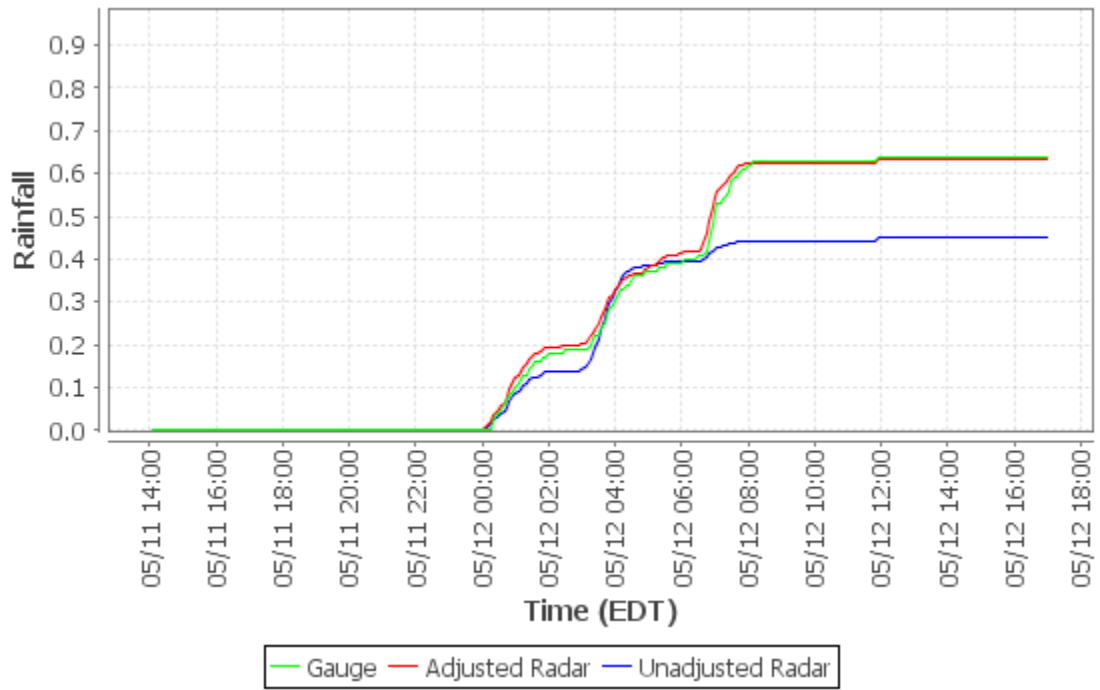
**Cumulative Distribution Plot - Kennedy Twp PS (Loc04)**



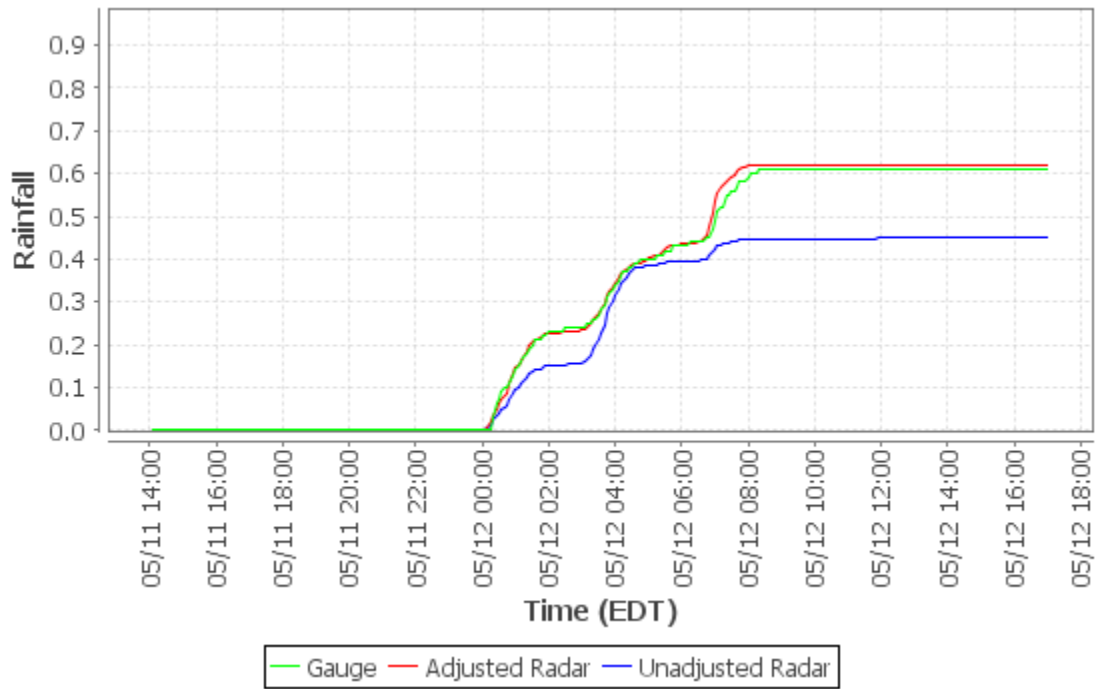
**Cumulative Distribution Plot - Upper St. Clair (Loc05)**



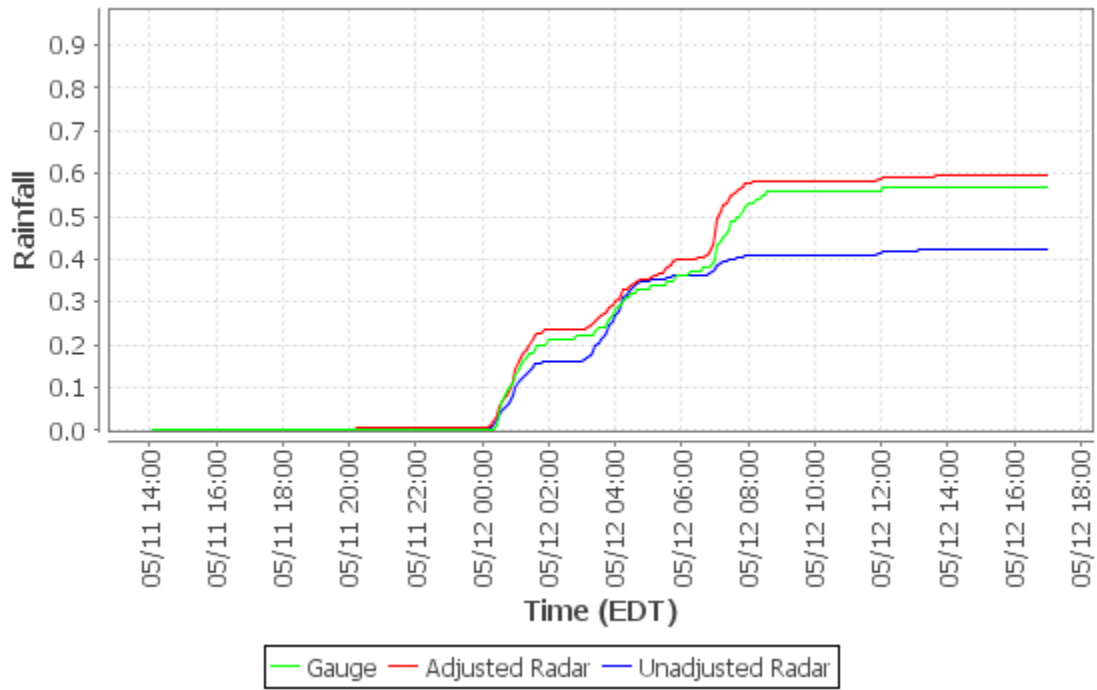
**Cumulative Distribution Plot - Carnegie Transit Time (Loc06)**



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

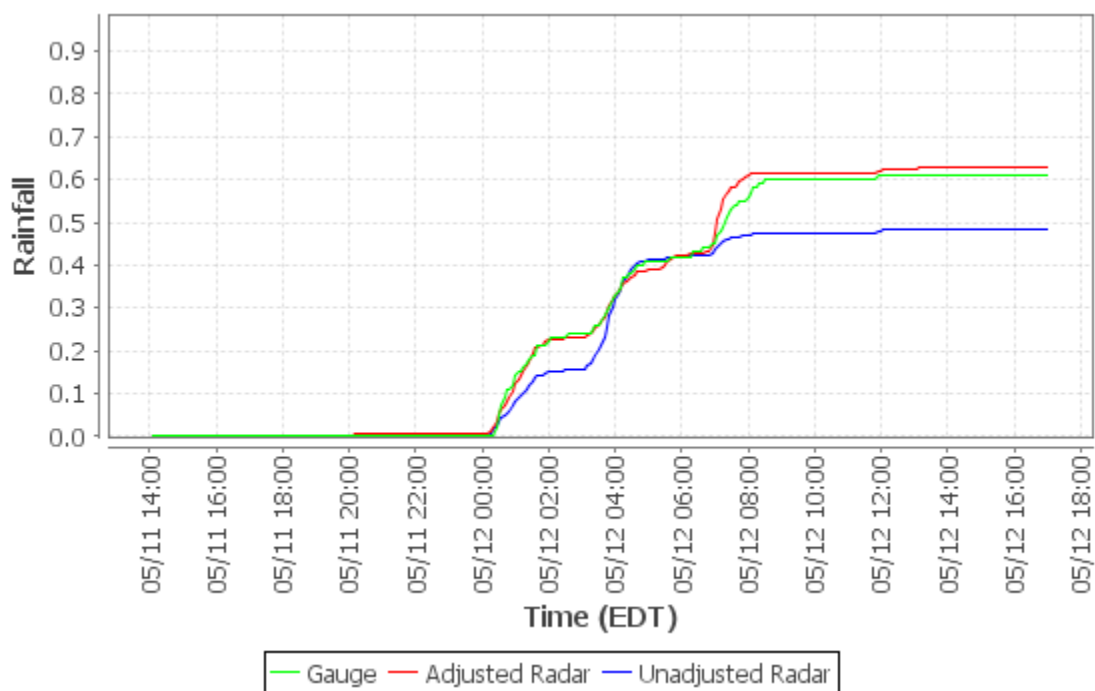


**Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)**

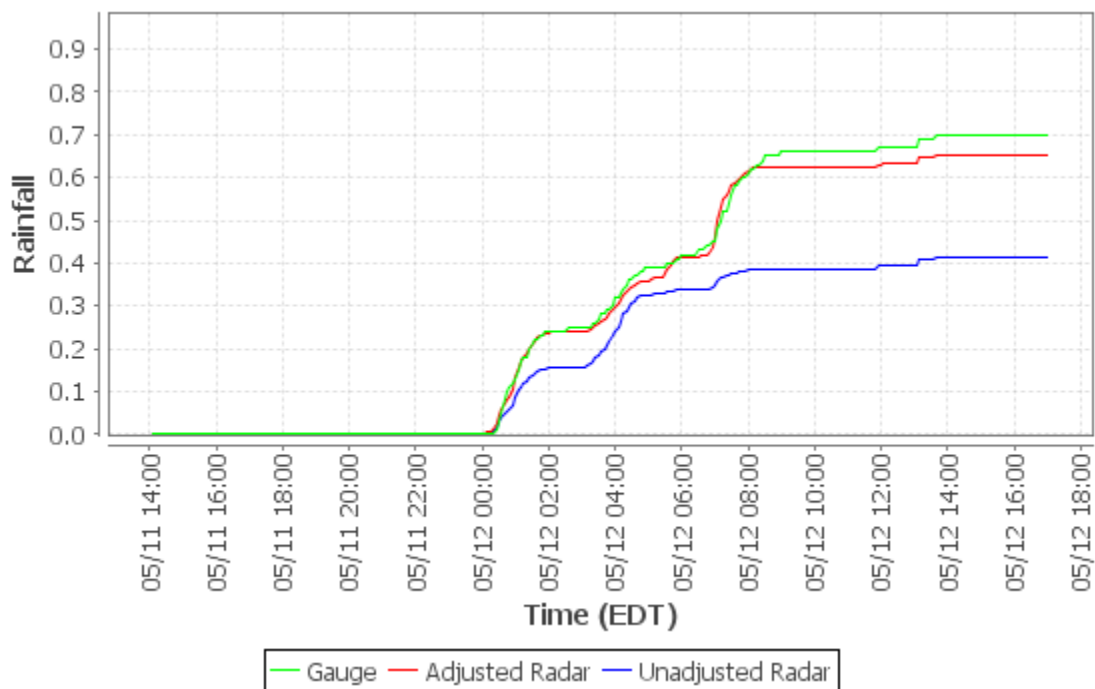




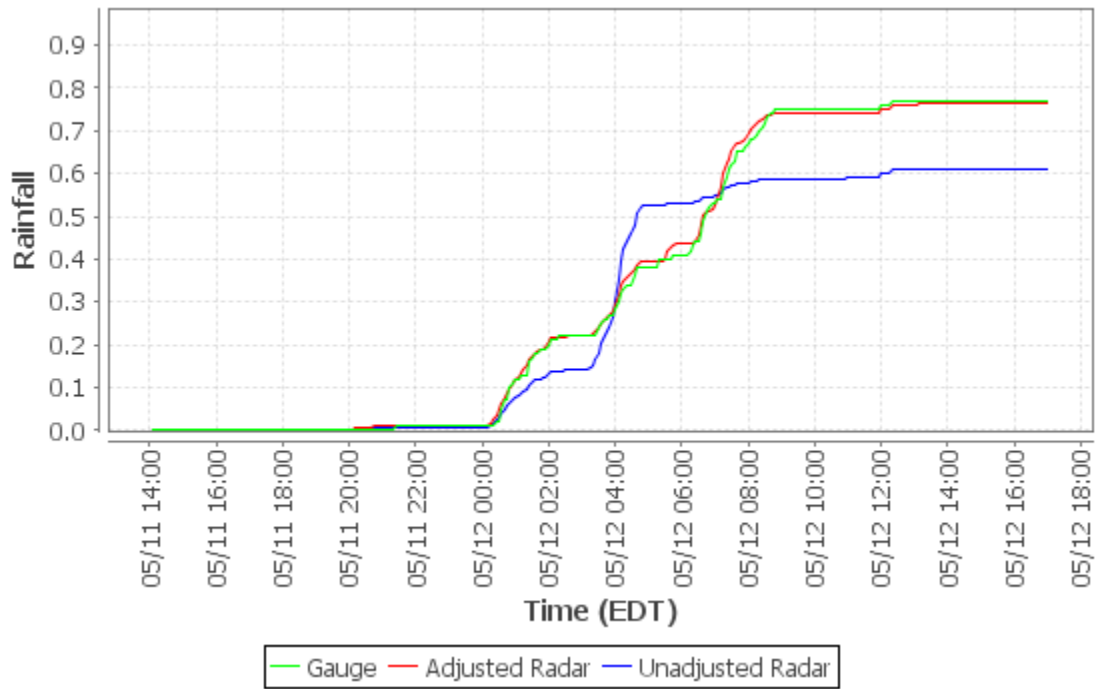
**Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)**



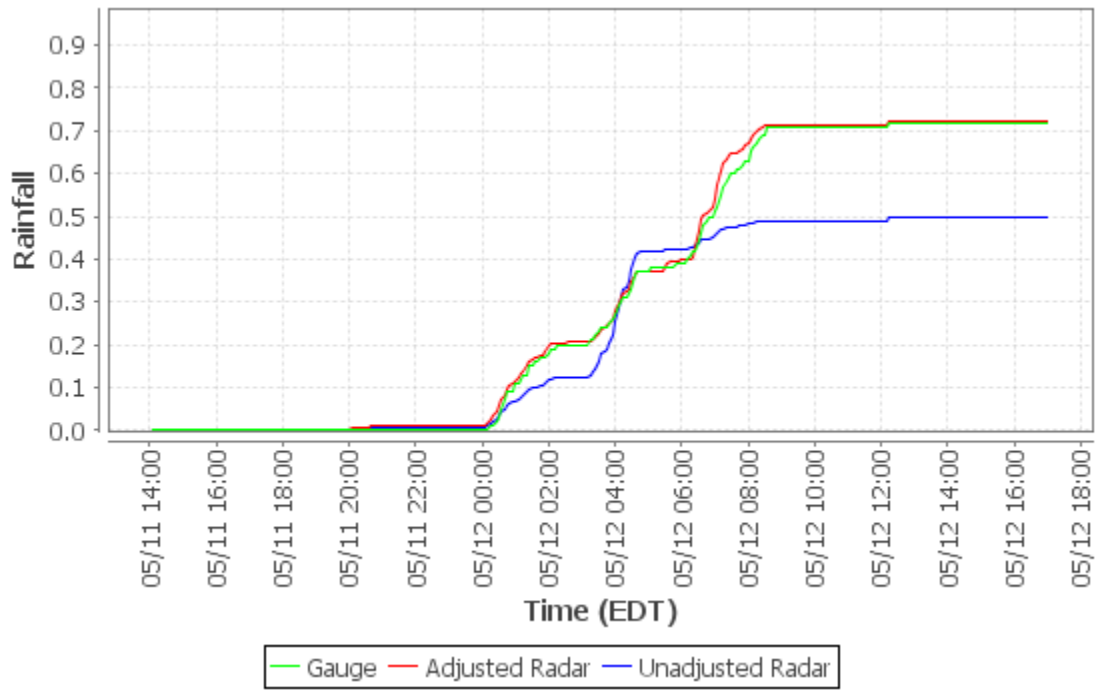
**Cumulative Distribution Plot - PWSA-Highland Park (Loc10)**



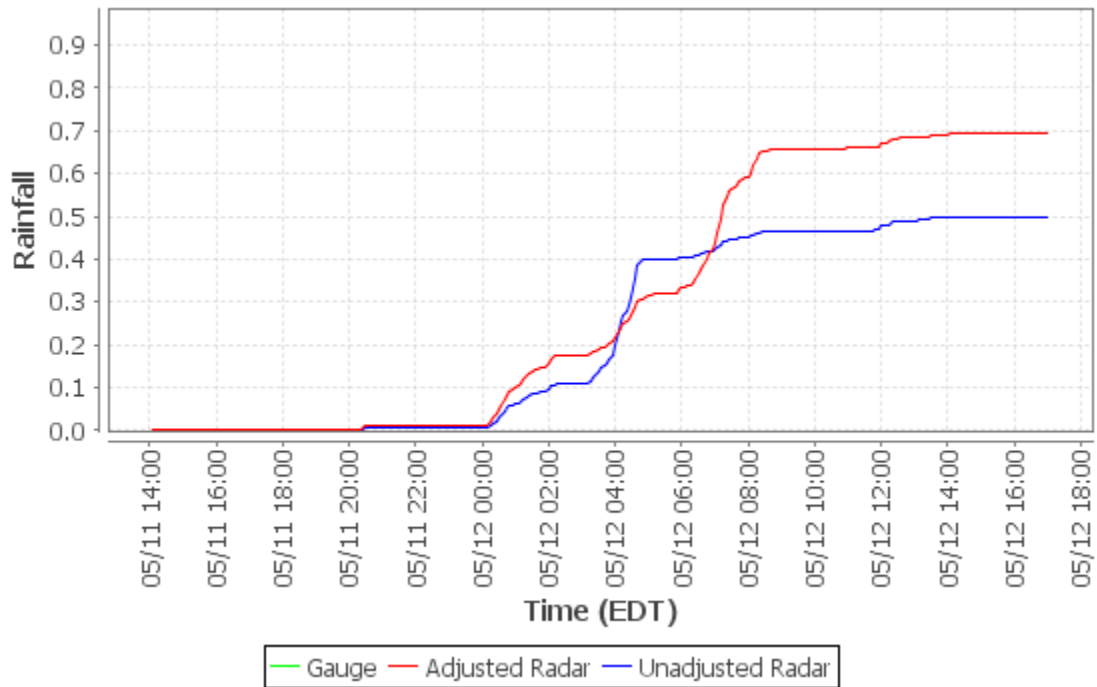
**Cumulative Distribution Plot - M-46 Access Shaft (Loc11)**



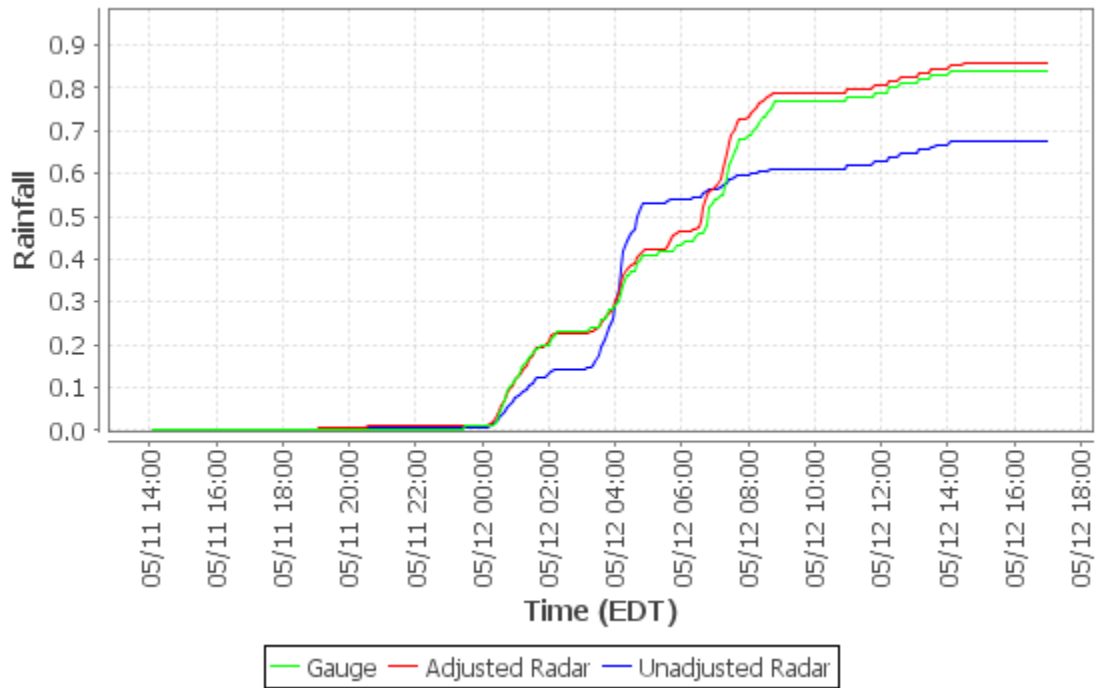
**Cumulative Distribution Plot - Baldwin (Loc12)**



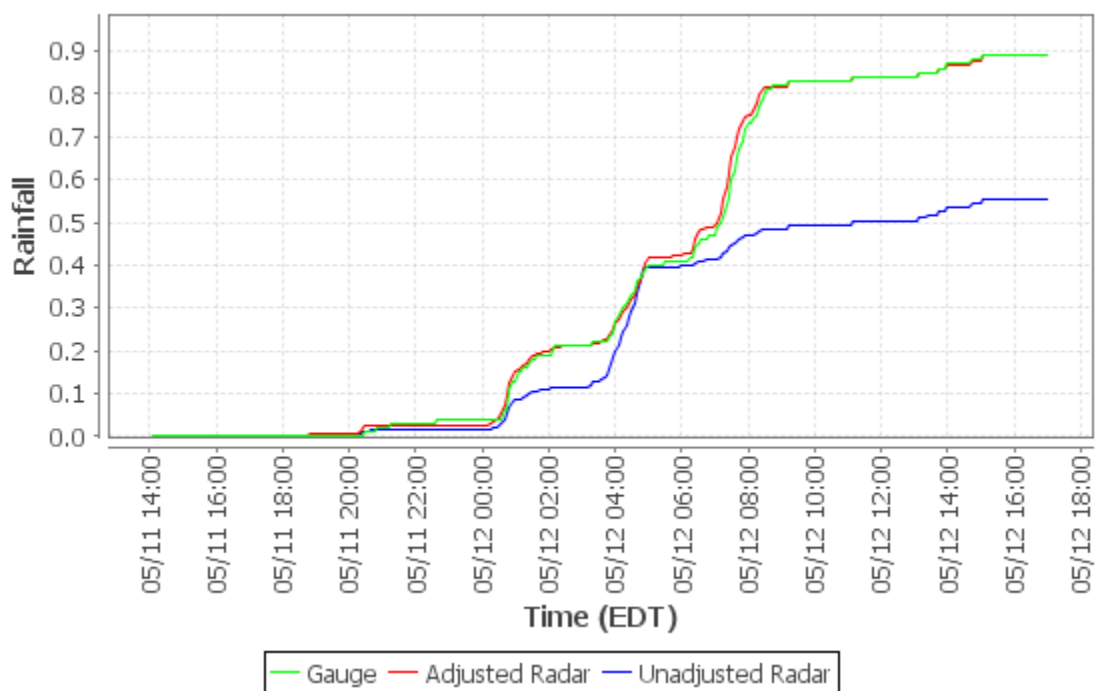
**Cumulative Distribution Plot - M-59 Access Shaft (Loc13)**



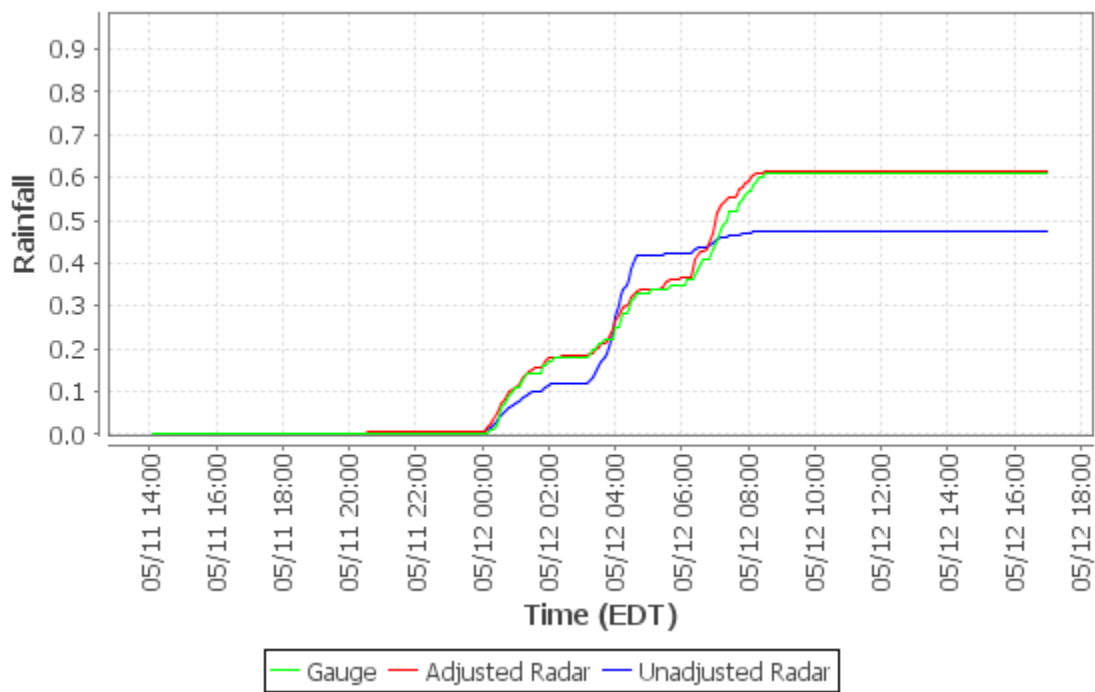
**Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)**



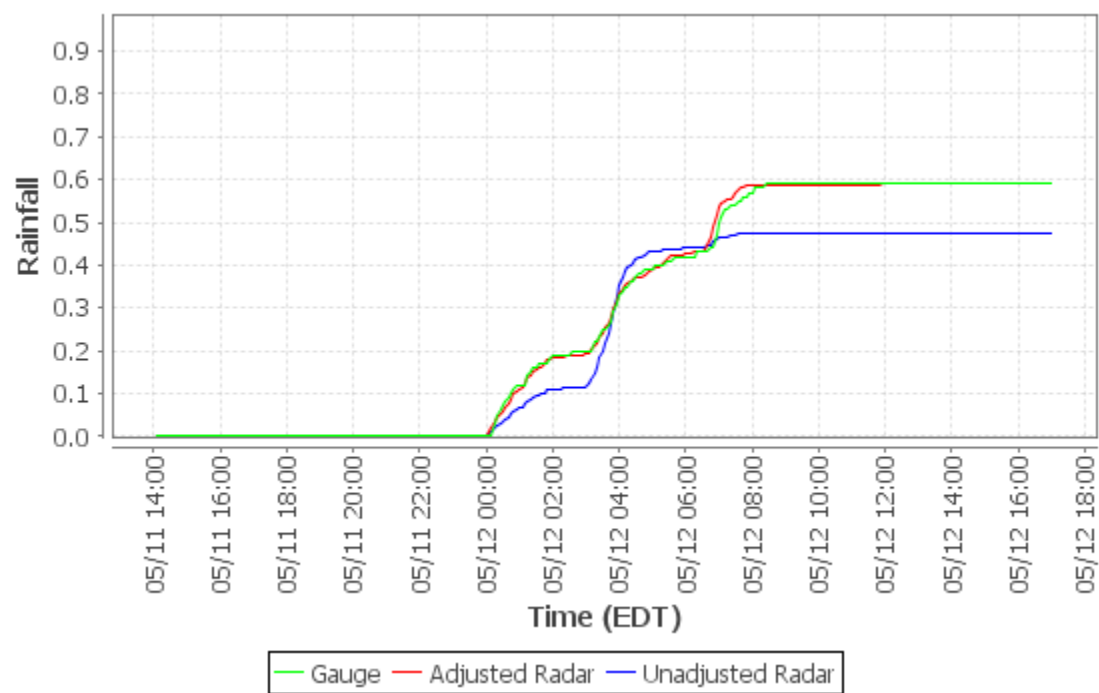
**Cumulative Distribution Plot - Trafford Maint Bldg (Loc15)**



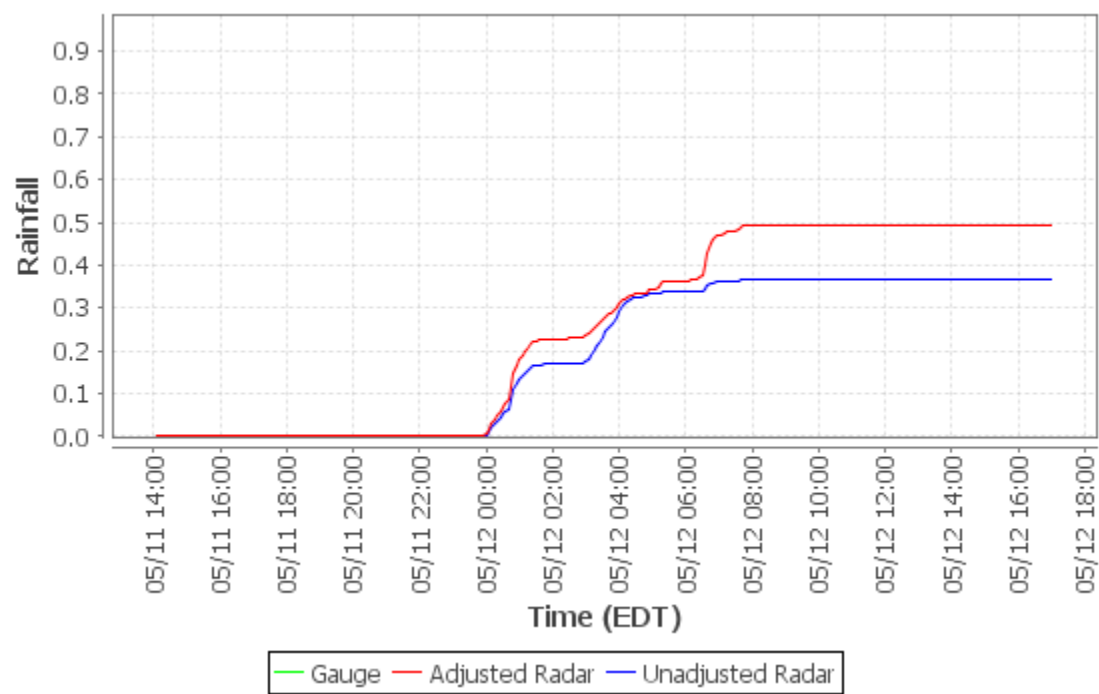
**Cumulative Distribution Plot - Castle Shannon (Loc16)**



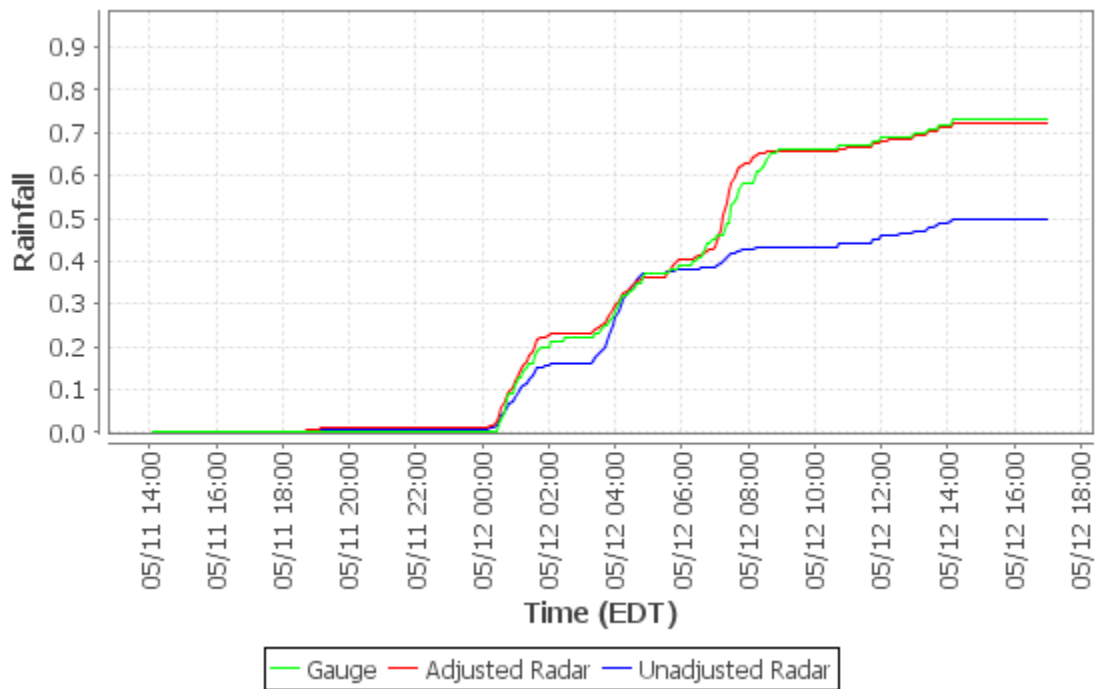
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



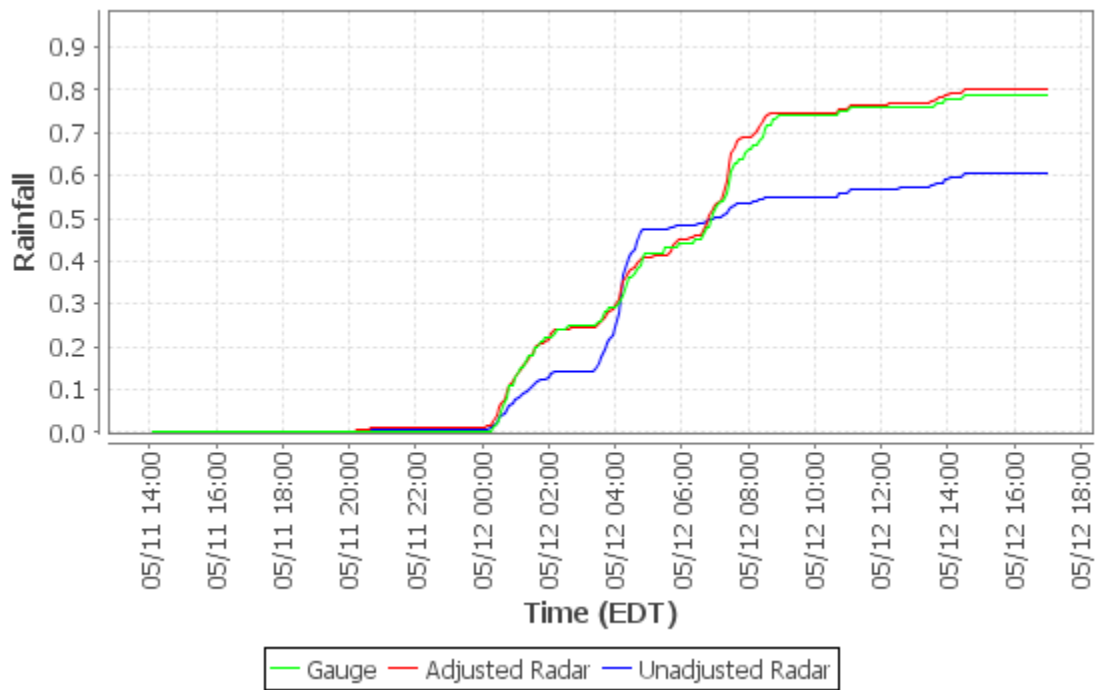
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



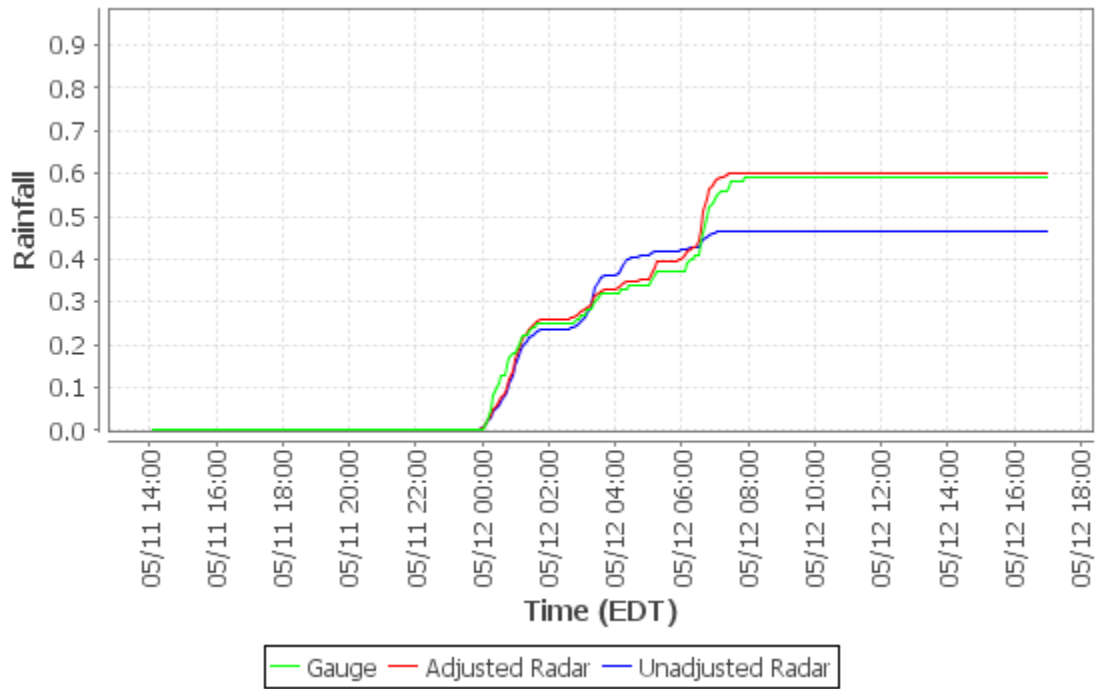
**Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)**



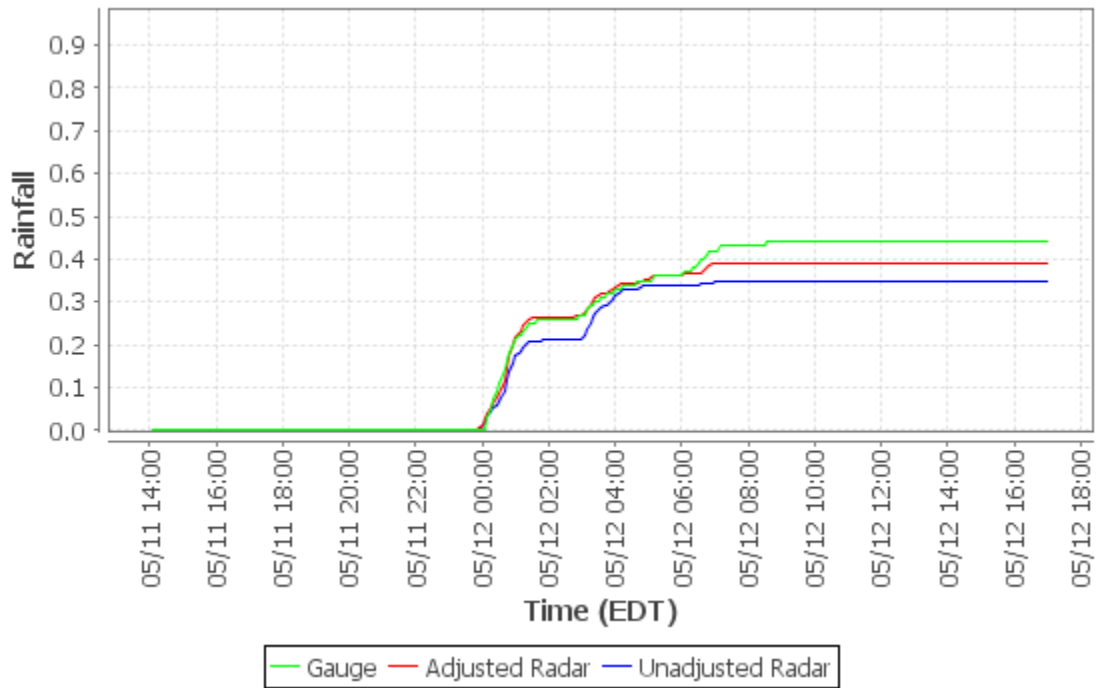
**Cumulative Distribution Plot - Gascola Eq Facility (Loc20)**



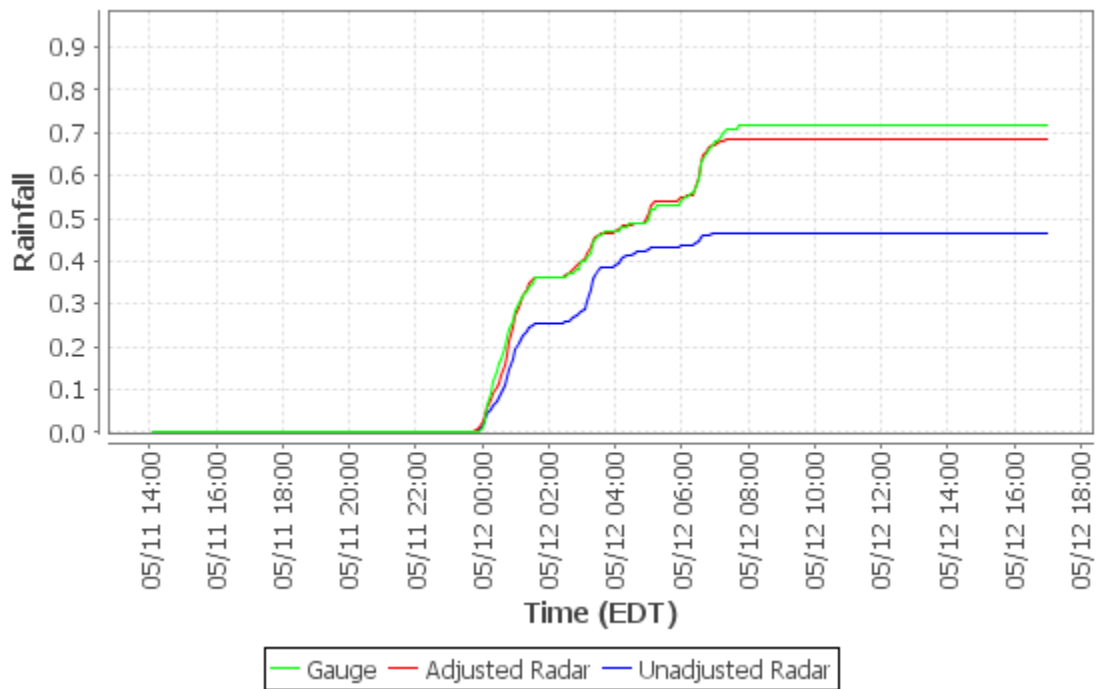
**Cumulative Distribution Plot - Moon TWP (Loc21)**



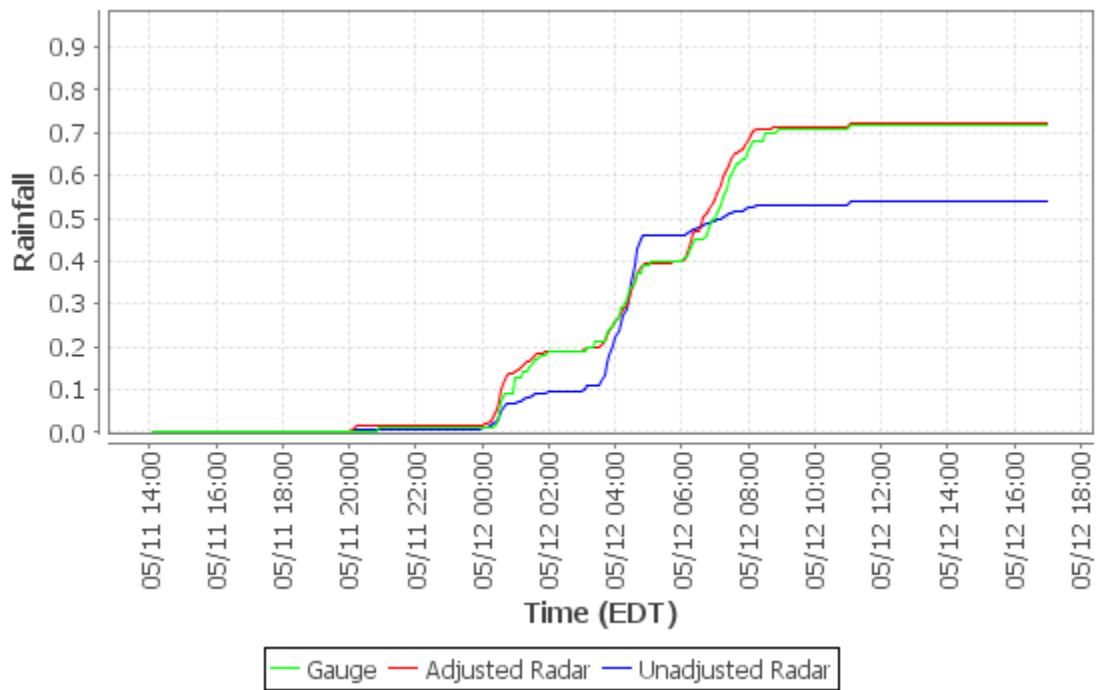
**Cumulative Distribution Plot - North Fayette TWP (Loc22)**



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

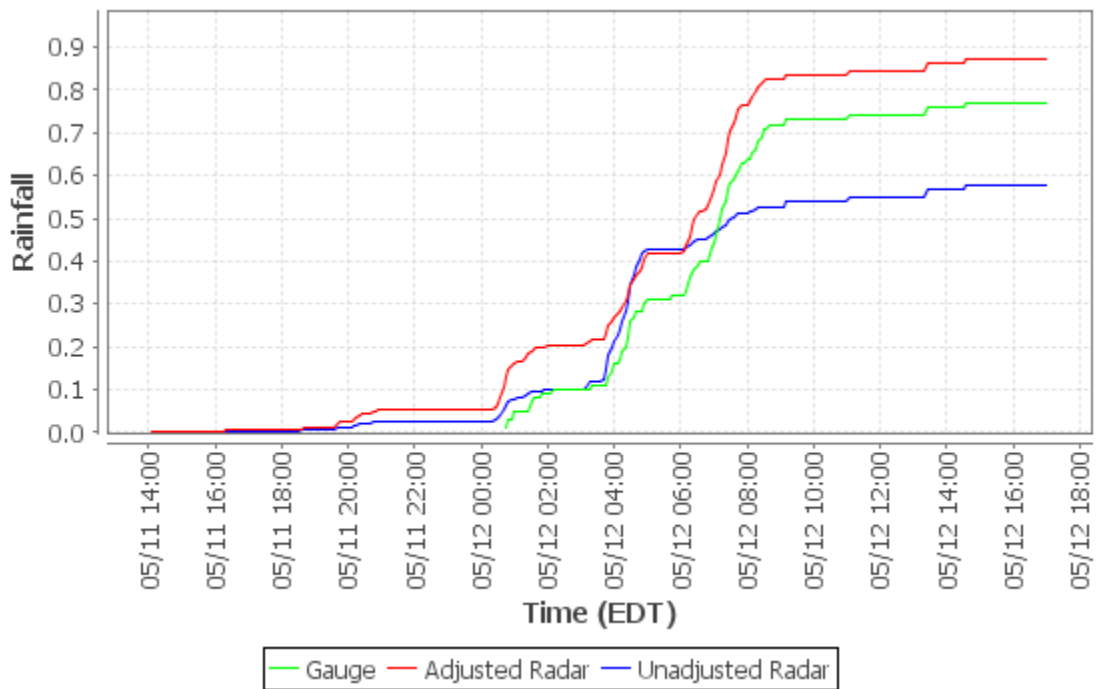


**Cumulative Distribution Plot - Jefferson Hills (Loc24)**

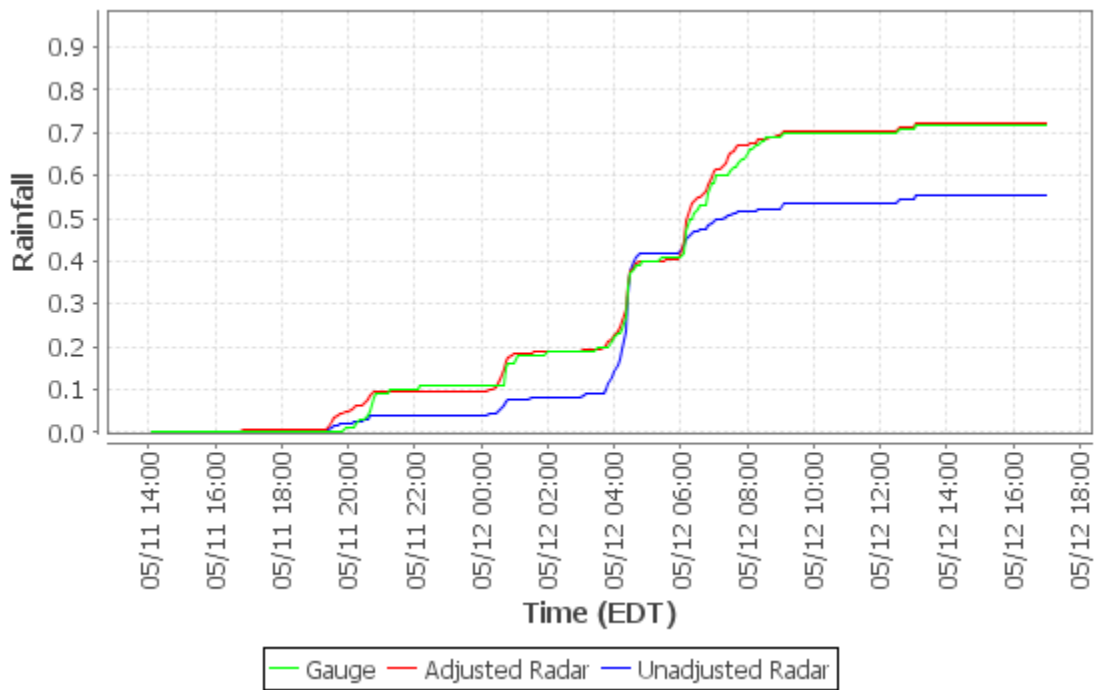




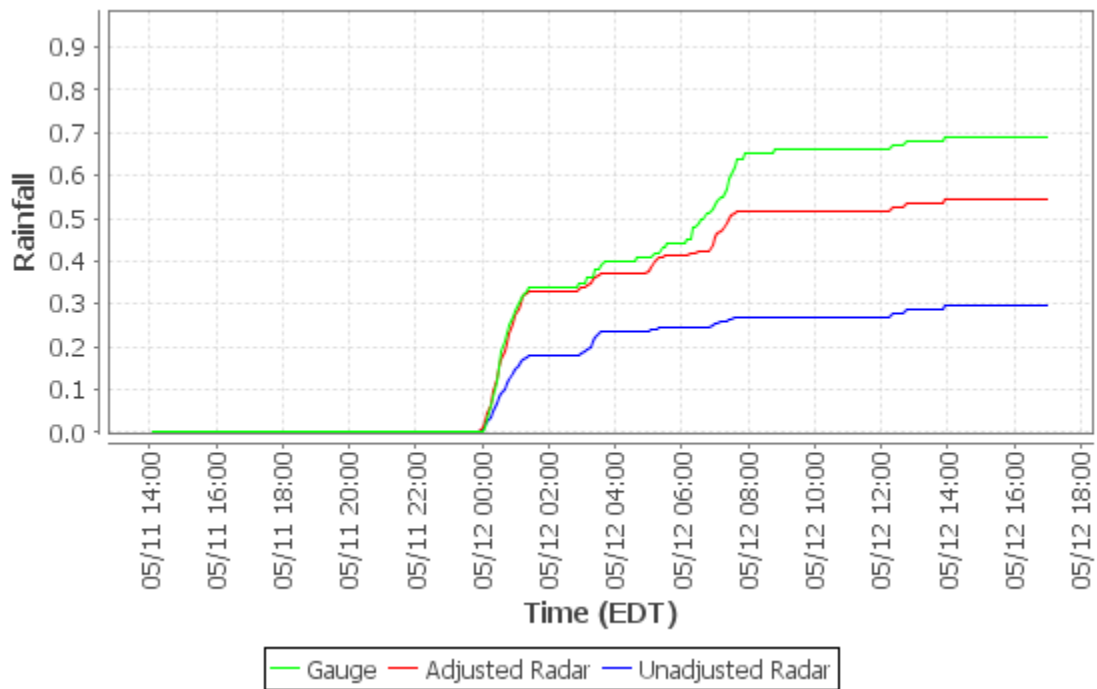
**Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)**



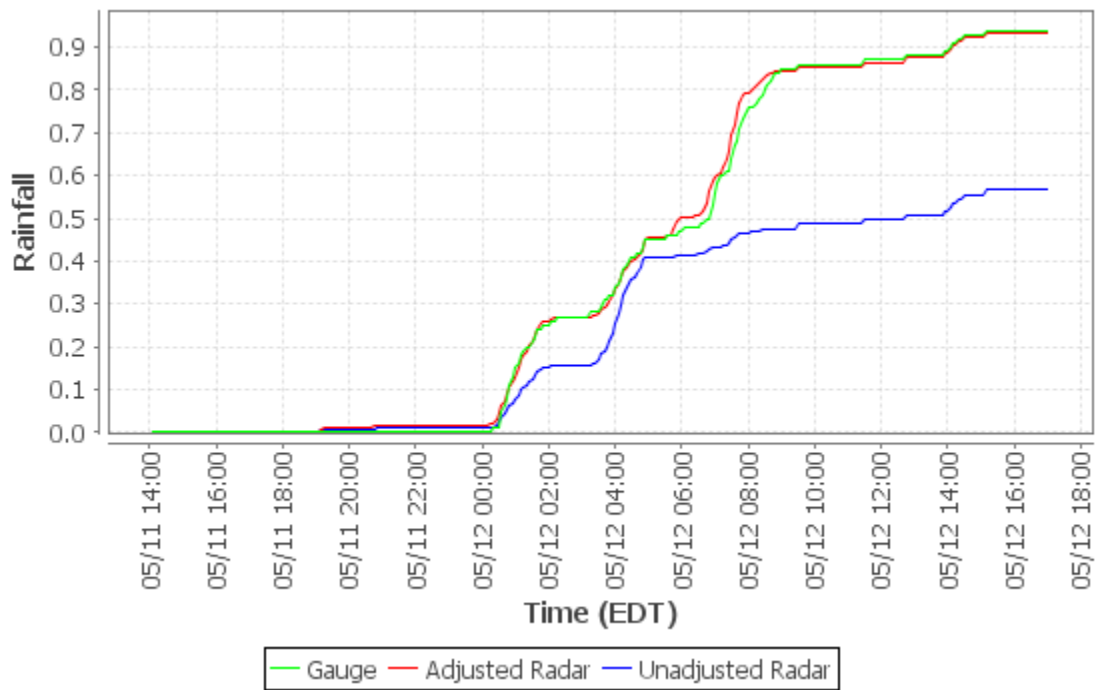
**Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)**



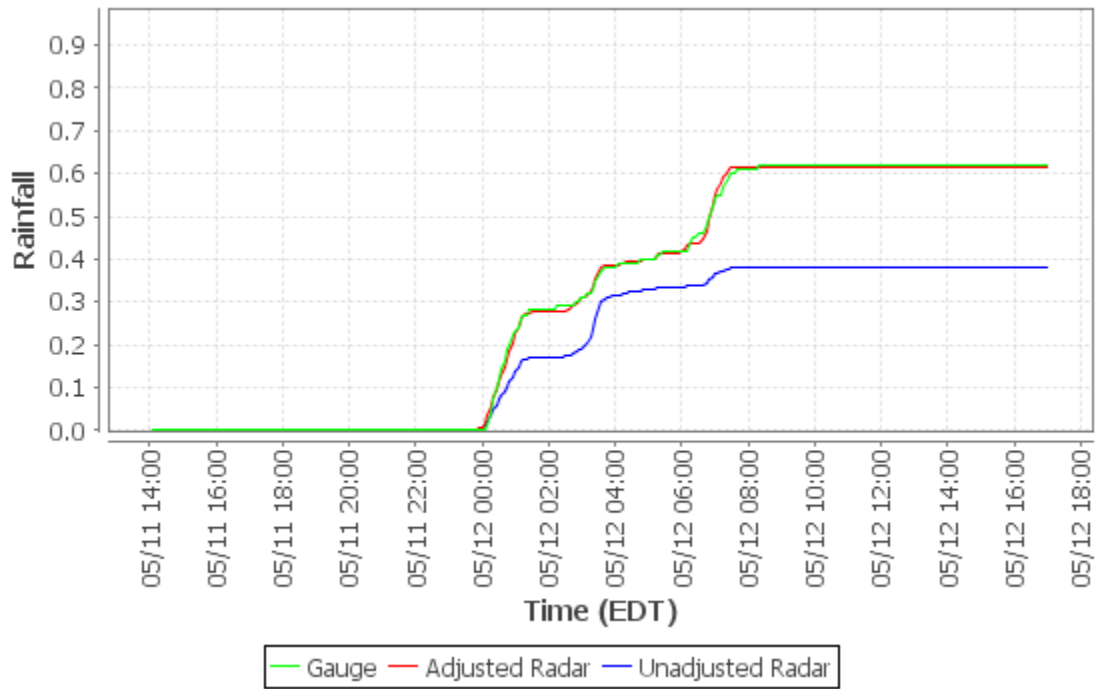
**Cumulative Distribution Plot - Marshall TWP (Loc27)**



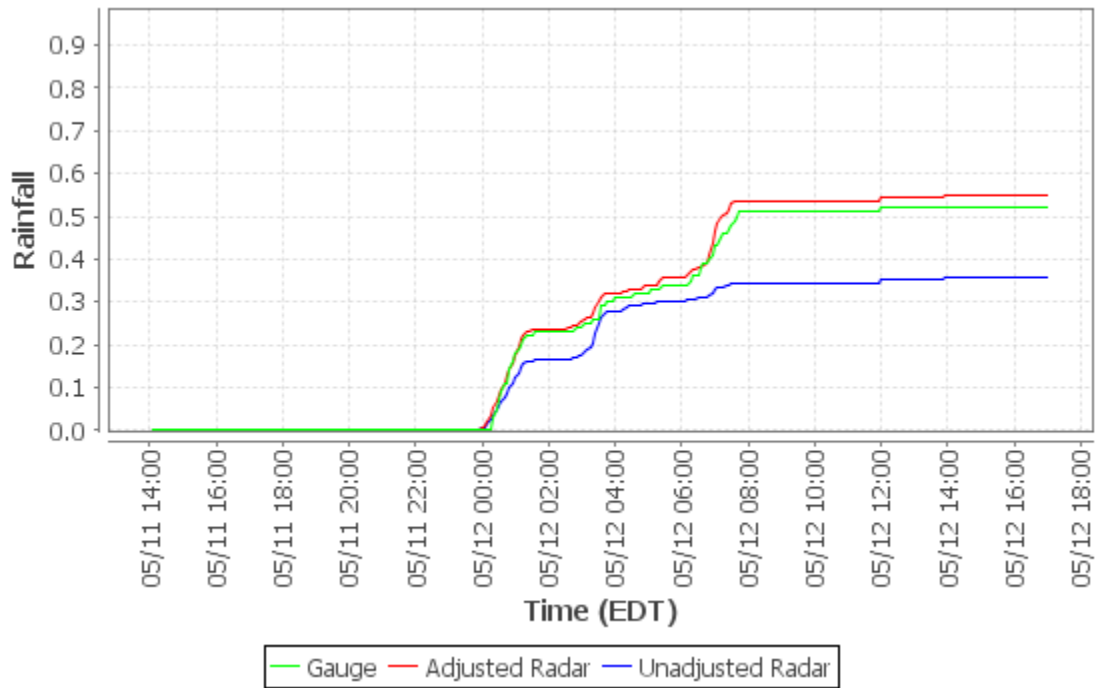
**Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)**



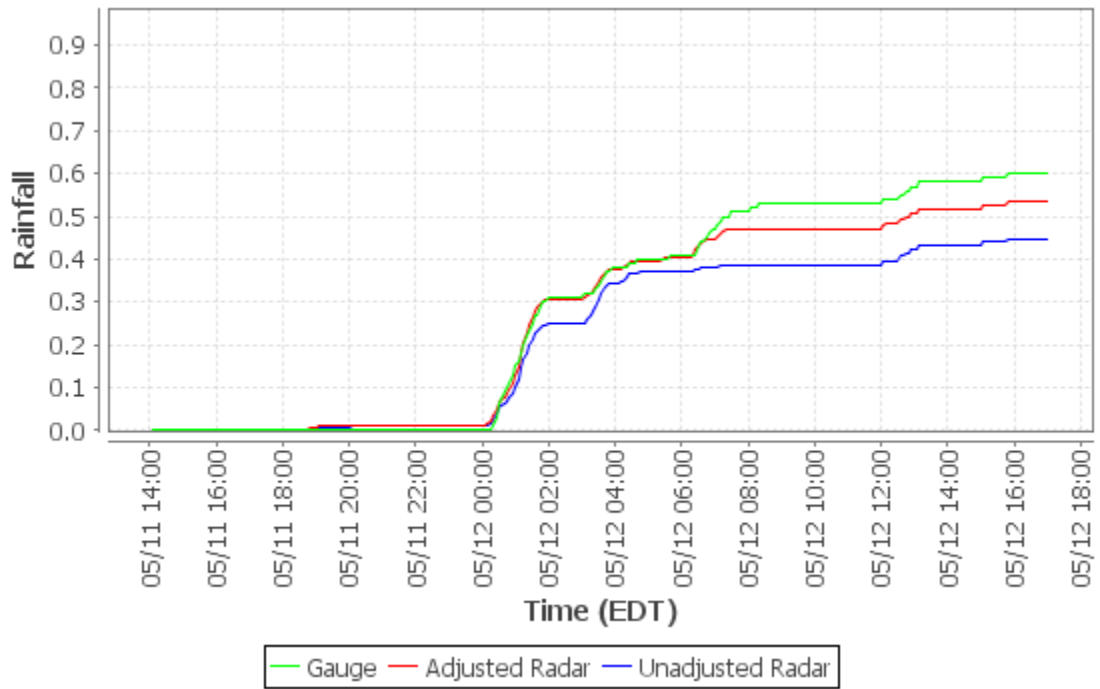
**Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)**



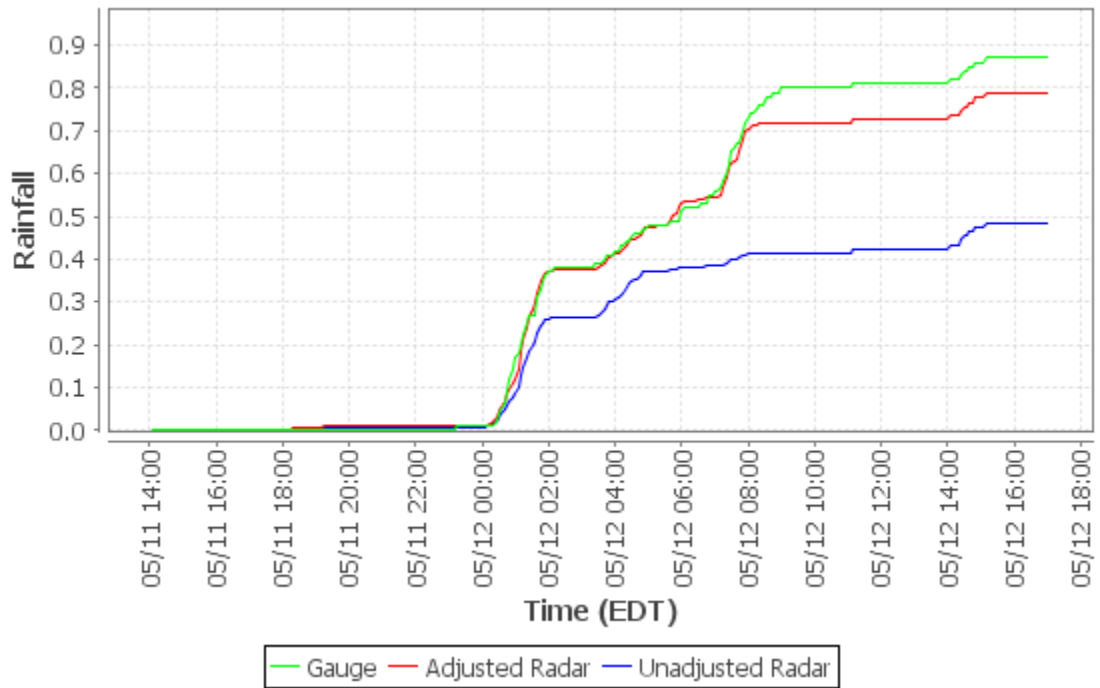
**Cumulative Distribution Plot - McCandless Twn Hall (Loc30)**



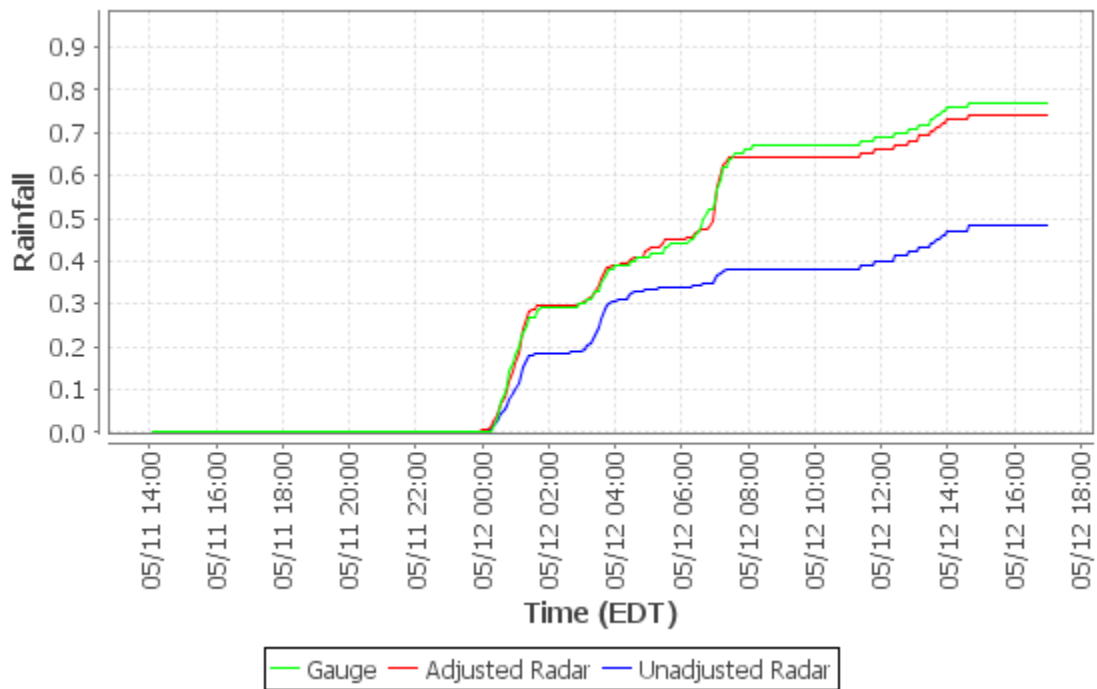
**Cumulative Distribution Plot - Hampton Municipal Bldg (Loc31)**



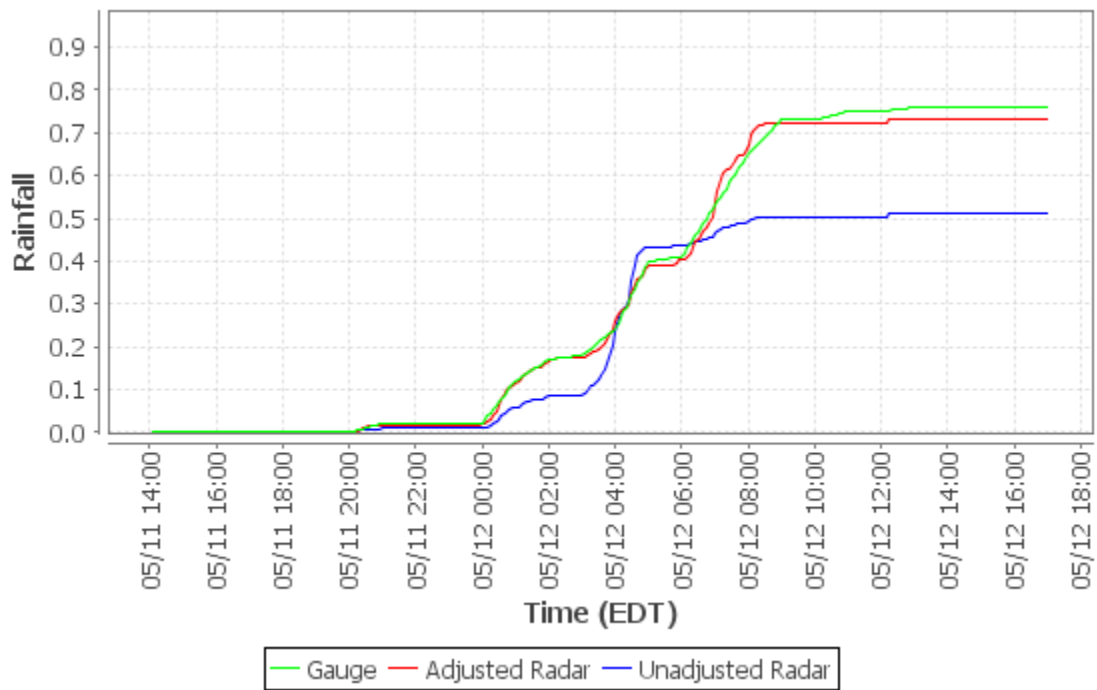
**Cumulative Distribution Plot - Arnold (Loc32)**



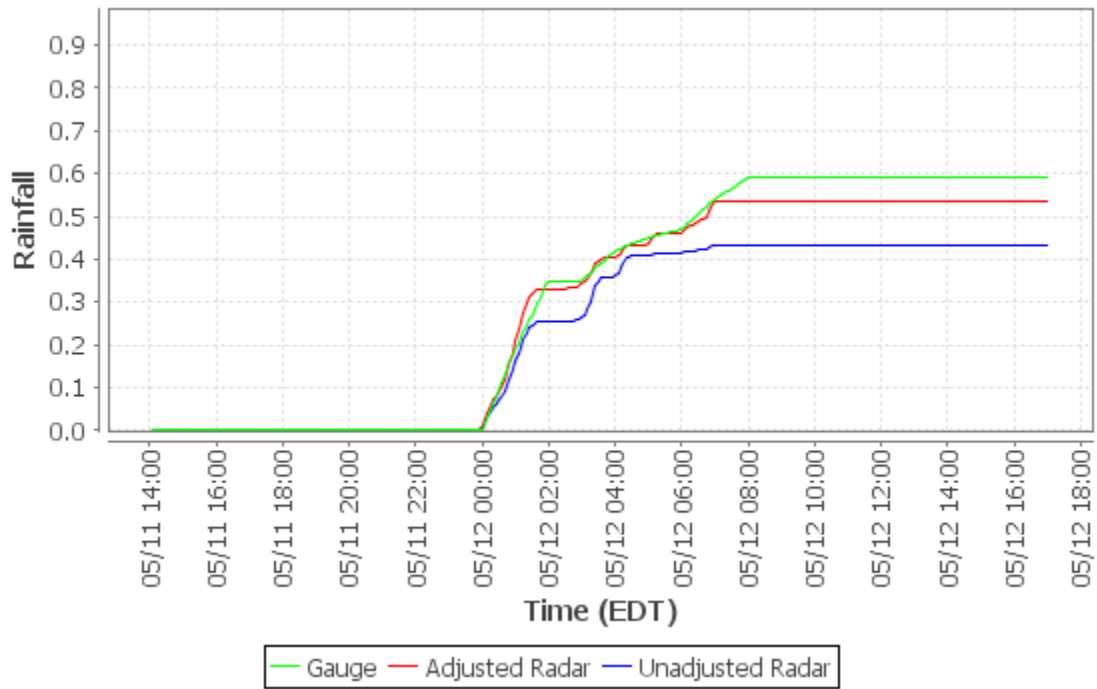
**Cumulative Distribution Plot - Richland TWP (Loc33)**



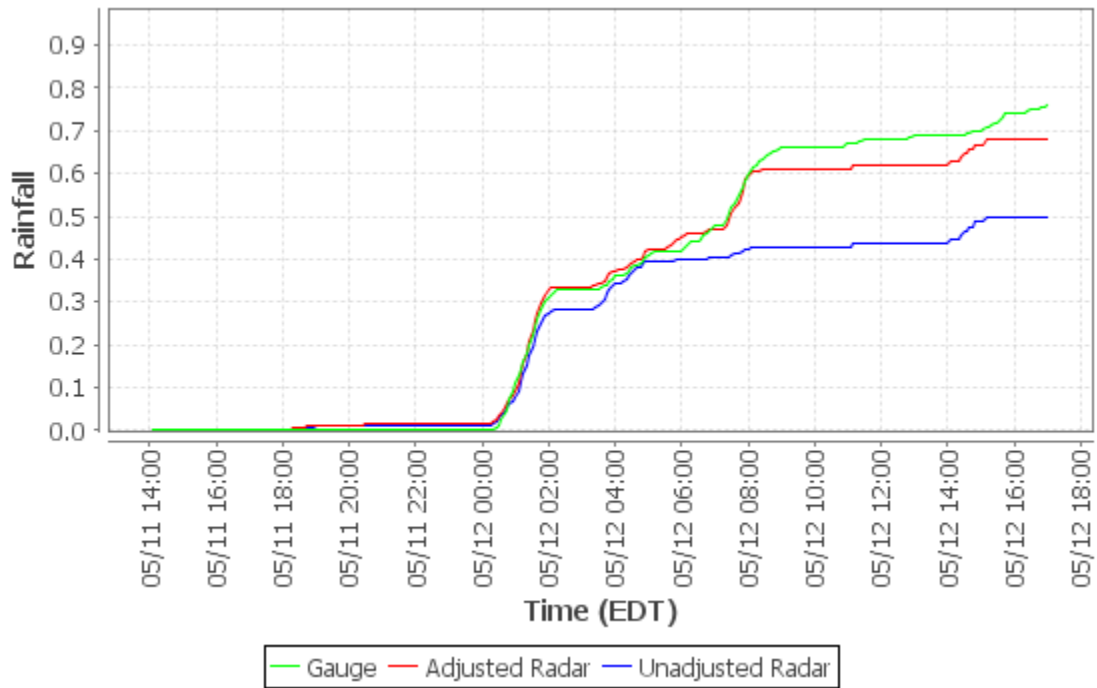
**Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)**



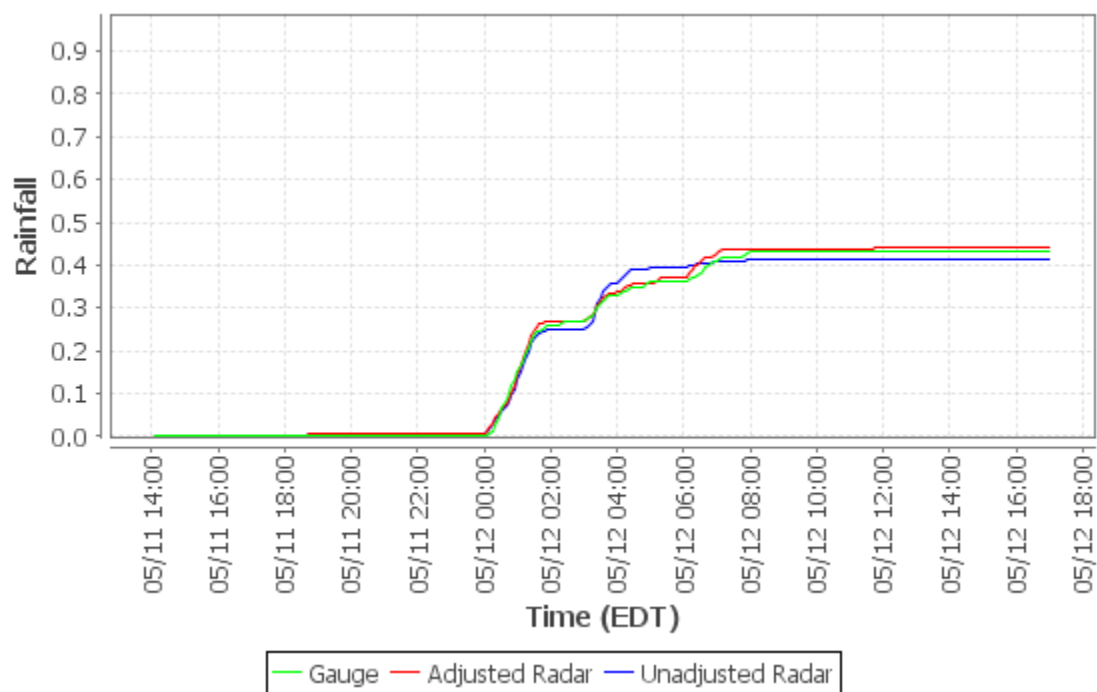
**Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)**



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



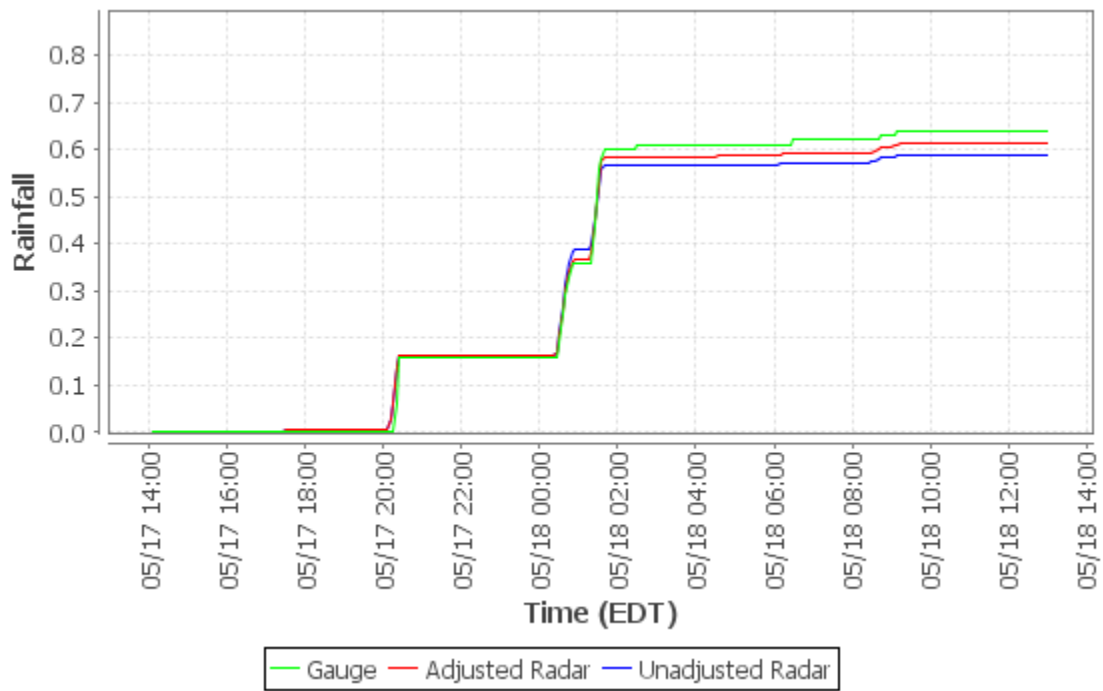
**Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth  
(03085734)**



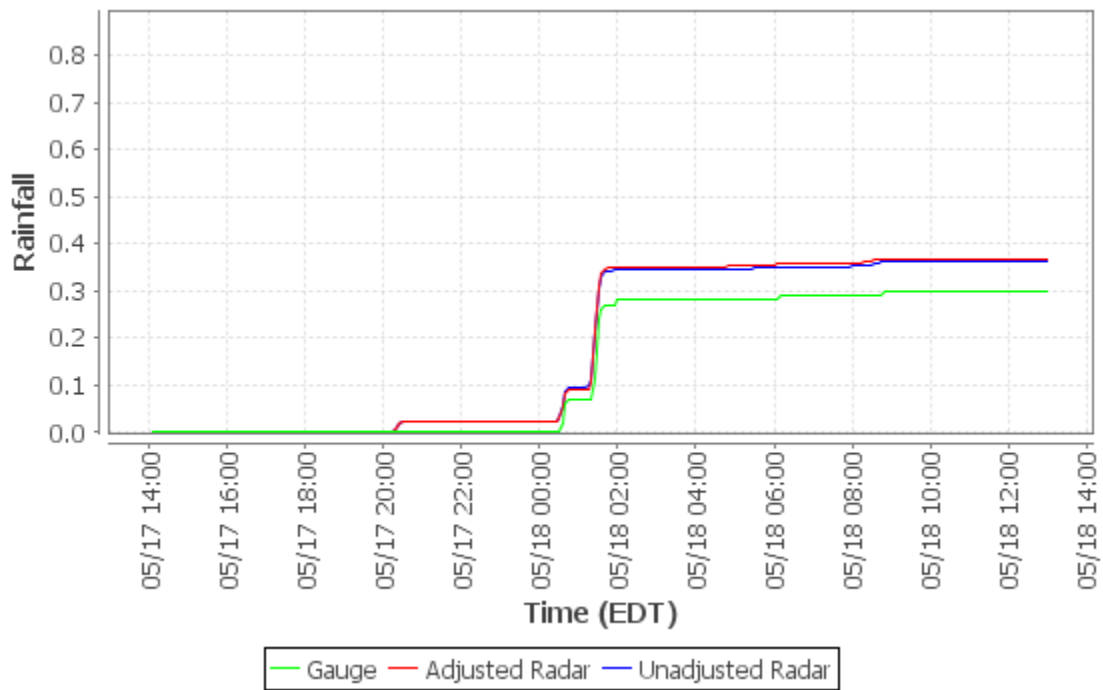
## **Appendix G - Event 5 (2019-05-17) CDPs**



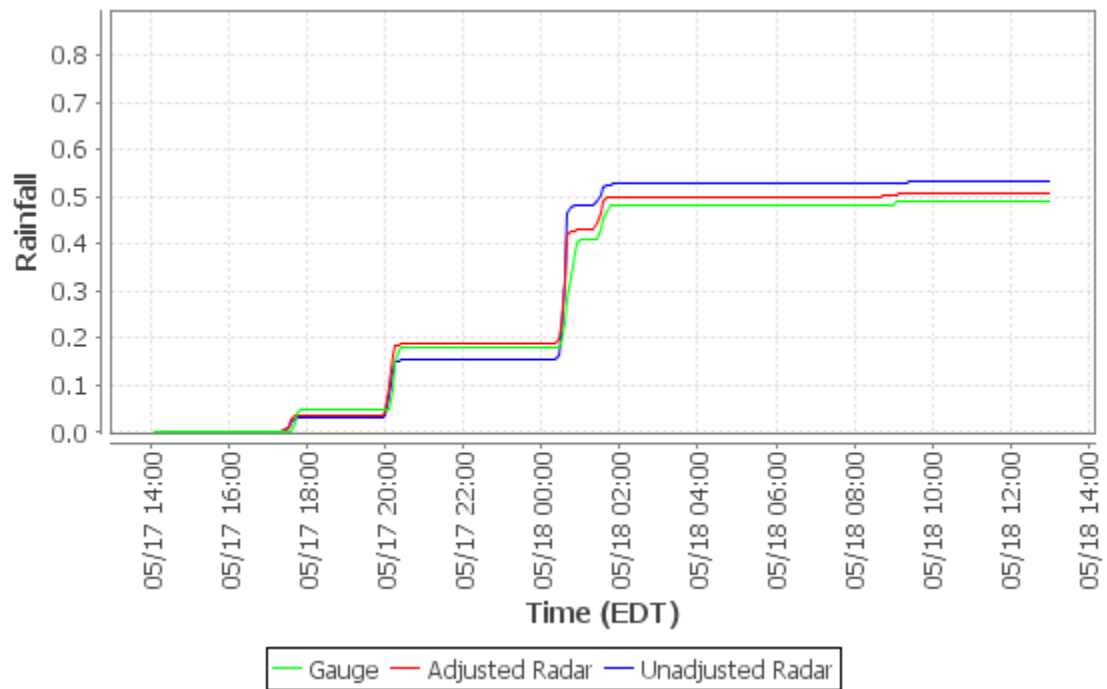
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



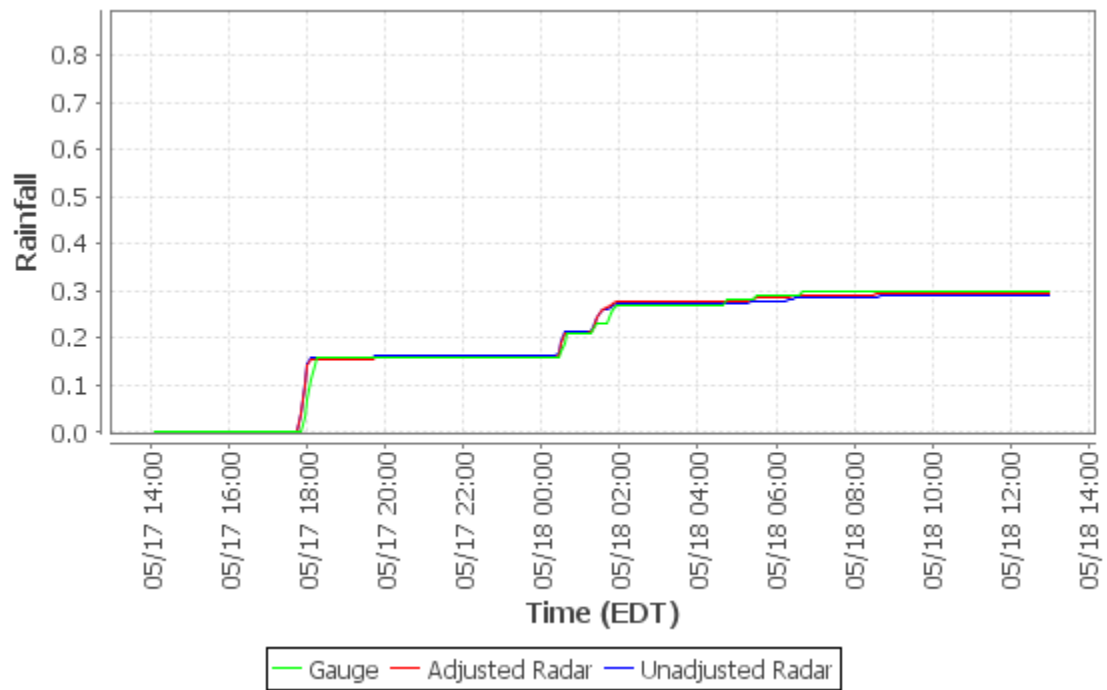
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



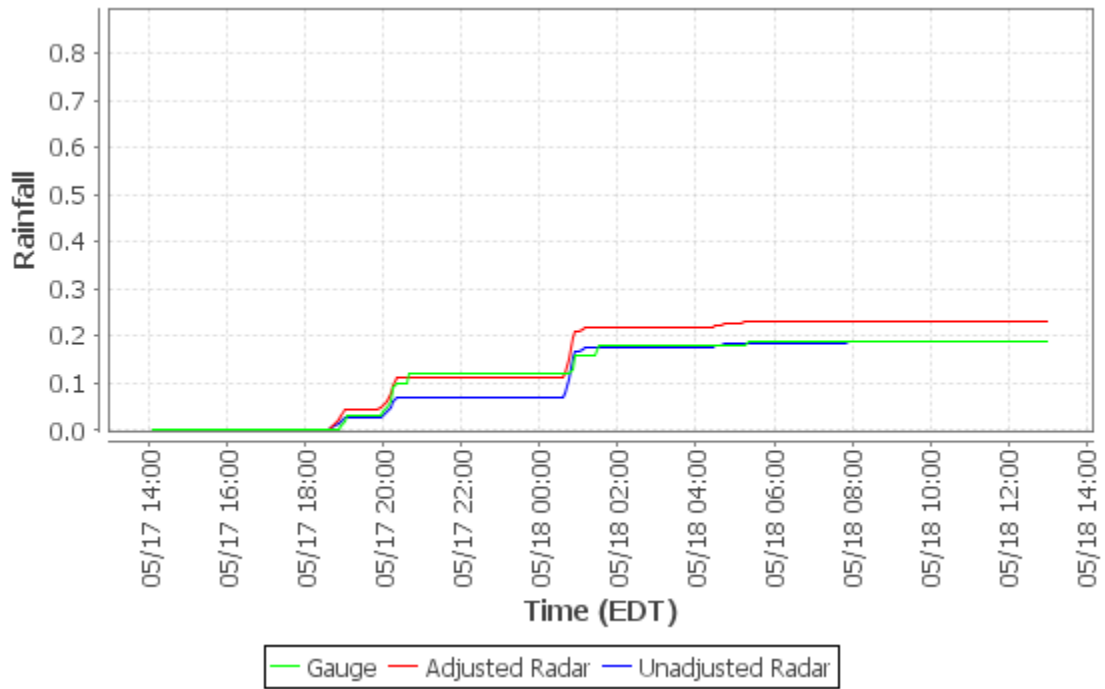
**Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)**



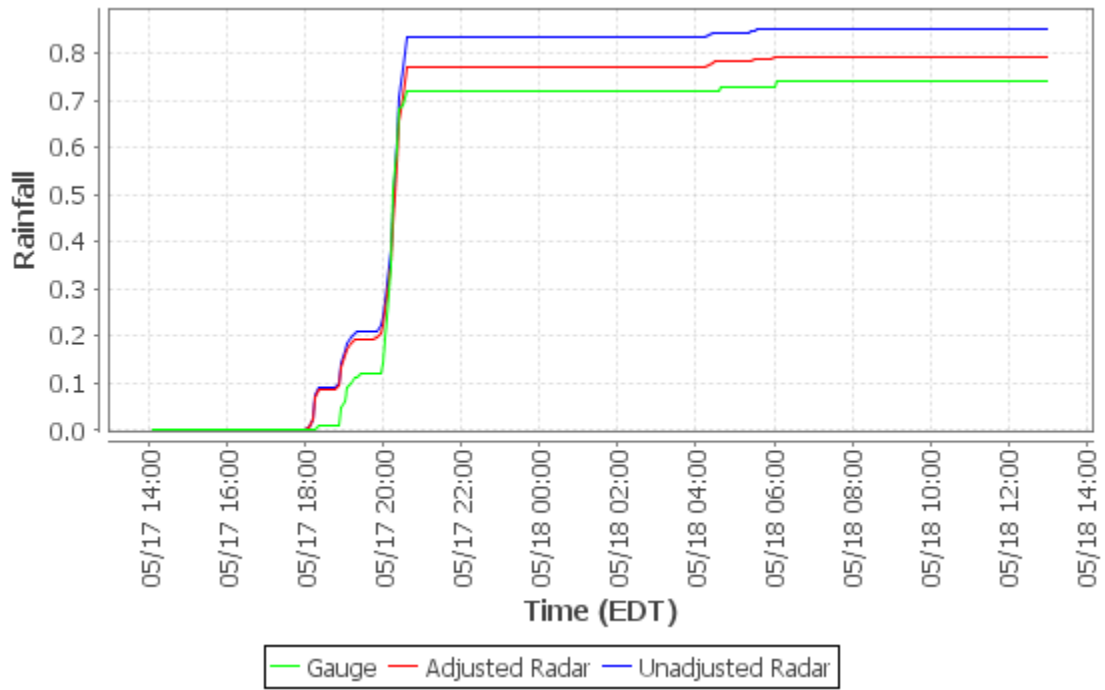
**Cumulative Distribution Plot - Kennedy Twp PS (Loc04)**



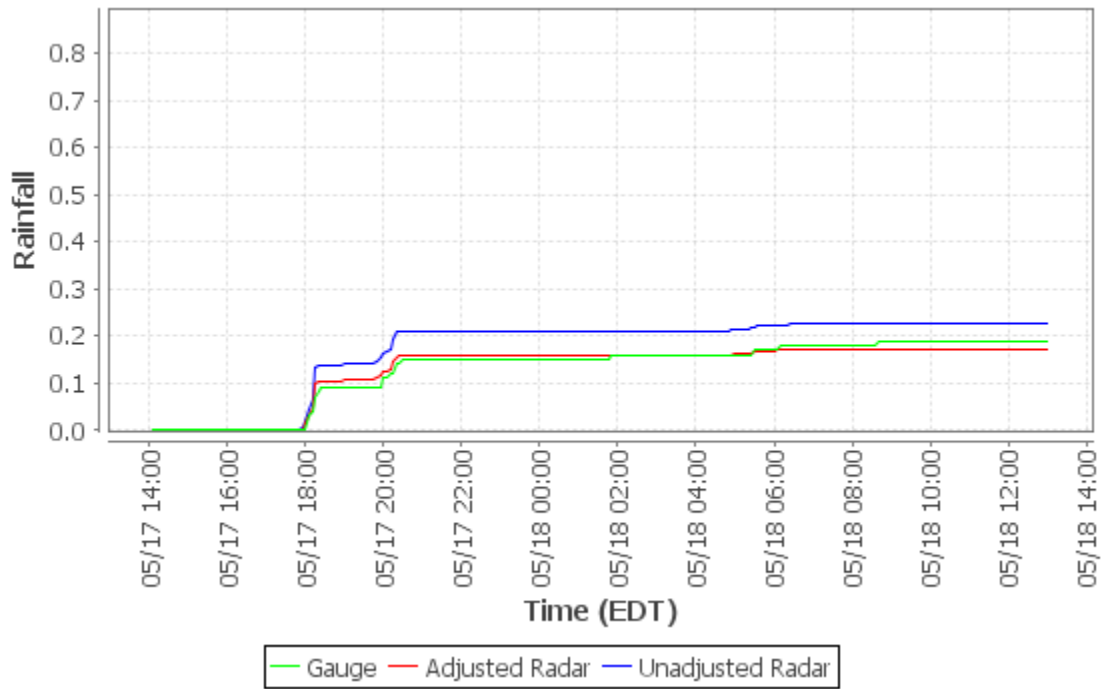
**Cumulative Distribution Plot - Upper St. Clair (Loc05)**



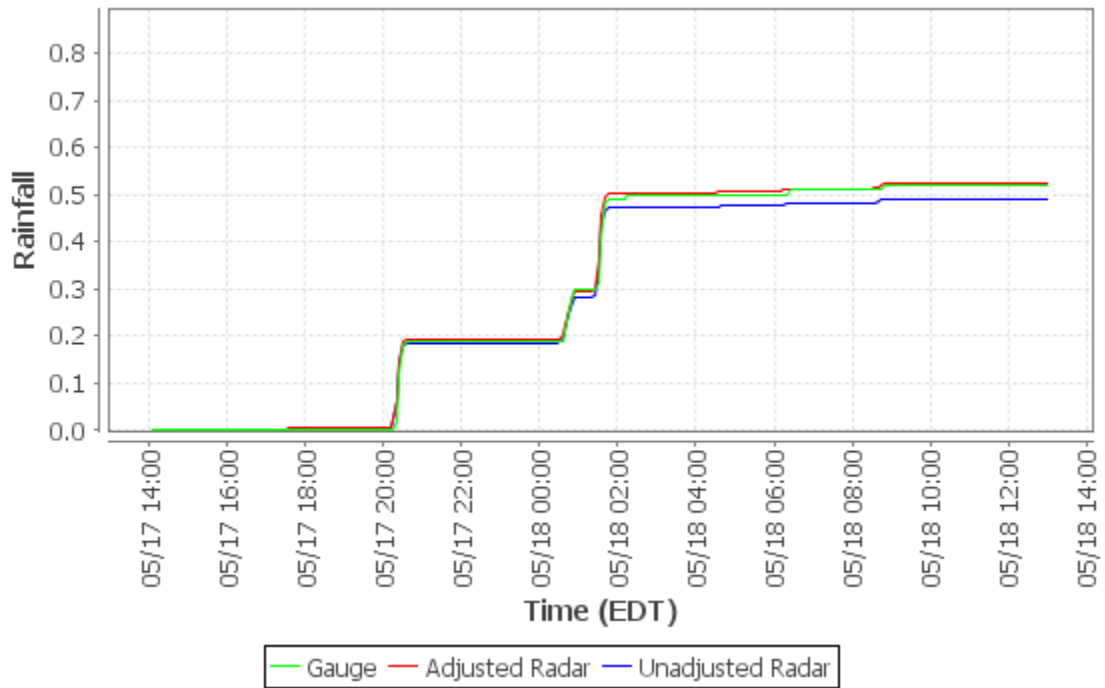
**Cumulative Distribution Plot - Carnegie Transit Time (Loc06)**



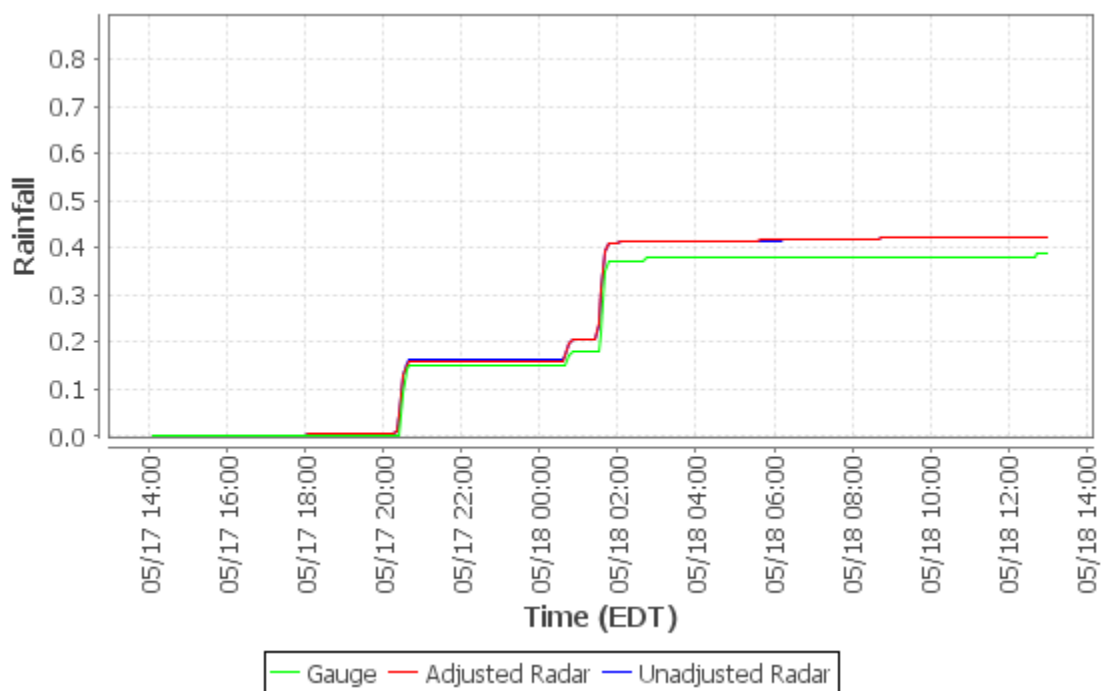
**Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)**



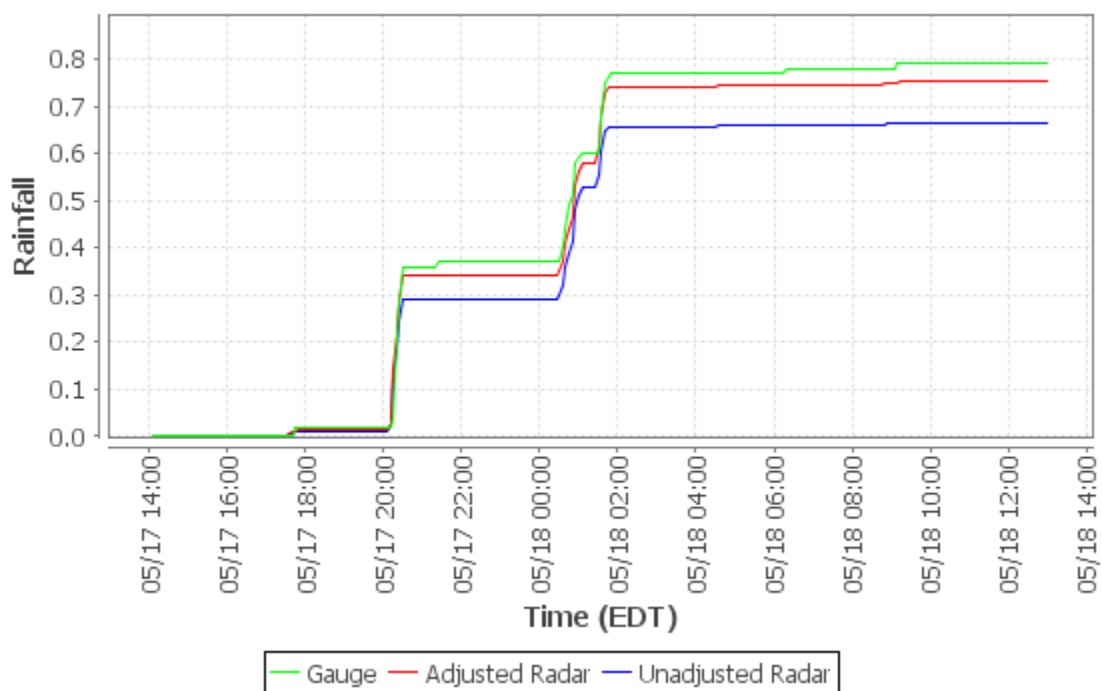
**Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)**



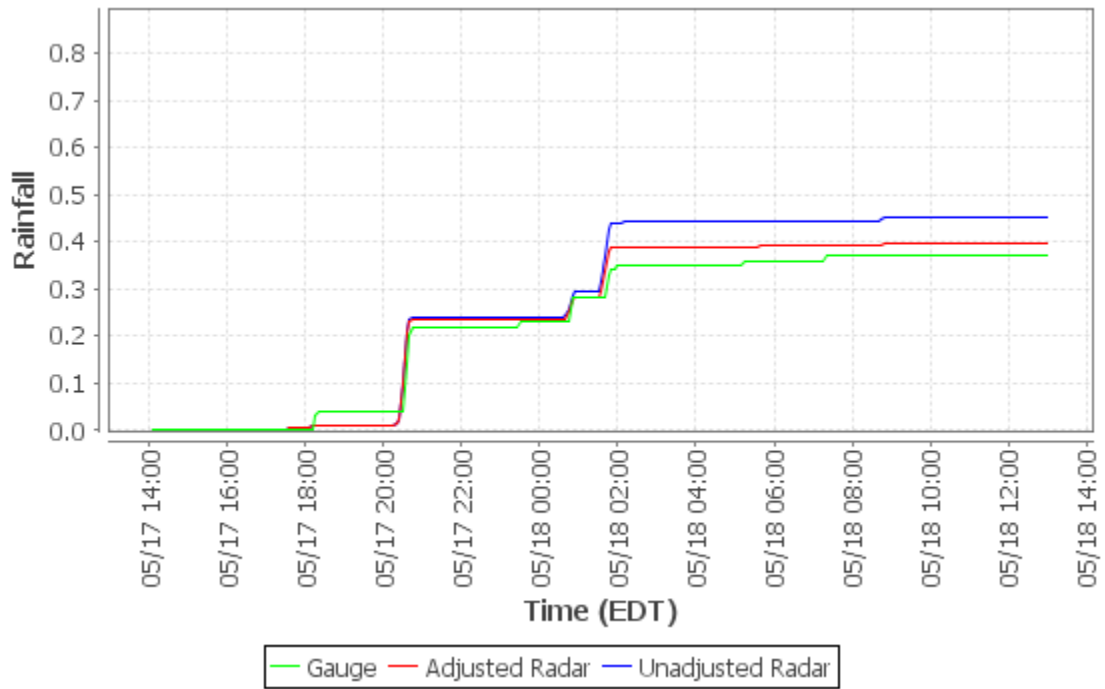
Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)



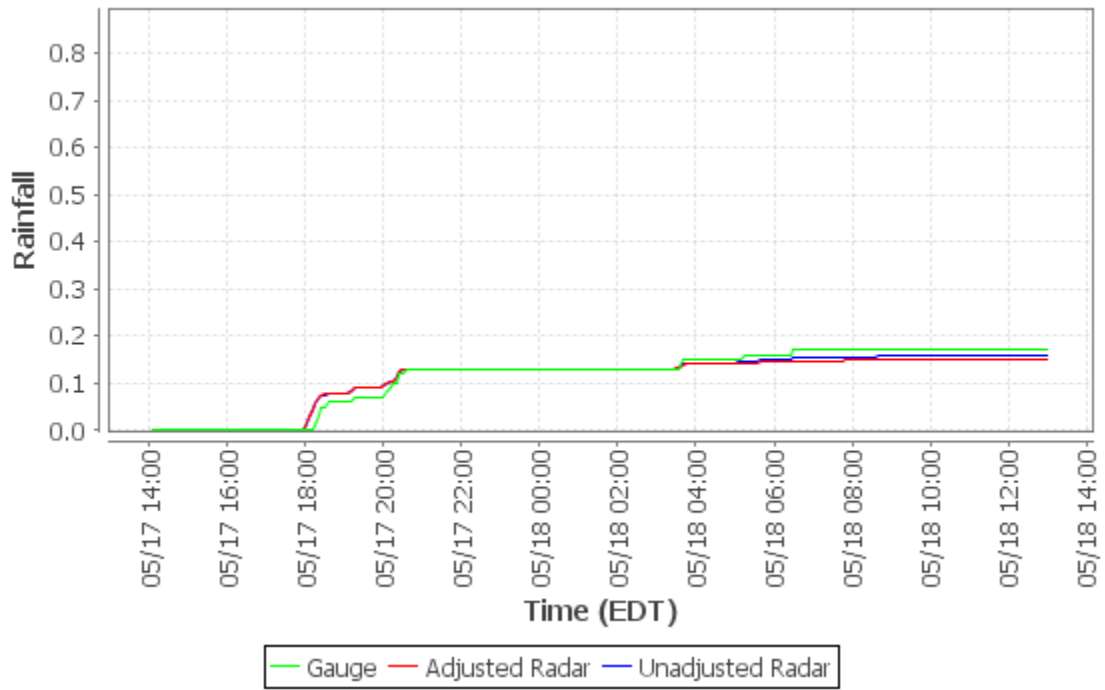
Cumulative Distribution Plot - PWSA-Highland Park (Loc10)



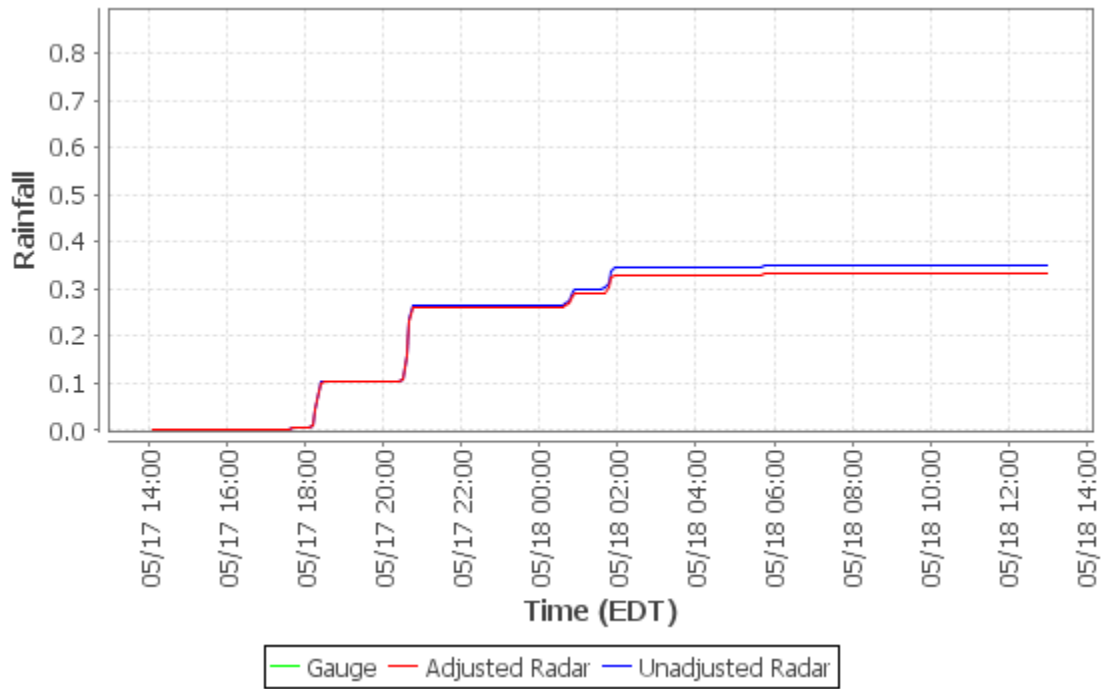
**Cumulative Distribution Plot - M-46 Access Shaft (Loc11)**



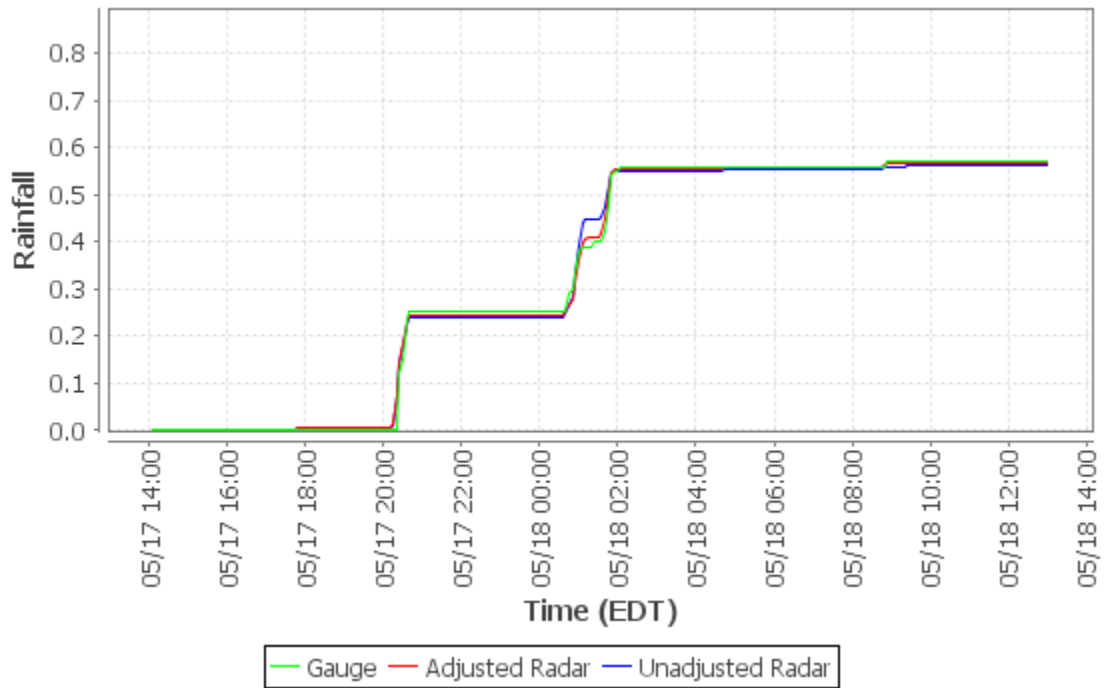
**Cumulative Distribution Plot - Baldwin (Loc12)**



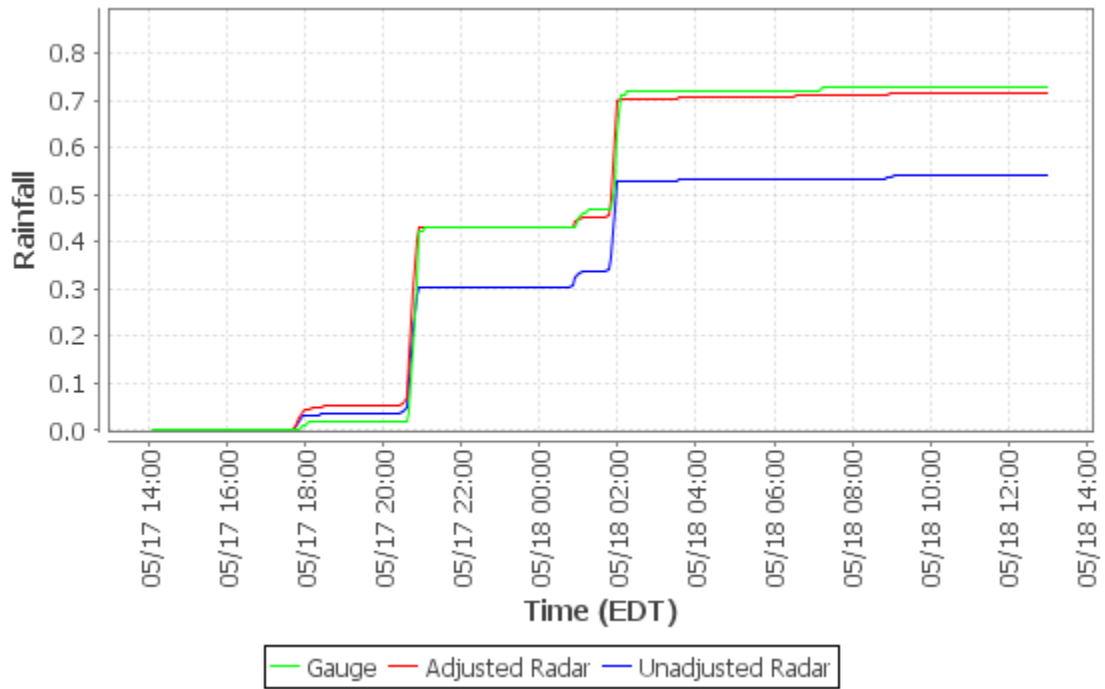
**Cumulative Distribution Plot - M-59 Access Shaft (Loc13)**



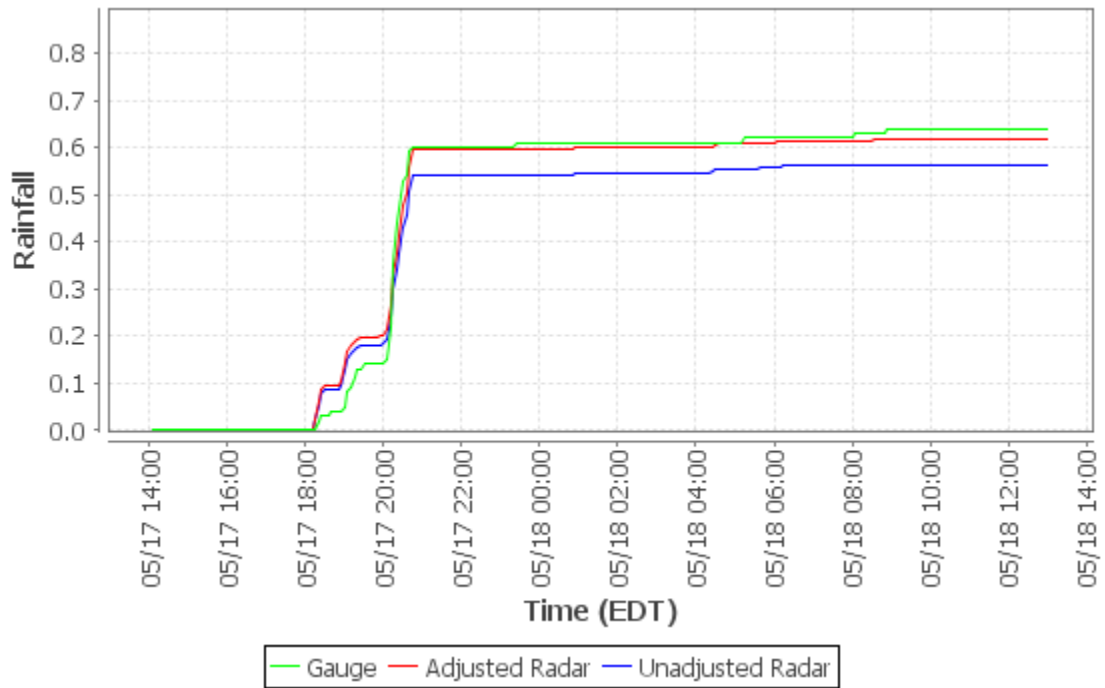
**Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)**



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

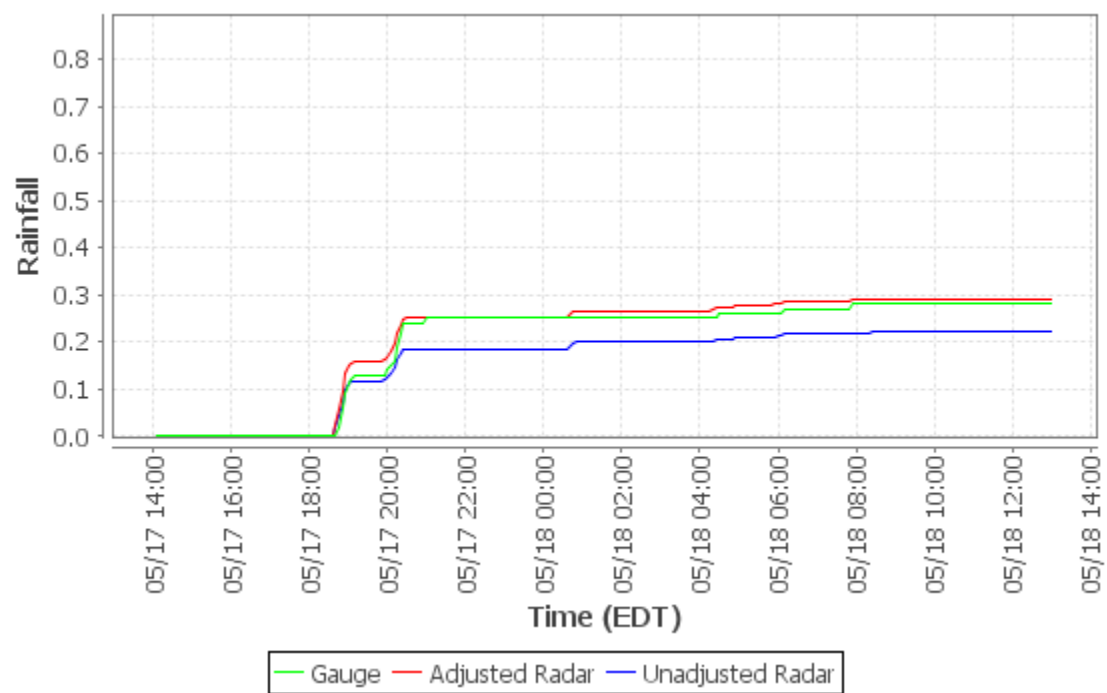


**Cumulative Distribution Plot - Castle Shannon (Loc16)**

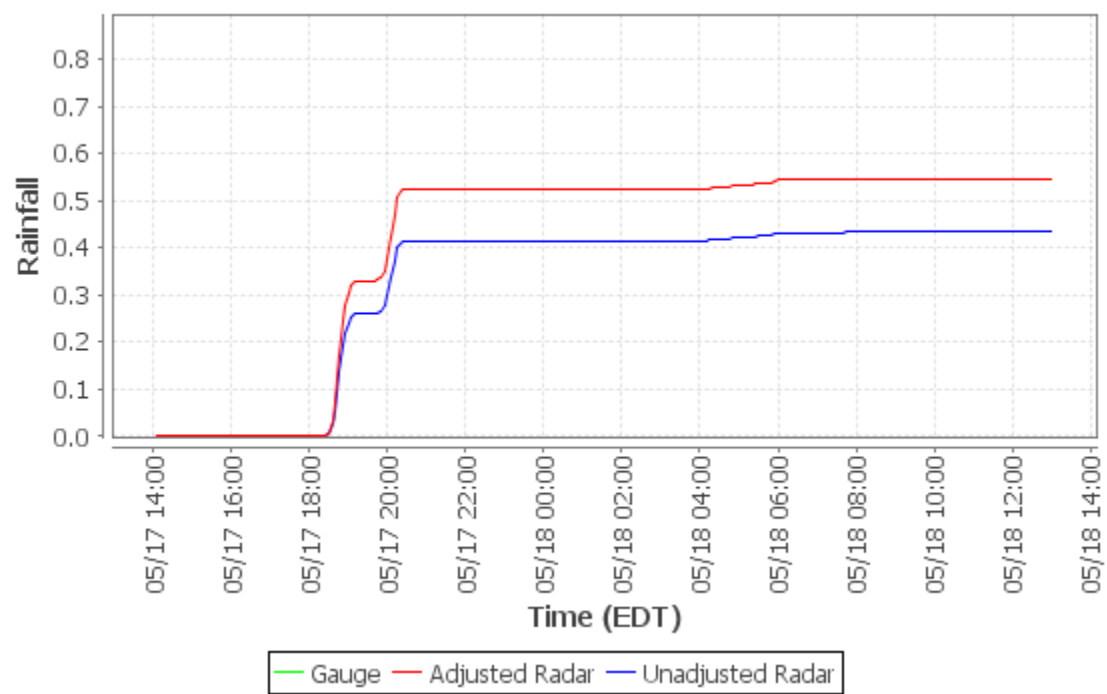




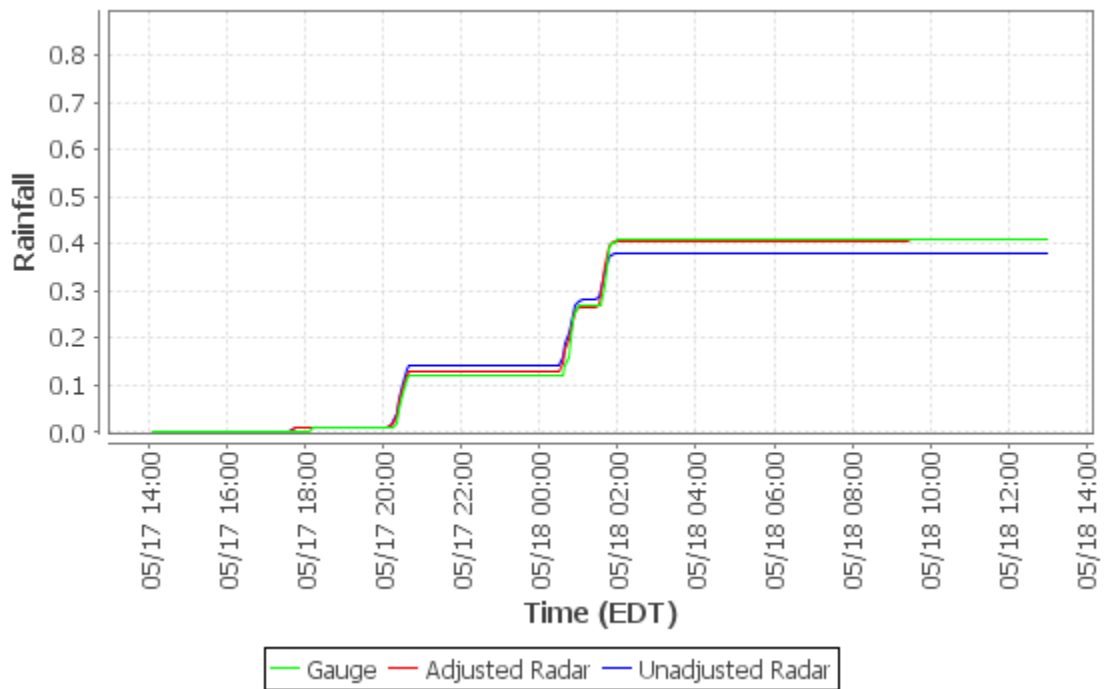
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



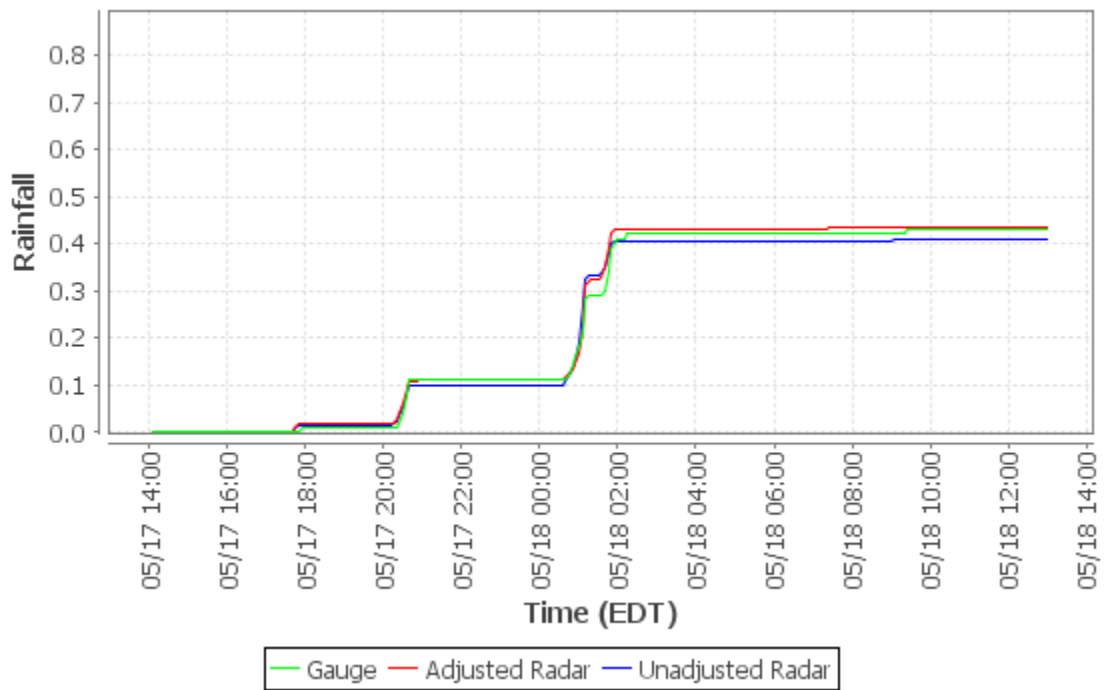
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



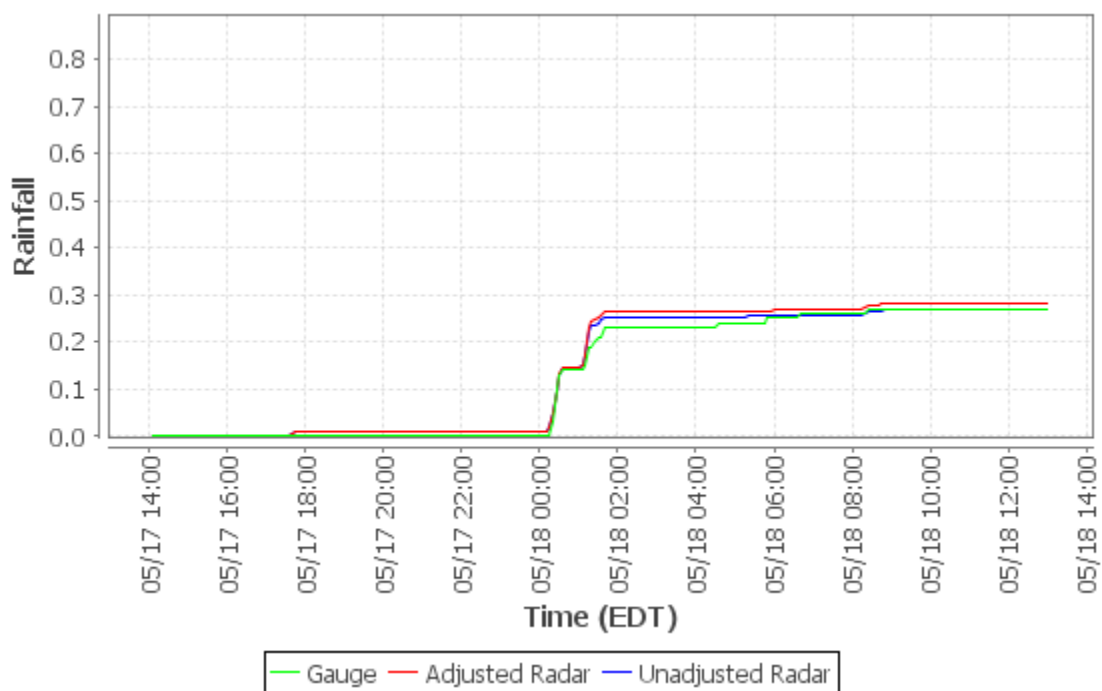
**Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)**



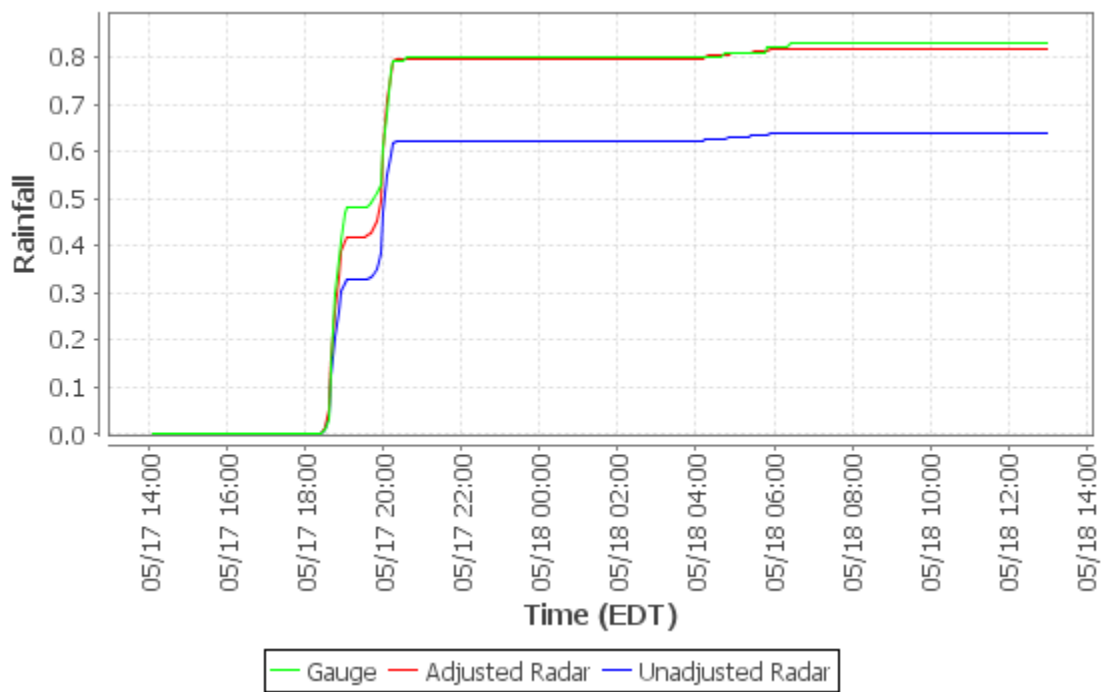
**Cumulative Distribution Plot - Gascola Eq Facility (Loc20)**



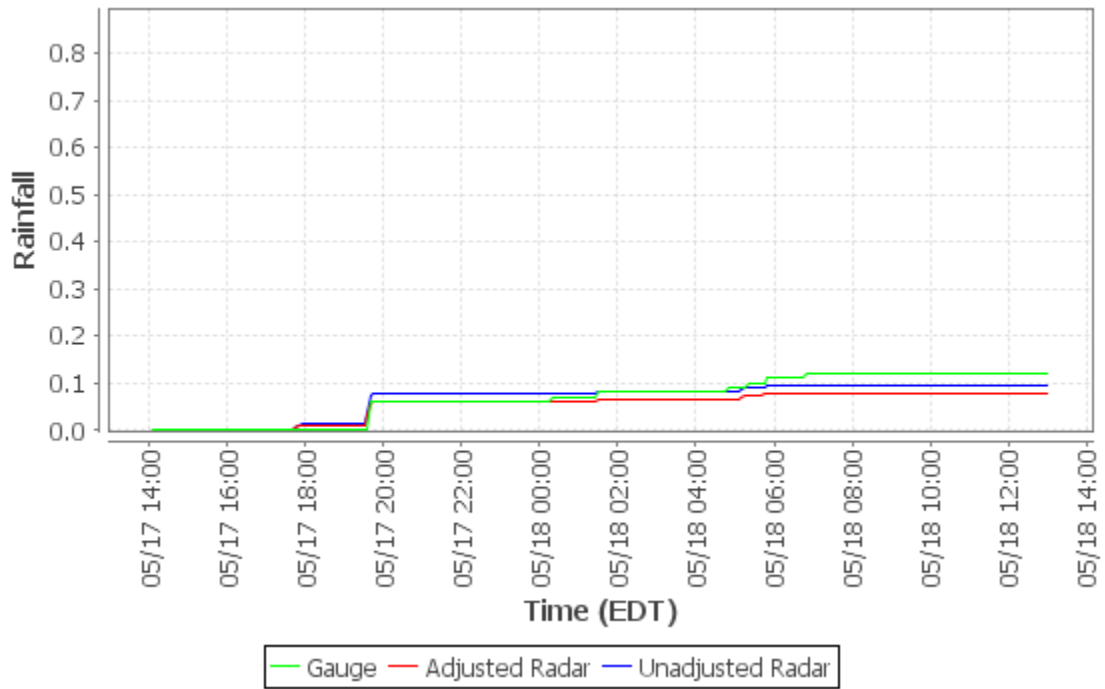
**Cumulative Distribution Plot - Moon TWP (Loc21)**



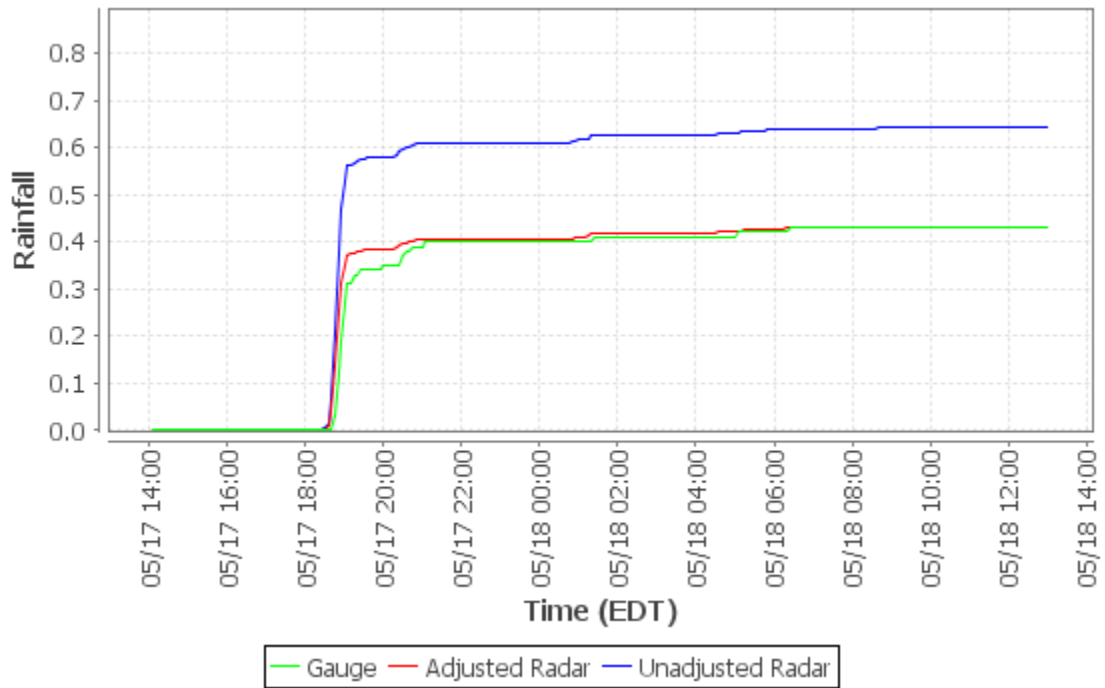
**Cumulative Distribution Plot - North Fayette TWP (Loc22)**



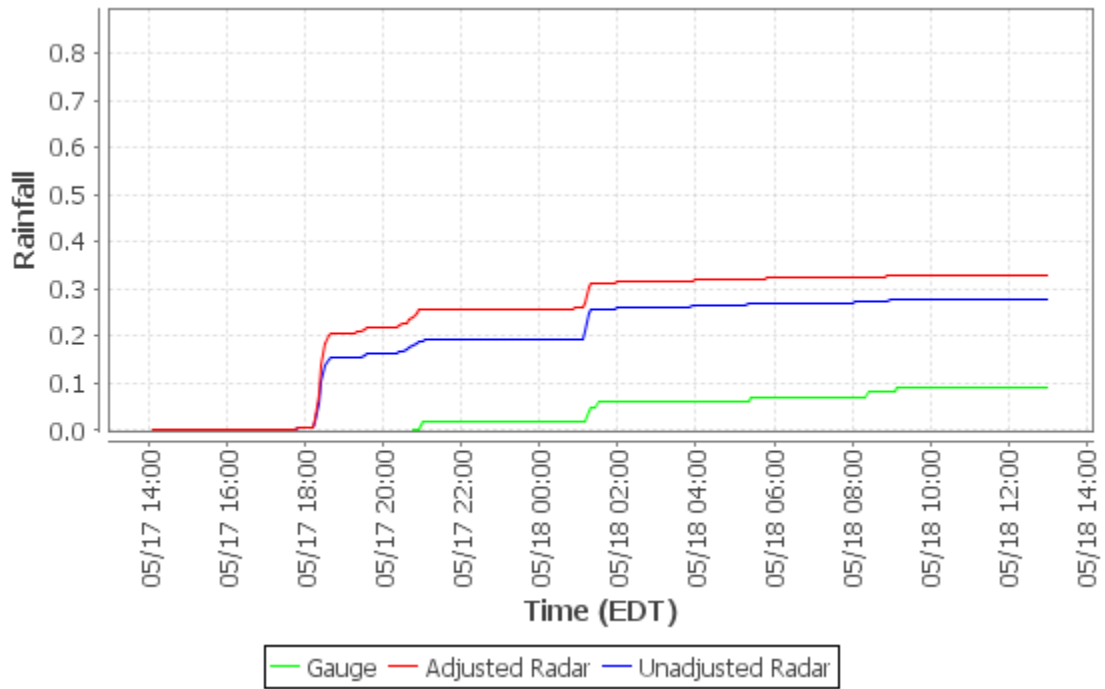
**Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)**



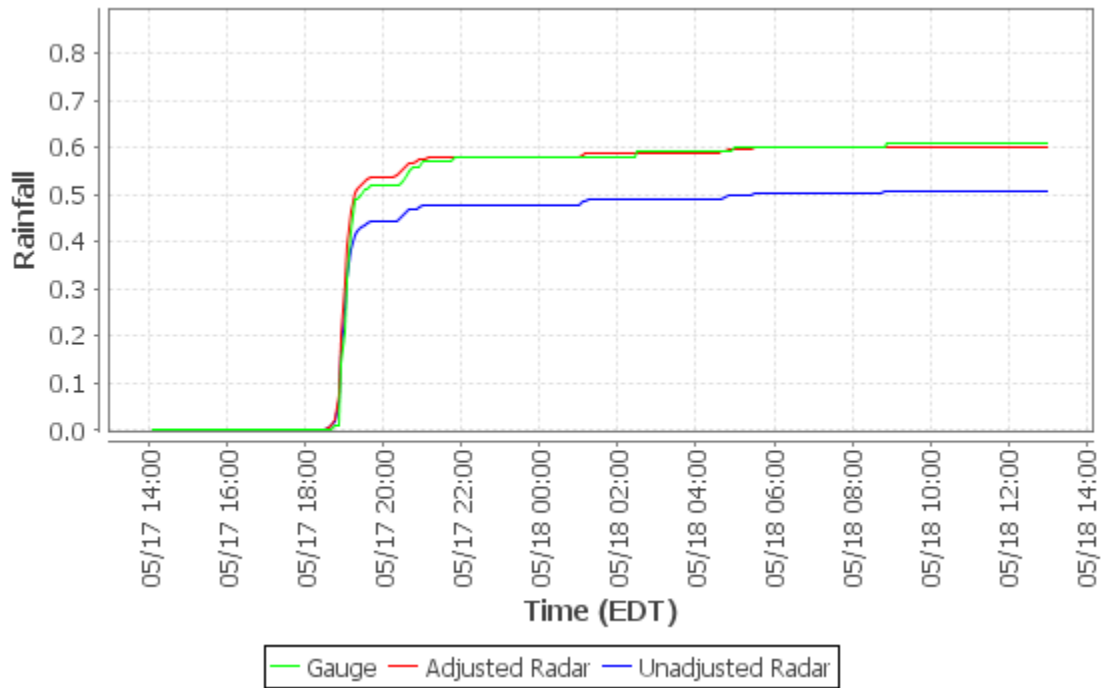
**Cumulative Distribution Plot - Jefferson Hills (Loc24)**



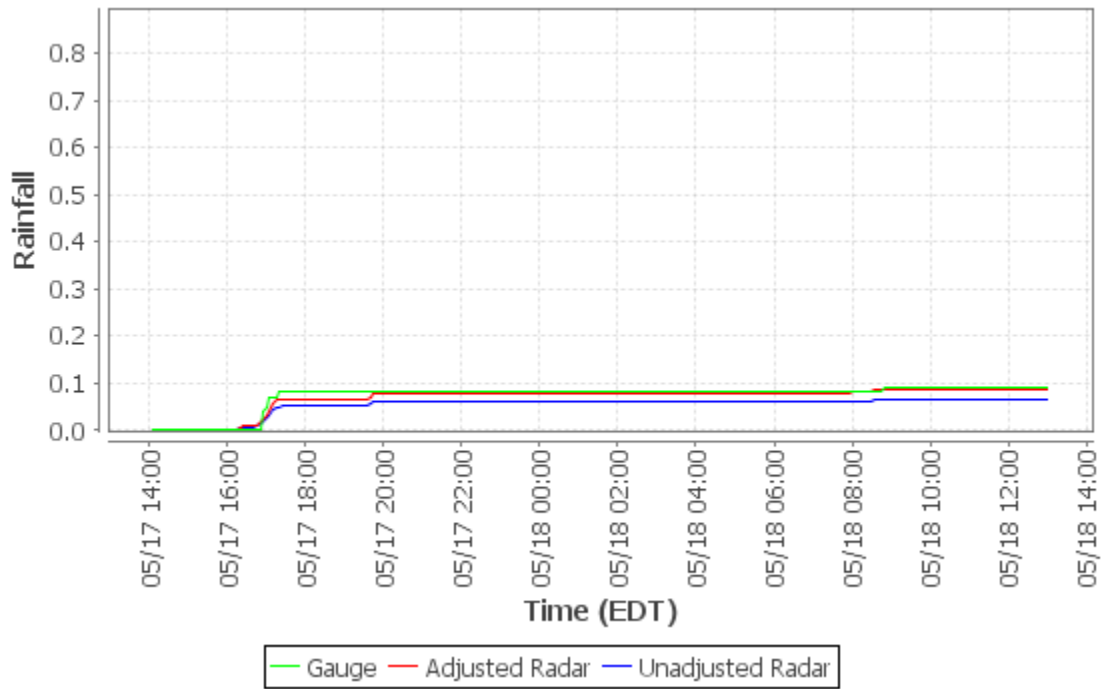
**Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)**



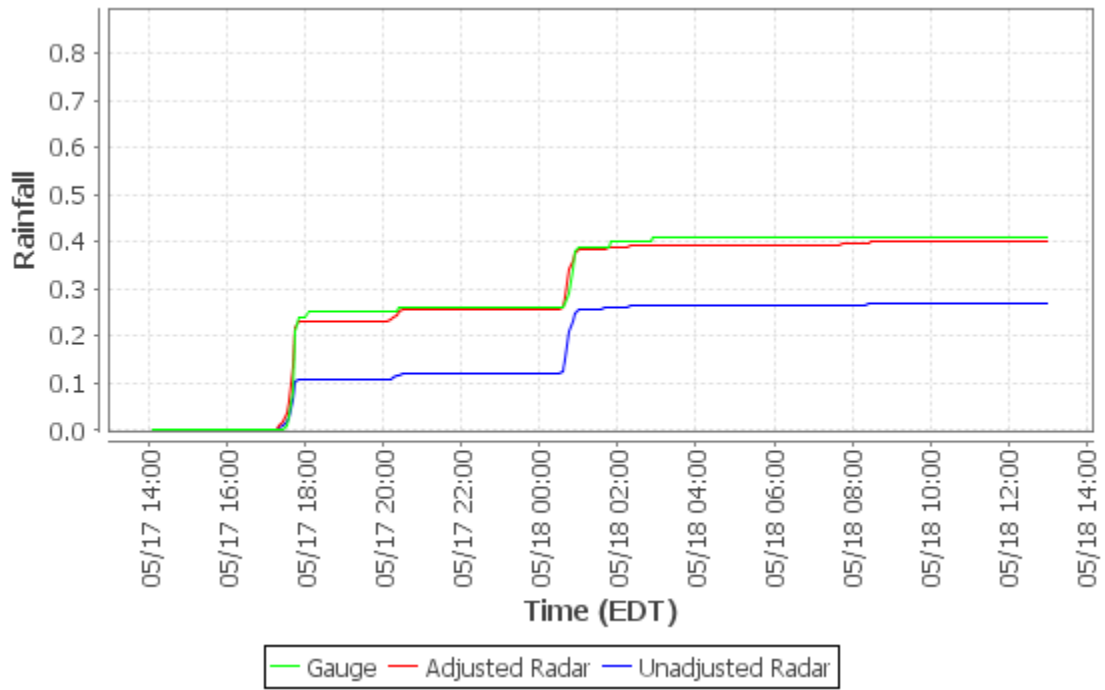
**Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)**



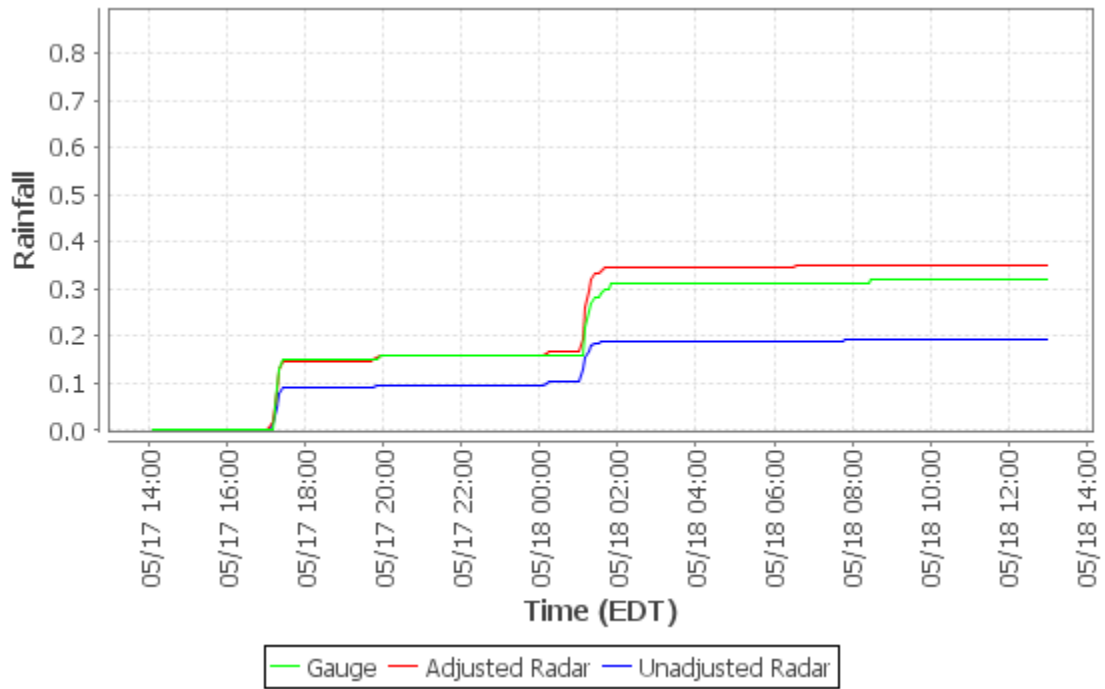
**Cumulative Distribution Plot - Marshall TWP (Loc27)**



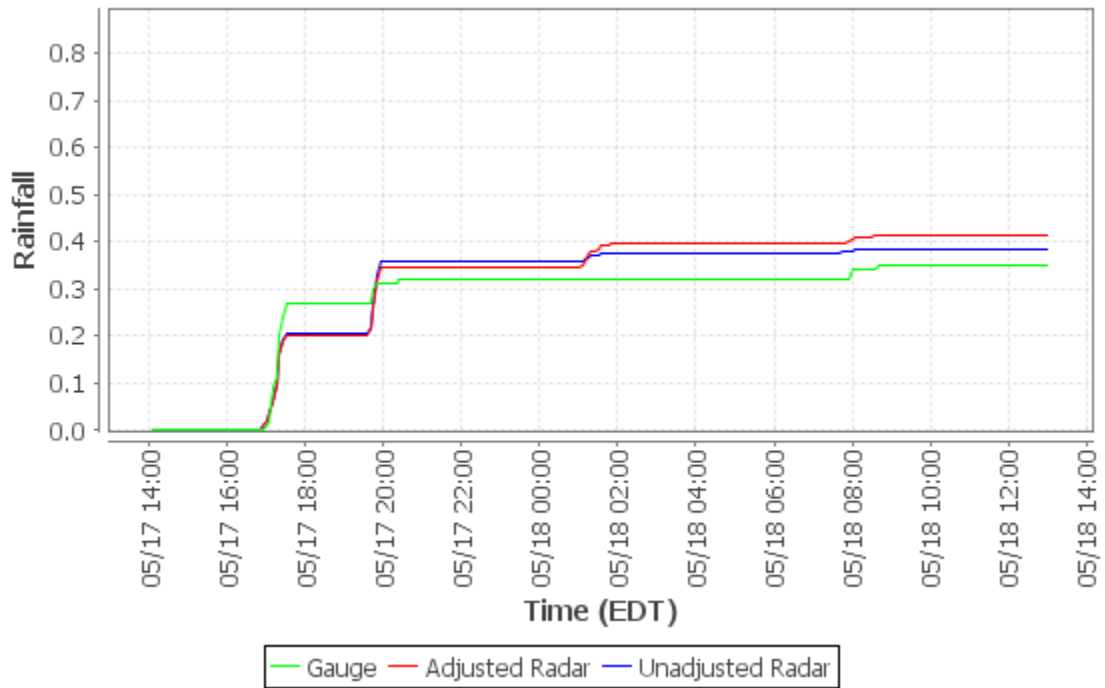
**Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)**



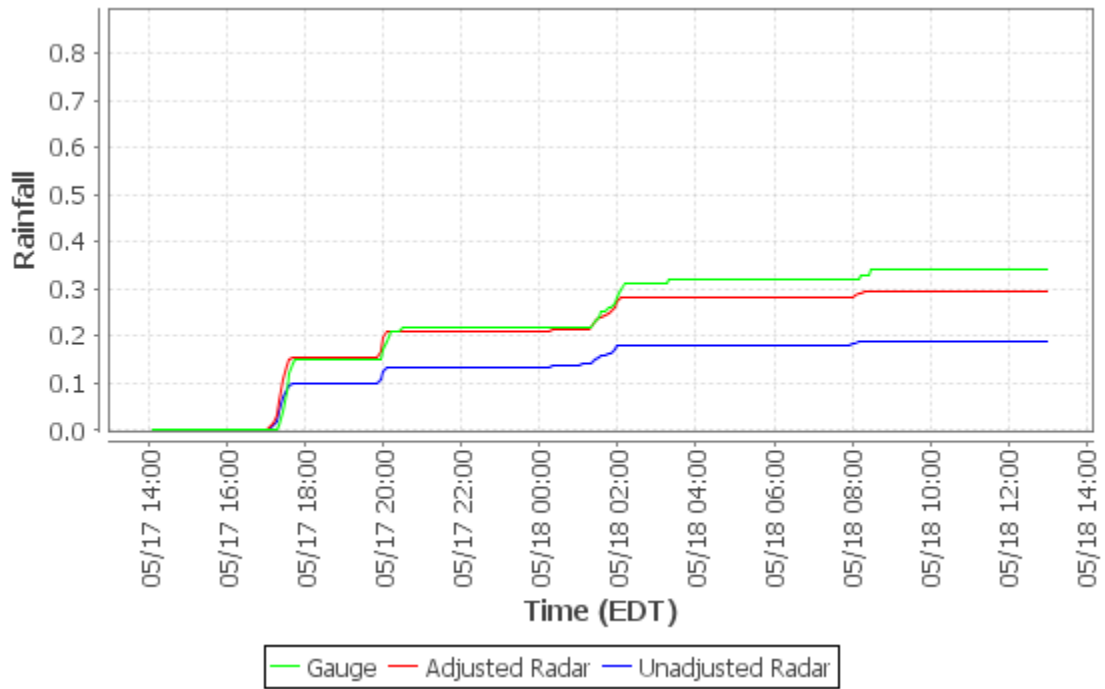
**Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)**



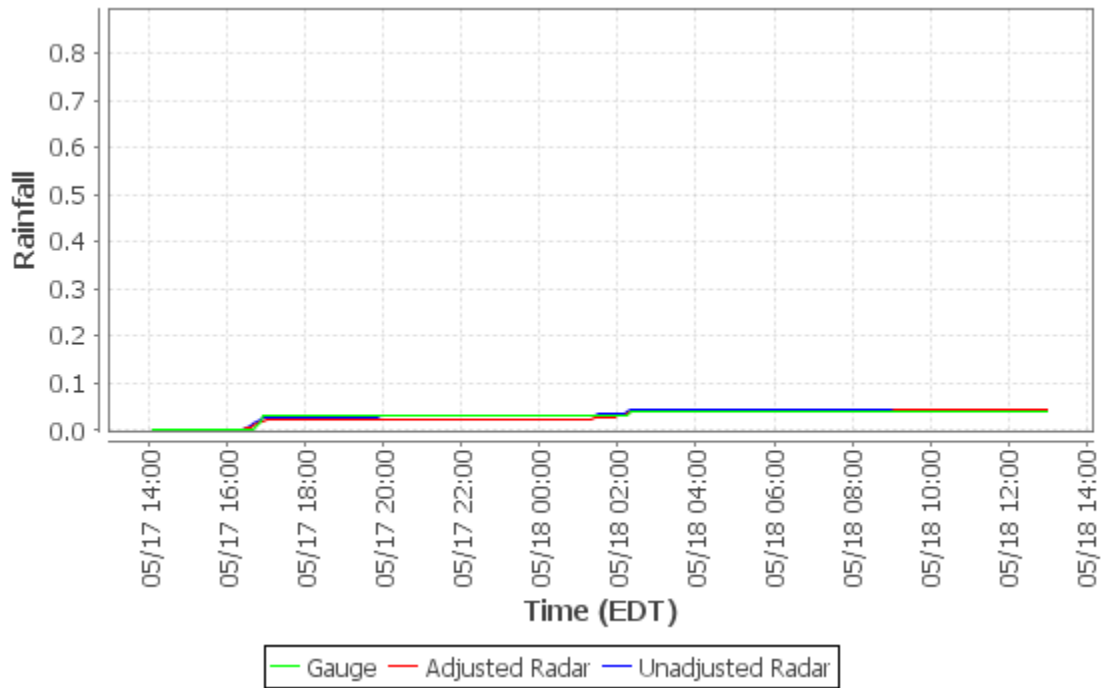
**Cumulative Distribution Plot - McCandless Twn Hall (Loc30)**



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

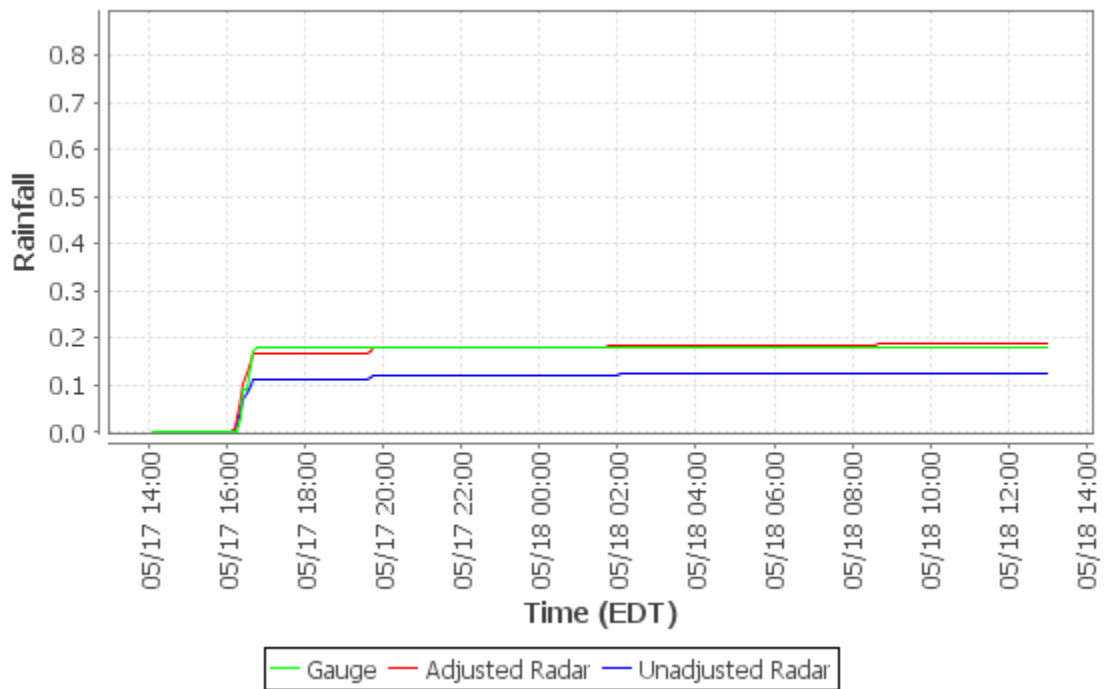


**Cumulative Distribution Plot - Arnold (Loc32)**

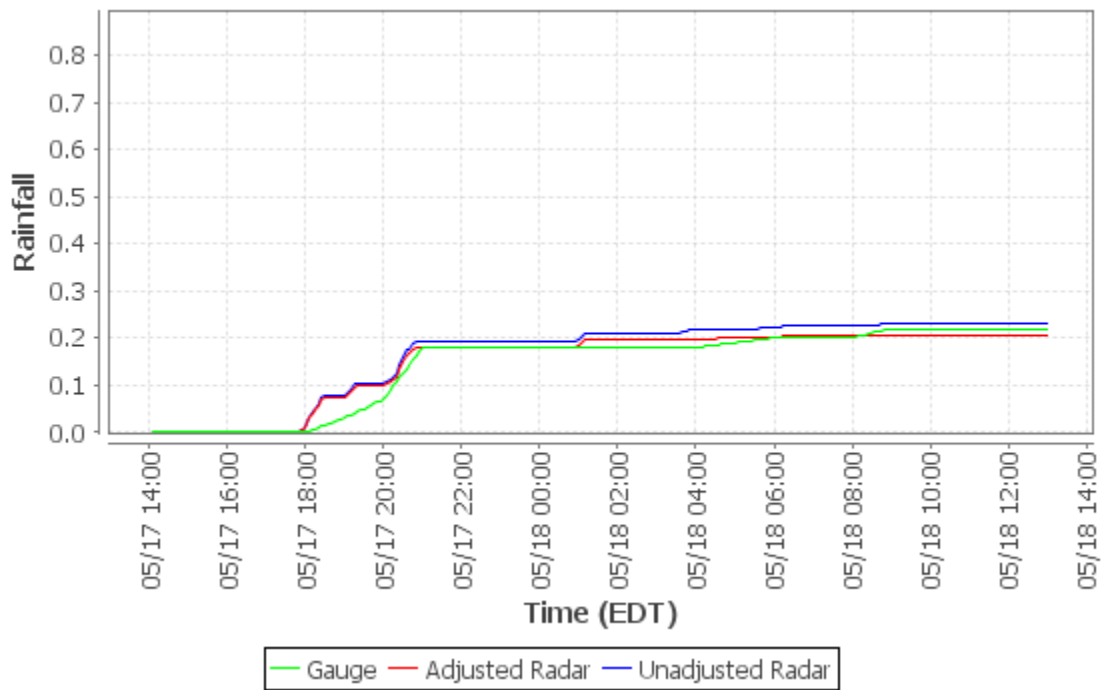




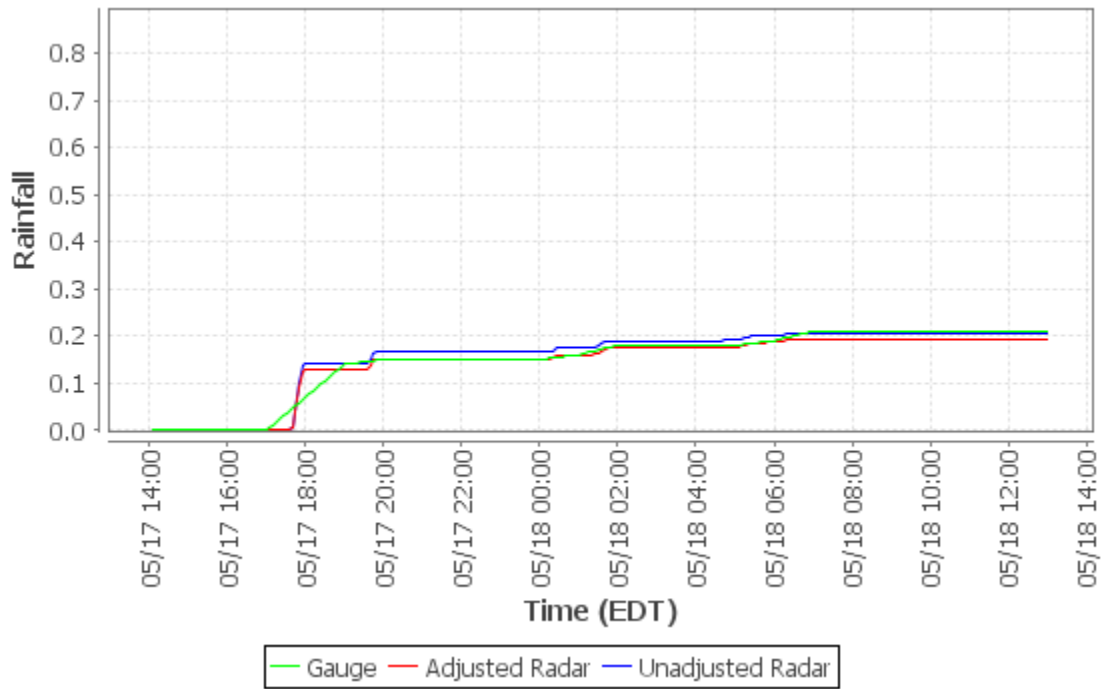
**Cumulative Distribution Plot - Richland TWP (Loc33)**



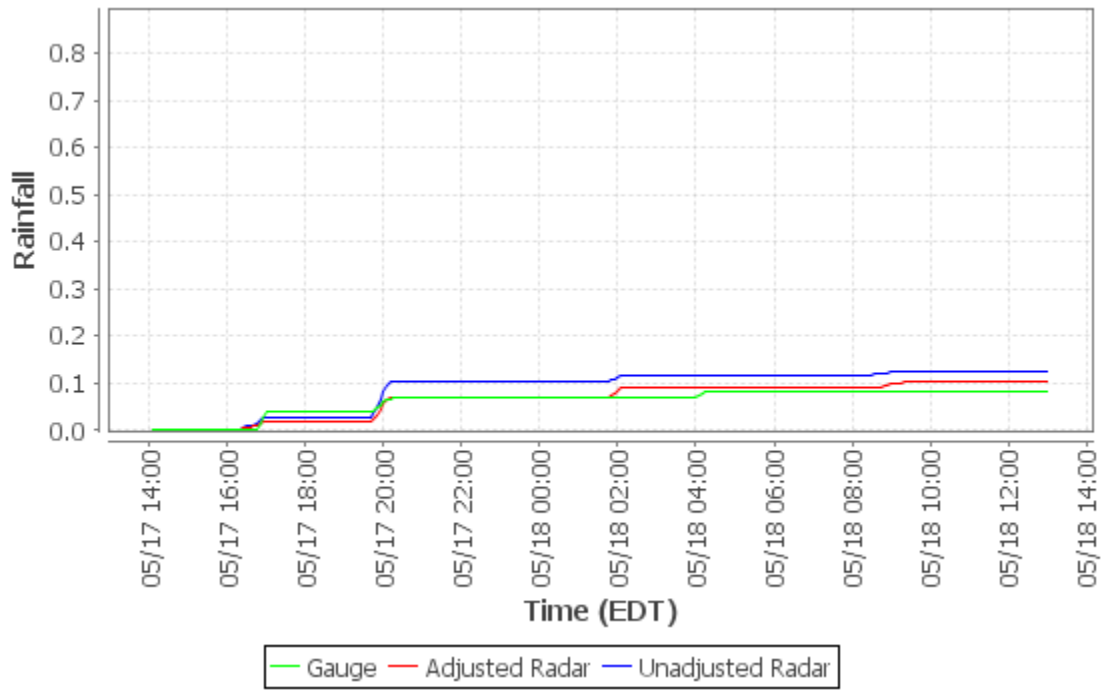
**Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)**



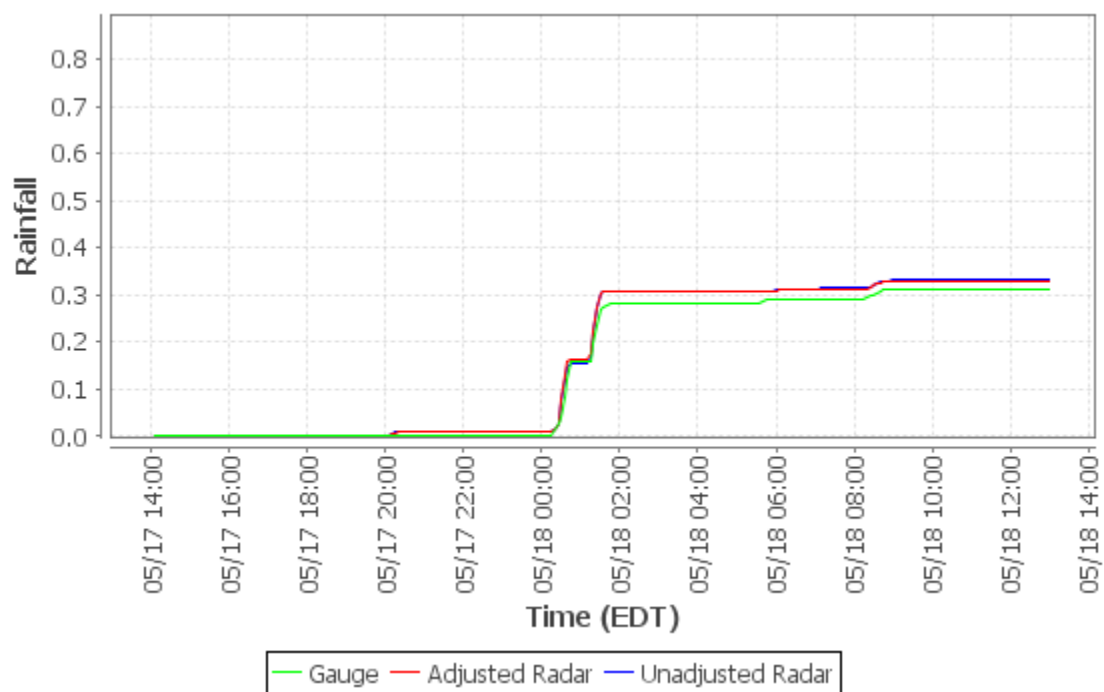
**Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)**



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

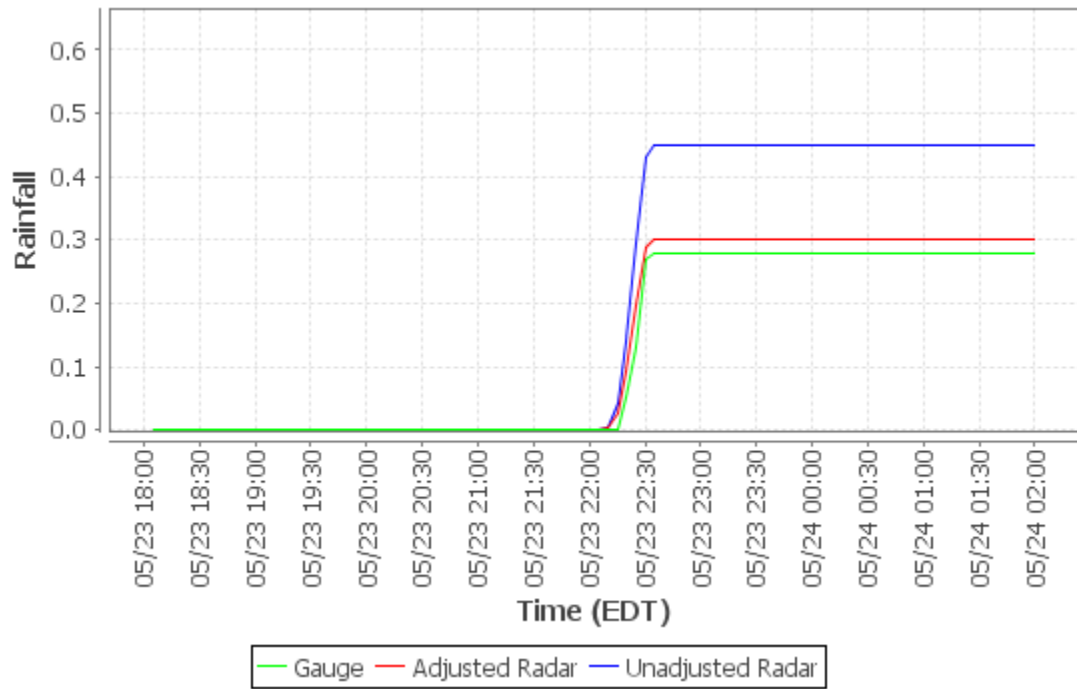


### Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth (03085734)

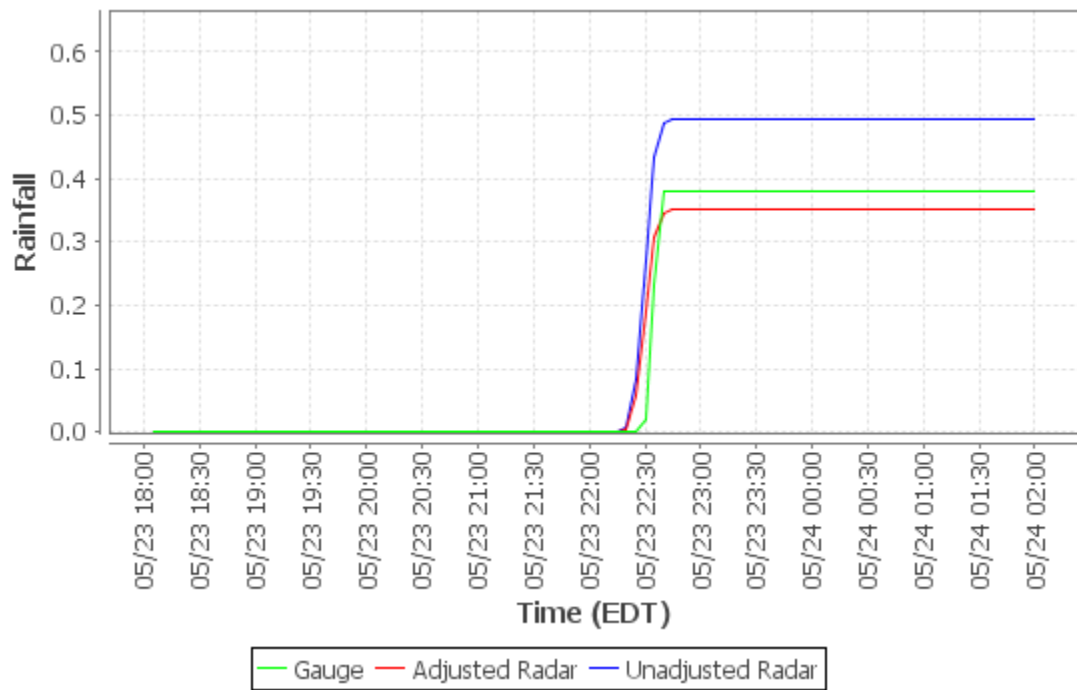


## **Appendix H - Event 6 (2019-05-23) CDPs**

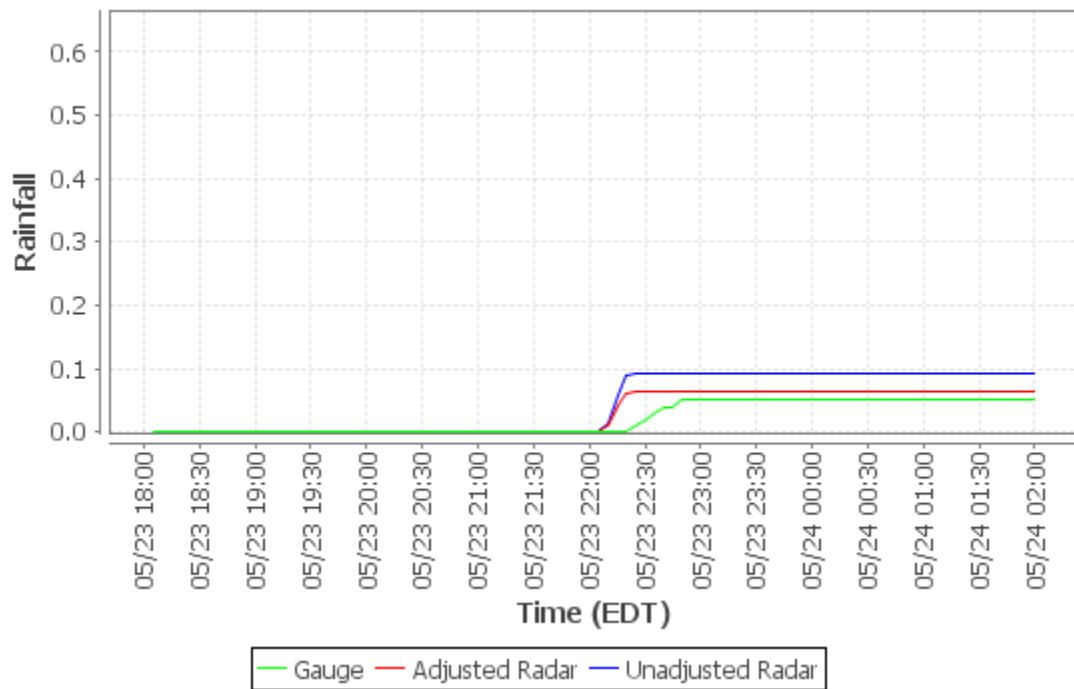
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



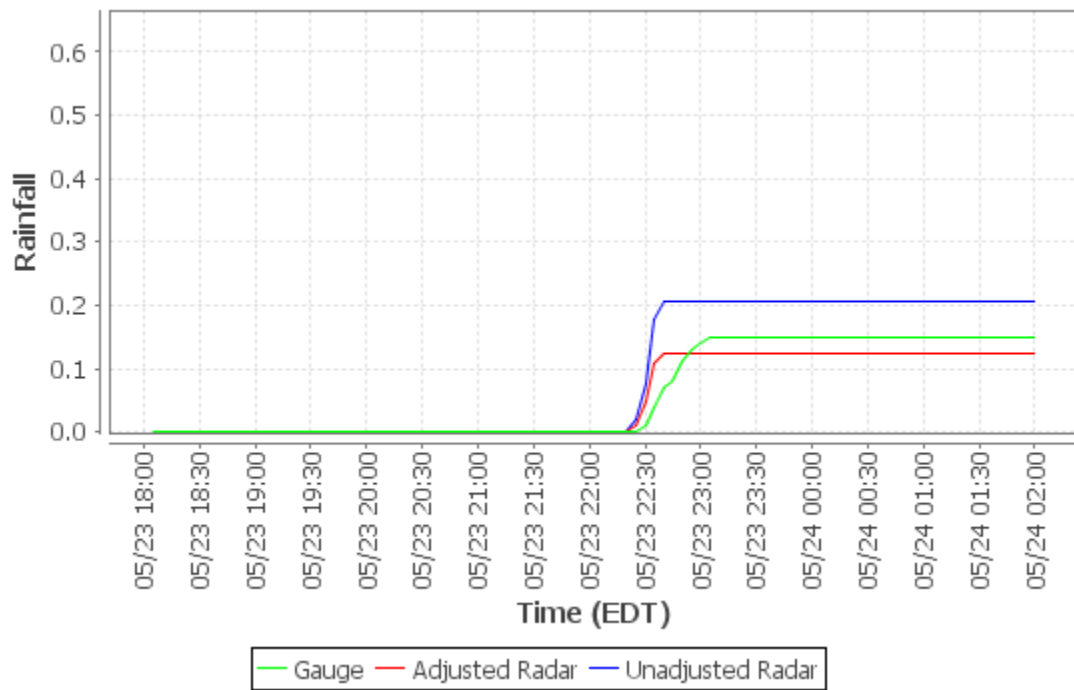
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



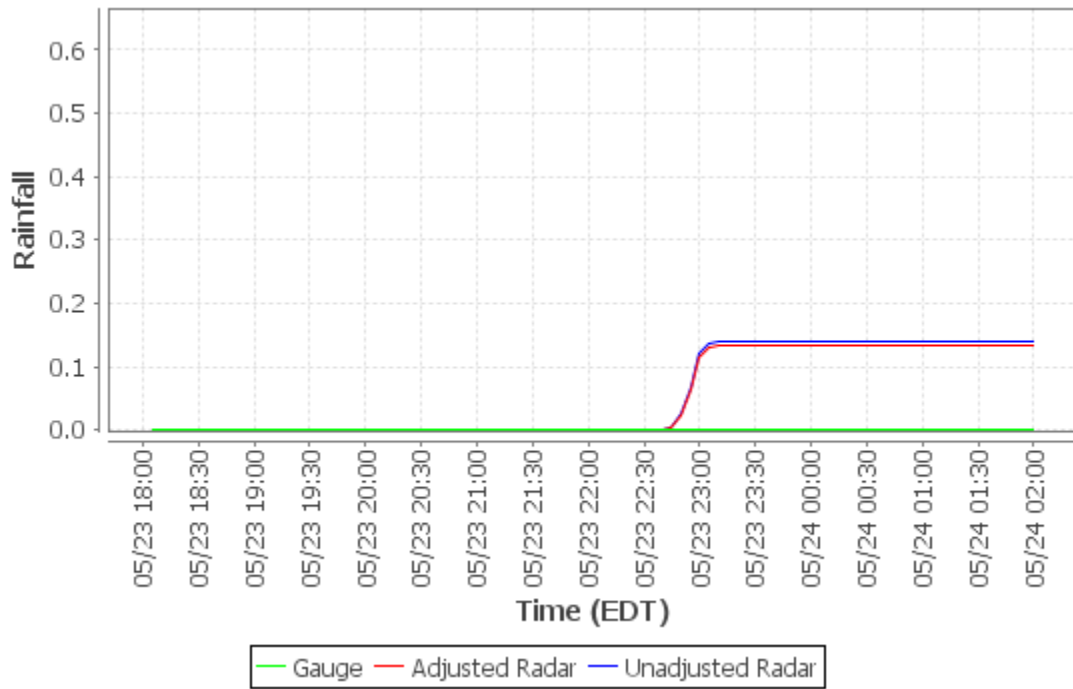
**Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)**



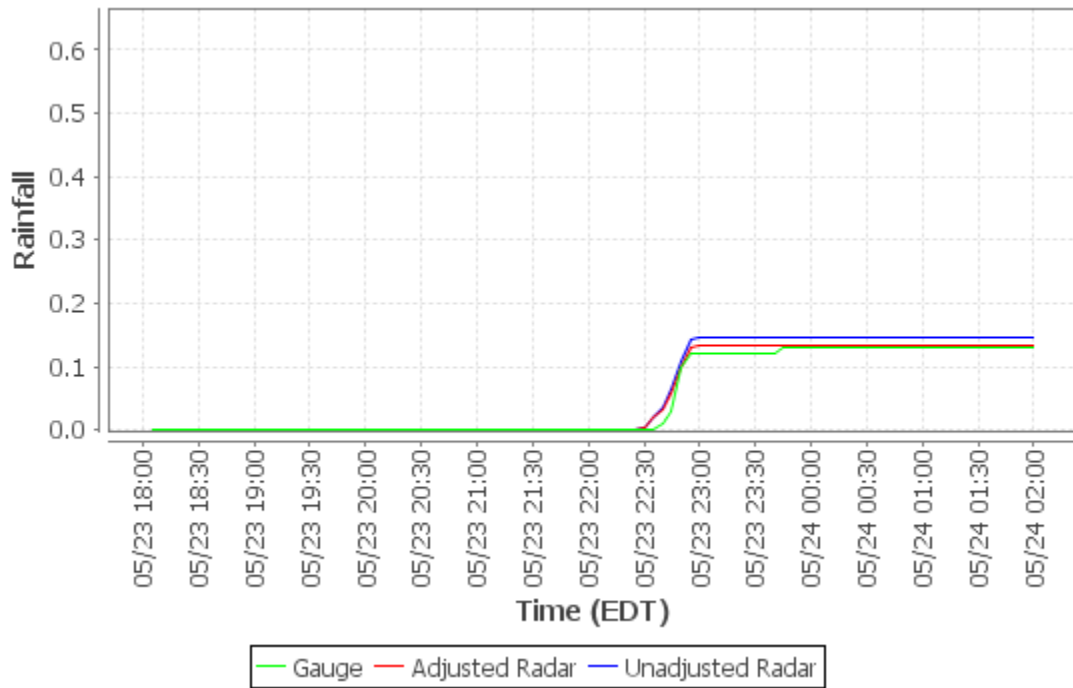
**Cumulative Distribution Plot - Kennedy Twp PS (Loc04)**



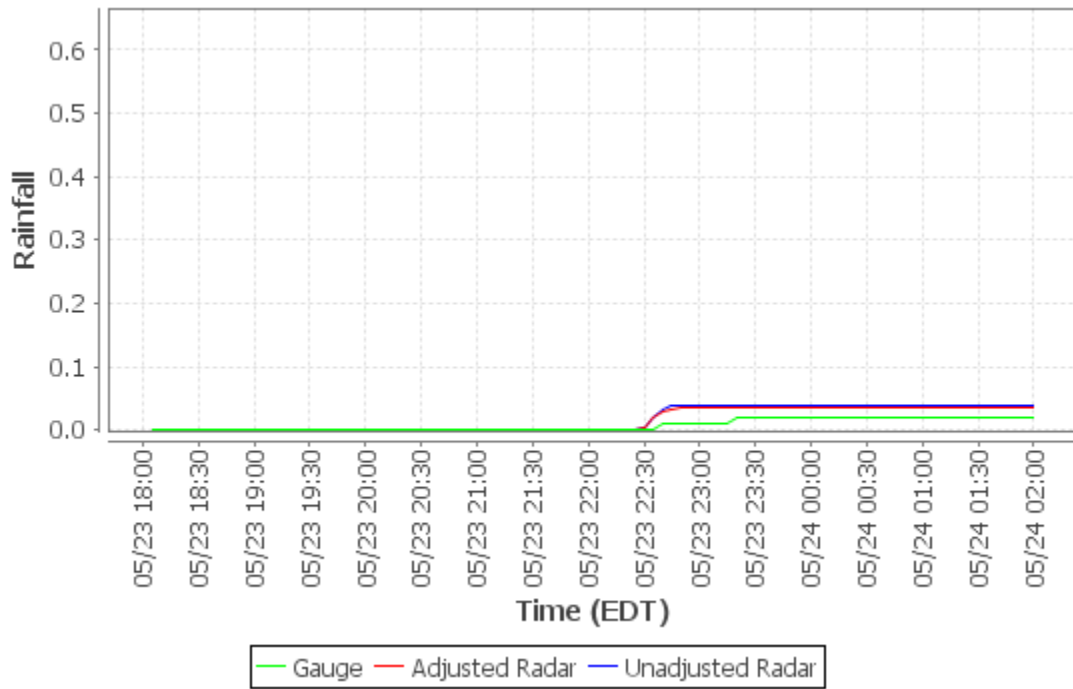
**Cumulative Distribution Plot - Upper St. Clair (Loc05)**



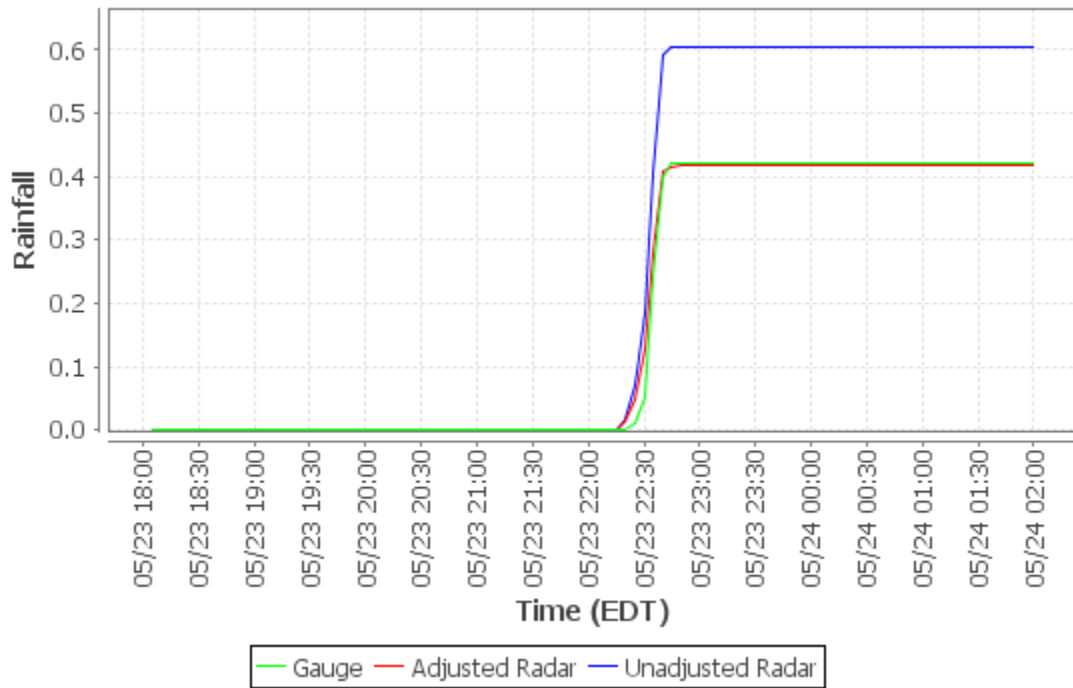
**Cumulative Distribution Plot - Carnegie Transit Time (Loc06)**



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

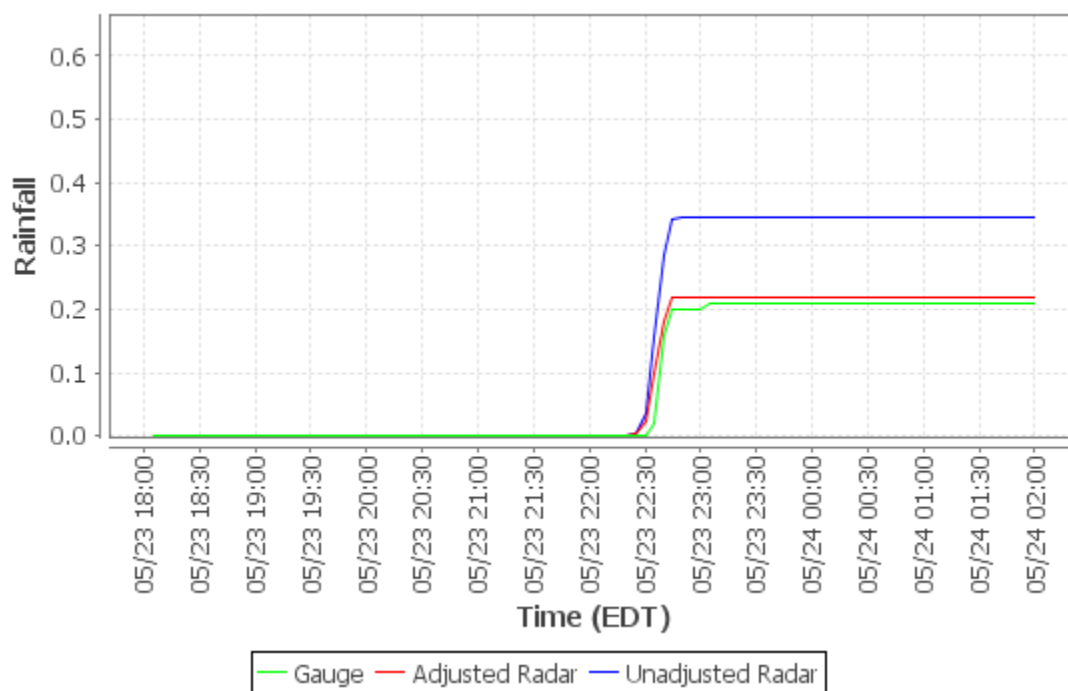


**Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)**

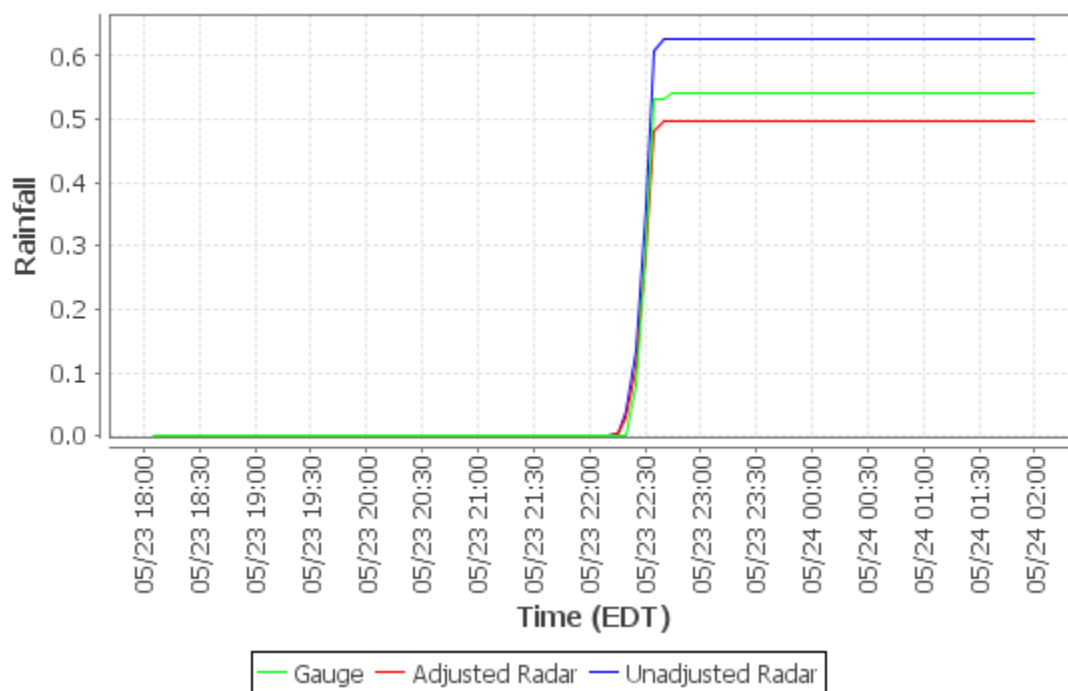




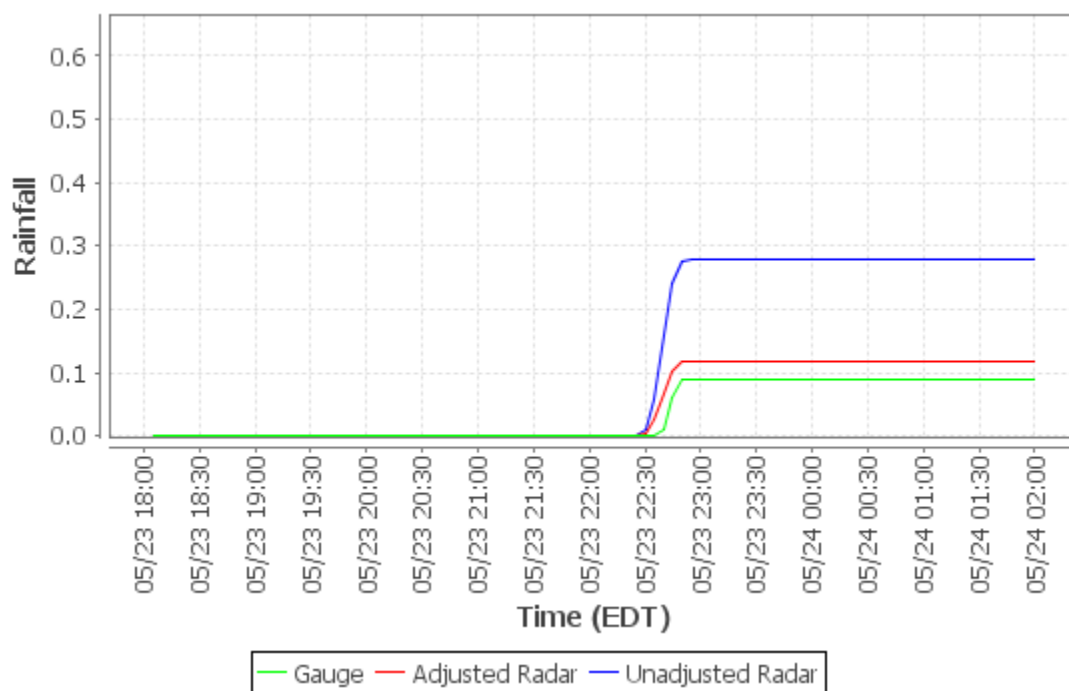
**Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)**



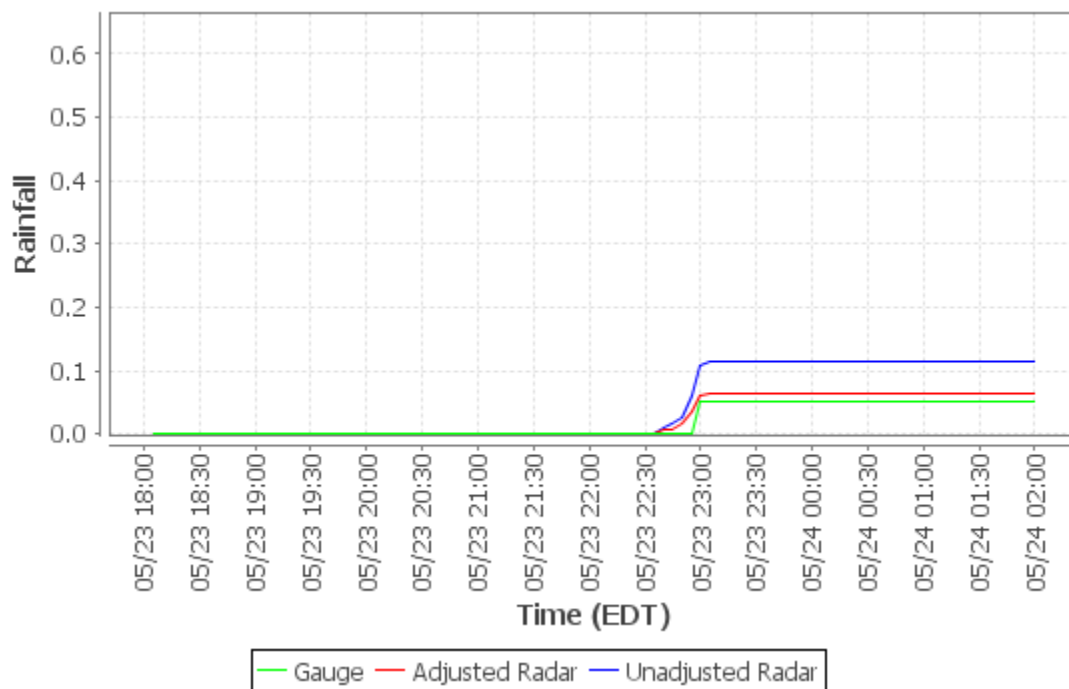
**Cumulative Distribution Plot - PWSA-Highland Park (Loc10)**



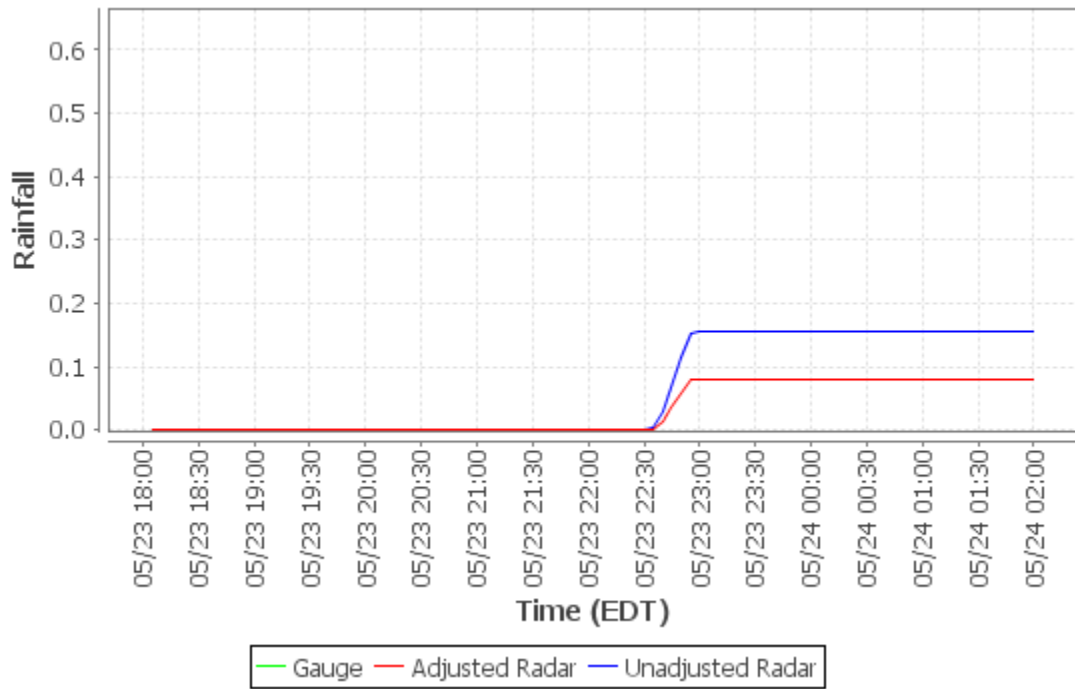
**Cumulative Distribution Plot - M-46 Access Shaft (Loc11)**



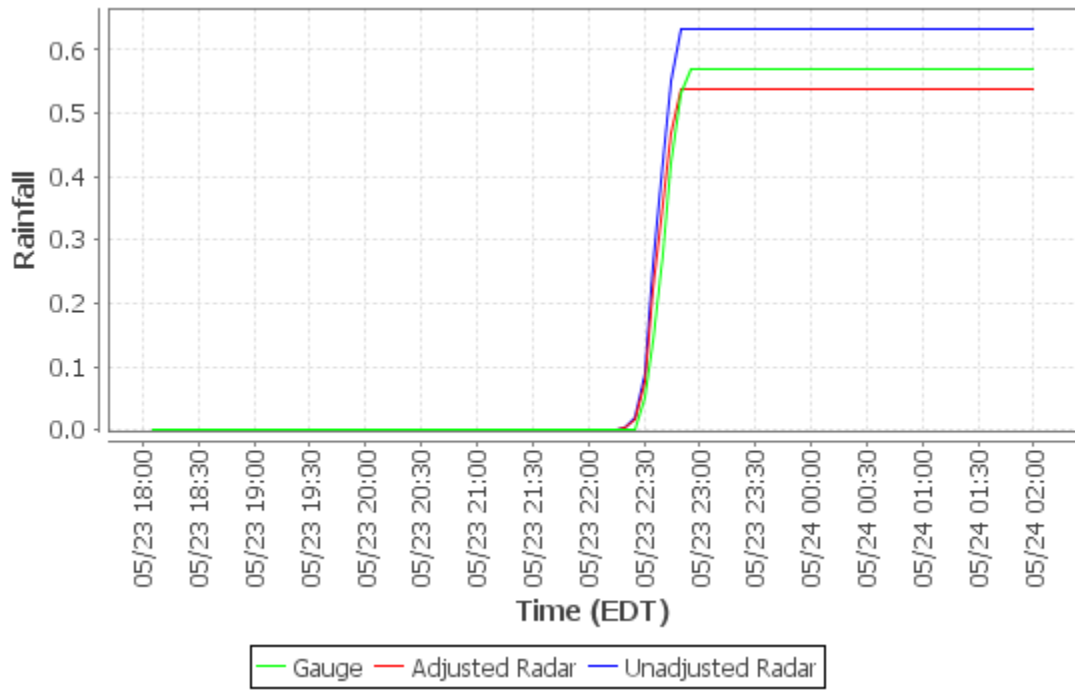
**Cumulative Distribution Plot - Baldwin (Loc12)**



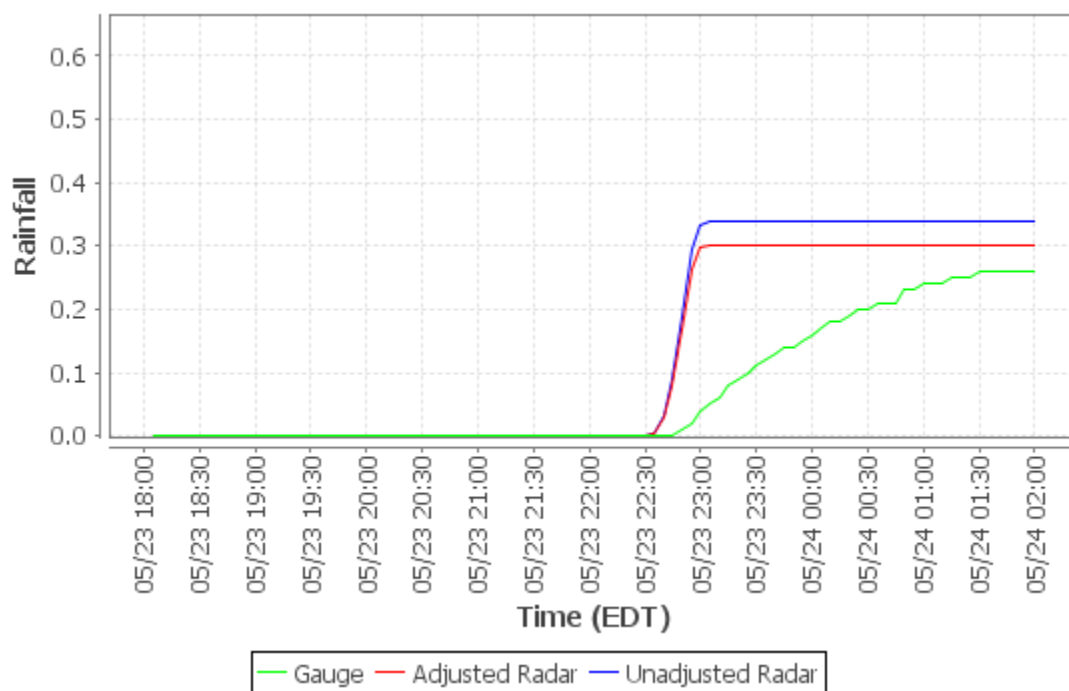
**Cumulative Distribution Plot - M-59 Access Shaft (Loc13)**



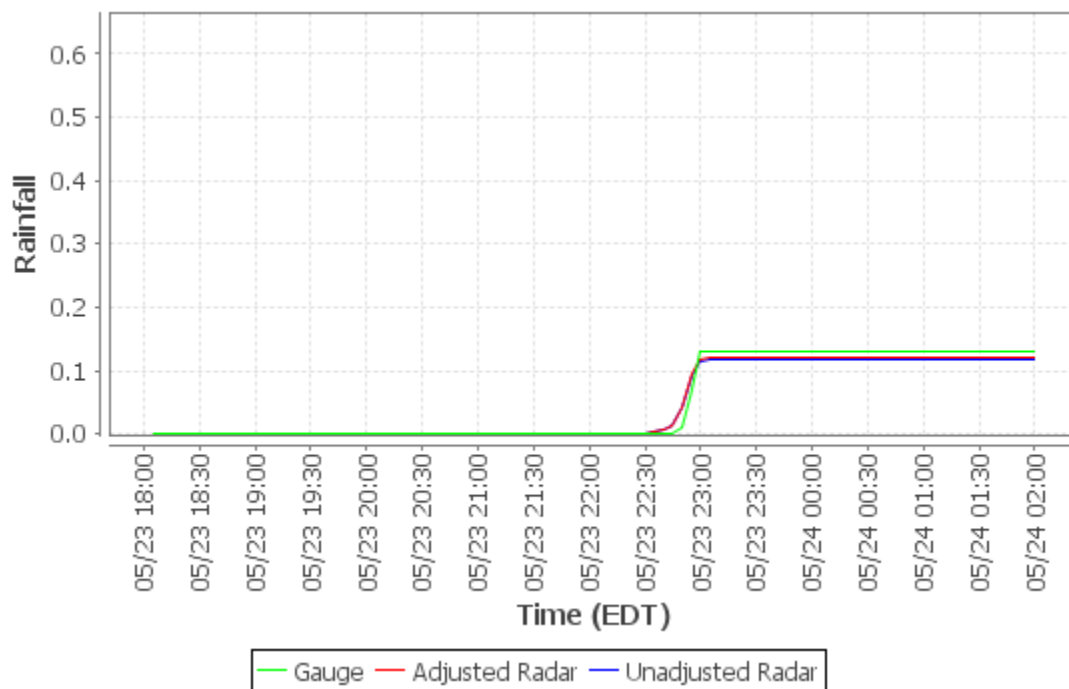
**Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)**



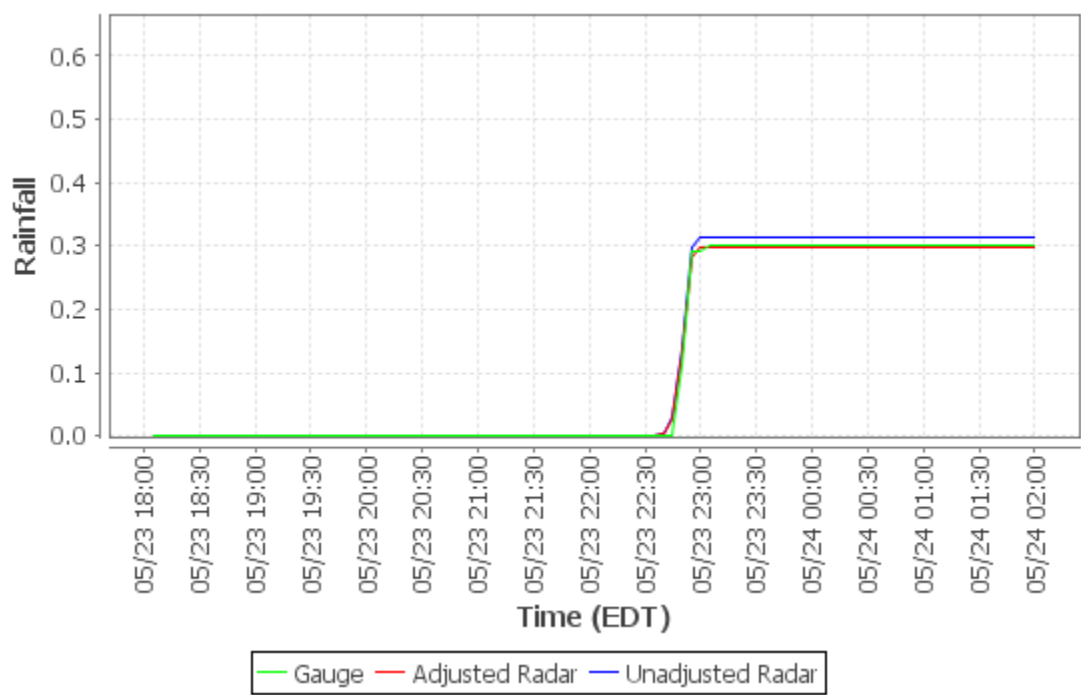
**Cumulative Distribution Plot - Trafford Maint Bldg (Loc15)**



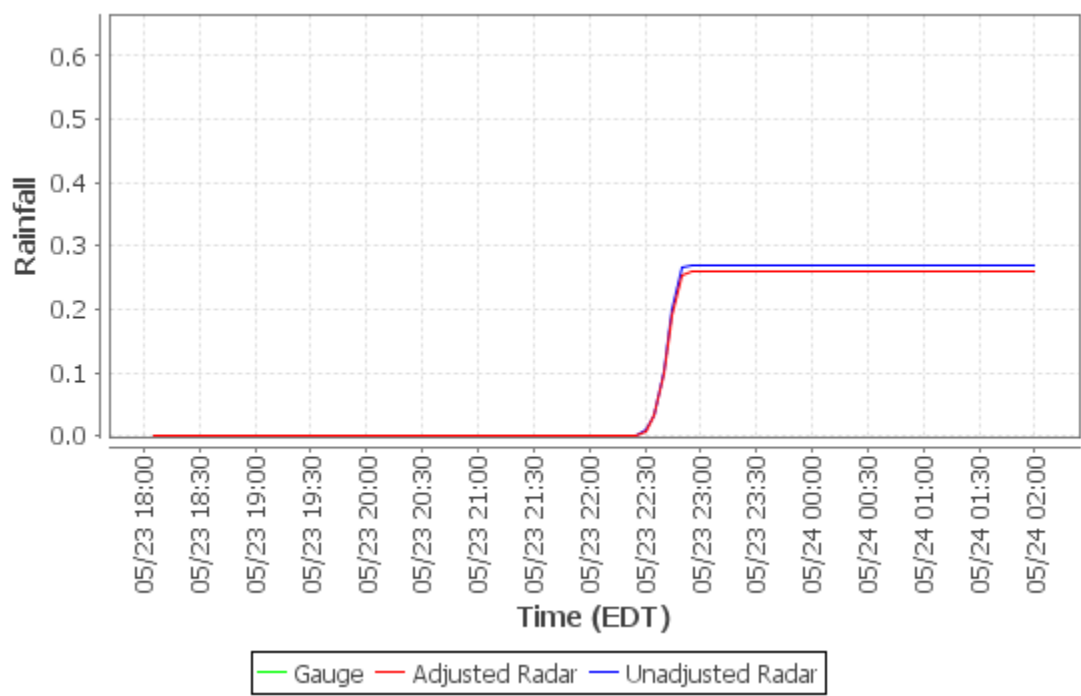
**Cumulative Distribution Plot - Castle Shannon (Loc16)**



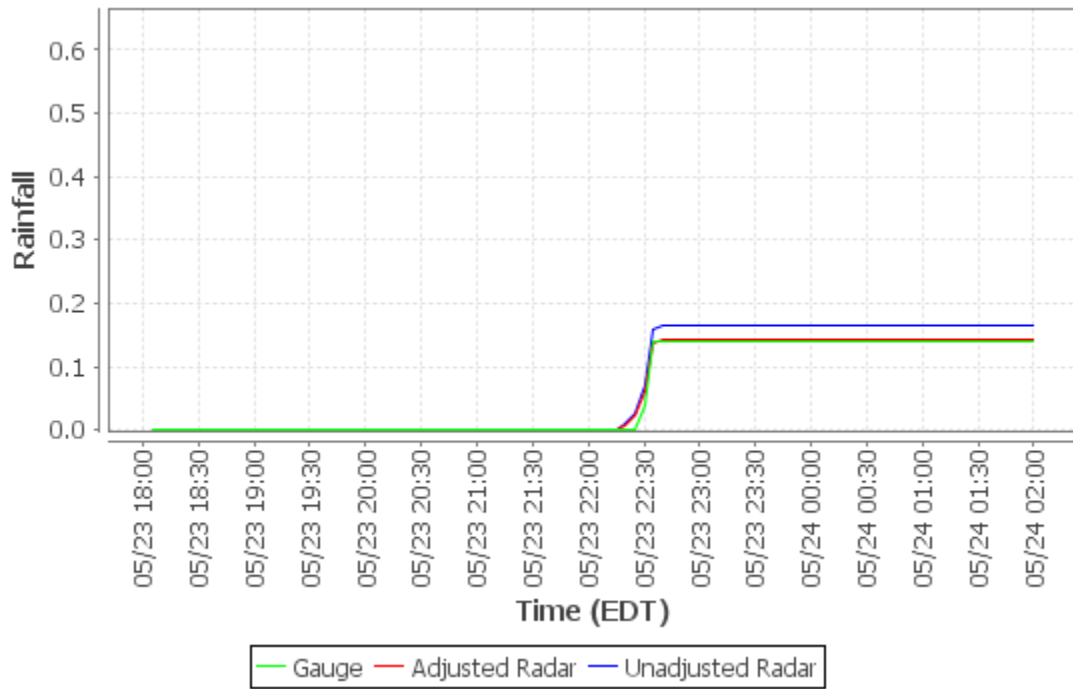
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



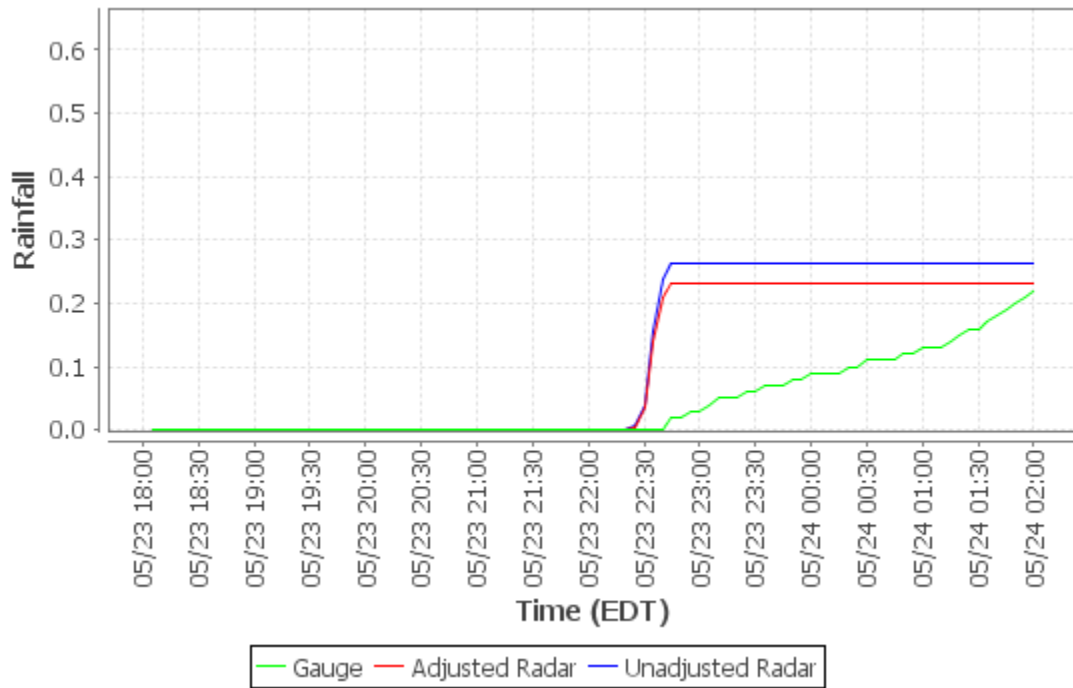
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



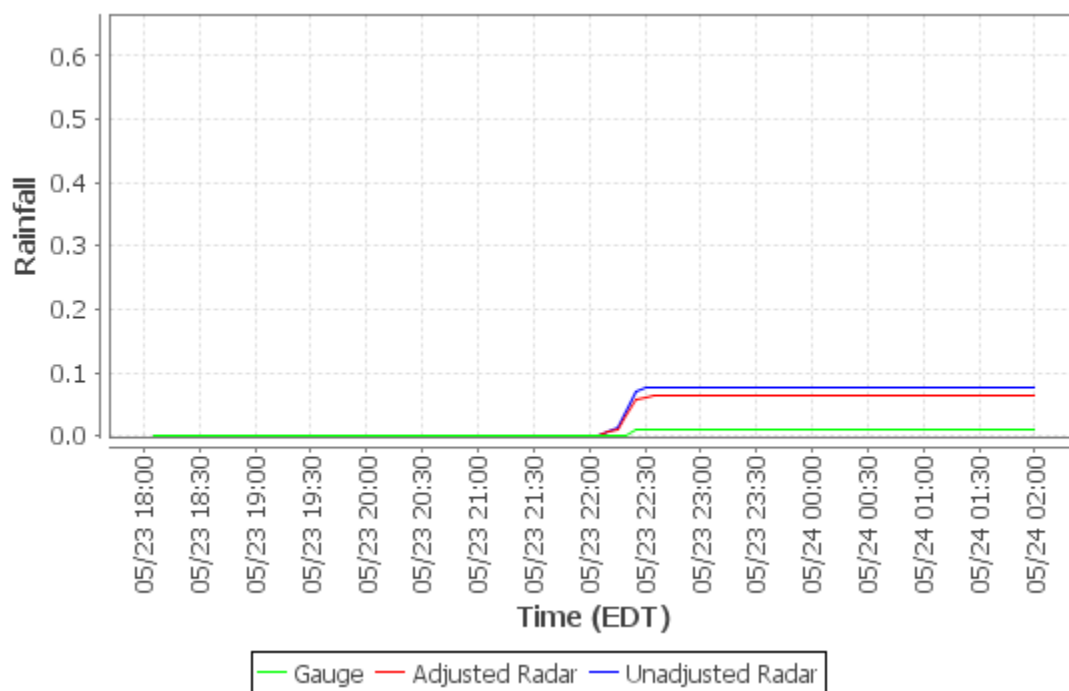
**Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)**



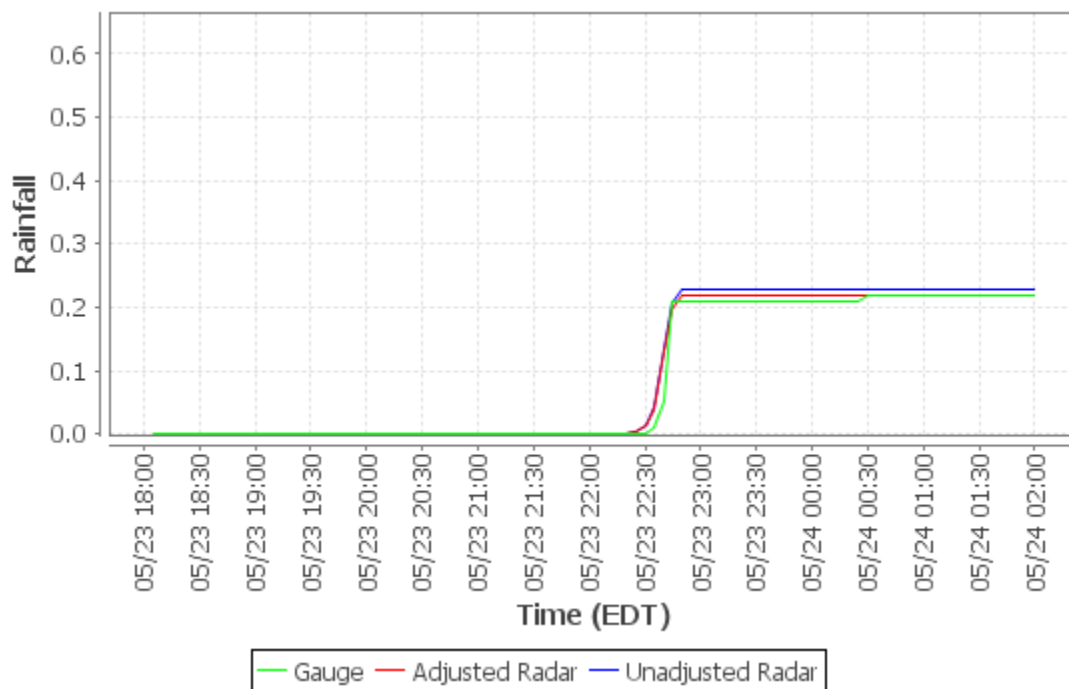
**Cumulative Distribution Plot - Gascola Eq Facility (Loc20)**



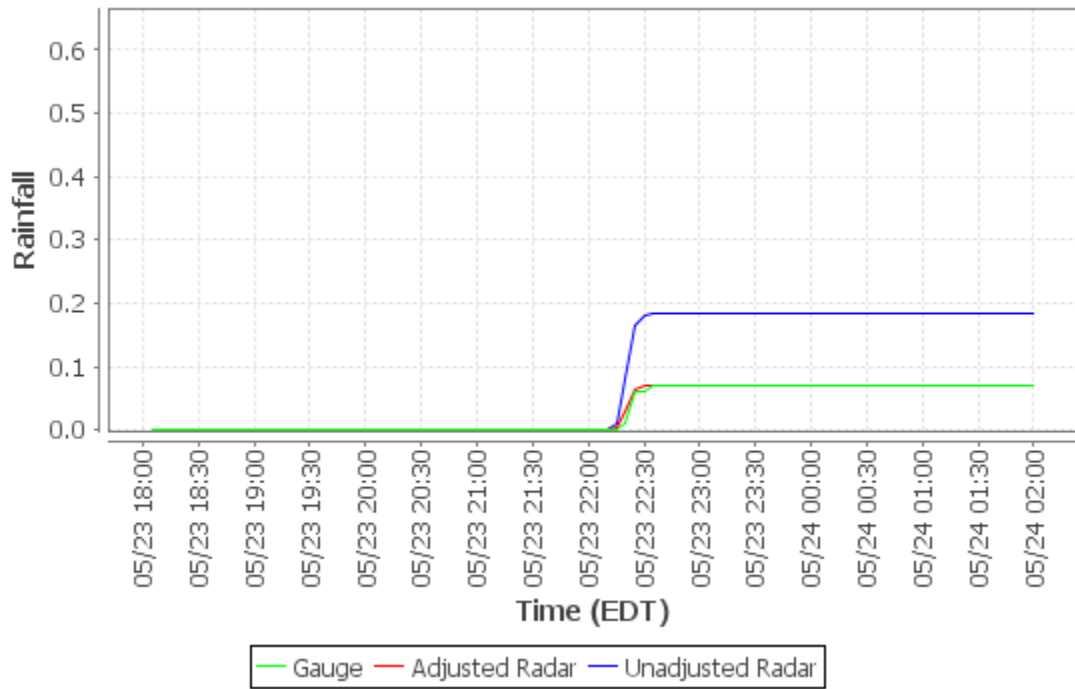
**Cumulative Distribution Plot - Moon TWP (Loc21)**



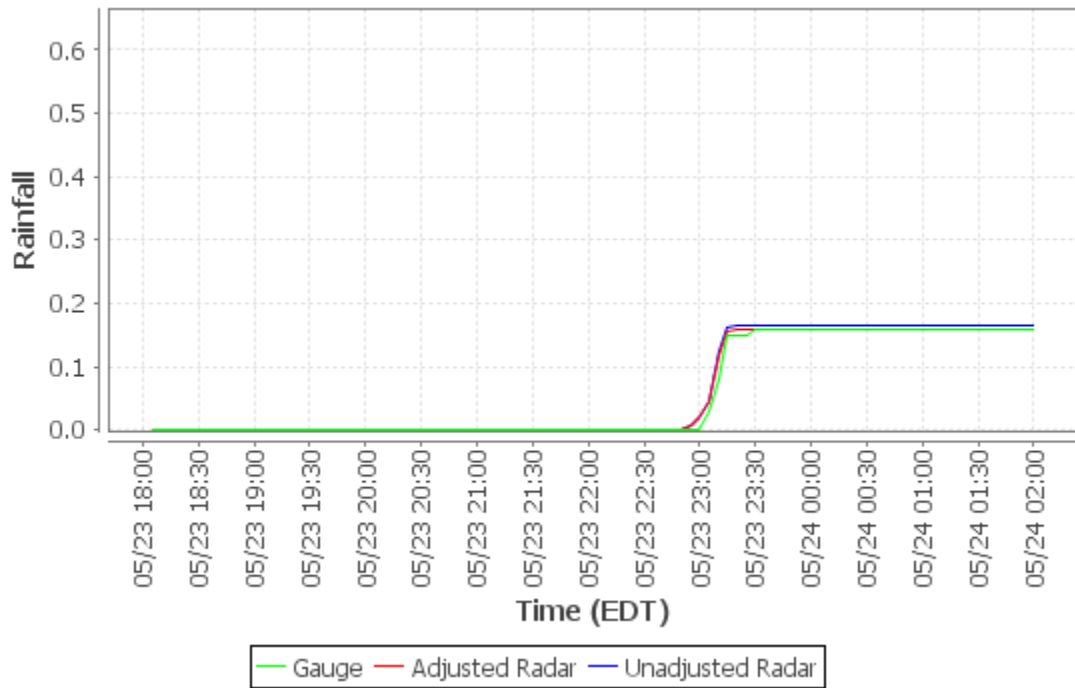
**Cumulative Distribution Plot - North Fayette TWP (Loc22)**



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

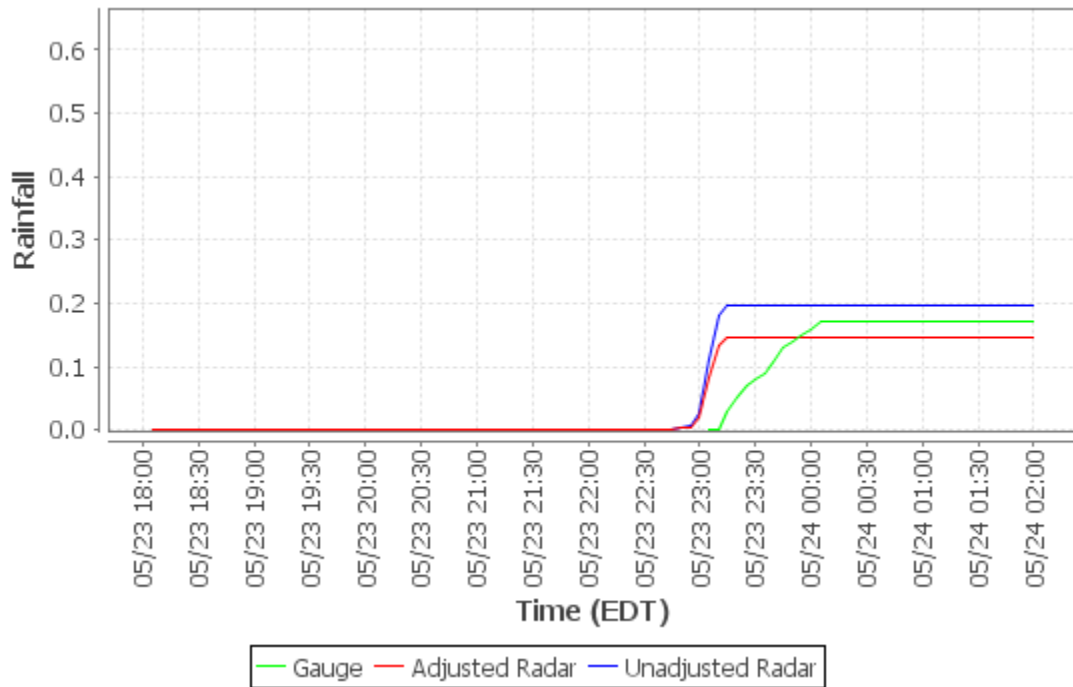


**Cumulative Distribution Plot - Jefferson Hills (Loc24)**

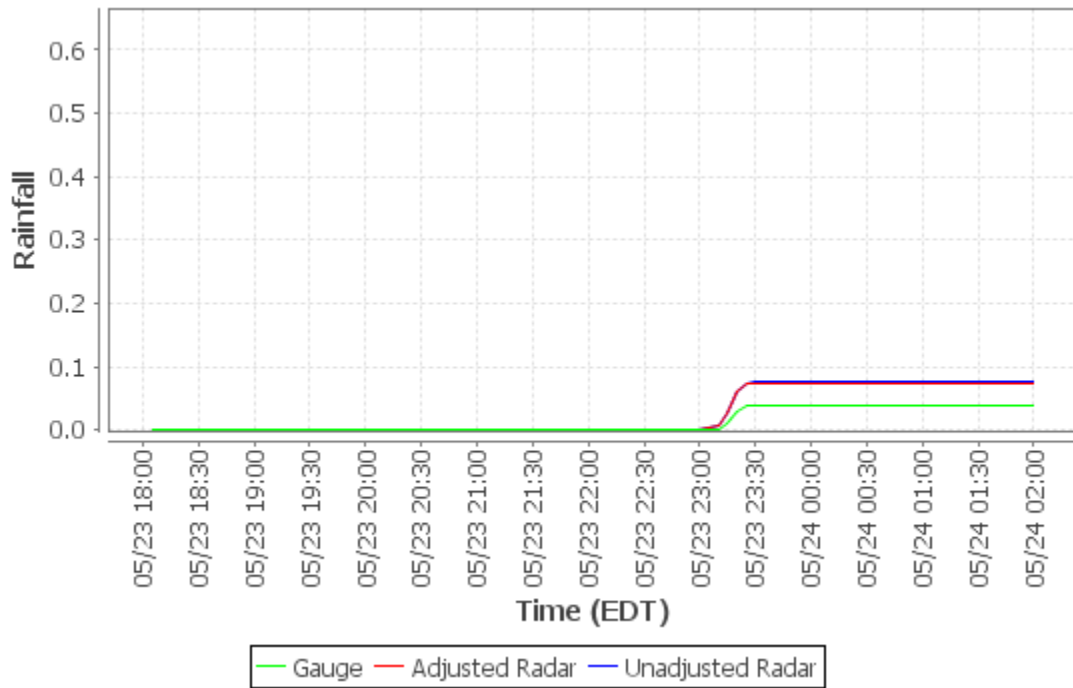




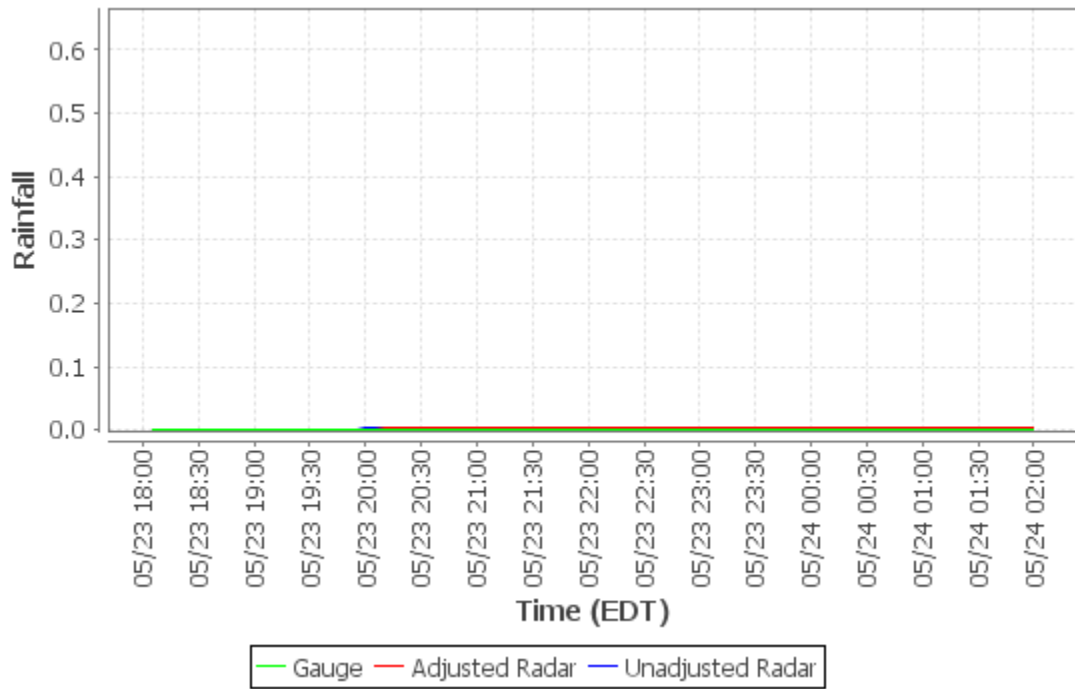
**Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)**



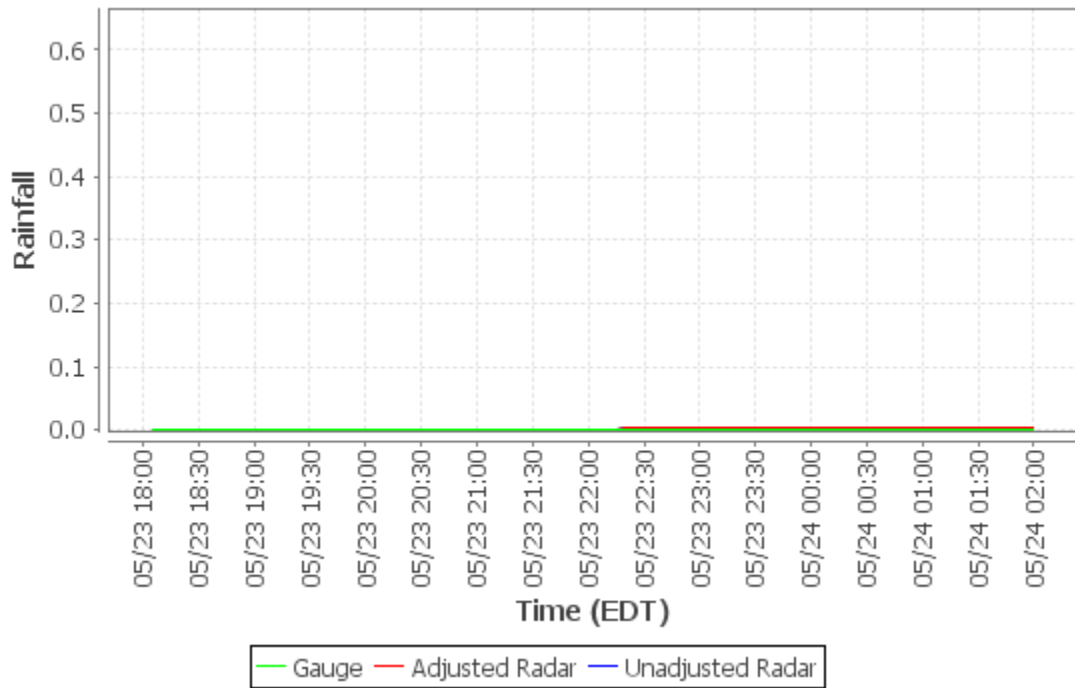
**Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)**



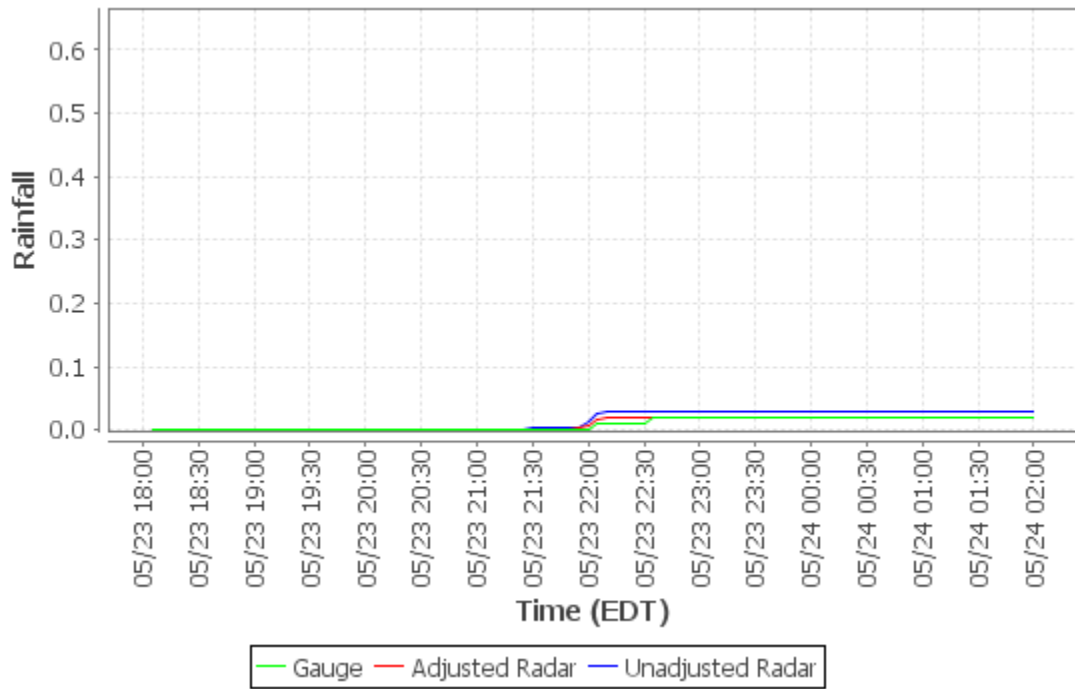
**Cumulative Distribution Plot - Marshall TWP (Loc27)**



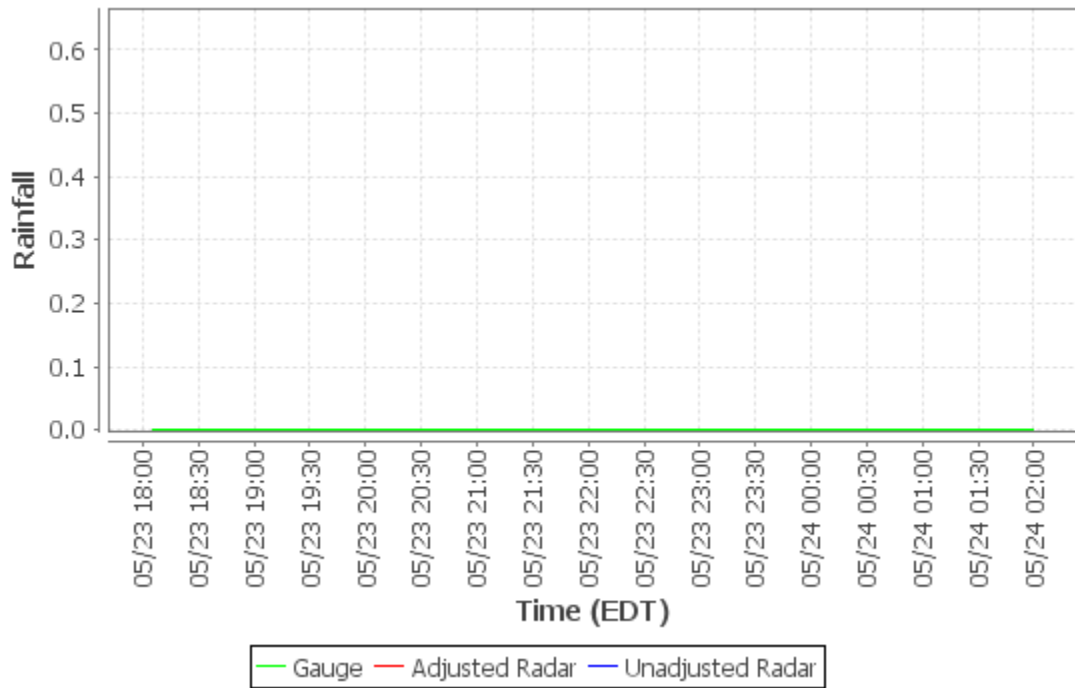
**Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)**



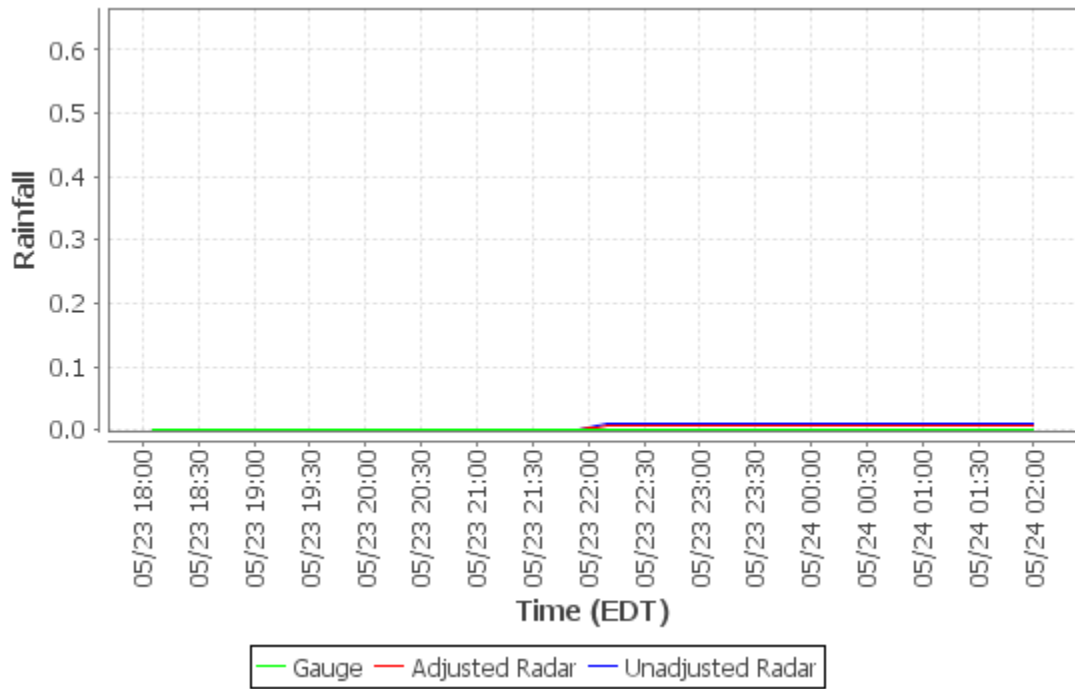
**Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)**



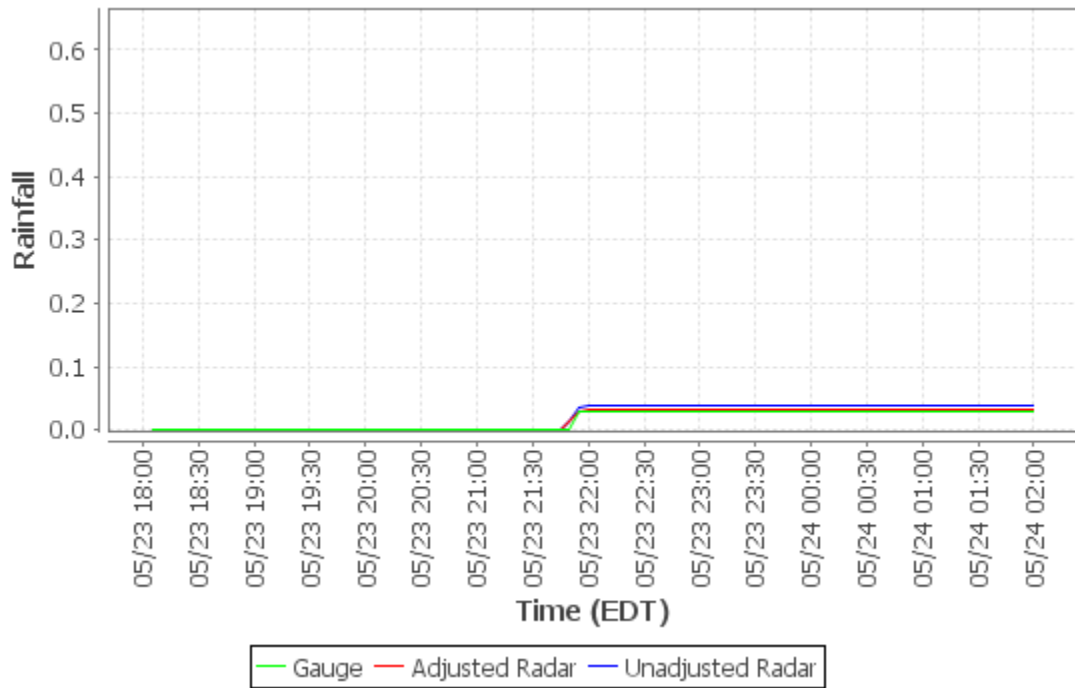
**Cumulative Distribution Plot - McCandless Twn Hall (Loc30)**



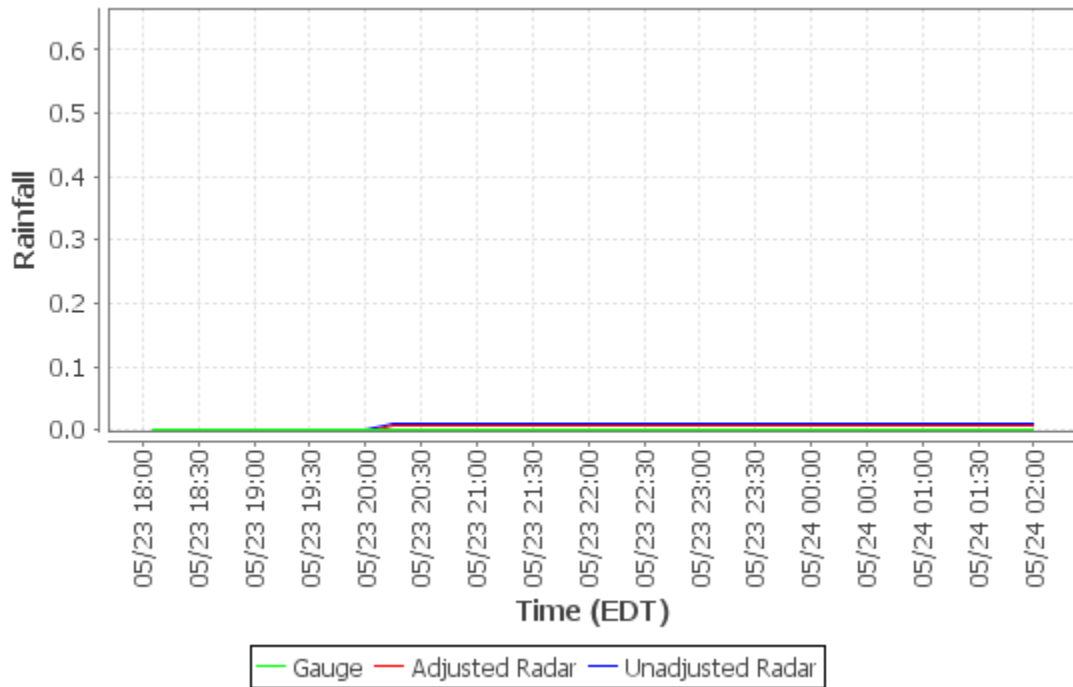
**Cumulative Distribution Plot - Hampton Municipal Bldg (Loc31)**



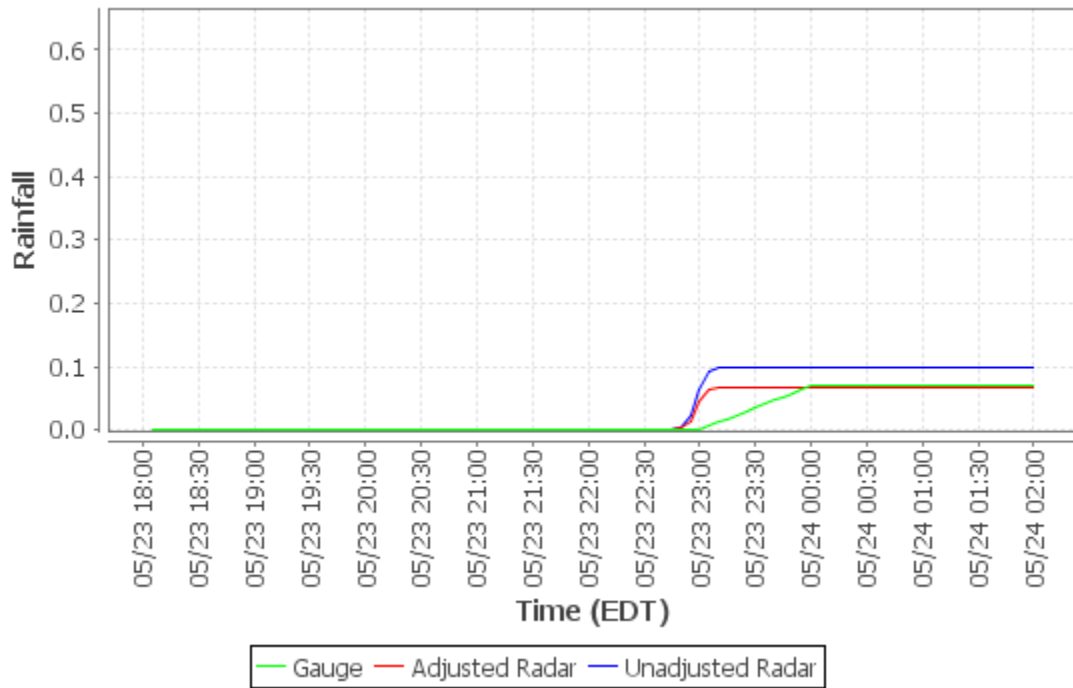
**Cumulative Distribution Plot - Arnold (Loc32)**



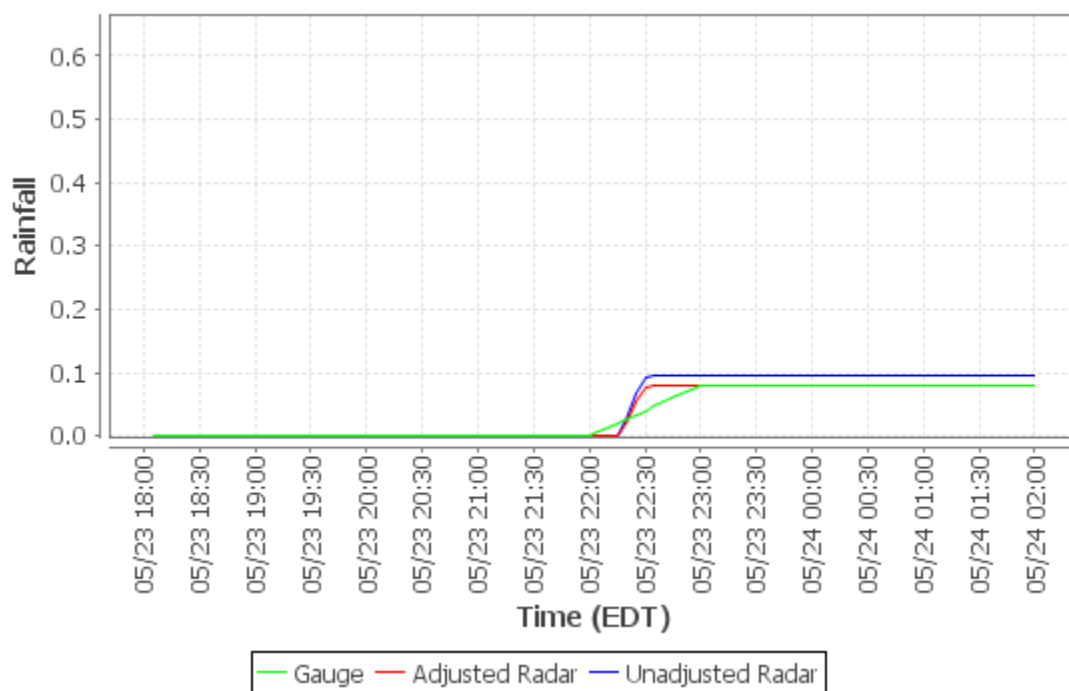
**Cumulative Distribution Plot - Richland TWP (Loc33)**



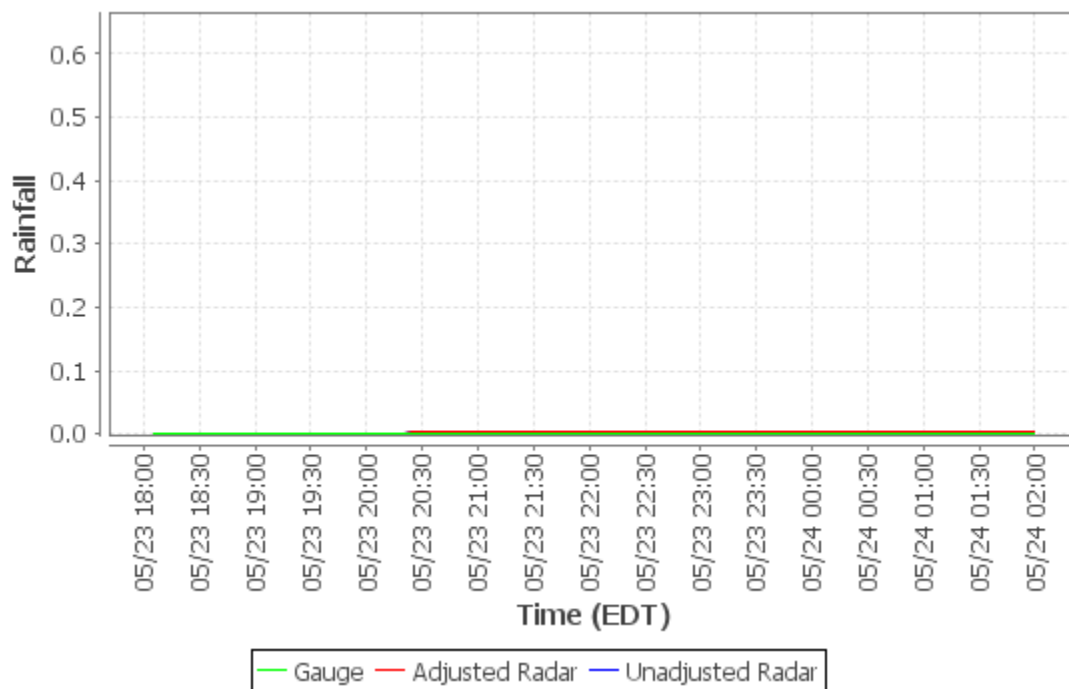
**Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)**



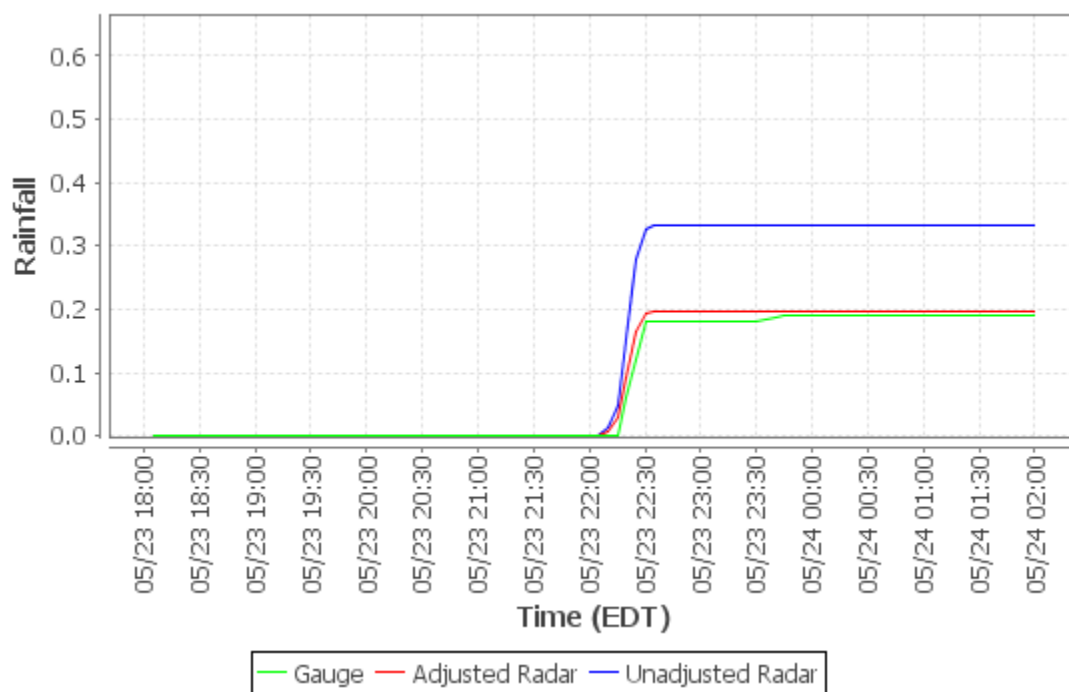
**Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)**



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



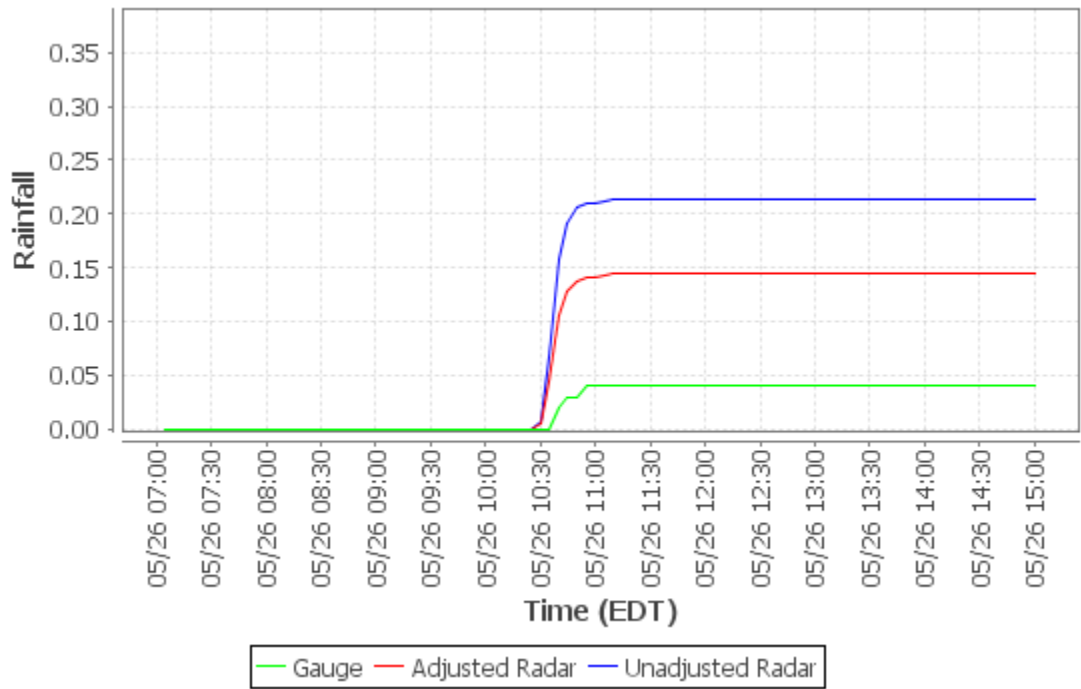
**Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth  
(03085734)**



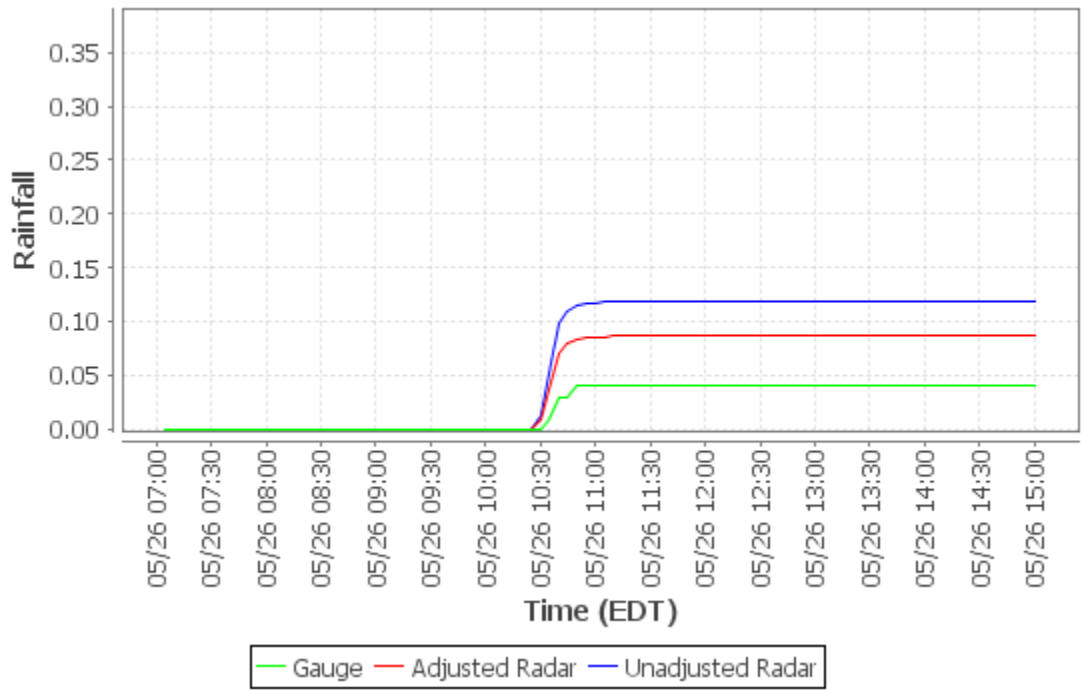
## **Appendix I - Event 7 (2019-05-26) CDPs**



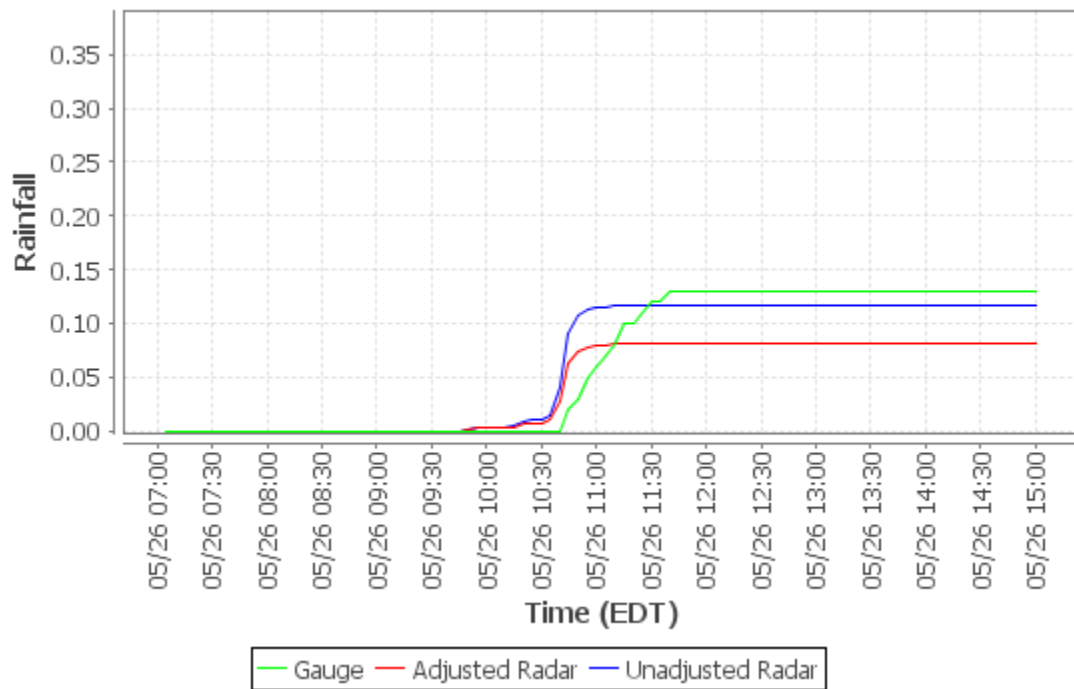
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



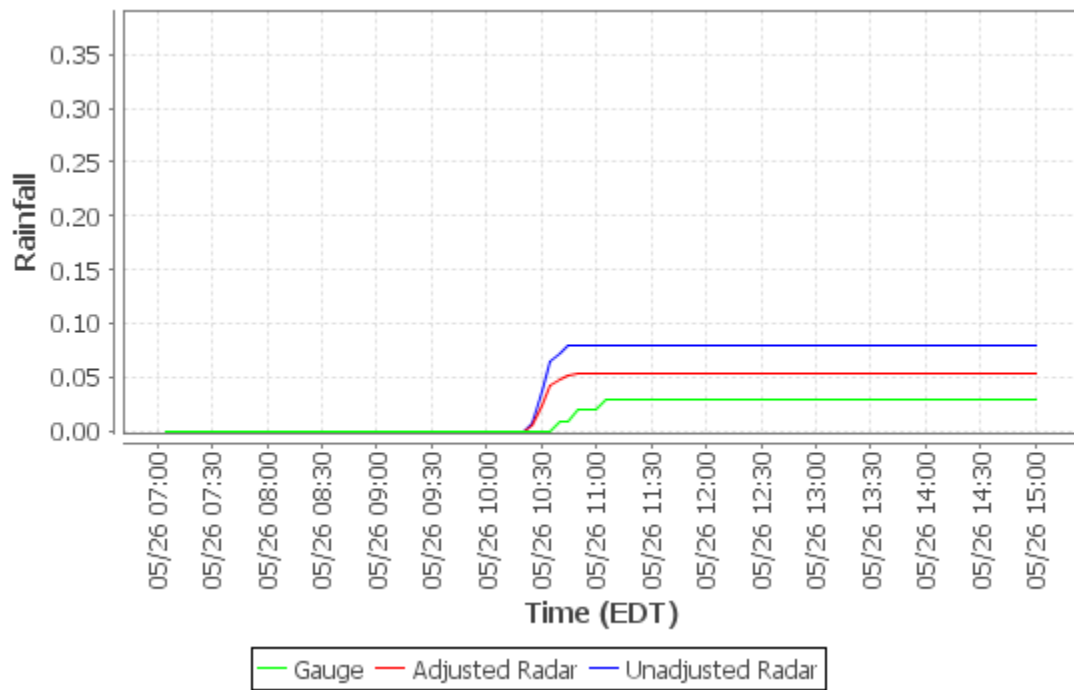
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



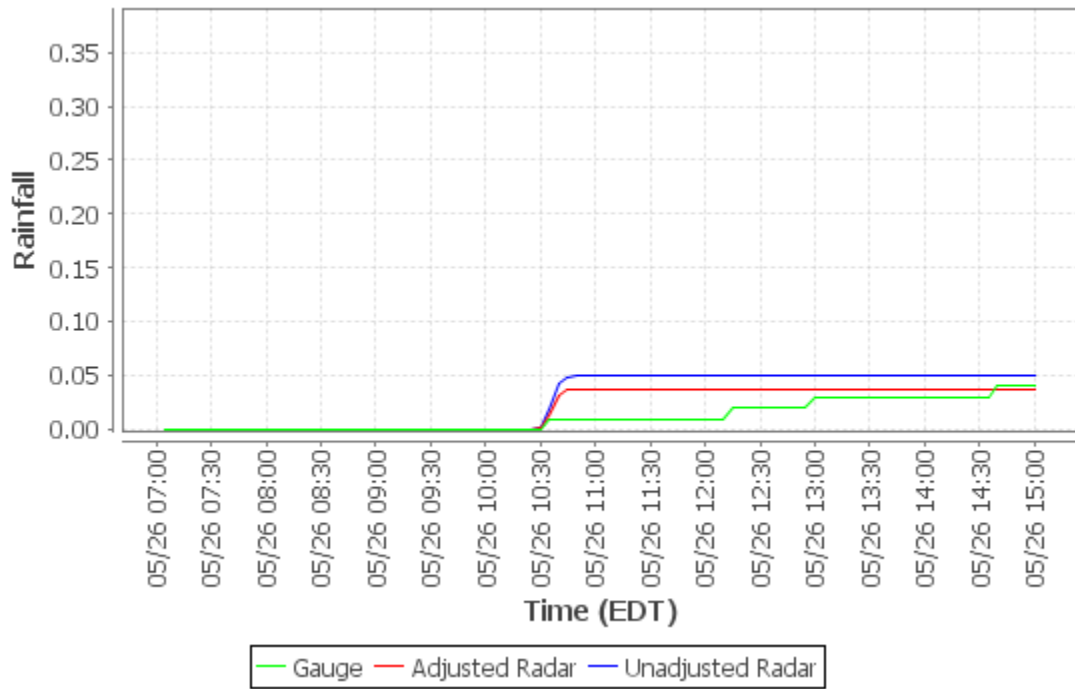
**Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)**



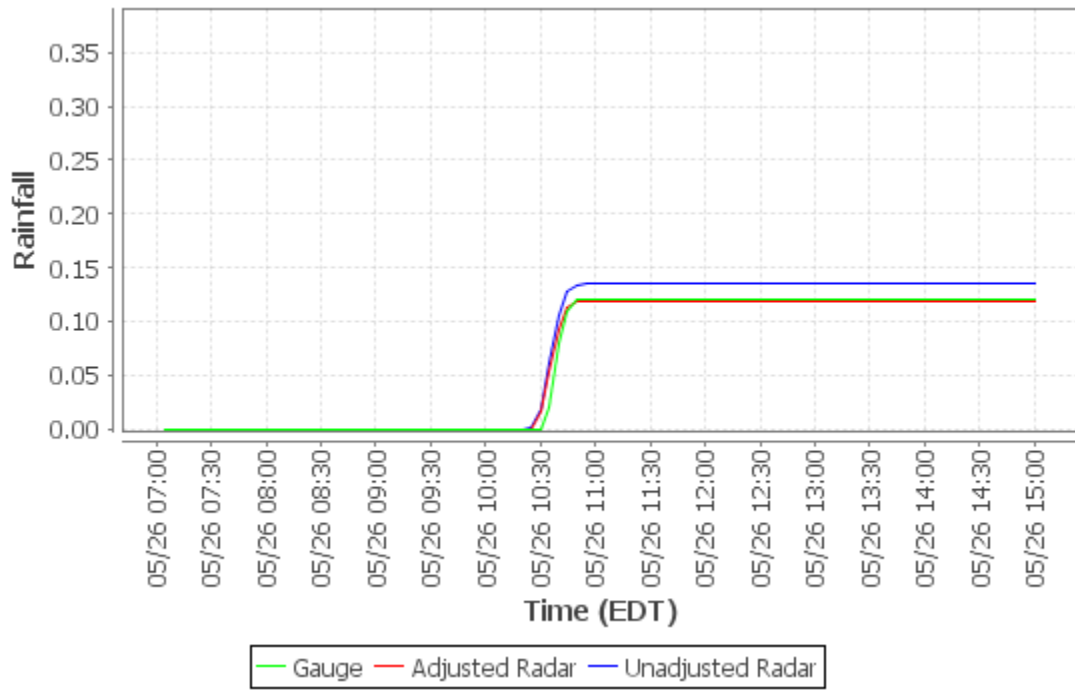
**Cumulative Distribution Plot - Kennedy Twp PS (Loc04)**



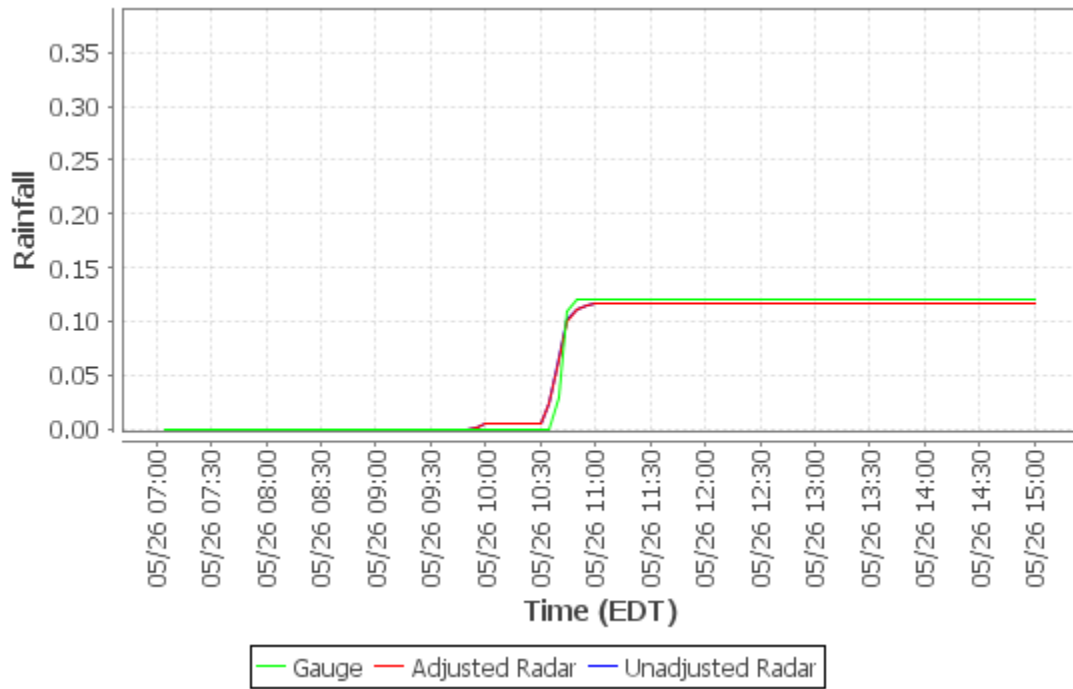
**Cumulative Distribution Plot - Upper St. Clair (Loc05)**



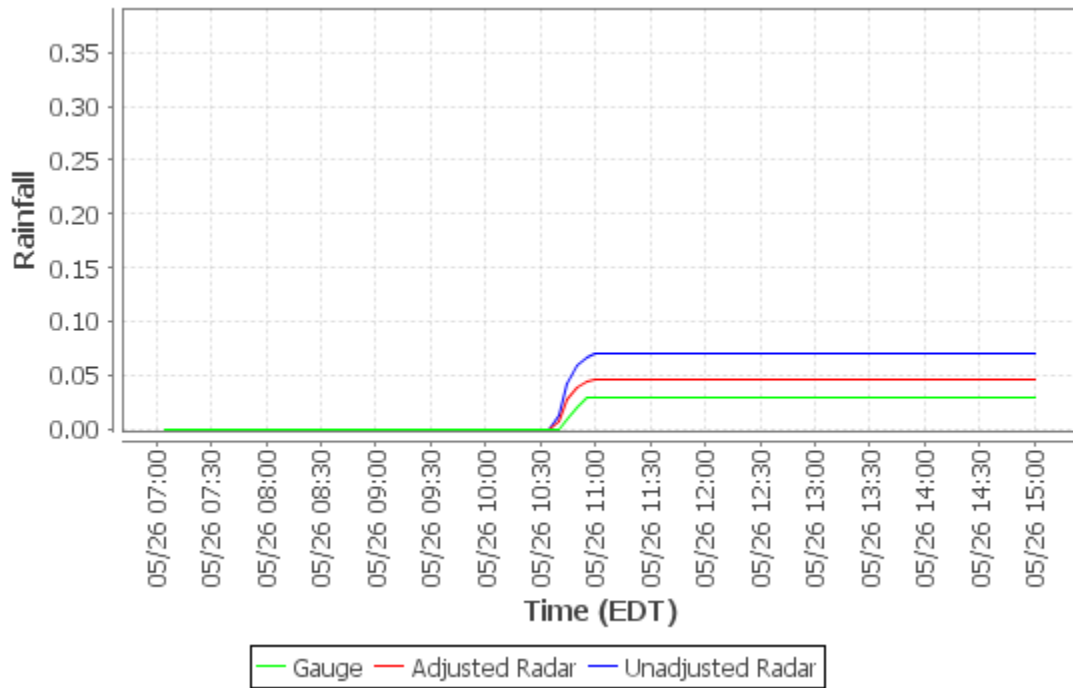
**Cumulative Distribution Plot - Carnegie Transit Time (Loc06)**



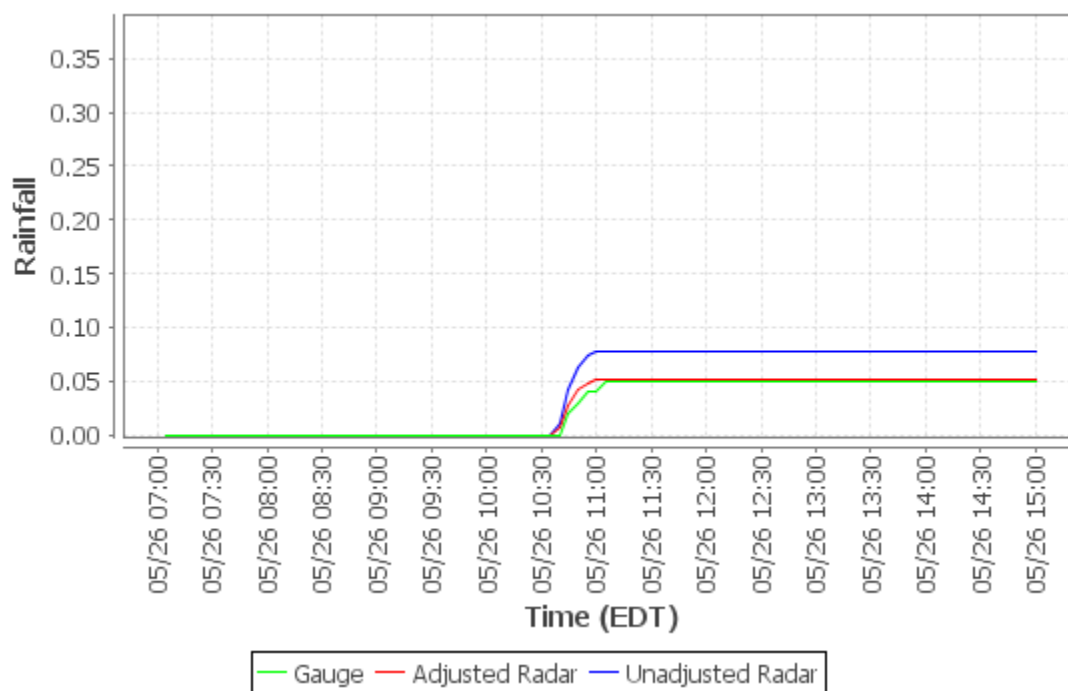
**Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)**



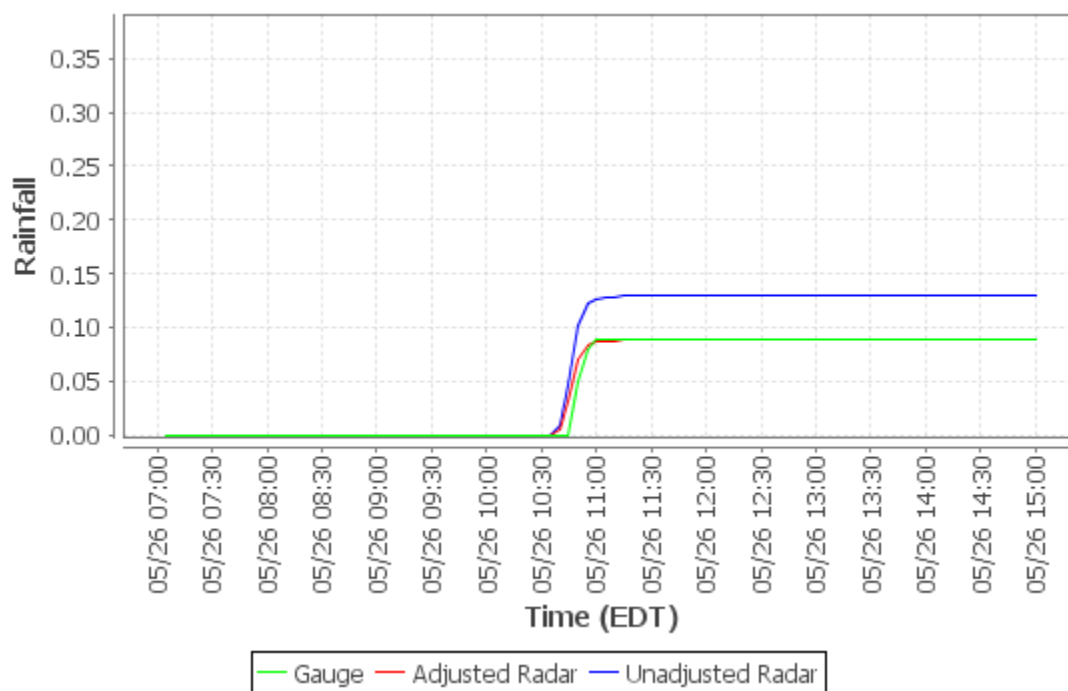
**Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)**



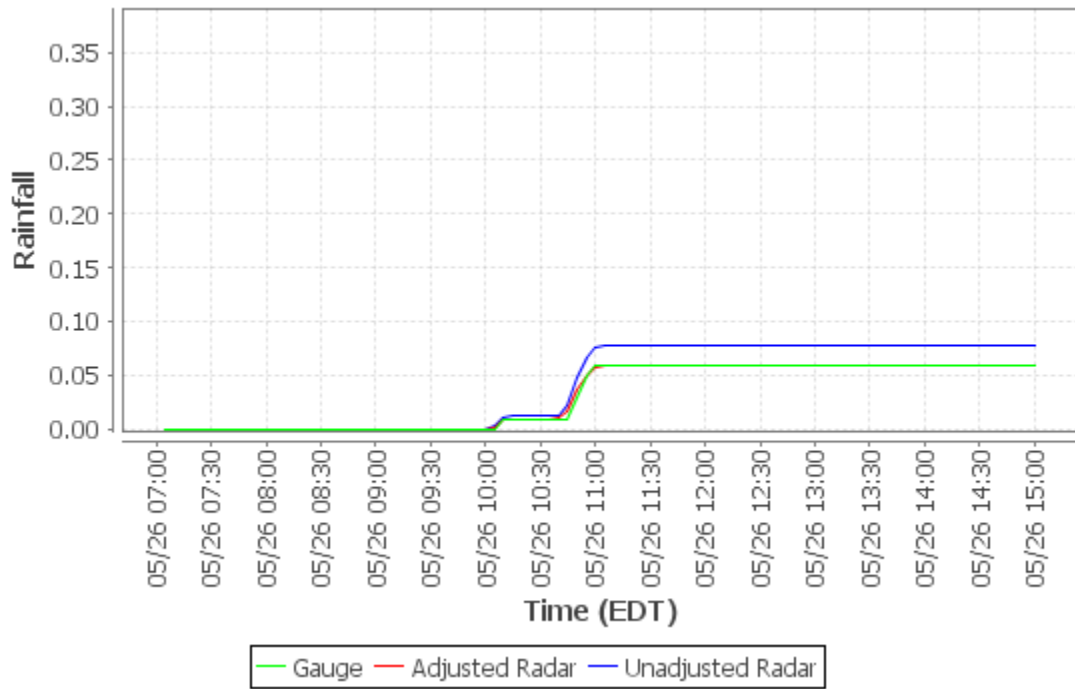
**Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)**



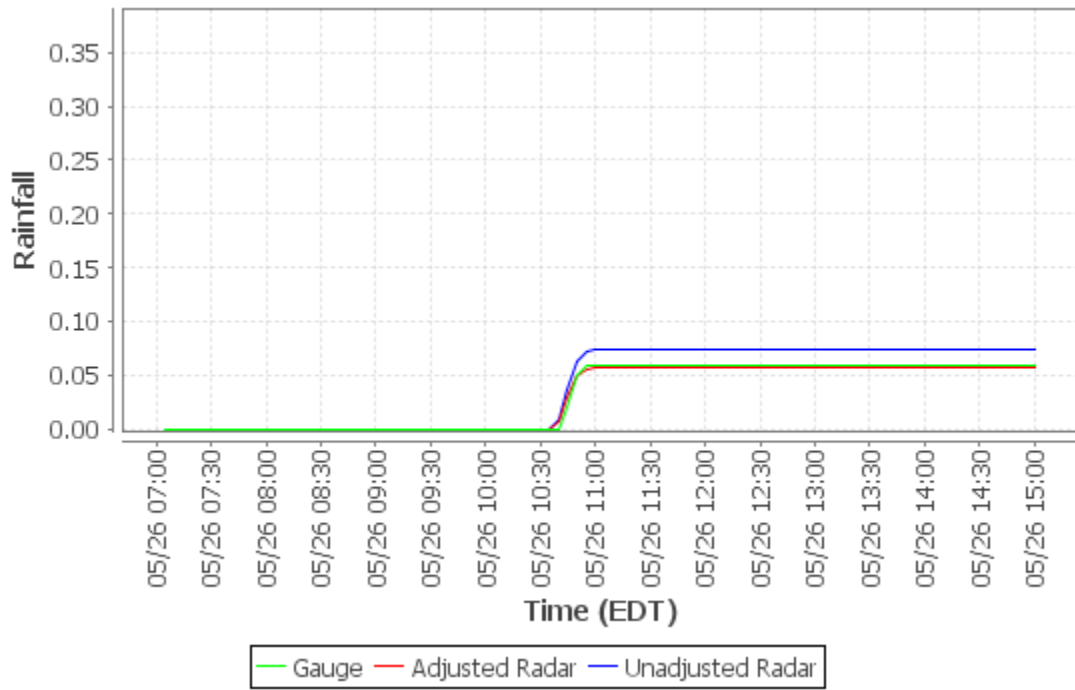
**Cumulative Distribution Plot - PWSA-Highland Park (Loc10)**



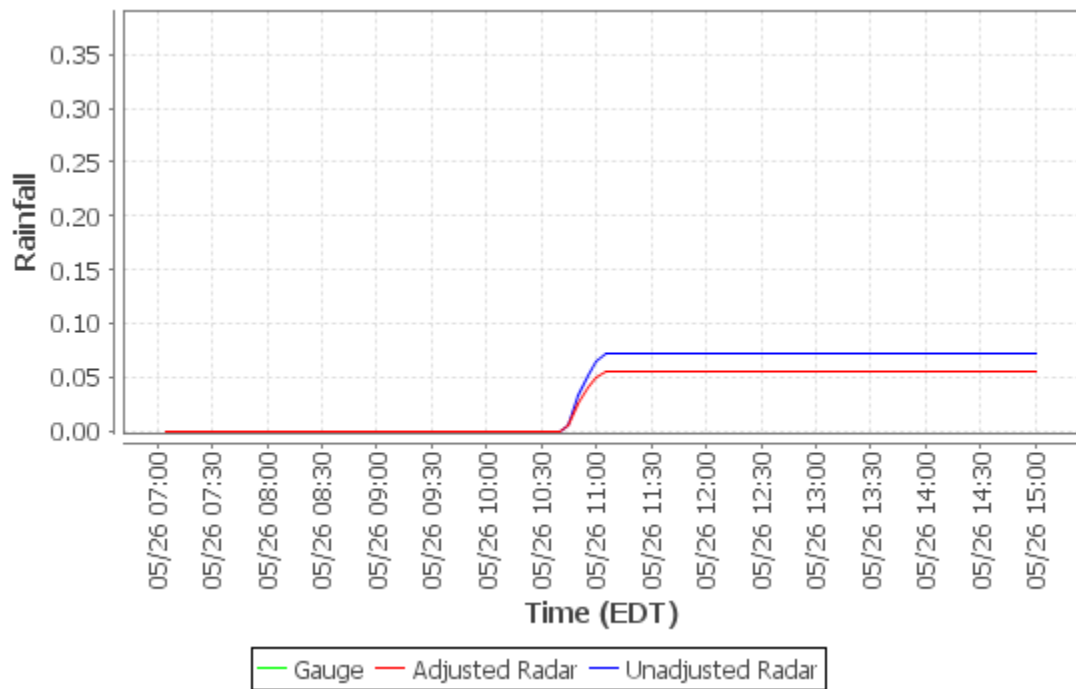
**Cumulative Distribution Plot - M-46 Access Shaft (Loc11)**



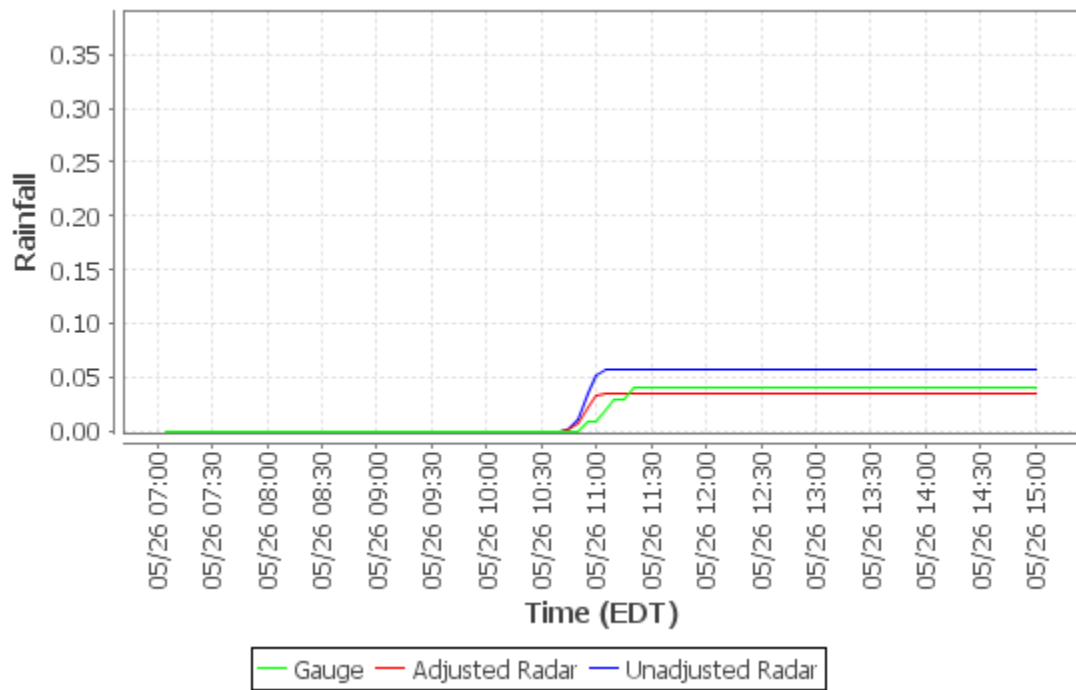
**Cumulative Distribution Plot - Baldwin (Loc12)**



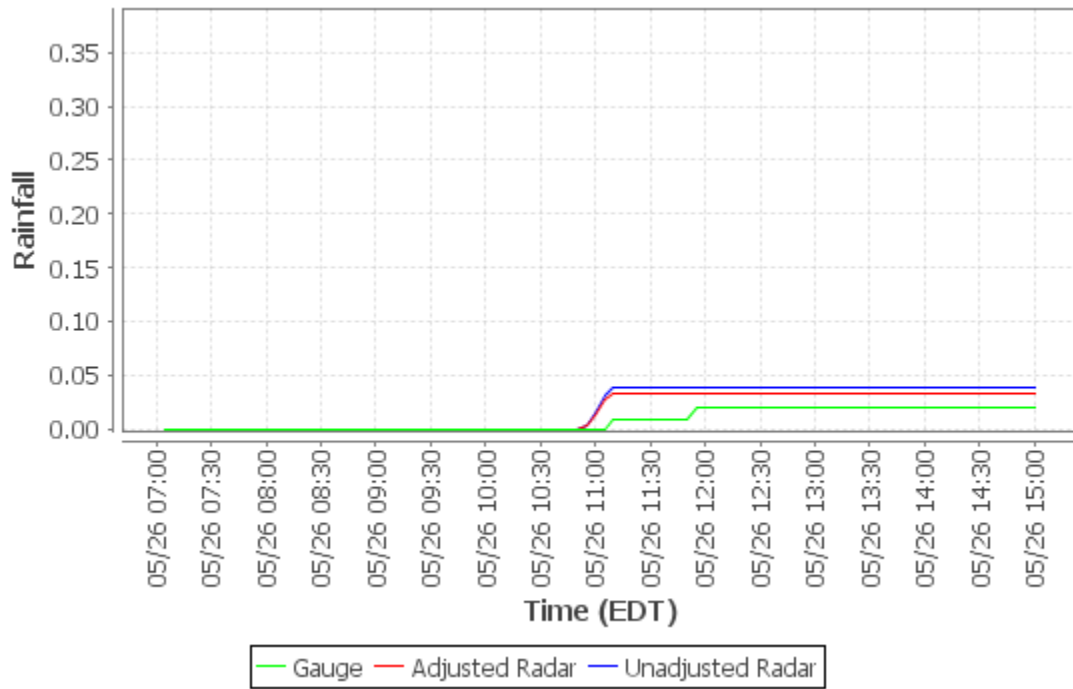
Cumulative Distribution Plot - M-59 Access Shaft (Loc13)



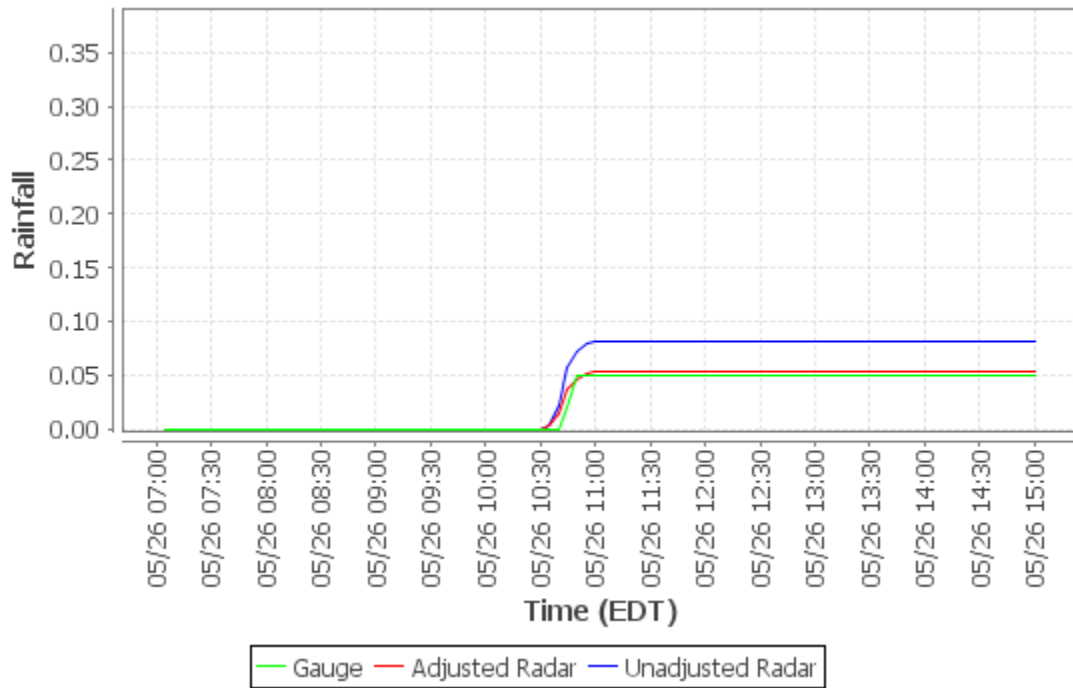
Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)



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

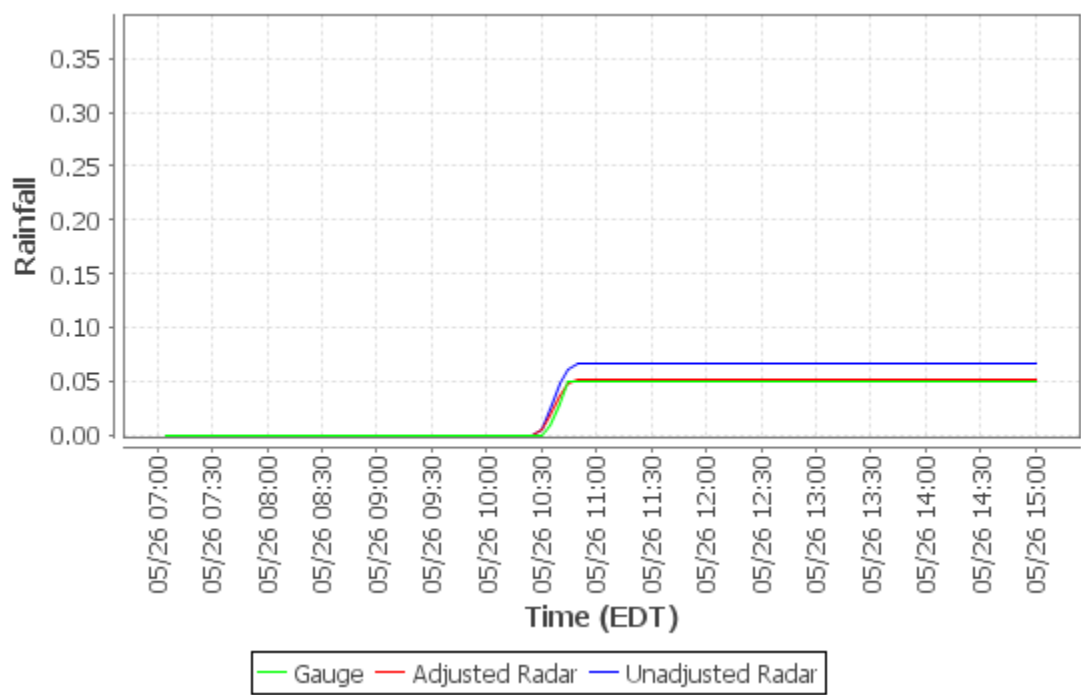


**Cumulative Distribution Plot - Castle Shannon (Loc16)**

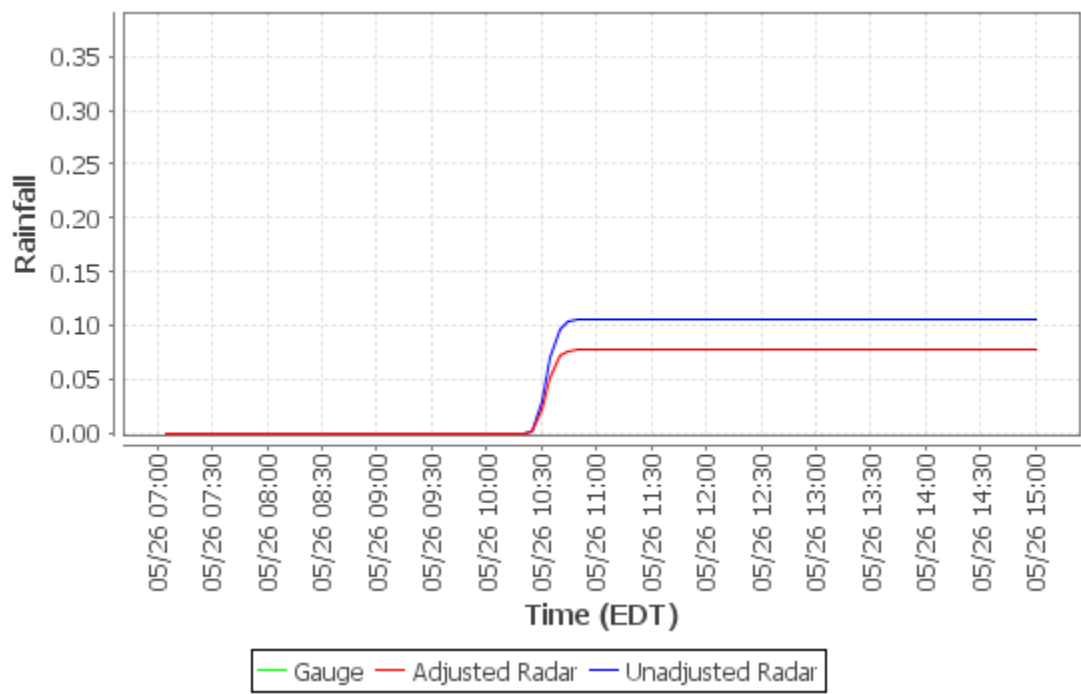




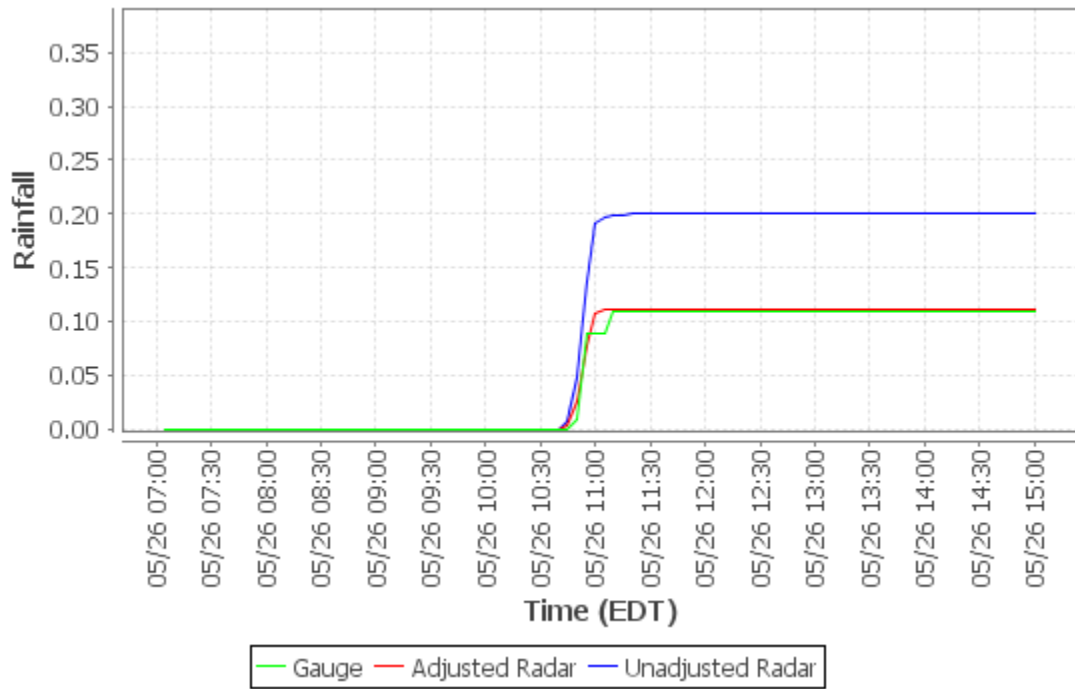
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



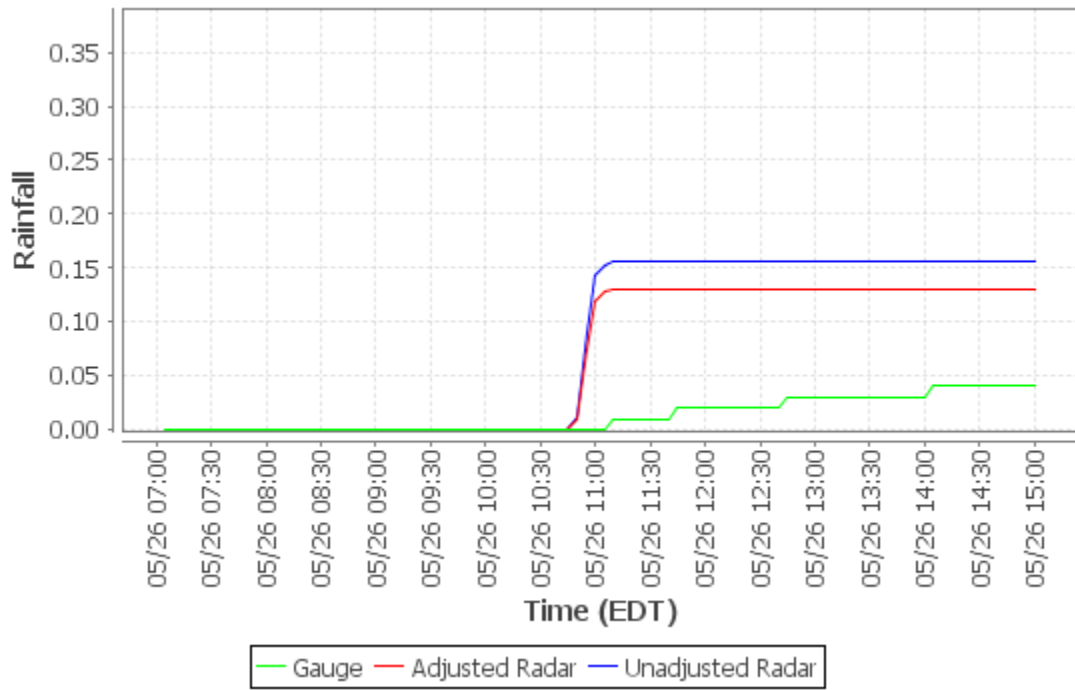
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



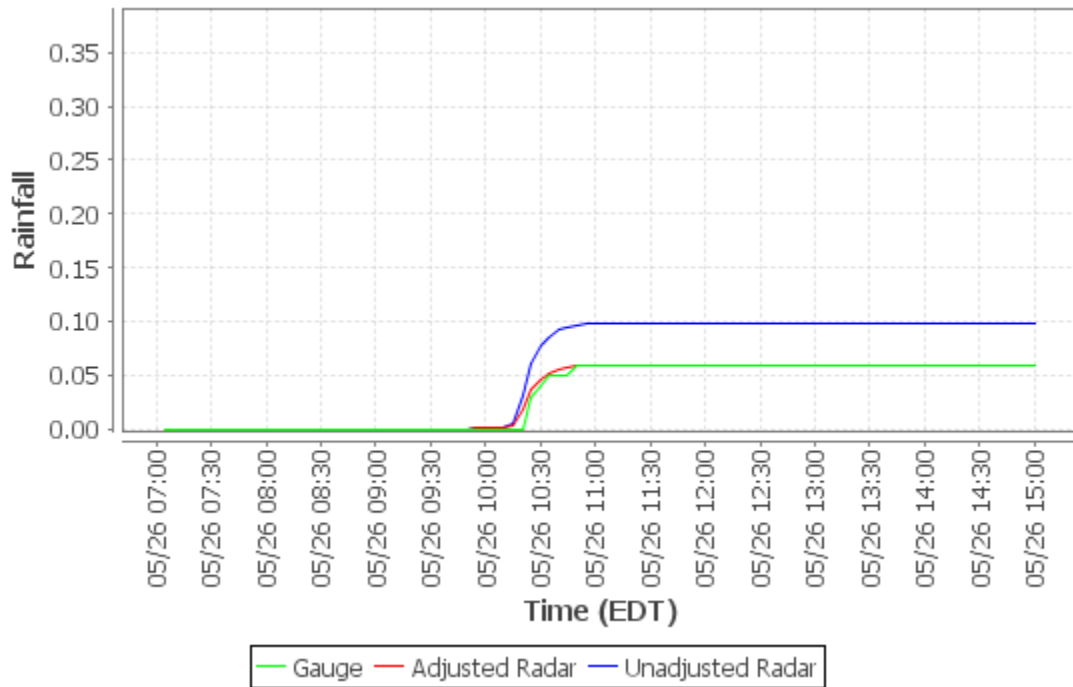
**Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)**



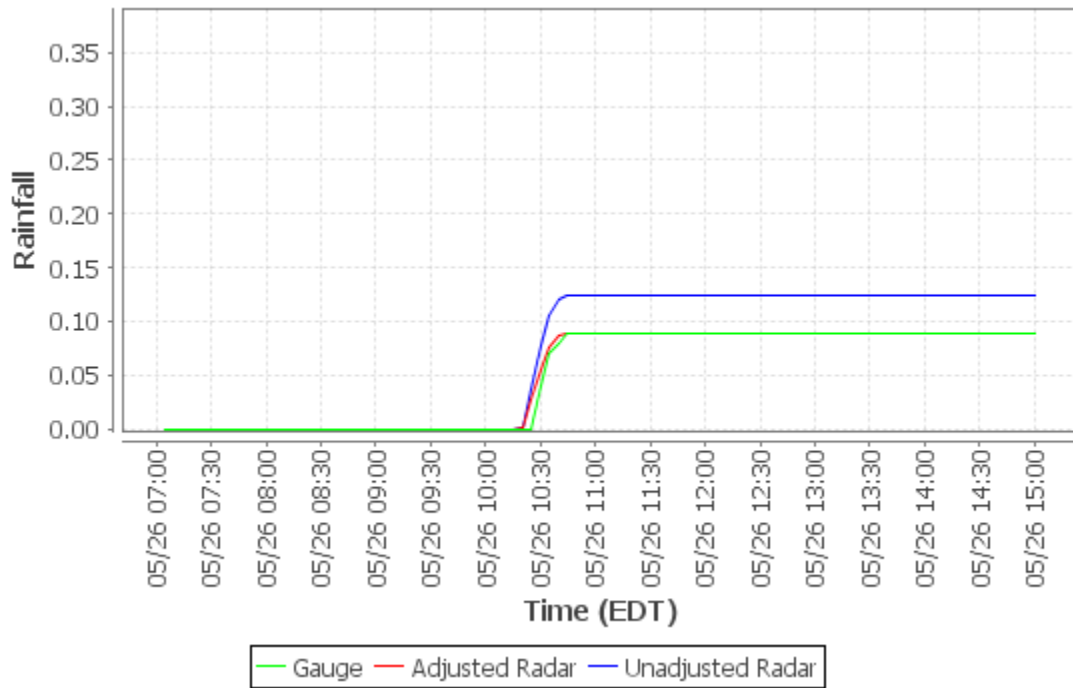
**Cumulative Distribution Plot - Gascola Eq Facility (Loc20)**



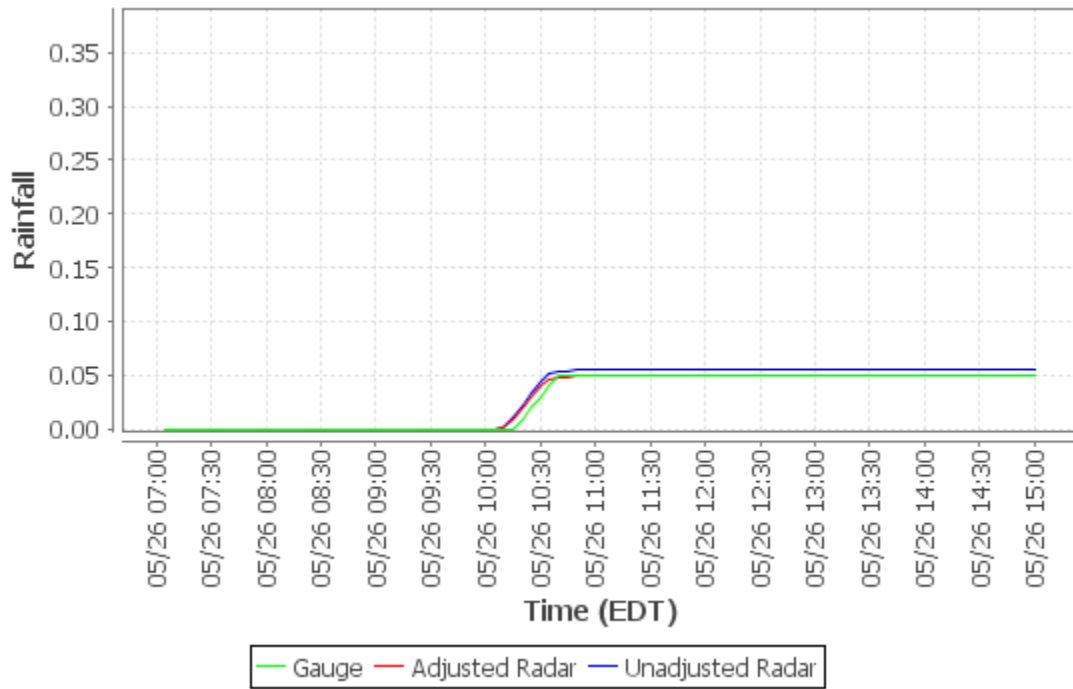
**Cumulative Distribution Plot - Moon TWP (Loc21)**



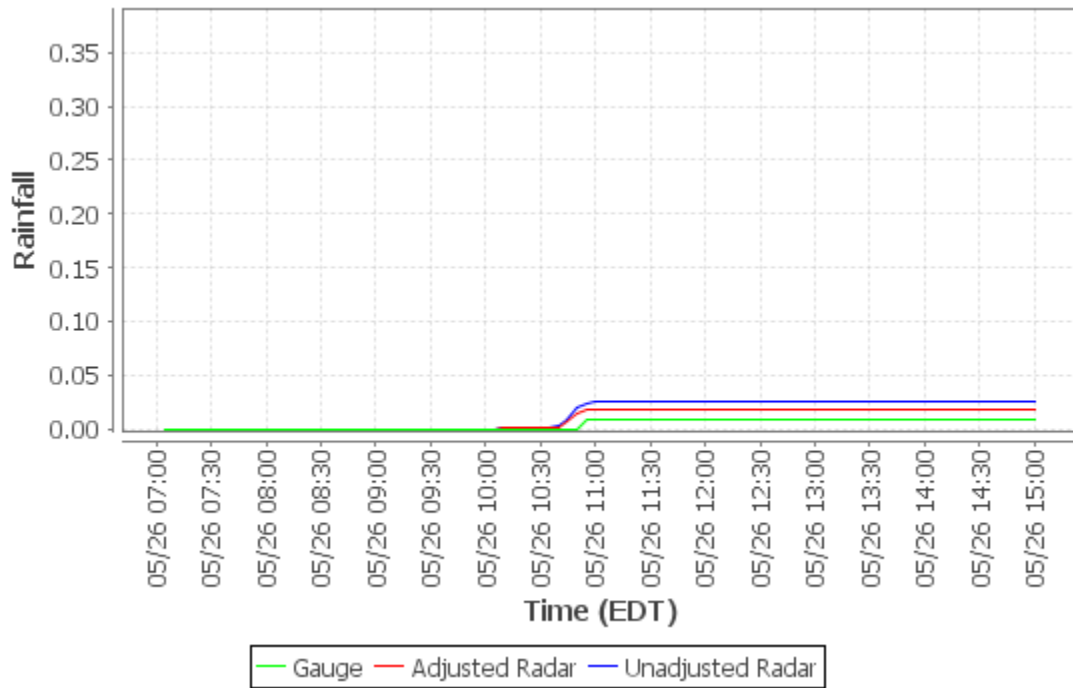
**Cumulative Distribution Plot - North Fayette TWP (Loc22)**



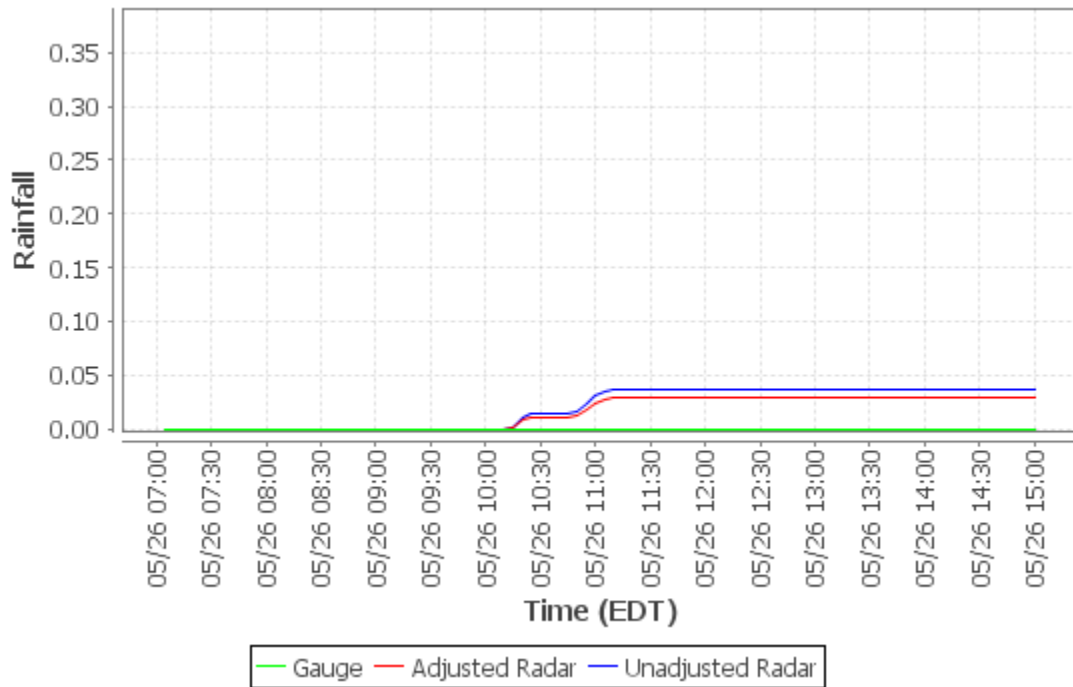
**Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)**



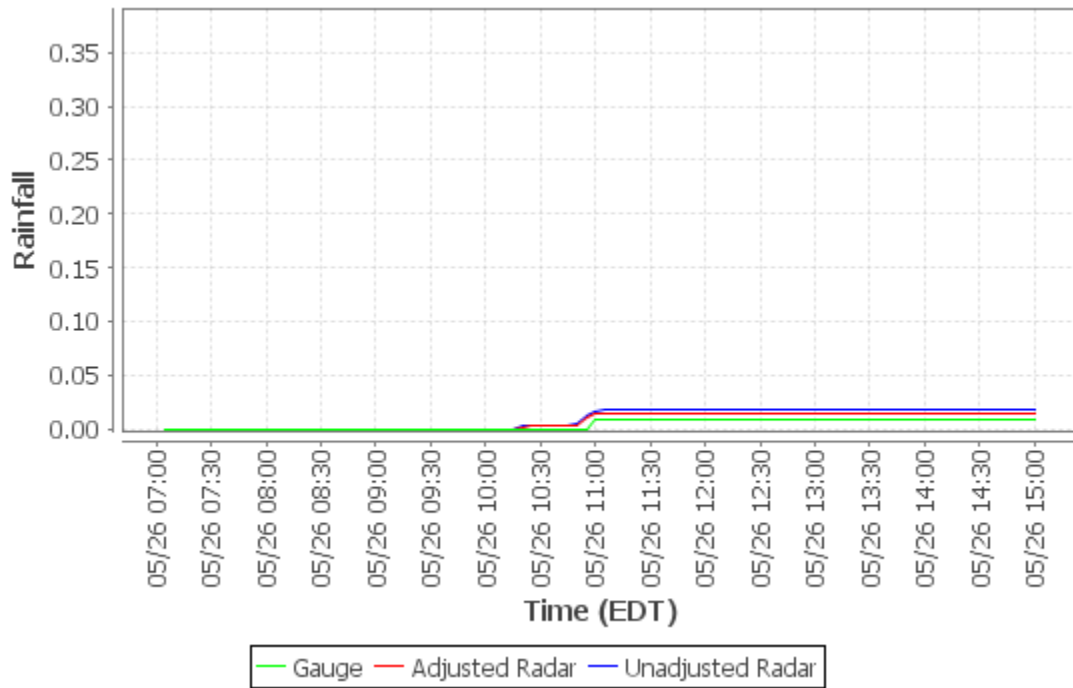
**Cumulative Distribution Plot - Jefferson Hills (Loc24)**



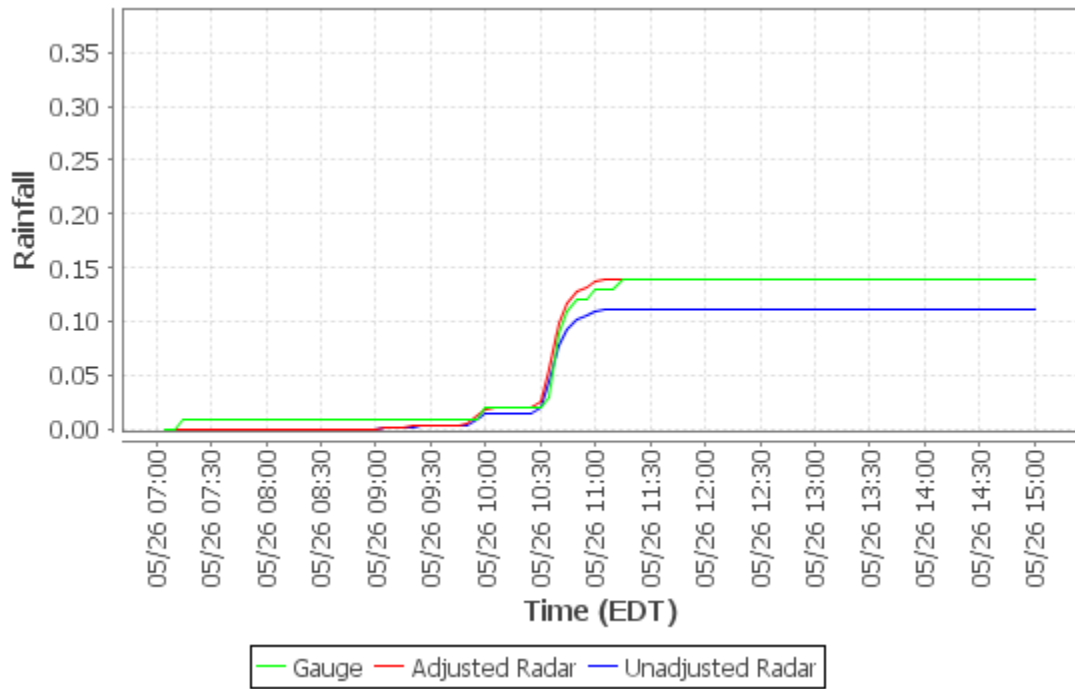
**Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)**



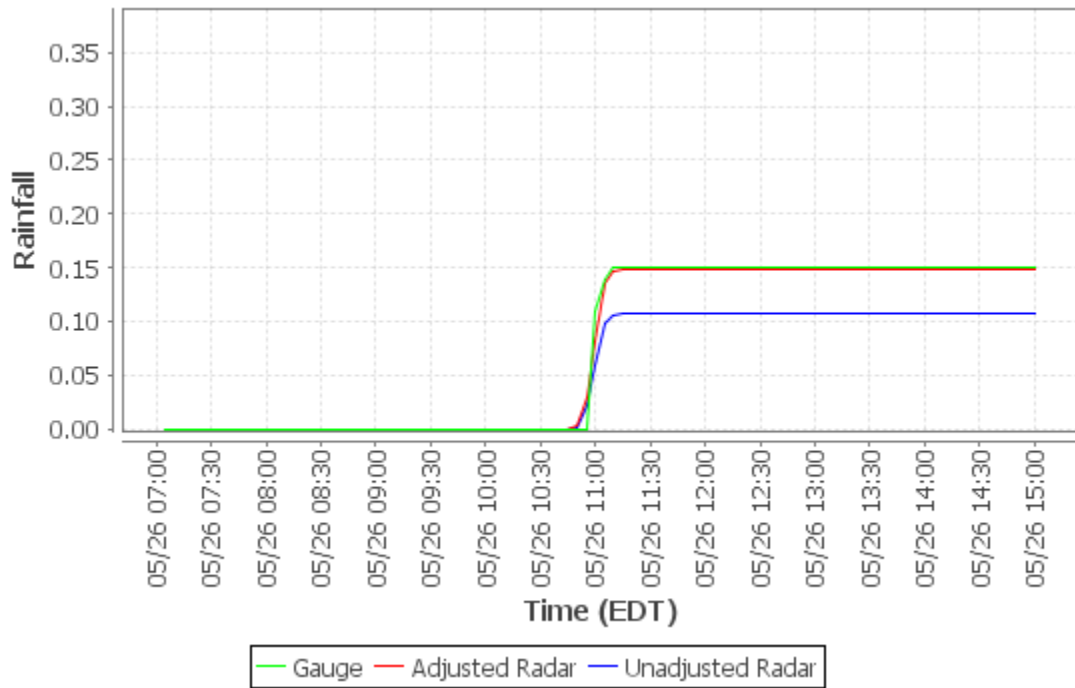
**Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)**



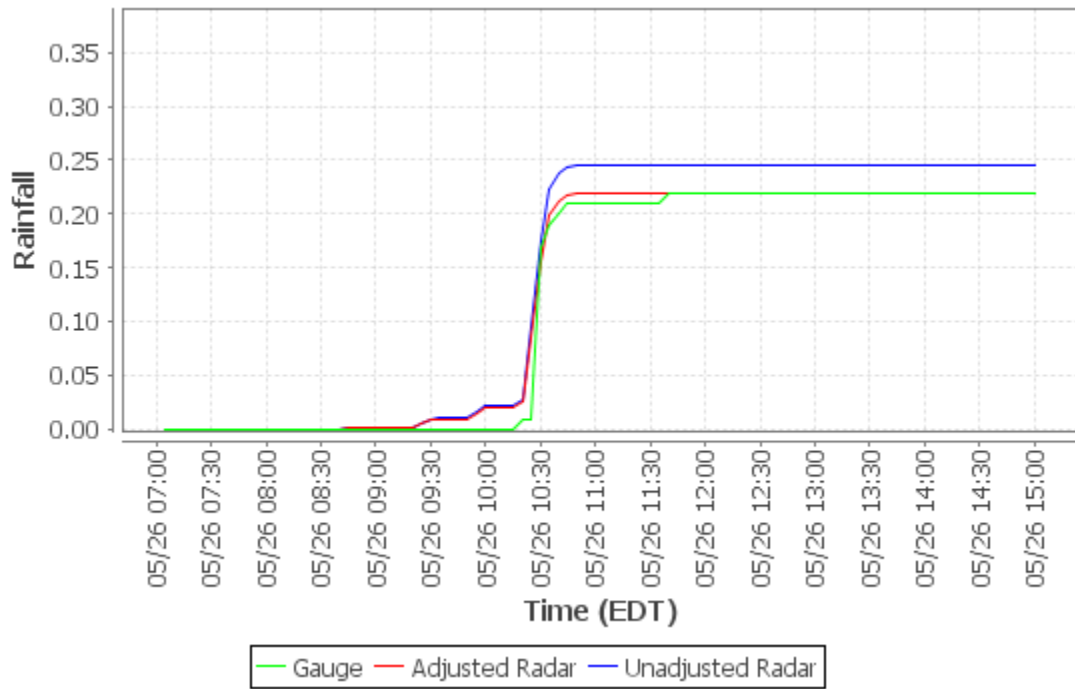
**Cumulative Distribution Plot - Marshall TWP (Loc27)**



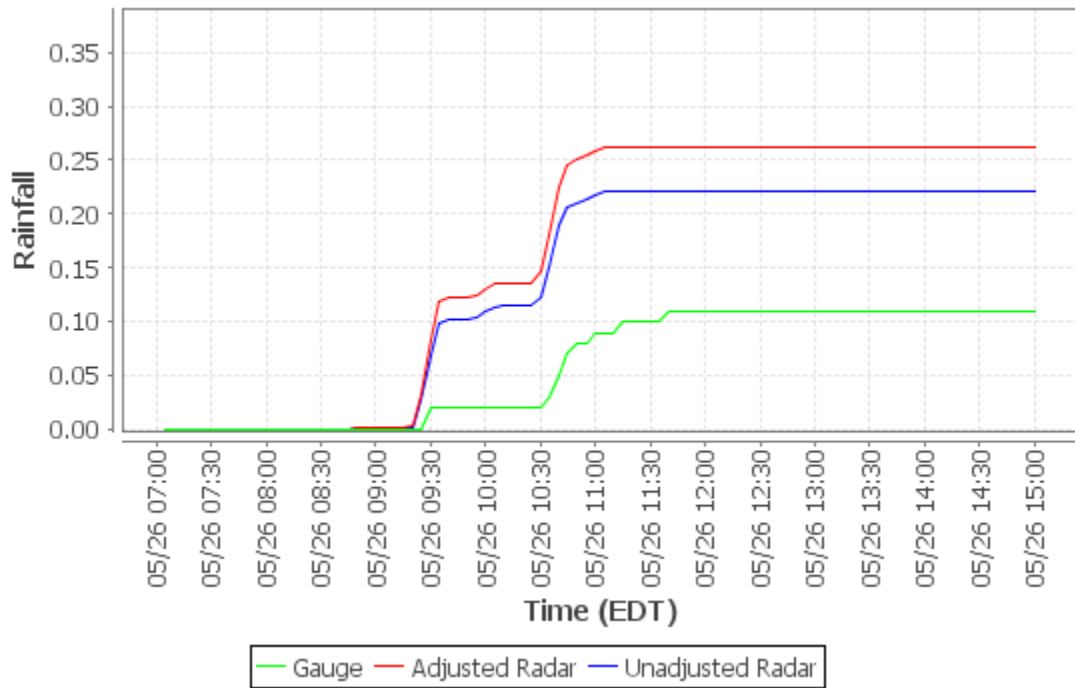
**Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)**



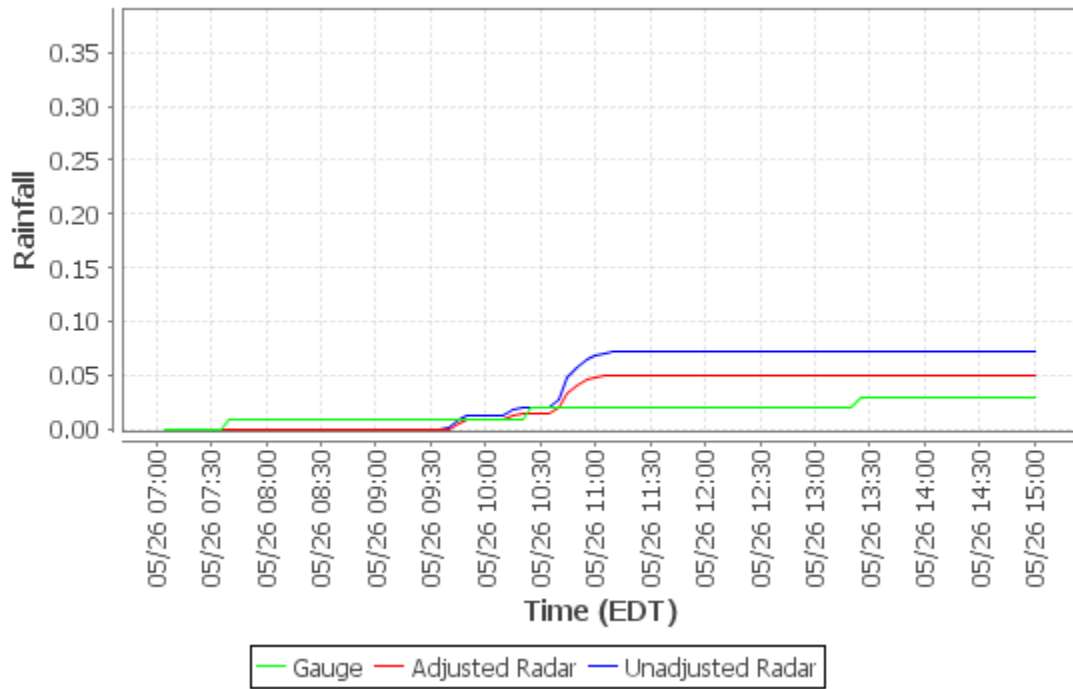
**Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)**



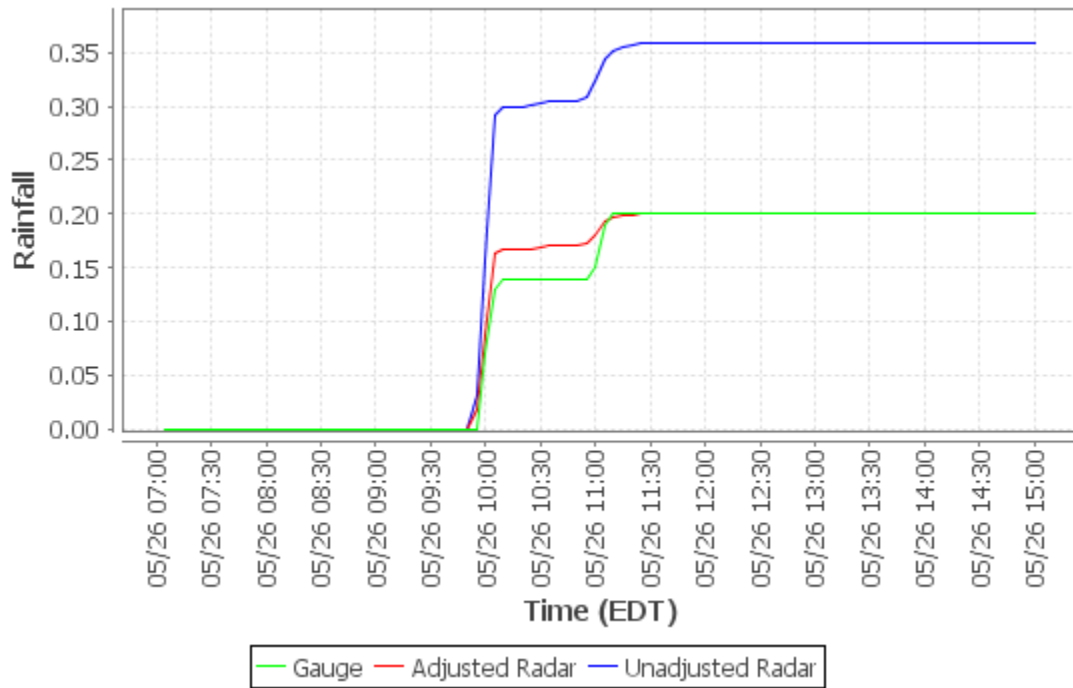
**Cumulative Distribution Plot - McCandless Twn Hall (Loc30)**



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

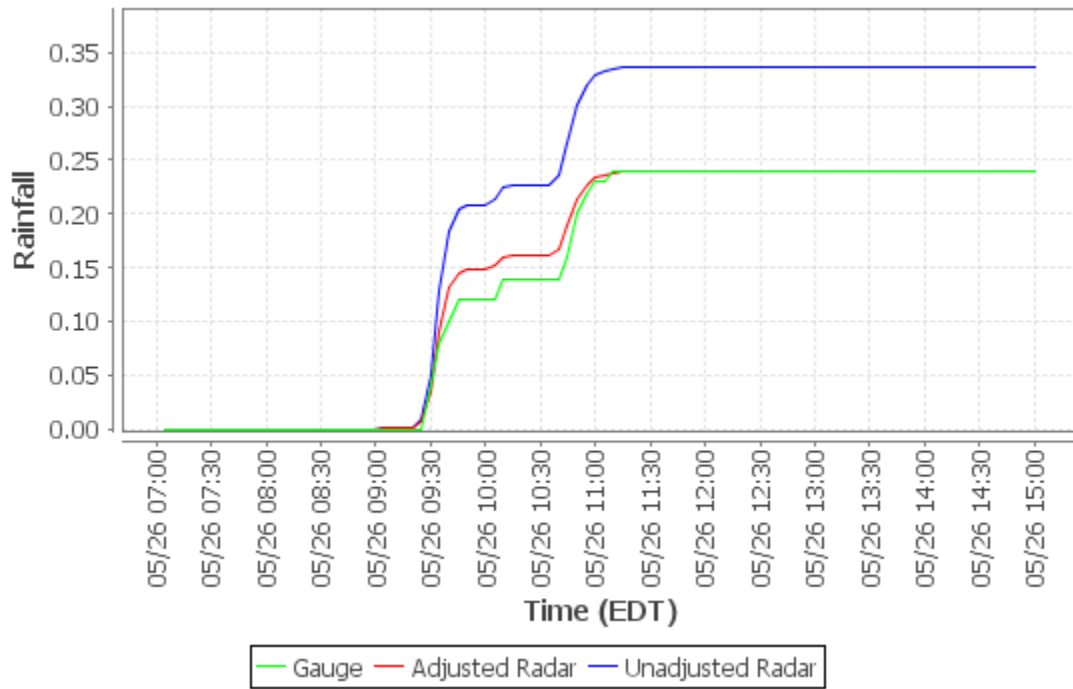


**Cumulative Distribution Plot - Arnold (Loc32)**

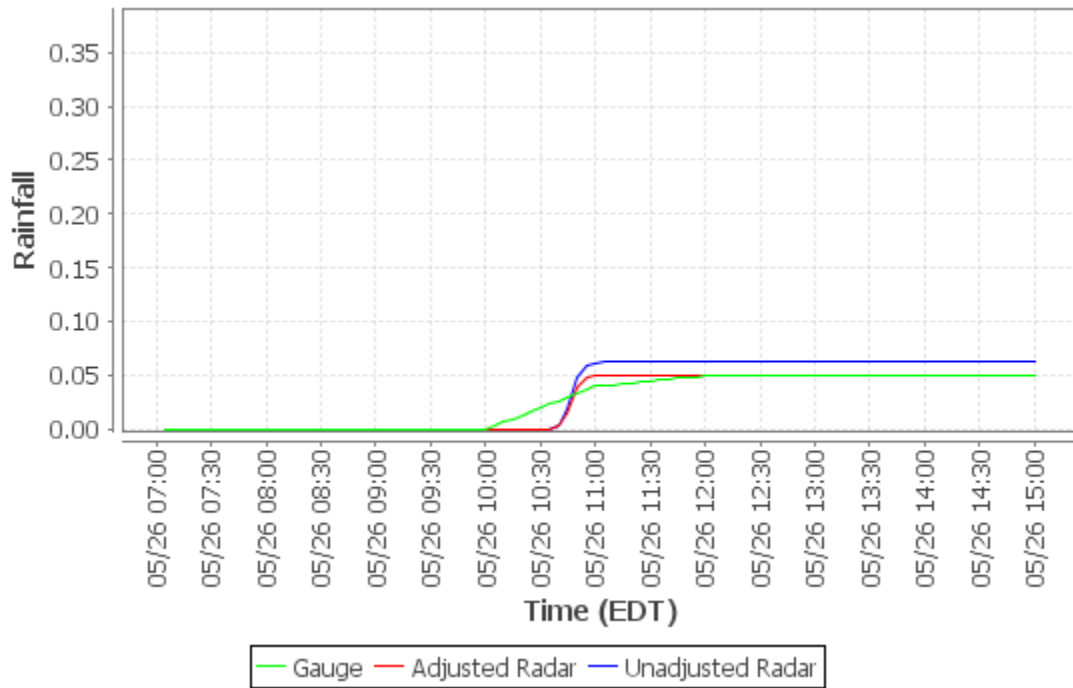




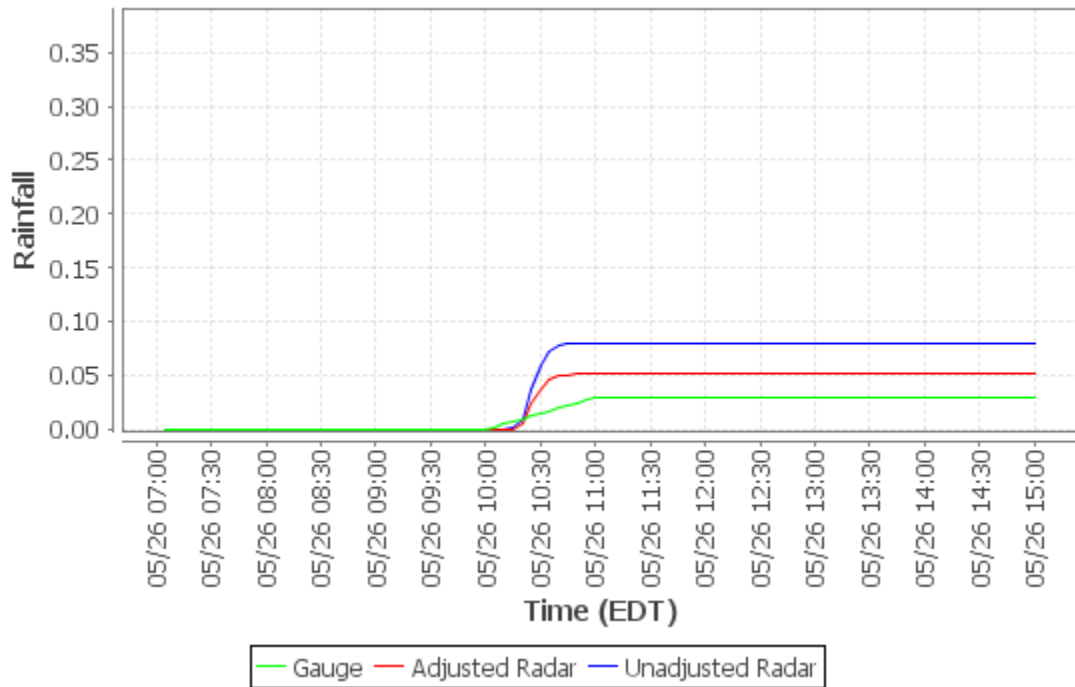
**Cumulative Distribution Plot - Richland TWP (Loc33)**



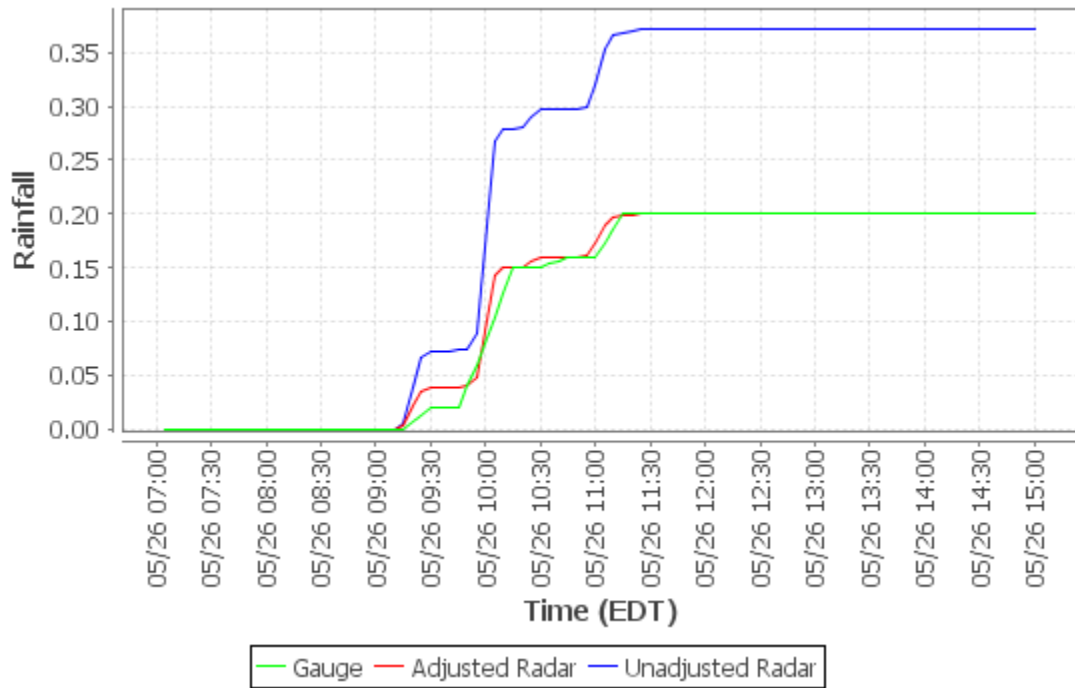
**Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)**



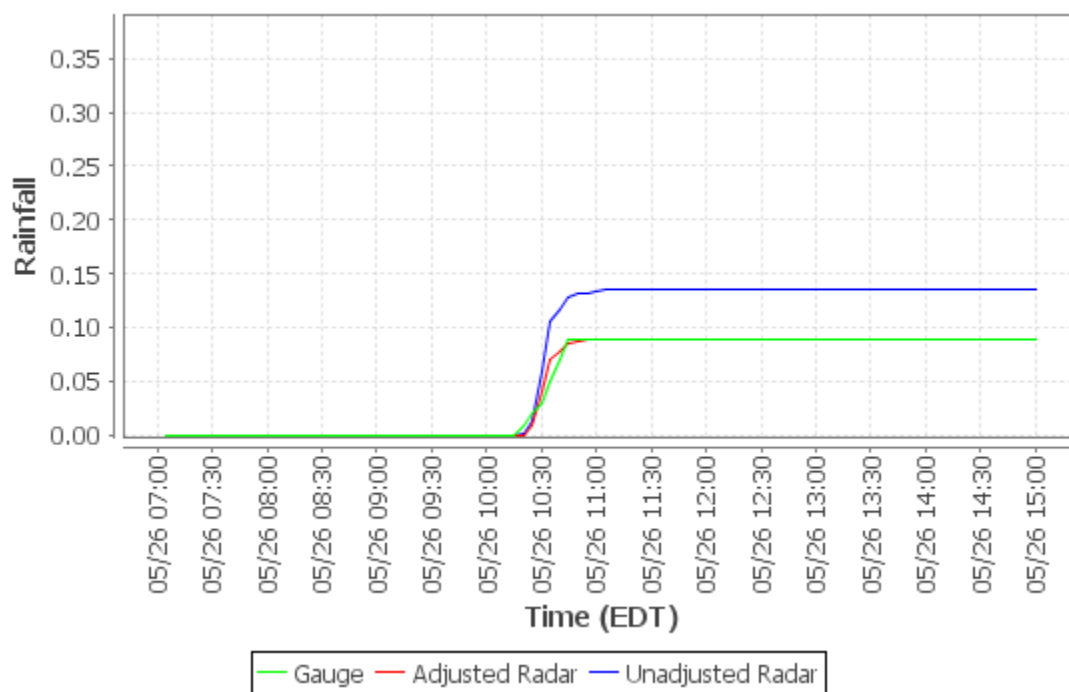
**Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)**



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

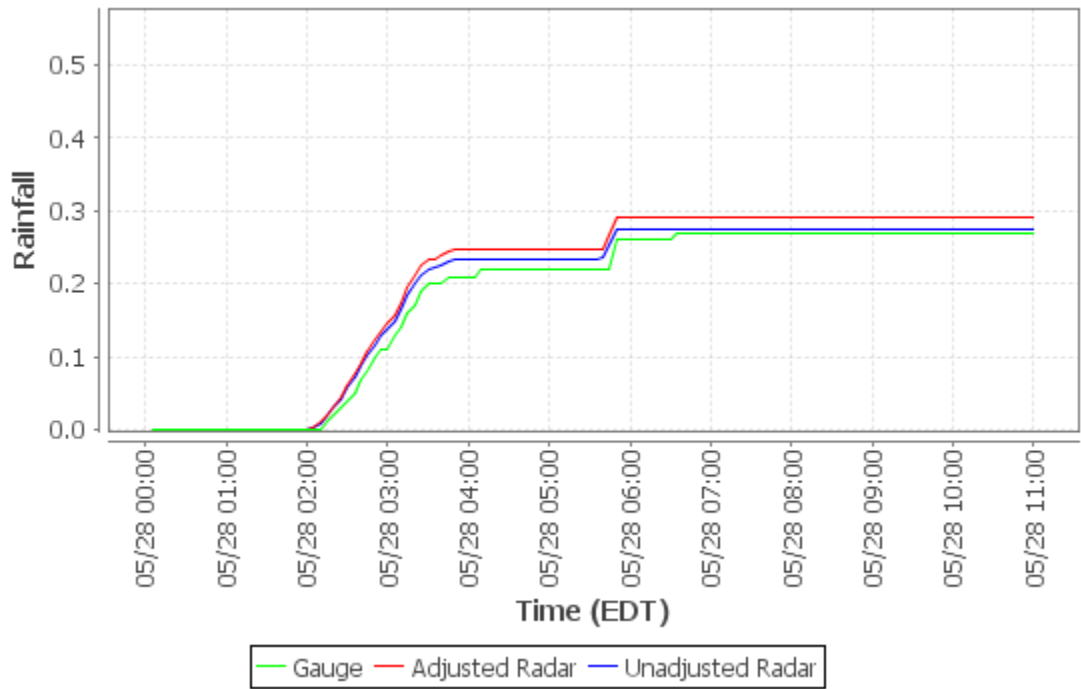


### Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth (03085734)

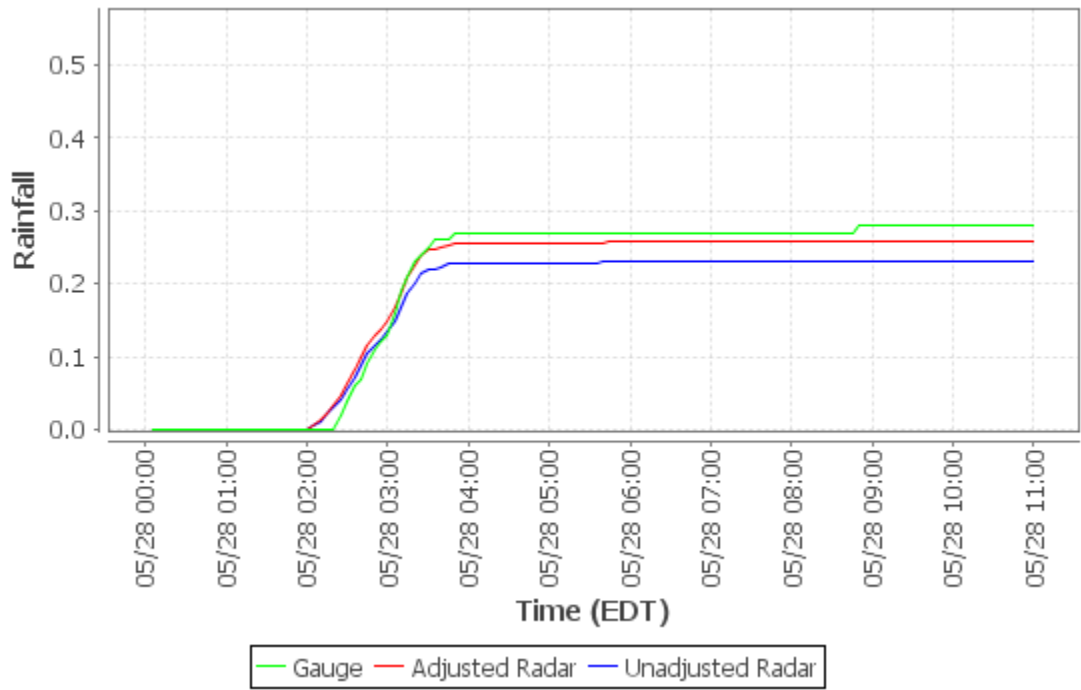


## **Appendix J - Event 8 (2019-05-28 AM) CDPs**

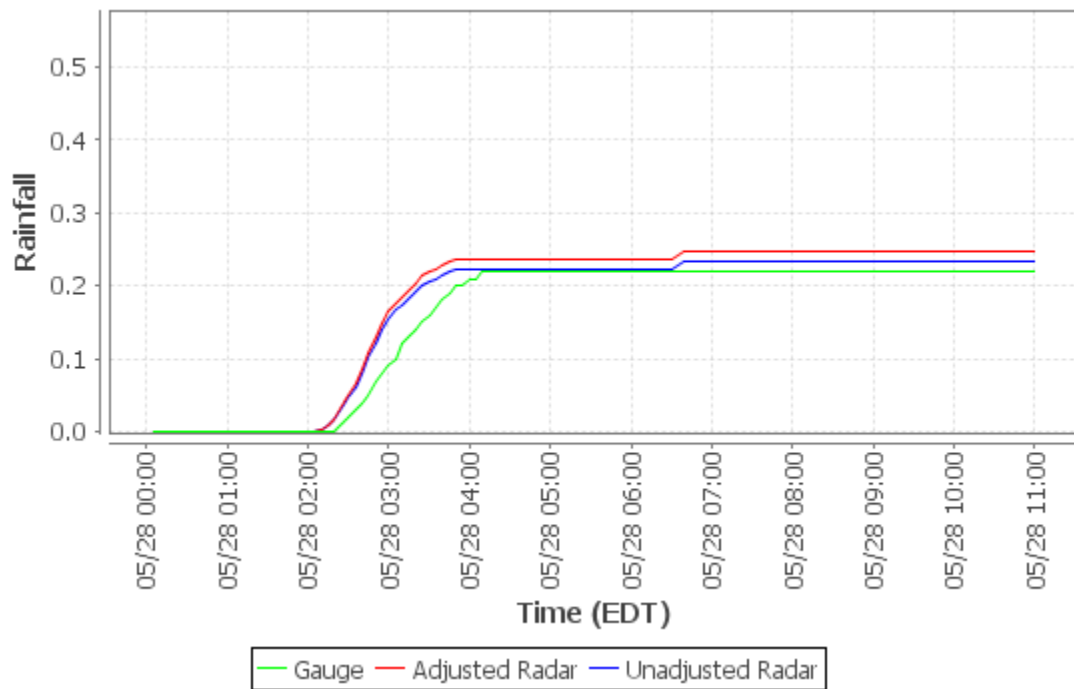
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



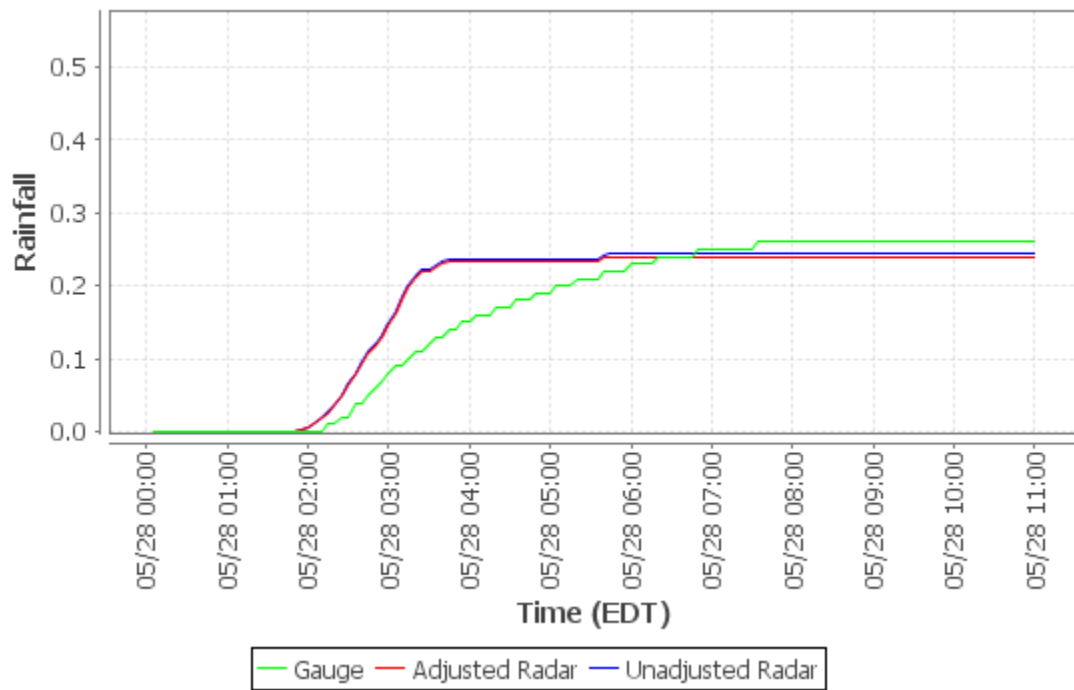
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



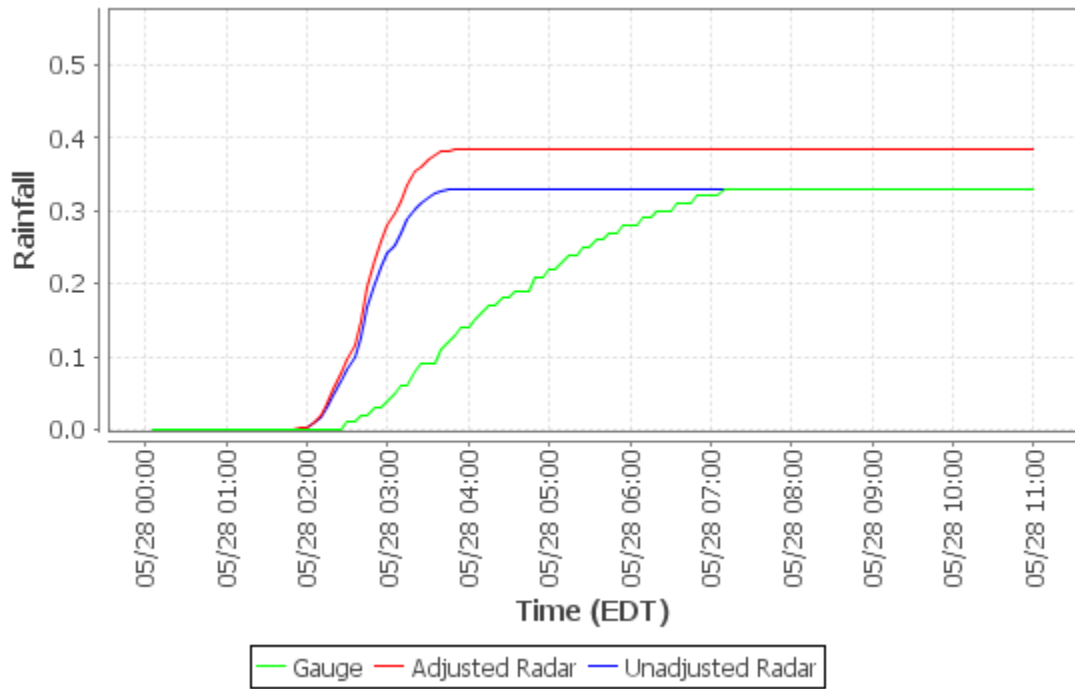
**Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)**



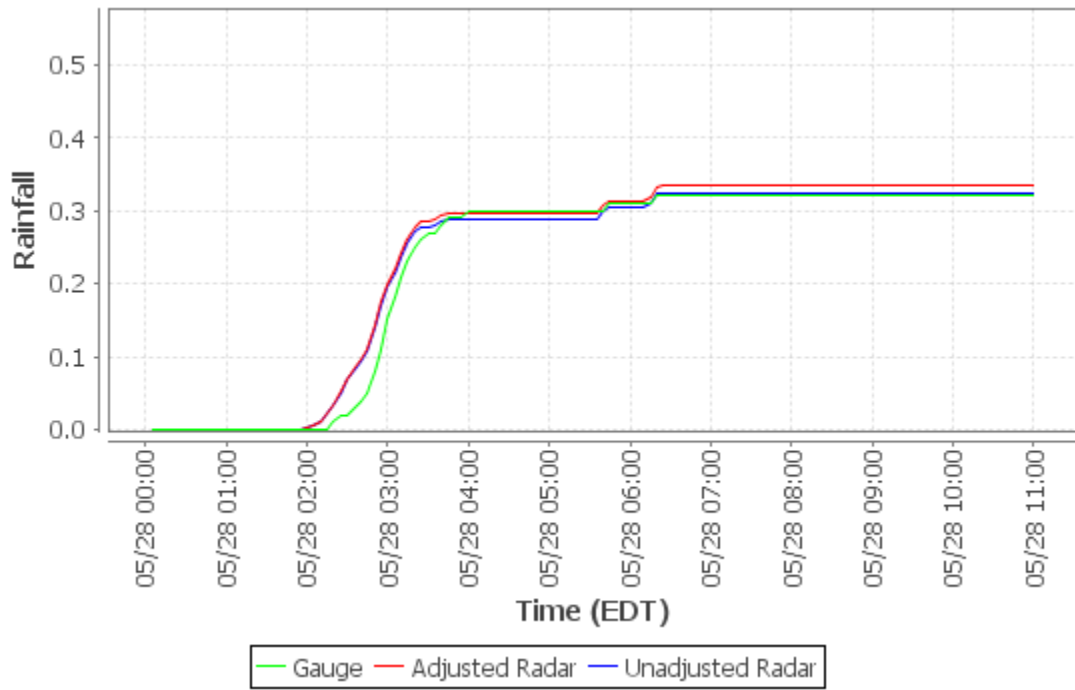
**Cumulative Distribution Plot - Kennedy Twp PS (Loc04)**



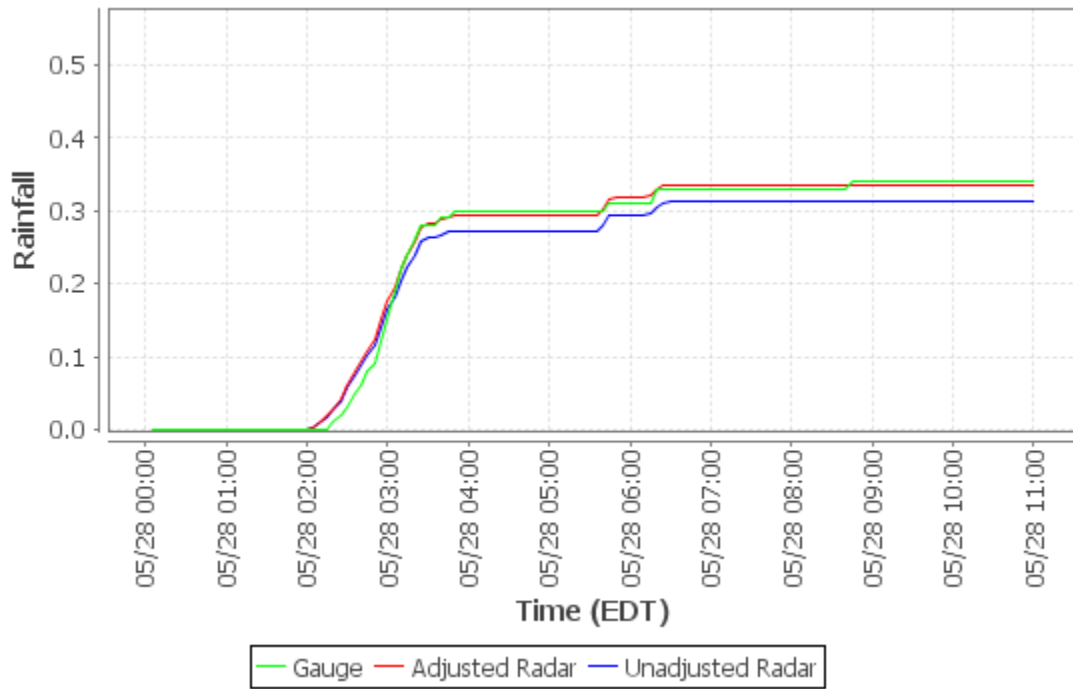
**Cumulative Distribution Plot - Upper St. Clair (Loc05)**



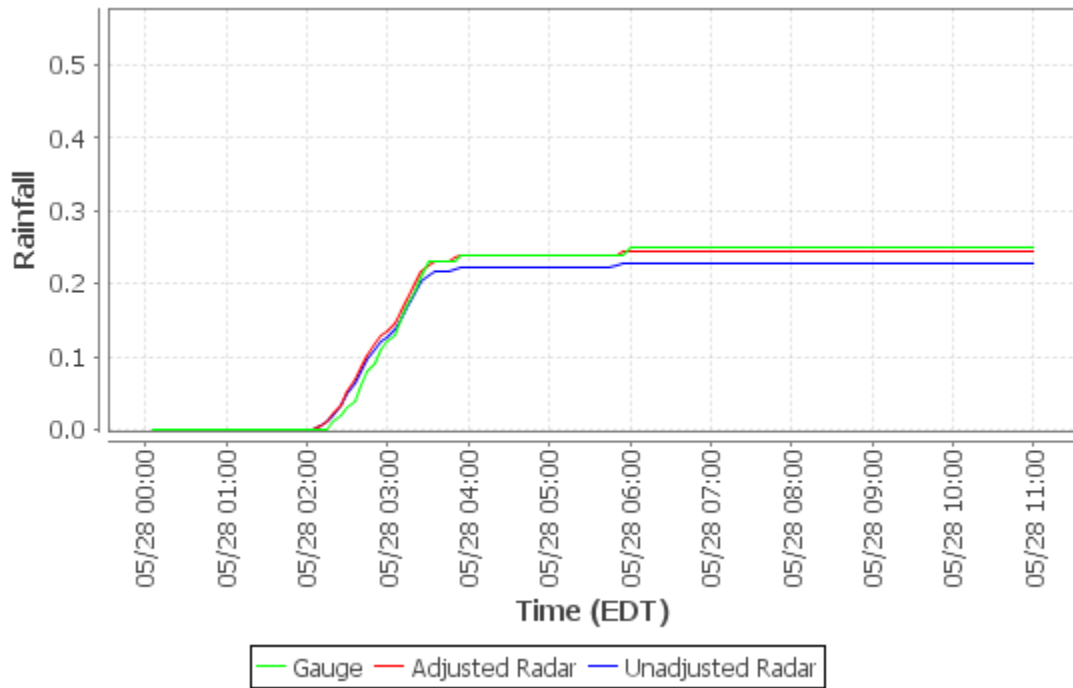
**Cumulative Distribution Plot - Carnegie Transit Time (Loc06)**



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

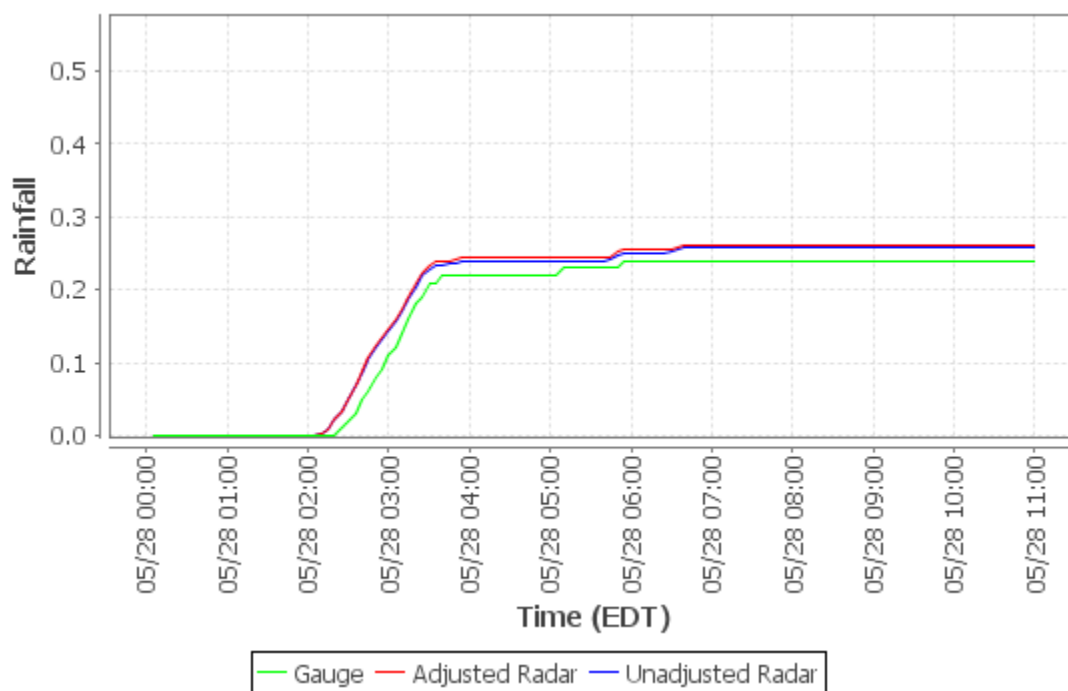


**Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)**

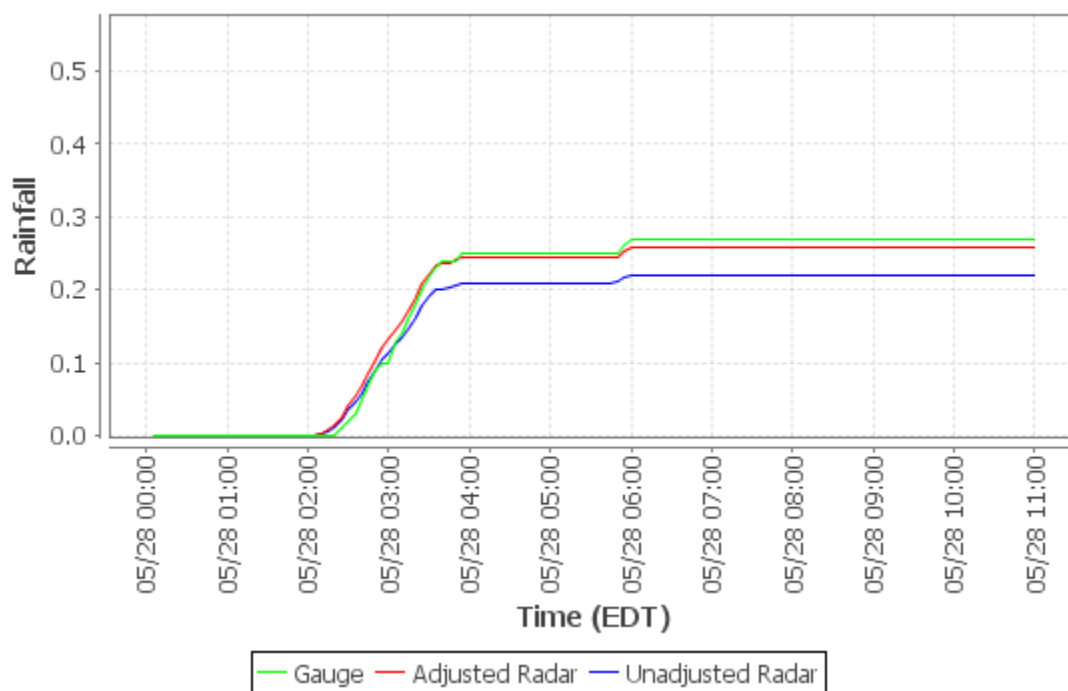




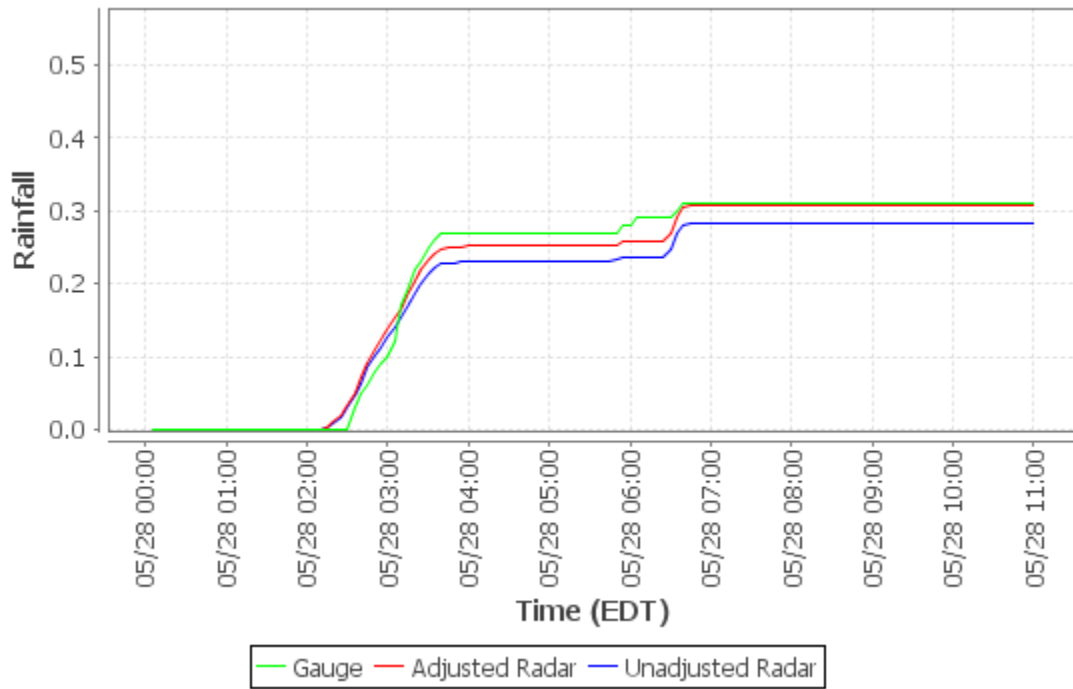
**Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)**



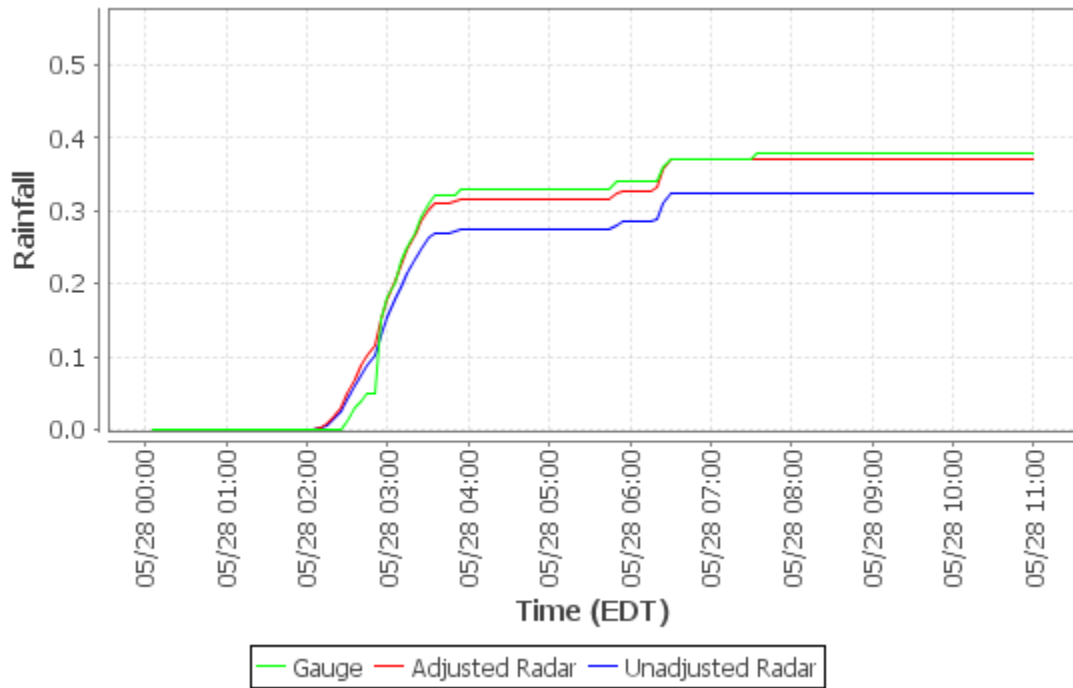
**Cumulative Distribution Plot - PWSA-Highland Park (Loc10)**



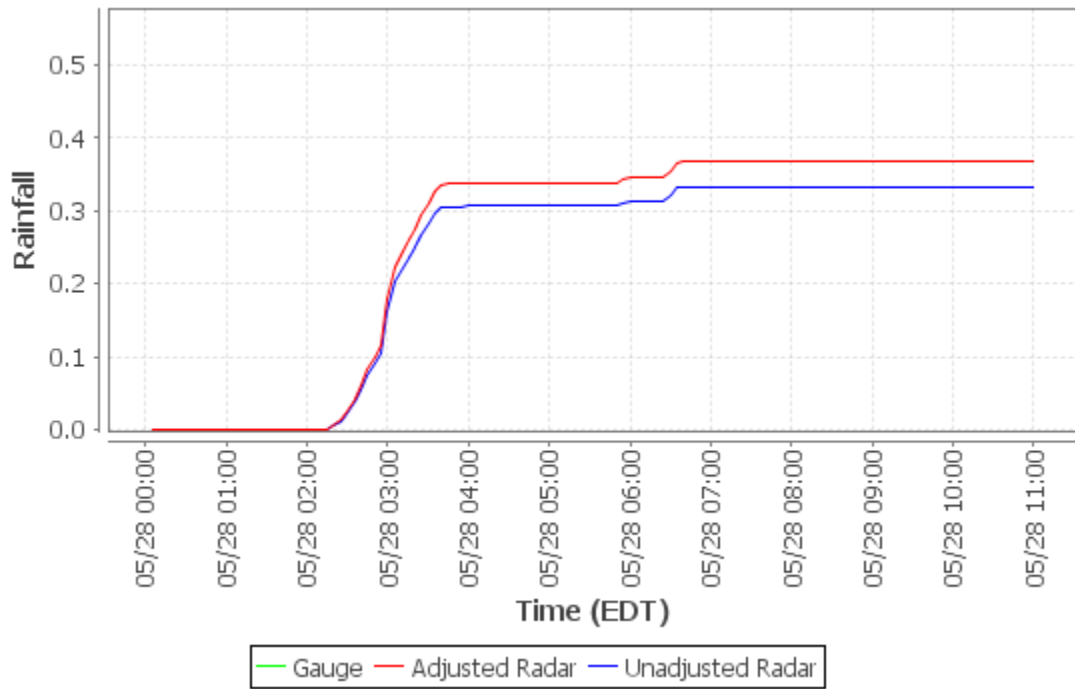
**Cumulative Distribution Plot - M-46 Access Shaft (Loc11)**



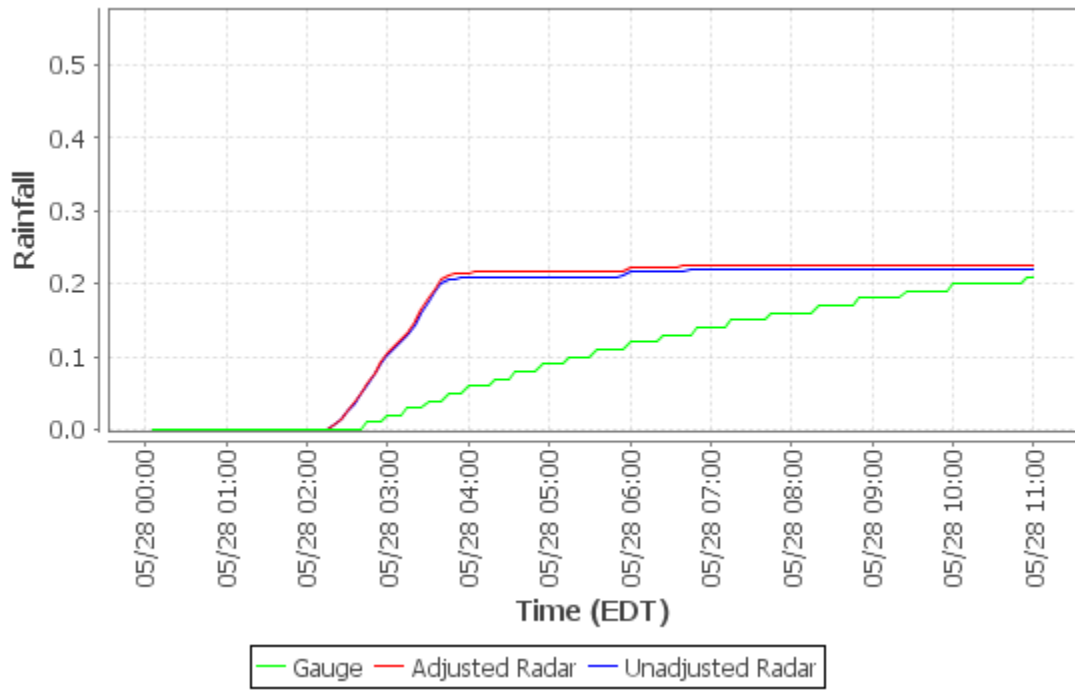
**Cumulative Distribution Plot - Baldwin (Loc12)**



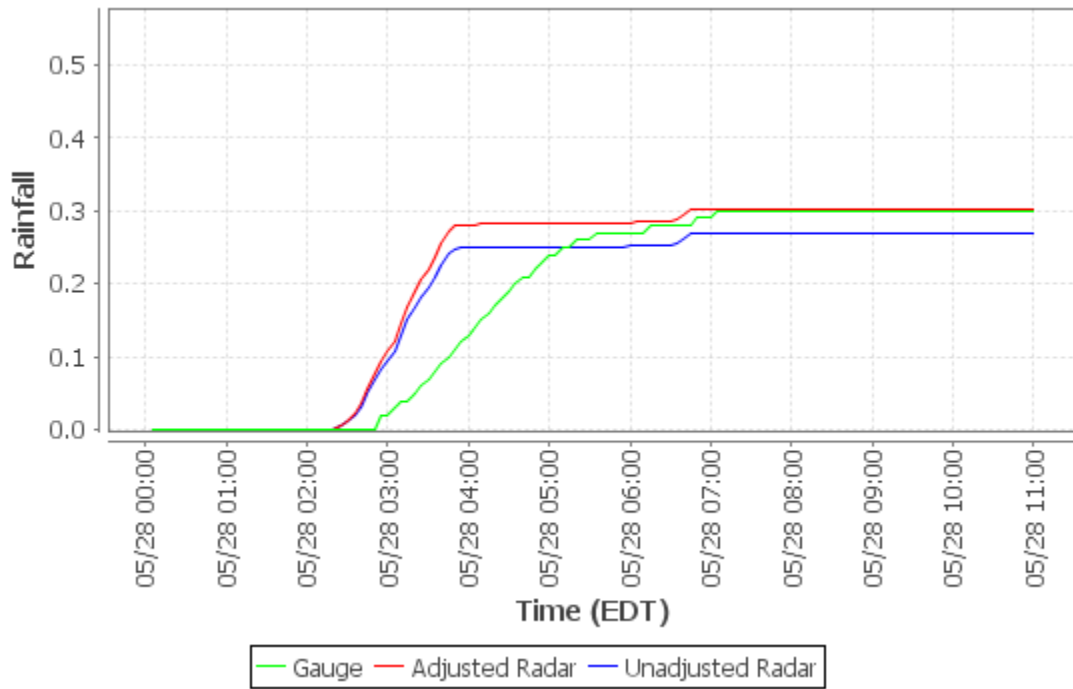
**Cumulative Distribution Plot - M-59 Access Shaft (Loc13)**



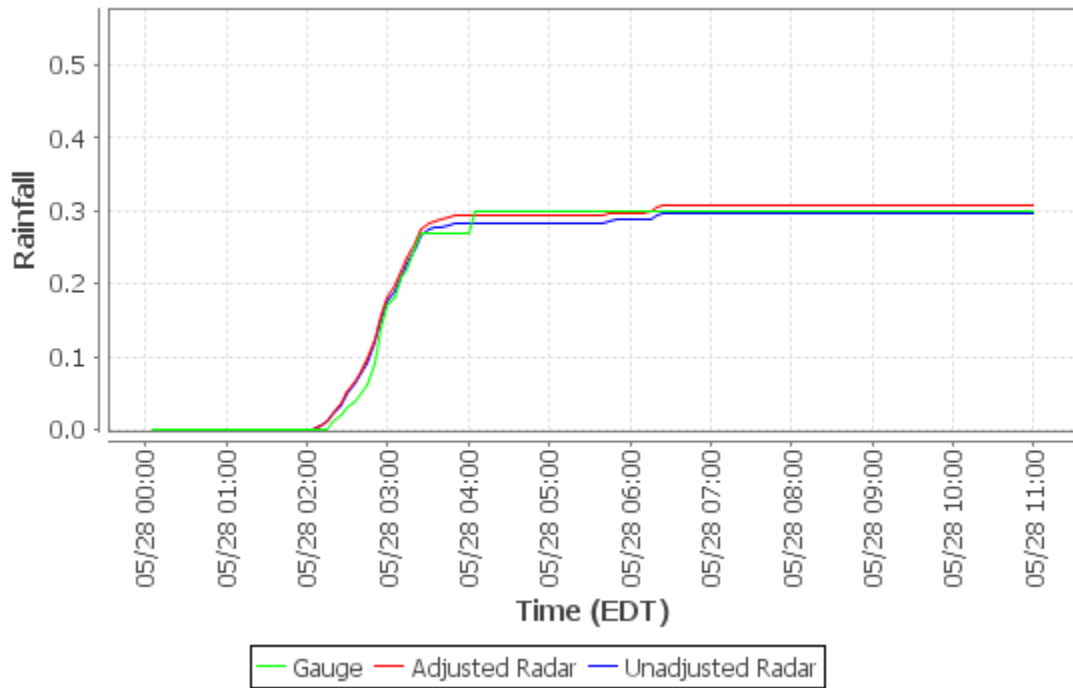
**Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)**



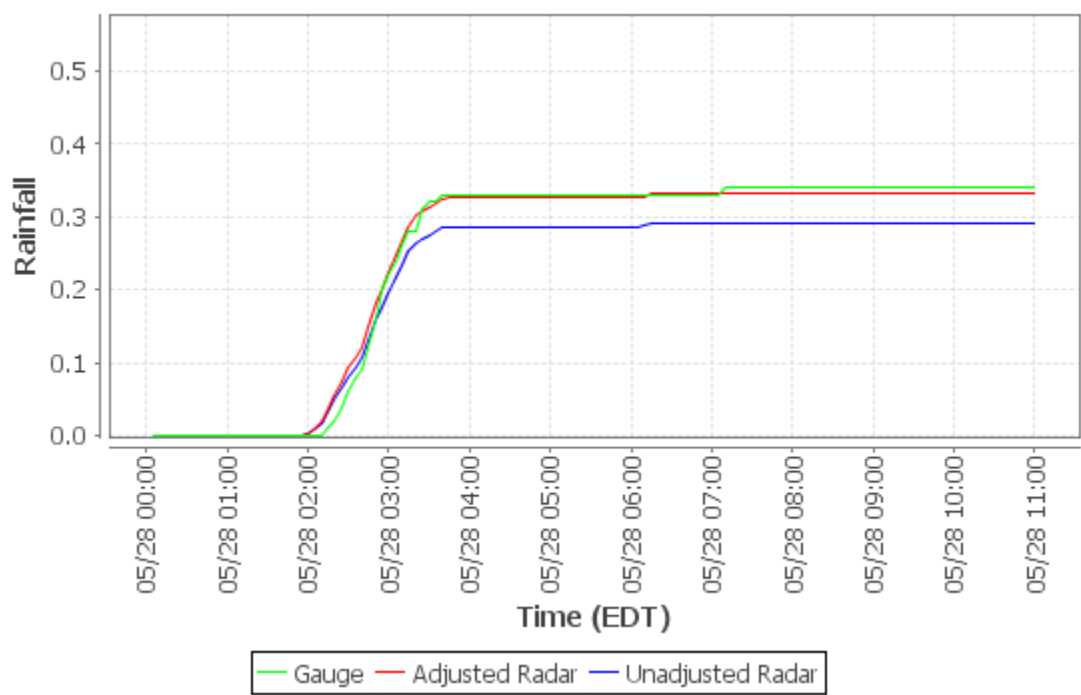
**Cumulative Distribution Plot - Trafford Maint Bldg (Loc15)**



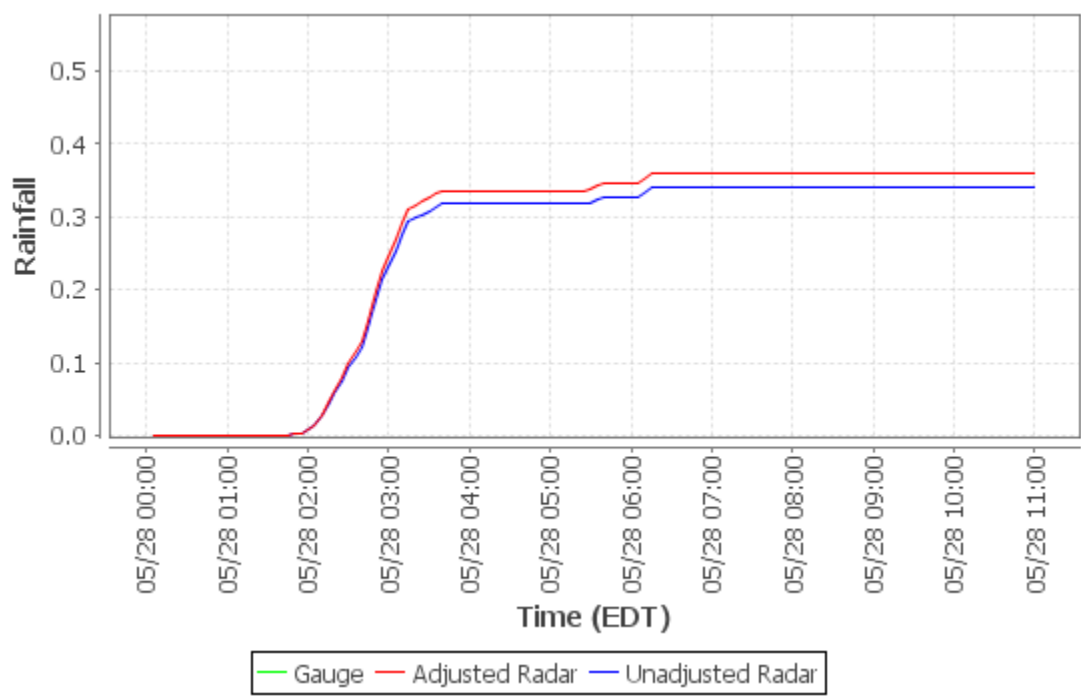
**Cumulative Distribution Plot - Castle Shannon (Loc16)**



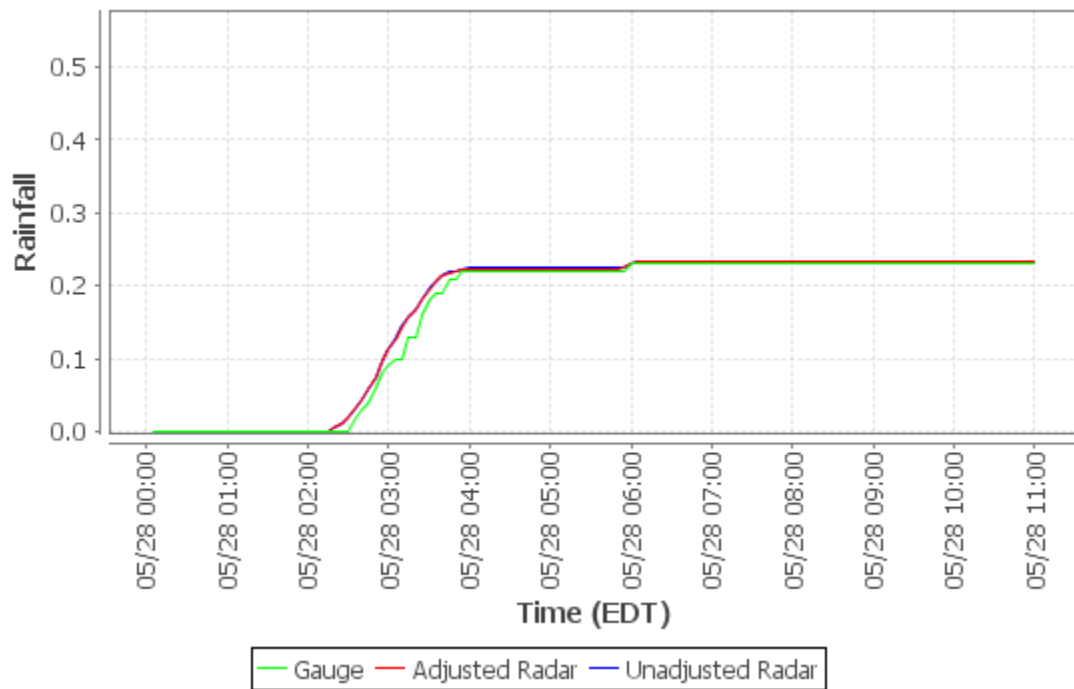
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



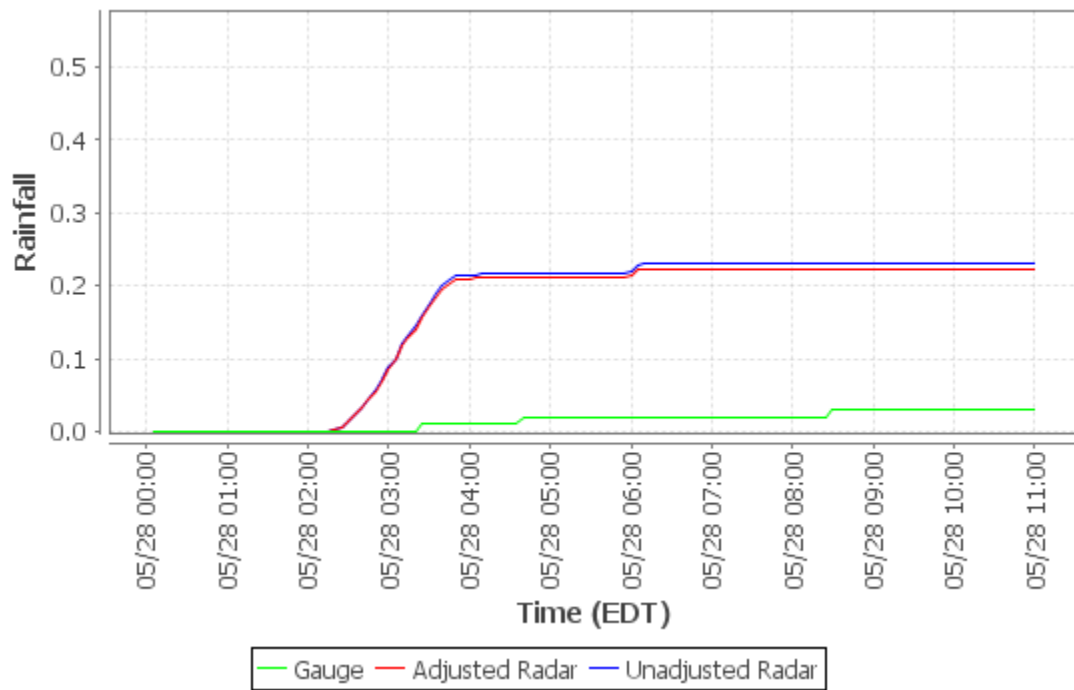
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



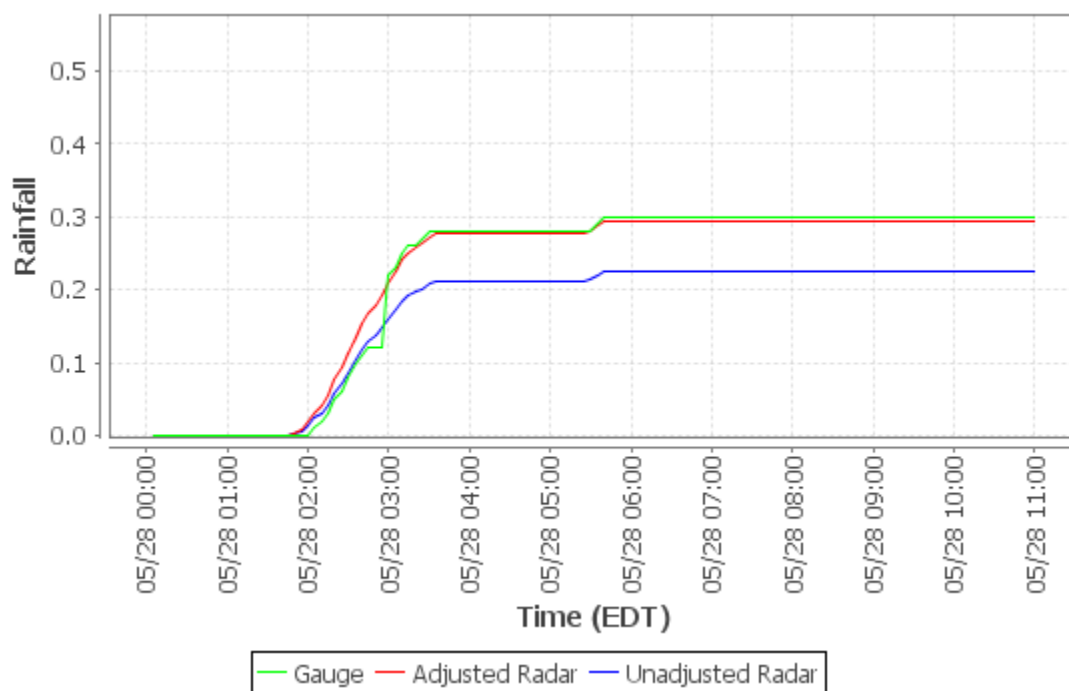
**Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)**



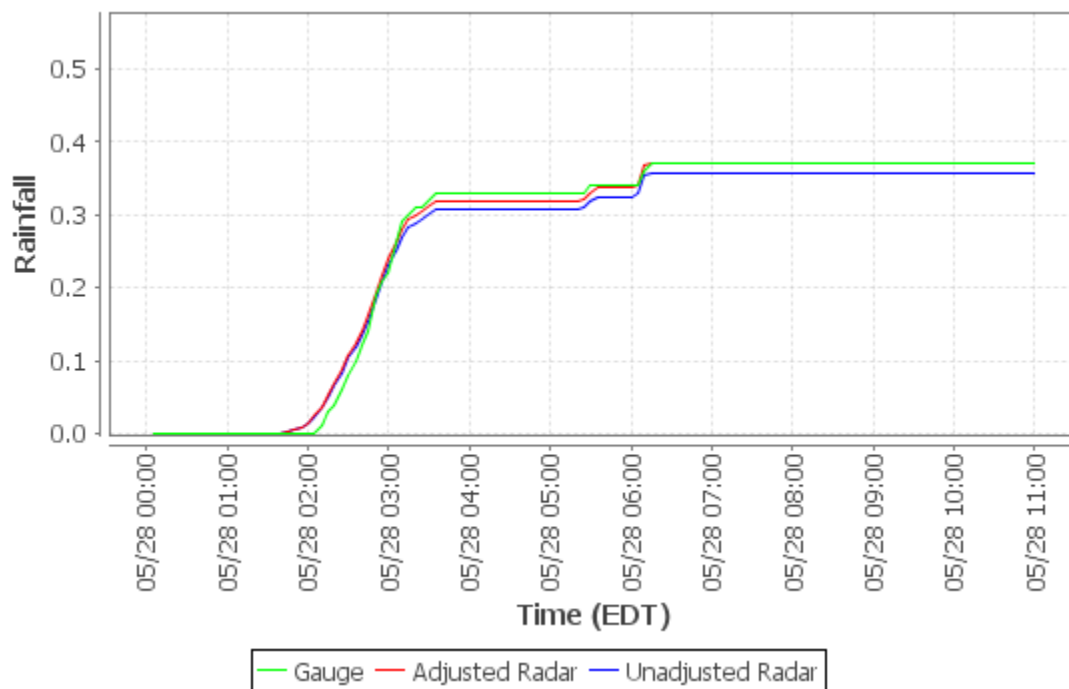
**Cumulative Distribution Plot - Gascola Eq Facility (Loc20)**



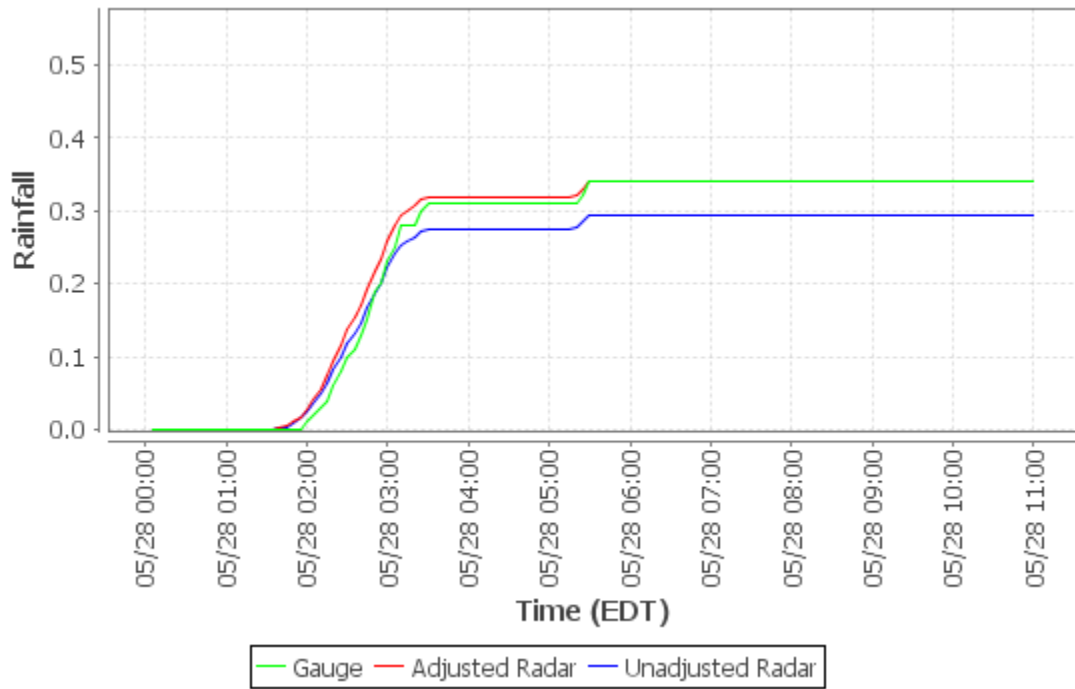
**Cumulative Distribution Plot - Moon TWP (Loc21)**



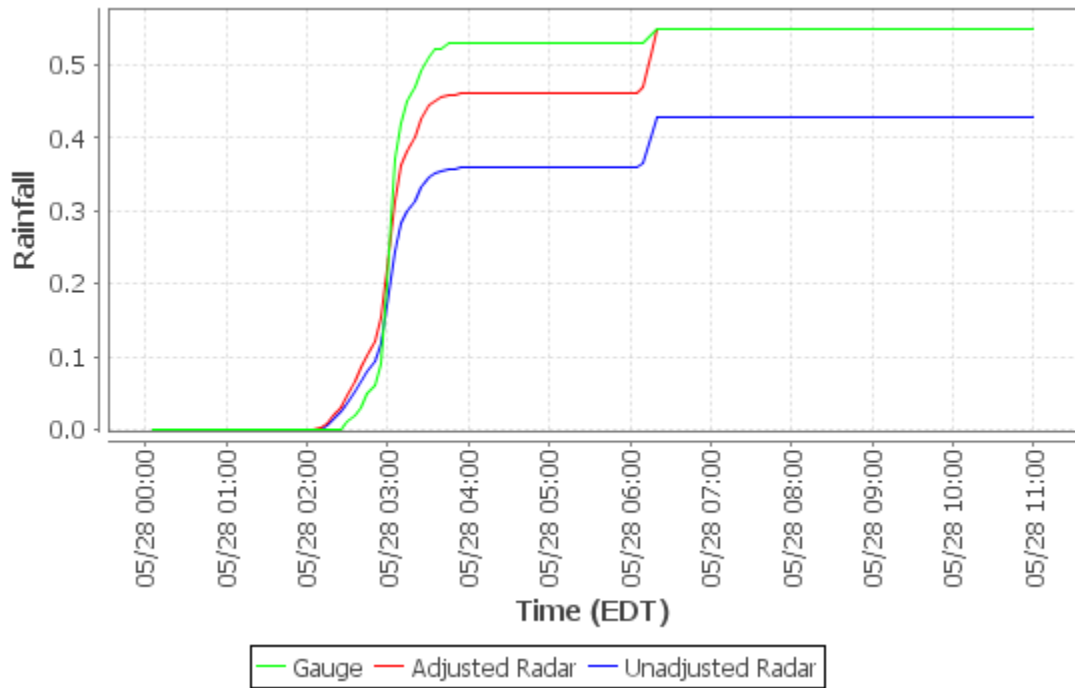
**Cumulative Distribution Plot - North Fayette TWP (Loc22)**



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

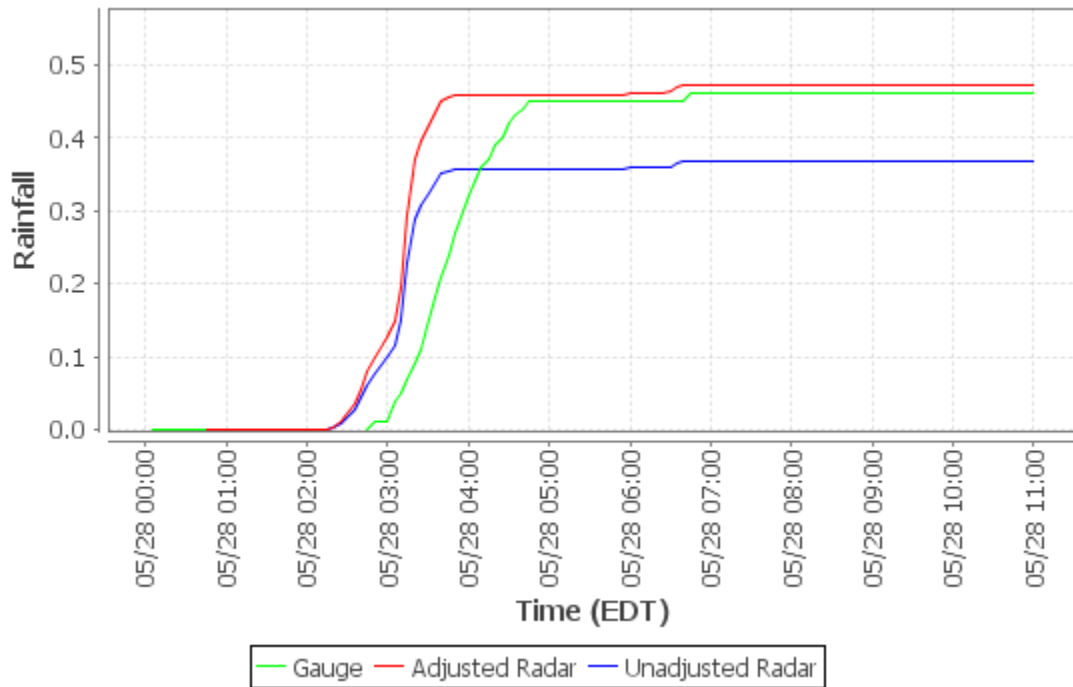


**Cumulative Distribution Plot - Jefferson Hills (Loc24)**

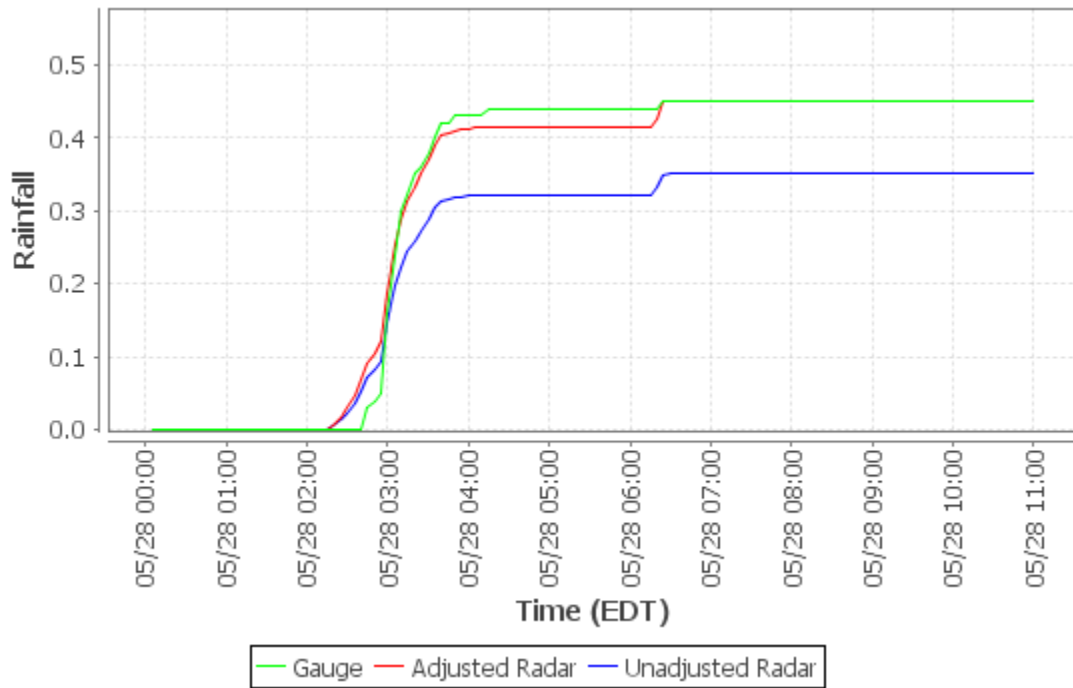




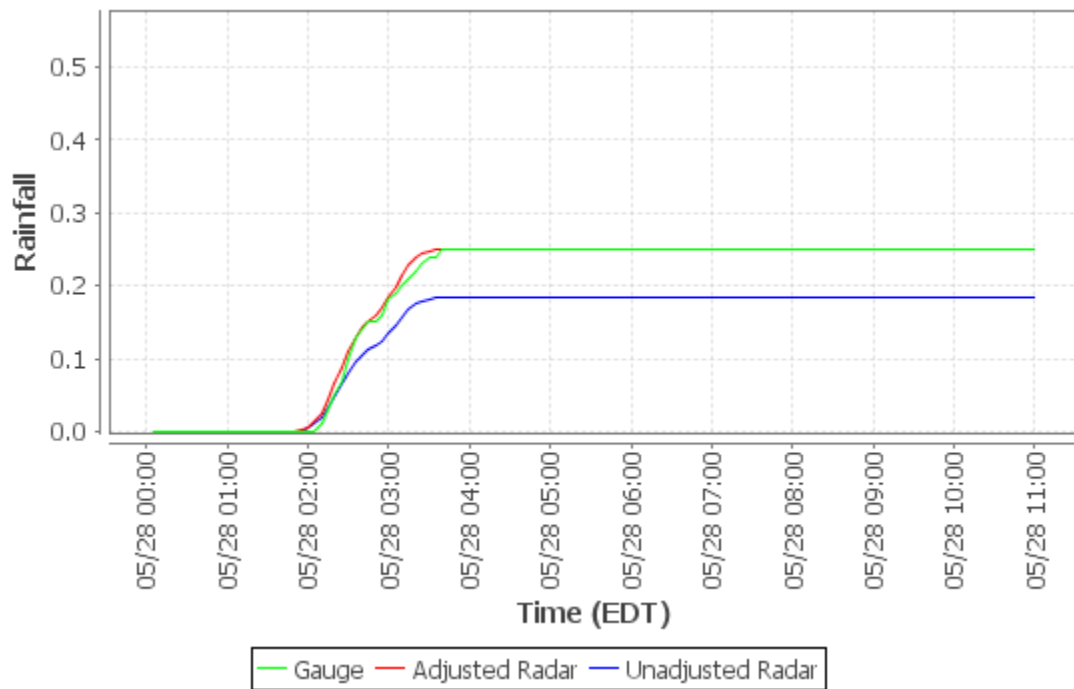
**Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)**



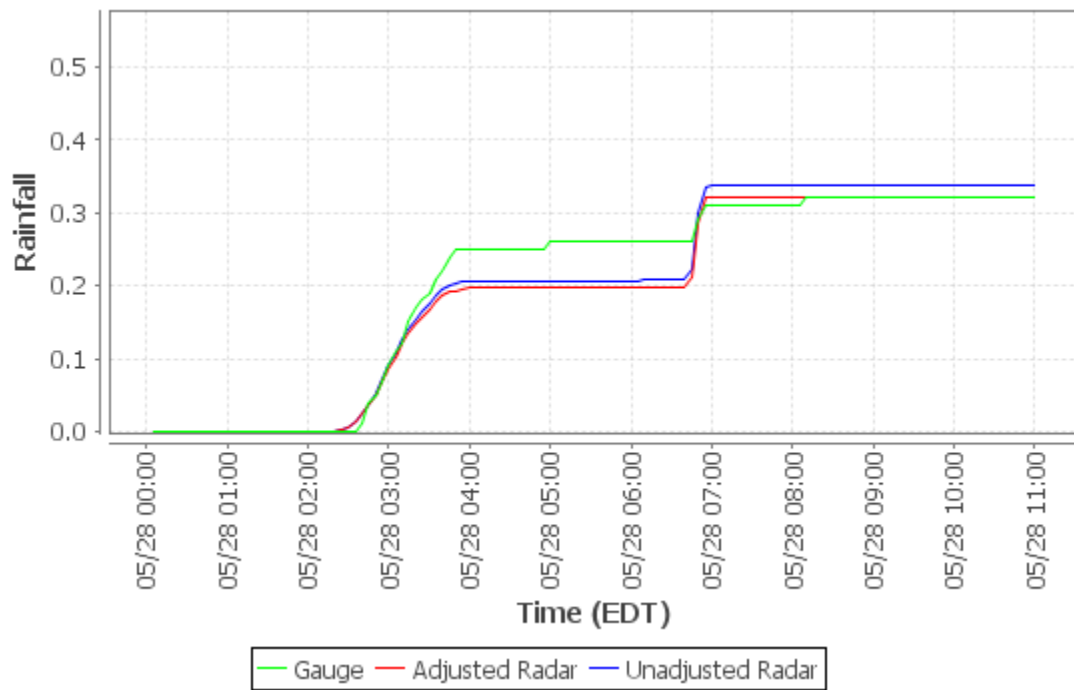
**Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)**



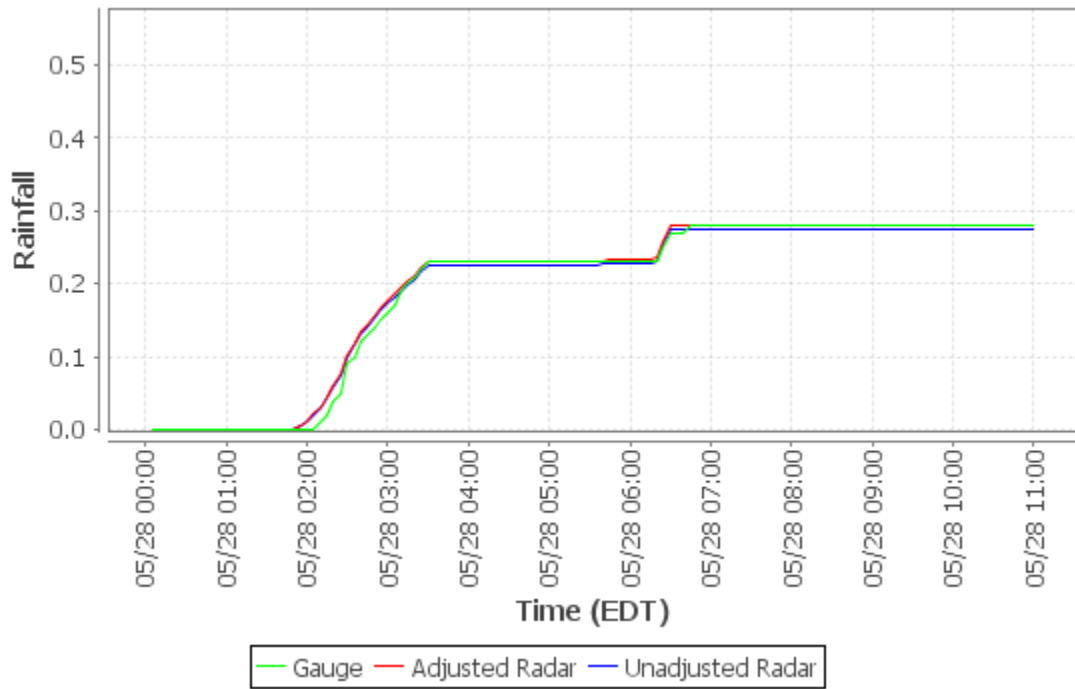
**Cumulative Distribution Plot - Marshall TWP (Loc27)**



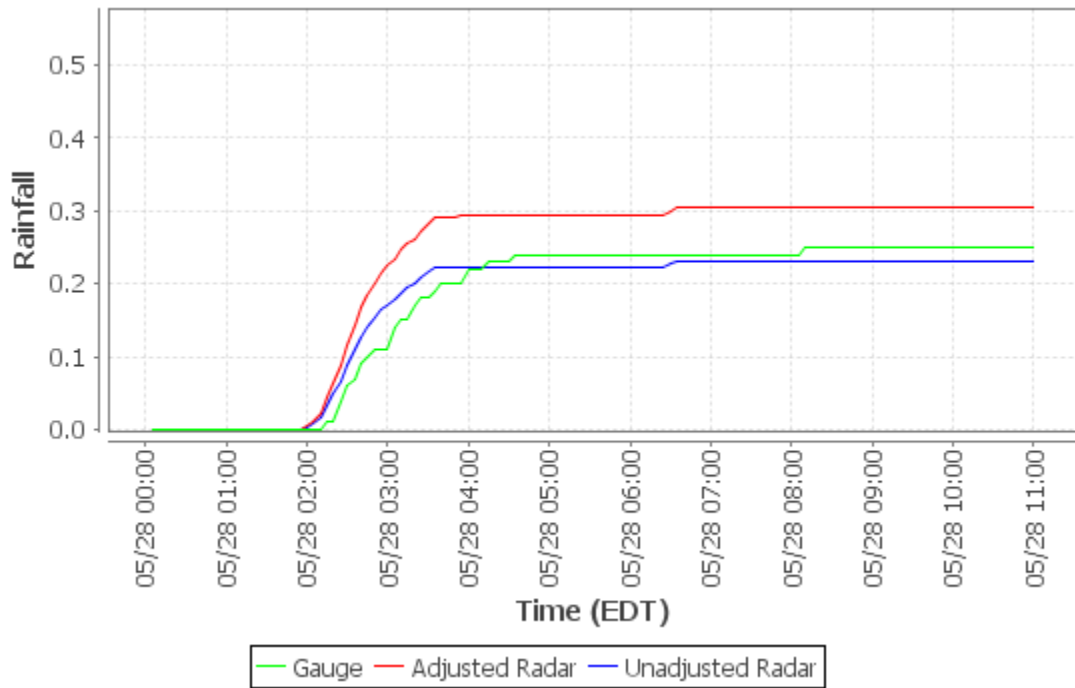
**Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)**



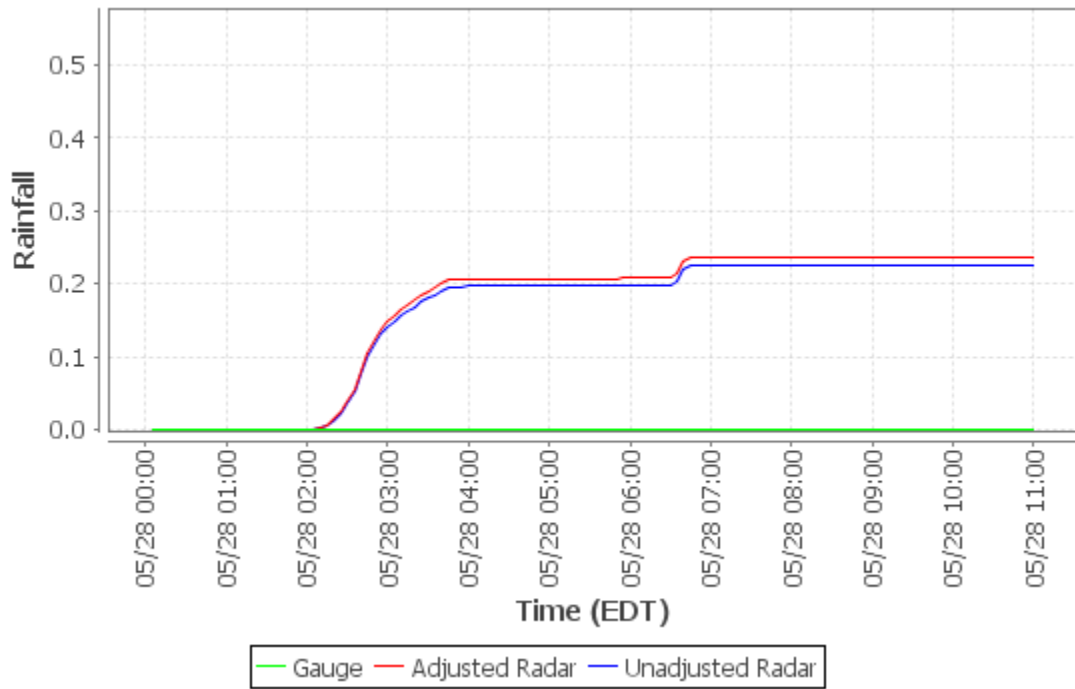
**Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)**



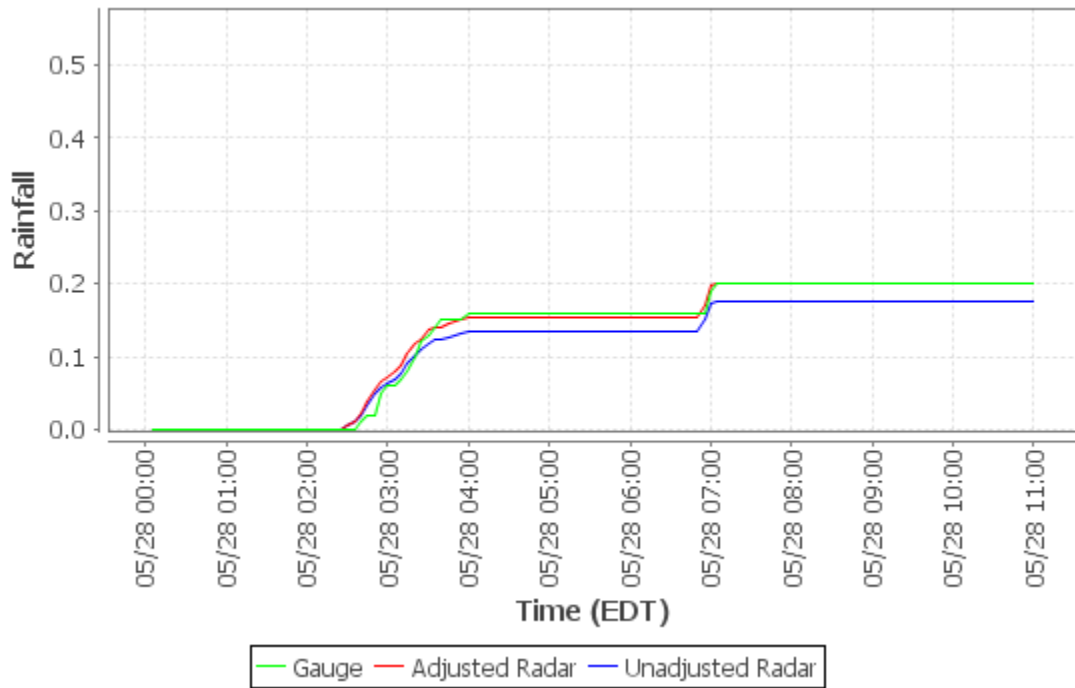
**Cumulative Distribution Plot - McCandless Twn Hall (Loc30)**



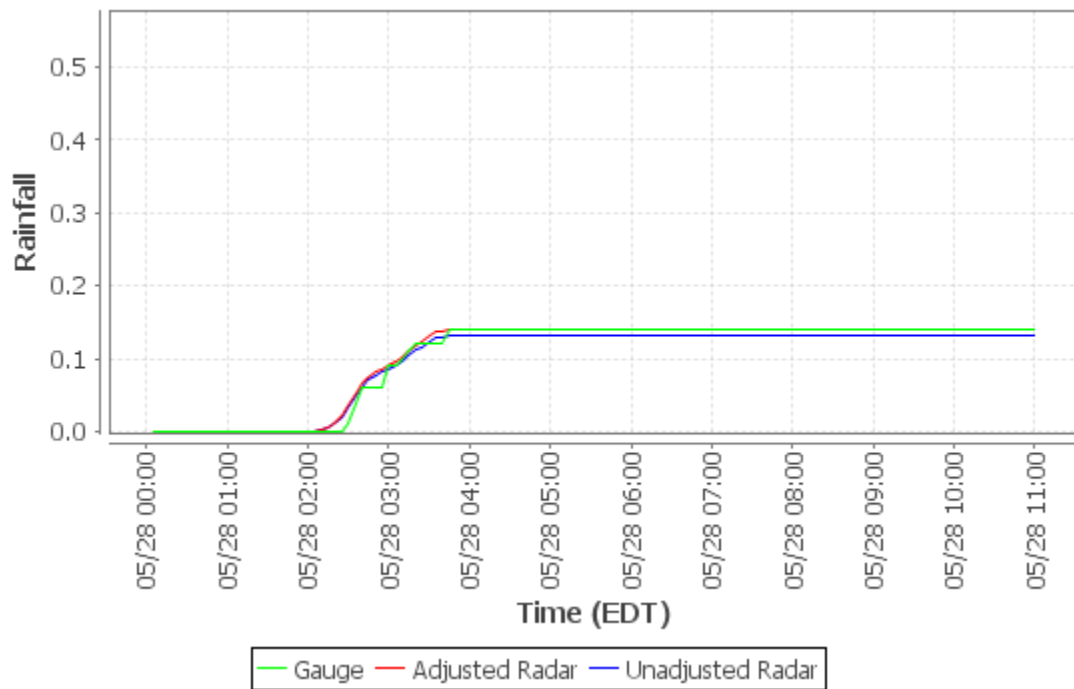
**Cumulative Distribution Plot - Hampton Municipal Bldg (Loc31)**



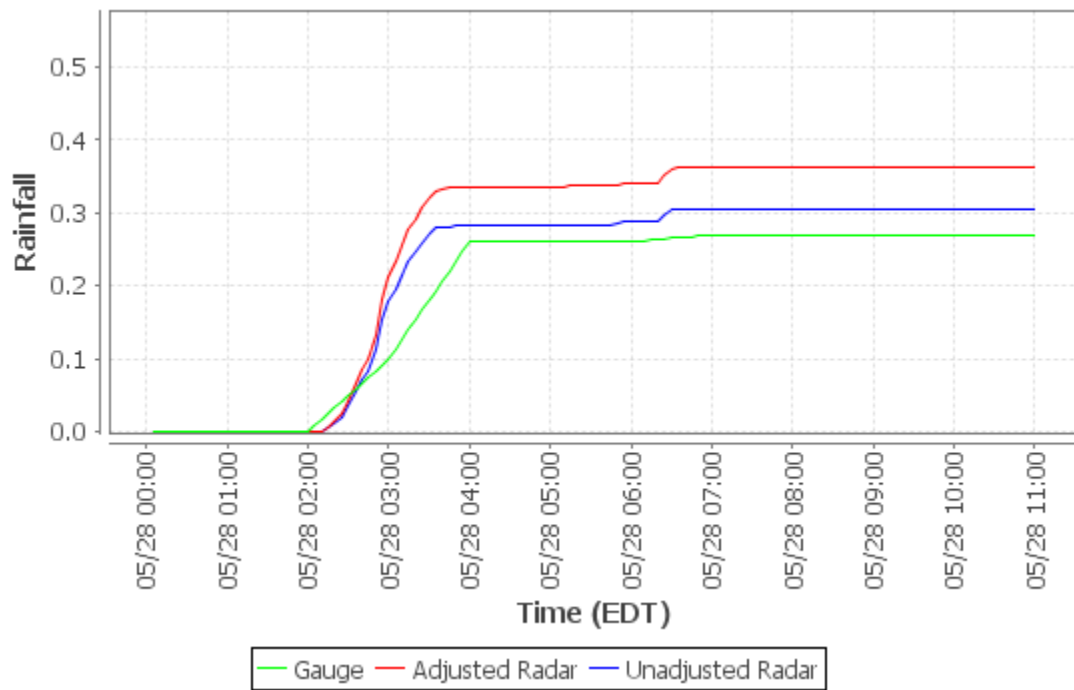
**Cumulative Distribution Plot - Arnold (Loc32)**



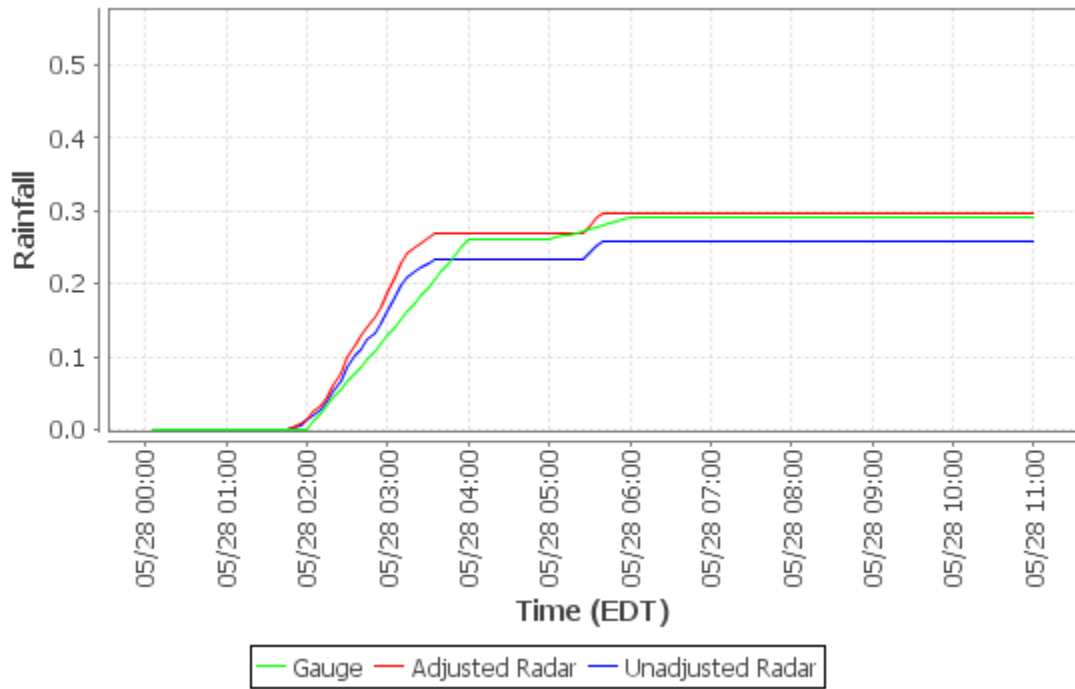
**Cumulative Distribution Plot - Richland TWP (Loc33)**



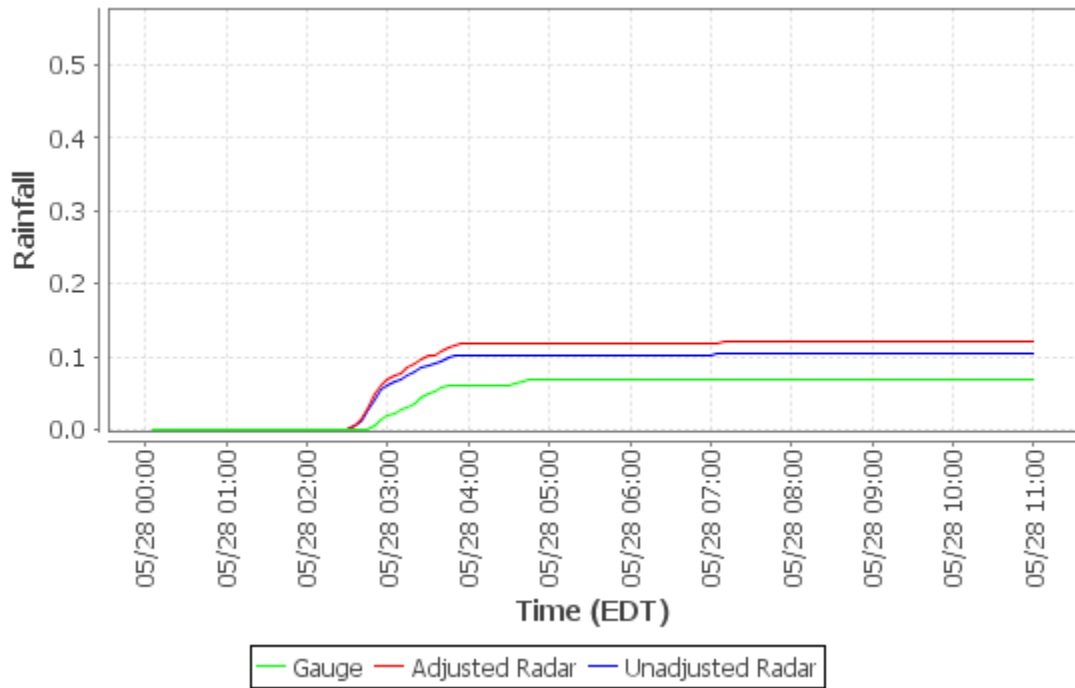
**Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)**



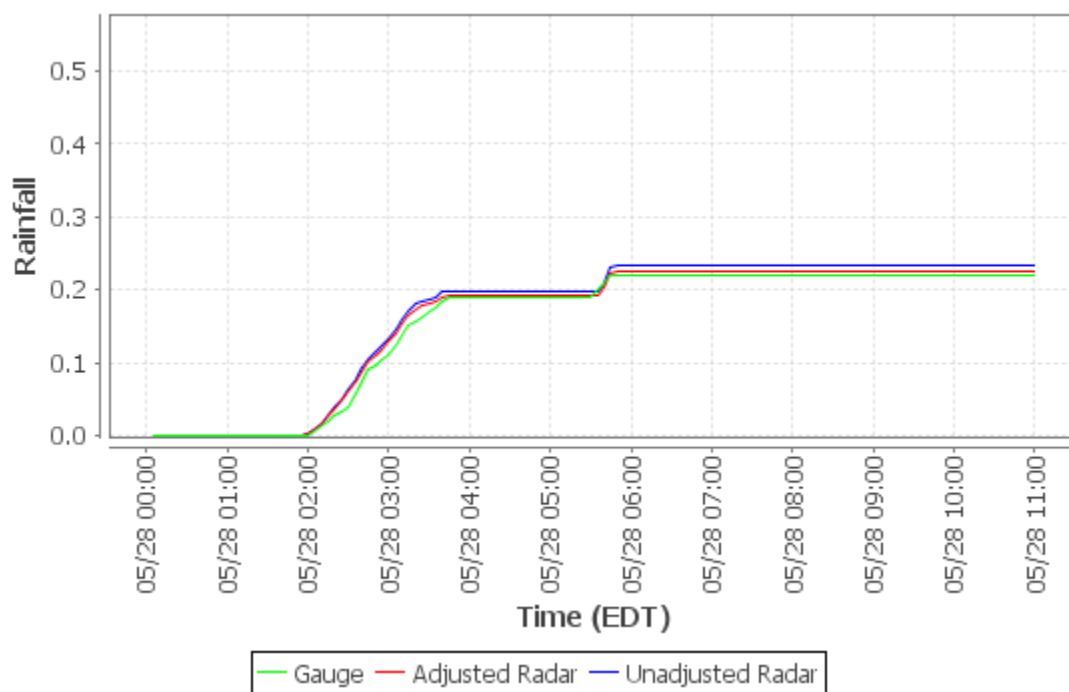
**Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)**



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



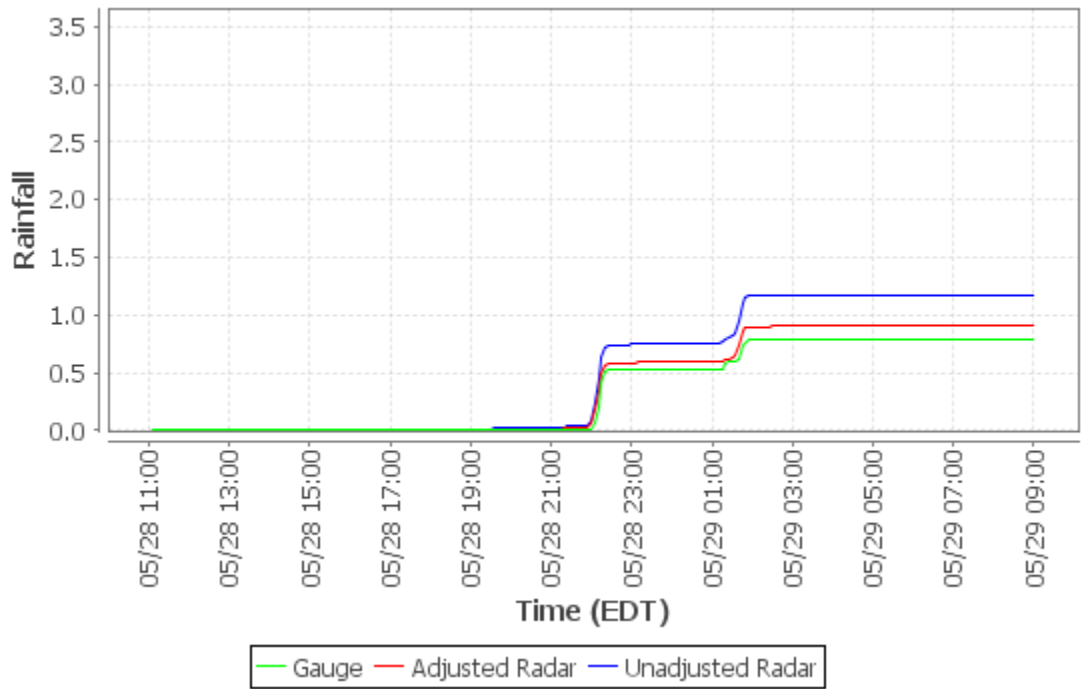
**Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth  
(03085734)**



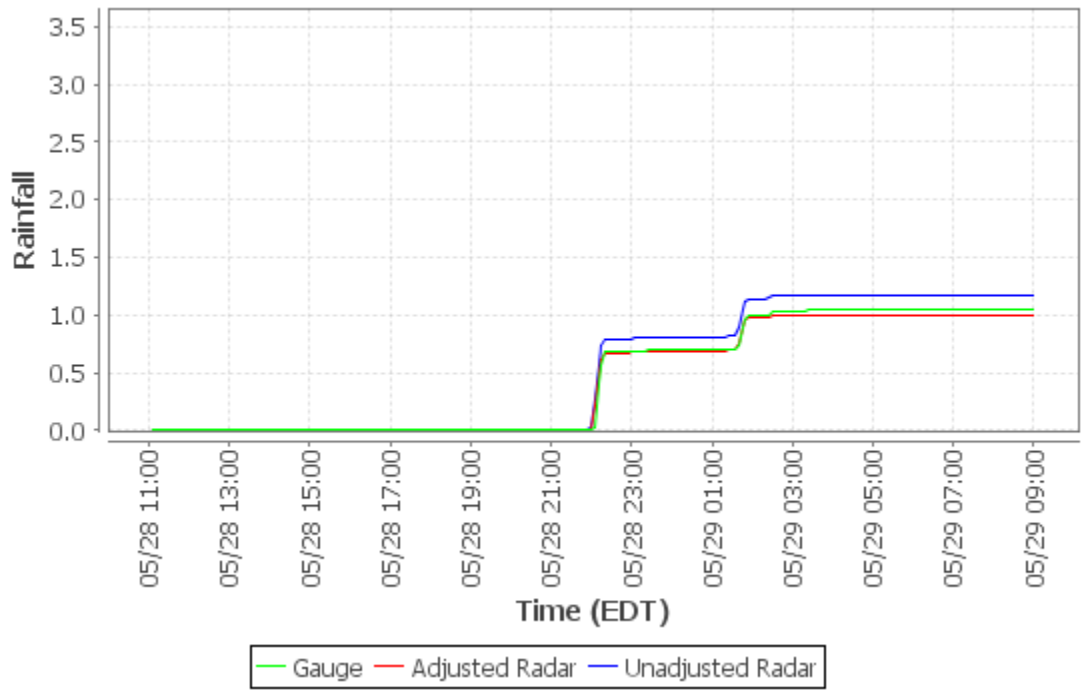
## **Appendix K - Event 9 (2019-05-28 PM) CDPs**



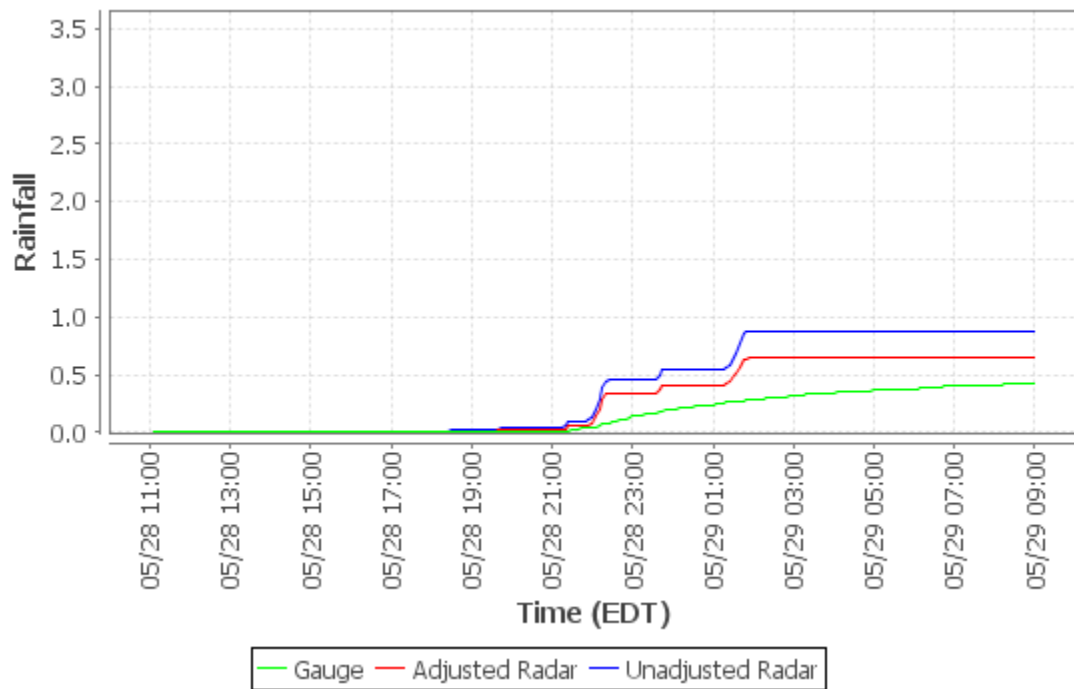
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



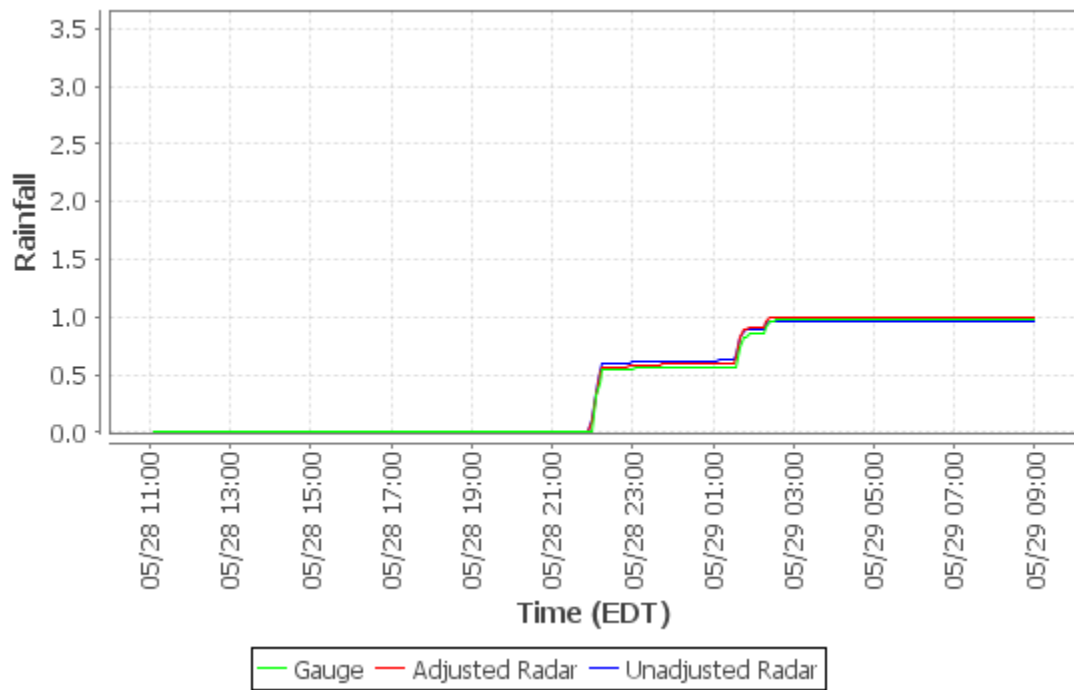
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



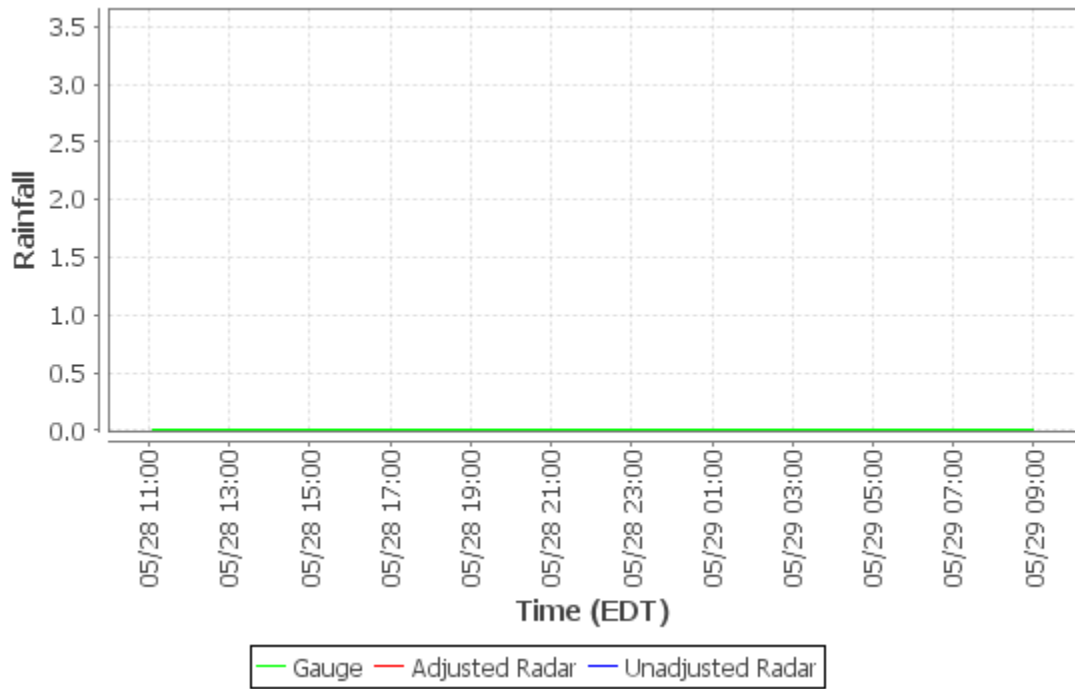
**Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)**



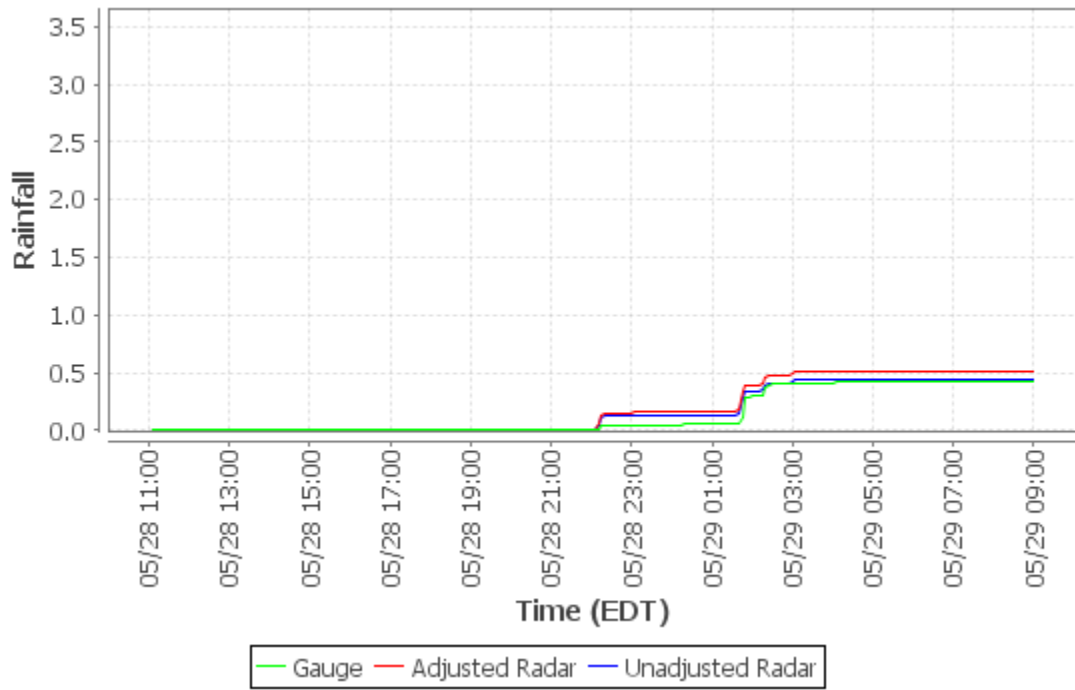
**Cumulative Distribution Plot - Kennedy Twp PS (Loc04)**



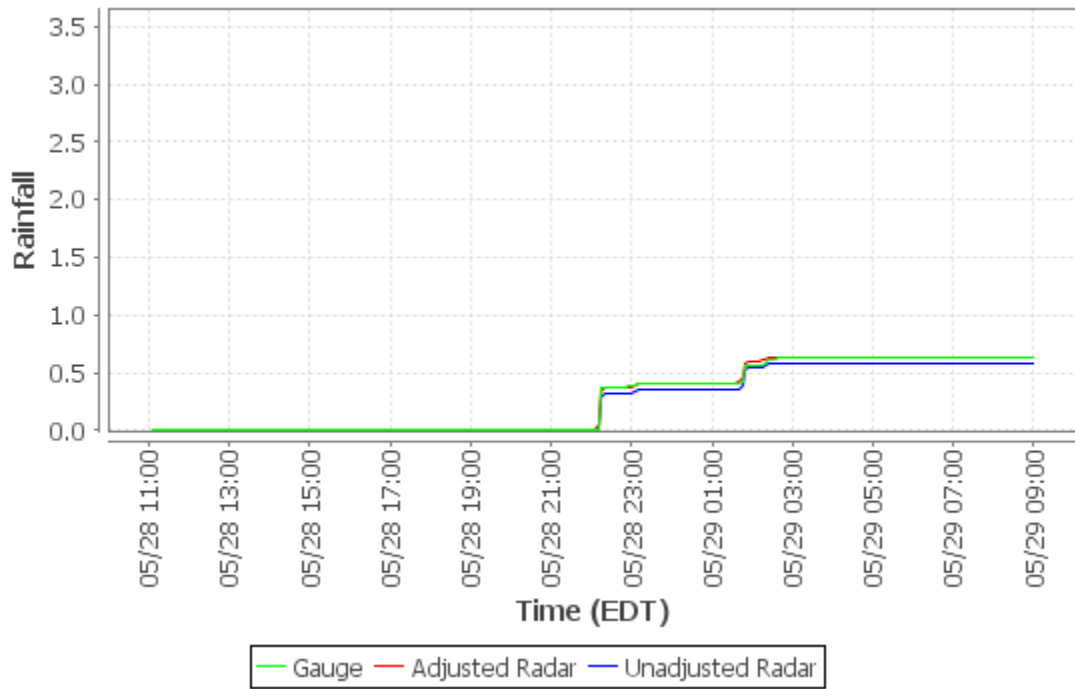
**Cumulative Distribution Plot - Upper St. Clair (Loc05)**



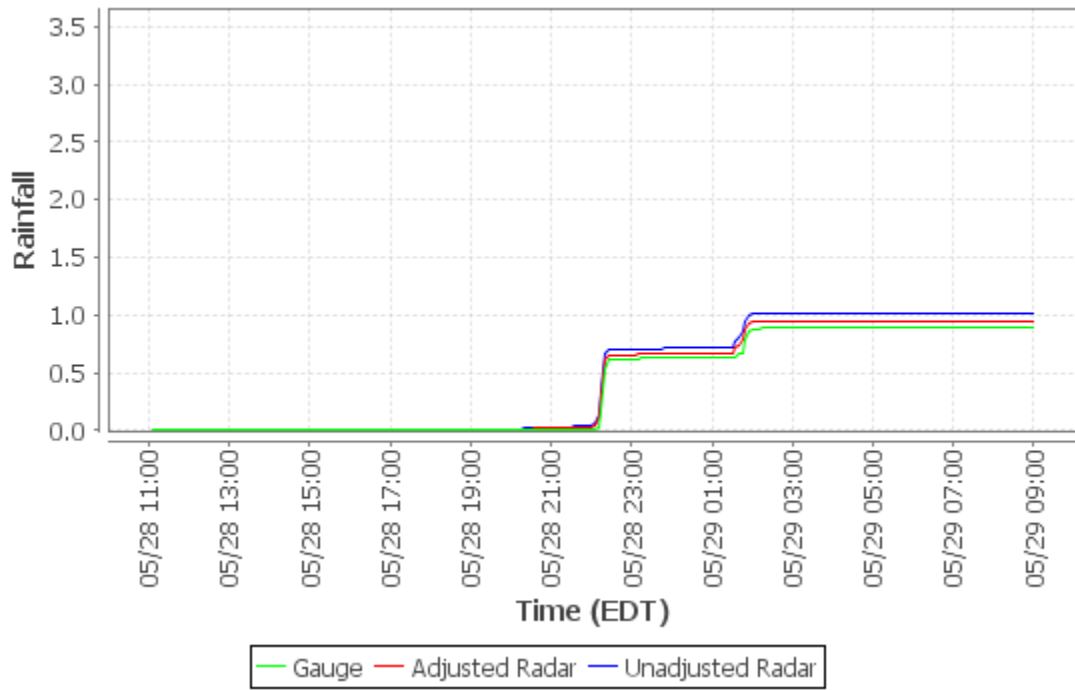
**Cumulative Distribution Plot - Carnegie Transit Time (Loc06)**



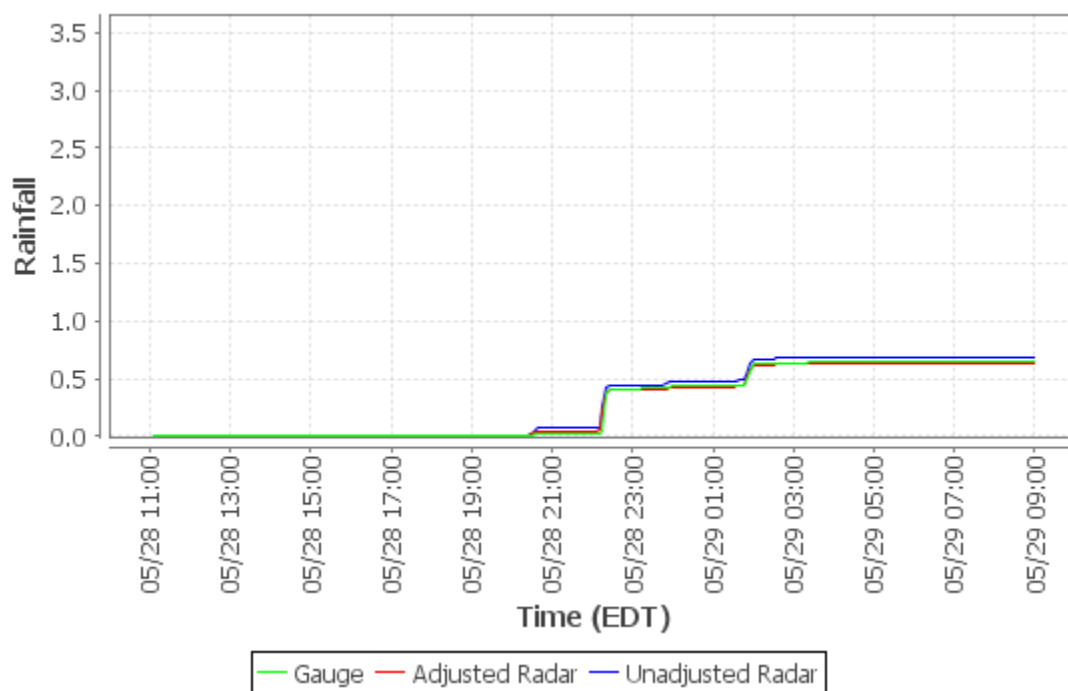
**Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)**



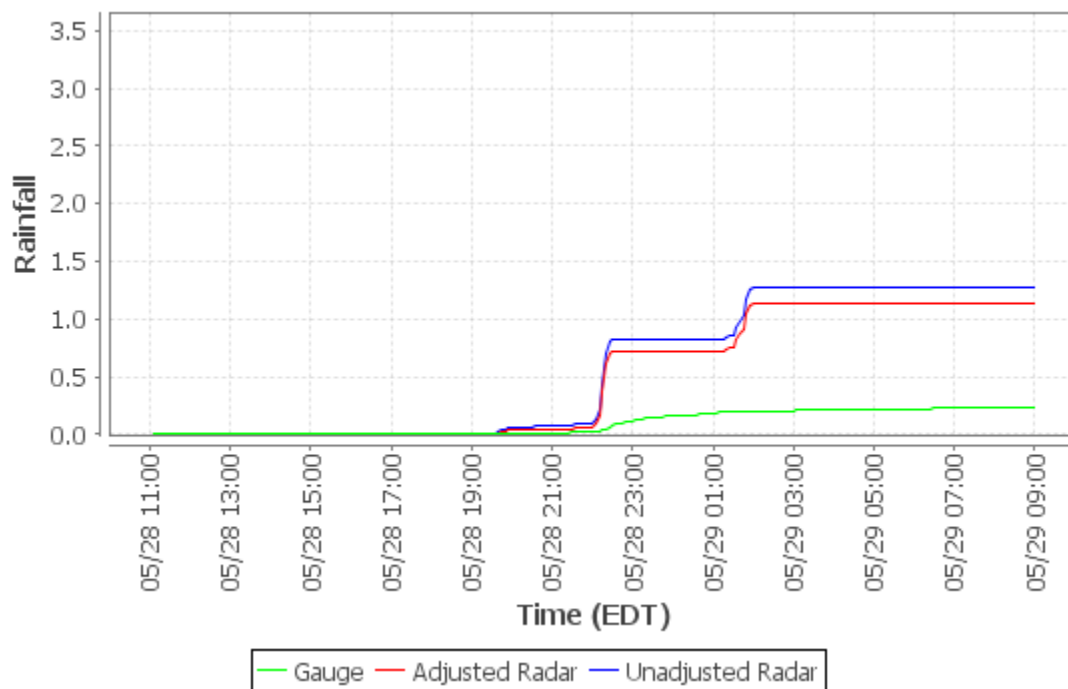
**Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)**



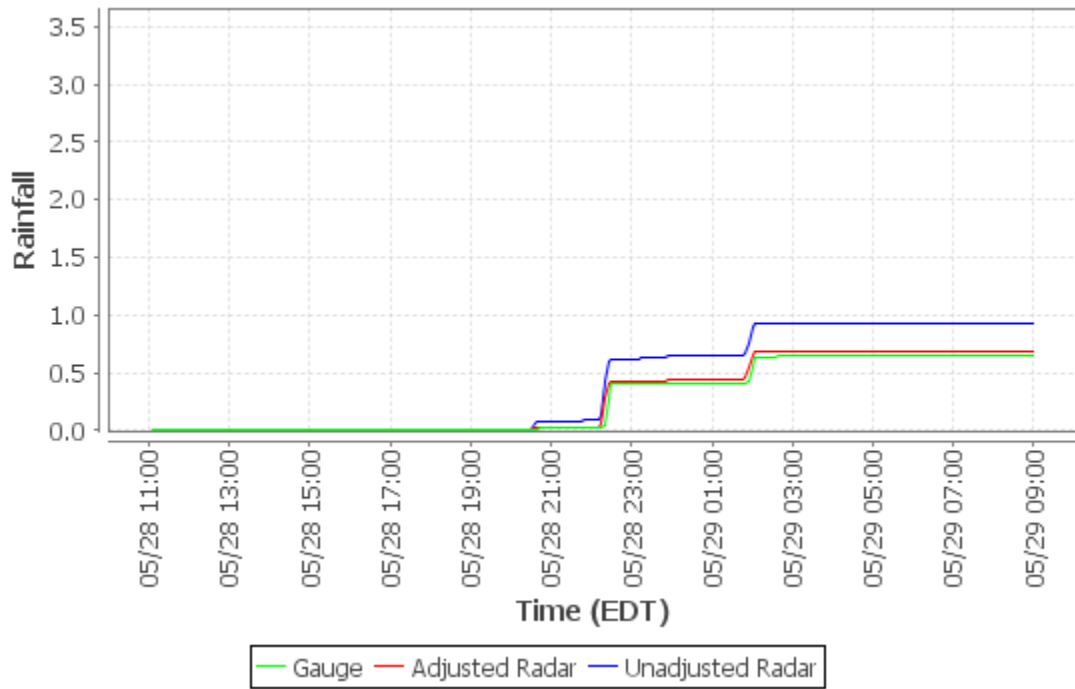
**Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)**



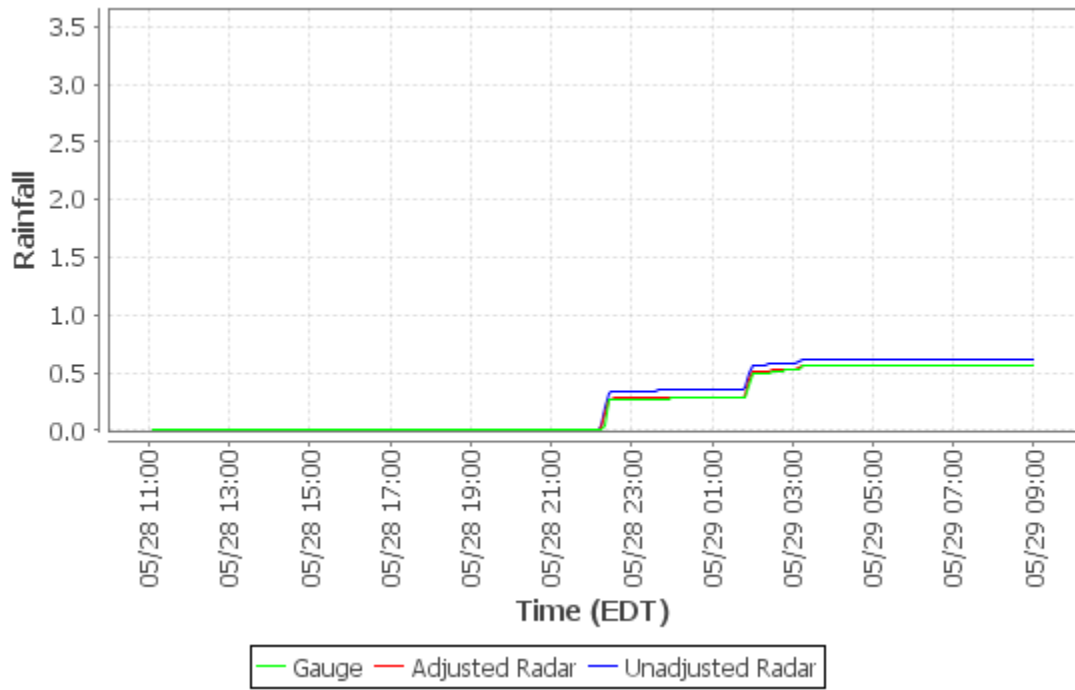
**Cumulative Distribution Plot - PWSA-Highland Park (Loc10)**



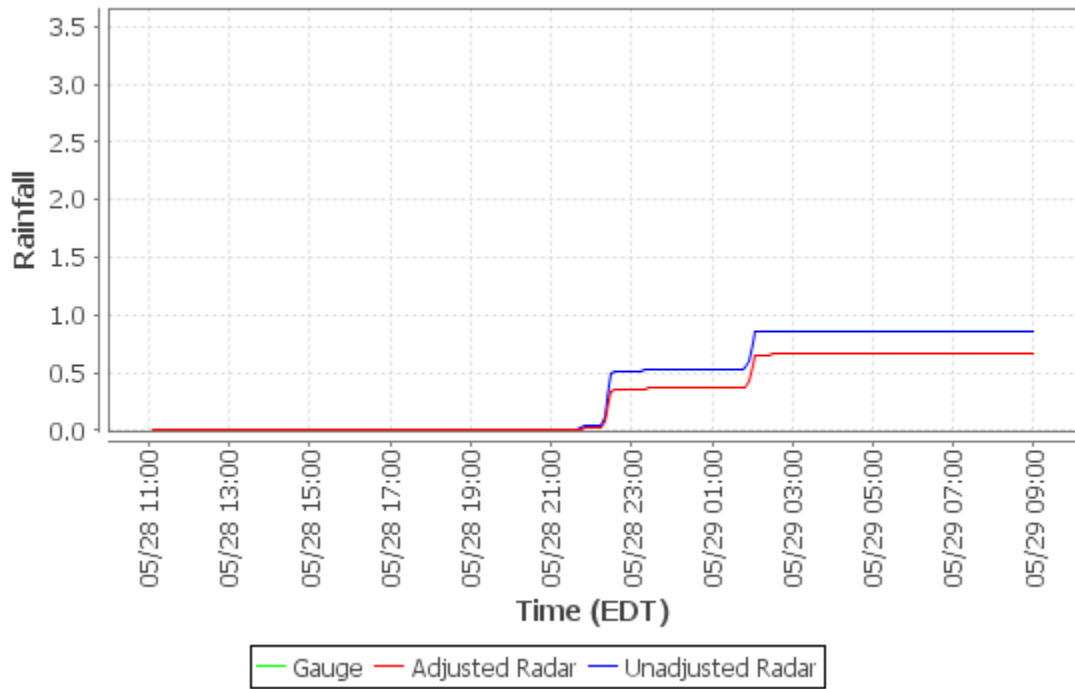
**Cumulative Distribution Plot - M-46 Access Shaft (Loc11)**



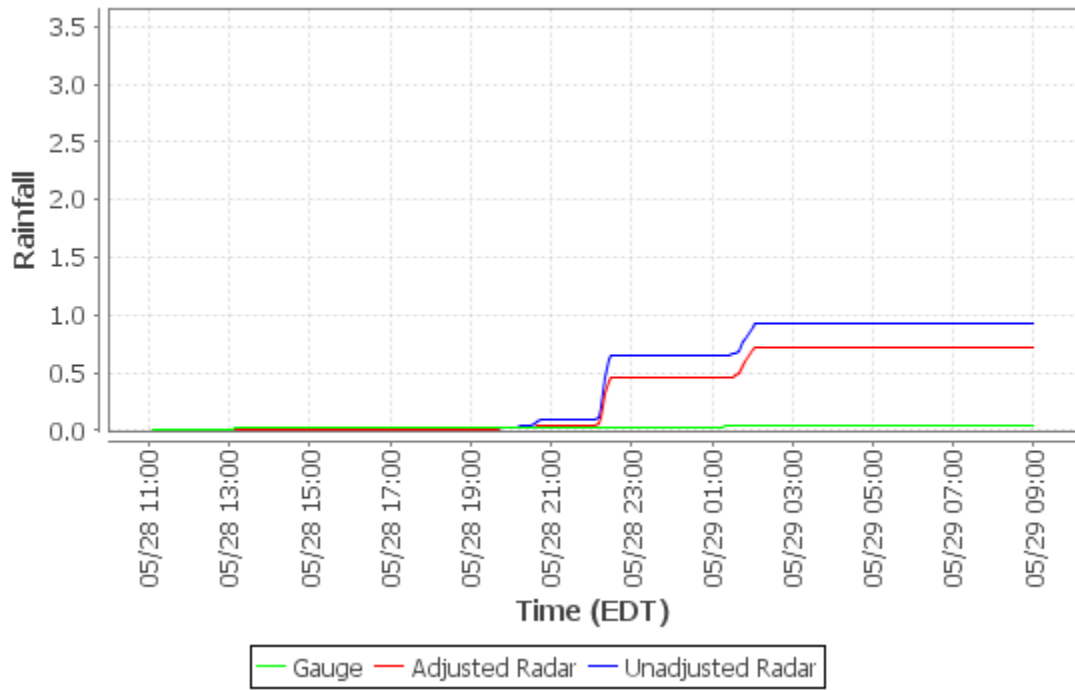
**Cumulative Distribution Plot - Baldwin (Loc12)**



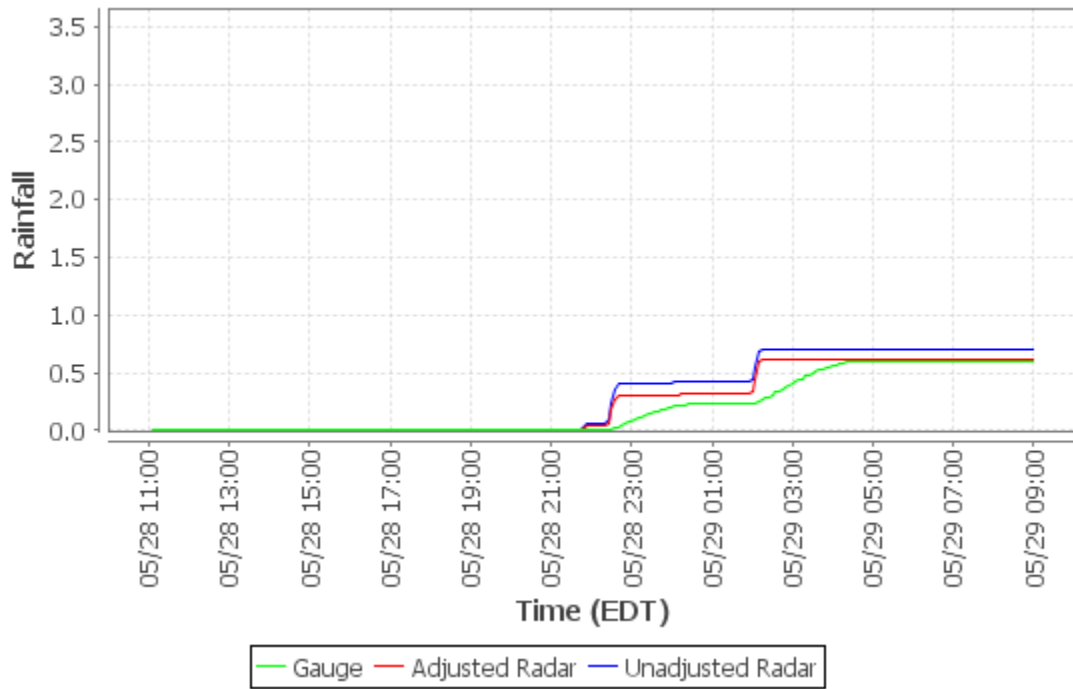
**Cumulative Distribution Plot - M-59 Access Shaft (Loc13)**



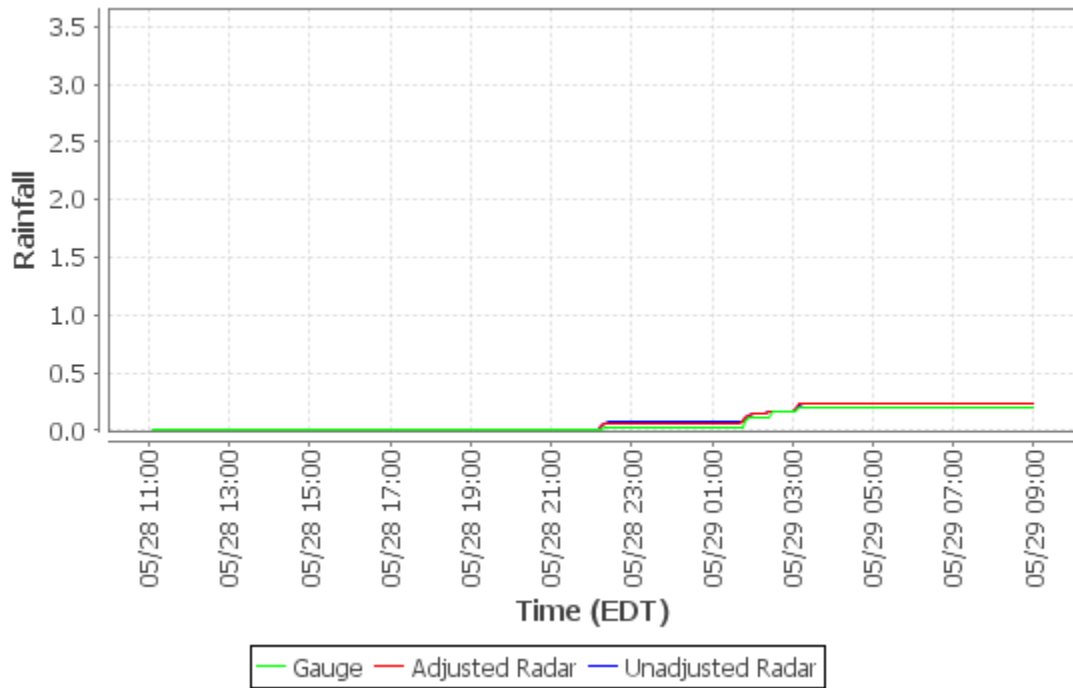
**Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)**



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

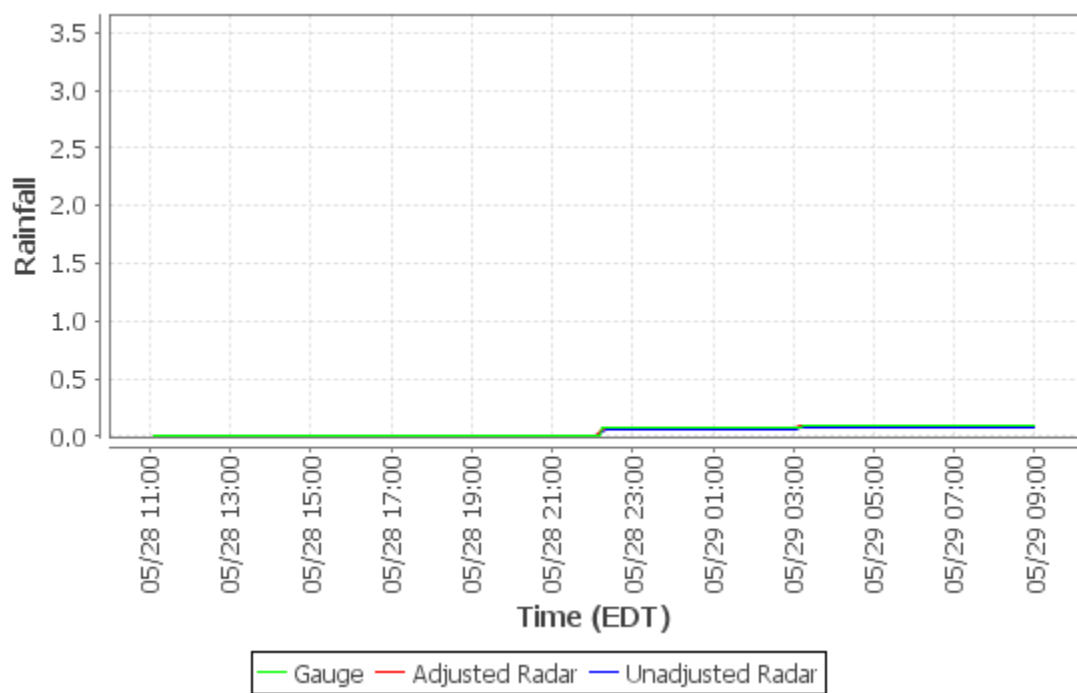


**Cumulative Distribution Plot - Castle Shannon (Loc16)**

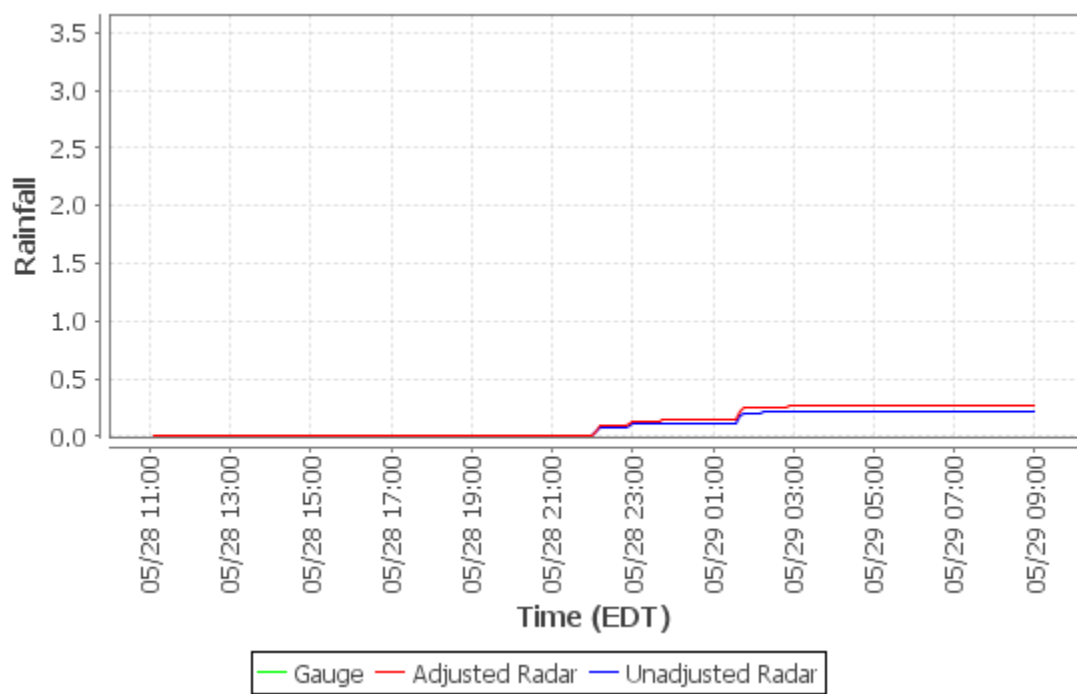




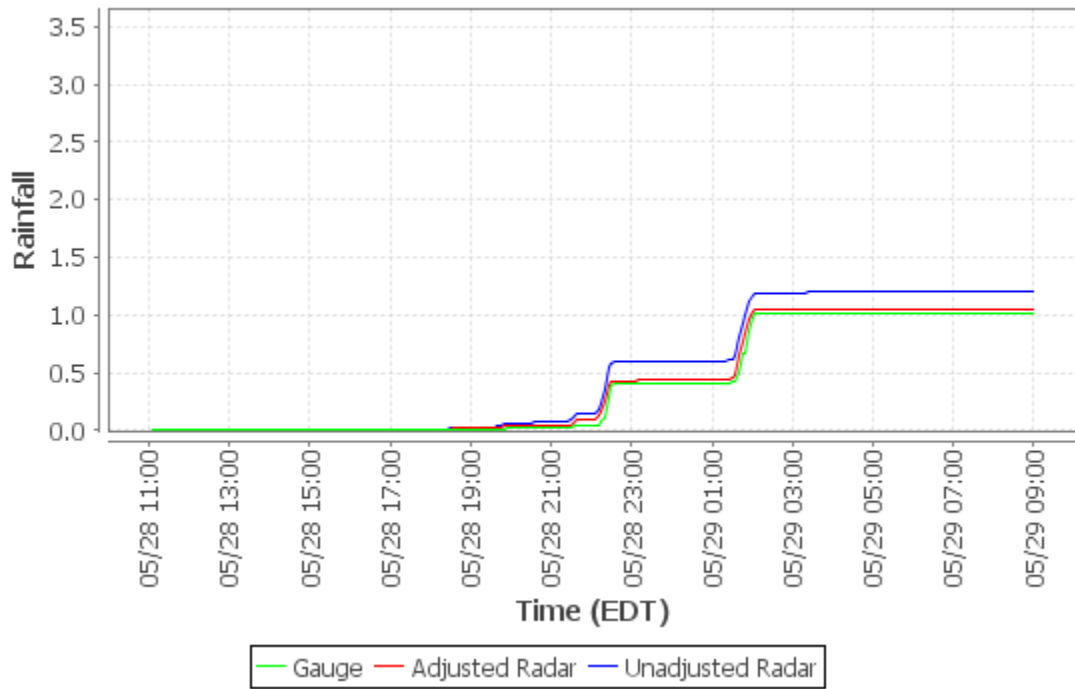
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



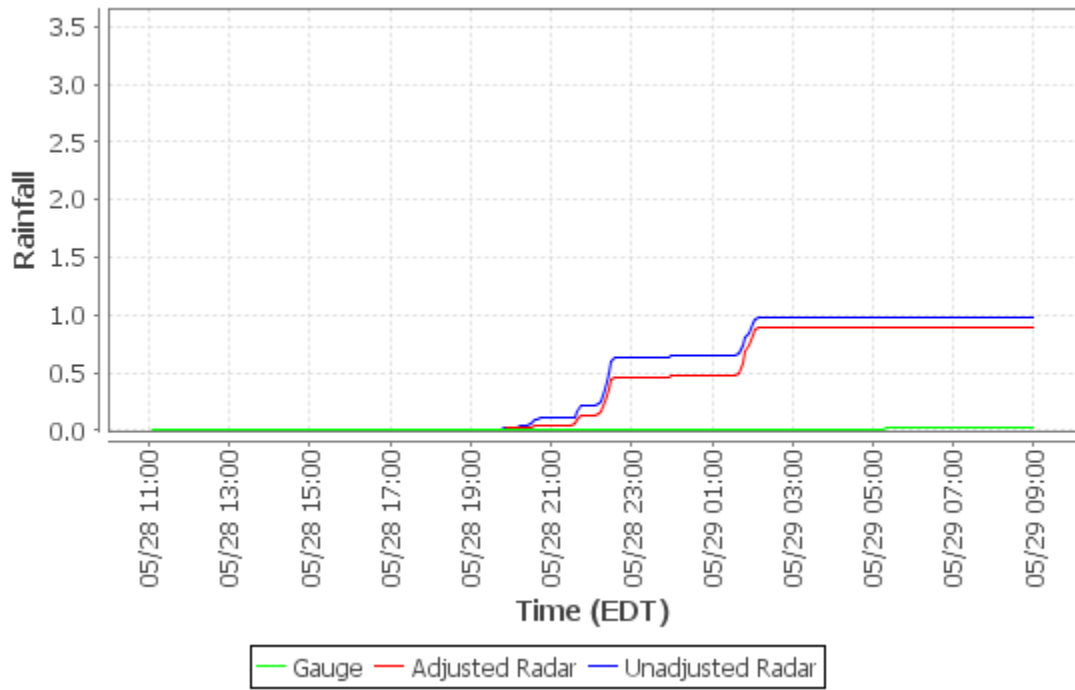
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



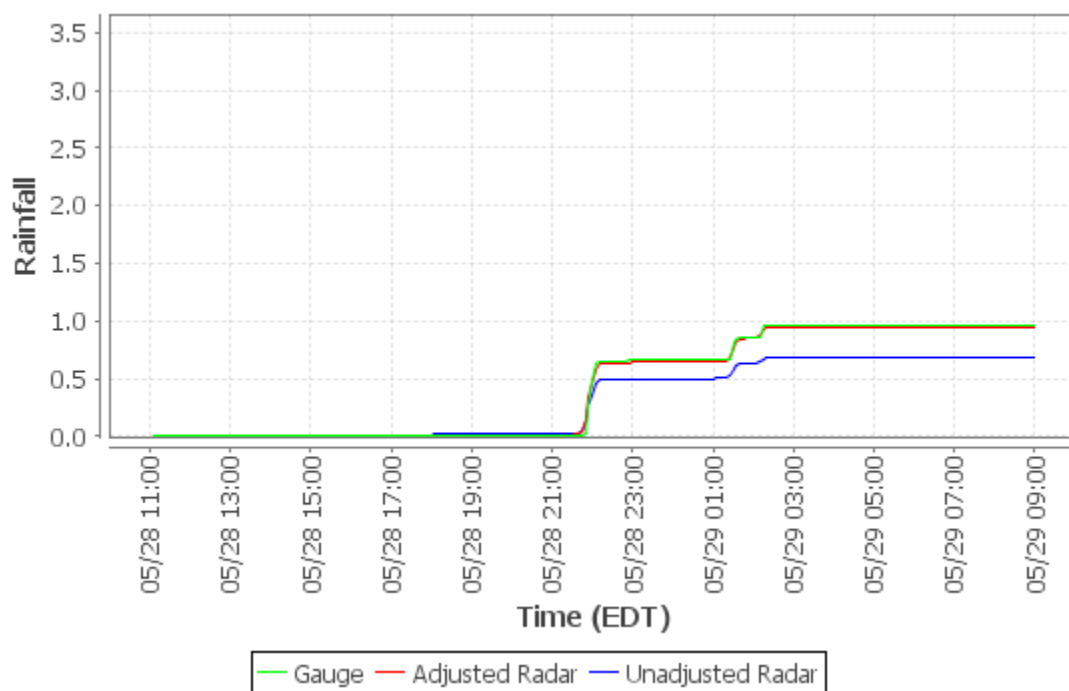
**Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)**



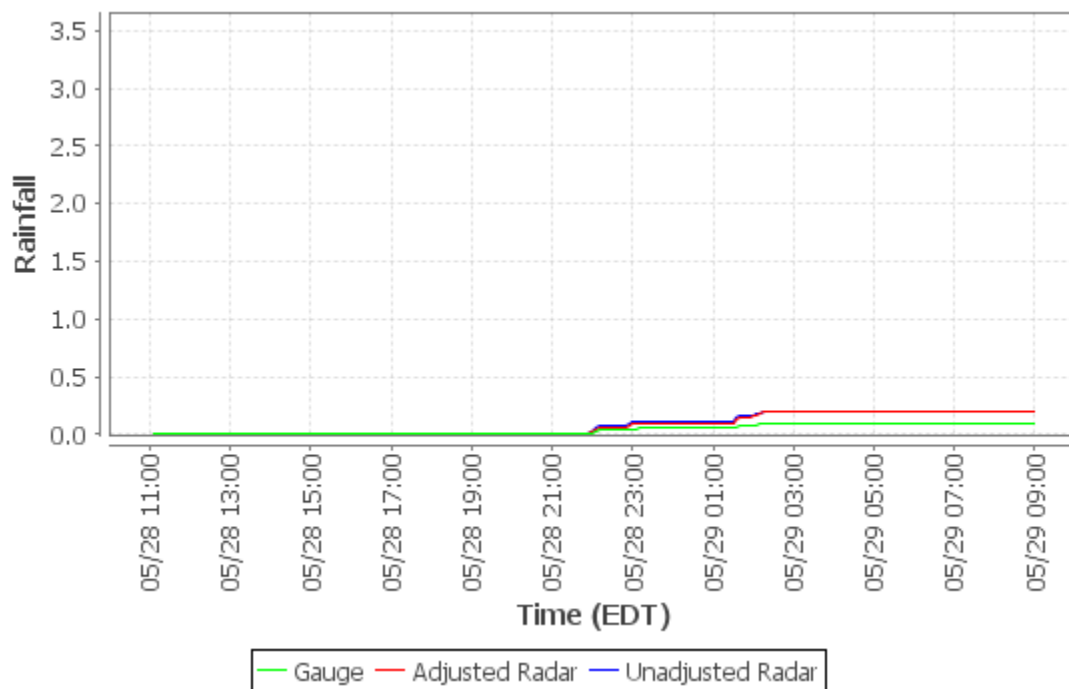
**Cumulative Distribution Plot - Gascola Eq Facility (Loc20)**



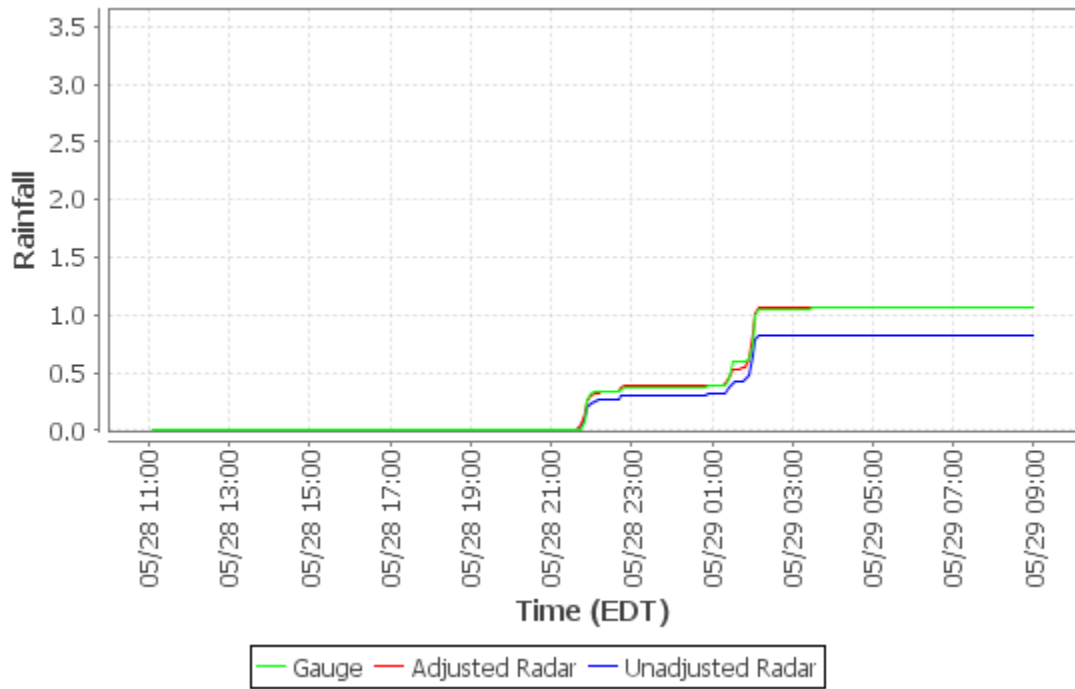
**Cumulative Distribution Plot - Moon TWP (Loc21)**



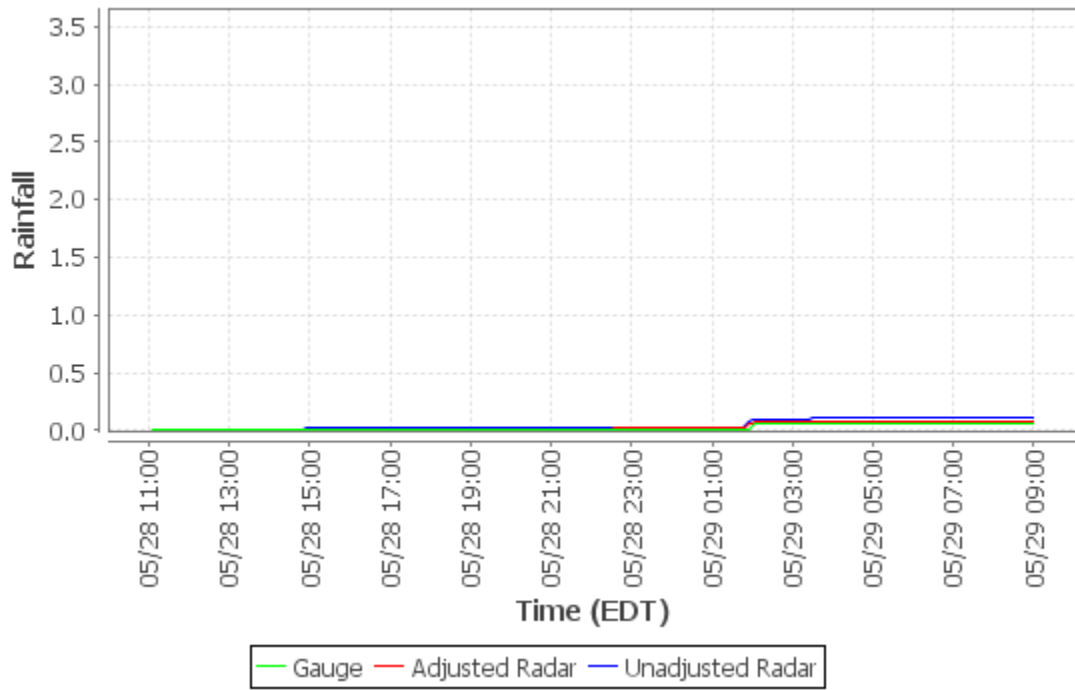
**Cumulative Distribution Plot - North Fayette TWP (Loc22)**



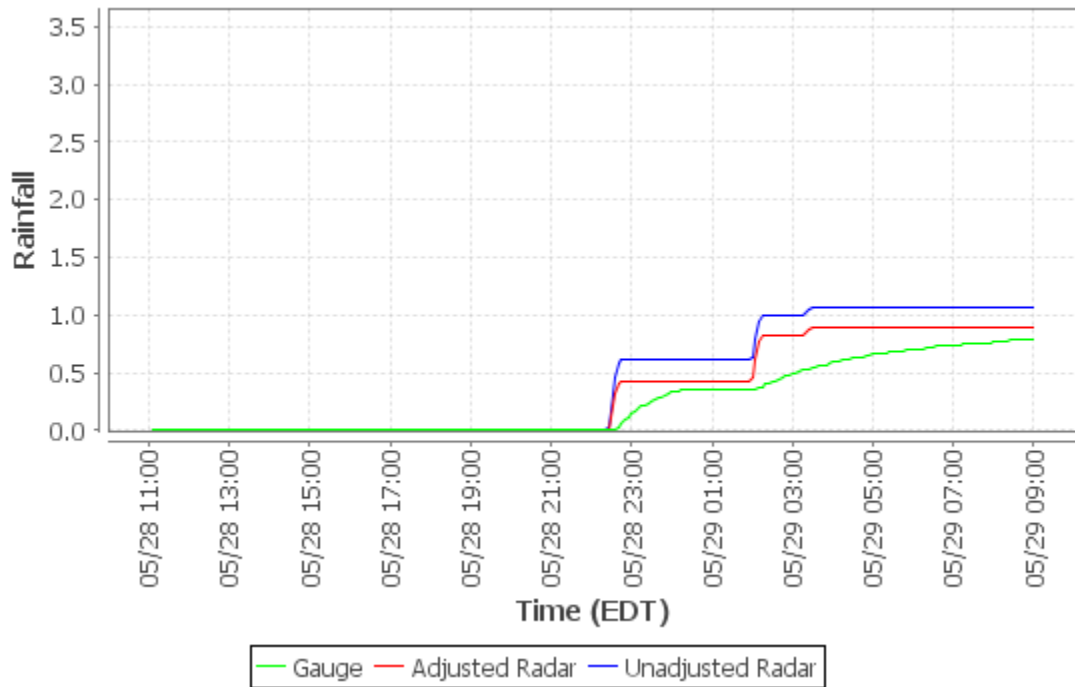
**Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)**



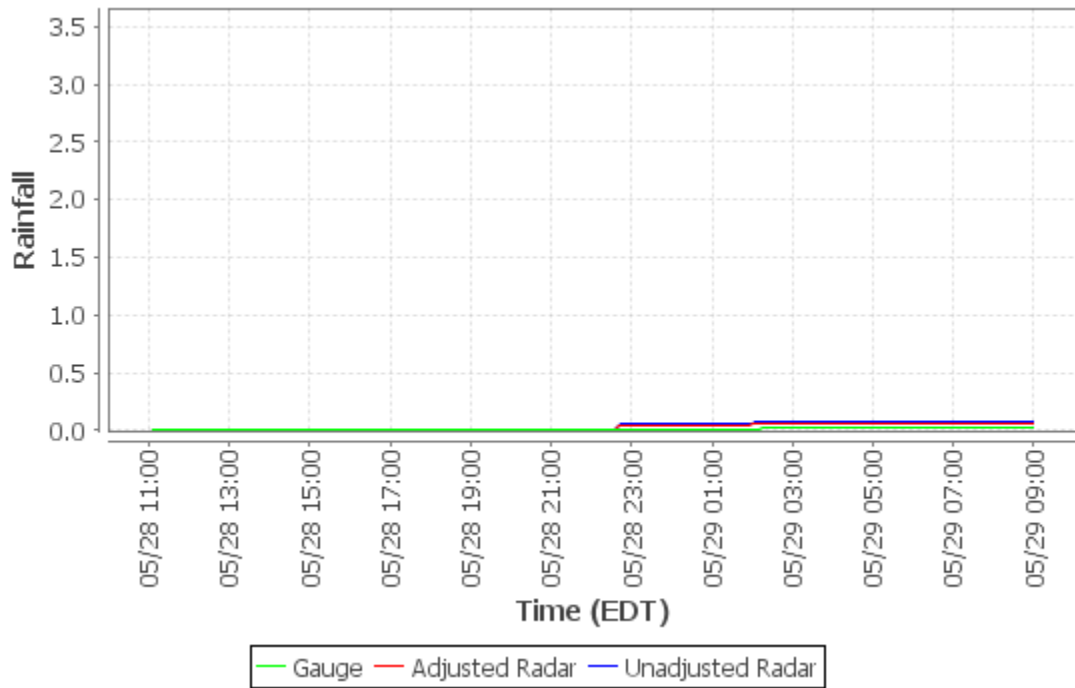
**Cumulative Distribution Plot - Jefferson Hills (Loc24)**



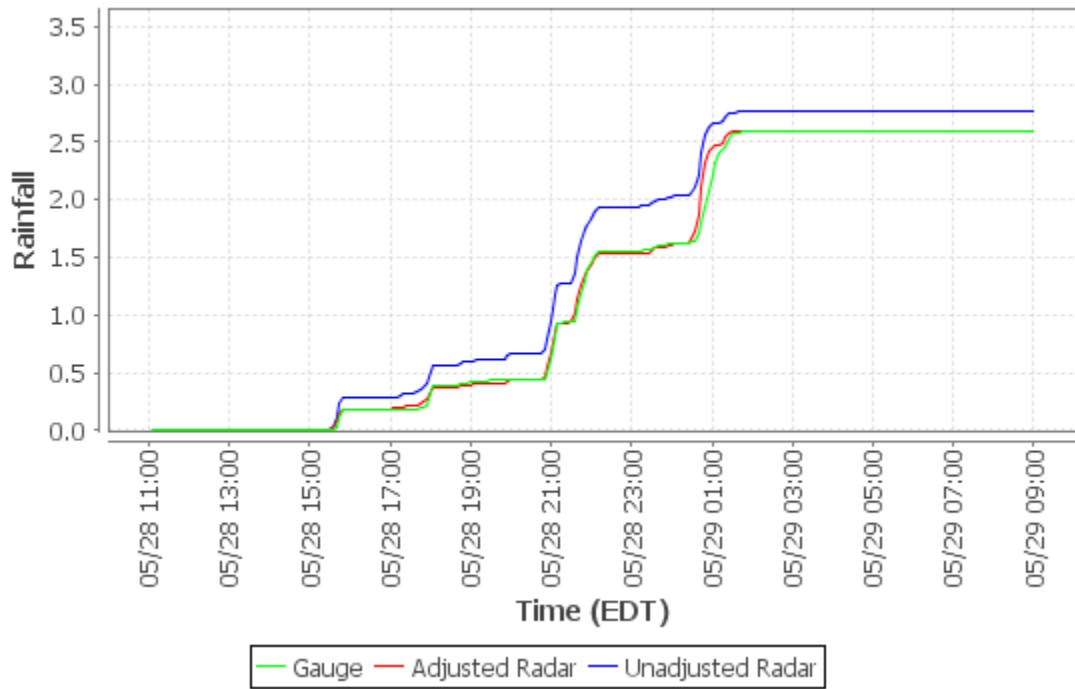
**Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)**



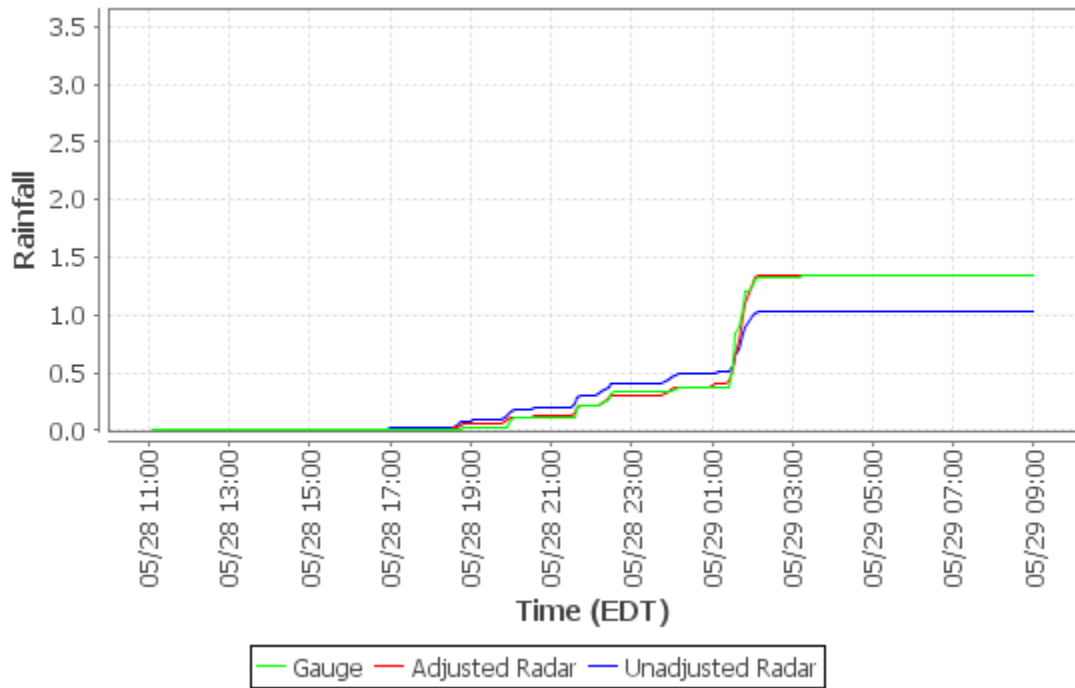
**Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)**



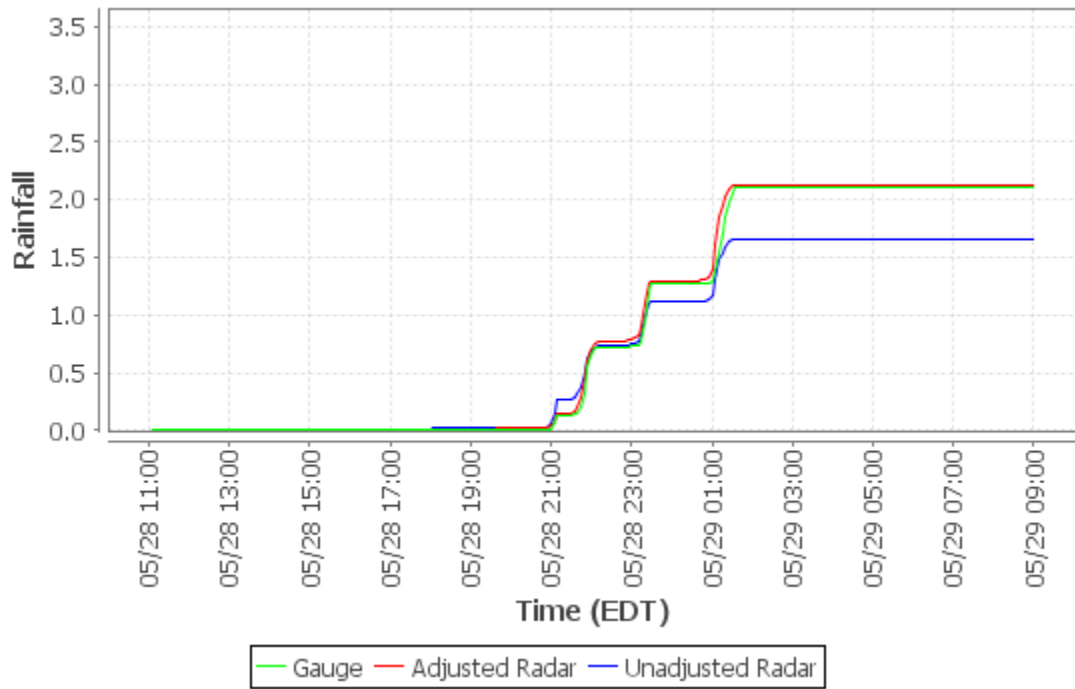
**Cumulative Distribution Plot - Marshall TWP (Loc27)**



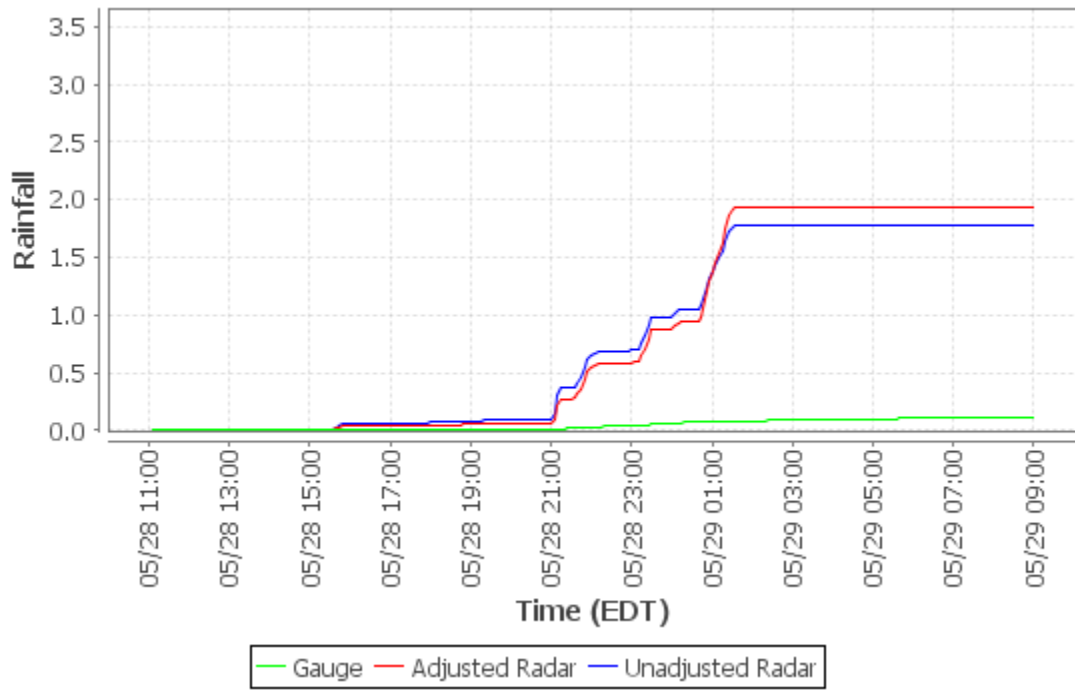
**Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)**



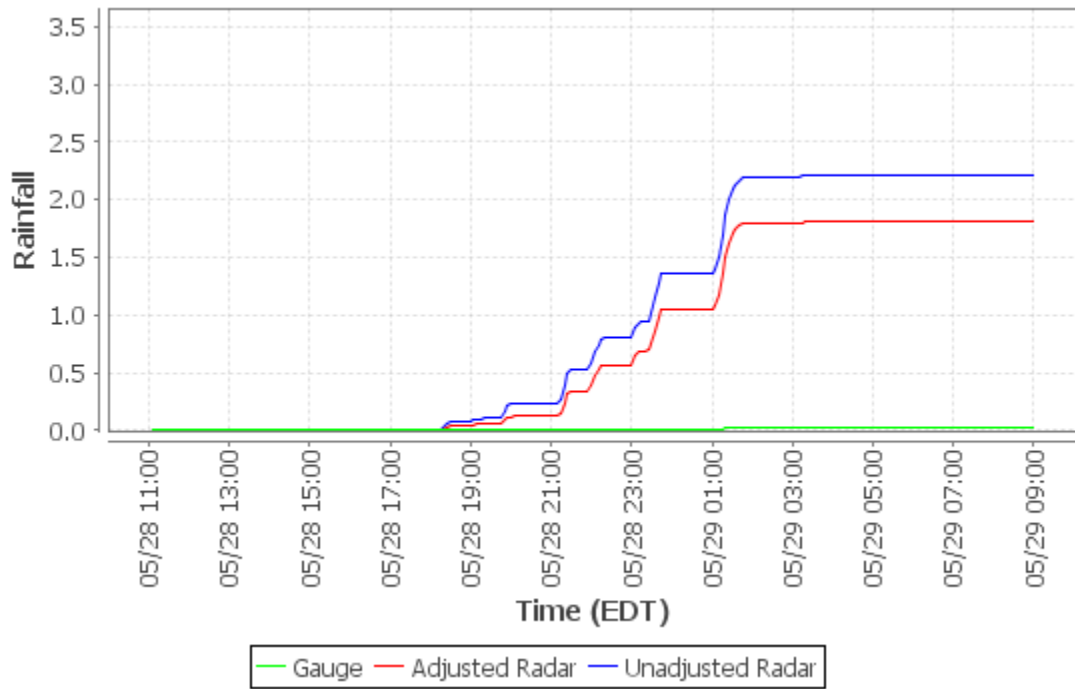
**Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)**



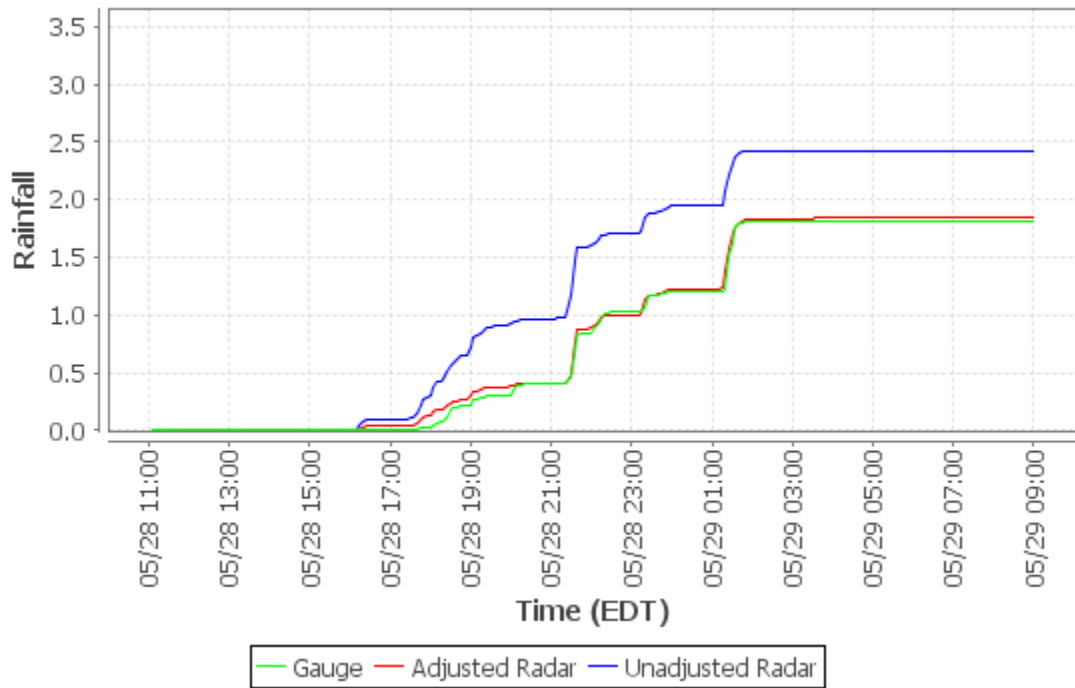
**Cumulative Distribution Plot - McCandless Twm Hall (Loc30)**



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

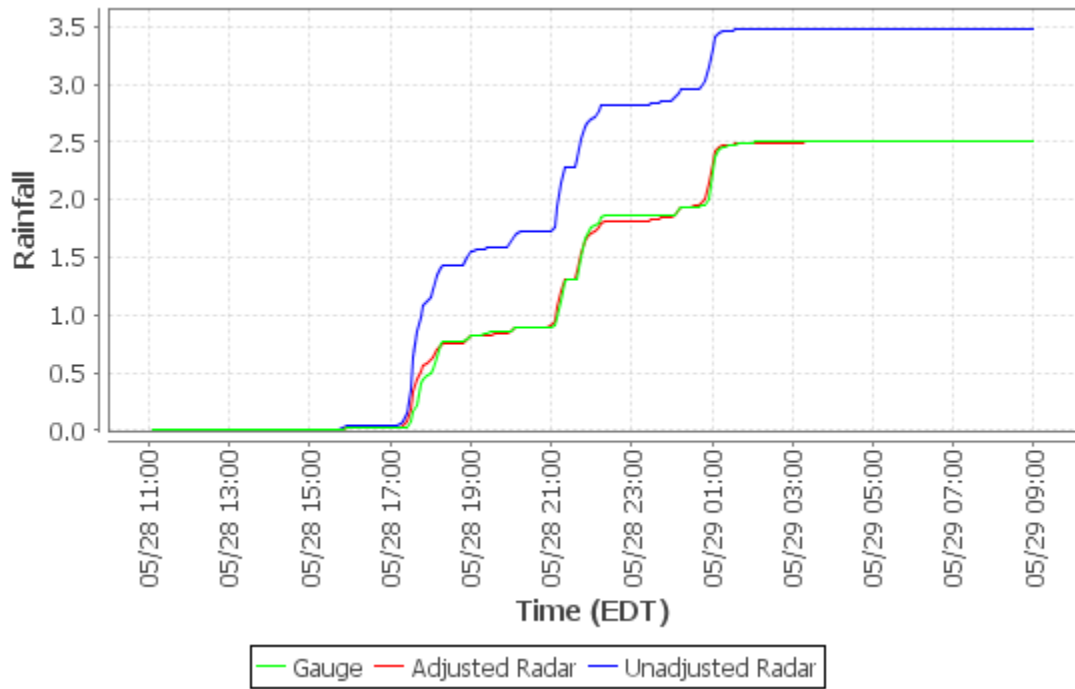


**Cumulative Distribution Plot - Arnold (Loc32)**

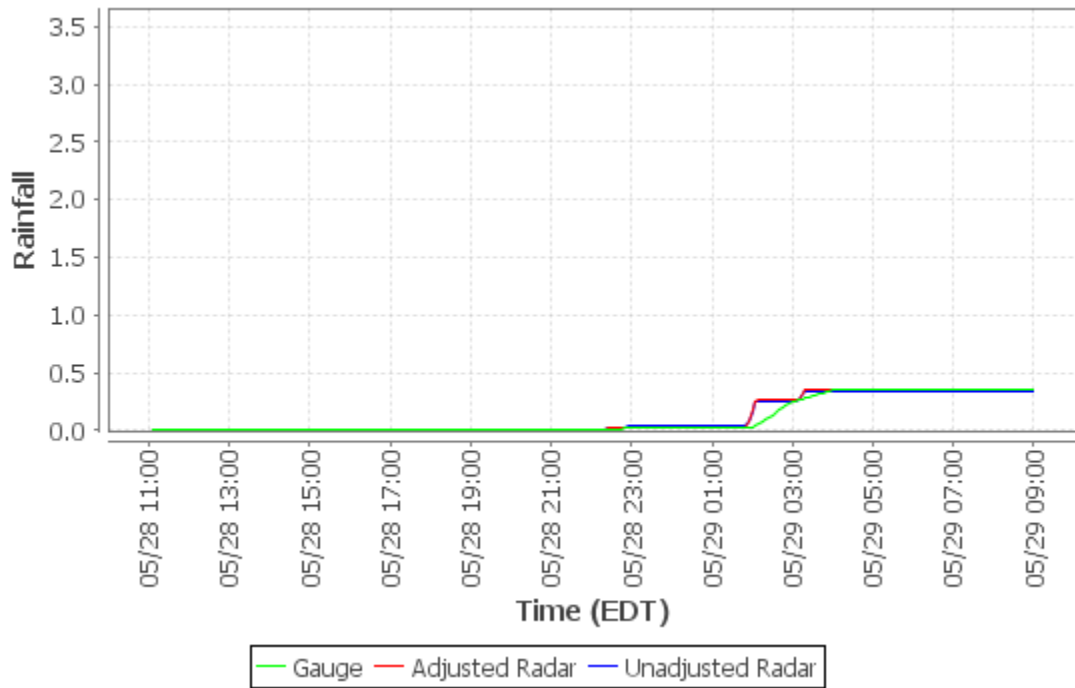




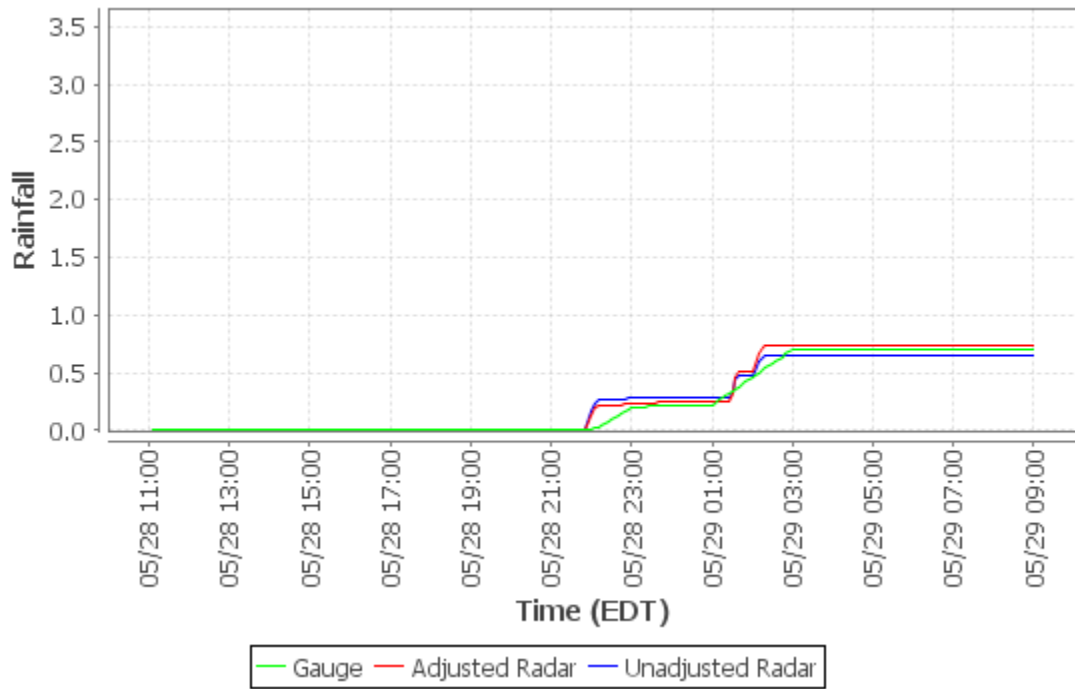
**Cumulative Distribution Plot - Richland TWP (Loc33)**



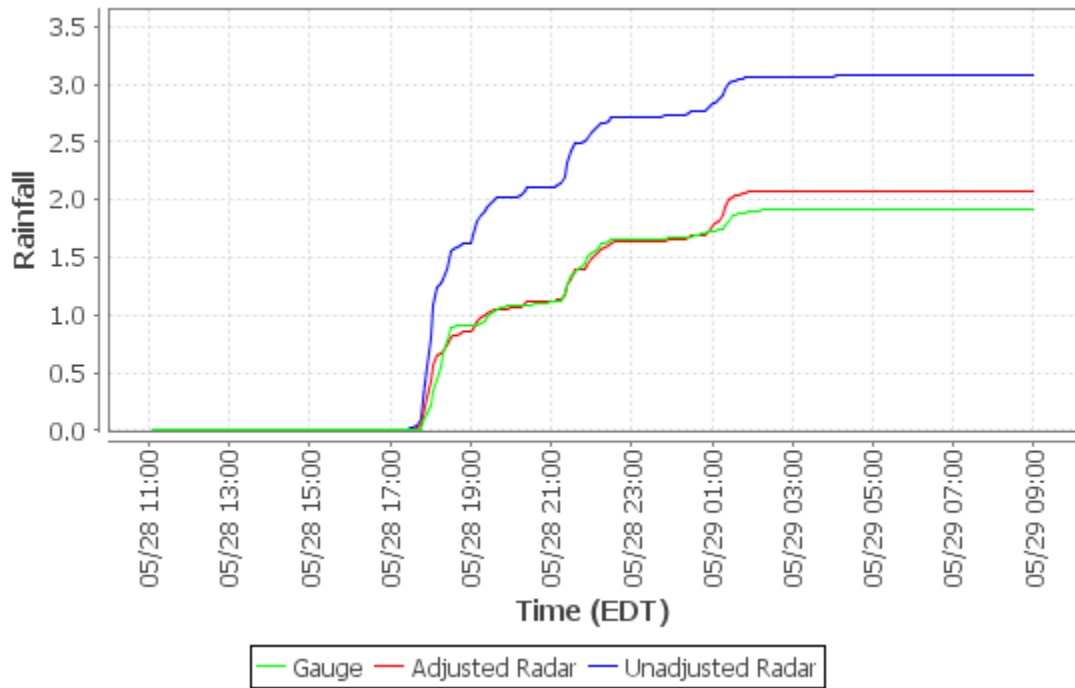
**Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)**



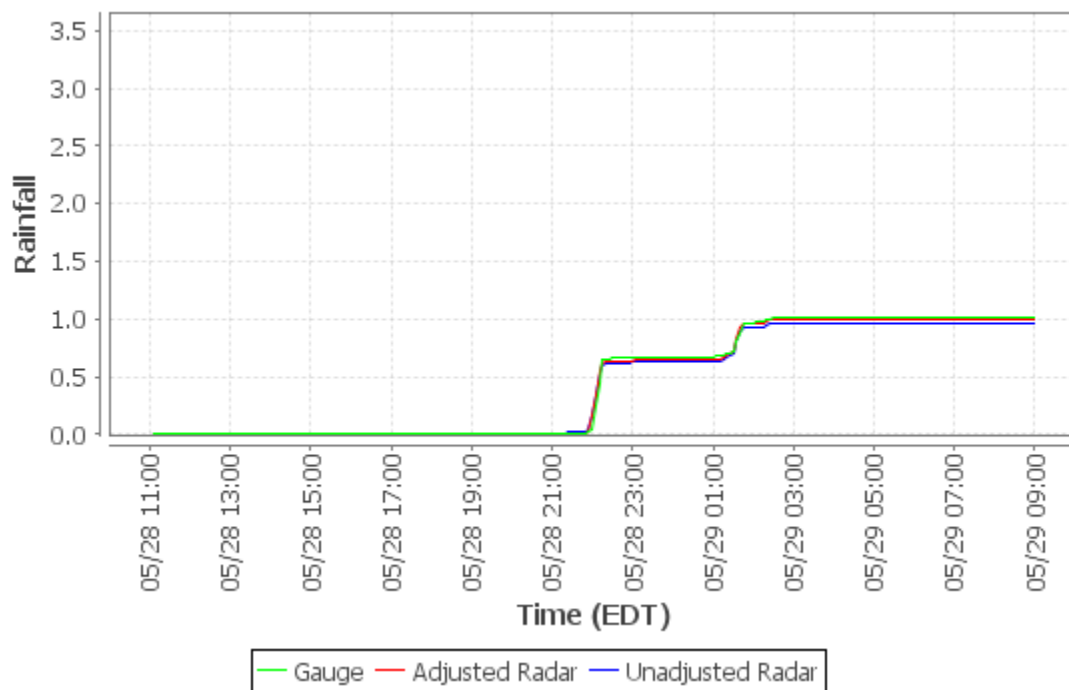
**Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)**



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

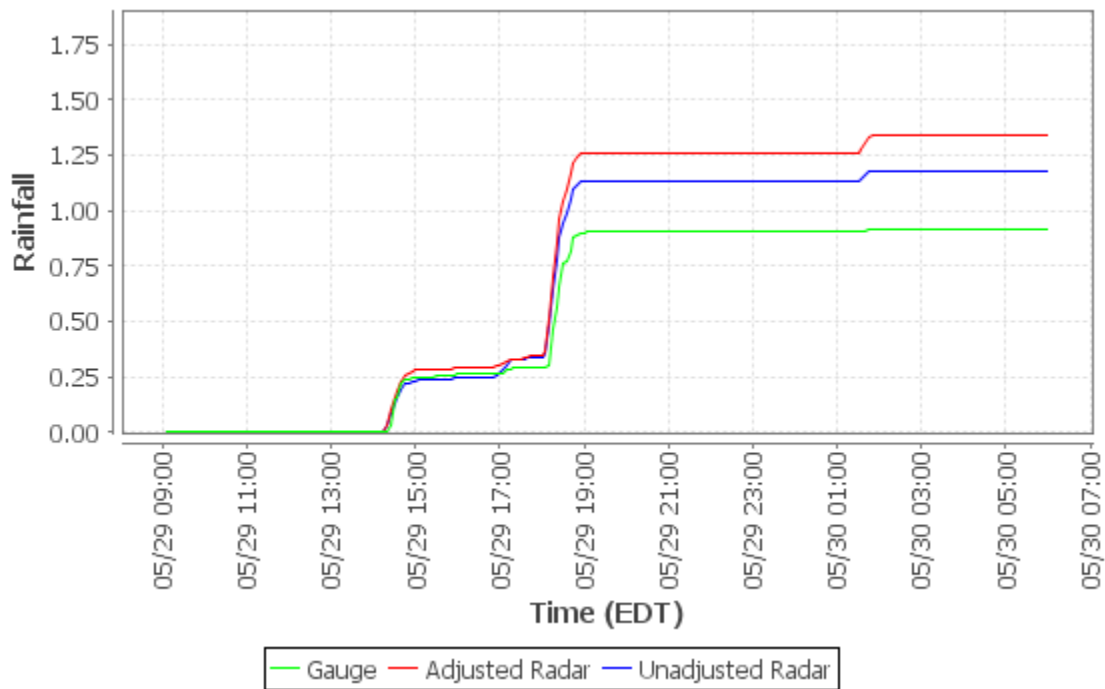


**Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth  
(03085734)**

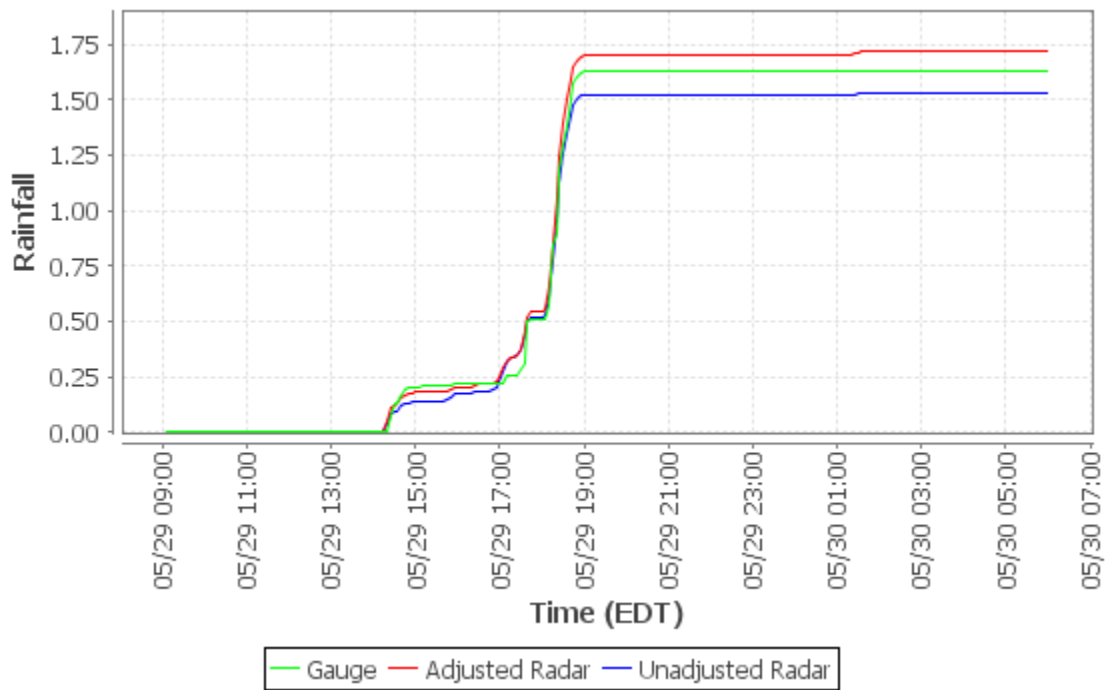


## **Appendix L - Event 10 (2019-05-29) CDPs**

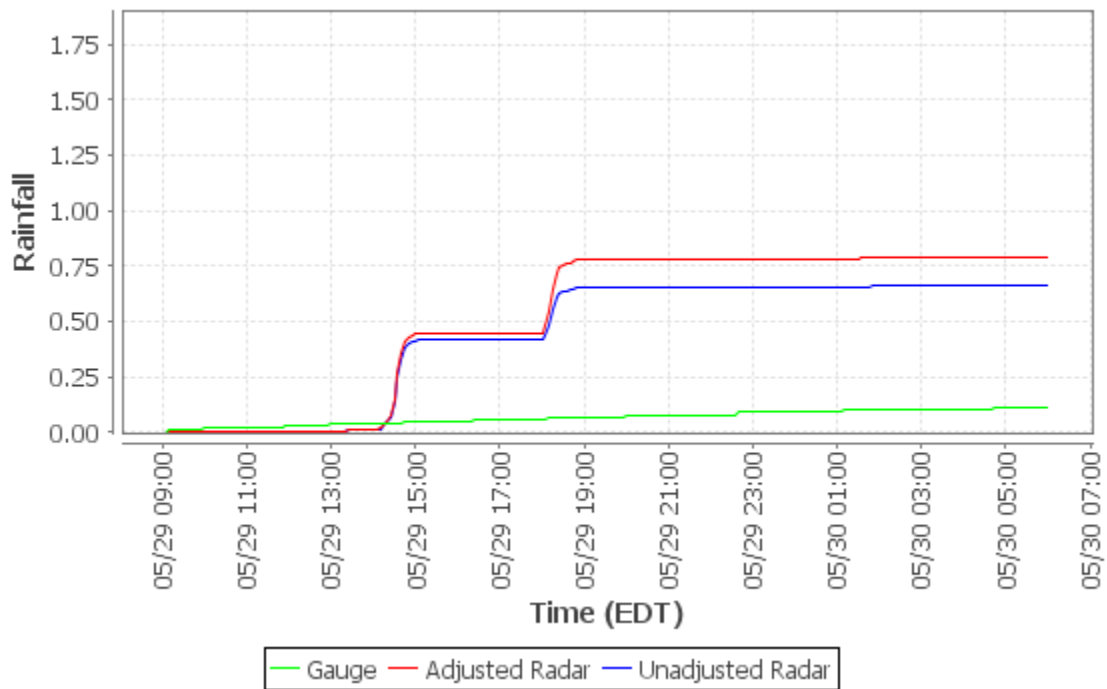
**Cumulative Distribution Plot - PWSA-Montana St. (Loc01)**



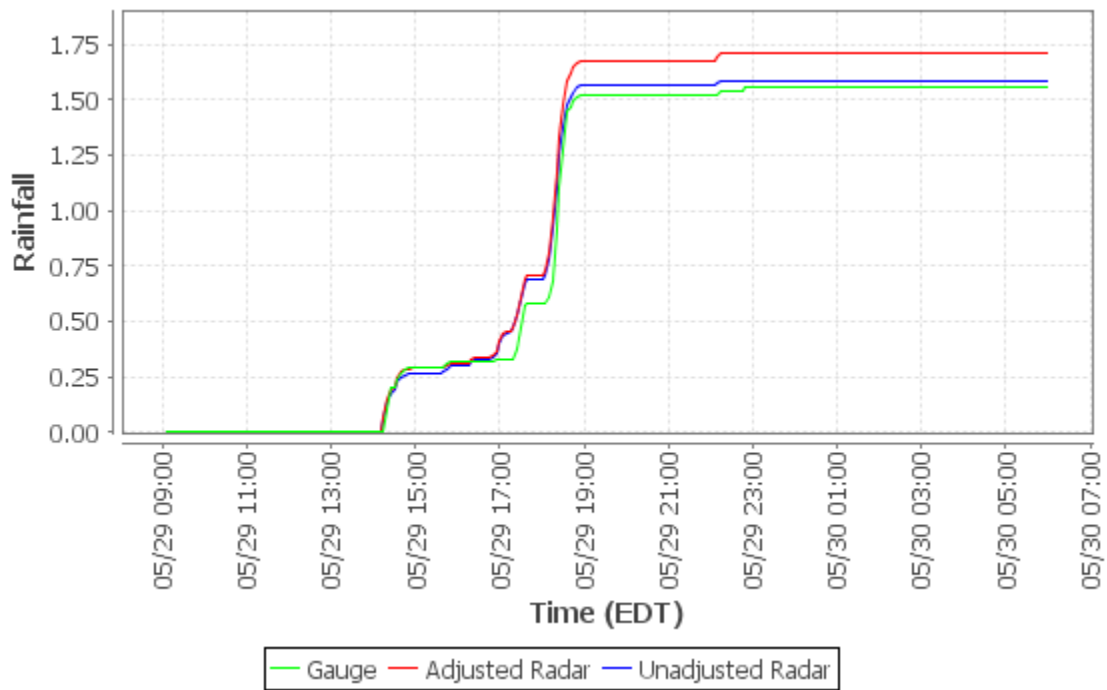
**Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)**



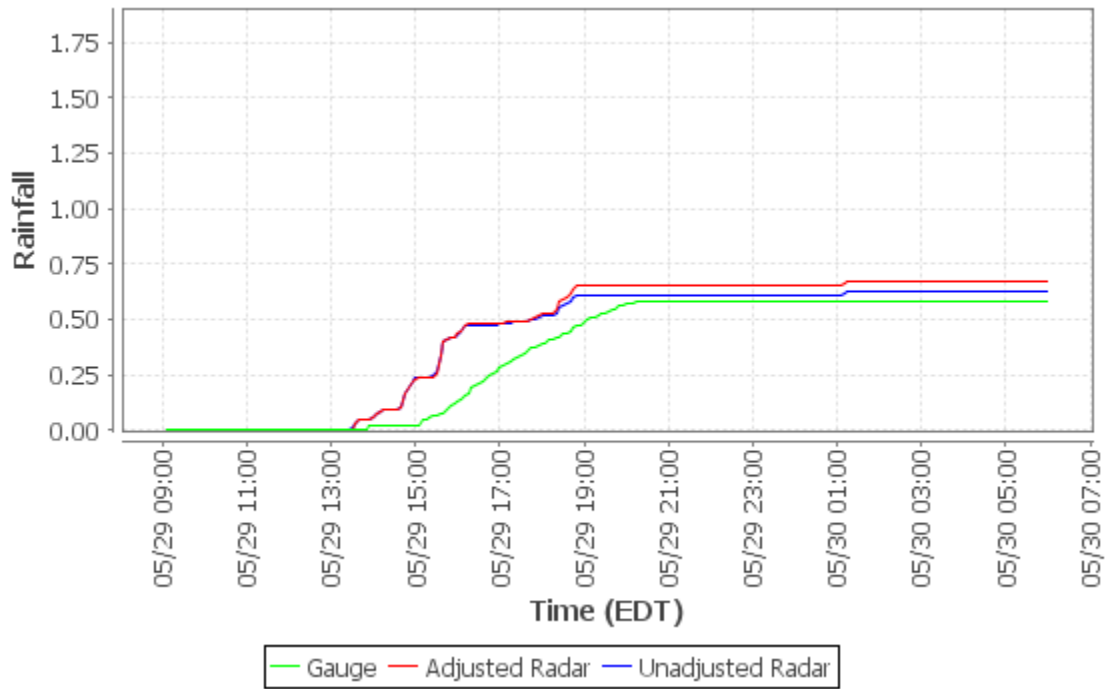
**Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)**



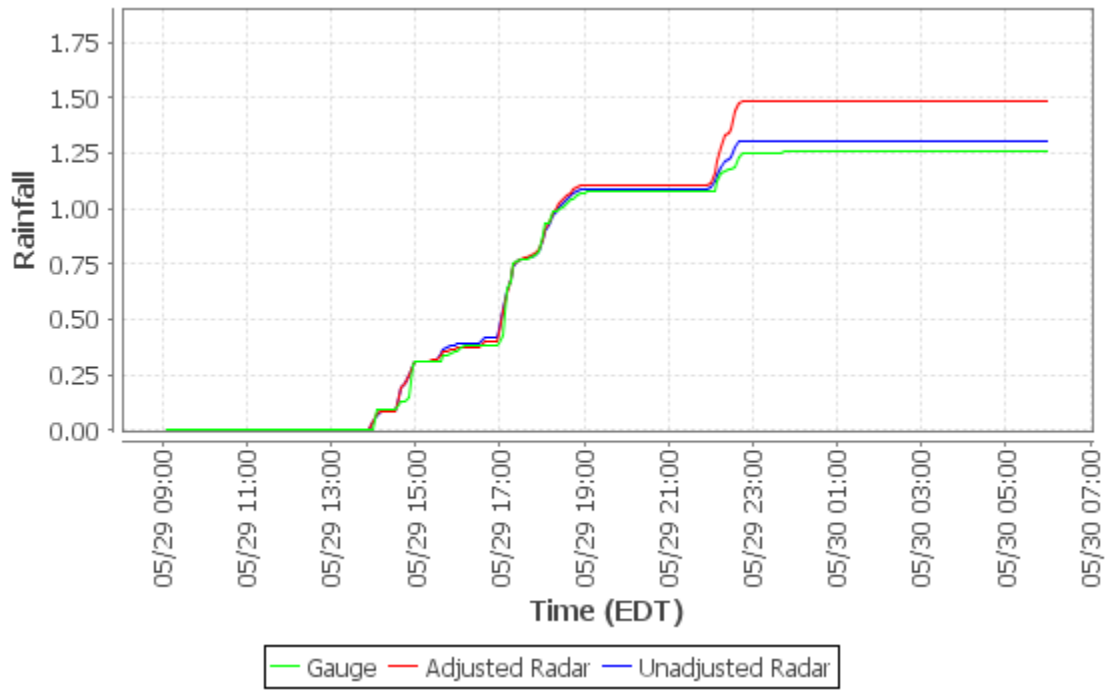
**Cumulative Distribution Plot - Kennedy Twp PS (Loc04)**



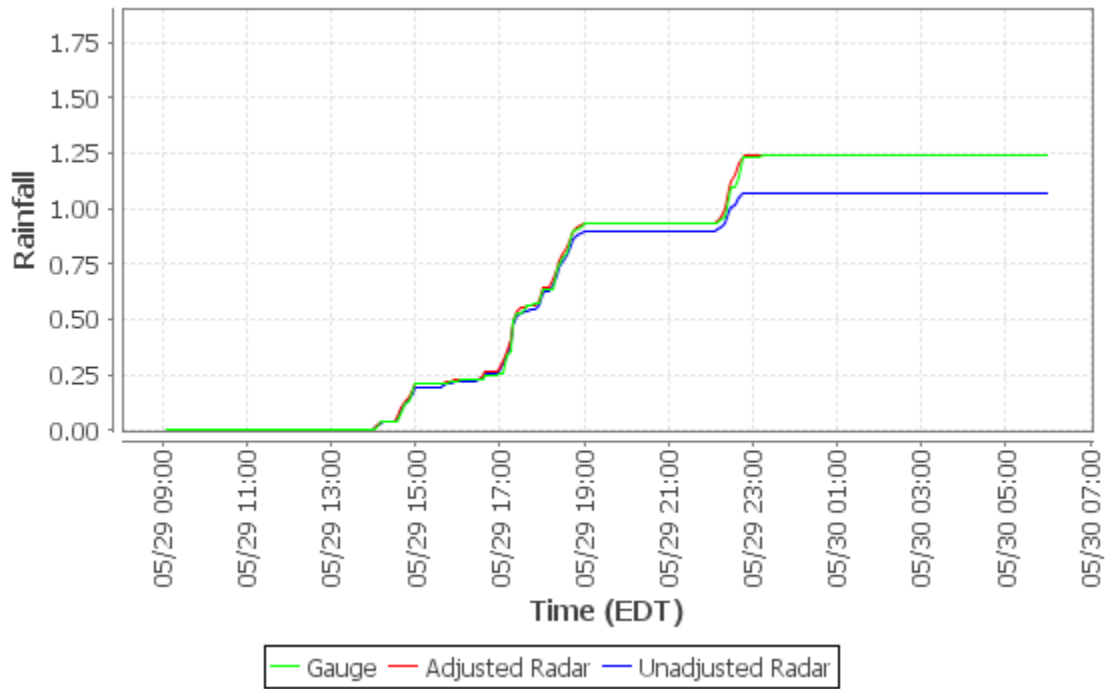
**Cumulative Distribution Plot - Upper St. Clair (Loc05)**



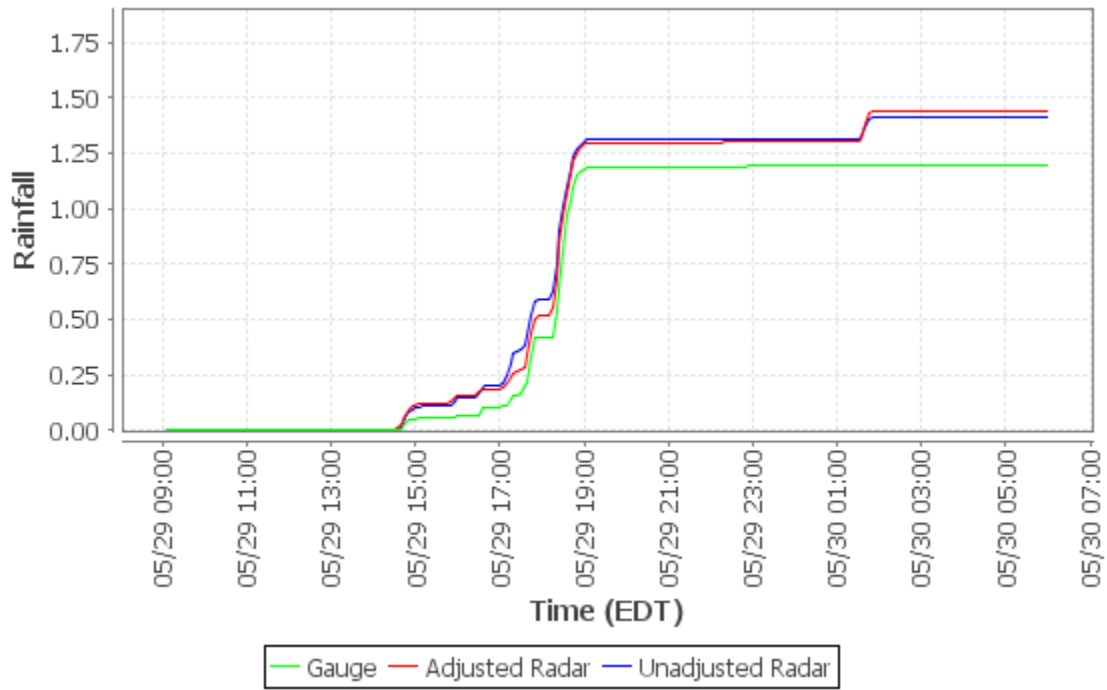
**Cumulative Distribution Plot - Carnegie Transit Time (Loc06)**



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

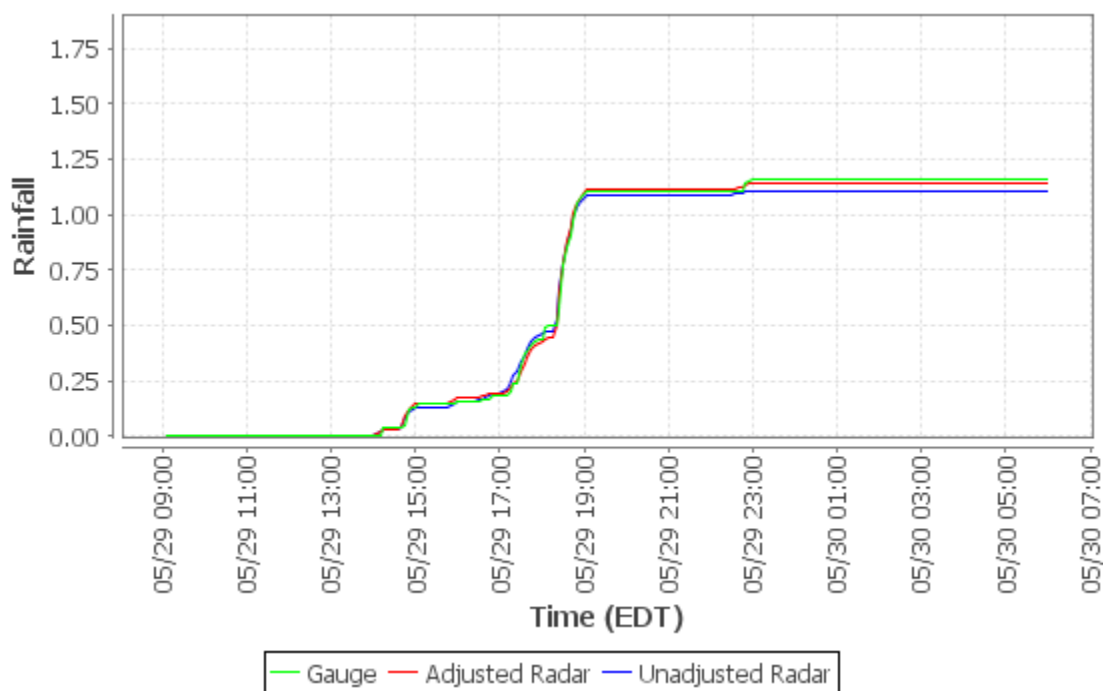


**Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)**

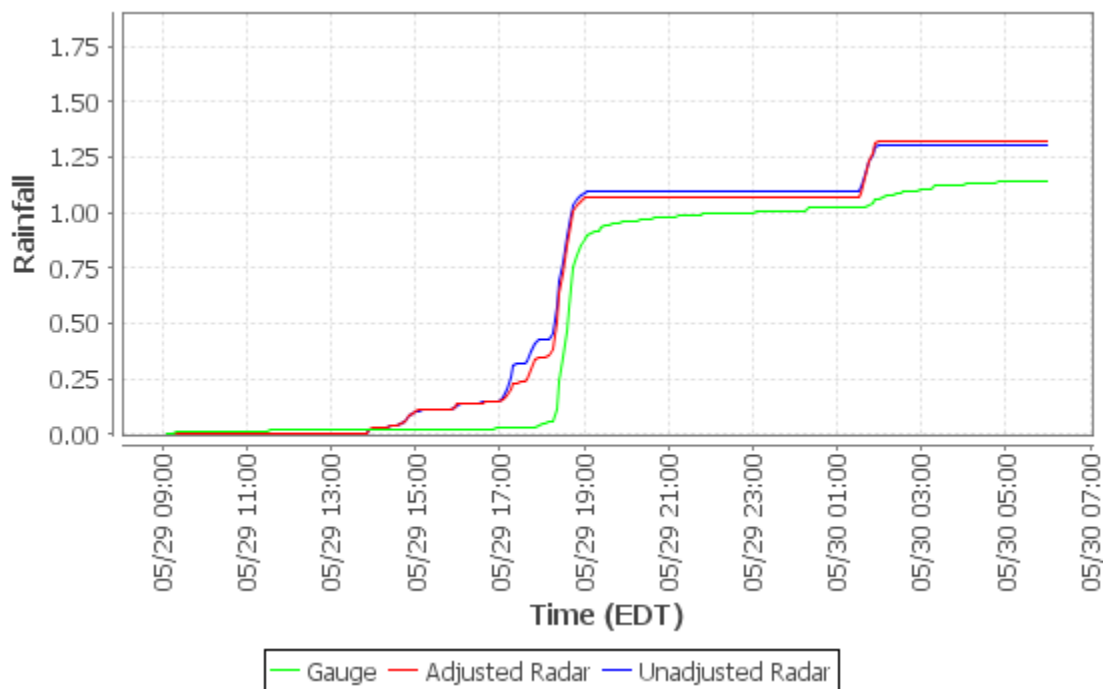




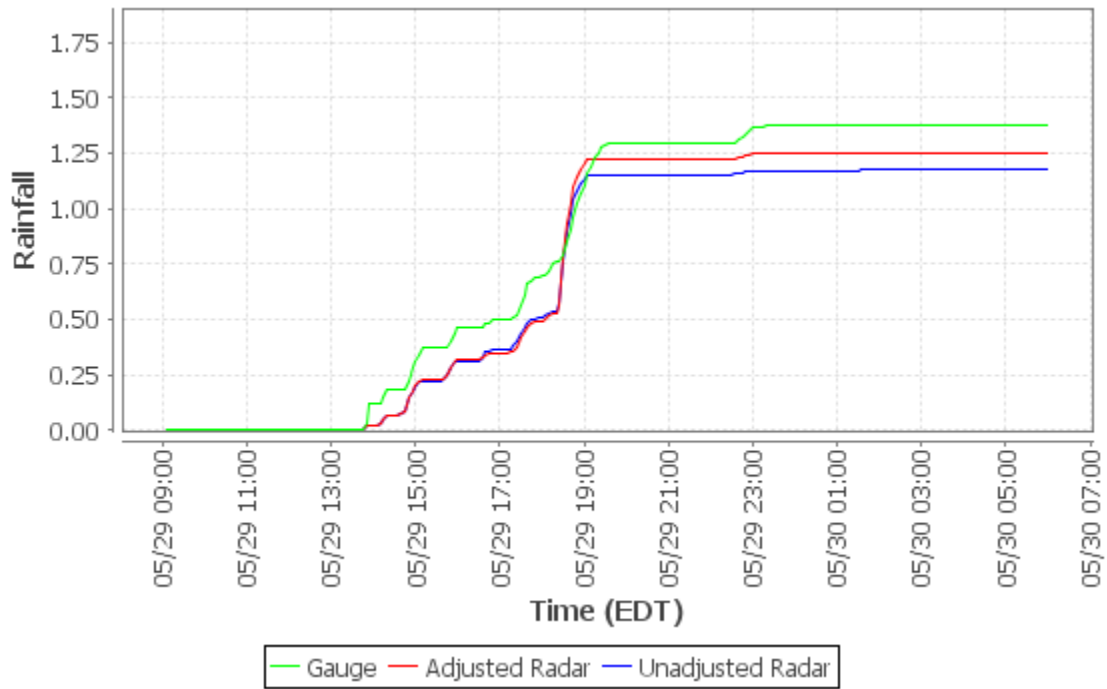
**Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)**



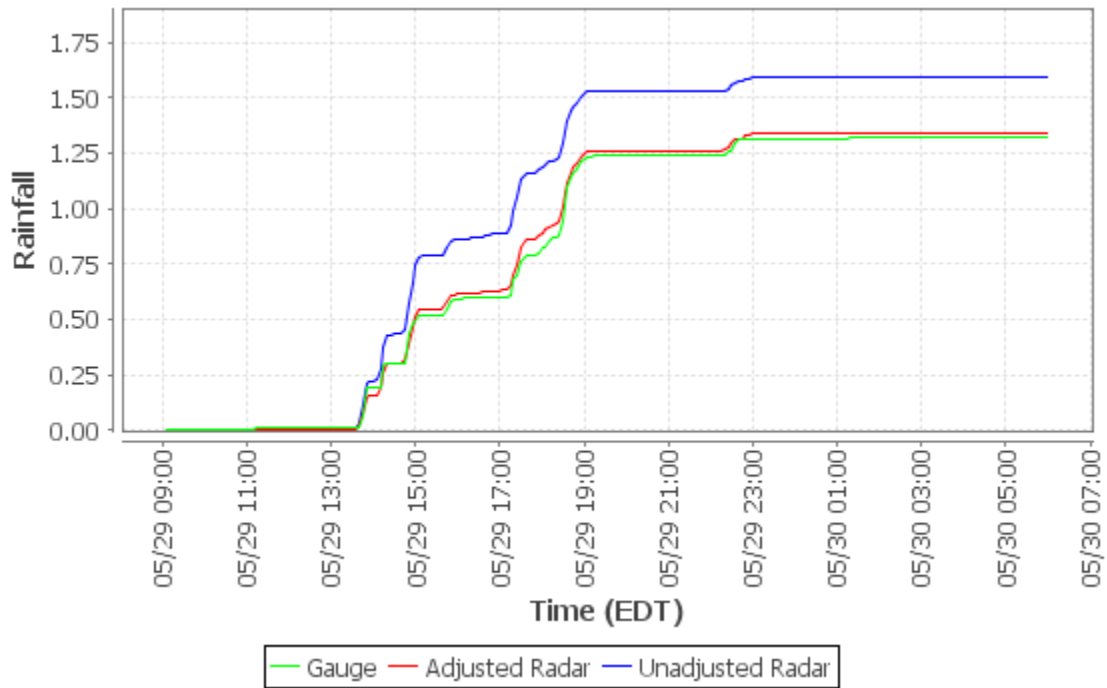
**Cumulative Distribution Plot - PWSA-Highland Park (Loc10)**



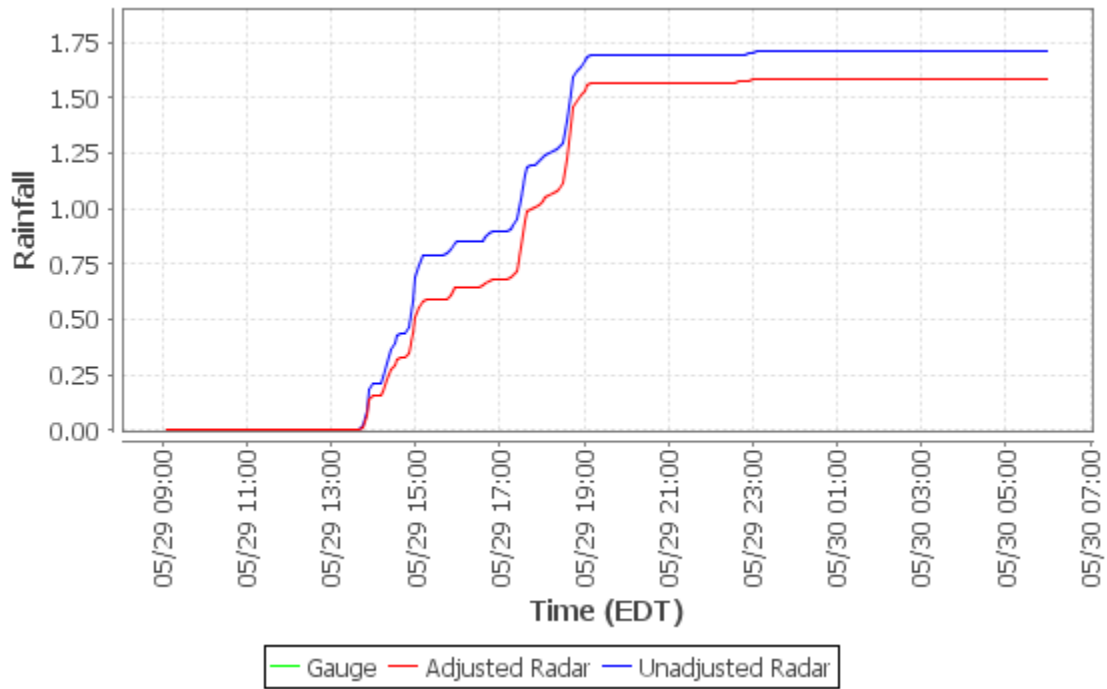
**Cumulative Distribution Plot - M-46 Access Shaft (Loc11)**



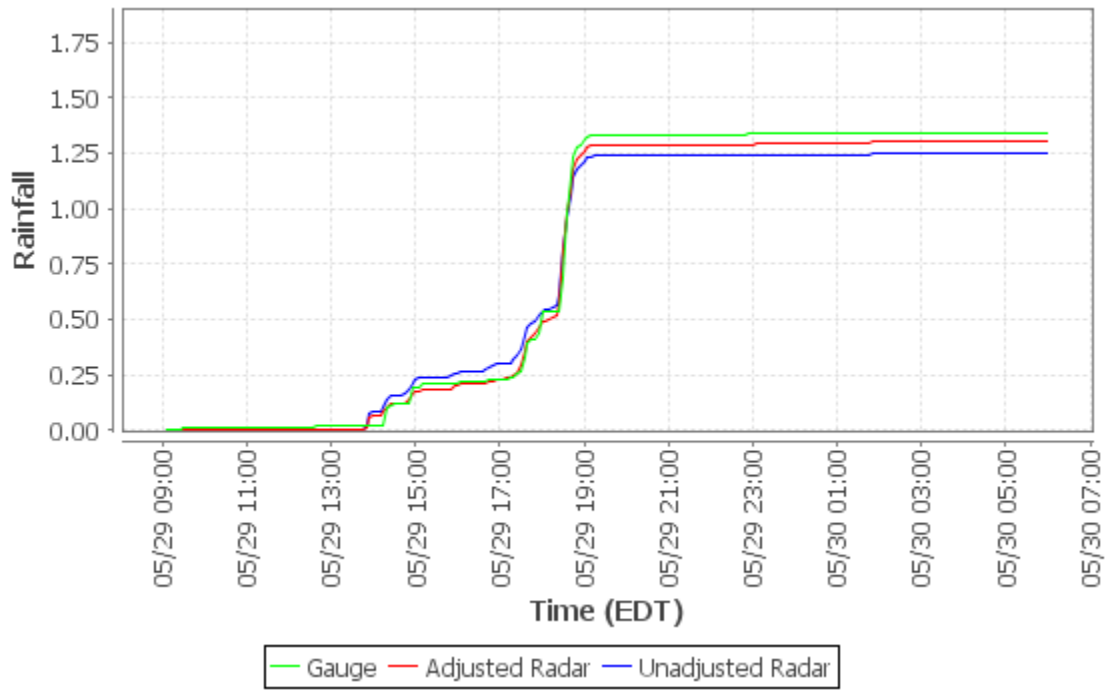
**Cumulative Distribution Plot - Baldwin (Loc12)**



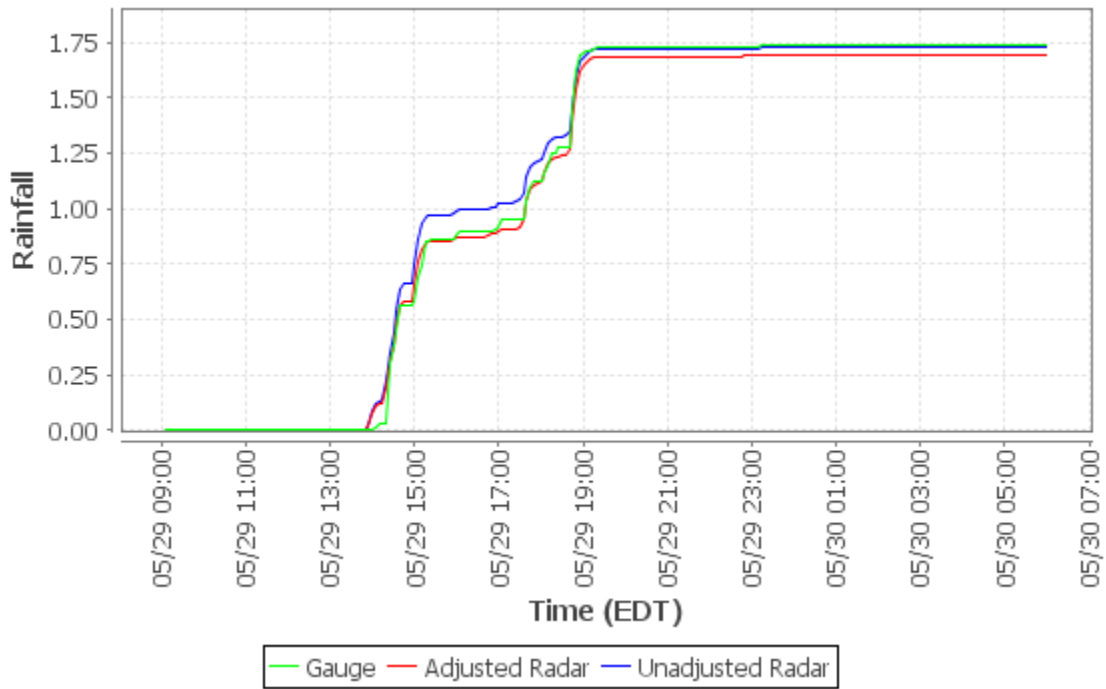
**Cumulative Distribution Plot - M-59 Access Shaft (Loc13)**



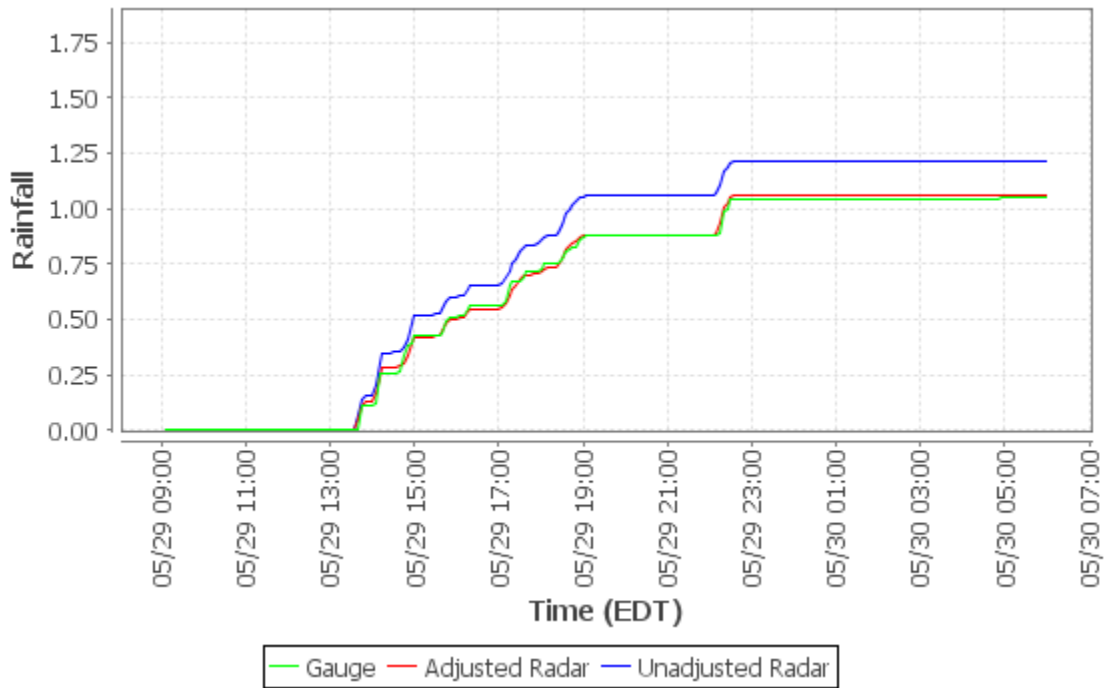
**Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)**



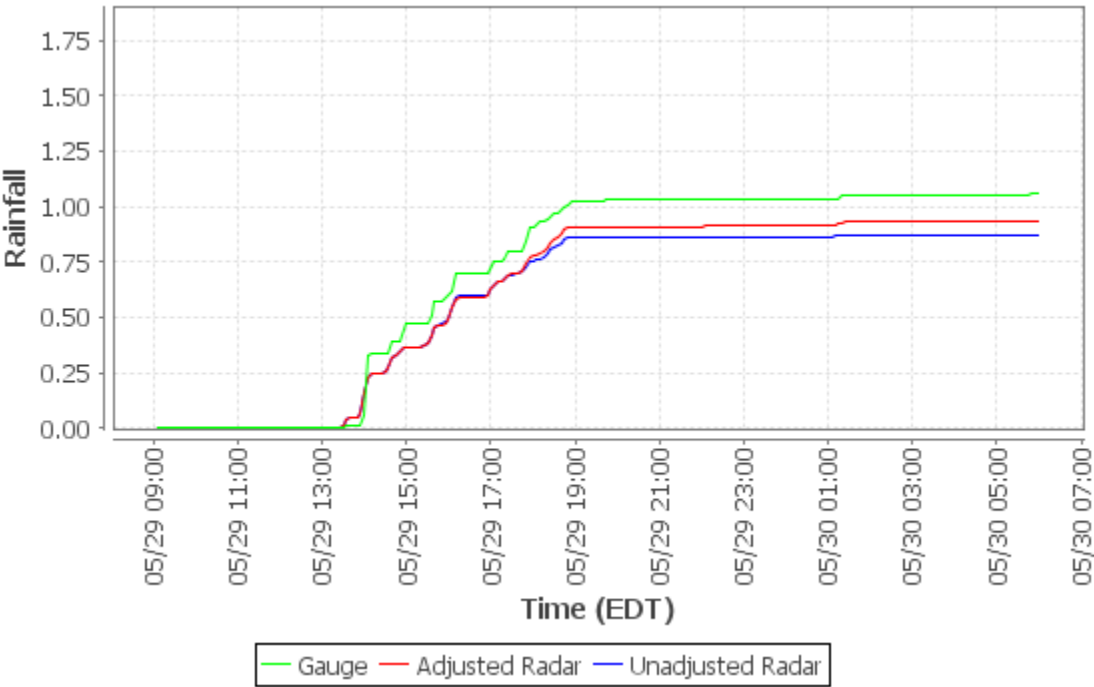
**Cumulative Distribution Plot - Trafford Maint Bldg (Loc15)**



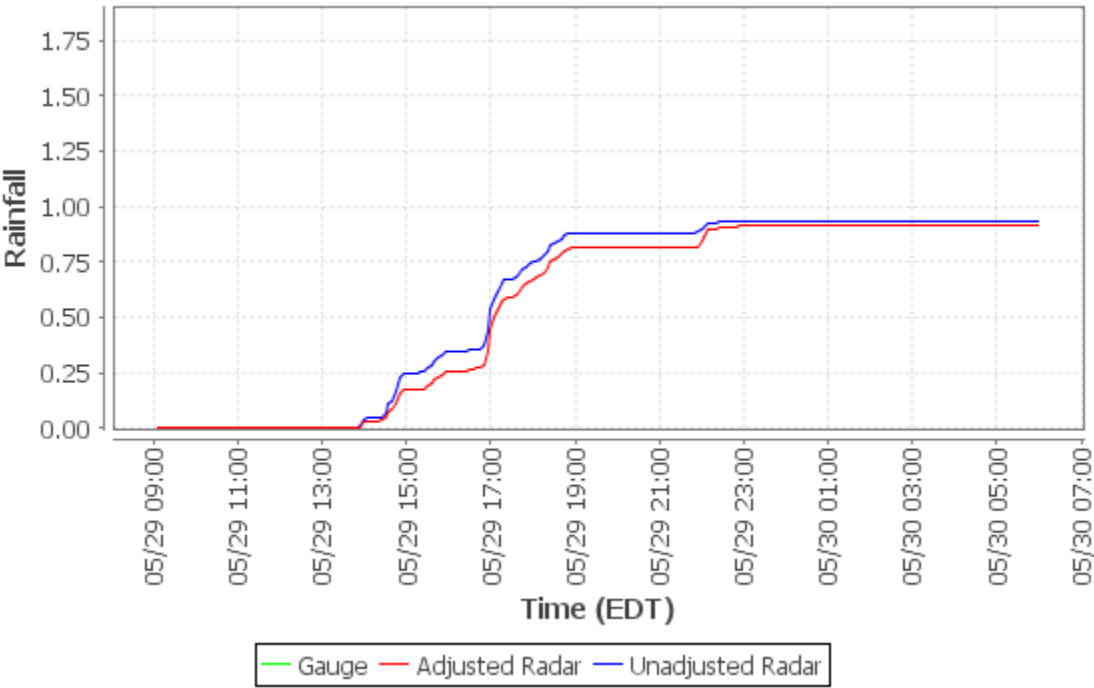
**Cumulative Distribution Plot - Castle Shannon (Loc16)**



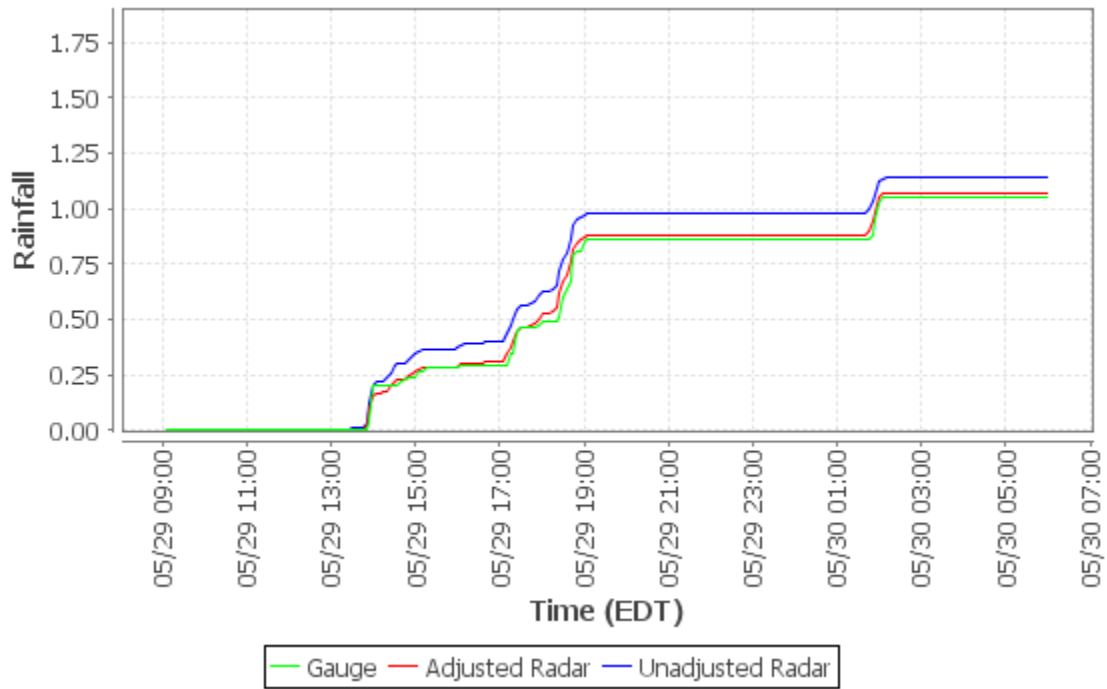
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



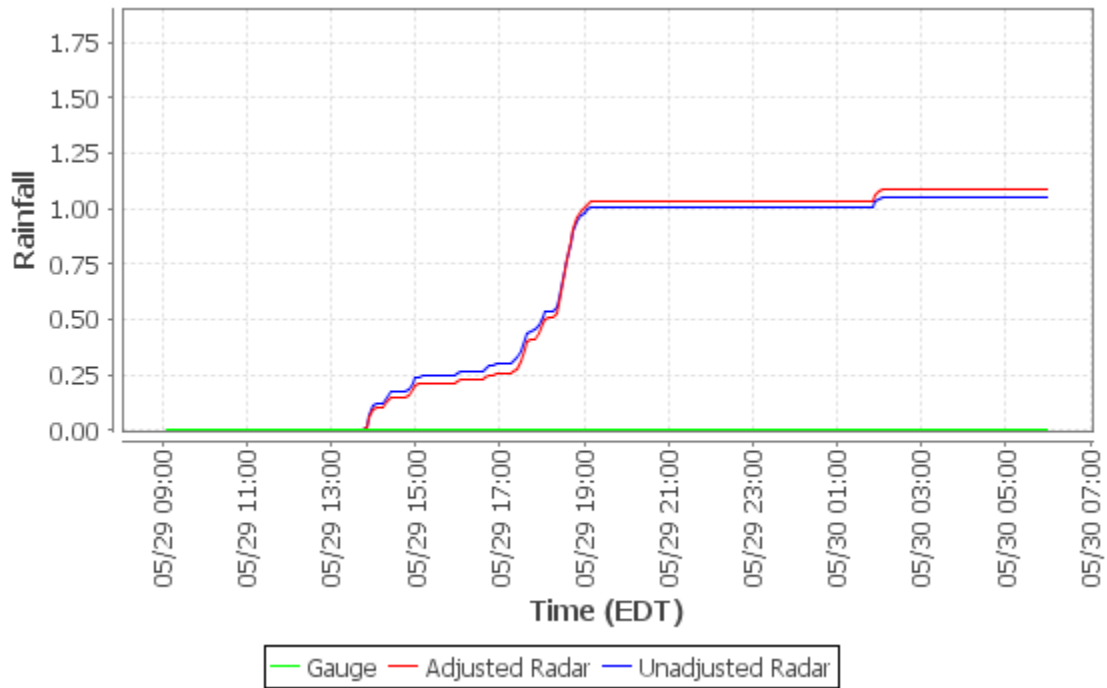
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



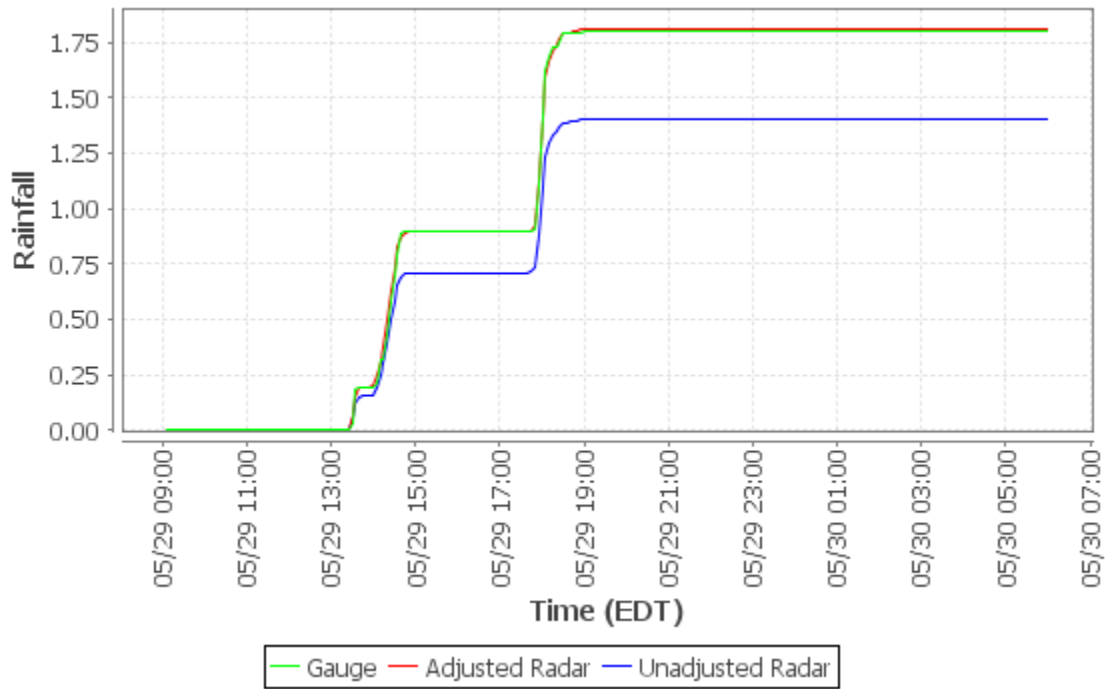
**Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)**



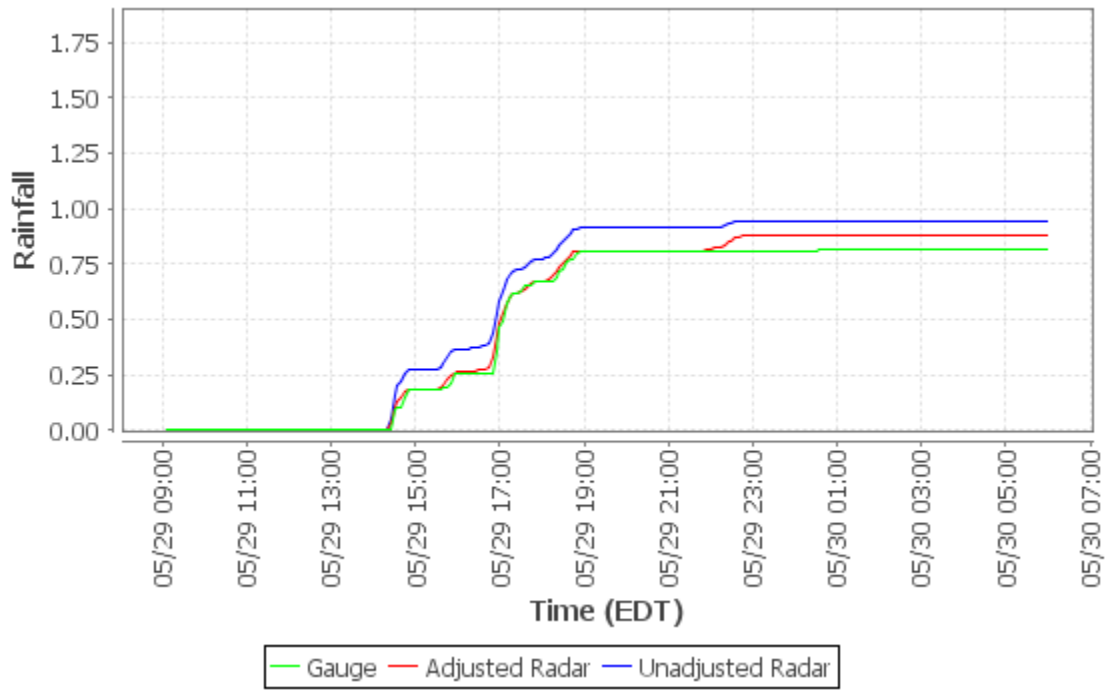
**Cumulative Distribution Plot - Gascola Eq Facility (Loc20)**



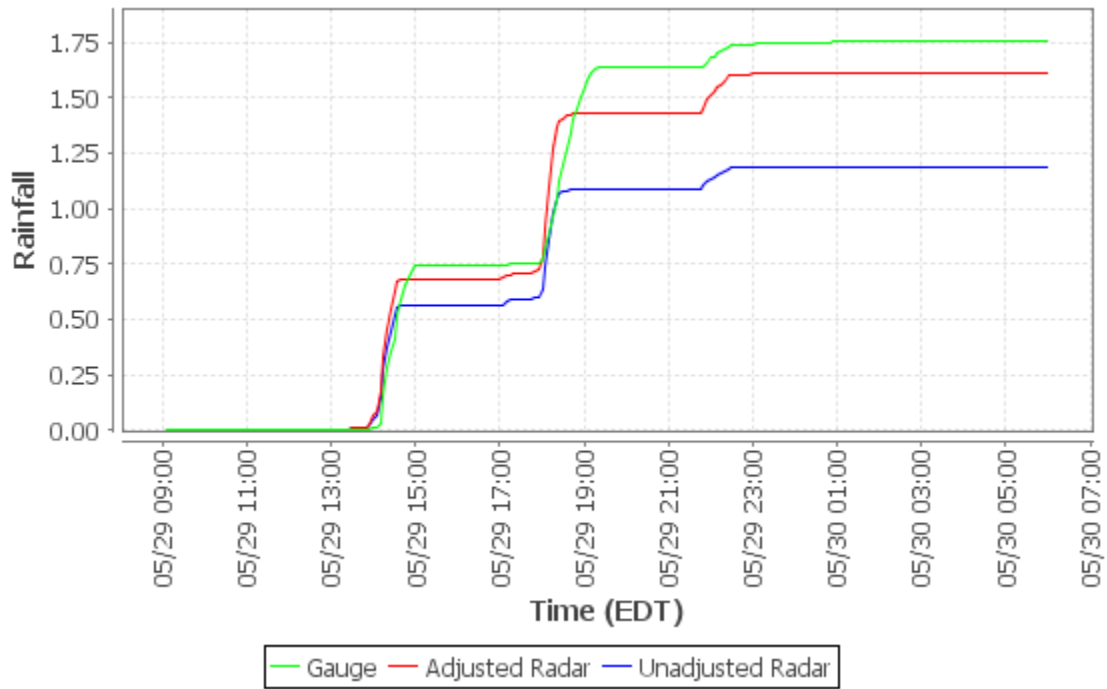
**Cumulative Distribution Plot - Moon TWP (Loc21)**



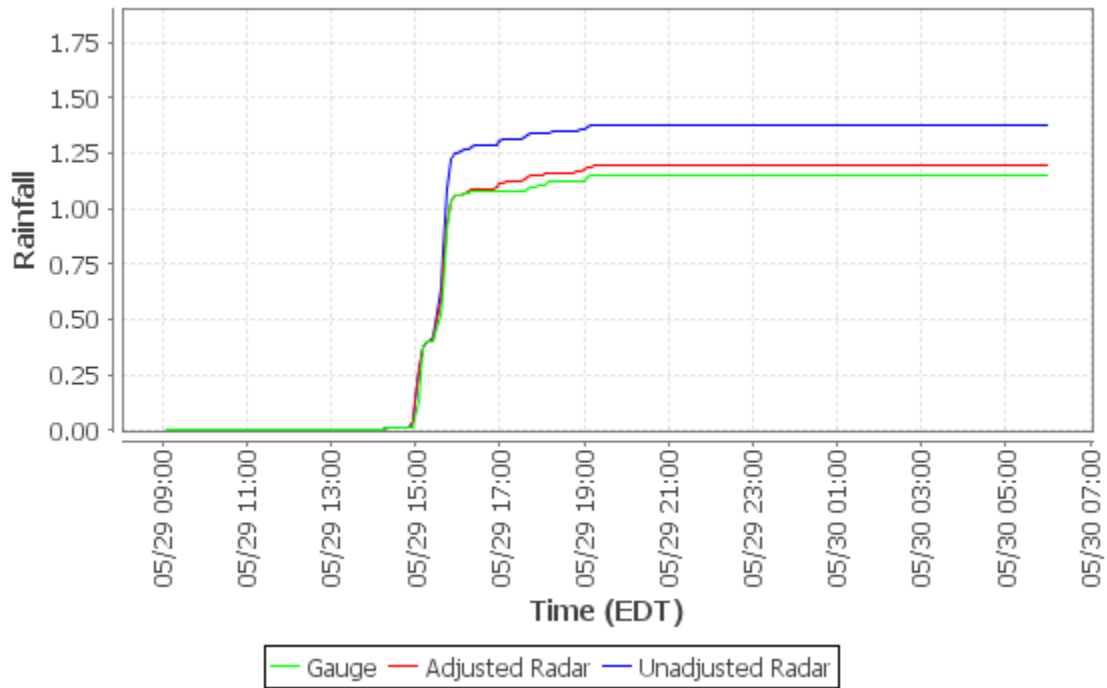
**Cumulative Distribution Plot - North Fayette TWP (Loc22)**



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

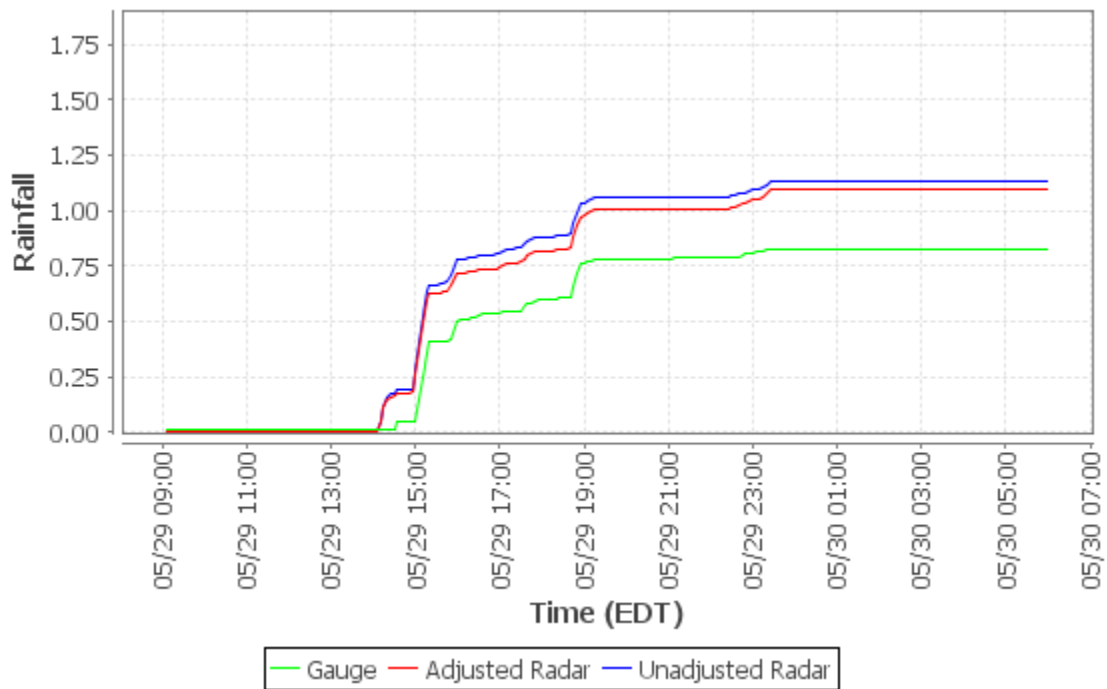


**Cumulative Distribution Plot - Jefferson Hills (Loc24)**

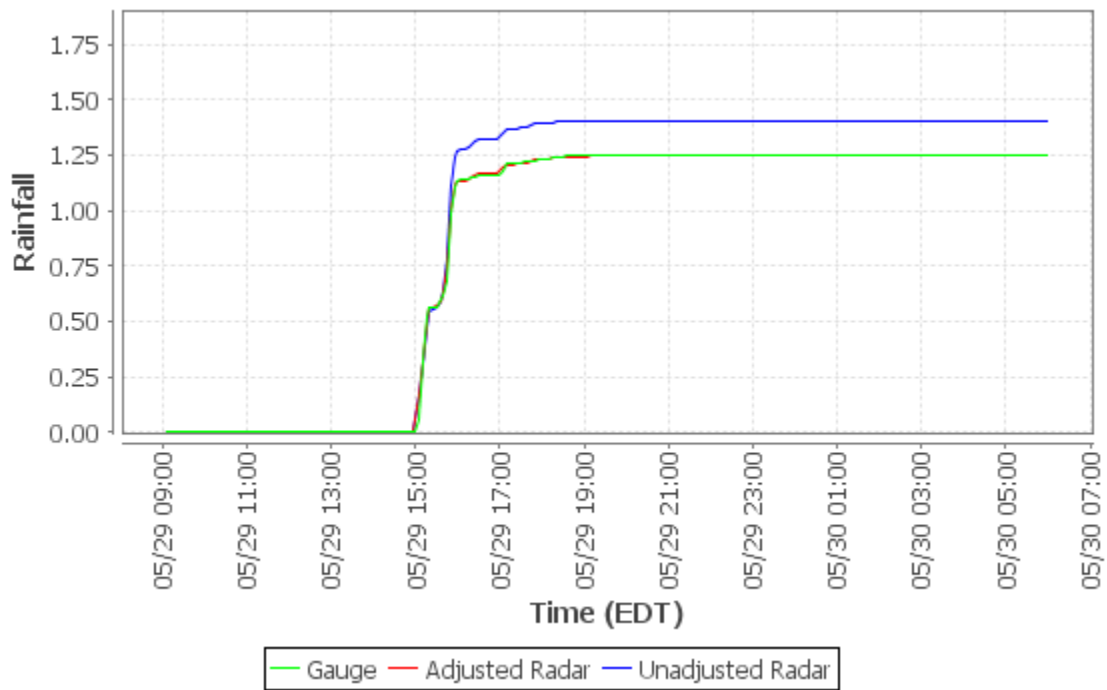




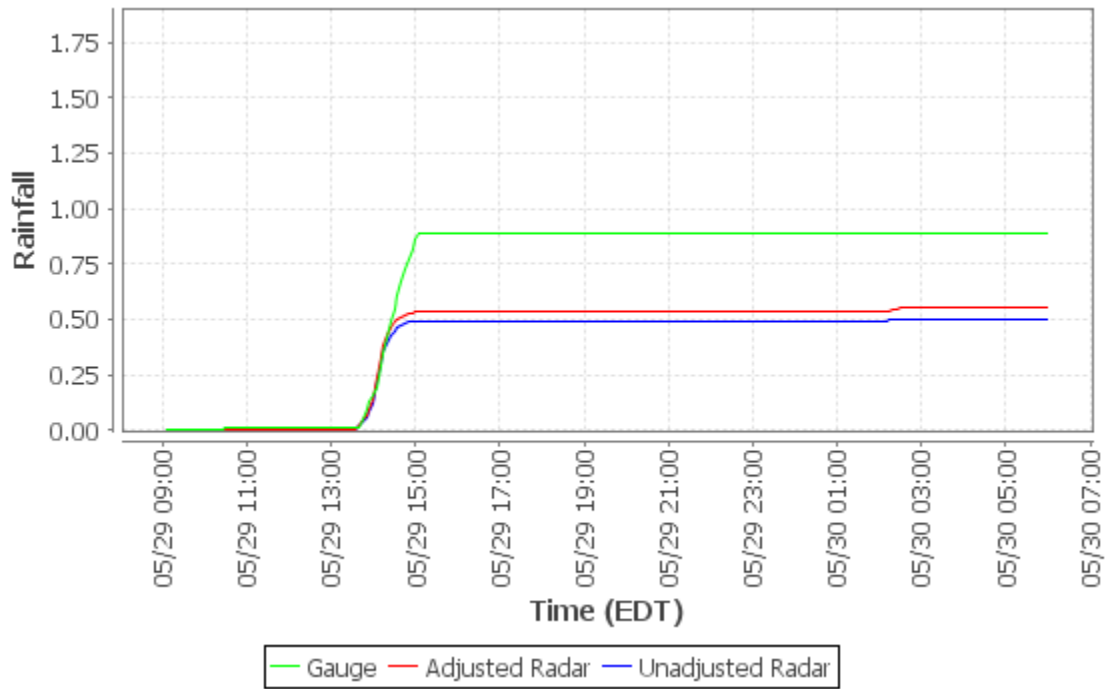
**Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)**



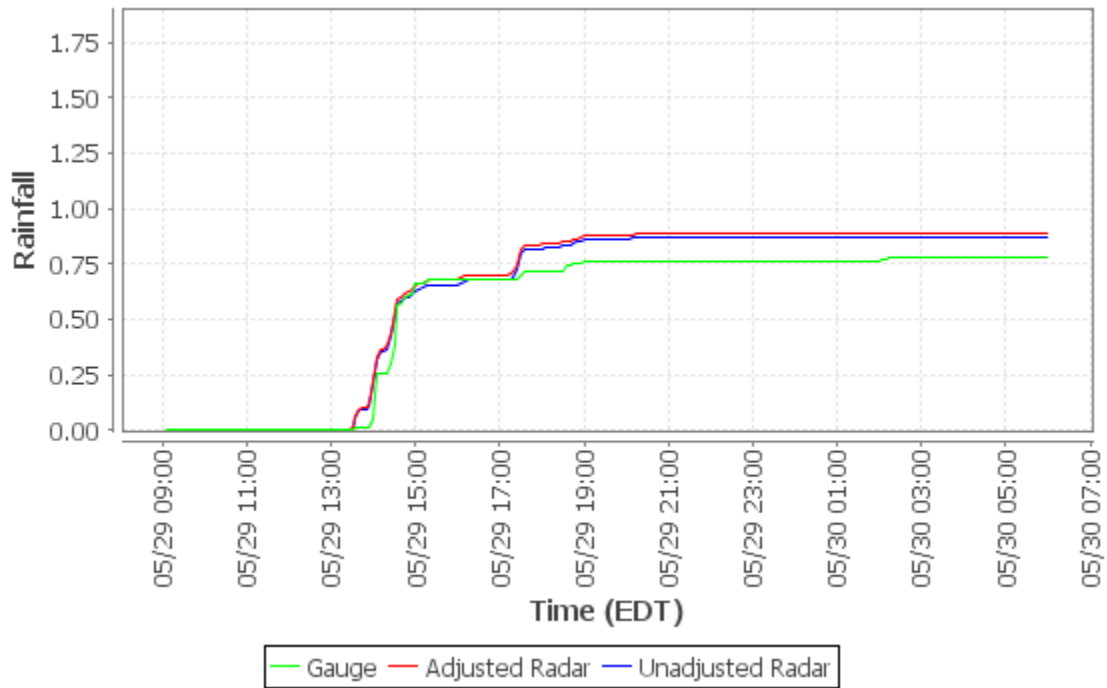
**Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)**



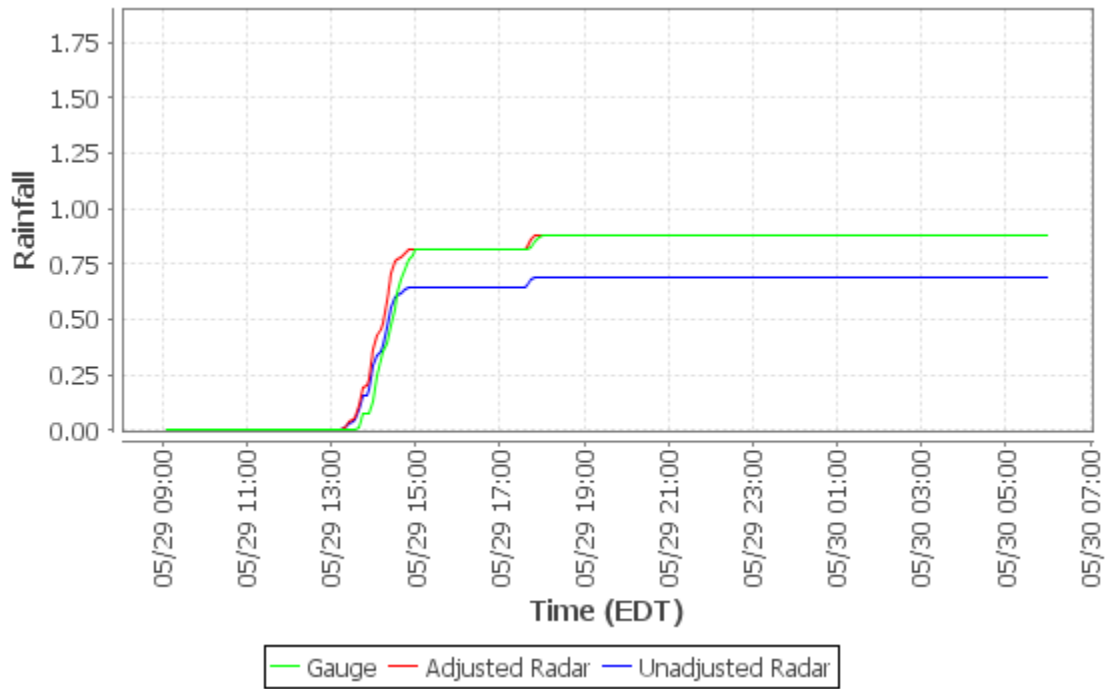
**Cumulative Distribution Plot - Marshall TWP (Loc27)**



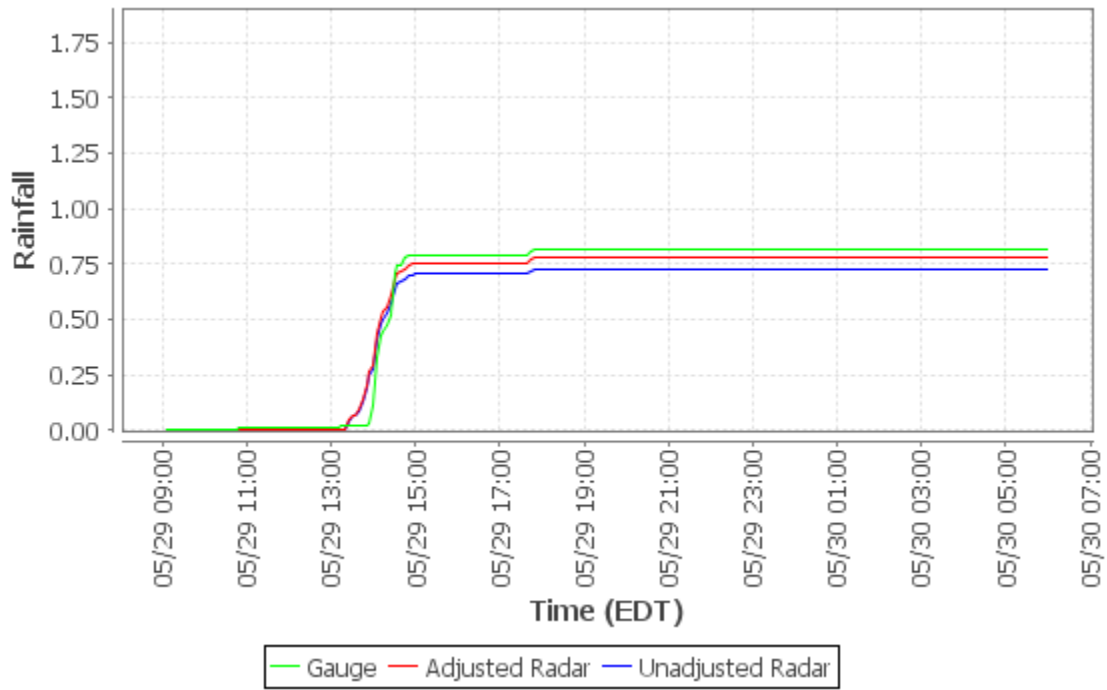
**Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)**



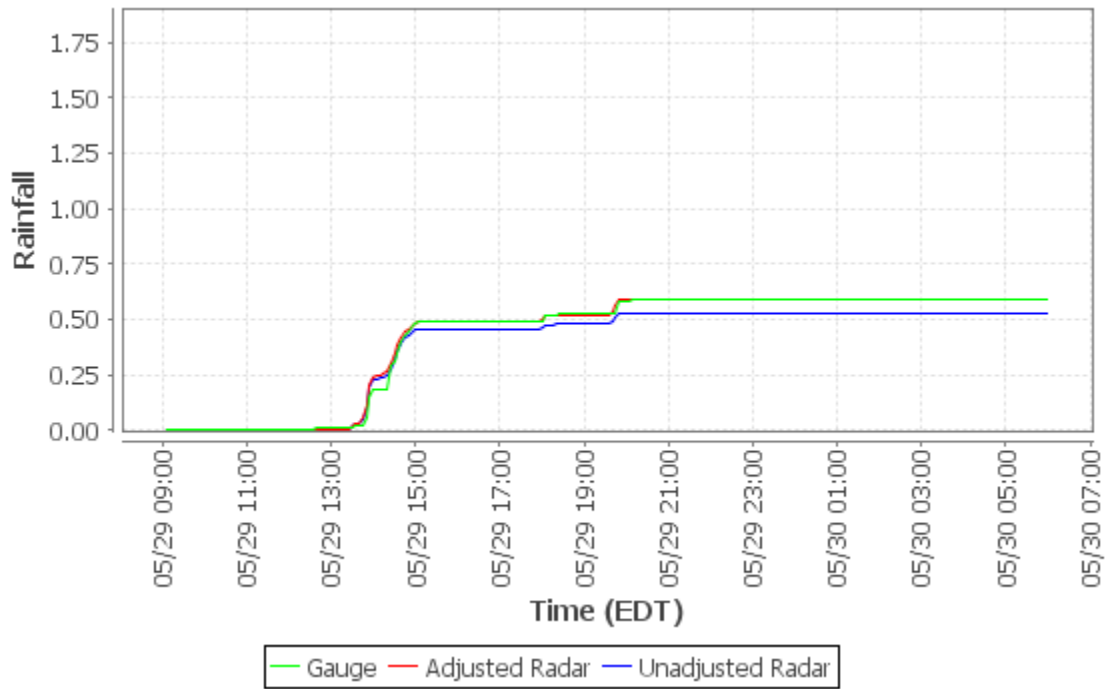
**Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)**



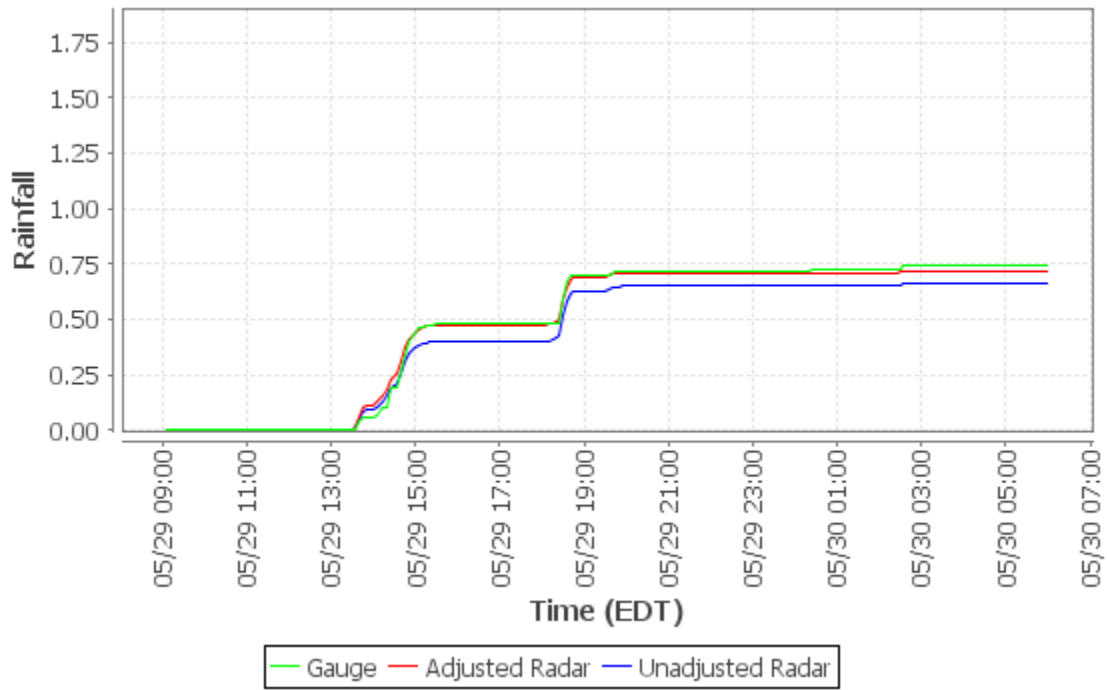
**Cumulative Distribution Plot - McCandless Twn Hall (Loc30)**



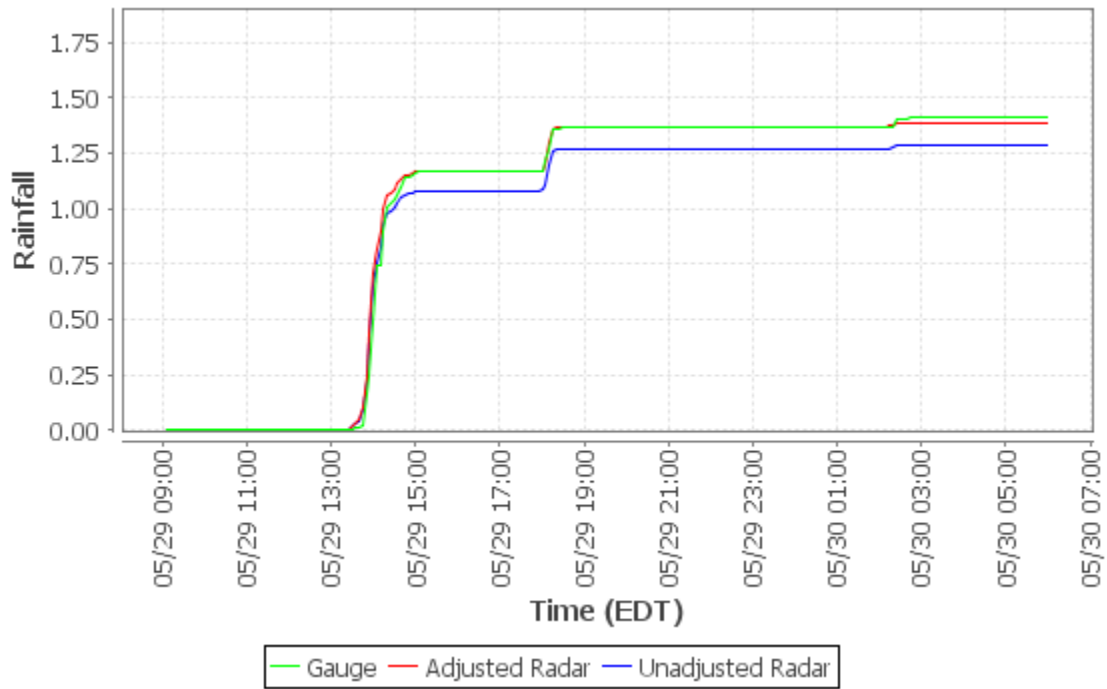
**Cumulative Distribution Plot - Hampton Municipal Bldg (Loc31)**



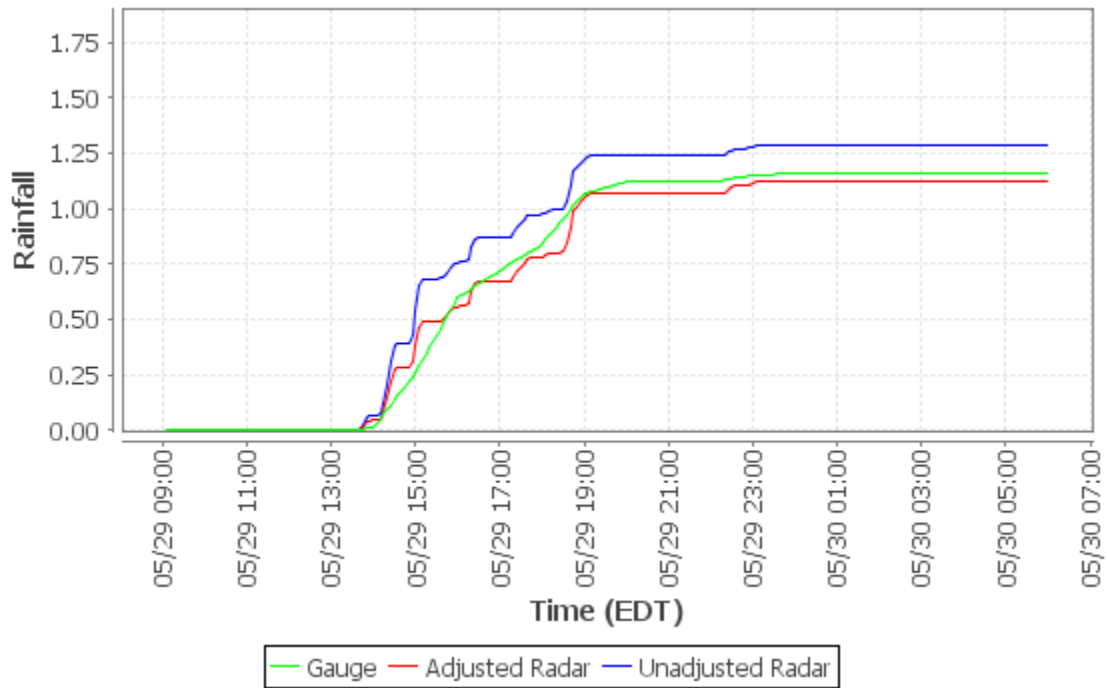
**Cumulative Distribution Plot - Arnold (Loc32)**



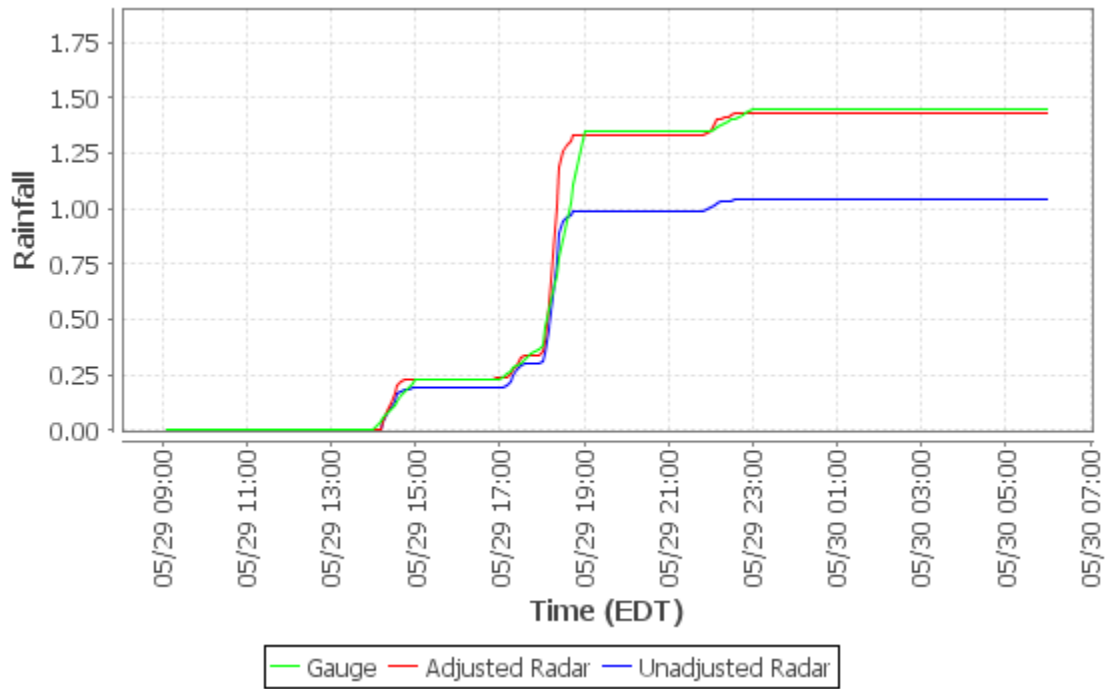
**Cumulative Distribution Plot - Richland TWP (Loc33)**



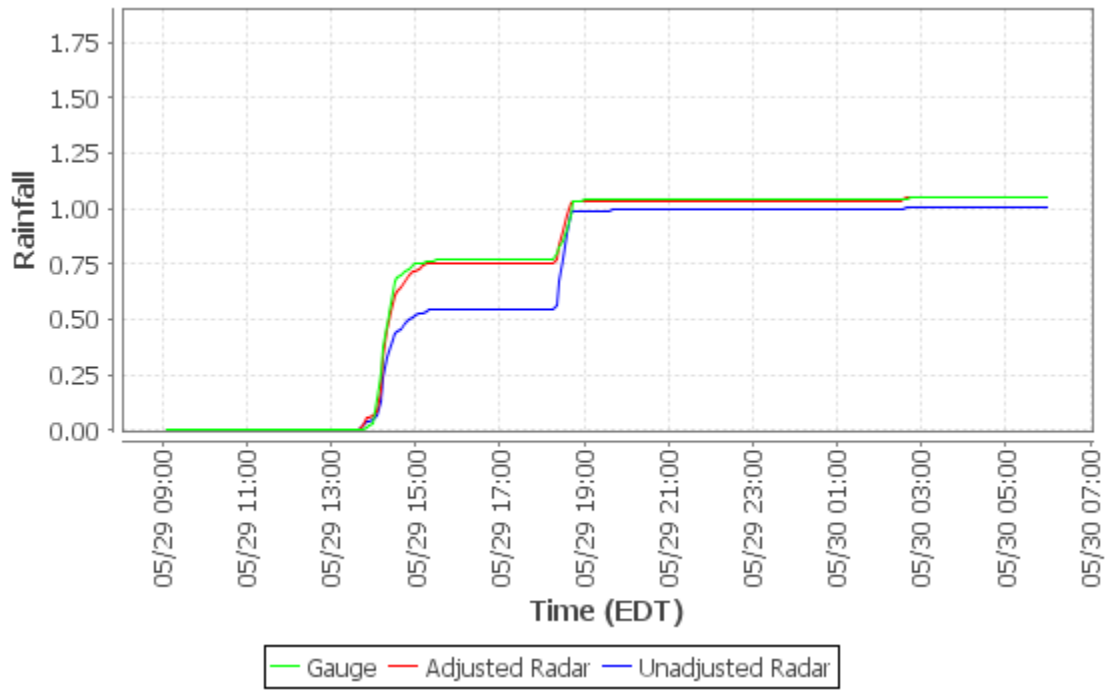
**Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)**



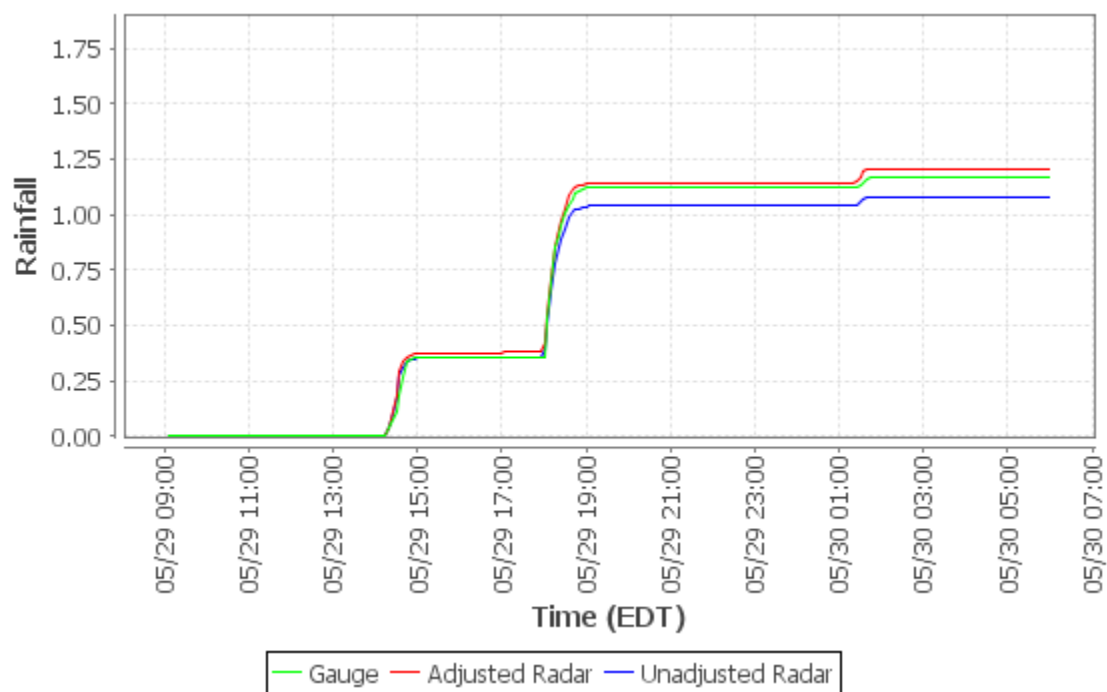
**Cumulative Distribution Plot - Greater Pittsburgh Int'l (KPIT)**



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



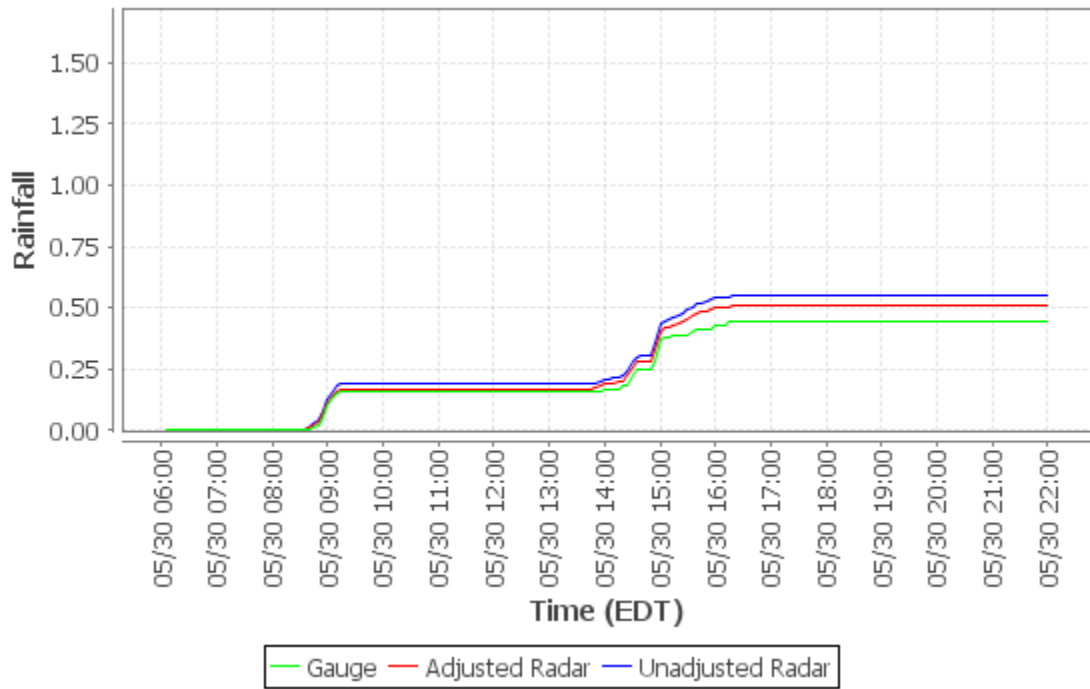
**Cumulative Distribution Plot - Ohio River at Emsworth Dam Lower Pool at Emsworth  
(03085734)**



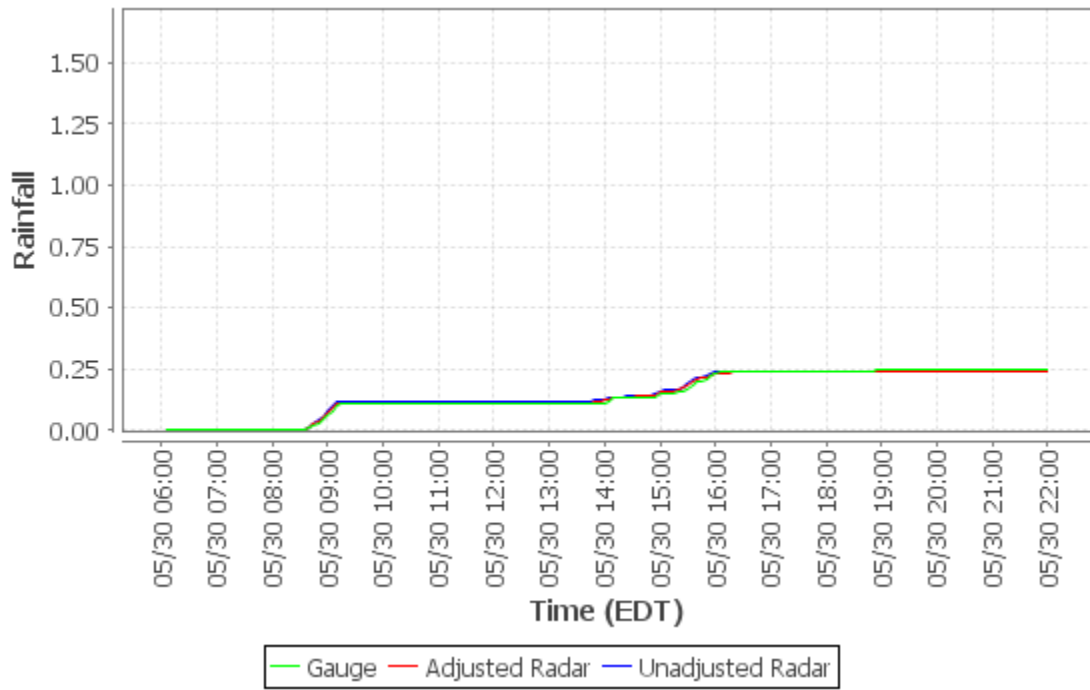
## **Appendix M - Event 11 (2019-05-30) CDPs**



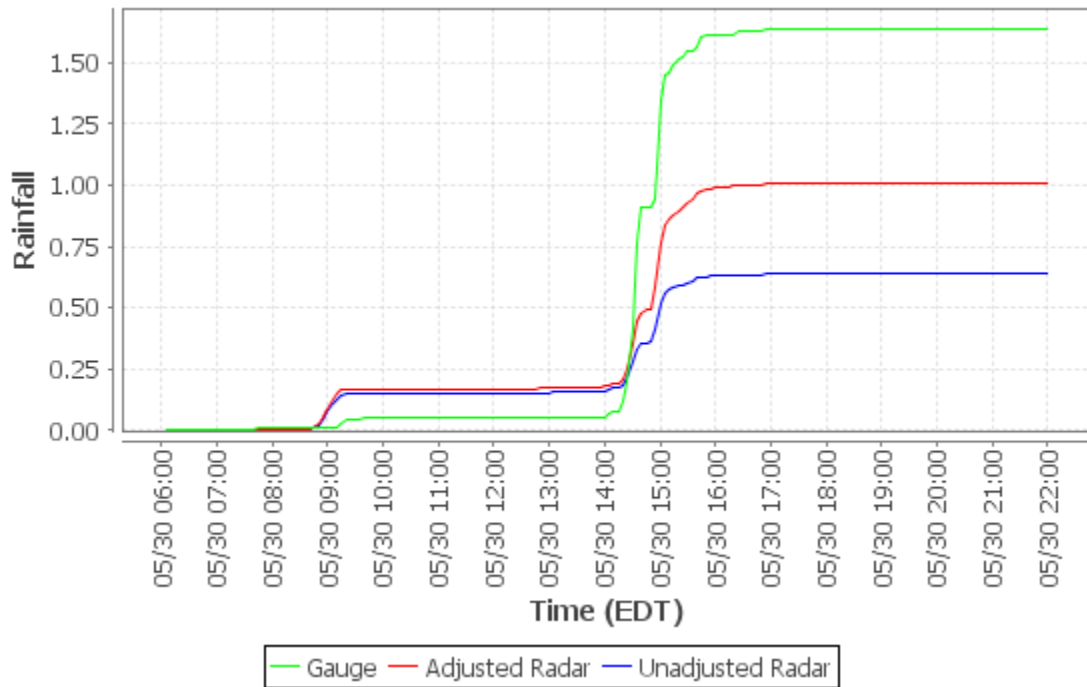
Cumulative Distribution Plot - PWSA-Montana St. (Loc01)



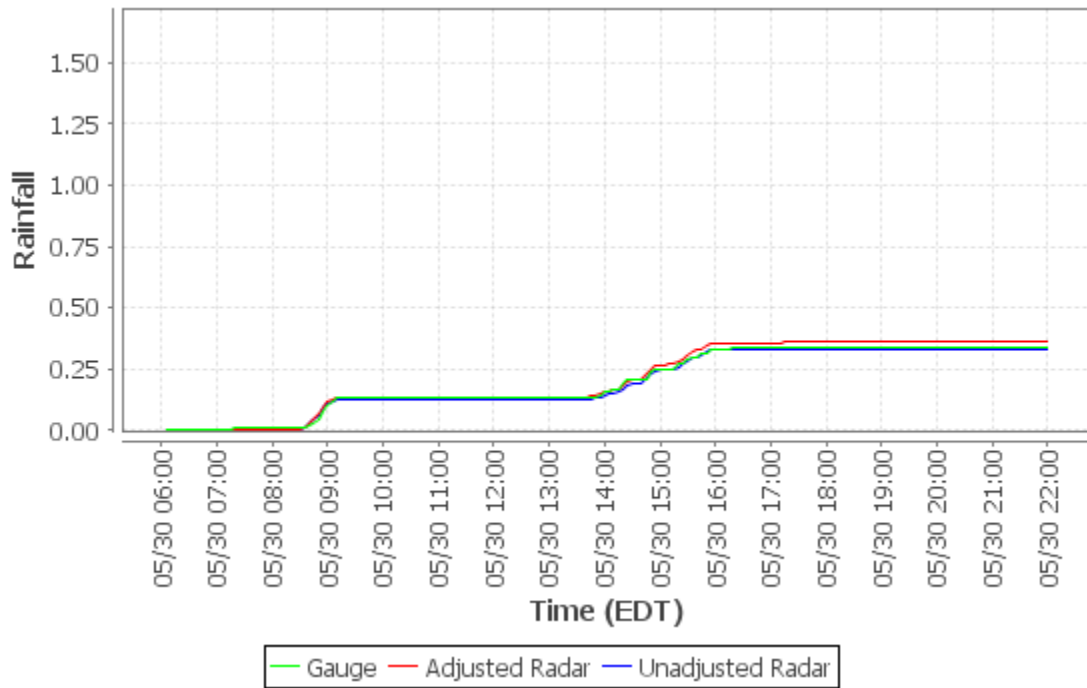
Cumulative Distribution Plot - ALCOSAN WWTP Lab (Loc02)



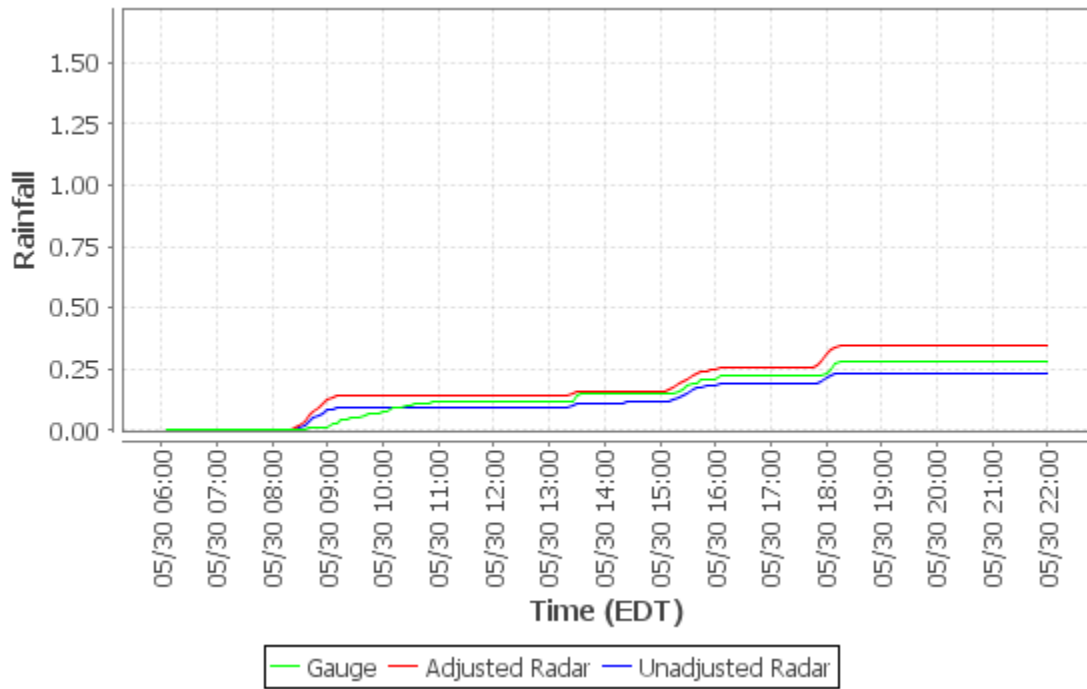
**Cumulative Distribution Plot - Shaler Munic Bldg (Loc03)**



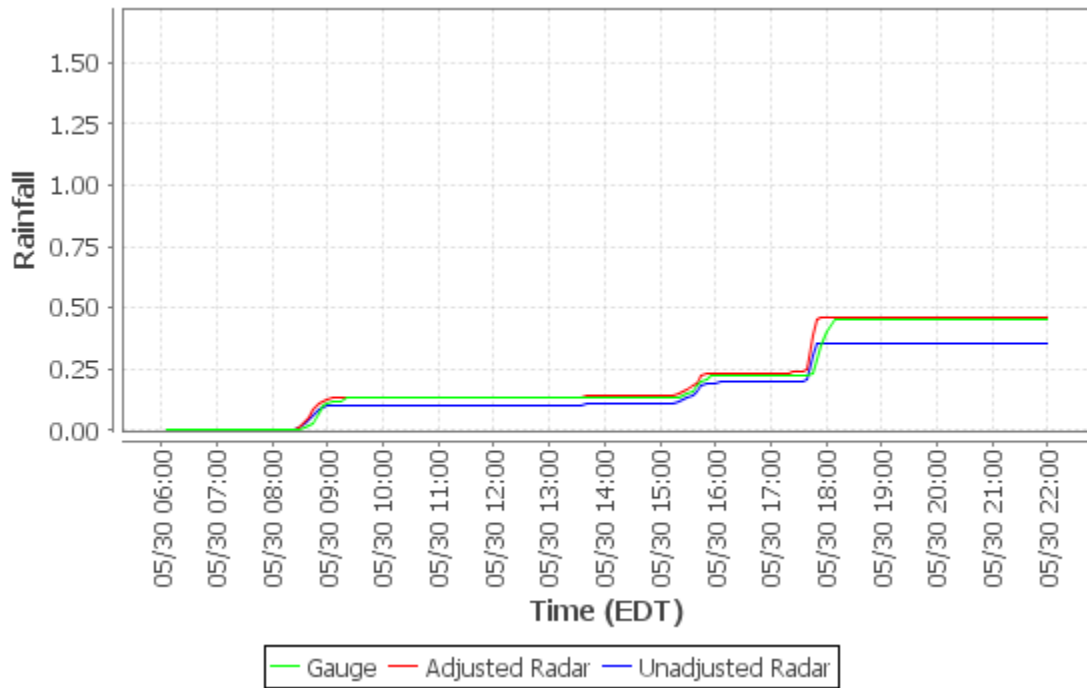
**Cumulative Distribution Plot - Kennedy Twp PS (Loc04)**



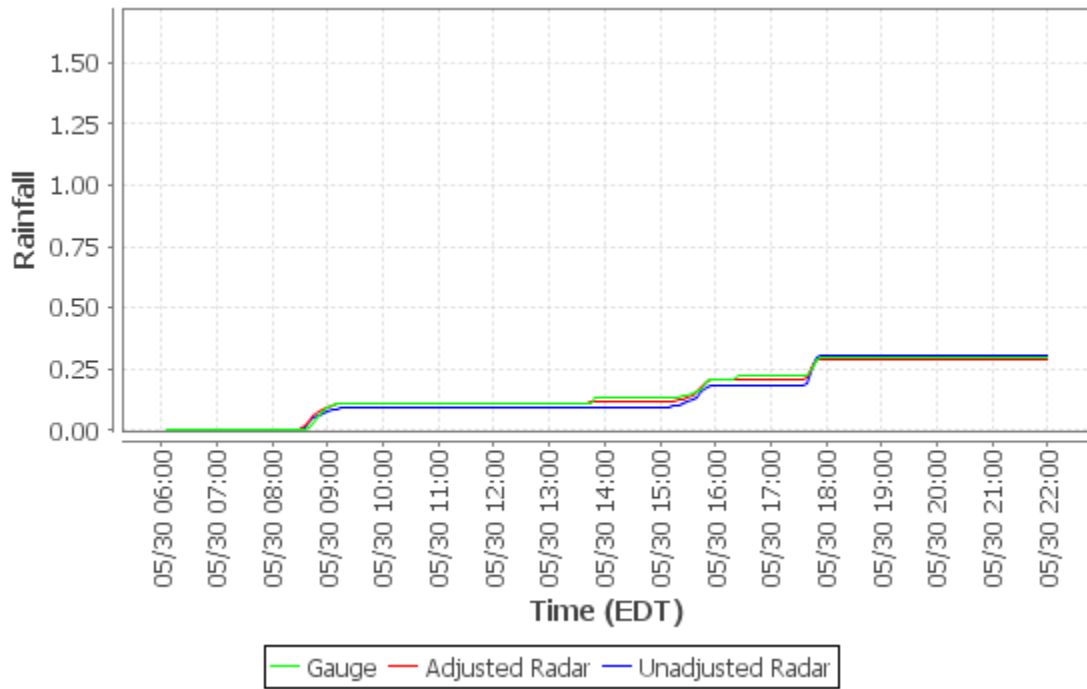
**Cumulative Distribution Plot - Upper St. Clair (Loc05)**



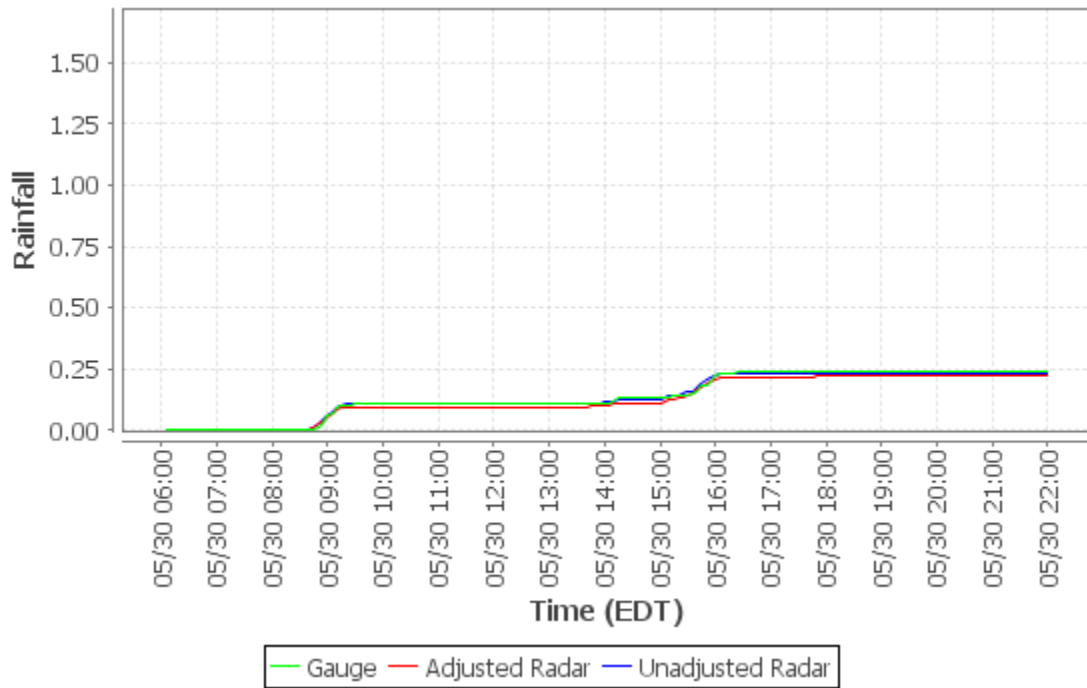
**Cumulative Distribution Plot - Carnegie Transit Time (Loc06)**



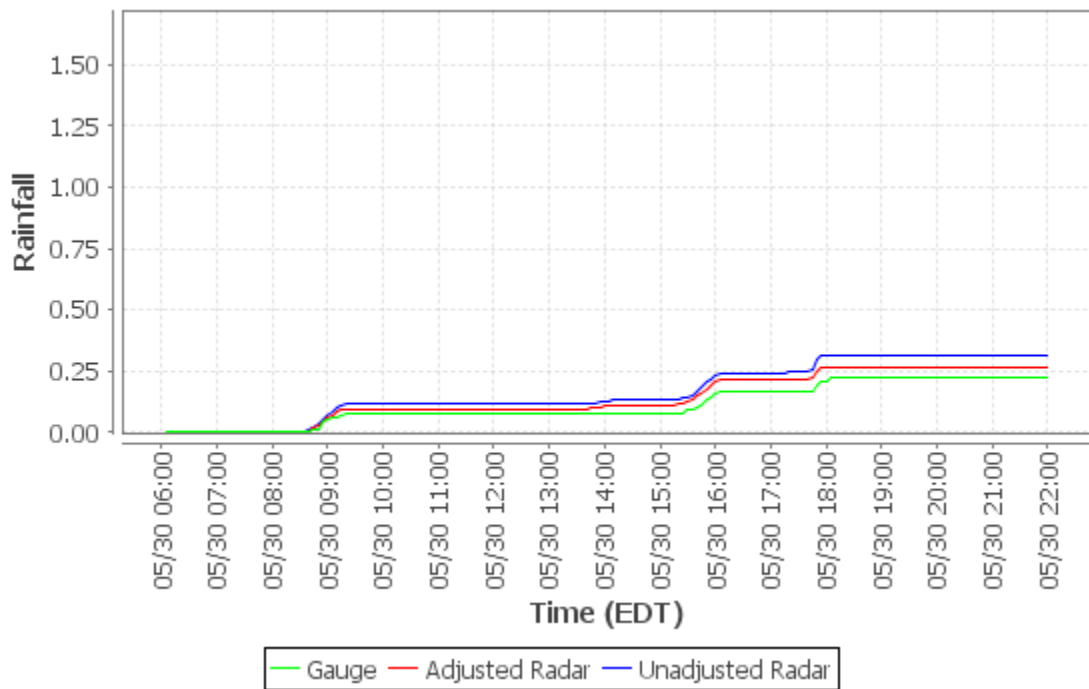
**Cumulative Distribution Plot - Greentree Munic Bldg (Loc07)**



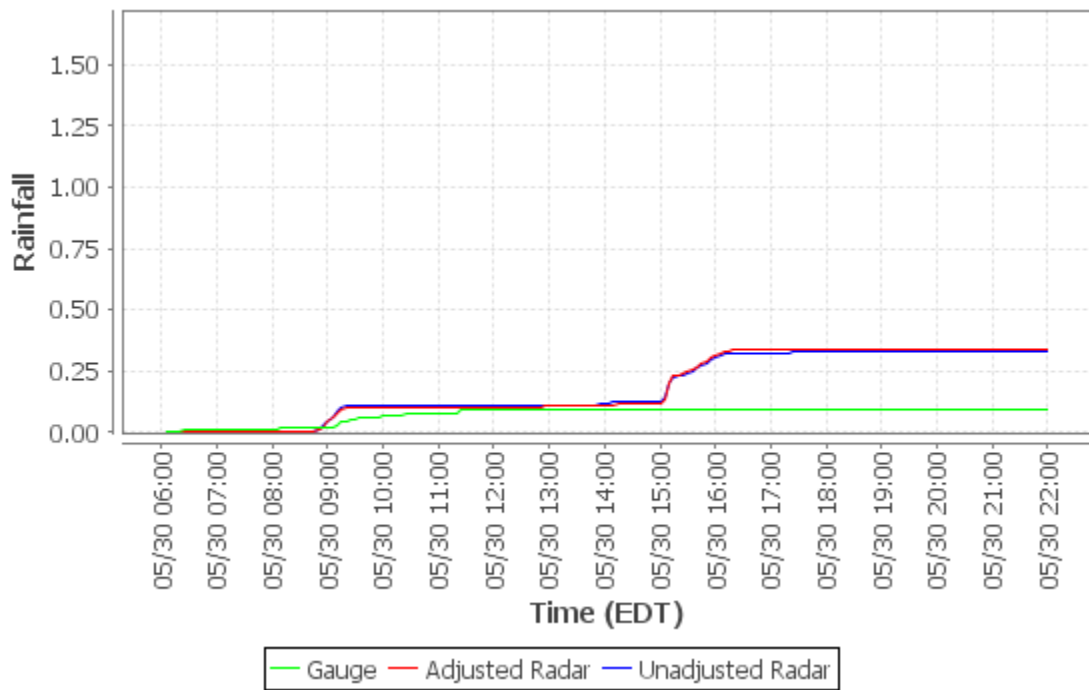
**Cumulative Distribution Plot - AC Health Dept Bldg (Loc08)**



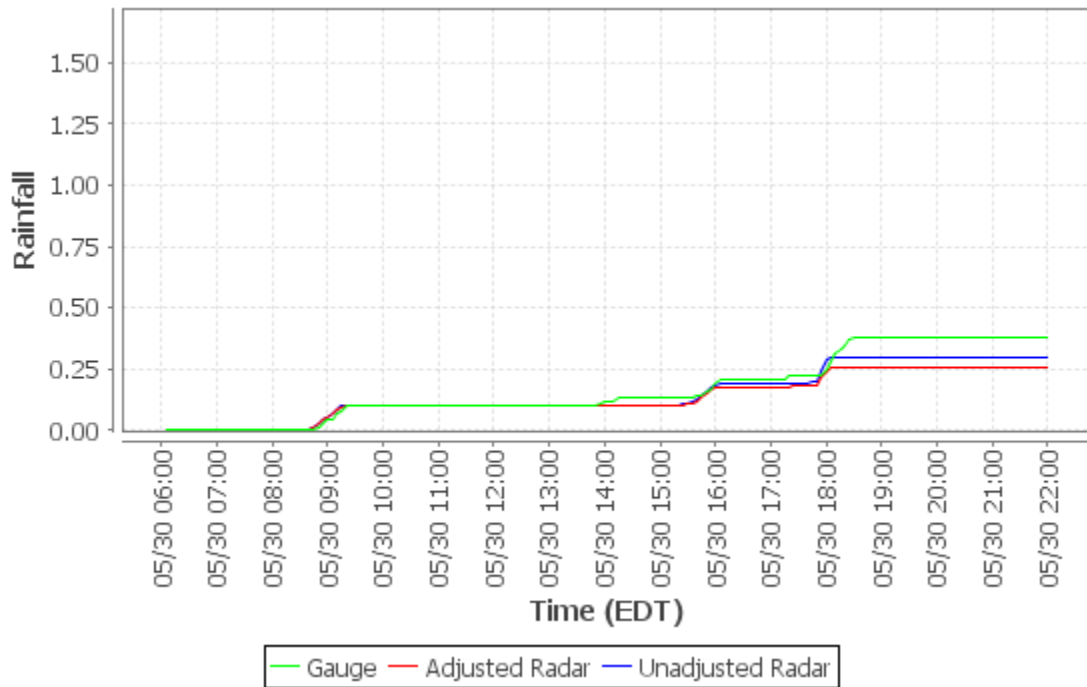
**Cumulative Distribution Plot - Univ of Pittsburgh (Loc09)**



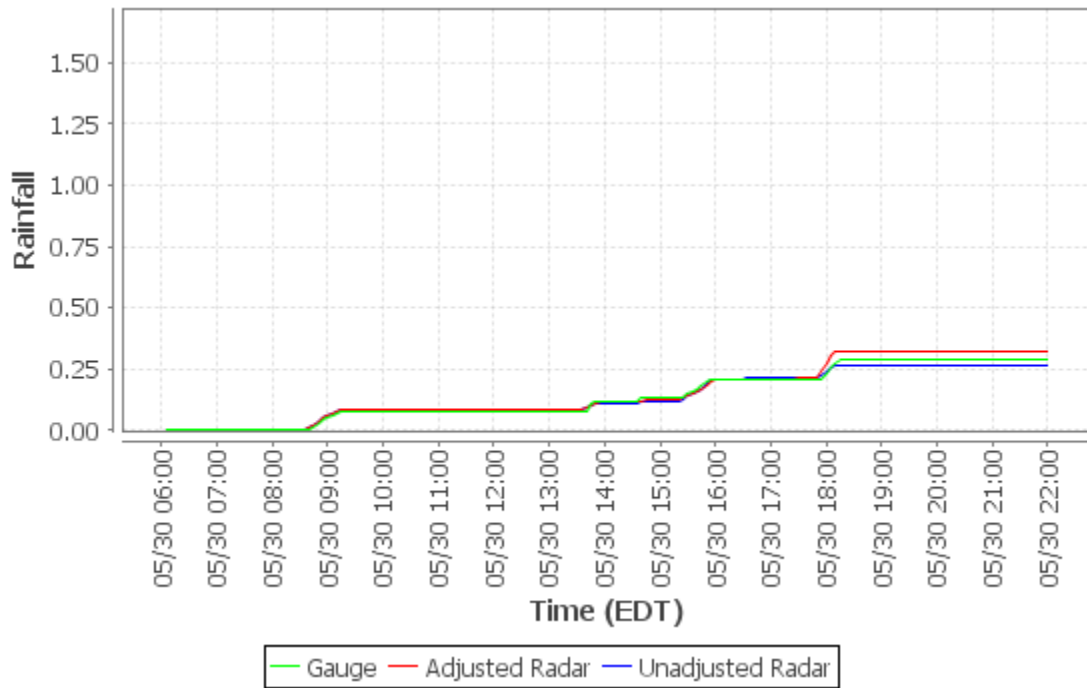
**Cumulative Distribution Plot - PWSA-Highland Park (Loc10)**



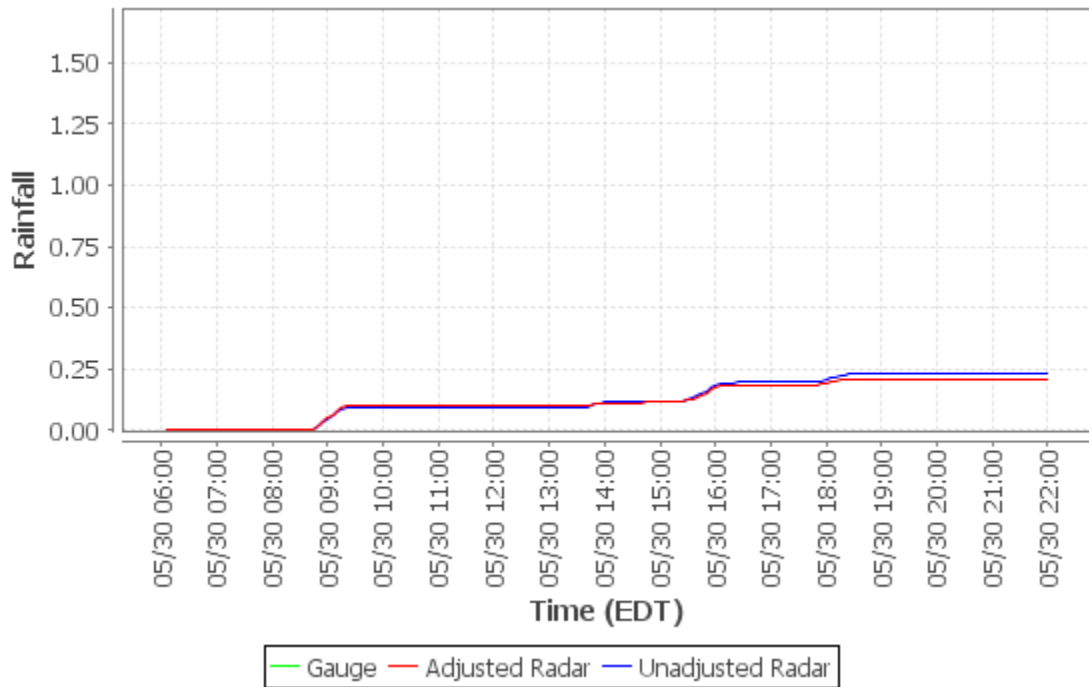
**Cumulative Distribution Plot - M-46 Access Shaft (Loc11)**



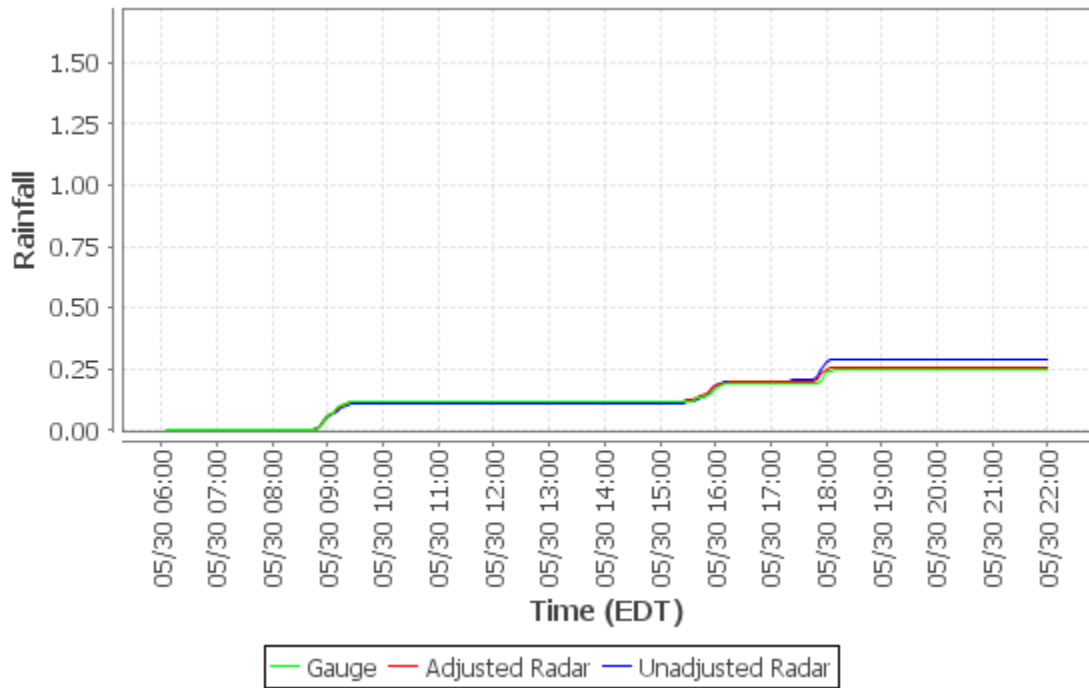
**Cumulative Distribution Plot - Baldwin (Loc12)**



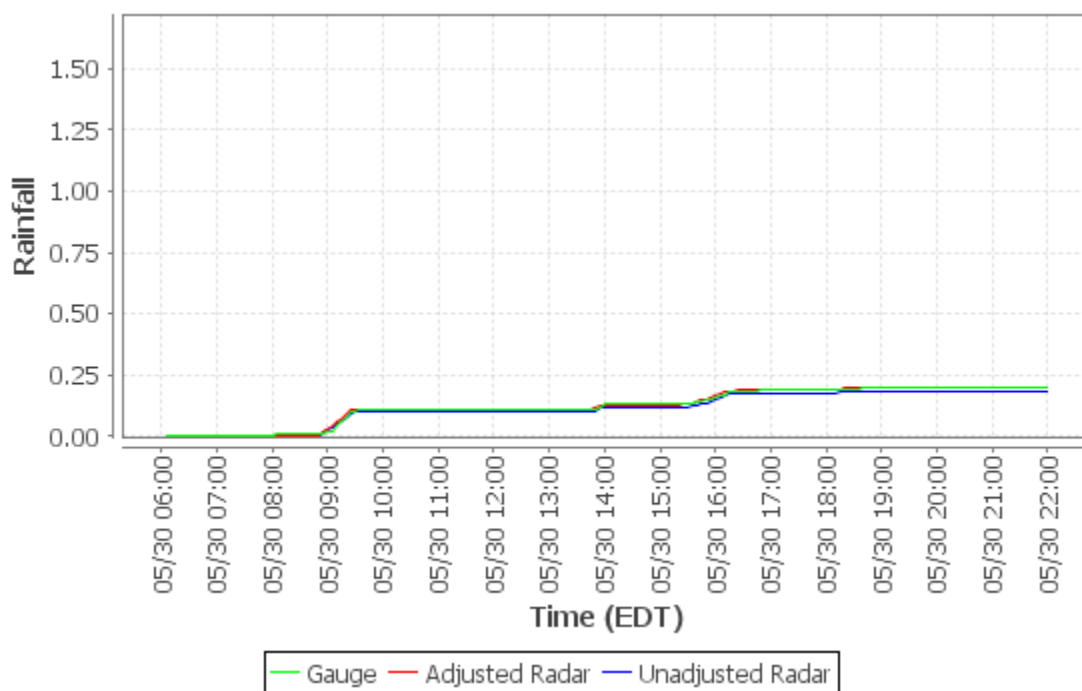
**Cumulative Distribution Plot - M-59 Access Shaft (Loc13)**



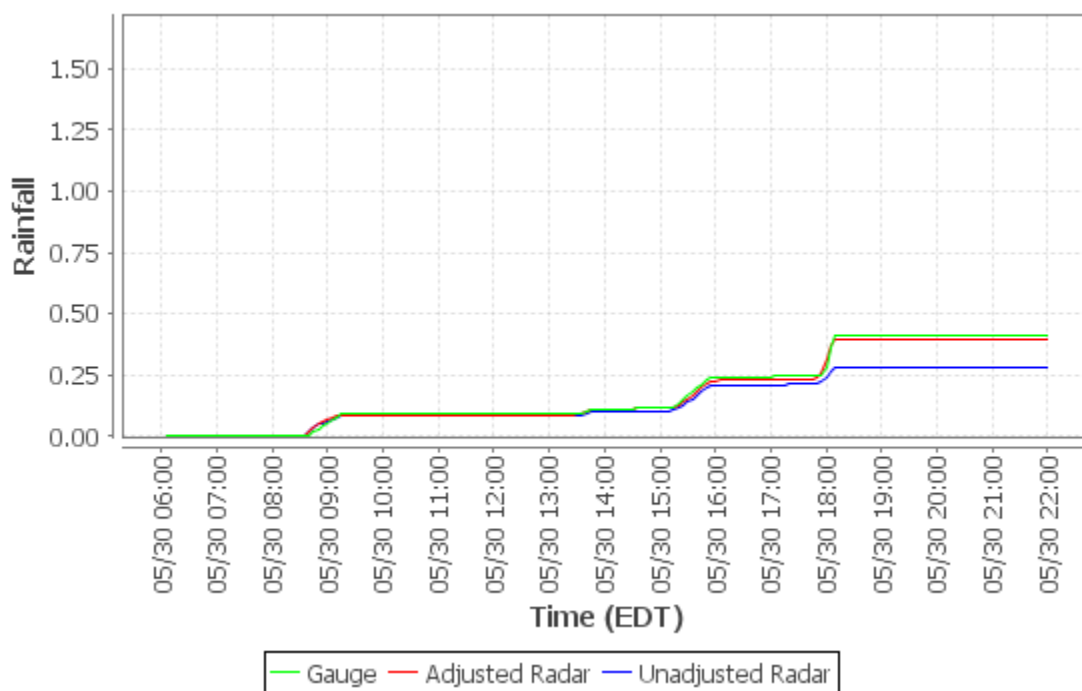
**Cumulative Distribution Plot - Churchill Munic Bldg (Loc14)**



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

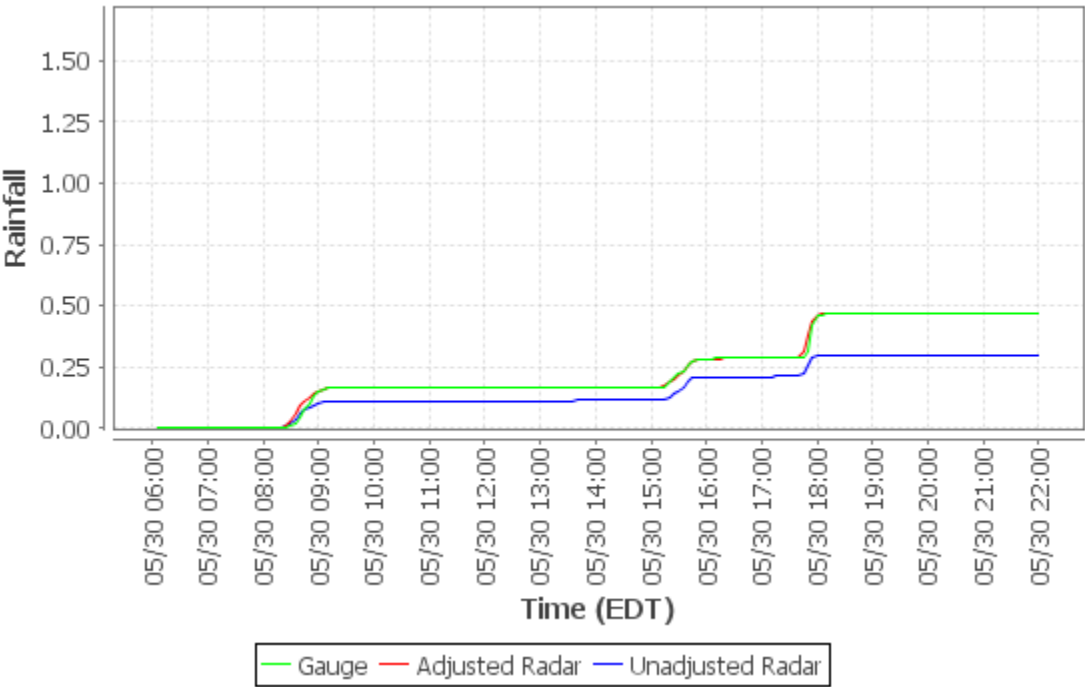


**Cumulative Distribution Plot - Castle Shannon (Loc16)**

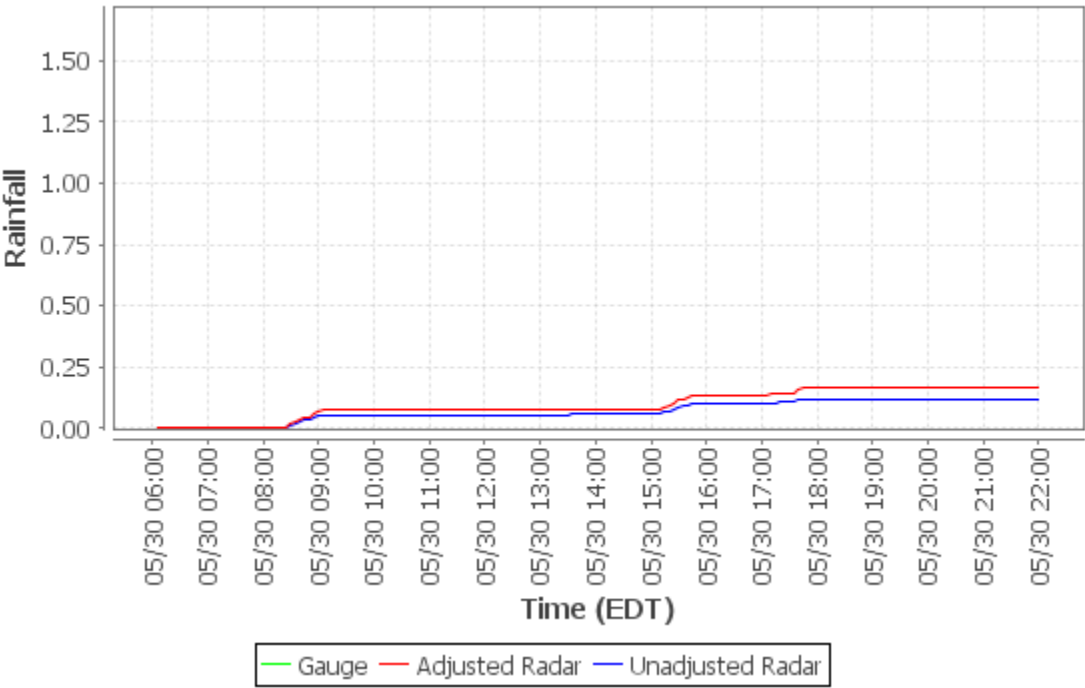




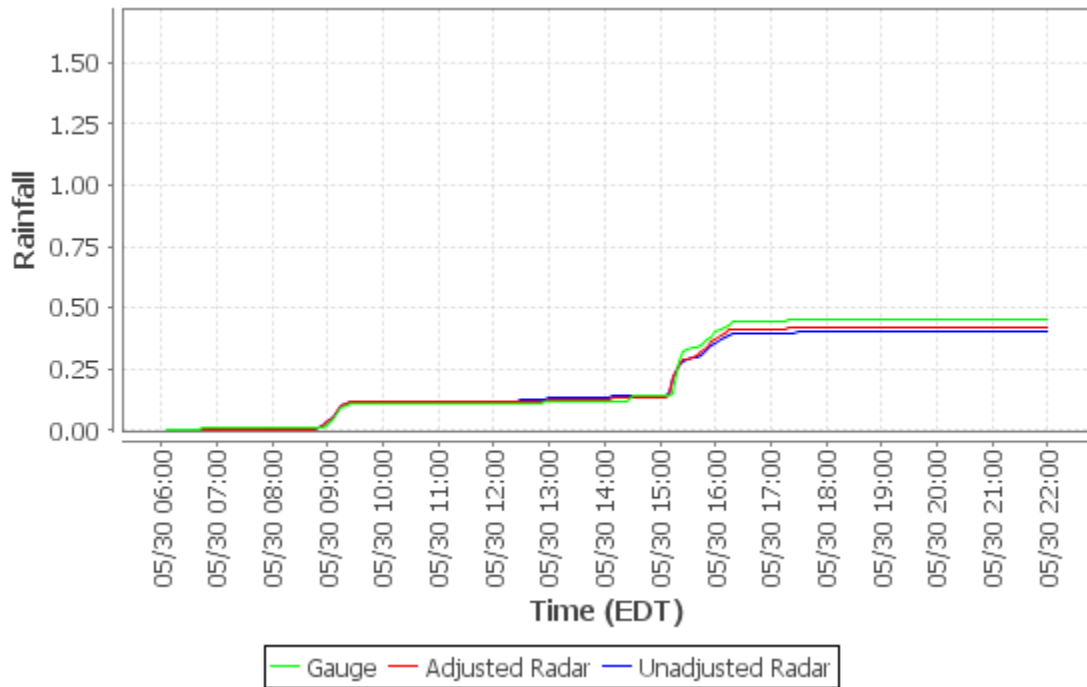
Cumulative Distribution Plot - Chartiers Pump Station (Loc17)



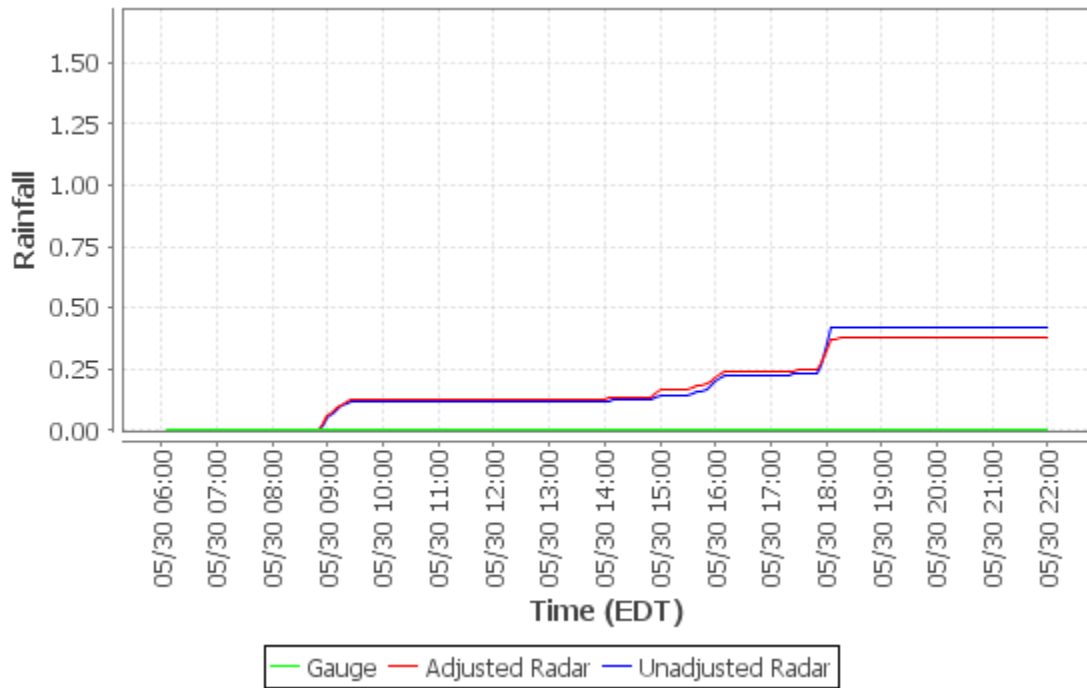
Cumulative Distribution Plot - Oakdale Pump Station (Loc18)



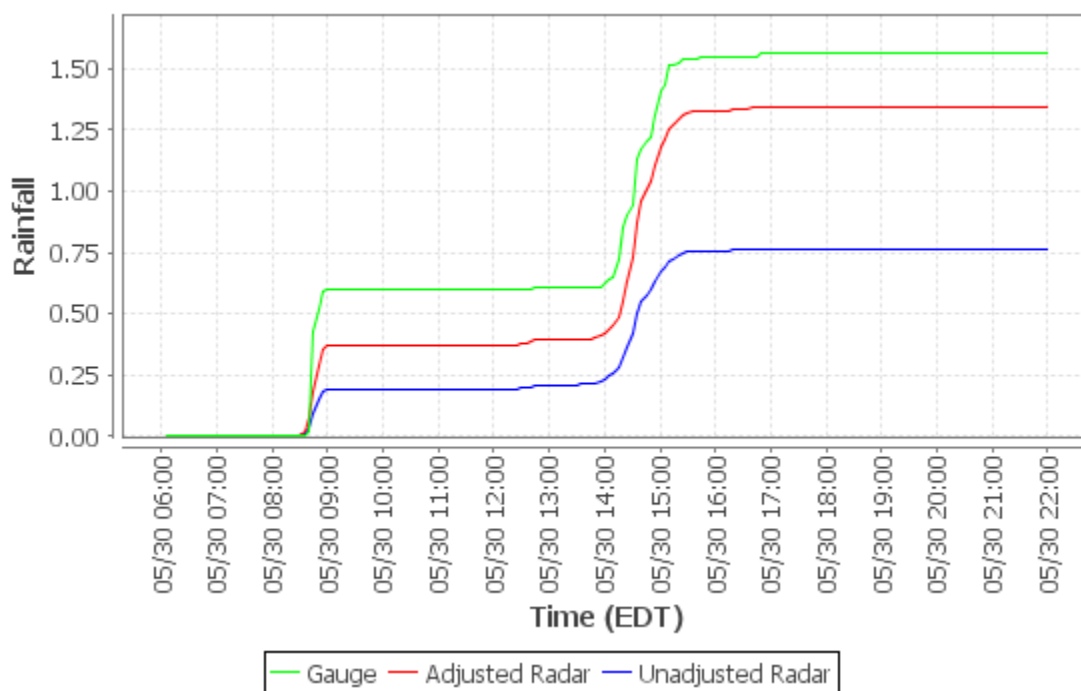
**Cumulative Distribution Plot - Sandy Creek Eq Facility (Loc19)**



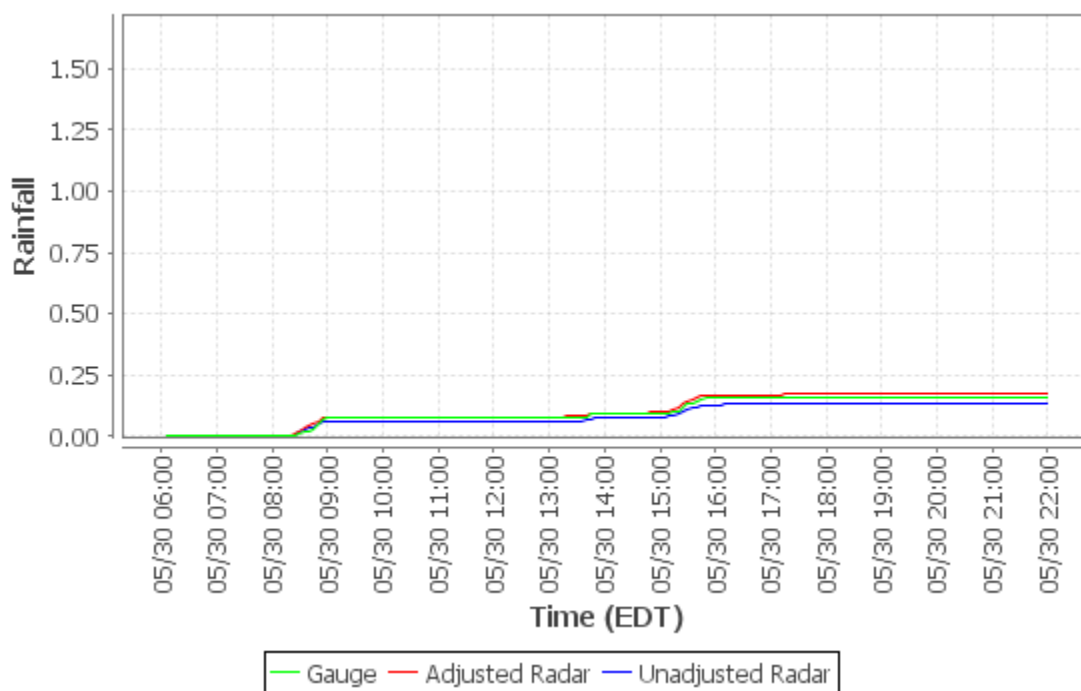
**Cumulative Distribution Plot - Gascola Eq Facility (Loc20)**



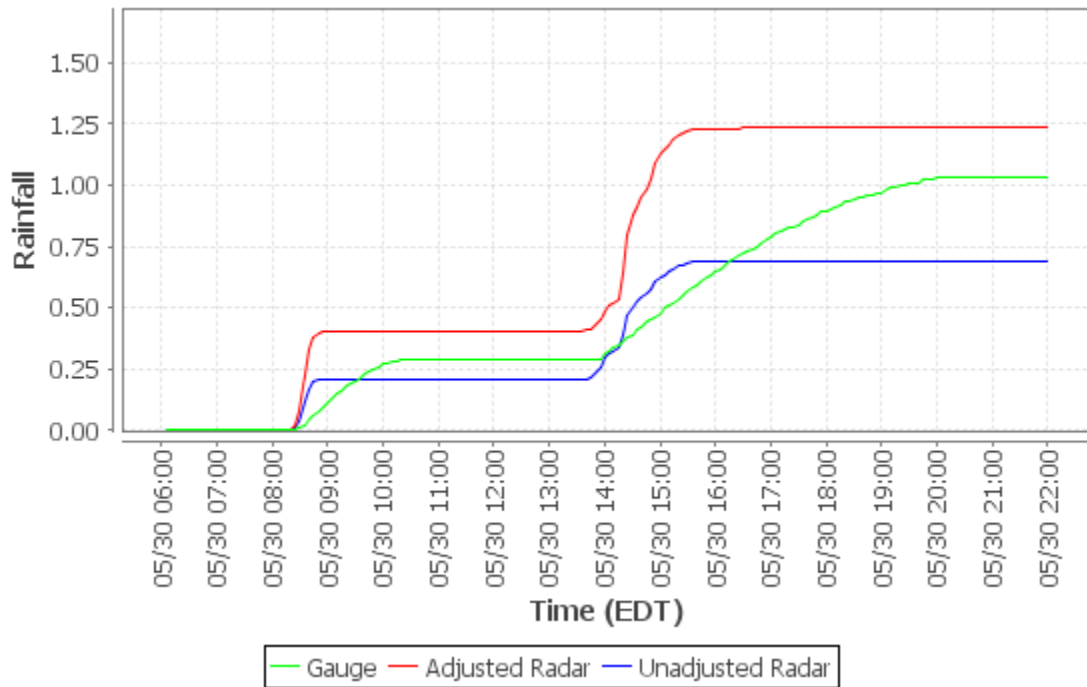
**Cumulative Distribution Plot - Moon TWP (Loc21)**



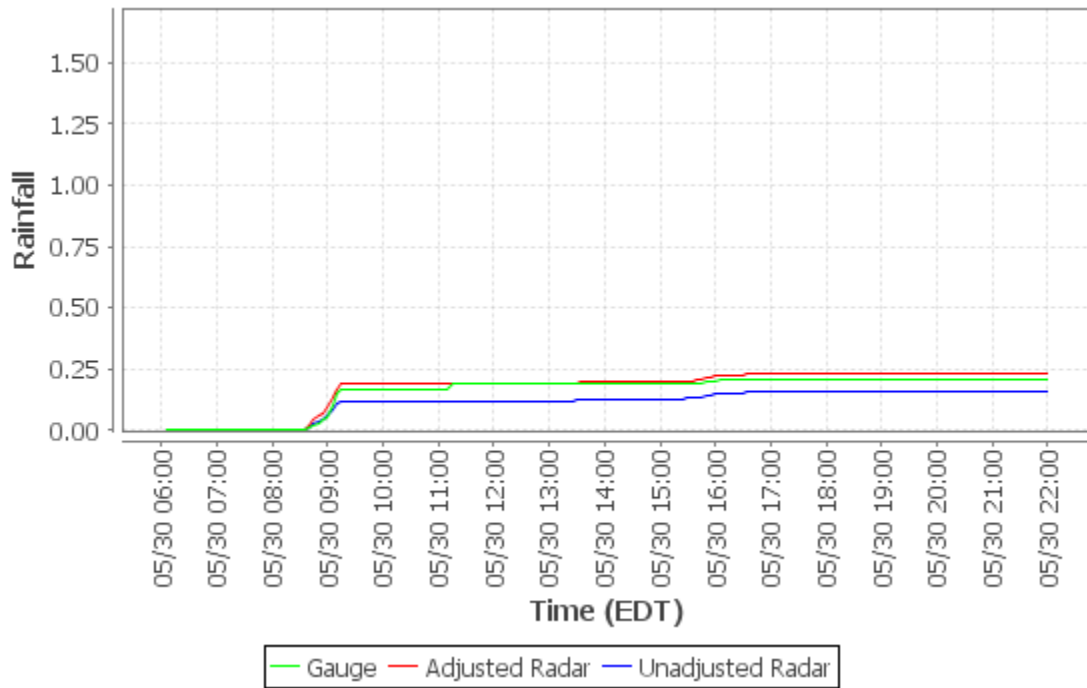
**Cumulative Distribution Plot - North Fayette TWP (Loc22)**



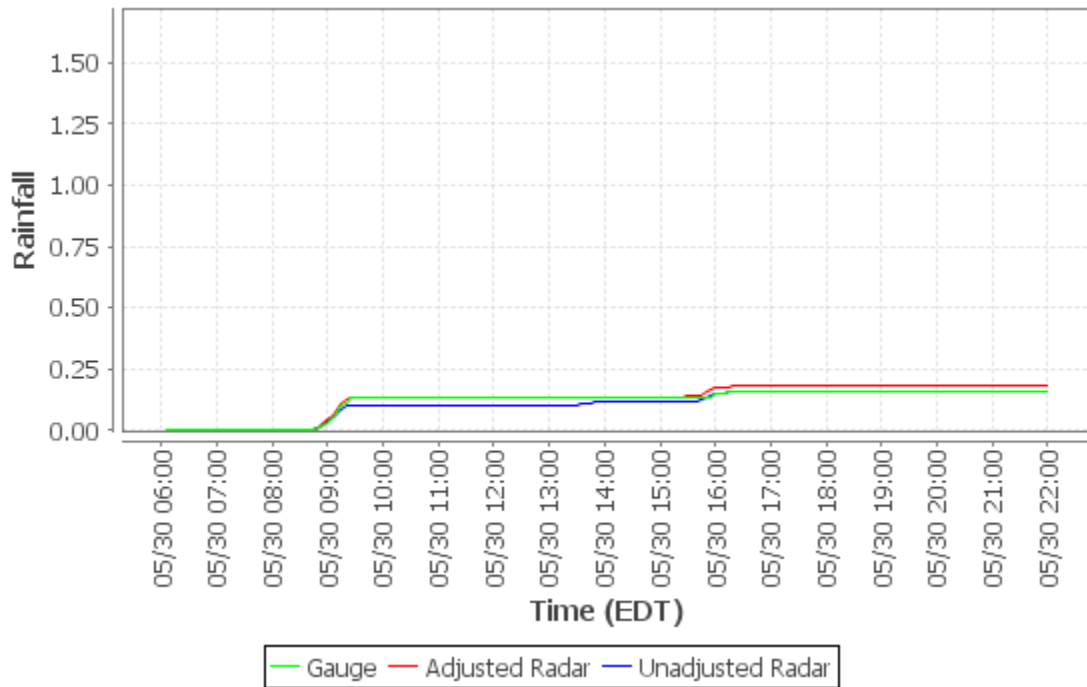
**Cumulative Distribution Plot - Clinton Munic Bldg (Loc23)**



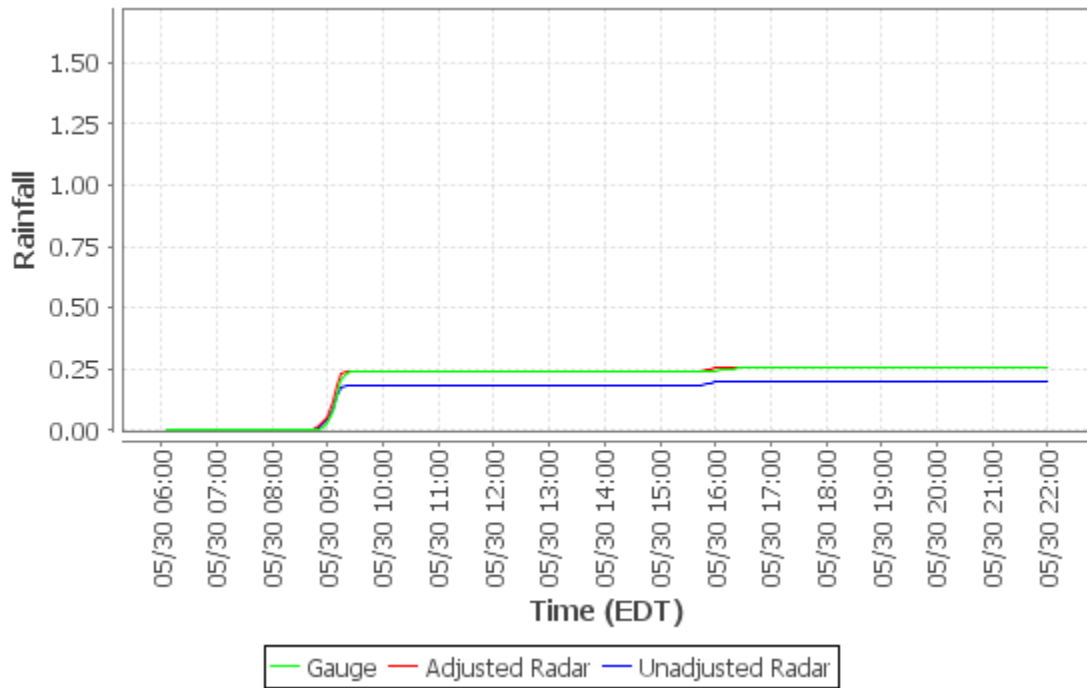
**Cumulative Distribution Plot - Jefferson Hills (Loc24)**



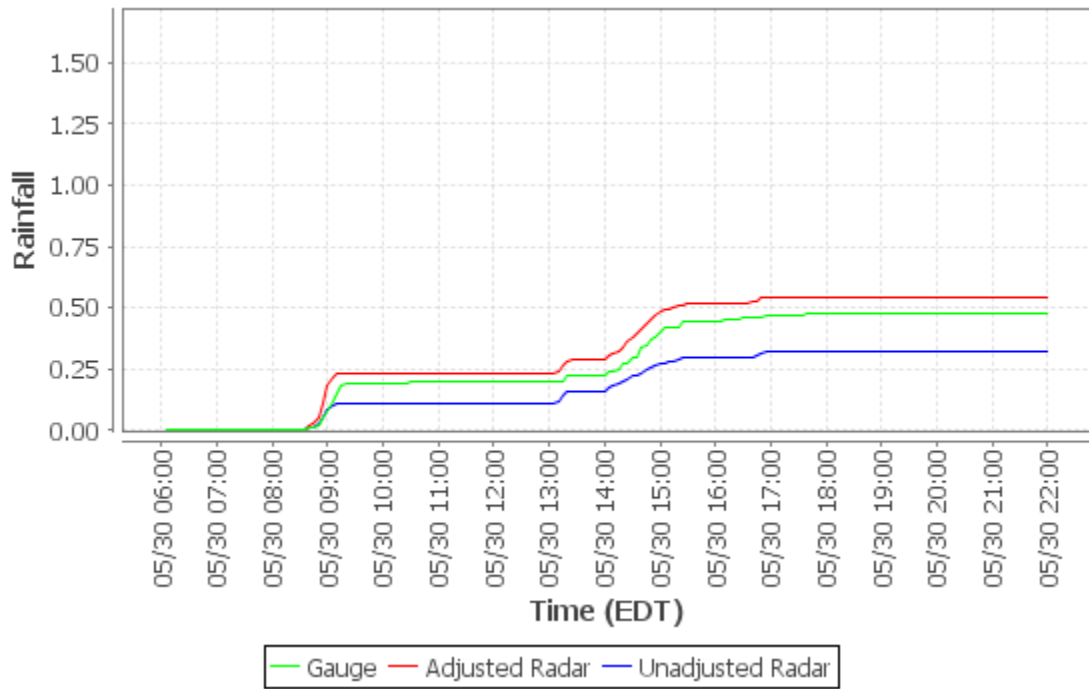
**Cumulative Distribution Plot - White Oak Public Works Bldg (Loc25)**



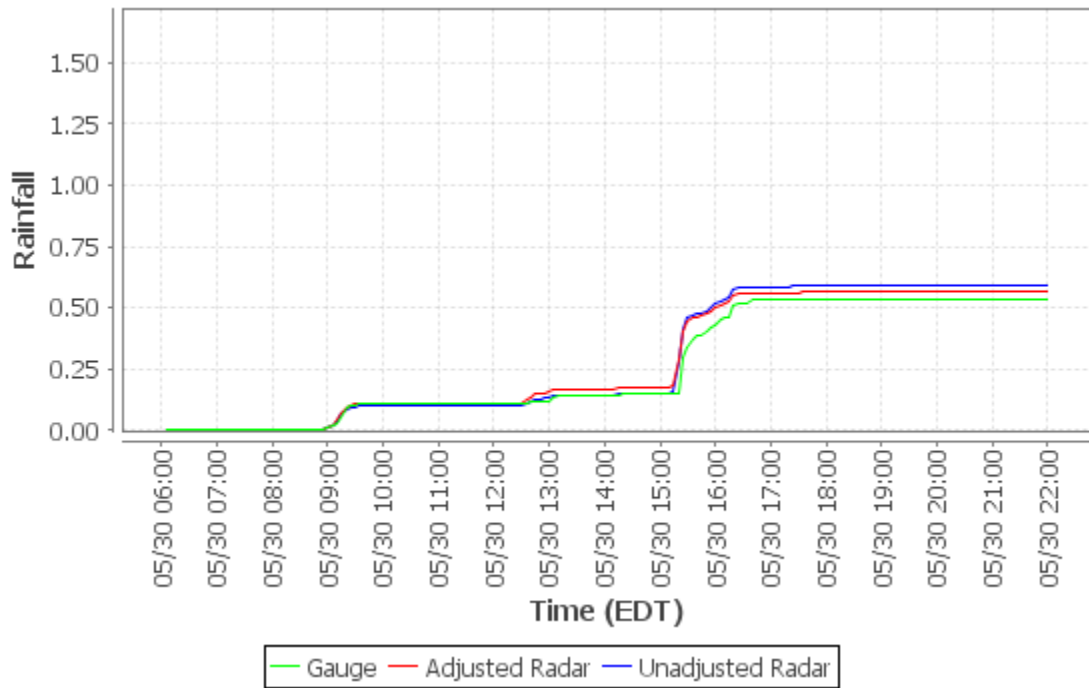
**Cumulative Distribution Plot - Elizabeth TWP Municipal Bldg (Loc26)**



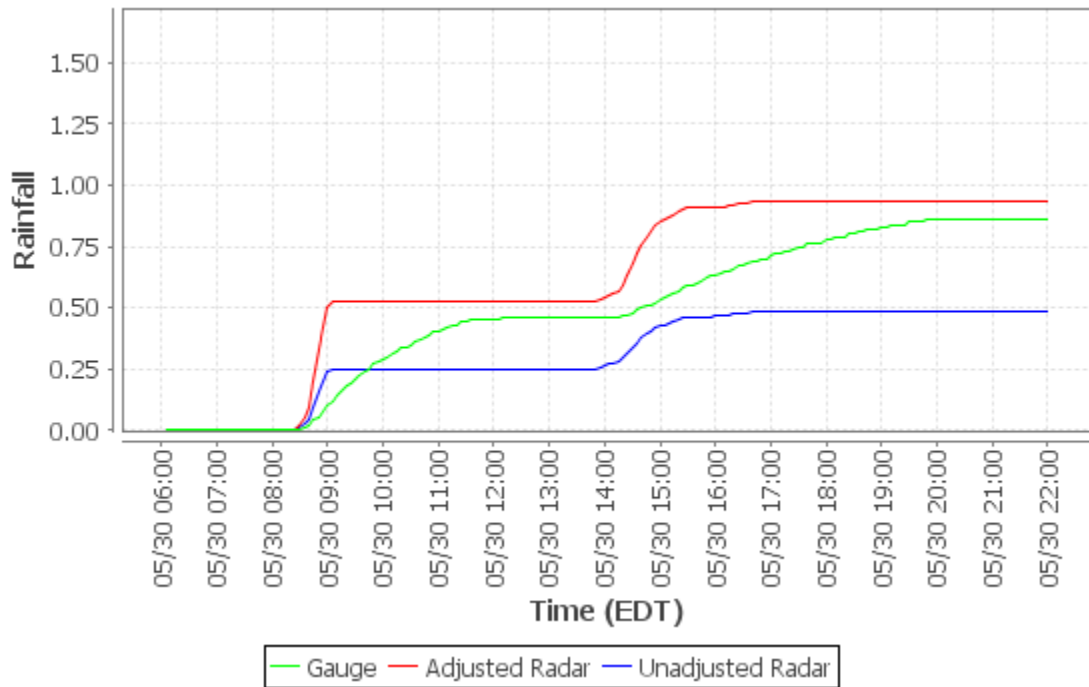
**Cumulative Distribution Plot - Marshall TWP (Loc27)**



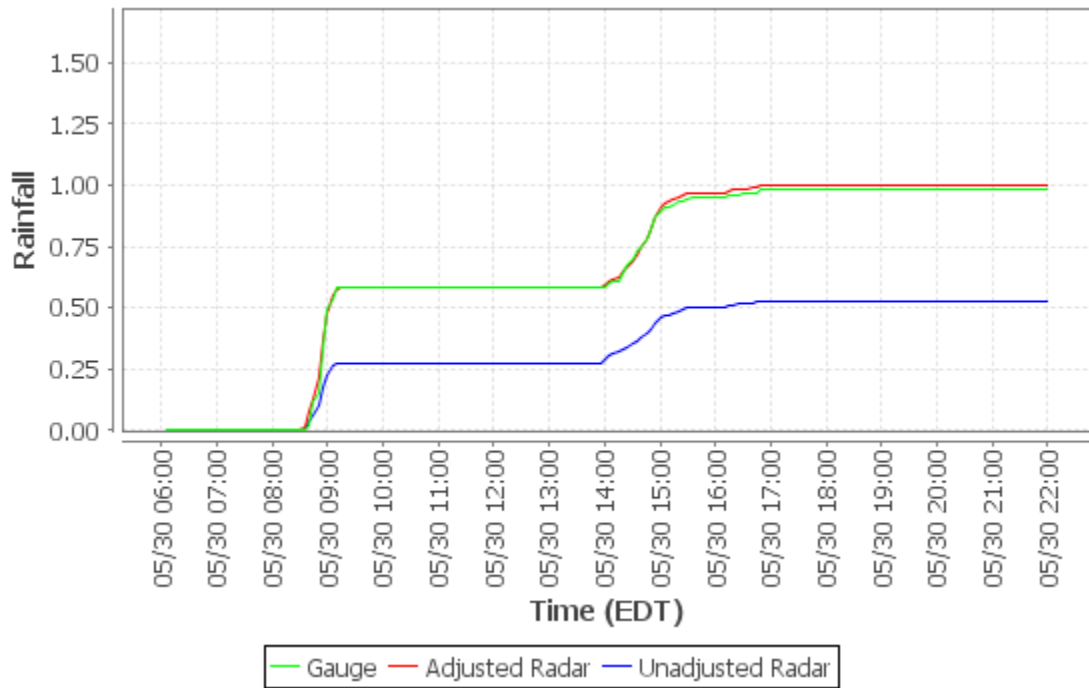
**Cumulative Distribution Plot - Plum Municipal Bldg (Loc28)**



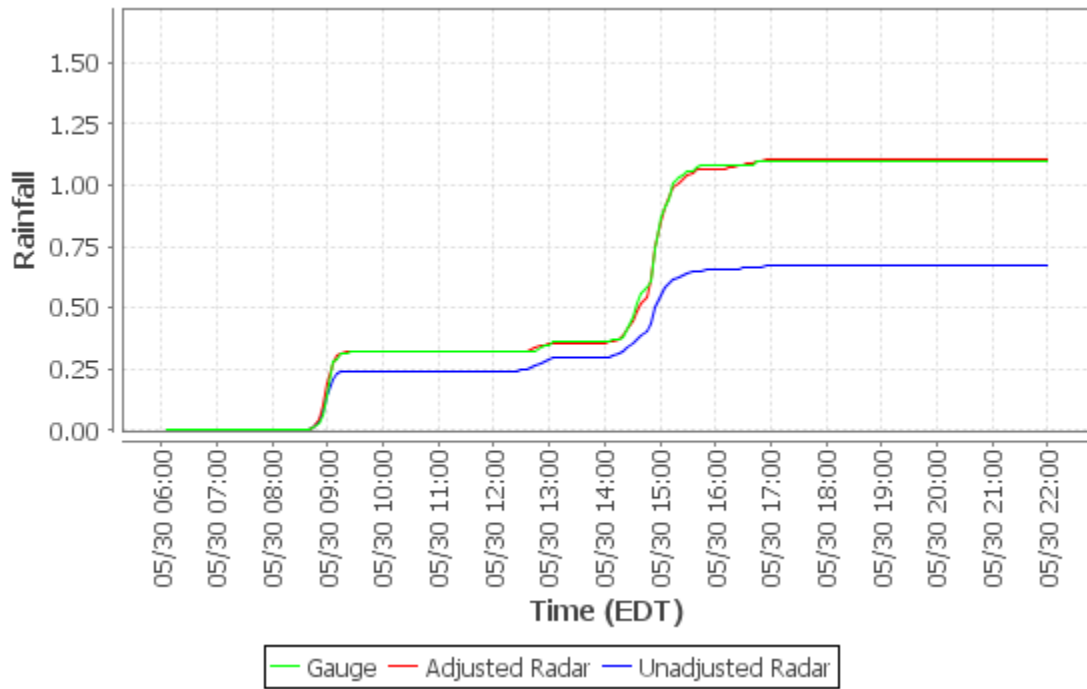
**Cumulative Distribution Plot - Bell Acres Munic Bldg (Loc29)**



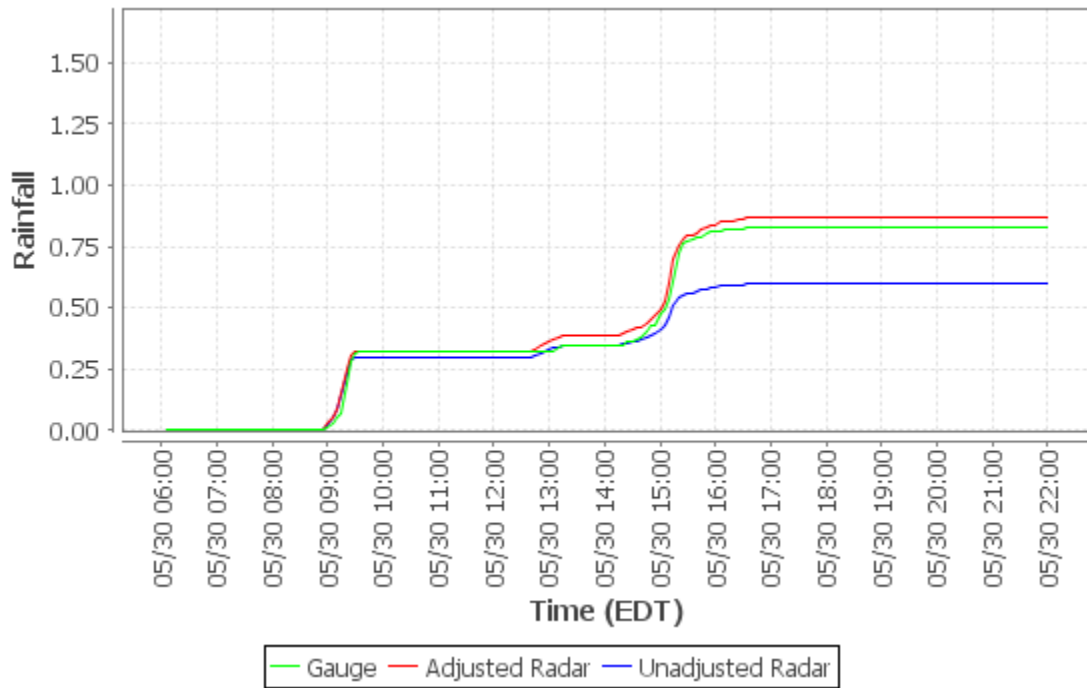
**Cumulative Distribution Plot - McCandless Twn Hall (Loc30)**



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

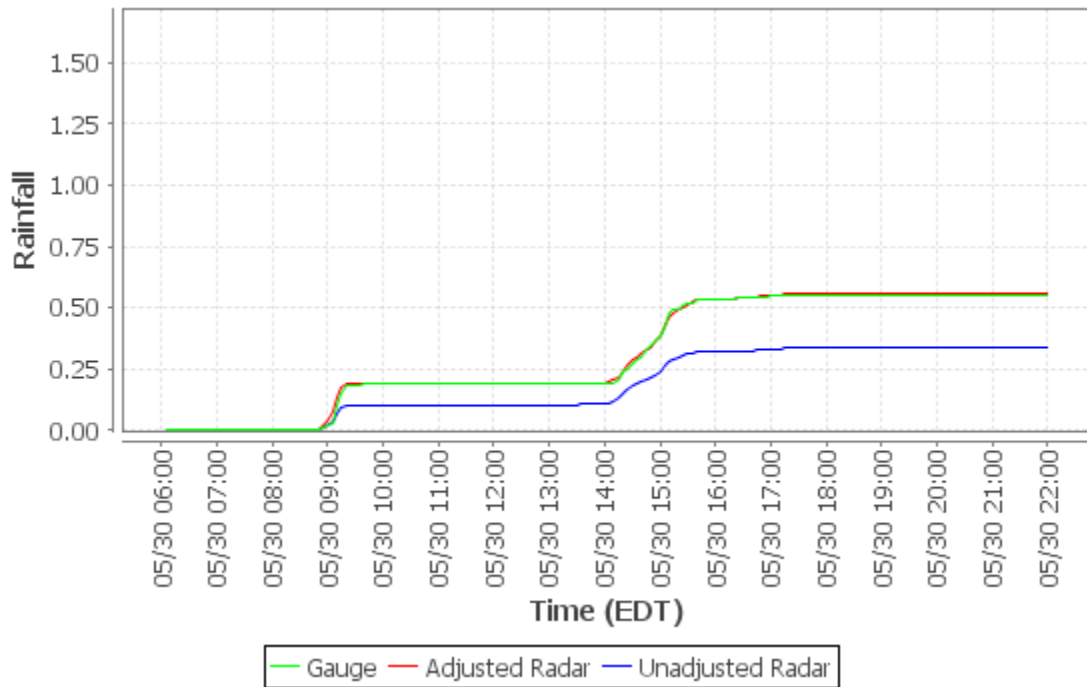


**Cumulative Distribution Plot - Arnold (Loc32)**

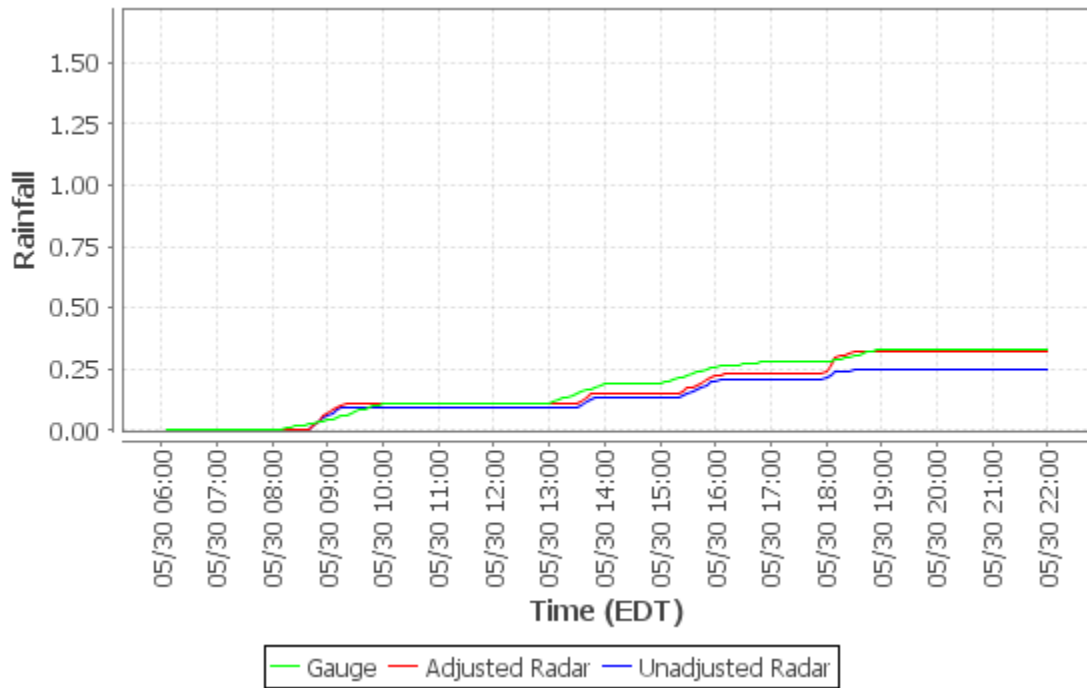




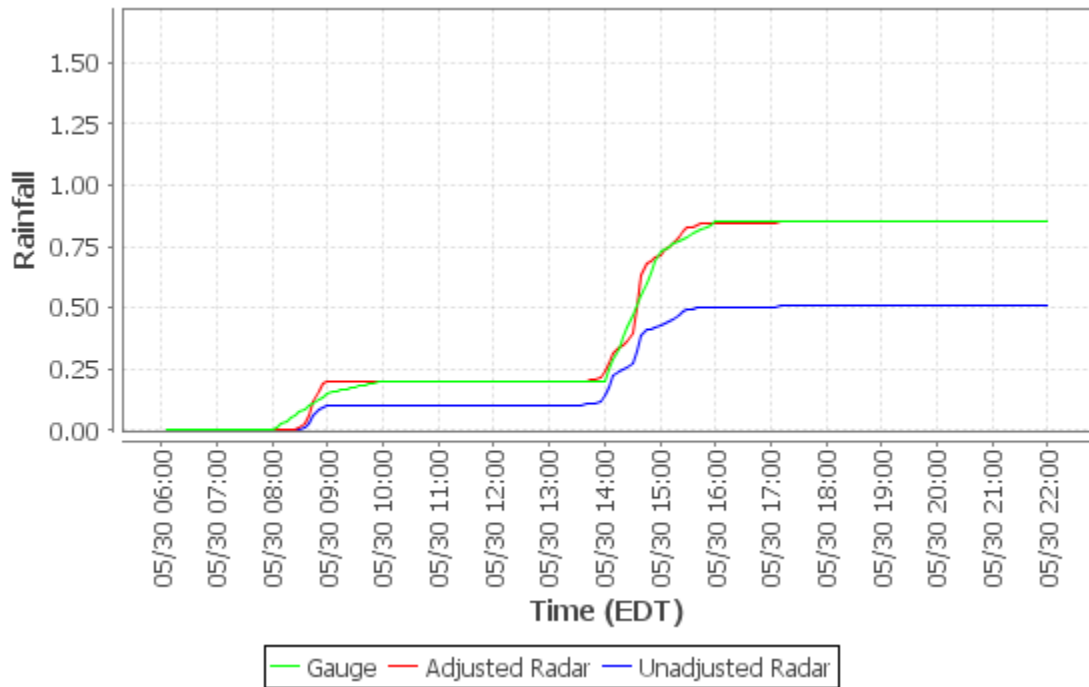
**Cumulative Distribution Plot - Richland TWP (Loc33)**



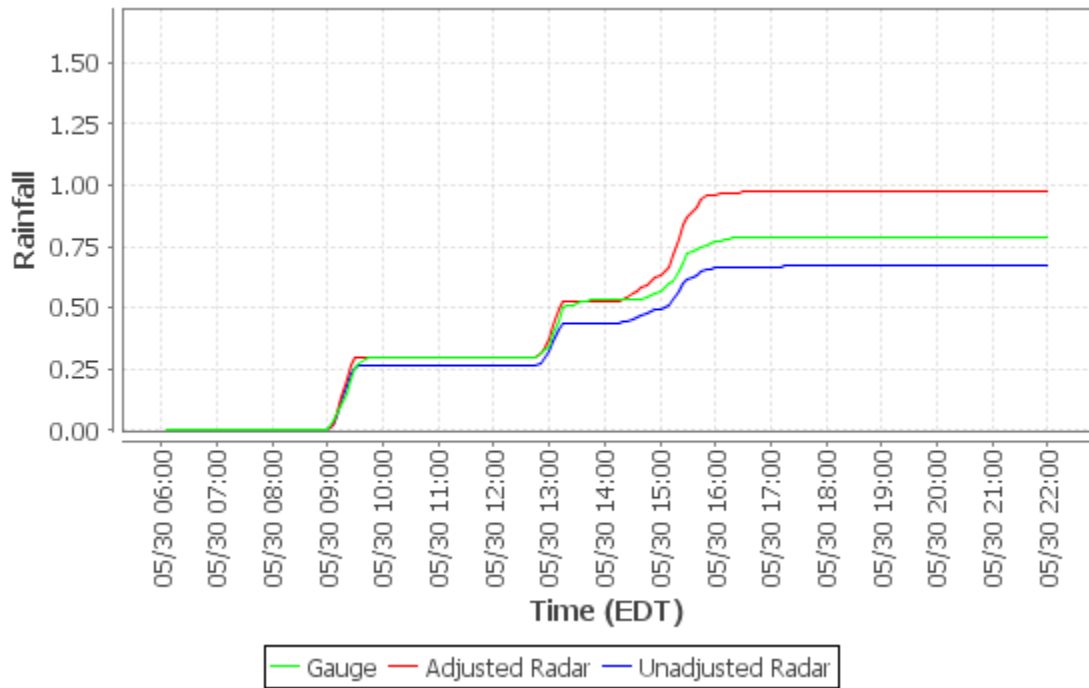
**Cumulative Distribution Plot - Pittsburgh Allegheny Cty (KAGC)**



**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)

