

Performance Evaluation of Tipping Bucket and Optical Rain Gauges for Hydrological Research

Department of Civil Engineering, Research Experience for Undergraduates

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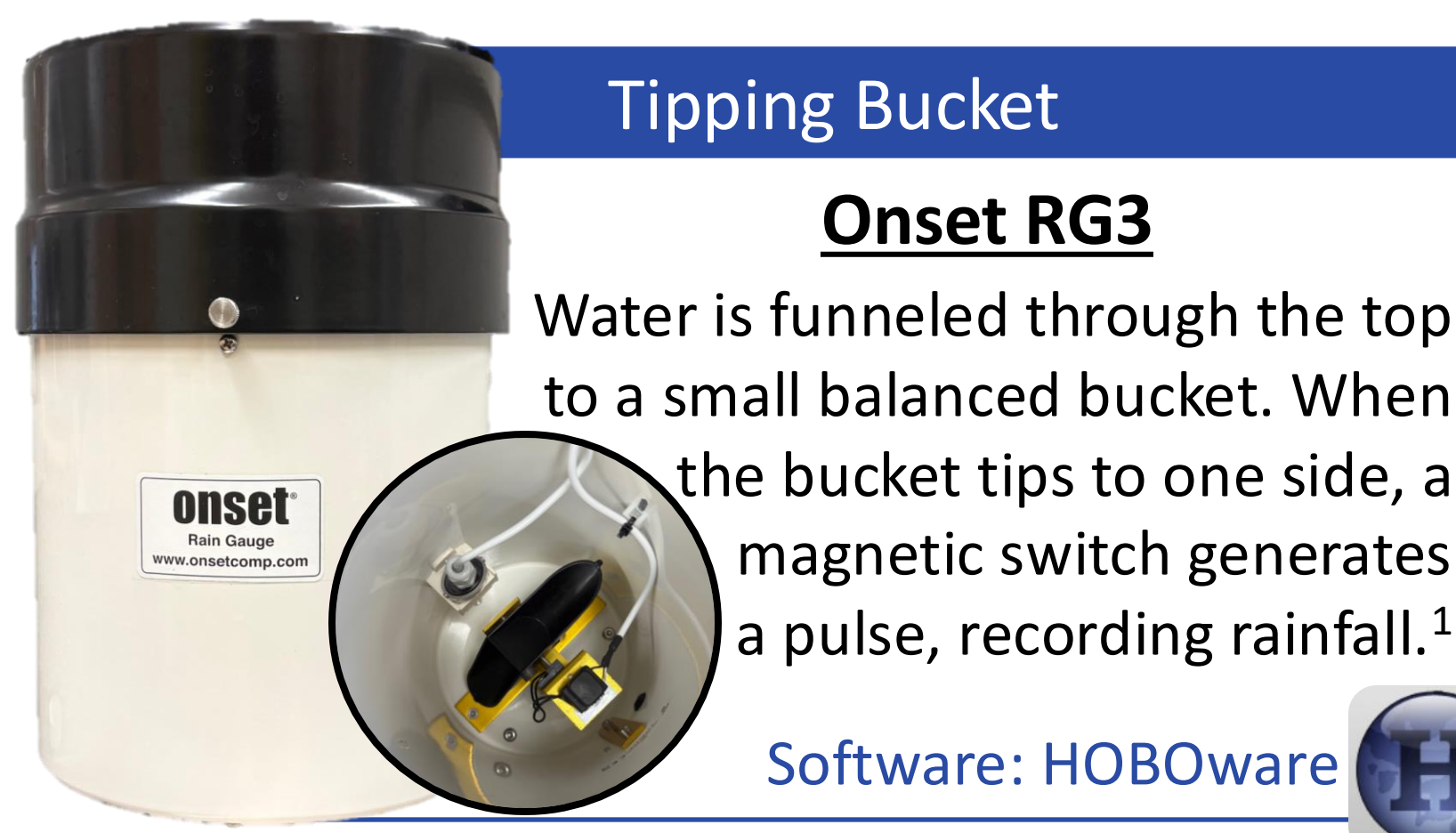
Background

Getting precise data in the fields of meteorology, hydrology, and flood forecasting serves as a foundation for developing the municipalities and infrastructure design in cities. Researchers rely on many different rain gauges to gather data. **The tipping bucket and optical rain gauges are widely used due to their cost effectiveness and ease of deployment.**¹ Despite their widespread use existing issues can limit the data collection, especially in high intense rain events. Minimum detection thresholds, reporting delay, mechanical error, and recalibrations can all result in inaccurate data. These rain gauges have it contributed to unaccounted rainfall in the July 2025 disaster in Kerrville and in Hurricane Harvey. **Missing data deny advancements in modeling the flood impacts and emergency preparation.** This study provides an evaluation of a tipping bucket and optical rain gauge by simulating low and high intensity rainfall events. This study aims to identify which one is the best to gather the data that is missing in these events.

Rain Gauges

Tipping Bucket

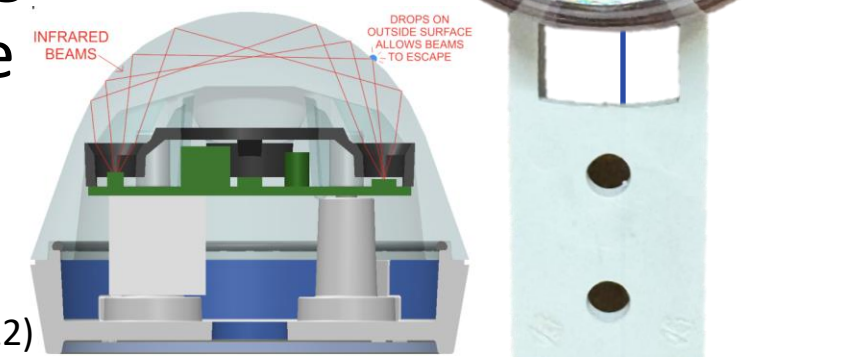
Onset RG3



Optical Sensor

Hydreon RG-15

Infrared beams reflect off the lens to detectors. Droplets of water deviate the infrared beams. Changes in the infrared beams determine droplet size.²



Parameter	Tipping Bucket ³	Optical Sensor ²
Calibration Accuracy	± 1.0%	± 10%
Resolution	0.01 inches	0.01 inches
Maximum Rainfall	5 inches/hr	Unreported

Programming the Optical Sensor

```
// Rain Detection
float delta = totalAccum - lastTotal;

if (delta > RAIN_THRESHOLD) {
  if (!isRaining) {
    Serial.println("\n Rain START detected!");
    isRaining = true;
  }

  Serial.print("Rain detected: ");
  Serial.print(delta, 3);
  Serial.println(" in");
}

else {
  if (isRaining) {
    Serial.println("\n Rain STOPPED");
    isRaining = false;
  }
}
```

Figure 1.

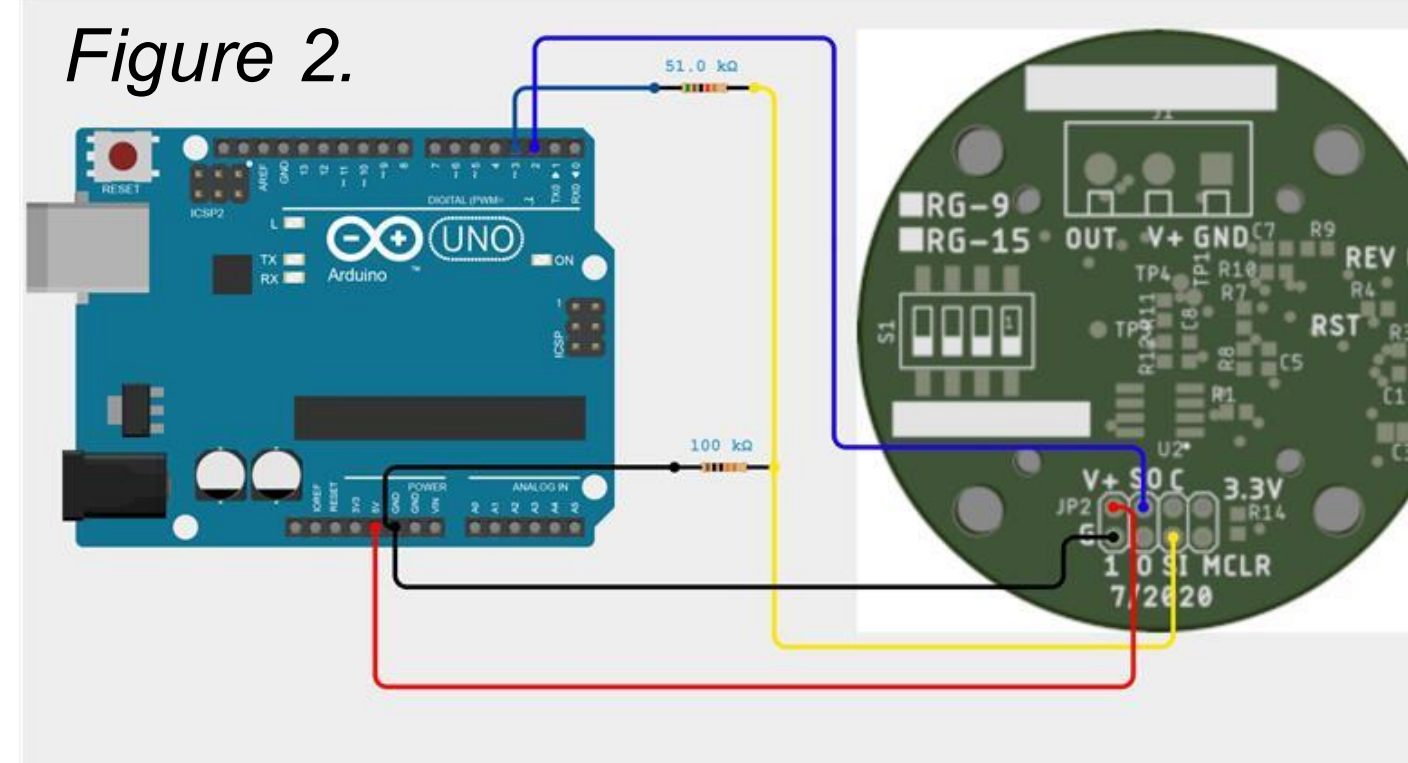


Figure 1. Rain detection code in C using the Arduino library produced by Hydreon for the RG-15 sensor.

Figure 2. Wiring diagram for connecting the Arduino with the RG-15 (Hydreon, 2022).

Simulation of High and Low Intensity Rainfall Events

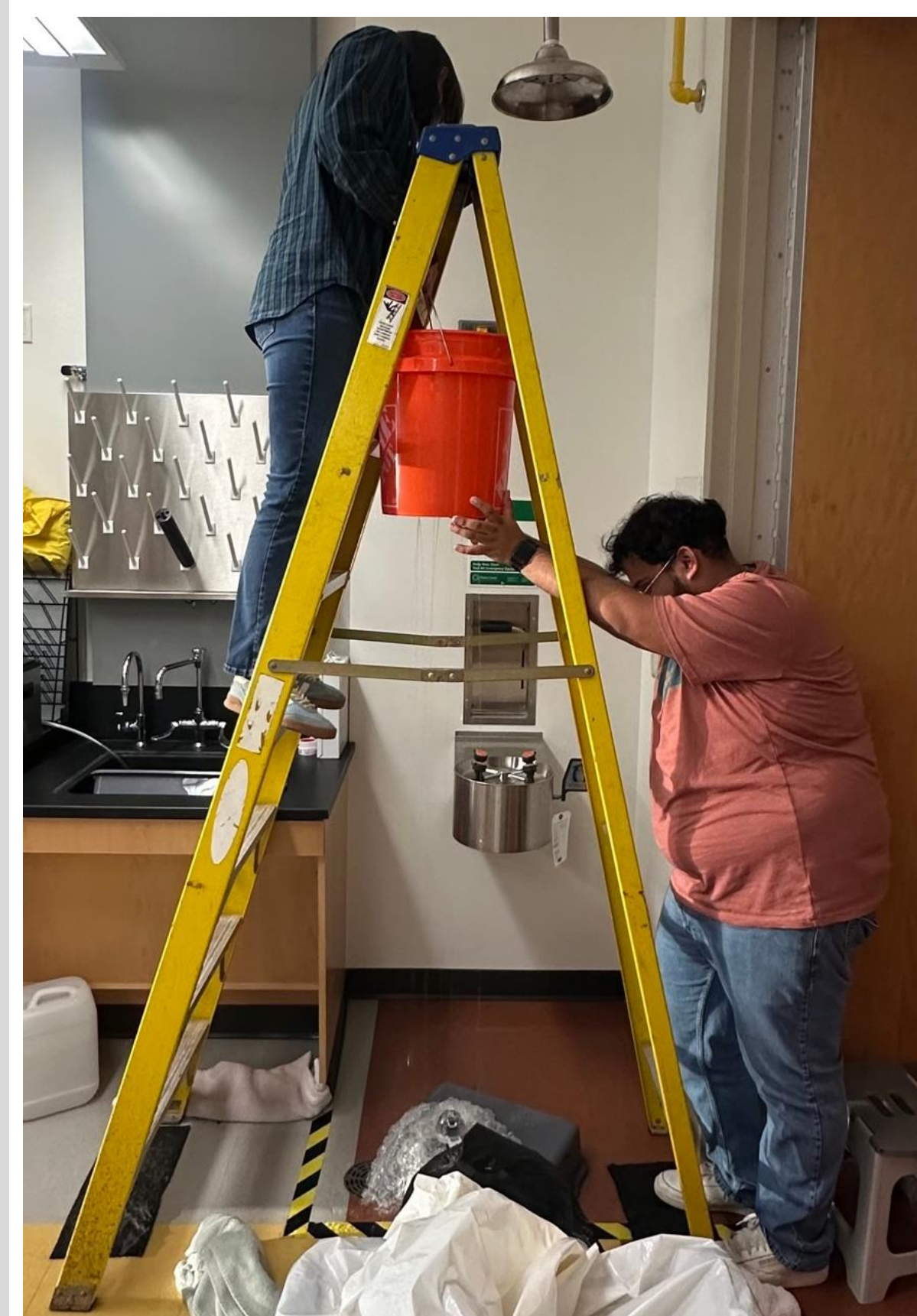
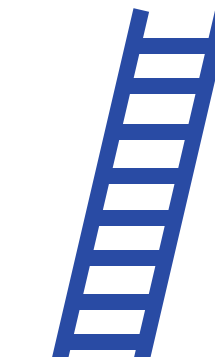


Figure 3. Rainfall simulation set up. Orange bucket with low intensity (left) or high intensity (right) hole patterns is held against the top ladder rung. Water falls 63 inches above the ground. Rain gauge is placed directly beneath rainfall.

Constant Conditions



Volume of Water:
4 gallons



Height of Rainfall:
63 inches



Performed **indoors**, reduced external influence

Low Intensity



Hole Diameter:
1/16 inches
Number of Holes: **10**

High Intensity



Hole Diameter:
1/8 inches
Number of Holes: **35**

Calculated Flow Rate

Determining Inches of Rainfall:

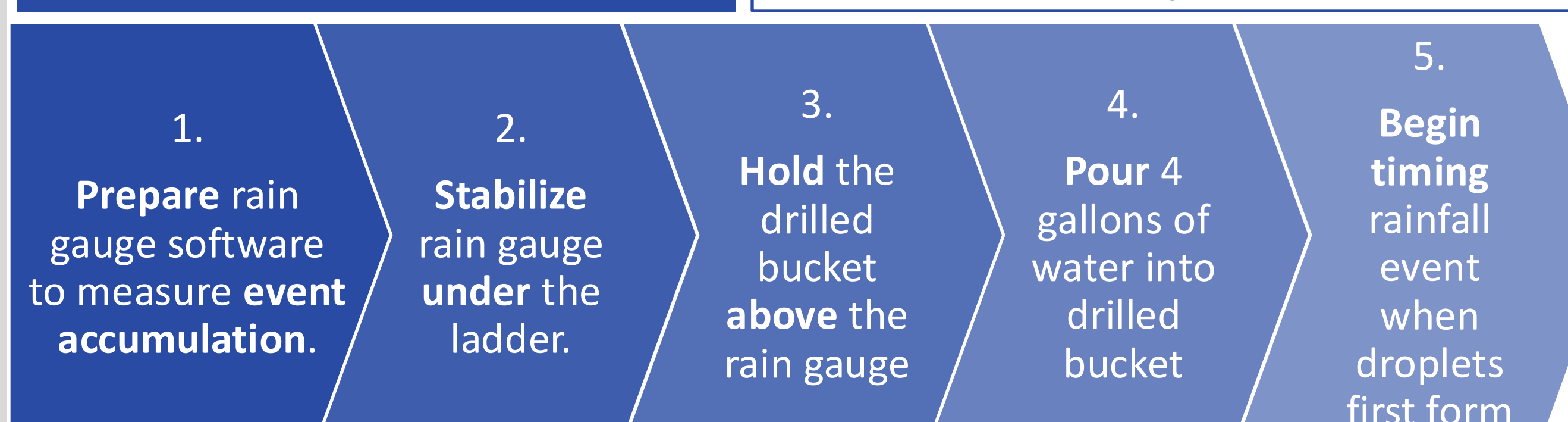
Depth =

(Gallons * 231 * (hole percentage)) / gauge area

Hole Percentage = Holes used / total holes

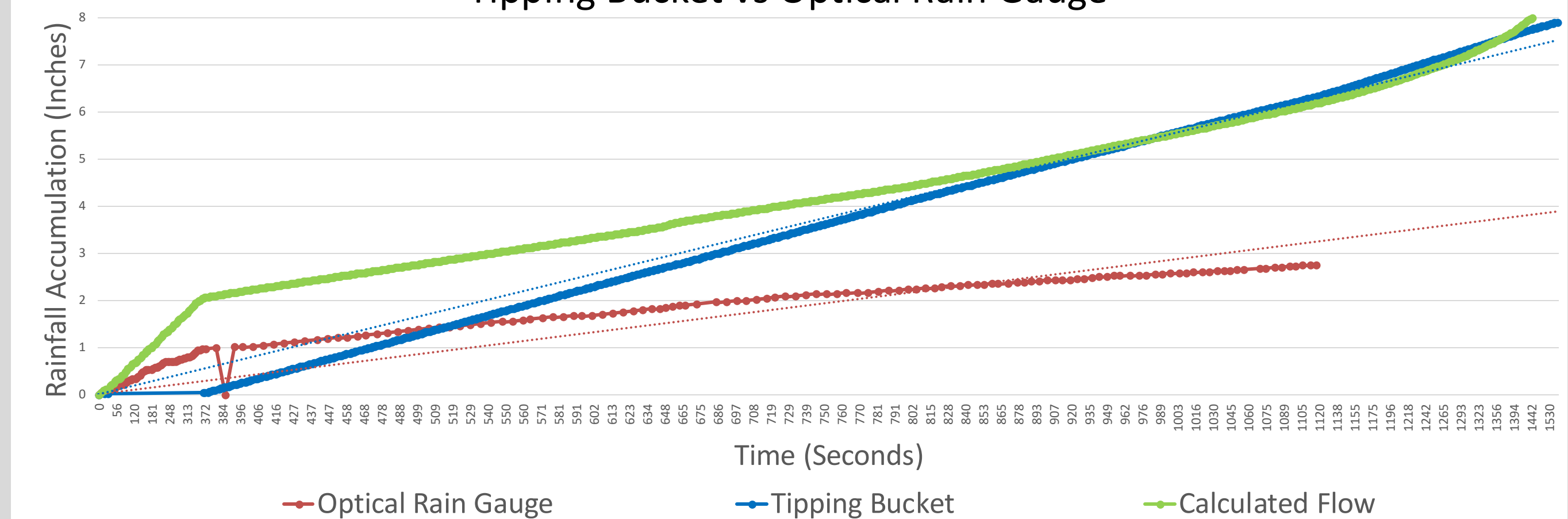
Flow = Depth / Time

Procedure

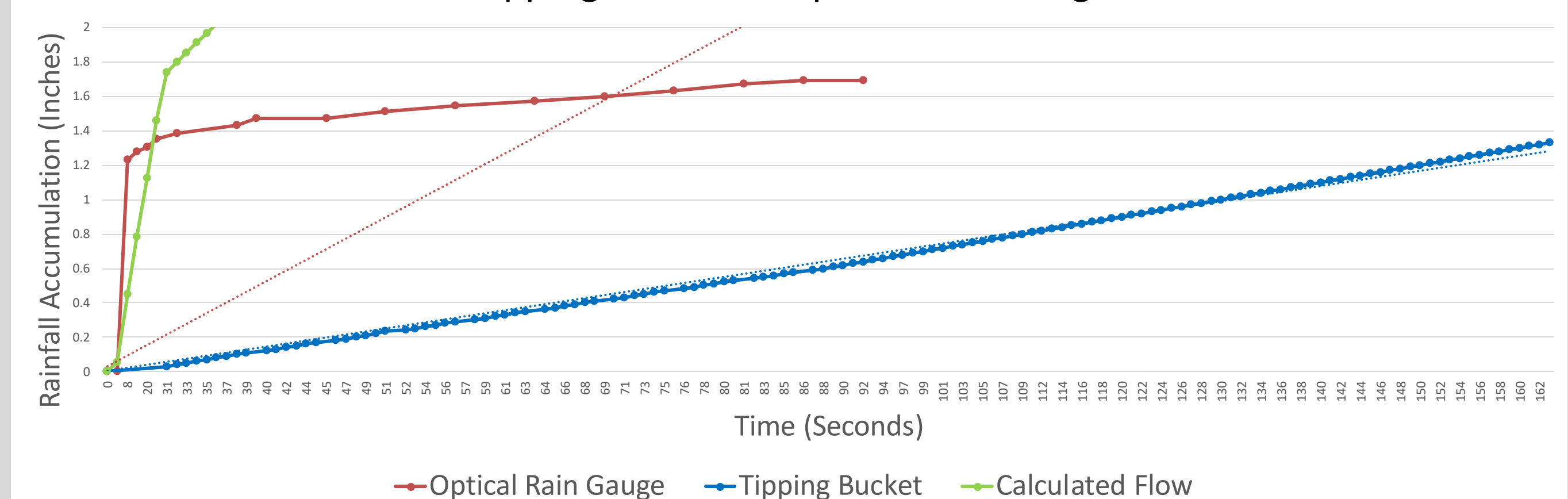


Experimental Results

Low Intensity Rainfall Accumulation Measured by a Tipping Bucket vs Optical Rain Gauge



High Intensity Rainfall Accumulation Measured by a Tipping Bucket vs Optical Rain Gauge



Conclusions

- Optical rain gauge had more gaps in the data due to a smaller collection surface area.
- Data from the tipping bucket lags past rainfall event duration due to the funnel.
- Optical rain gauge better measures total rainfall accumulation in a high intensity rainfall event.
- Tipping bucket rain gauge better measures total rainfall accumulation in a low intensity rainfall event.

References

- Segovia-Cardozo, Daniel A et al. "Tipping Bucket Rain Gauges in Hydrological Research: Summary on Measurement Uncertainties, Calibration, and Error Reduction Strategies." *Sensors (Basel, Switzerland)* vol. 23,12 5385. 7 Jun. 2023, doi:10.3390/s23125385
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- Rain Sensors. (2022, July 18). How it Works | Rain Sensors. Rain Sensors | Hydreon Optical Rain Sensor. <https://rainsensors.com/support/how-it-works/>

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