Quantifying Representative Sampling Using a Hydrologic Analysis Tool

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Outline

- Introduction
- Data Review Process
  - Step 1 - Flow Data Quality
  - Step 2 - Sample Collection Timing
  - Step 3 - Percent Capture
- Conclusion
- Questions

Perspective…and Disclaimer

- OWP has over 15 year of stormwater research experience.
- Research based monitoring with some regulatory compliance monitoring.
- Primarily flow-weighted composite Event Mean Concentration (EMC) water quality sampling.

What is representative sampling?

Statistics

Subset from a population such that the group of samples has the same distribution of characteristics as the entire population.

Stormwater Monitoring

Flow and water quality data that has the same range and frequency of occurrences as the entire runoff event from a particular location.

Locations have the same characteristics as the larger system of interest.

Representative Sample

Defined in the study plan, Quality Assurance Project Plan (QAPP), Sampling and Analysis Plan (SAP) or similar document.

Lots of resources available to plan for and incorporate representative sampling.

Not many resources available to determine if a sample is still representative after it has been collected.

Data Review Process

Step 1 - Flow Data Quality

- Study plan requirements
- Collection errors
- Known Relationships

Step 2 - Sample Collection Timing

- Individual samples taken at appropriate times during event.

Step 3 - Percent Capture

- Quantify how much of the runoff event was sampled.

Step 1 – Flow Data Quality

Flow-Weighted Sampling

- Most accurate intra-event sampling scheme.
- Typically used to obtain Event Mean Concentration (EMC).
- Error in flow measurements = inappropriate sample timing.
- Not a true EMC composite sample.

Load Calculations

- Load = EMC x Runoff Volume
- Error in runoff volume directly translates to error in load calculations.

Study Plan Requirements

Rainfall Data

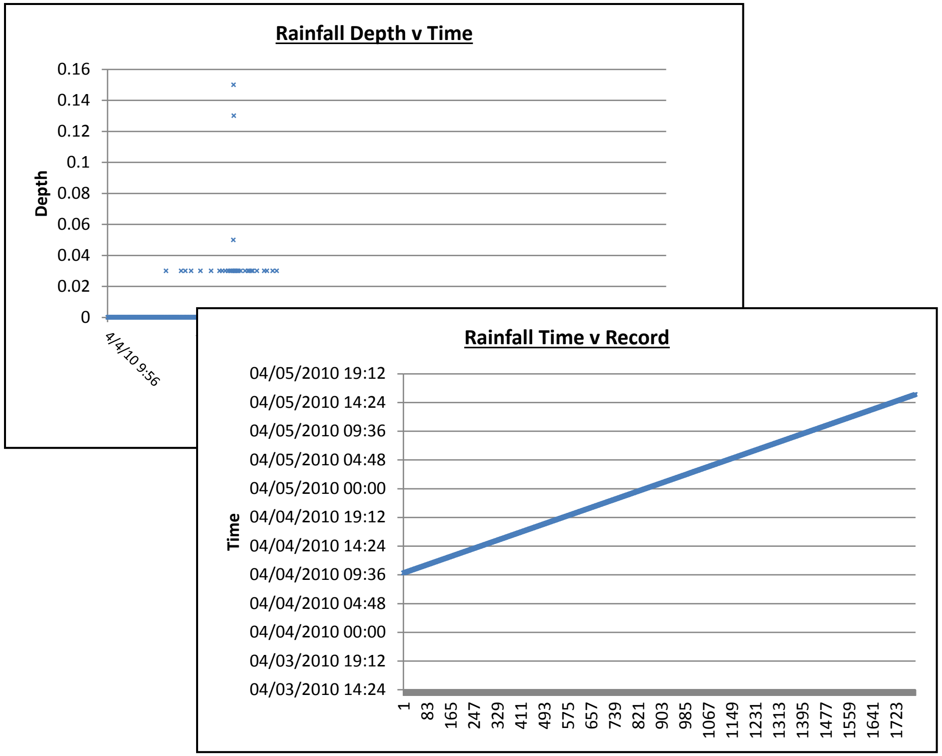
- Duration
- Depth
- Volume
- Intensity
  - Average
  - Instantaneous Max
  - 1-hr Max

Runoff Data

- Duration
- Time to Peak
- Peak Flow Rate
- Total Volume

Collection Errors

View Raw Data for Inconsistencies



Physical Constraints

- Flow begins after rainfall begins.
- Flow ends after rainfall ends.
- Samples collected during runoff.

Known Relationships

Volumetric Runoff Coefficient (R_v)

Measured: $R_v = \frac{V_{runoff}}{V_{rainfall}}$

(Driscoll 1983)

Predicted: $\bar{R}_v = 0.858i^3 - 0.78i^2 + 0.774i + 0.04$

(Urbonas 1999; WEF and ASCE 1998)

Relative Percent Difference (RPD)

$$If\ RPD = \frac{|Predicted - Measured|}{Predicted} \leq ThresholdValue\ (e.g., 0.2)\ then\ Accept$$

Time of Concentration (T_c)

Measured: Time from hyetograph center-of-mass to hydrograph center-of-mass or other method.

Predicted: NRCS Method from TR-55 or other method.

Step 2 - Sample Collection Timing

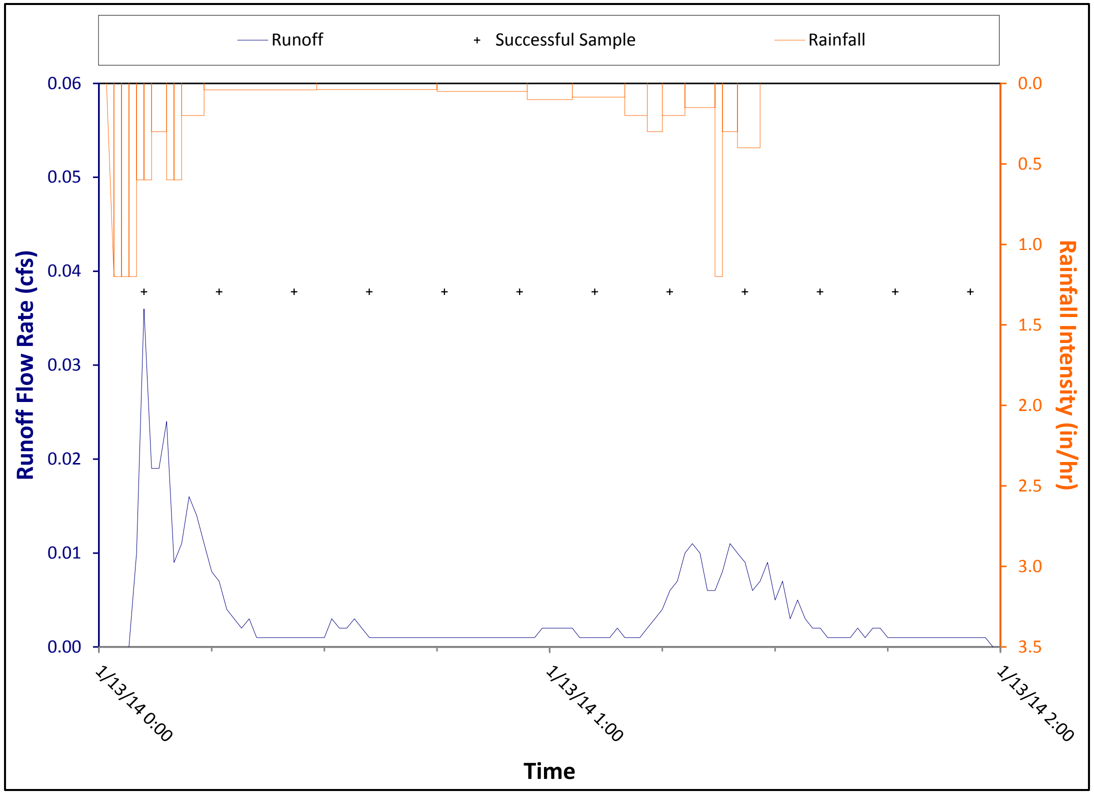
Check to see if samples were collected at an appropriate time so that they are representative of the runoff.

Qualitative - Graphs

Quantitative - Uniformity Index

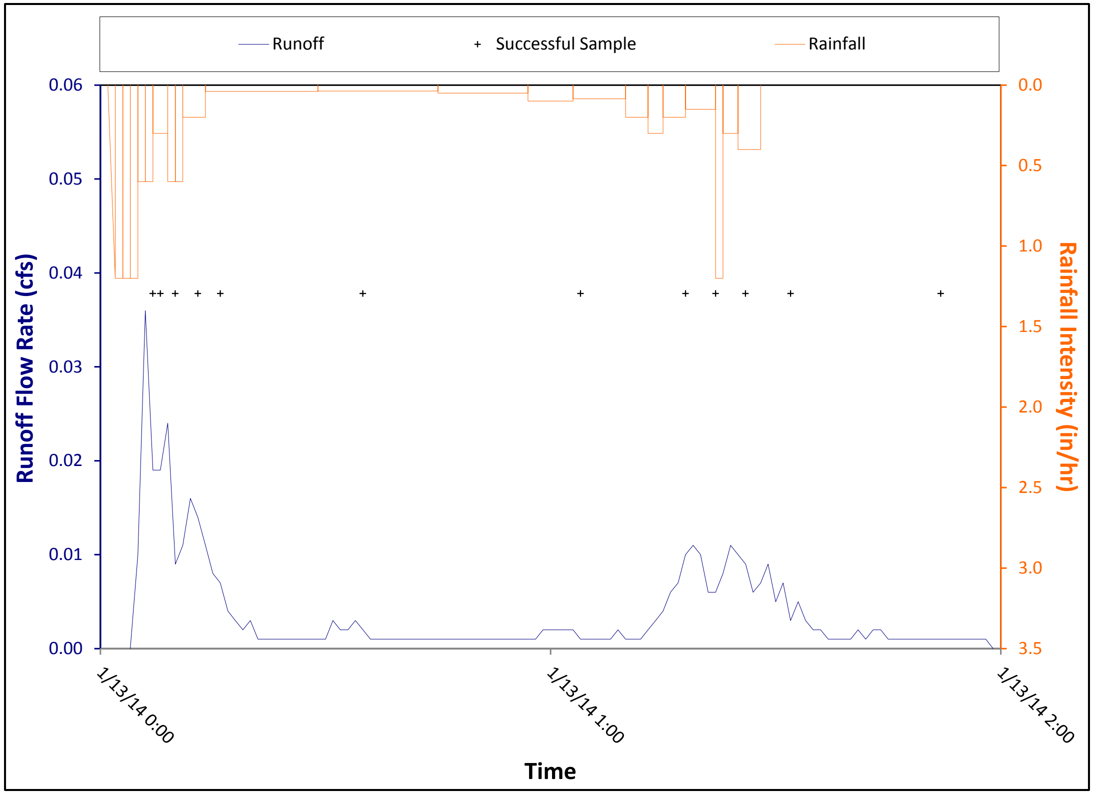
Rate Graph

Time-Weighted Sampling



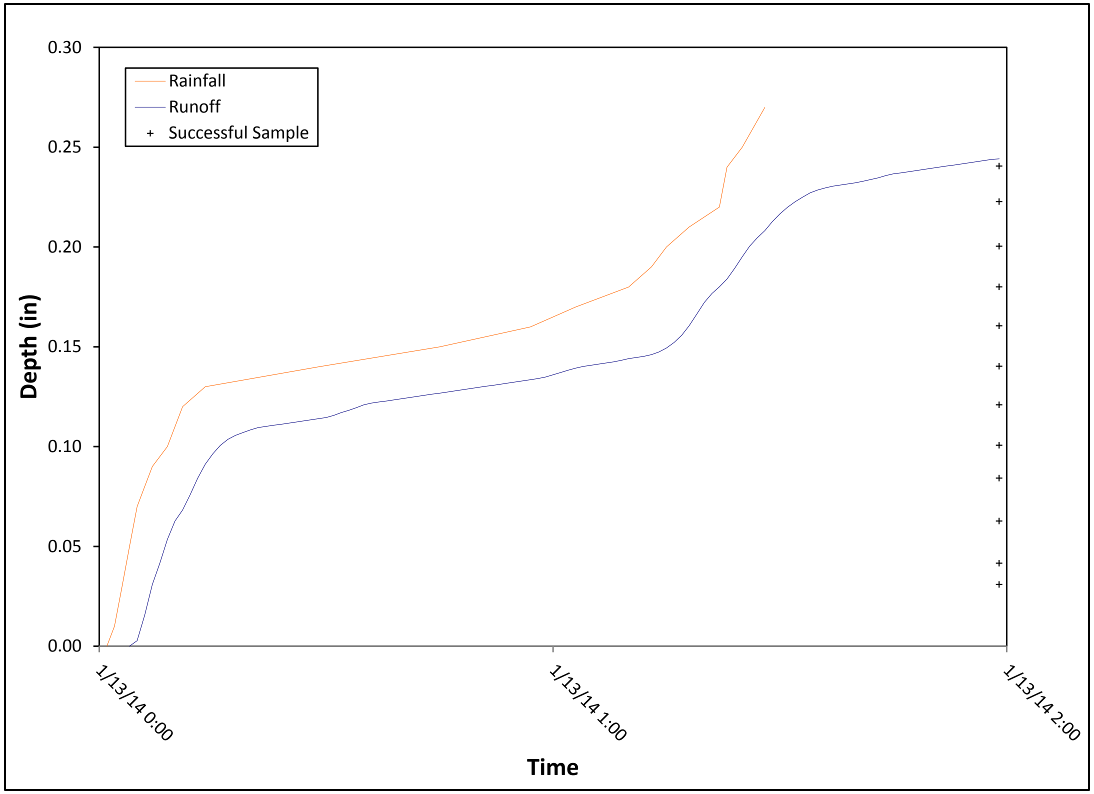
Rate Graph

Flow-Weighted Sampling



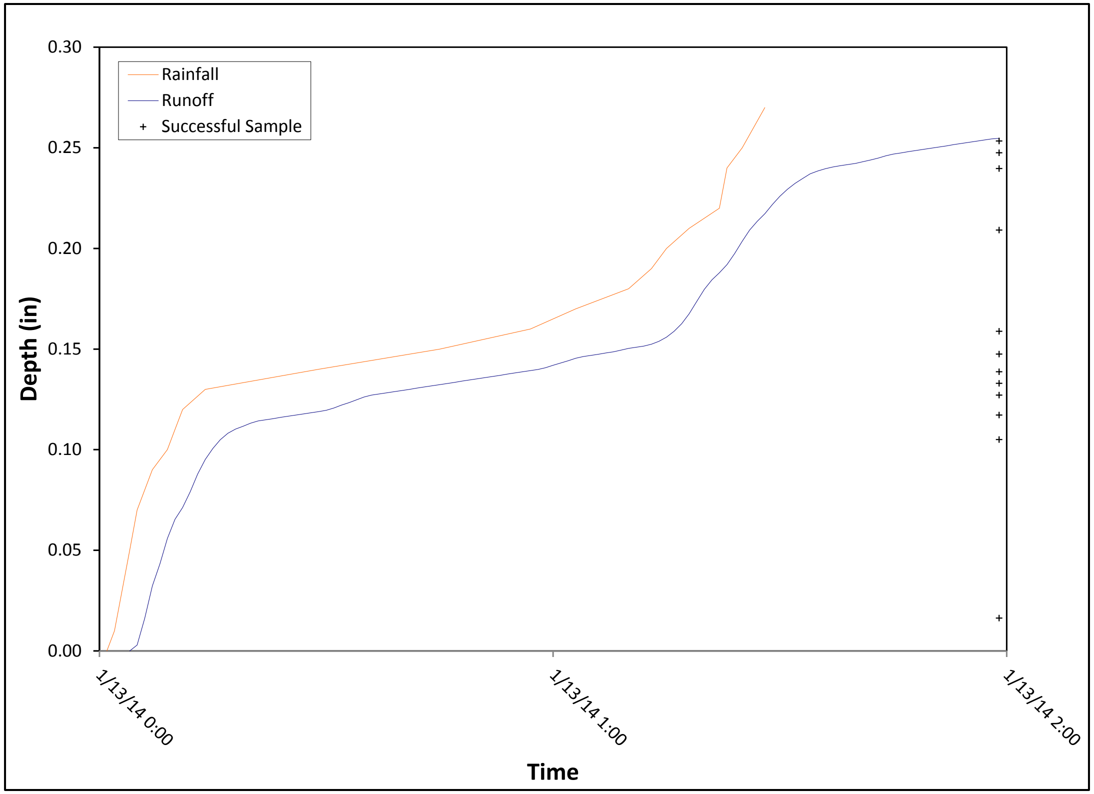
Cumulative Depth Graph

Flow-Weighted Sampling



Cumulative Depth Graph

Time-Weighted Sampling



Autosampler Backlog

Autosampler sample routine

- Purge
- Rinse
- Sample
- Purge

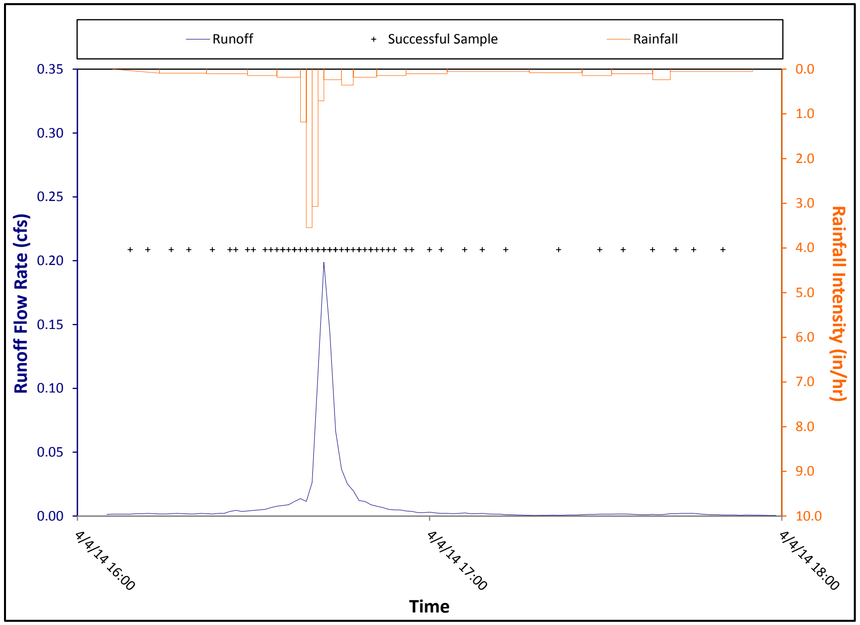
Routine can take 2+ minutes to complete

Urban drainages can have very flashy runoff responses.

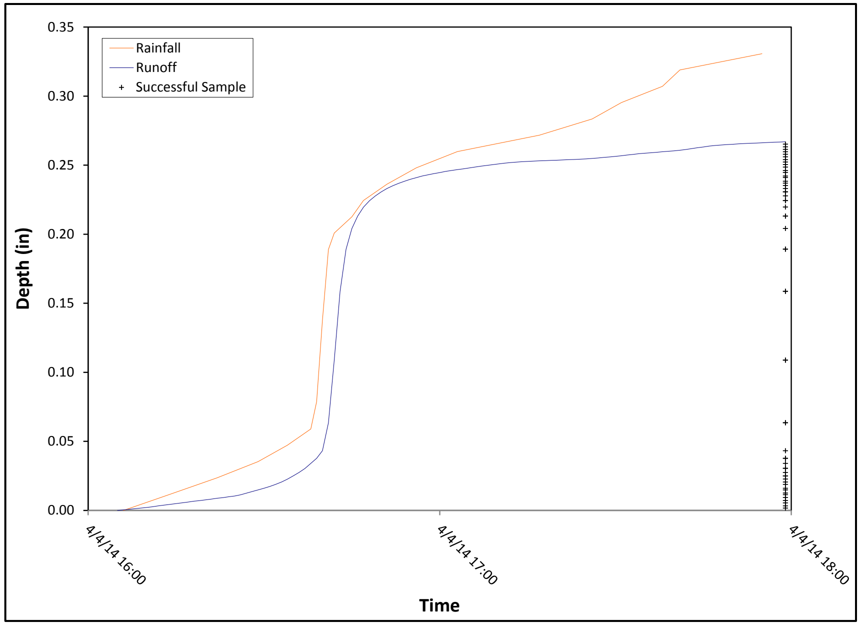
If the trigger for the next sample is received before the previous sample routine is completed, then it is added to the sample queue.

Autosampler Backlog

Rate Graph



Cumulative Depth Graph



Qualitative

Uniformity Index

Want to determine if the intervals are equal.

- Time or volume interval between samples

Uniformity Index

Coefficient of Variation (COV)

$$UI = COV = \frac{Standard\ Deviation\ (\sigma)}{Mean\ (\mu)}$$

COV is a normalized standard deviation

Allows for comparison of the variability between different data sets.

- Small COV -> Little Variation
- Big COV -> Large Variation

Uniformity Threshold (UT)

$$If\ UI \leq UT\ then\ Uniform\ Interval$$

(0.5 Threshold determined by trial-and error.)

Step 3 - Percent Capture

- For composite samples.
- Many different methods
  - Percentage of entire runoff time occurring between first and last samples.
  - Percentage of entire runoff volume occurring between first and last samples.
  - Etc.

OWP Method

Assumes flow-weighted sampling

$$PC = \frac{V_{rep}}{V_{runoff}} \times 100$$

V_{rep} = represented volume

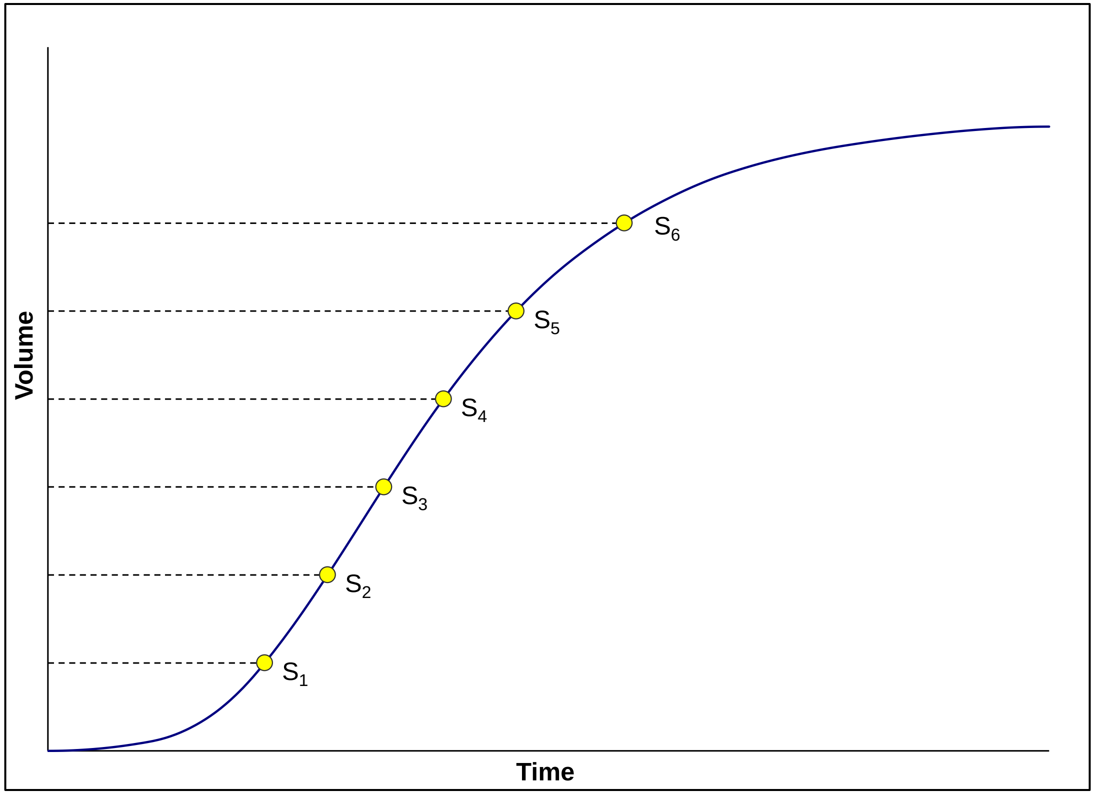
V_{runoff} = total runoff volume

Represented Volume (V_{rep})

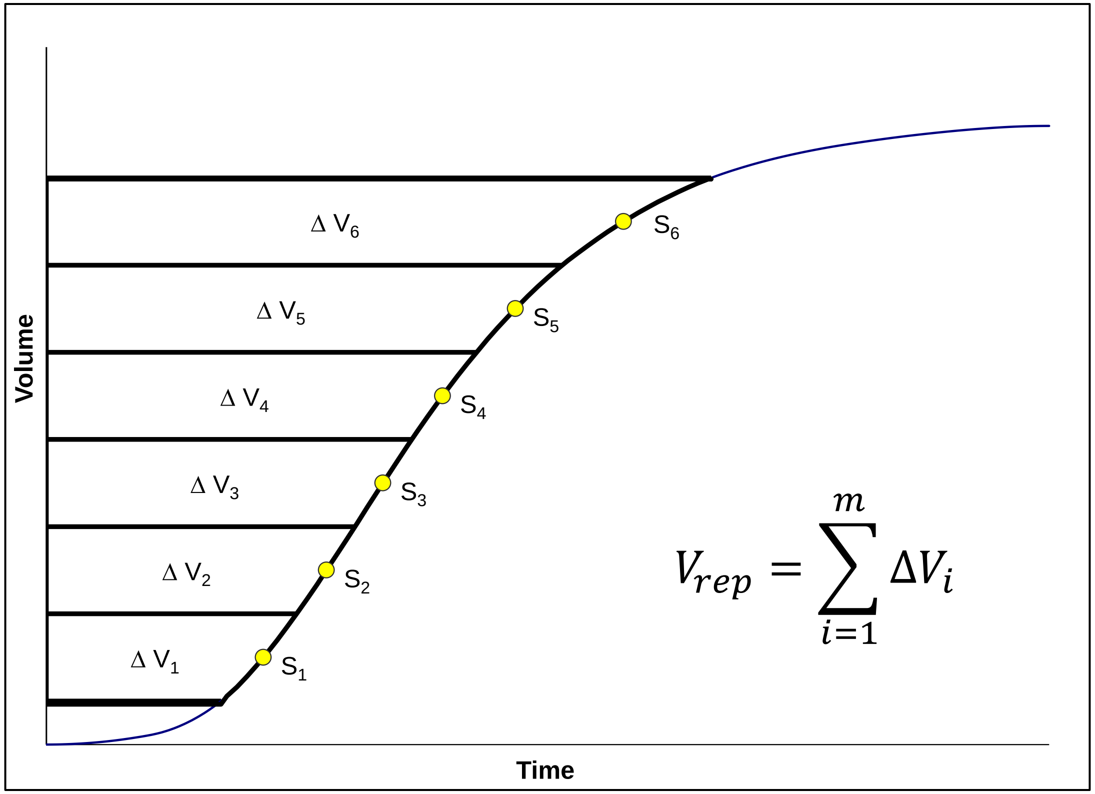
Volume represented in the sample.

Best visualized with a cumulative runoff (mass curve) hydrograph.

Represented Volume (V_{rep})

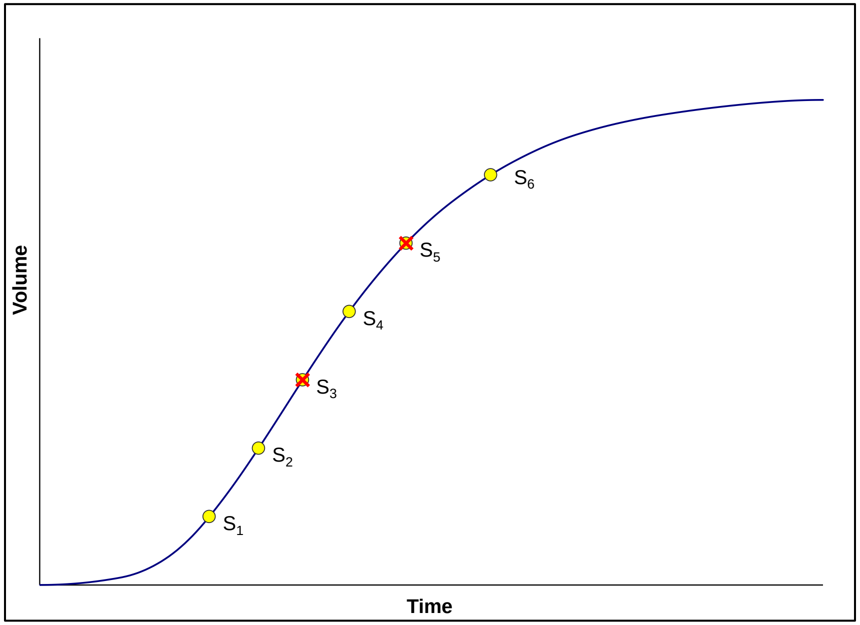


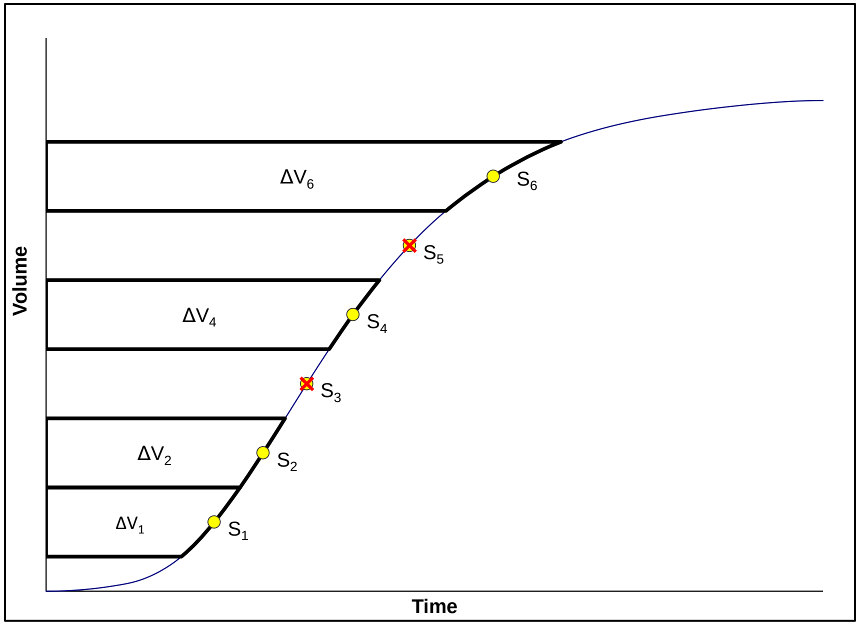
Represented Volume (V_{rep})



$$V_{rep} = \sum_{i=1}^{m} \Delta V_i$$

Represented Volume (V_{rep})





$$V_{rep} = \sum_{i=1}^{m} \Delta V_i = \Delta V_1 + \Delta V_2 + \Delta V_4 + \Delta V_6$$

Total Runoff Volume (V_{runoff})

Total event runoff volume.

Numeric integration method.

$$V_{runoff} = \int_{t=0}^{t=n} q(t) = \sum_{t=0}^{n-1} \frac{q(t) + q(t+1)}{2} \left((t+1) - (t)\right)$$

Percent Capture

$$PC = \frac{V_{rep}}{V_{runoff}} \times 100$$

V_{rep} = represented volume

V_{runoff} = total runoff volume

Minimum Allowable PC

If PC ≥ Minimum Allowable them Representative

Conclusion

Any monitoring project should have a post-data collection QC process.

3-point data review process

- Flow Data Quality
  - Project Requirements
  - Data Errors
  - Known Relationships
- Sample Collection Timing
  - Rate Graph
  - Cumulative Depth Graph
  - Uniformity Index
- Percent Capture

Intent is to ensure quality monitoring data is generated, either for research or regulatory compliance purposes.

Questions?

Thank You

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