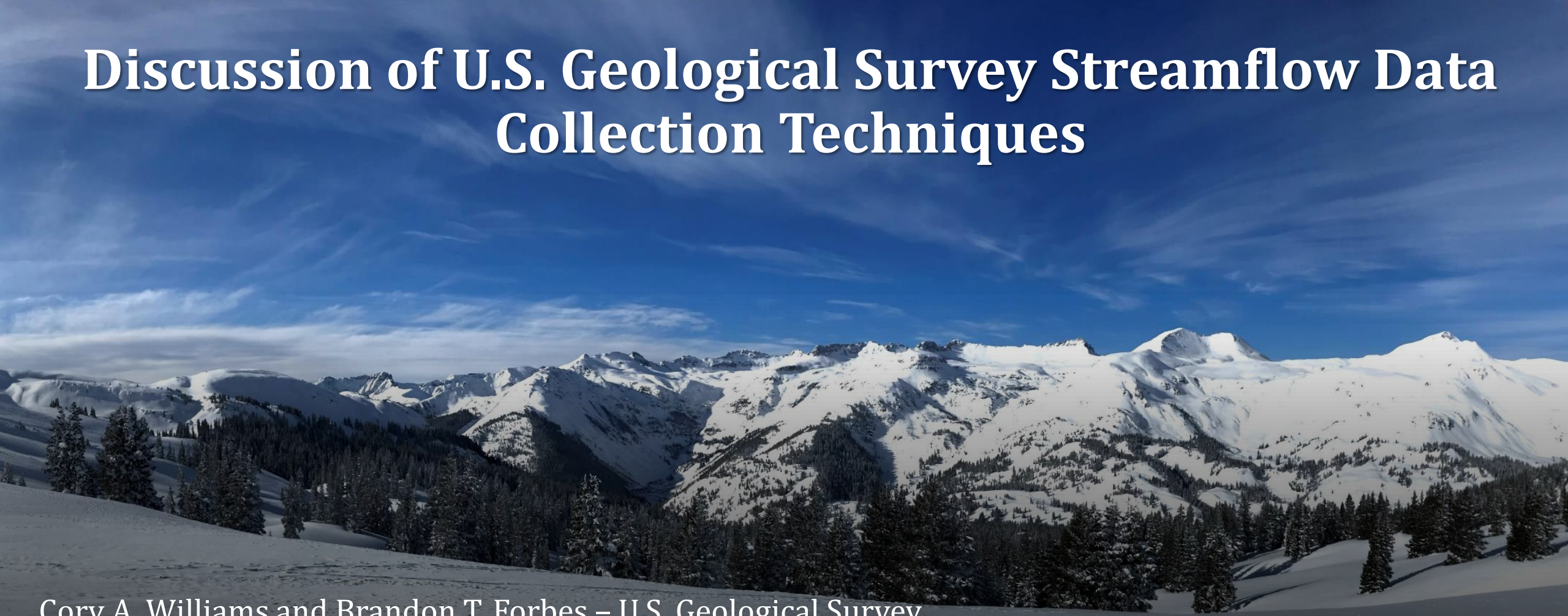
Discussion of U.S. Geological Survey Streamflow Data Collection Techniques



Cory A. Williams and Brandon T. Forbes – U.S. Geological Survey

PAC Meeting, Meeker Colorado, March 14, 2023 – U.S. Geological Survey

Colorado Water Science Center
USGS Streamgaging

USGS science for a changing world

Presentation Overview

- What is a USGS Streamgage?
- Site Selection
- Gage Calibration
- Data Analysis
- Data Publication

- Goals-Accuracy at all flows!!

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What is a USGS Streamgage?

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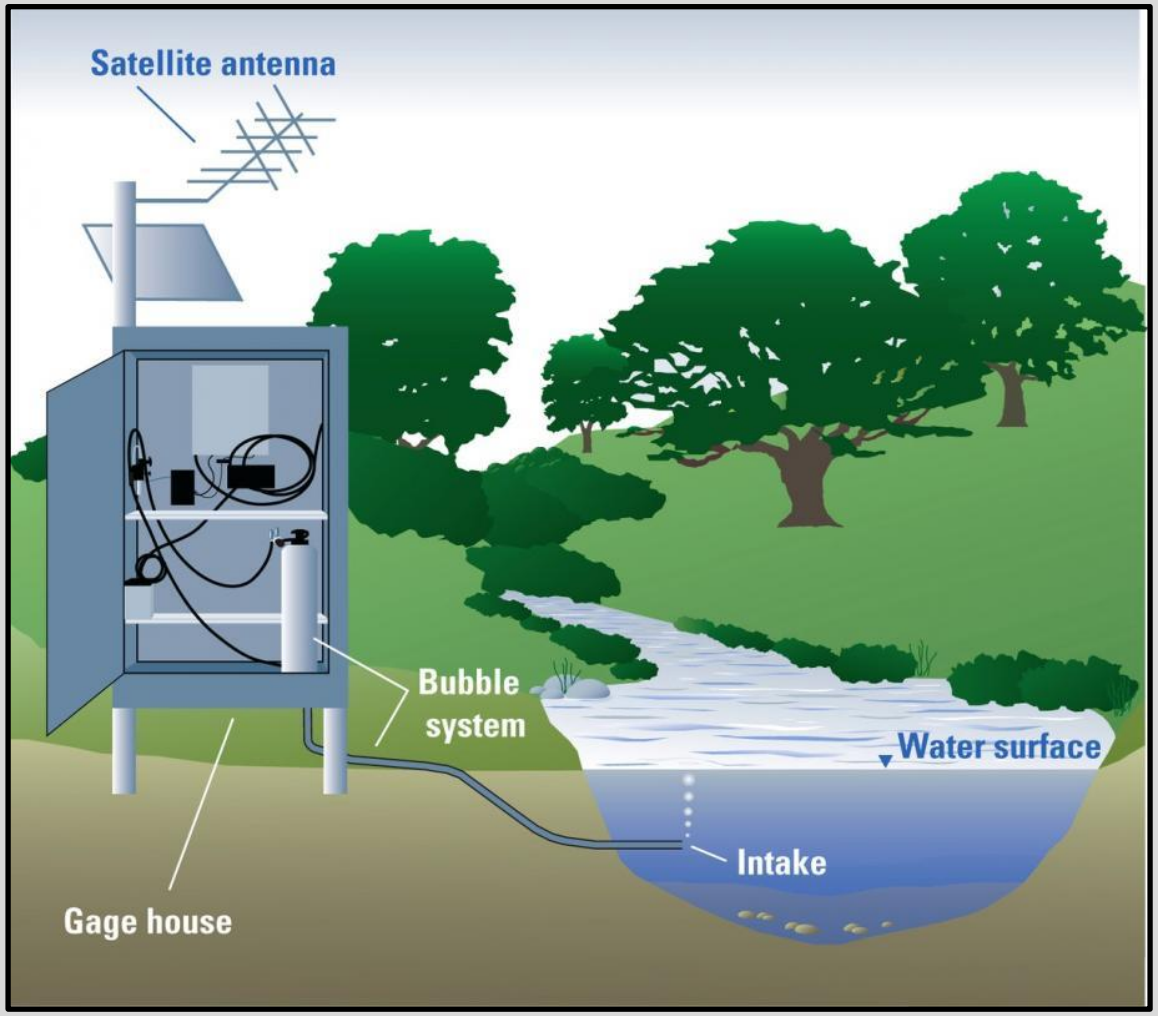
What is a gage?

- Extremely accurate measure of water depth
  - +/- 0.01 ft
- Data Recorder
- Telemetry



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What is a USGS Streamgage?

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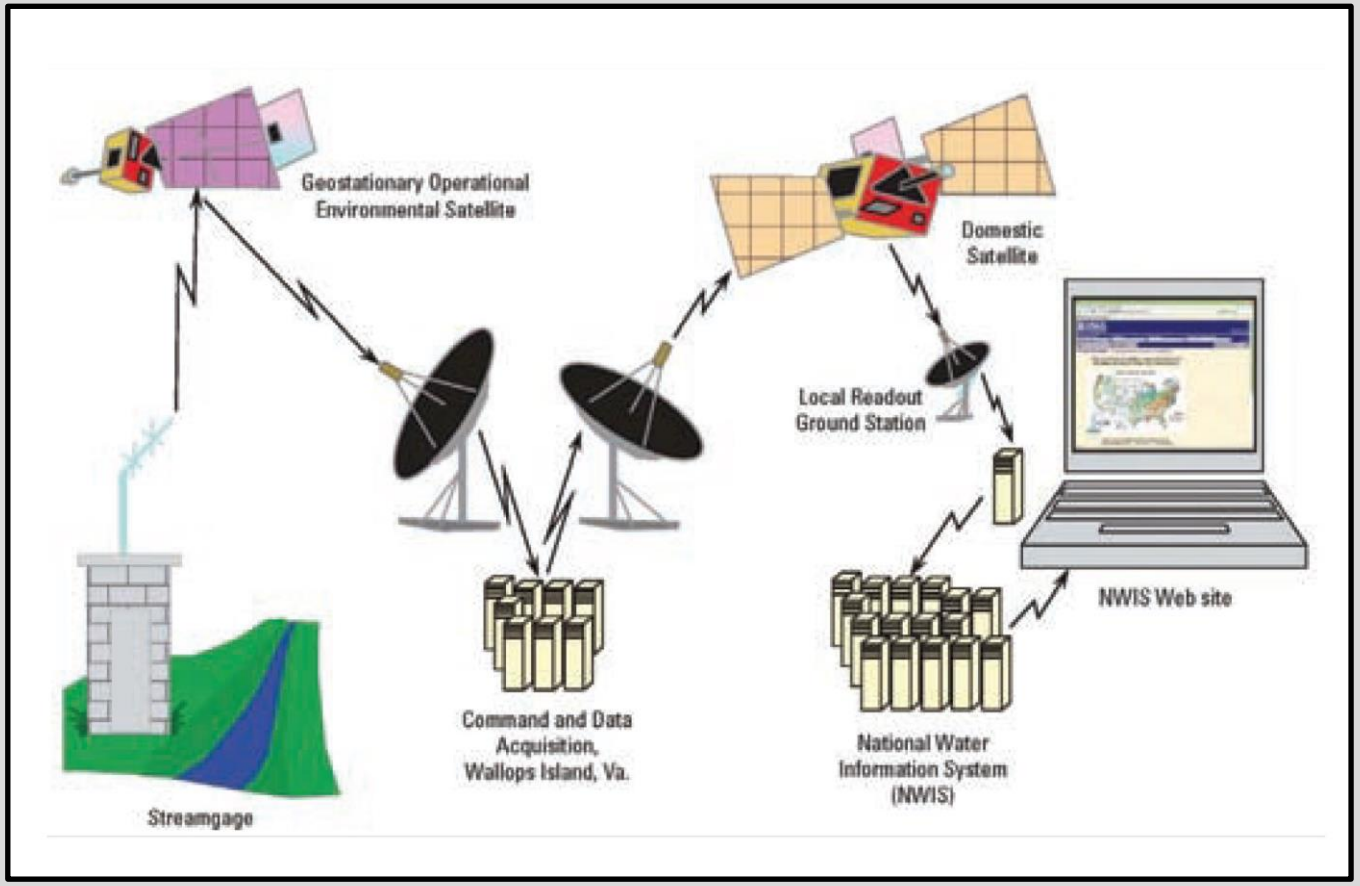

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Site Selection

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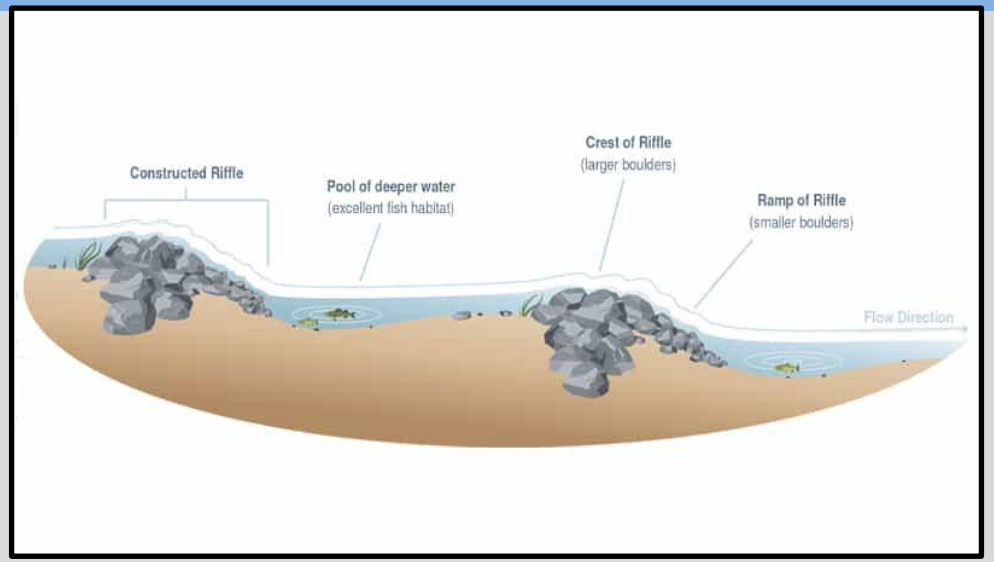
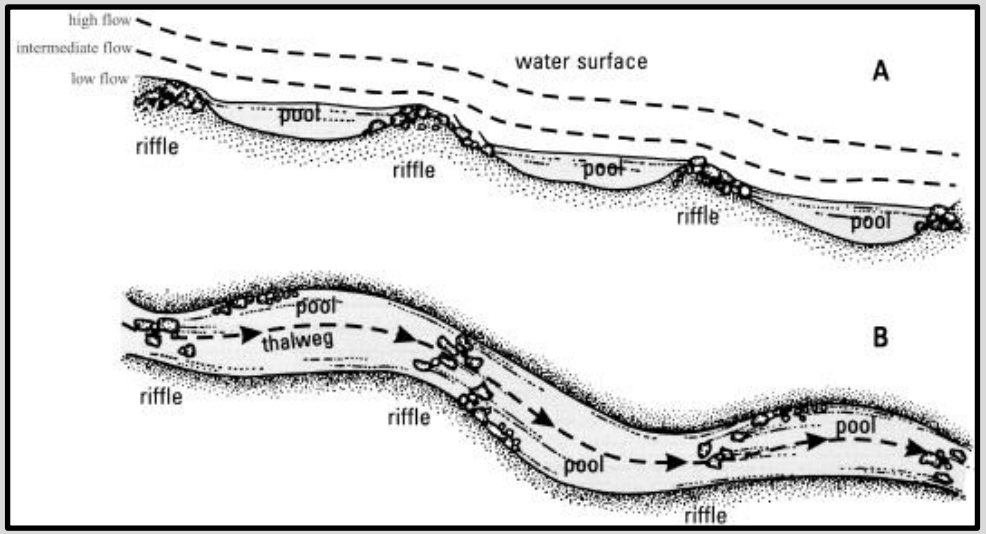
How do we chose a gaging location?

- Control
- Banks
- Depth Resolution
- Constricting Channel





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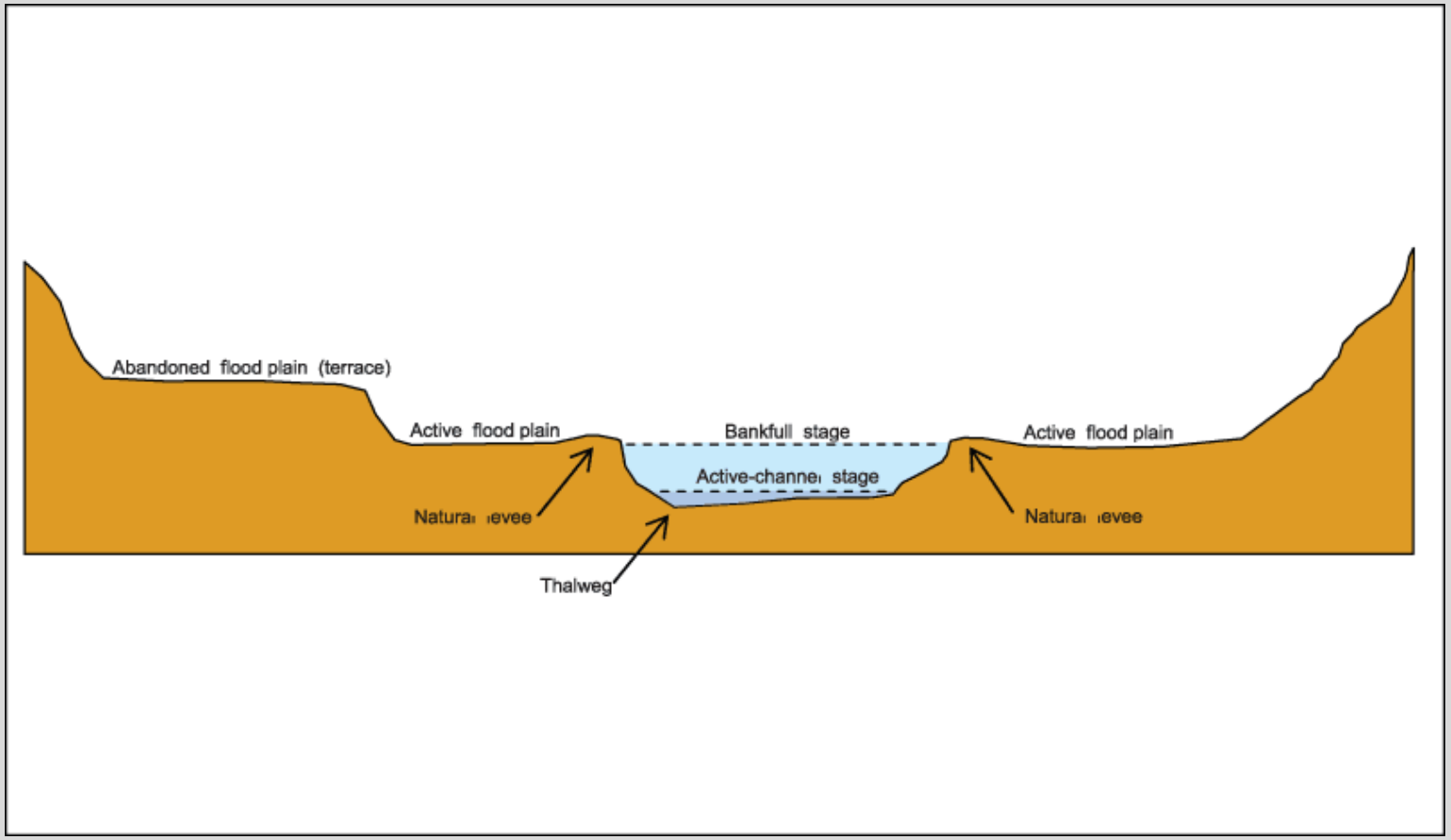

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Site Selection

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How do we chose a gaging location?

- Control
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- Constricting Channel

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Gage Calibration

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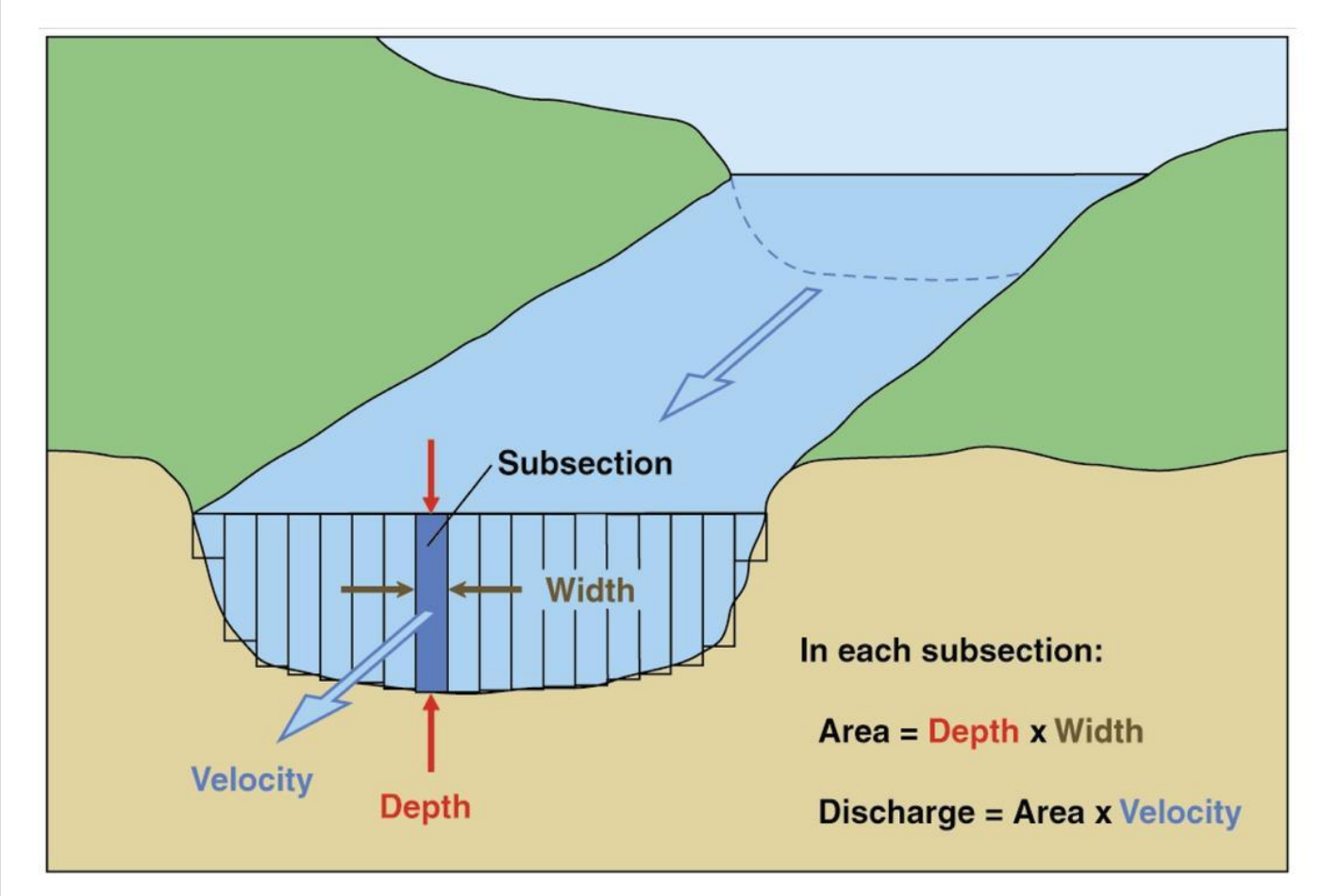
We want to know river flow!

- We measure:
  - Depth
  - Velocity (40 Seconds)

- Compile subsections
- Calculate Flow



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Gage Calibration

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Gage Calibration

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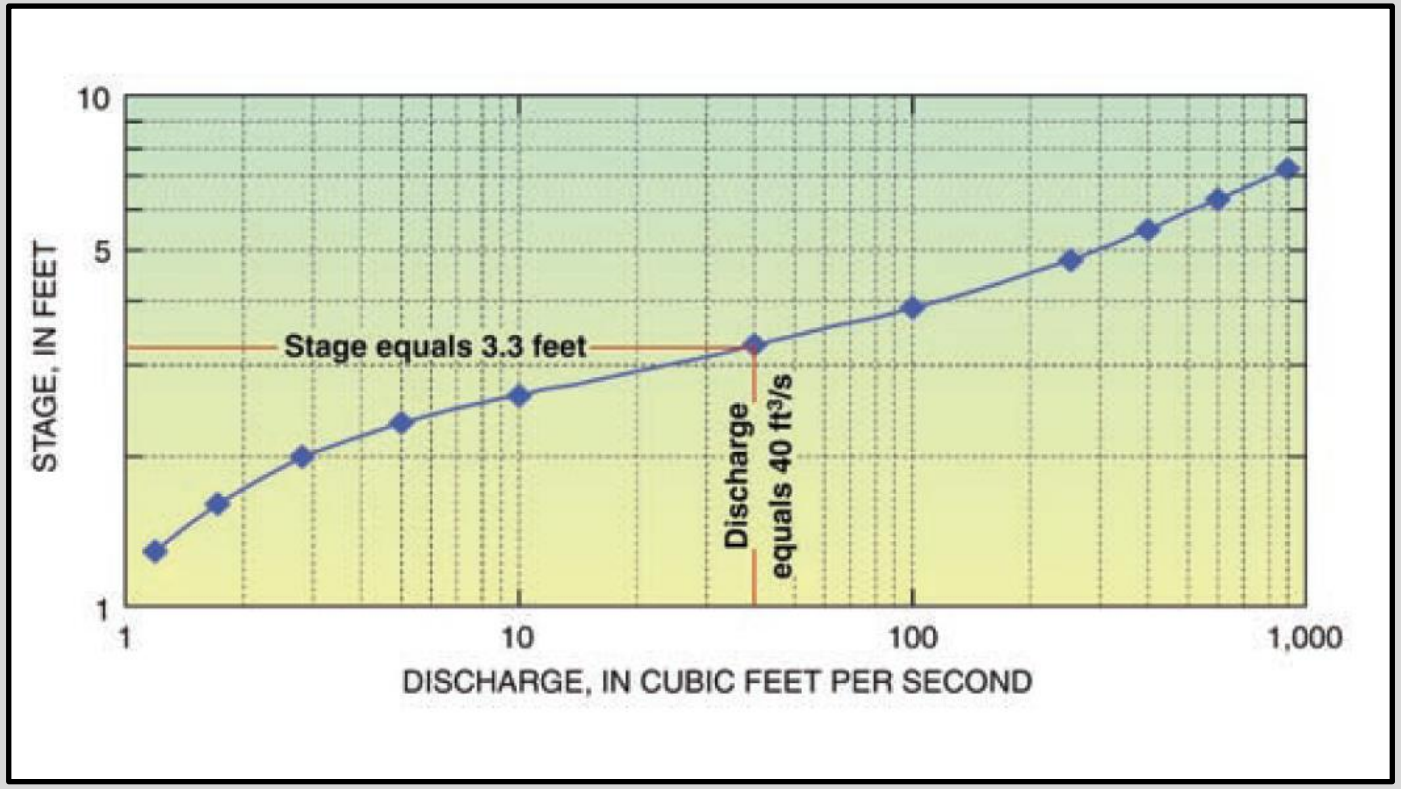
We want to know river flow!

- Development of a rating
  - Simple example



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Gage Calibration

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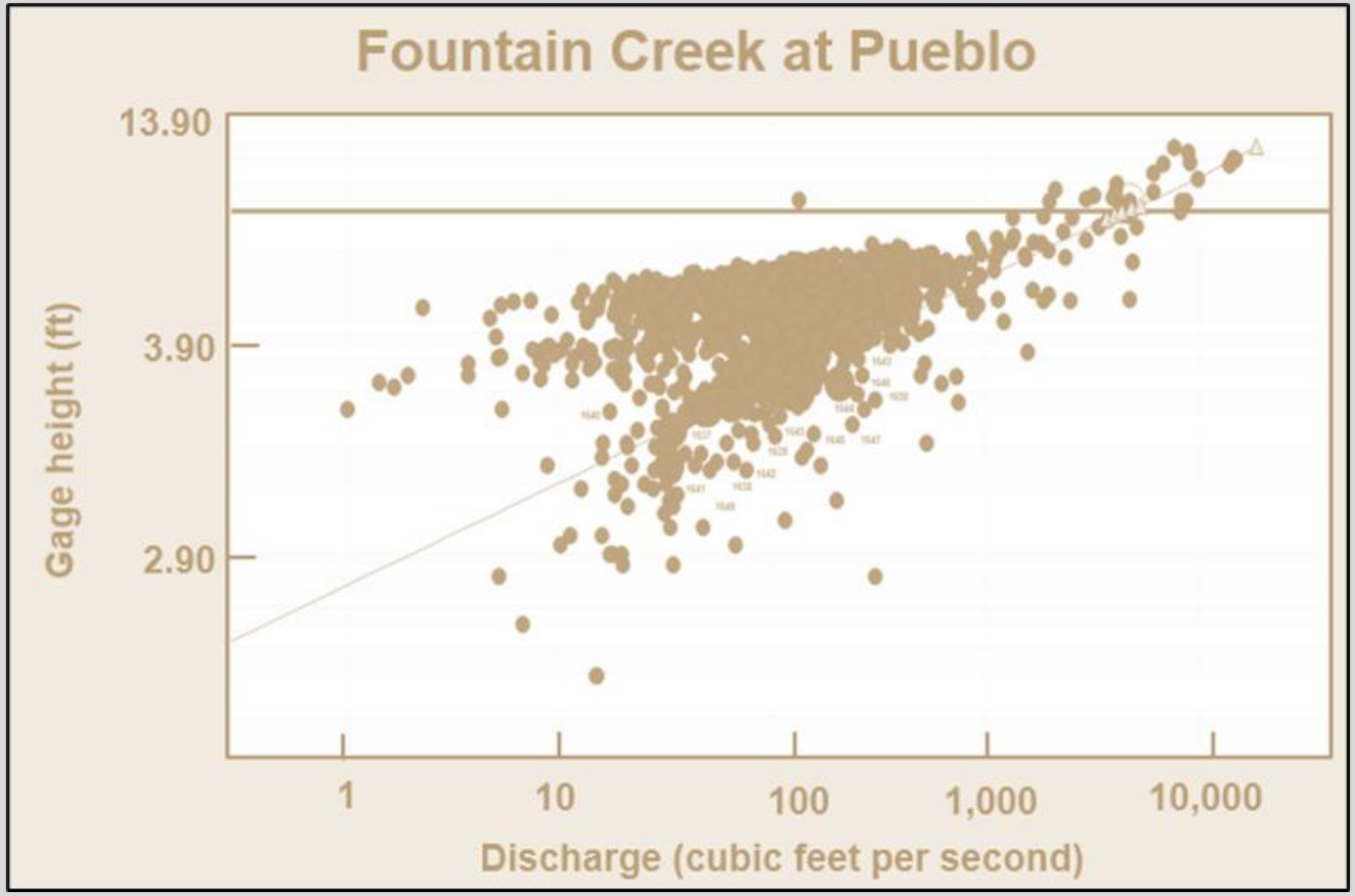
We want to know river flow!

- Development of a rating
  - Complex Example



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Gage Calibration

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How do we measure the flow?

- Pigmy Meter
- Flow Tracker
- Price AA
- Acoustic Doppler Current Profilers
- Drones

Photographs by H. Zajd, U.S. Geological Survey, November 6, 2006

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Gage Calibration

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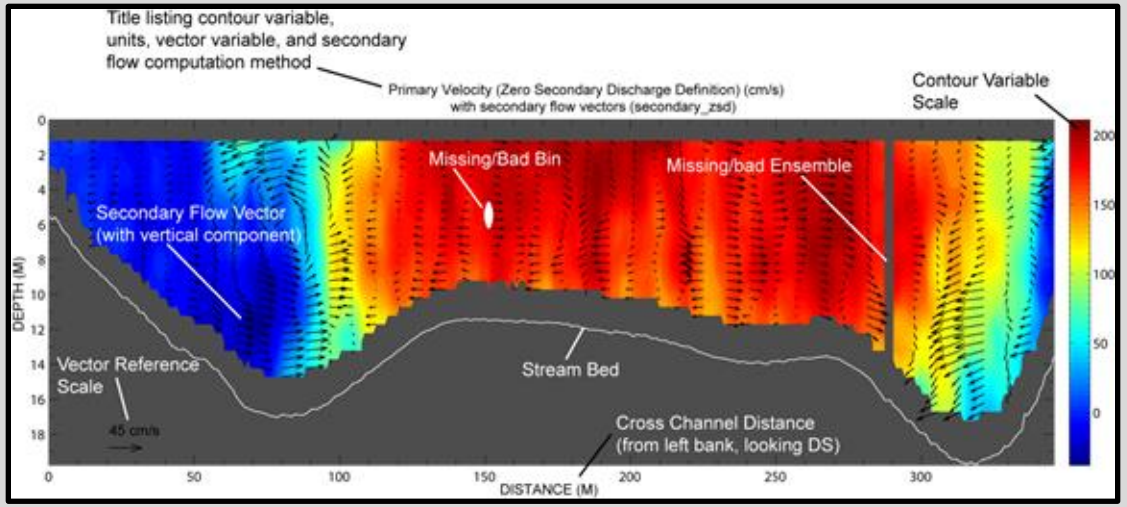

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Gage Calibration

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How do we measure the flow?

- Pigmy Meter
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Data Analysis

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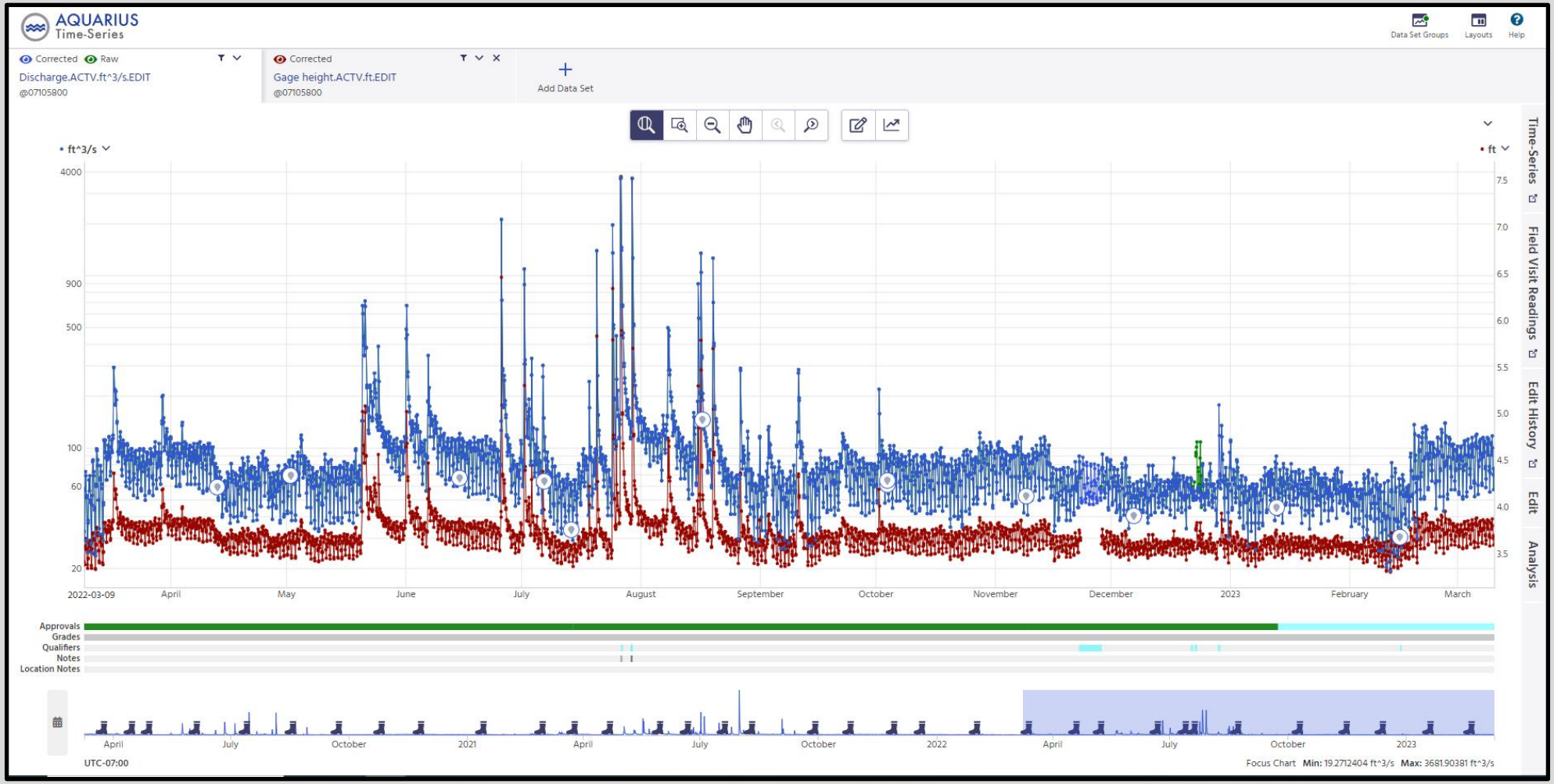

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Data Analysis

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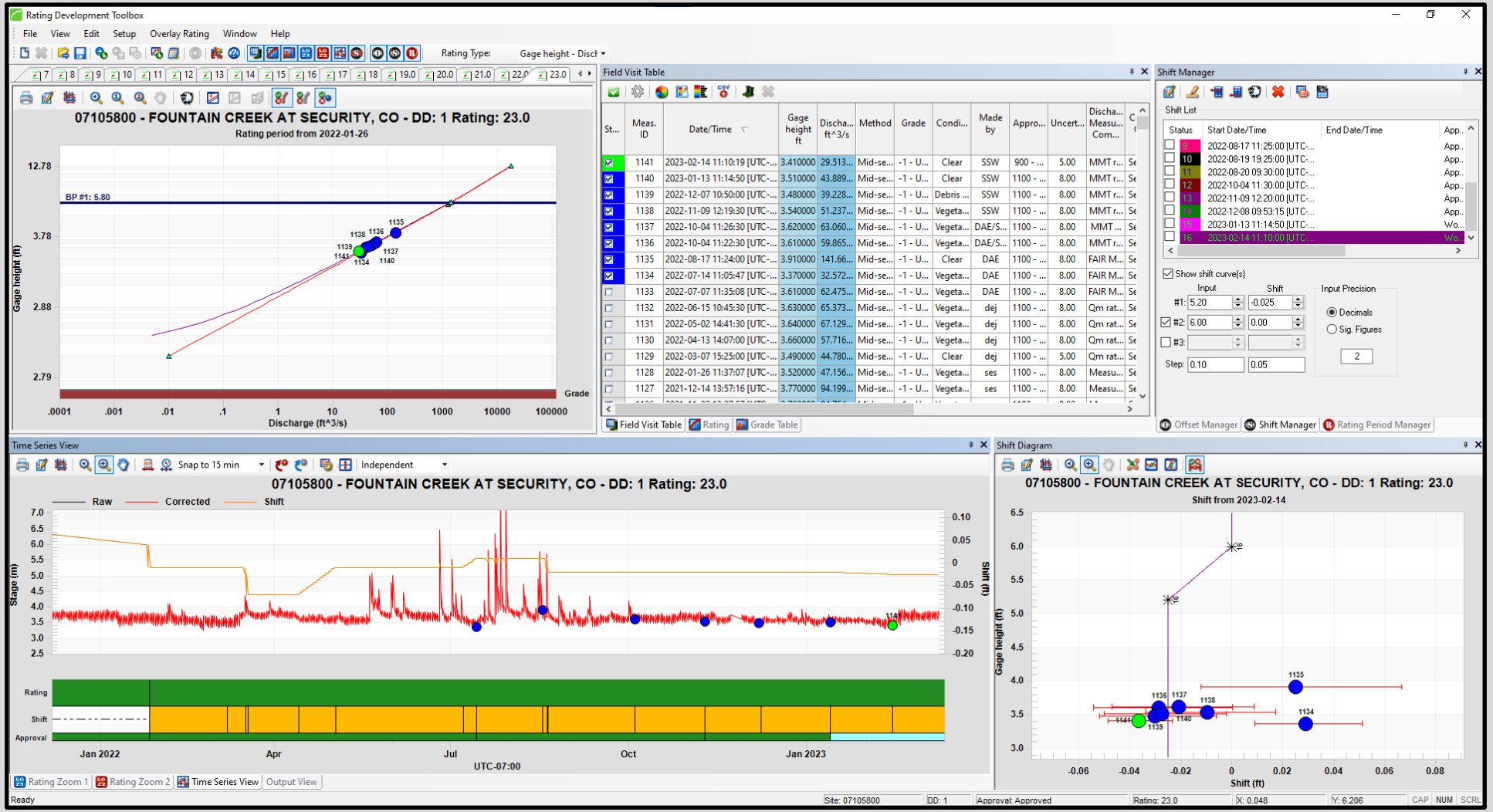

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Data Publication

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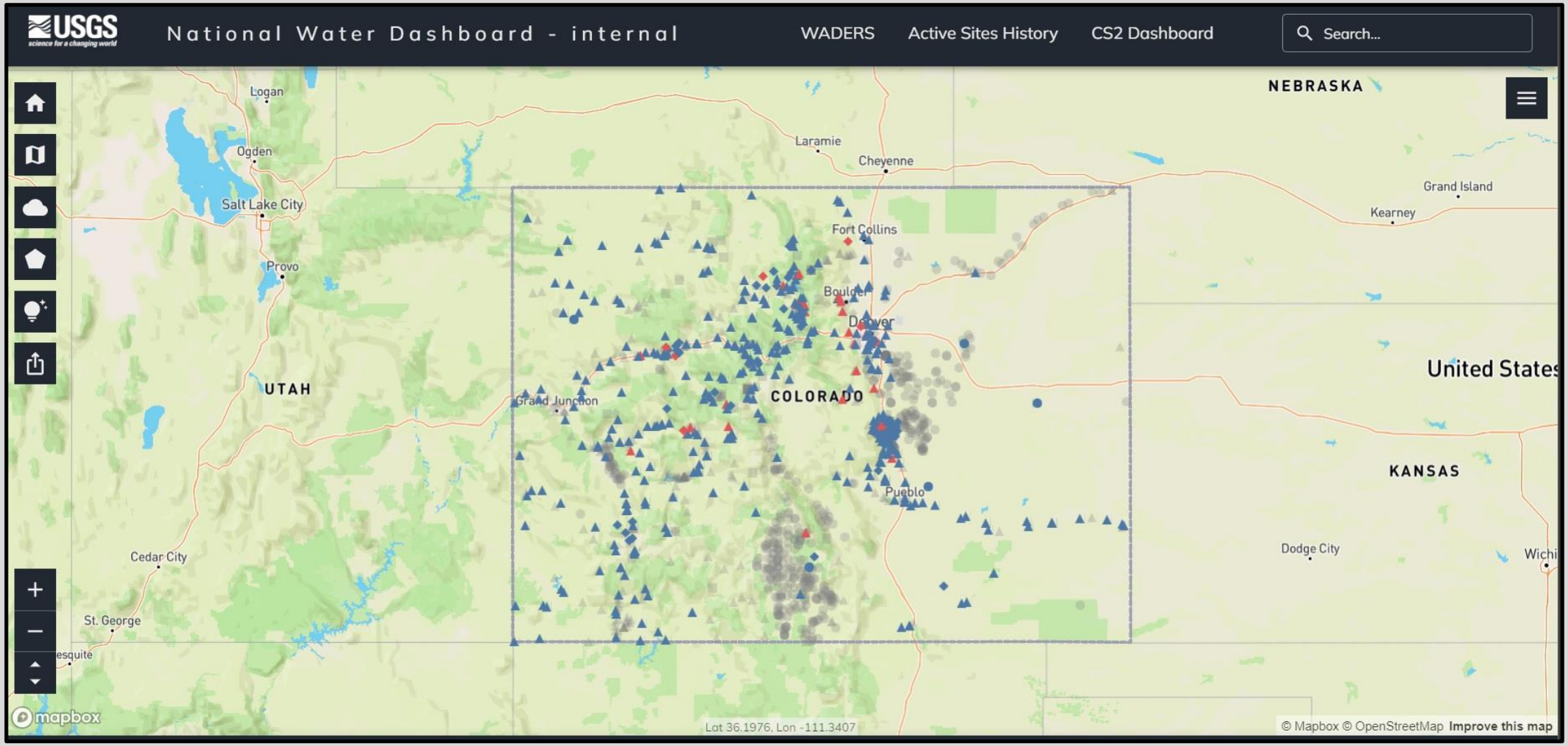

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Data Publication

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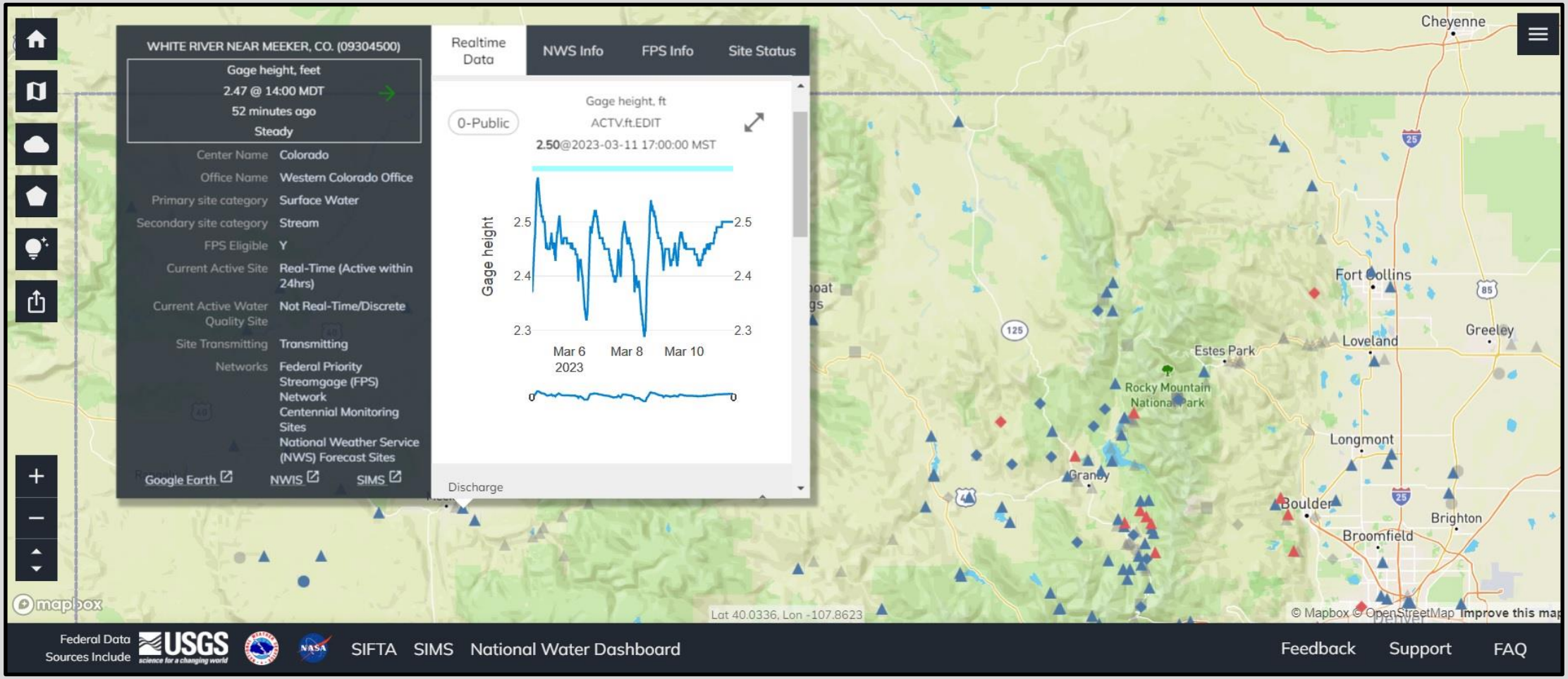

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Data Publication

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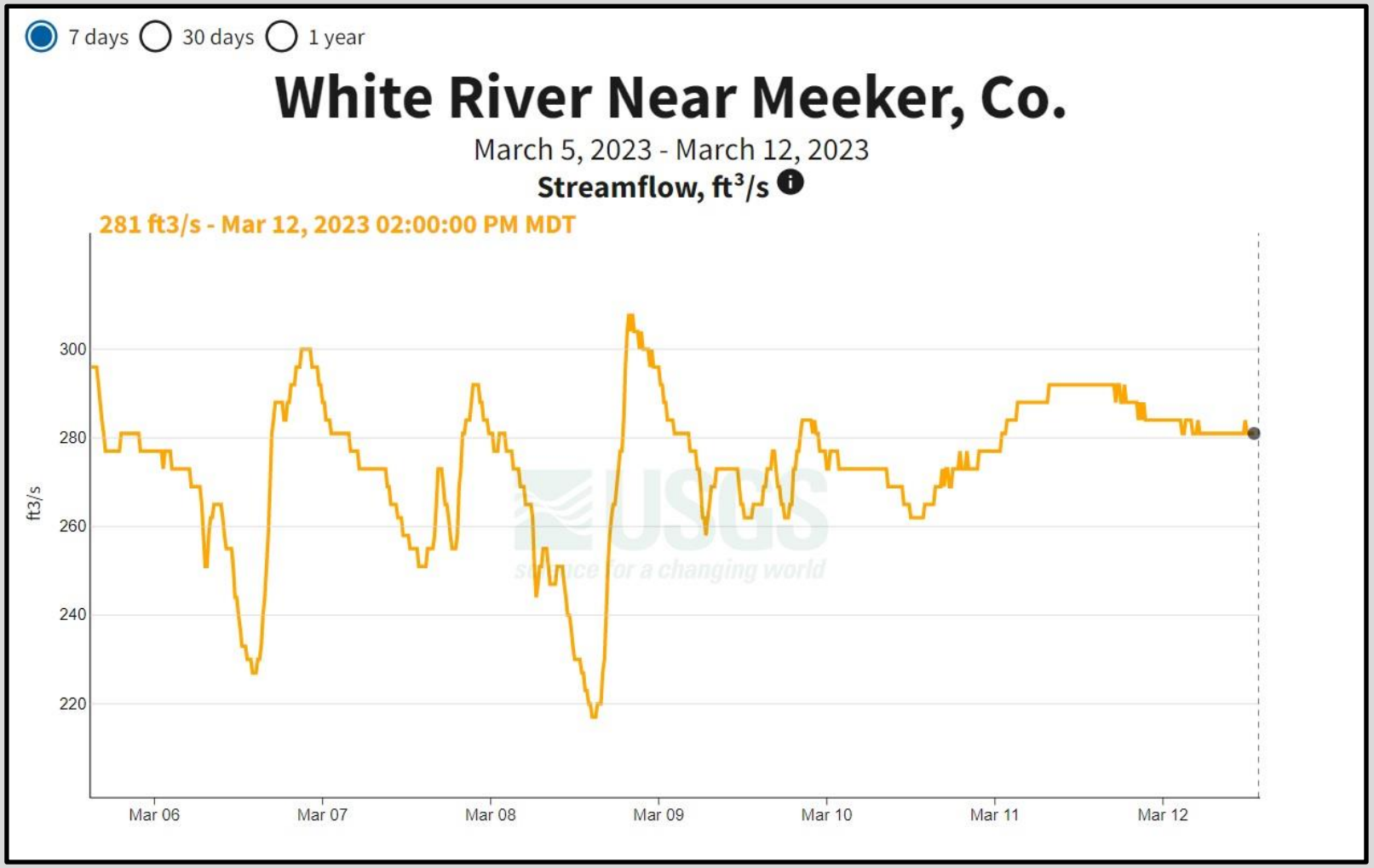
Data available since 1987



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Random Error vs Systematic Error (via accuracy and precision)

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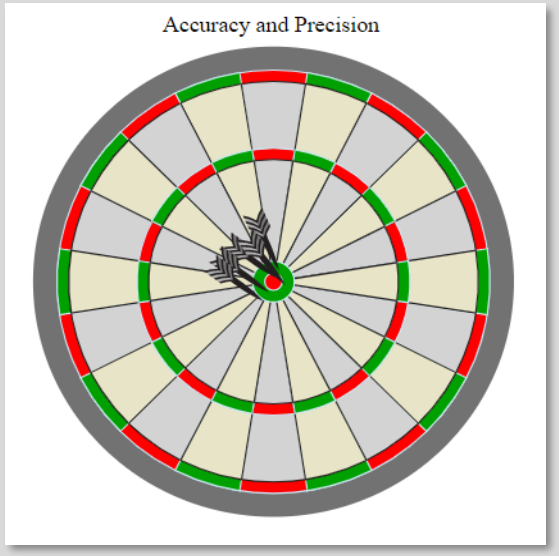
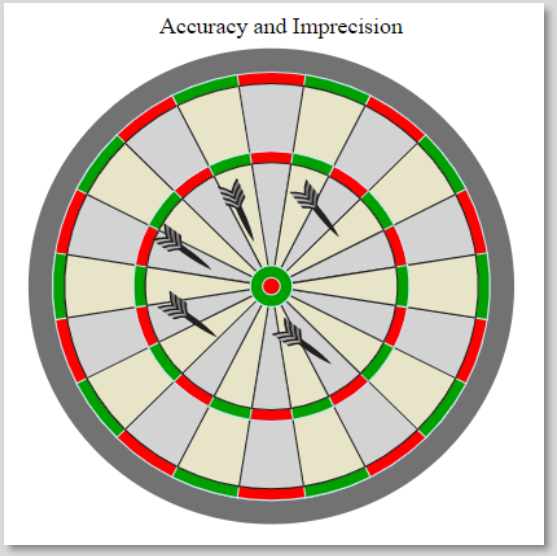
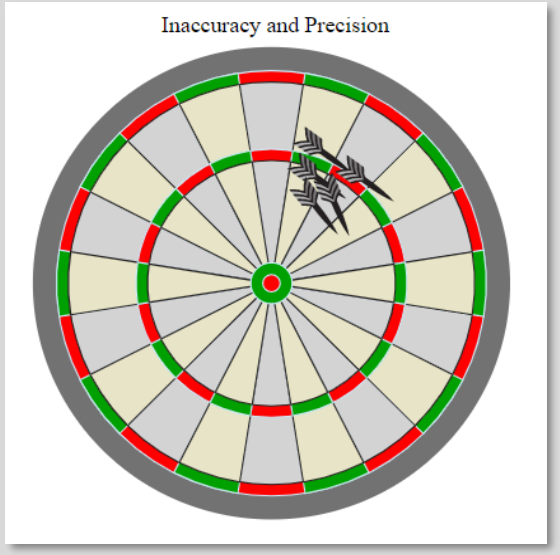
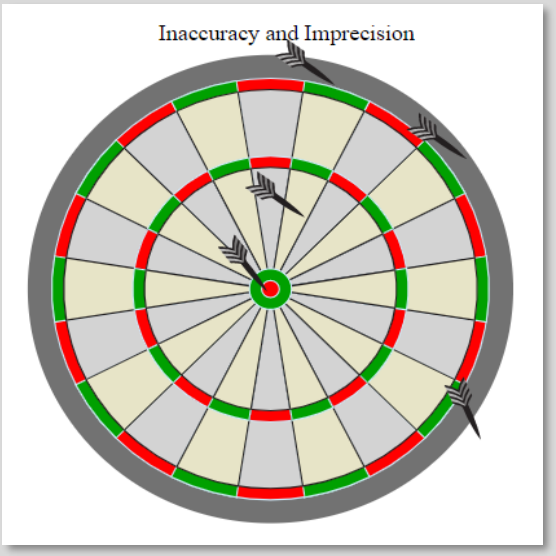
- Random Error – (also known as independent error) variability, random variation, or “noise in the system” can affect measurements quality
- Systematic Error – (also known as bias) shift towards over- or underestimation









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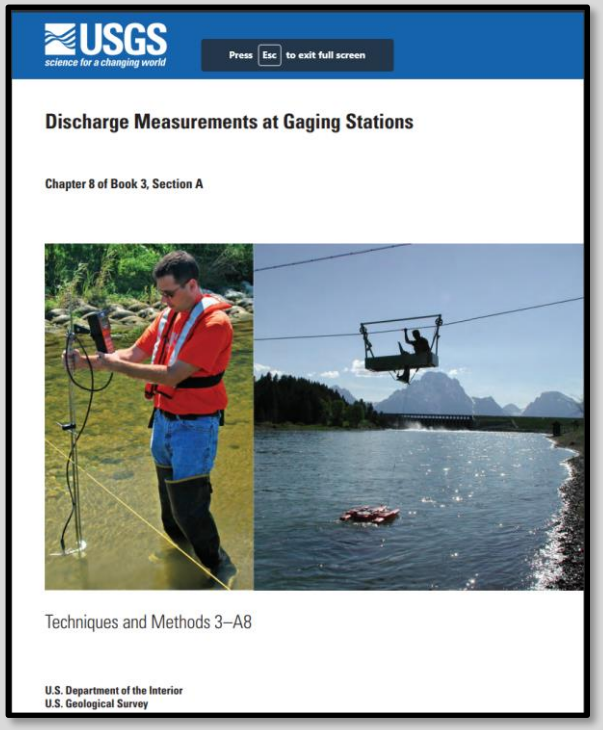
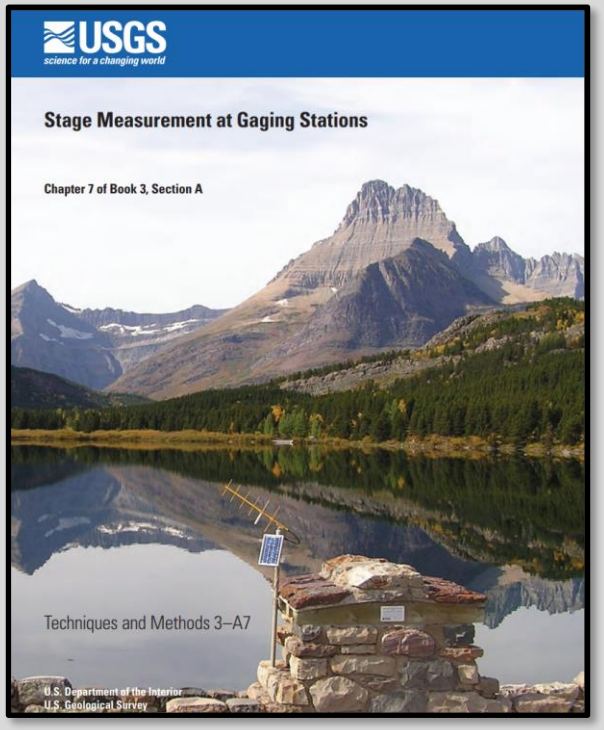
Independent Error– Controlling Bias and Measures of Uncertainty

- How Streamflow is Measured | U.S. Geological Survey
- Streamgaging Basics | U.S. Geological Survey

Follow standardizing procedures

- Techniques and Methods
- User manuals
- Training





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Independent Error– Across the Landscape

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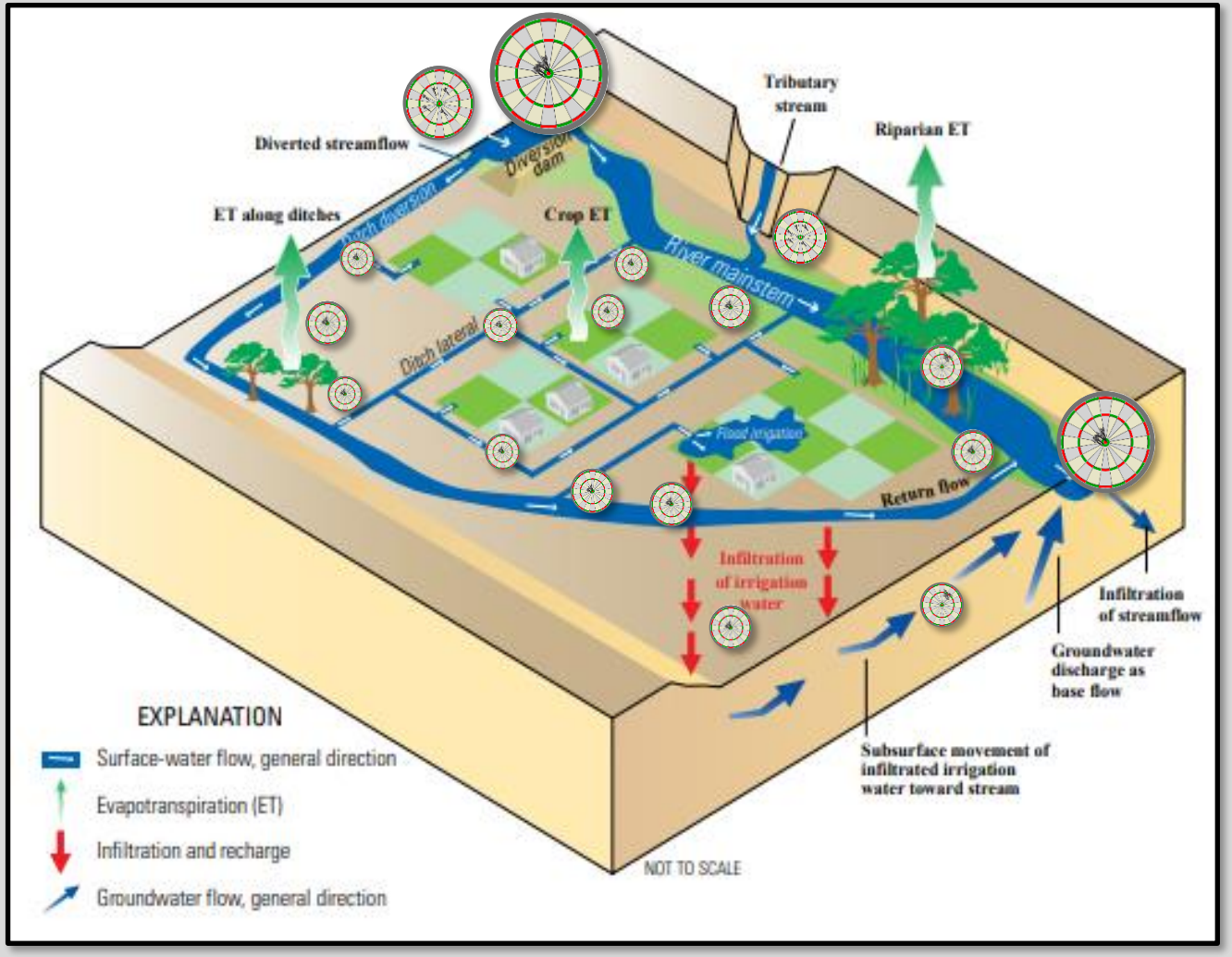
Conceptualizing the system

- Spatial domain



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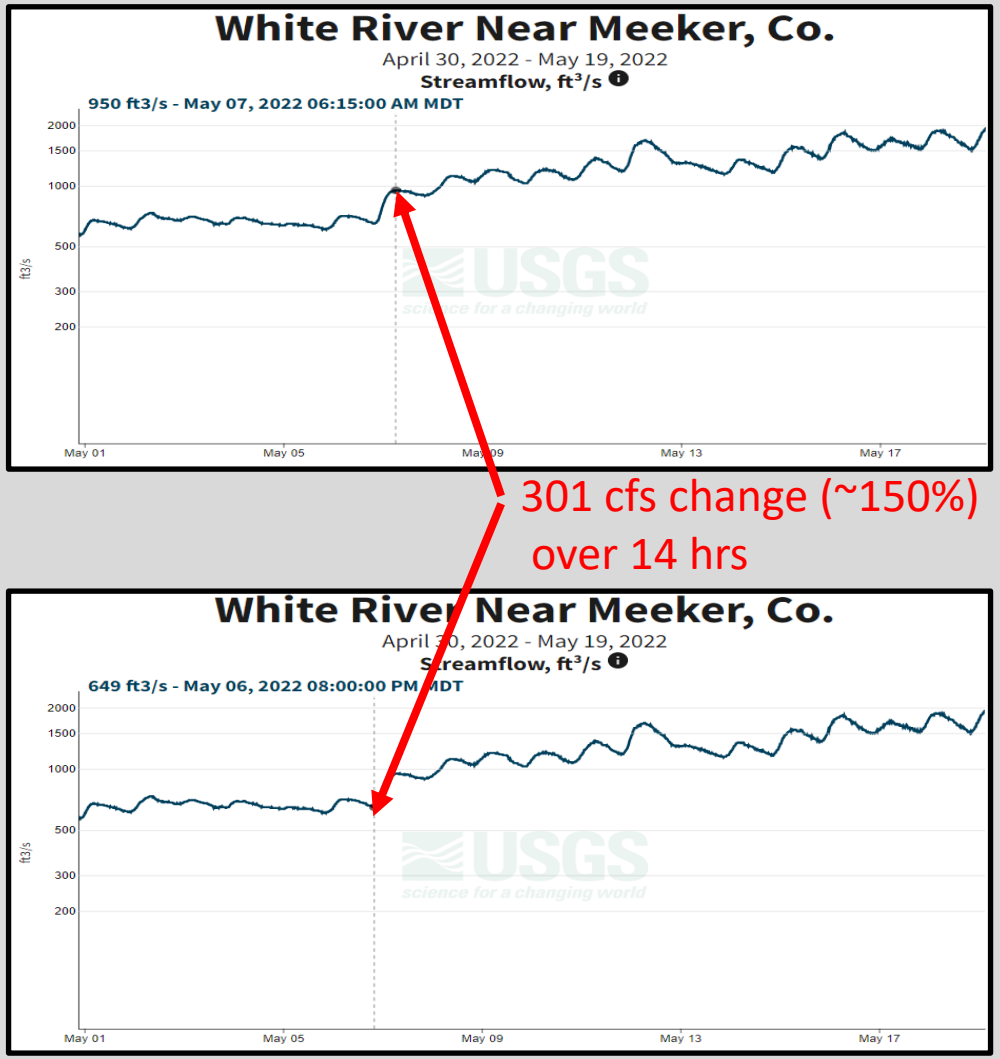
Independent Error–Measures of Certainty

Conceptualizing the system

- Spatial domain
- Timing
  - Seasonal
  - Diel cycles



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Approaches– Across the Landscape

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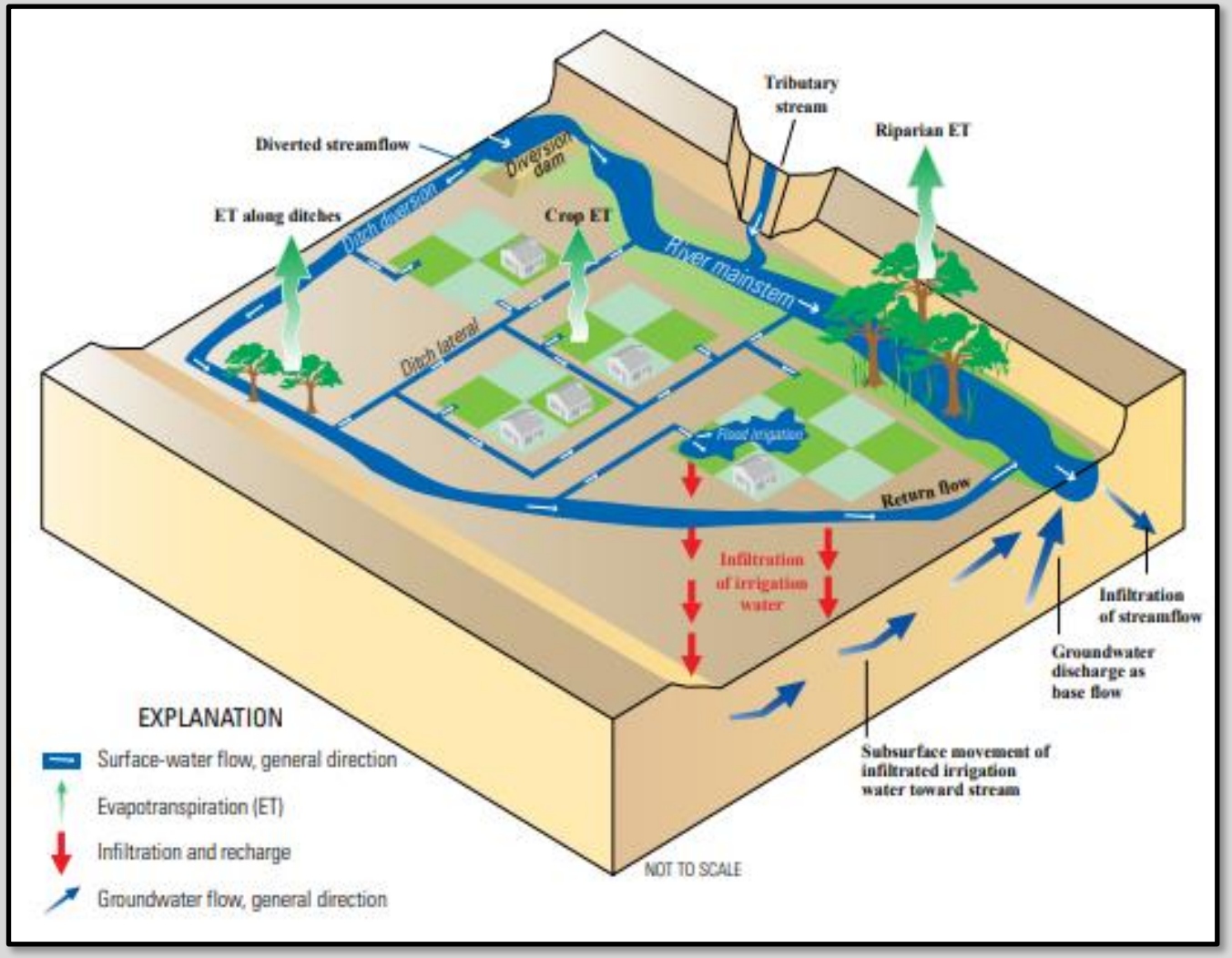
Conceptualizing the system

- Spatial domain
- Timing

Approaches

- Lagrangian
- Steady-state
- Average of conditions



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Independent Error– Controlling Bias and Measures of Certainty

USGS science for a changing world

Follow standardizing procedures

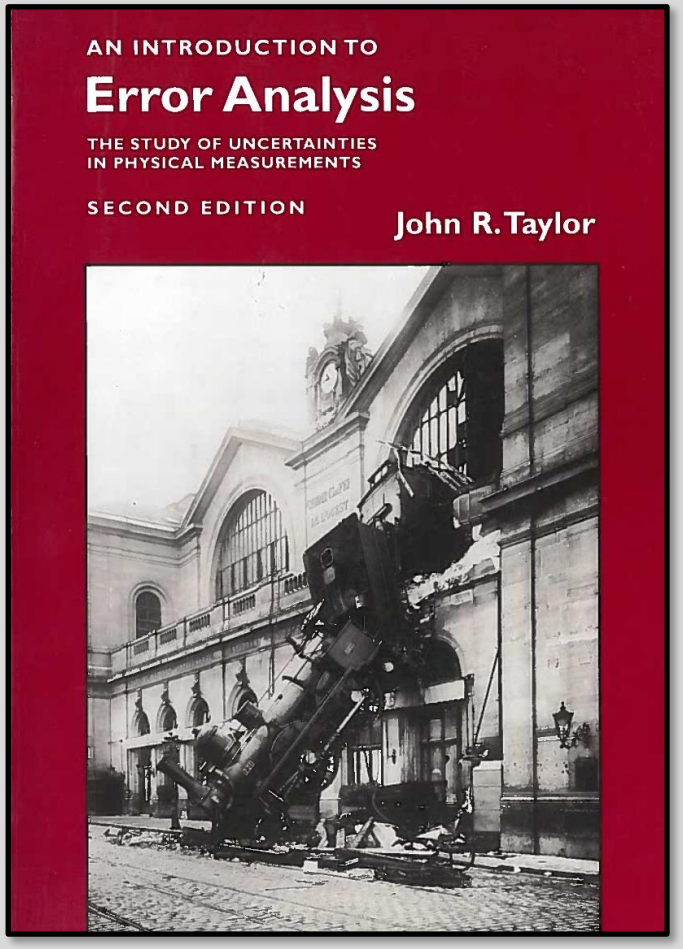
- Techniques and Methods
- User manuals
- Training

Conceptualizing the system

- Spatial domain
- Timing

Error Analysis

- Measures of uncertainty
- Error propagation



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Error Analysis – Error propagation and constraint

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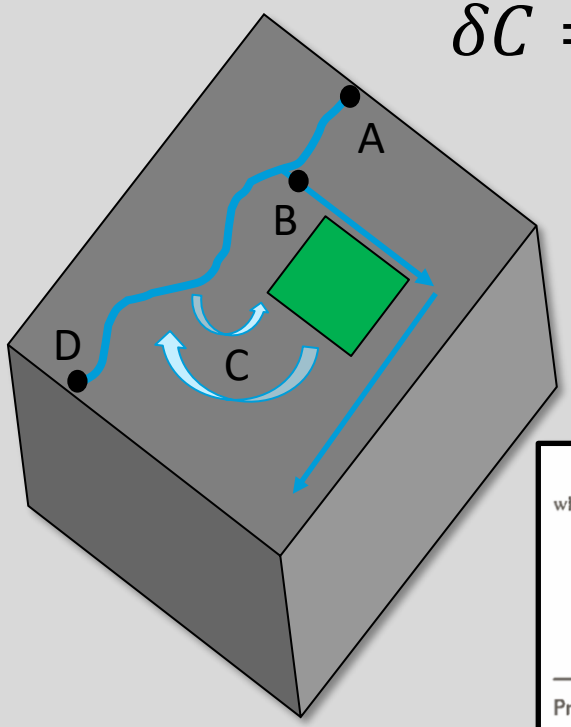
- Error propagation
  - Comparison of measures
- Example calculation:
- Sum of measurements
- A. 104.4 cfs $\pm$ 5.2 cfs
- B. 41.2 cfs $\pm$ 2.6 cfs
- C. GW return flow
- D. 63.2 cfs $\pm$ 3.1 cfs
  - A – B + C = D
  - 104.4 - 41.2 + C = 63.2
    - C = 0 $\pm \delta C$?



$$\delta C = \pm\sqrt{5.2^2 + 2.6^2 + 3.1^2}$$

$$\delta C = \pm 6.59 \text{ cfs}$$

(Measured value of x) = $x_{best} \pm \delta x$, (p. 13)

where

x_{best} = best estimate for x,

δx = uncertainty or error in the measurement.

Fractional uncertainty = $\frac{\delta x}{|x_{best}|}$. (p. 28)

Propagation of Uncertainties (Chapter 3)

If various quantities $x, \ldots, w$ are measured with small uncertainties $\delta x, \ldots, \delta w$, and the measured values are used to calculate some quantity q, then the uncertainties in $x, \ldots, w$ cause an uncertainty in q as follows:
If q is the sum and difference, $q = x + \cdots + z - (u + \cdots + w)$, then

$$\delta q \begin{cases} = \sqrt{(\delta x)^2 + \cdots + (\delta z)^2 + (\delta u)^2 + \cdots + (\delta w)^2} \\ \quad \text{for independent random errors;} \\ \leq \delta x + \cdots + \delta z + \delta u + \cdots + \delta w \\ \quad \text{always.} \end{cases}$$

(p. 60)

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Questions?

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Examples investigation approaches:

Garner, B.D., Pool, D.R., Tillman, F.D., and Forbes, B.T., 2013, Human effects on the hydrologic system of the Verde Valley, central Arizona, 1910–2005 and 2005–2110, using a regional groundwater flow model: U.S. Geological Survey Scientific Investigations Report 2013–5029, 47 p.

Kuhn, G., and Williams, C.A., 2004, Evaluation of Streamflow Losses Along the Gunnison River from Whitewater Downstream to the Redlands Canal Diversion Dam, near Grand Junction, Colorado, Water Years 1995–2003: U.S. Geological Survey Scientific Investigations Report 2004-5095, 22 p.

Ruddy, B.C., and Williams, C.A., 2010, Evaluation of streamflow gain-loss characteristics of Hubbard Creek, in the vicinity of a mine-permit area, Delta County, Colorado, 2007: U.S. Geological Survey Series Scientific Investigations Report 2009–5271, 20 p.

Stevens, M.R., Leib, K.J., Thomas, J.C., Bauch, N.J., and Richards, R.J., 2018, Streamflow and selenium loads during synoptic sampling of the Gunnison River and its tributaries near Delta, Colorado, November 2015: U.S. Geological Survey Scientific Investigations Report 2018–5029, 17 p.

Williams, C.A., and Leib, K.J., 2005, Using tracers to evaluate streamflow gain-loss characteristics in the vicinity of a mine-permit area, Delta County, Colorado, Water Year 2003: U.S. Geological Survey Scientific Investigations Report 2005-5018, 27 p.