Watershed 201, Discharge and Total Suspended Solids

Measuring discharge, collecting TSS samples, measuring TSS, and setting up a low-cost TSS lab

June 7, 2019, 9:00a-4:00p, at Willistown Conservation Trust, Rushton Conservation Center, 915 Delchester Rd, Newtown Square, PA 19073
Overview for the day

**Agenda**

- 9:00-9:15 – Welcome, refreshments, light breakfast
- 9:15-9:30 – Introductions, overview for the day
- 9:30-10:00 – Presentation on discharge, suspended sediment, rating curves, and loads
- 10:00-10:15 – Break and prep for group work
- 10:15-12:30 – Lab and Field, two groups
  - Lab – Review of two low-cost TSS lab setups; measuring TSS
  - Field – Measuring discharge and collecting grab samples for TSS
- 12:30-1:00 – Lunch (attendees bring bagged lunches)
- 1:00-3:15 – Lab and Field, two groups switch
- 3:15-4:00 – Overflow, discussion, rating curves
- 4:00-6:00 – 1:1 meetings

*Everyone does everything, working in pairs*
Everyone does everything, working in pairs. We will be using attendee lab and field results in comparison study
Today

- With Lauren McGrath and Marion Waggoner in Lab
  - Demonstration of methods
  - In pairs
    - Filter samples (already prepared with known concentrations, to be dried and weighed later)
    - Weigh samples (already dried)
- With Dave Bressler, Regan Dohm (plus Maddy and Kacy), and Dave Yake in Field
  - Demonstration of methods
  - In pairs
    - Discharge measurements, flow meter
    - Discharge measurements, orange float
    - Collect and label grab samples
Stream Discharge and TSS

- **Discharge (or flow)** is the volumetric flow rate of water that is transported through a given cross-sectional area
  - Cubic feet per second
  - Cubic feet per meter

- **Total suspended solids (TSS)** is the dry-weight of suspended particles, *that are not dissolved*, in a sample of water that can be trapped by a filter that is analyzed using a filtration apparatus
  - Milligrams per liter
Discharge

In each subsection:

Area = Depth \times Width

Discharge = Area \times Velocity
# Sediment

<table>
<thead>
<tr>
<th>Φ scale</th>
<th>Size range (metric)</th>
<th>Size range (approx. inches)</th>
<th>Aggregate name (Wentworth Class)</th>
<th>Other names</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; −8</td>
<td>&gt; 256 mm</td>
<td>&gt; 10.1 in</td>
<td>Boulder</td>
<td></td>
</tr>
<tr>
<td>−6 to −8</td>
<td>64–256 mm</td>
<td>2.5–10.1 in</td>
<td>Cobble</td>
<td></td>
</tr>
<tr>
<td>−5 to −6</td>
<td>32–64 mm</td>
<td>1.26–2.5 in</td>
<td>Very coarse gravel</td>
<td>Pebble</td>
</tr>
<tr>
<td>−4 to −5</td>
<td>16–32 mm</td>
<td>0.63–1.26 in</td>
<td>Coarse gravel</td>
<td>Pebble</td>
</tr>
<tr>
<td>−3 to −4</td>
<td>8–16 mm</td>
<td>0.31–0.63 in</td>
<td>Medium gravel</td>
<td>Pebble</td>
</tr>
<tr>
<td>−2 to −3</td>
<td>4–8 mm</td>
<td>0.157–0.31 in</td>
<td>Fine gravel</td>
<td>Pebble</td>
</tr>
<tr>
<td>−1 to −2</td>
<td>2–4 mm</td>
<td>0.079–0.157 in</td>
<td>Very fine gravel</td>
<td>Granule</td>
</tr>
<tr>
<td>0 to −1</td>
<td>1–2 mm</td>
<td>0.039–0.079 in</td>
<td>Very coarse sand</td>
<td></td>
</tr>
<tr>
<td>1 to 0</td>
<td>½–1 mm</td>
<td>0.020–0.039 in</td>
<td>Coarse sand</td>
<td></td>
</tr>
<tr>
<td>2 to 1</td>
<td>¼–½ mm</td>
<td>0.010–0.020 in</td>
<td>Medium sand</td>
<td></td>
</tr>
<tr>
<td>3 to 2</td>
<td>125–250 μm</td>
<td>0.0049–0.010 in</td>
<td>Fine sand</td>
<td></td>
</tr>
<tr>
<td>4 to 3</td>
<td>62.5–125 μm</td>
<td>0.0025–0.0049 in</td>
<td>Very fine sand</td>
<td></td>
</tr>
<tr>
<td>8 to 4</td>
<td>3.90625–62.5 μm</td>
<td>0.00015–0.0025 in</td>
<td>Silt</td>
<td>Mud</td>
</tr>
<tr>
<td>&gt; 8</td>
<td>&lt; 3.90625 μm</td>
<td>&lt; 0.00015 in</td>
<td>Clay</td>
<td>Mud</td>
</tr>
<tr>
<td>&gt;10</td>
<td>&lt; 1 μm</td>
<td>&lt; 0.000039 in</td>
<td>Colloid</td>
<td>Mud</td>
</tr>
</tbody>
</table>

[http://www.horiba.com/?id=2780](http://www.horiba.com/?id=2780)
Context

- Delaware River Watershed Initiative, William Penn Foundation
- Citizen Science, Stroud Center facilitation of continuous monitoring using EnviroDIY Mayfly sensor stations
  - ~70 sensor stations deployed across Delaware River Basin
    - Conductivity, Temperature, **Depth** (CTD) and **Turbidity**
    - Solar powered
    - Logging data every 5 minutes
    - Some online, always log to microSD card on-site
  - Stroud Center facilitating use of stations among watershed groups in Delaware Basin (next slide)
Ridley Creek SL155

http://drwisensors.dreamhosters.com/

SL155 Turbidity/CTD Logger

This is data from logger SL155.
The logger is equipped with a Decagon CTD which measures water conductivity, temperature, and depth; and a Campbell Scientific OBS2t which measures turbidity in two ranges.

Show all data in the database as table or as CSV text
Get raw CSV text file

Latest readings:
At 2019-06-06 11:21:05 EST:
CTD Depth= 205.3mm, CTD Temp= 20.1 degreesC, CTD Conductivity= 474.3 uS/cm
Turbidity Low= 2.4 NTU, Turbidity High= 1.8 NTU, Board Temp= 23.8 degreesC, Battery= 4.02 volts

Water Depth and Conductivity, last 48 hours

Historic Data

- Water depth
- Conductivity

Stroud
Water Research Center
Ridley Creek SL155

http://drwisensors.dreamhosters.com/

Water Depth and Turbidity

2019/05/07 14:25:04:
CTDdepth: 210.3
TurbLow: 1.5
TurbHigh: 0.8

STROUD™
WATER RESEARCH CENTER
What do the stations have to do with today?

- Developing rating curves to enhance sensor station data – make data more useful
  - Converting **Depth** (mm) to **Discharge** (m$^3$/s)
  - Converting **Turbidity** (NTU) to **Total Suspended Solids** (mg/L)

*Once rating curves developed you can start to talk about concentrations and quantities of material moving in stream (e.g., “sediment loads”)
Hydrologic rating curve

- Depth ("stage") to Discharge

Data from Pickering Creek at Montgomery School (SHPK5S, SL135)
Hydrologic rating curve
Hydrologic rating curve

https://www.usgs.gov/media/images/usgs-stage-discharge-relation-example
Sediment rating curve

- TSS to Turbidity

Turbidity/TSS Rating Curve

\[ y = 2.0818x - 3.8108 \]

Data from Pickering Creek at Montgomery School (SHPK5S, SL135)
Sediment rating curve

![Graph showing regression relations of turbidity to suspended-sediment concentration for West Branch Brandywine Creek near Honey Brook, Pennsylvania.](image)

**Figure 4.** Regression relations of turbidity to suspended-sediment concentration for West Branch Brandywine Creek near Honey Brook, Pennsylvania.

Sediment rating curve

Figure 1. Relationship curve between turbidity and total suspended solids at the Duke Forest site.

What to do with rating curves?

**USE THE EQUATION**

Apply depth/discharge rating curve equation to Depth data to transform it to Discharge data

<table>
<thead>
<tr>
<th>Date, time</th>
<th>CTDepth (mm)</th>
<th>Discharge ((m^3/s)) Sensor Depth (x) into Discharge Rating Curve</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/7/19, 8:00a</td>
<td>465.3</td>
<td>0.286</td>
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<tr>
<td>6/7/19, 8:05a</td>
<td>480.4</td>
<td>0.299</td>
</tr>
<tr>
<td>6/7/19, 8:10a</td>
<td>491.4</td>
<td>0.308</td>
</tr>
<tr>
<td>6/7/19, 8:15a</td>
<td>503.5</td>
<td>0.318</td>
</tr>
<tr>
<td>6/7/19, 8:20a</td>
<td>515.3</td>
<td>0.328</td>
</tr>
</tbody>
</table>

*Example only*
What to do with rating curves?

Apply turb/tss rating curve equation to Turbidity data to transform it to TSS data.

<table>
<thead>
<tr>
<th>Date, time</th>
<th>Turbidity (NTU)</th>
<th>TSS (mg/L)</th>
<th>TSS (mg/m³)</th>
<th>Sediment Flux (mg/s)</th>
<th>Sediment Load (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/7/##, 8:00a</td>
<td>8.56</td>
<td>7.95</td>
<td>7953</td>
<td>2280</td>
<td>688579</td>
</tr>
<tr>
<td>6/7/##, 8:05a</td>
<td>9.7</td>
<td>10.42</td>
<td>10425</td>
<td>3121</td>
<td>930158</td>
</tr>
<tr>
<td>6/7/##, 8:10a</td>
<td>10.79</td>
<td>12.78</td>
<td>12788</td>
<td>3947</td>
<td>1196090</td>
</tr>
<tr>
<td>6/7/##, 8:15a</td>
<td>11.27</td>
<td>13.82</td>
<td>13829</td>
<td>4409</td>
<td>1309710</td>
</tr>
<tr>
<td>6/7/##, 8:20a</td>
<td>11.74</td>
<td>14.84</td>
<td>14848</td>
<td>4882</td>
<td>1459852</td>
</tr>
</tbody>
</table>

*Example only*

*Sum to get individual storm, daily, monthly, seasonal loads, etc.*
Citizen Science, Stroud Center facilitation of usage of EnviroDIY sensor stations

- Technical support, troubleshooting, etc.
- Coordinating efforts among managers, volunteers/citizen scientists, professional scientists, teachers, students
- Online tools
  - Sensor station data: Monitor My Watershed (http://monitormywatershed.org/)
  - Sensor station data: http://drwisensors.dreamhosters.com/ - SL155 for today
  - Delaware Basin Sensor Stations online group (private group via https://wikiwatershed.org/)
  - EnviroDIY (https://www.envirodiy.org/)
- Manuals and guidance materials – all posted to online group and available from Stroud Center
- Data sheets - Field Visit Data sheet, Stream Discharge Data sheet
- Data analysis tools – Stage to Area predictor, discharge rating curve calculator, load calculator
- Workshops, trainings, user group meetings, 1:1 work
- Presentations and articles
Stroud support

- Citsci support personnel
  - **David Bressler**, Stroud – main contact
  - **Shannon Hicks**, Stroud – high level technical support
  - **Rachel Johnson**, Stroud – technical support, field assistance, small workshop facilitation
  - **Matt Gisondi**, Stroud – data analysis (rating curves, loads), field assistance, 1:1 training
  - **Christa Reeves**, Stroud/Musconetcong WA – regional assistance, northern Delaware Basin
  - **Carol Armstrong**, Stroud/PSU Master Watershed Stewards – citizen science volunteer assistance, field maintenance and storm sampling, PSU Master Watershed Stewards mentor
  - **WHAT (Yake/Waggoner/Ward)** – Watershed Hydrological Assessment Team, technical support on hydrology and sediment
  - **Dave Arscott** (ex dir), **John Jackson** (senior sci), and **Matt Ehrhart** (dir of restoration) – original citsci project designers
Important Field Work

- **Maintenance – every two weeks**
  - Clean sensors
  - Clean around logger
  - Complete Field Visit Data sheet
  - Other site observations, upkeep, photos, etc.
  - Enter data online - [https://wikiwatershed.org/drwi/](https://wikiwatershed.org/drwi/); pass: drwi

- **Quality Control – quarterly**
  - Clean sensors
  - QC Depth
  - QC Chemistry
  - SD card swapping (data download)
Enter all data online: wikiwatershed.org/drwi; password: drwi
Quarterly – Quality Control

**EnviroDIY Field Visit Data**

- Enter all data online: wikiwatershed.org/drwi; password: drwi

### Sensor Cleaning

- **Recommended frequency:** weekly or biweekly, monthly if only CTD sensor
- *Cleaned Sensors?* Yes/No
  - If Yes, exact time: AM/PM? EST/EDT?
  - *Clean > 5 min. before grab sampling*

### Grab Samples

- **Frequency:** Situational; for rating curves, collect when water is high/buried or higher than normal conductivity

<table>
<thead>
<tr>
<th>Parameter</th>
<th>QC Hand-held Meter Result</th>
<th>QC Time</th>
<th>QC AM/PM?</th>
<th>QC EST/EDT?</th>
<th>Sensor Station Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductivity (uS/cm)</td>
<td>AM/PM</td>
<td>EST/EDT</td>
<td>AM/PM</td>
<td>EST/EDT</td>
<td></td>
</tr>
<tr>
<td>Temperature (degC)</td>
<td>AM/PM</td>
<td>EST/EDT</td>
<td>AM/PM</td>
<td>EST/EDT</td>
<td></td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>AM/PM</td>
<td>EST/EDT</td>
<td>AM/PM</td>
<td>EST/EDT</td>
<td></td>
</tr>
<tr>
<td>Dissolved Oxygen (mg/L)</td>
<td>AM/PM</td>
<td>EST/EDT</td>
<td>AM/PM</td>
<td>EST/EDT</td>
<td></td>
</tr>
</tbody>
</table>

### Other In-situ Parameters

- **E.g.:** Nitrate, Phosphate, Chloride, pH, Dissolved Oxygen

### Quality Control - Water Level Data

- **Recommended frequency:** quarterly and/or more frequently as needed

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Result</th>
<th>Band/Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field Duplicate Taken of Grab Sample?</td>
<td>Yes/No</td>
<td></td>
</tr>
<tr>
<td>Performed Cross Section Survey?</td>
<td>Yes/No</td>
<td></td>
</tr>
<tr>
<td>Flow Measurement w/ Neutrally Buoysant Object?</td>
<td>Yes/No</td>
<td></td>
</tr>
<tr>
<td>Flow Measurement w/ another method?</td>
<td>Yes/No</td>
<td></td>
</tr>
</tbody>
</table>

### Other Information

- **Retrieved Memory Card?** Yes/No
  - **Frequency:** quarterly if online, biweekly-monthly if not online

- **Changing Batteries?** Yes/No

- **Cleaned Solar Panel?** Yes/No

- **Other Sensor Station Maintenance?** Yes/No
  - (If Yes, describe in Notes)

**Notes:** Describe specific sensor station management actions and any other issues.

**QUALITY CONTROL - CHEMISTRY DATA**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Field Meter Brand/Model</th>
<th>IF or unique ID</th>
<th>Meter calibrated?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductivity (uS/cm)</td>
<td>AM/PM</td>
<td>EST/EDT</td>
<td>Am/PM</td>
</tr>
<tr>
<td>Temperature (degC)</td>
<td>AM/PM</td>
<td>EST/EDT</td>
<td>Am/PM</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>AM/PM</td>
<td>EST/EDT</td>
<td>Am/PM</td>
</tr>
<tr>
<td>Dissolved Oxygen (mg/L)</td>
<td>AM/PM</td>
<td>EST/EDT</td>
<td>Am/PM</td>
</tr>
</tbody>
</table>

**SENSOR MAINTENANCE**

- Sensors Submerged? Yes/No
- Location of Sensors Changed? Yes/No
- Location of Sensors to be Changed to? No/Yes
- *Please consult Stroud Center before changing location of sensors*
Importance of sensor cleaning and QC

Conductivity, temperature and depth readings **before** cleaning
Importance of sensor cleaning and QC

Conductivity, temperature and depth readings *after* cleaning

**Conductivity** change of ~60 uS/cm

**Depth** change of ~5mm;

**Temp** change of 0 deg C
Manuels

- EnviroDIY Sensor Station Operation Manual V1, DRWI
  - Operation manual for CTD/Turbidity EnviroDIY sensor stations (Delaware River Watershed Initiative context)
  - Access web link via Delaware Basin Sensor Station online group, Uploaded Files tab, “Guidance docs” category; link: https://docs.google.com/document/d/17iWKFOjD6tSFT6-a5mItXlgO8uhXjsA_voGDVRxEBTI/edit?usp=sharing

- EnviroDIY Mayfly Sensor Station Manual
  - Comprehensive – building, coding, installation, management
    - Does not contain DRWI specific info, e.g., online EnviroDIY Field Visit Data sheet
Videos

- Stroud sensor station video tutorials:
  - Installation
    - https://www.envirodiy.org/videos/
    - Youtube: https://www.youtube.com/results?search_query=envirodiy+mayfly+data+logger+steps+1-5
    - Link also on Delaware Basin Sensor Stations online group forum
  - Sensor cleaning
  - Data download
  - Sensor bundle removal
  - Discharge calculator, Stage-to-Area predictor, Load calculator
Delaware Basin Sensor Station online group

- Weekly reports from Carol Armstrong
- General updates from Bressler
- **Uploading lab results, rating curves, etc.**
- Uploaded Files tab – multiple categories – lots of files here
- Guidance docs for use of the site and the forum
- Forum topics – important ones pinned to the top
Stream Discharge Data sheet

- Names of all individuals involved on-site
- SiteID = specific site identifier
- Identifier for specific data logger (depth and/or turbidity)
- General locational info, e.g., ~100m upstream of Rte 1 bridge
- Decimal degrees
- Information on specific flow meter used for measurements

<table>
<thead>
<tr>
<th>Name(s)</th>
<th>Site ID:</th>
<th>GPS (Lat/Long):</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Staff Gage Height at start (m):</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Staff Gage Height at end (m):</td>
</tr>
</tbody>
</table>

**CROSS SECTION AND VELOCITY**

- When safely wearable, take a wetted cross section measurement, recording the distance along the measuring tape (tagline) and the water depth across the stream. The tagline should be strung between the bank pins. If a velocity meter is available, record the water velocity at each interval. Make note of the RPI5/PIN (right/left bank pin) and REW/LEW (right/left edge of water). Right and left are determined when facing downstream. If wearable, whether using a flow meter or neutrally buoyant object, always record Points to Note, Distance Along Tagline, and Water Depth. If not wearable, use Predicted Wetted Cross-Sectional Area estimate (from Stage/Area/Predictor spreadsheet) and measure/record velocity data in Neutrally Buoyant Object section (right) or Unwearable Flow Meter Velocity section (back).

<table>
<thead>
<tr>
<th>Point</th>
<th>Points to Note</th>
<th>Distance Along Tagline (m)</th>
<th>Water Depth (m)</th>
<th>Velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>along the stream.</td>
<td>along the measuring tape</td>
<td>along the stream.</td>
<td>along the measuring tape</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Float #</th>
<th>Travel Time (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
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<td>2</td>
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<td>10</td>
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</tbody>
</table>
EST = Eastern Standard Time - for 2017/2018 EST was from November 5, 2017 to March 11, 2018

EDT = Eastern Daylight Time – for 2018 EST is from Sunday, March 11, 2:00am to Sunday, November 4, 2:00am
Stream Discharge Data sheet

Water level as measured by staff gauge at time when flow measurements started and when flow measurements finished.

Water level as measured depth sensor at time when flow measurements started and when flow measurements finished.

<table>
<thead>
<tr>
<th>Name(s):</th>
<th>GPS (Lat/Long):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site ID:</td>
<td>Date:</td>
</tr>
<tr>
<td>Logger ID:</td>
<td>Start Time: AM / PM</td>
</tr>
<tr>
<td>Stream Name:</td>
<td>Stop Time: AM / PM</td>
</tr>
<tr>
<td>Location:</td>
<td>Time Zone: EST / EDT</td>
</tr>
<tr>
<td>Serial Number:</td>
<td>Calibration Date:</td>
</tr>
</tbody>
</table>

**Stream Discharge Data**

**CROSS SECTION AND VELOCITY**

When safely wadeable, take a wetted cross section measurement, recording the distance along the measuring tape (tagline) and the water depth across the stream. The tagline should be strong between the bank pins. If a velocity meter is available, record the water velocity at each interval. Make note of the RPI's PIN (right/pink bank pin) and RE/W/E/W (right/white edge of water). Right and left are determined when facing downstream. If wadeable, whether using a flow meter or neutrally buoyant object, always record Points to Note, Distance Along Tagline, and Water Depth. If not wadeable, use Predicted Wetted Cross Sectional Area estimate (from StagetoAreaPredictor spreadsheet) and measure/record velocity data in Neutrally Buoyant Object section (right) or Unwadeable Flow Meter Velocity section (back).

<table>
<thead>
<tr>
<th>Point</th>
<th>Points to Note</th>
<th>Distance Along Tagline (m)</th>
<th>Water Depth (m)</th>
<th>Velocity (m/s) (Using Flow Meter)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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**TOTAL**

- **Travel Distance (m):**
- **Start-to-Transsect Distance (m):**
- **Transsect-to-End Distance (m):**

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<th>Travel Time (seconds)</th>
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</table>
Staff Gauge Height:
On-site visual measure of water depth; this is used for QC of sensor depth and also used for discharge/depth rating curve
QUALITY CONTROL WATER LEVEL DATA

**Staff Gauge Height** – on-site visual measure of water depth; this is used for QC of sensor depth and also used for discharge/depth rating curve

**Sensor Station Water Depth** – water depth as measured by the CTD sensor

**Offset** – difference between water depth as measured by staff gauge and water depth as measured by CTD sensor (see above diagram)

*NOTE – RECOMMENDATION IS TO DO QUALITY CONTROL ON AT LEAST A QUARTERLY BASIS (EVERY 3 MONTHS)*
QC Sensor Station Water Depth – hand check of sensor depth – use metric ruler to measure from top of sensor window (where pressure transducer [white disc] is located) to water surface. Compare this number to the depth produced by CTD sensor.

This is intended as a coarse check of sensor function and also is a calibration to the individual sensor function (i.e., it may not be exactly the same as the ruler measurement but the difference should be consistent over time).
Stream Discharge Data sheet

Left and Right Bank Pins, Left and Right Edge of Water

Measuring tape strung between bank pins across stream

Depth of water at points along measuring tape

Velocity measured with meter at points along measuring tape – velocity at 60% total depth...

Or... measure Velocity by timing a floated object over a defined distance (use this method if a flow meter isn’t available OR if water is too high to use flow meter)
Or… measure Velocity by using flow meter where possible, i.e., if water is not wadeable (visually assess velocity across channel and use flow meter in a spot that seems representative of overall flow)
Q = Area x Velocity

Discharge (m³/s) = Wetted Area (m²) x Velocity (m/s)
Discharge

- Amount of water flowing in stream as a measure of time
  - Cubic feet per second, cfs
  - Cubic meters per second
- “Q” = Discharge

\[ Q = \text{Area} \times \text{Velocity} \]
Discharge

\[ Q = \text{Area (of wetted stream cross section)} \times \text{Velocity (of flowing water)} \]

\[ Q = A \times V \]
\[ Q = \text{Area} \times \text{Velocity} \]

**Width** (stream width, wetted width)

**Wetted cross sectional area**

**Depth** (water depth)

\[ \text{Area} = \text{Width} \times \text{Depth} \]
Q = \textbf{Area} \times \text{Velocity}

Measure stream width with measuring tape – wetted edge to wetted edge

\textbf{Width} \times \text{Depth} = \text{Area}
Q = Area × Velocity

Measure stream depth across the channel

Width × Depth = Area
Q = Area \times Velocity

Coarse by-hand calculation of Area

Get Coarse Depth by averaging your different depth measurements

\[
(D_1 + D_2 + \ldots + D_{10})/10 = \text{Average Depth}
\]

Average Depth \times \text{Width} = \text{Area}
Q = Area \times Velocity

More precise calculation of Area

Width of individual block \times Depth individual block = \text{Area of single block}

*triangles at edges \((1/2\text{base} \times \text{height})\)

Area of Block 1 + A_{B2} + A_{B3} \ldots + A_{B10} = Total Area
Q = Area x Velocity

Measure Velocity with:

- **Flow Meter** - measure velocity at the same place where depth measurements were made

OR

- **Neutral Buoyant Object** (e.g., an orange) – measure velocity in main flow of stream multiple times
Flow meters

Hach

OTT

Swoffer

Hach/Marsh-Mcbirney
Q = Area \times \text{Velocity}

Flow meter – measure \textbf{Velocity} at 60\% of total depth (a little over half way down in the water column)
Q = Area x Velocity

Left Bank Pin (LPIN)  
Left Edge of Water (LEW) – if bank is gradual, Water Depth=0 and Velocity=0

Measuring Tape

Right Edge of Water (REW) – if bank is steep/undercut, Water Depth will be greater than 0 and Velocity may be greater than 0

Right Bank Pin (RPIN)

60% total depth – measure velocity here using flow meter

<table>
<thead>
<tr>
<th>Point</th>
<th>Points to Note</th>
<th>Distance Along Tagline (m)</th>
<th>Water Depth (m)</th>
<th>Velocity (m/s) (Using Flow Meter)</th>
<th>Comments</th>
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</table>

NEUTRAL BUOYANT OBJECT

Float object through main path of the stream. The measured transect should be halfway between the start and stop point. The total distance should be enough to ensure a travel time of >5 seconds.

TOTAL

Travel Distance (m):
Start-to-Transsect Distance (m):
Transsect-to-End Distance (m):

Travel Time (seconds) (record at least 5)
Q = Area x Velocity

5-10 timed floats over a defined distance

Start to transect (m)

Transect to end (m)

<table>
<thead>
<tr>
<th>Point</th>
<th>Points to Note</th>
<th>Distance Along Tagline (m)</th>
<th>Water Depth (m)</th>
<th>Velocity (m/s) (Using Flow Meter)</th>
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**NEUTRALLY BUOYANT OBJECT**

Float object through main path of the stream. The measured transect should be halfway between the start and stop point. The total distance should be enough to ensure a travel time of ≥5 seconds.

<table>
<thead>
<tr>
<th>TOTAL</th>
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<td>Transect-to-End Distance (m):</td>
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**Travel Time (seconds) (record at least 6)**

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<tbody>
<tr>
<td>Start-to-Transect Distance (m):</td>
<td>15</td>
<td>16</td>
<td>16</td>
<td>18</td>
<td>14</td>
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<td>16</td>
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</table>
Q = Velocity x Area

Calculate Q coarsely by hand:

\[ Q = (\text{Width} \times \text{Average Depth}) \times \text{Average Velocity (by flow meter or by NBO float)} \]

Width = 7.4 - 2.1 = 5.3m

Avg water depth = 0.35m

Avg velocity w flow meter = 0.27m/s

\[ Q_{\text{flowmeter}} = (5.3 \times 0.35) \times 0.27 = 0.5m^3/s \]

Avg velocity w NBO = 0.31m/s

\[ Q_{\text{neutralbuoyobj}} = (5.3 \times 0.35) \times 0.31 = 0.58m^3/s \]
Q = Velocity x Area

OR...Use Discharge Rating Curve Calculator spreadsheet (or other spreadsheet)
Q = Area \times Velocity

Segment Area = \left( \frac{1}{2}a + \frac{1}{2}b \right) \times d

Segment Discharge = \text{area} \times \text{velocity}
<table>
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</table>

**Pickering Creek, Phoenixville YMCA**

0.40Q via coarse average
0.48Q via individual blocks

1.43Q via coarse average
1.62Q via individual blocks
Grab samples

- Storm grab samples analyzed at Stroud only for:
  - Total Suspended Solids
  - Chloride

- Collect samples from the range of observed turbidity values at site – i.e., **collect samples from dirty water!**
Grab samples

- Labeling samples is super important
  - Site identifier
  - Date
  - **Time – to the minute**
    - Very important so that grab sample results can be matched up with sensor reading at the specific time grab was collected
  - Collector
Developing rating curves across the Delaware Basin

- Stroud (Matt Gisondi and interns) to facilitate rating curve development this summer, *as time and storms allow*
  - Discharge and grab samples
  - Matt will be in touch with groups if he’s in the area
    - Assistance welcomed, opportunity for on-site training
    - Spur of the moment because of the nature of storms and field sampling
Rating curves

Data from Ridley Creek at Ashbridge Preserve (PURC1S, SL155), Willistown Conservation Trust, Lauren McGrath
Figure 3. Regression relations of turbidity and suspended-sediment concentration for French Creek near Phoenixville, Pennsylvania.

Rating curves

Turbidity/TSS Rating Curve

\[ y = 2.0818x - 3.8108 \]

Data from Pickering Creek at Montgomery School (SHPK5S, SL135), Carol Armstrong, George Seeds, and David Kline (and students)
Measuring discharge for rating curve

For developing a discharge rating curve, measure discharge over the range of observed sensor depths – measure discharge at different sensor depths during one or multiple storms.
If possible, measure discharge multiple times over the course of one storm – this allows you to develop rating curve quickly.
Measuring discharge for rating curve

- Take discharge measurements at different water levels – these are then related to the staff gauge levels and sensor depths associated with these discharges.
- Discharge (m³/s) = Wetted area (m²) × Velocity of water (m/s)

Max depth for rating curve development

Discharge at baseflow – acquired at time of station installation
Collecting grab samples for rating curve

- How to know when to collect grab samples
  - Observe your stream on-site and watch sensor data to know when water gets muddy (see next slide)
  - Collect samples from a range of turbidity values, especially trying to get very muddy water
    - Collect multiple samples ranging in turbidity from a single storm (see next slide) or several storms
Collecting grab samples for rating curve

SL138, Pickering Creek

- Understand range of turbidity values observed at the site, so that you know when to collect grab samples – distribute grabs across the observed range (here 0-140 NTU)
- Understand what amount of rainfall and sensor depth increases cause what levels of turbidity – use this to focus the timing of your grab sampling efforts
- Turbidity sensor must be kept clean through the storm to ensure accurate data
Collecting grab samples for rating curve

SL138, Pickering Creek

Water Depth and Turbidity

Take grab samples at different turbidity levels (right y-axis)

Baseflow – grab sample acquired at time of station installation
Spreadsheet Calculators

- Discharge Rating Curve Calculator
- Stage to Area Predictor
- Load Calculator
Stage to Area Predictor

- **Predict Area** (“predicted wetted cross sectional area”) – for use when water is too high to measure width and depth across the channel
- Use predicted Area with measured Velocity (via NBO or point flow meter measurements) to calculate Discharge
Stage to Area Predictor

Measured Stream Cross Section with Predicted Water Level

Distance Along Tagline (m)

Depth from Line Level (m)

Min: 0.000
Max: 1.247

Staff Gauge Height (m): 1.100

--- OR ---

Recorded Sensor Depth (mm):
Sensor-to-Stage Offset (m):

Stage Used (m): 1.100
Predicted Depth from Line Level to Water Surface (m): 0.288
Predicted Wetted Width (m): 21.86

Predicted Wetted Cross Sectional Area (m²): 22.972
### Load Calculator

**Discharge Calculation Rating Curve Equation**

- \( y = mx + b \)
- \( m = 0.843 \)
- \( b = -0.2 \)

**TSS/Turbidity Rating Curve Equation**

- \( y = mx + b \)
- \( m = 2.1692 \times 10^{-6} \)
- \( b = 2.1862 \times 10^{-2} \)

**Chloride/Conductivity Rating Curve Equation**

- \( y = mx + b \)
- \( m = 4.50534 \)
- \( b = 224 \)

**Load Calculations**

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Data Import</td>
</tr>
<tr>
<td>B</td>
<td>Load Calculations</td>
</tr>
</tbody>
</table>

**TSS (mg/L)**

- \( 263.8 \) to \( 343.41 \)
- \( 2012.824 \) to \( 2012.824 \)
- \( 419.306784 \) to \( 419.306784 \)
- \( 516.143025 \) to \( 516.143025 \)
- \( 1618.67136 \) to \( 1618.67136 \)
- \( 635.0037458 \) to \( 635.0037458 \)
- \( 667.685459 \) to \( 667.685459 \)
- \( 395.123213 \) to \( 395.123213 \)
- \( 692.778873 \) to \( 692.778873 \)
- \( 830.956617 \) to \( 830.956617 \)
- \( 754.914272 \) to \( 754.914272 \)

**Chloride (mg/L)**

- \( 263.8 \) to \( 343.41 \)
- \( 2012.824 \) to \( 2012.824 \)
- \( 419.306784 \) to \( 419.306784 \)
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- \( 830.956617 \) to \( 830.956617 \)
- \( 754.914272 \) to \( 754.914272 \)

**Sediment Flux (mg/s)**

- \( 7.02754324 \) to \( 12882.601 \)
- \( 419.306784 \) to \( 419.306784 \)
- \( 516.143025 \) to \( 516.143025 \)
- \( 1618.67136 \) to \( 1618.67136 \)
- \( 635.0037458 \) to \( 635.0037458 \)
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- \( 830.956617 \) to \( 830.956617 \)
- \( 754.914272 \) to \( 754.914272 \)

**Sediment Load (mg)**

- \( 354.566841 \) to \( 354.566841 \)
- \( 11275.22635 \) to \( 11275.22635 \)
- \( 10809.5068 \) to \( 10809.5068 \)
- \( 11870.31226 \) to \( 11870.31226 \)
- \( 20202.0907 \) to \( 20202.0907 \)
- \( 23957.9247 \) to \( 23957.9247 \)
- \( 29073.1258 \) to \( 29073.1258 \)
- \( 35429.8682 \) to \( 35429.8682 \)
- \( 41004.069 \) to \( 41004.069 \)
- \( 35856.6841 \) to \( 35856.6841 \)

**Notes**

1. All values on this page will be filled once every value and equation found on the "Data Import" worksheet is appropriately filled out.
2. The data under the "Load Calculations" section will correspond to how many lines of data you copied over from the logger station webpage.
3. This table will only be able to read up to 1000 data entries. If including more than 1000, scroll.
Discharge and TSS literature


Today

- With Lauren McGrath and Marion Waggoner in Lab
  - Demonstration of methods
  - In pairs
    - Filter samples (already prepared with known concentrations, to be dried and weighed later)
    - Weigh samples (already dried)
- With Dave Bressler and Dave Yake in Field
  - Demonstration of methods
  - In pairs
    - Discharge measurements, flow meter
    - Discharge measurements, orange float
    - Collect and label grab samples
Preparing for the rest of the day

- Get into pairs
- Half stay at Lab, half go in field
  - Field
    - “Ashbridge Preserve” – put this into GPS
    - Carpool as you’d like
    - Everyone bring waders
    - Everyone bring your grab bottle, data sheet, clipboard, pencil
    - Bring other supplies as needed