A User's Guide to Measuring Streamflow

Prepared for:

Province of British Columbia

Prepared by:

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Definitions

Streamflow / Discharge: Is the total volume of water in the stream. It is a function of the cross-sectional area of the stream (width and depth) and the velocity. This is typically measured in cubic meters per second or m^3/s.

Velocity: a measure of the water's speed within the stream. This is typically measured as meters per second or m/s.

1 Purpose

The document supports the *Decisions on Applications for Water Diversion and Use in the Blueberry, Upper Beatton, and Lower Sikanni Chief Watersheds: Phase Two* Policy (WLRS, 2023).

When a water licence (Section 9) or short-term use approval (Section 10), as issued under the Water Sustainability Act (WSA) within the pilot area, requires the authorization holder to measure streamflow prior to and/or during water withdrawals, as per the terms and conditions or supporting letter, this document may be recommended for guidance.

2 Simple Streamflow Measuring Approaches

Streamflow is measured by calculating the volume of water that passes a particular point in a stream within a specific amount of time. It is expressed as cubic meters per second (m^3/s) and often referred to as streamflow or discharge.

Below is a list of options that may be used to estimate streamflow. Prior to conducting streamflow estimates refer to Section 3 - Safety and Equipment for additional information and details.

- Velocity-Area Method
- Stream Velocity Board Method
- Stream Depth
- Timed Volume Method

A representative photo of the stream, at the same location where the streamflow measurement is being conducted, must be taken each time. The photo should incorporate the full width of the stream (i.e., bank to bank) and note the streams condition such as any beaver activity or debris that may impact the streamflow. The photo must also include a date and time stamp.

If it is unsafe to physically measure the streamflow, as per Section 3, then a photo must be taken to represent the streamflow conditions.

The photo(s) may be required to be submitted with the streamflow measurement or be kept on record for a period as stated in the terms and conditions of the authorization (water licence or short-term Use Approval).

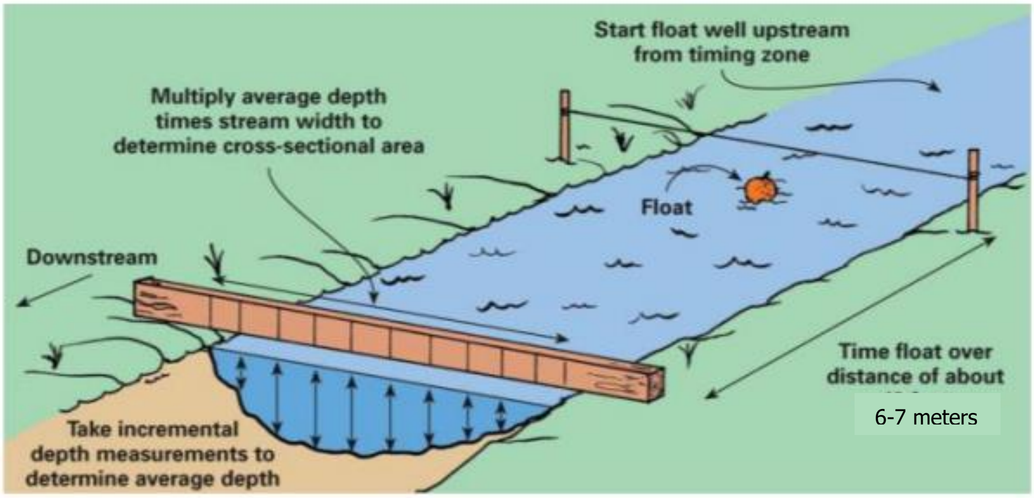
Appendix A, B and C support the information recording and submission as outlined in the authorization or the supporting letter.

2.1 Velocity-Area Method

This is the preferred option in this guidance document to measure streamflow or discharge. If using this method, it is recommended that you refer to Appendix A – Velocity-Area Measuring Data Sheet to assist with the data collection.

Streamflow estimated using the velocity-area method is determined by multiplying the cross-sectional area of water by the average velocity of the water. The cross-sectional area can be determined by direct measurement of the channel dimensions and the velocity can be estimated by timing the passage of a small float through a measured length of channel as shown in Figure 1.

Figure 1. Overview of the Velocity-Area Method (Othman et al., 2017).



This section has been adapted from the Volunteer Stream Monitoring: A Method's Manual (EPA, 2017). The formula to use when calculating streamflow is:

$$Streamflow = ALC/T$$

Where:

A = Cross-sectional area of the stream (stream width multiplied by average water depth in meters).
L = Length of stream reach measured (usually 6-7m)
C = A coefficient or correction factor (0.8 for rocky-bottom streams or 0.9 for muddy-bottom streams).
T = Time, in seconds, for the float to travel the length of L.

Equipment

The following equipment is recommended, in addition to the basic equipment (Section 3 - Safety and Equipment).

- Ball of heavy-duty string, four stakes, and a hammer to drive the stakes into the ground.
  - The string will be stretched across the width of the stream perpendicular to the bank at the upstream and downstream transect locations.
  - The stakes are to anchor the string on each bank to form a transect line.
- Tape measure (~15 m).
- Waterproof meter stick or other implement to measure water depth in meters.
- Twist ties to mark off intervals on the string of the transect line.
- Something that floats and is easily visible, like an orange or piece of wood and a fishing net to scoop out the orange from the stream. An orange is a good object to use because it has enough buoyancy to float just below the water surface.
- Stopwatch, or watch with a second hand.
- Calculator.

Where to measure

The authorization or associated letter should provide direction on where to measure the streamflow in relation to the point of diversion.

The section of stream chosen for the streamflow measurement should:

- be straight and approximately 6-7 meters in length.

be a single channel as shown in

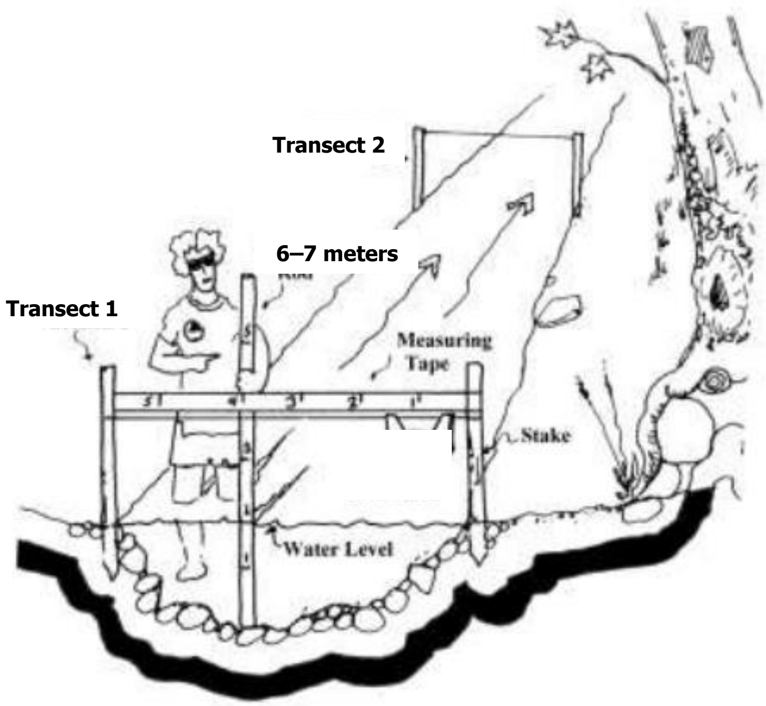
- Figure 1.
- contain unobstructed riffles or runs and should not contain areas of slower water such as a pool. Try to find a place where the water is flowing uniformly and free from plants/branches so the float will flow easily and smoothly.
- contain no additional inflow or outflow of water.

The length of the stream section that you select will be equal to L in the formula.

Measure and mark your section of channel by running a transect line across the stream perpendicular to the banks using the string and stakes to mark the upstream (Transect 1) and downstream (Transect 2) ends (Figure 2). The transect stakes should be as close to the waters edge as possible. The string should be near the water surface. Authorization and letters will allow for flexibility to change locations of conditions change, unless the channel conditions are no longer favorable, and a new location must be found.

Photos of the transects and channel section must be taken each time a streamflow measurement is taken.

Figure 2. Diagram of the 6–7-meter section of channel the upstream and downstream transects. Note that the transect stakes are at the stream's edge. (California Water Boards, 2023).



Channel Cross-Sectional Area:

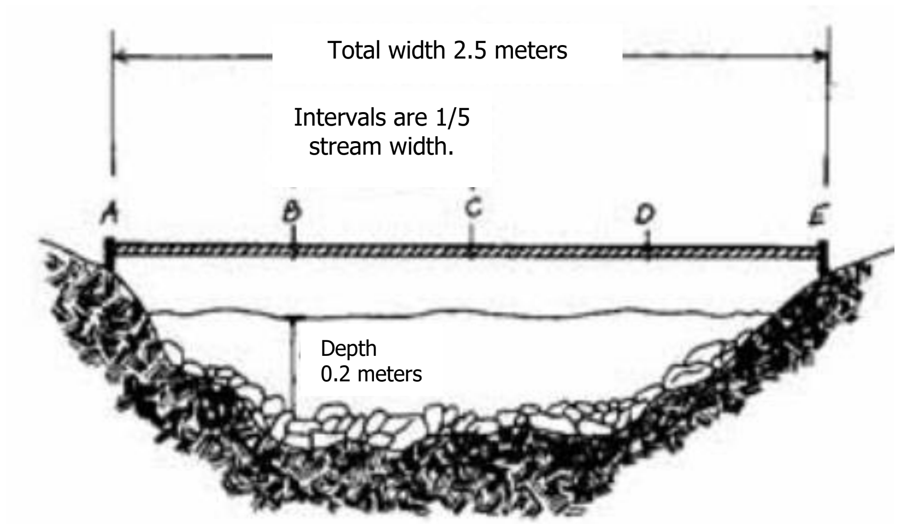
Cross-sectional area (A in the formula) is the product of stream width multiplied by average water depth. Refer to Step 1a and 1b in Appendix A.

Determine the width of either Transect 1 or Transect 2 by measuring the distance from shoreline to shoreline (where the stream's edge meets the land (called wetted width) – refer to Figure 2).

Determine the average depth of a transect (either Transect 1 or 2) by marking off equal intervals along the string with the twist ties. Measure the water's depth at each interval point (Figure 3). For example, the intervals may be measured at 1/5, 2/5, 3/5, and 4/5 of the distance across the stream from shoreline to shoreline. To calculate the average depth for the transect, divide the sum of the depth measurements by the total number of intervals. For example, if along Transect 1 the depth at 1/5 = 0.2 m; depth at 2/5 = 0.15 m; depth at 3/5 = 0.2 m; depth at 4/5 = 0.1. The average depth of Transect #1 would be 0.1625 m ((0.2 + 0.15 + 0.2 +0.1 = 0.65) / 4).

Calculate the cross-sectional area of the transect by multiplying the channel width times the average depth. For example, if the width of the channel is 2.5 m then the cross-sectional area is 0.406 m^2 (2.5 m width X 0.1625 m depth).

Figure 3. A cross section view to measure stream width and depth at each transect (EPA, 1997). Ensure that the stakes are as close to the waters edge as possible.



Measure Travel Time

Put the float in the stream a few meters upstream of Transect 1. The clock starts when the float fully passes the upstream transect line and stops when the float passes fully under the downstream transect line. Once under the final transect line, the float can be scooped out of the water with the fishing net. This "time of travel" measurement should be conducted at least four times at equal intervals across the stream and the results averaged. The averaged results are equal to T in the formula. For example, if the stream is greater than five (5) meters wide, then velocity measurements should be taken at approximately every 0.6 meters across the stream in order to derive four measurements. For a stream width of five (5) meters or greater, velocity measurements should be taken at approximately one (1) meter increments across the stream to derive four measurements. This method of measuring the stream velocity will ensure that velocity measurements are recorded for the slow and fast portions of the stream. You should discard any float trials if the object gets hung up in the stream (by cobbles, roots, debris, etc.).

Refer to Step 2 in Appendix A.

Calculating Streamflow

In this example, let's say the average time of travel for the float between Transect #1 and #2 is 15 seconds and the stream had a muddy bottom (refer to Step 3 of Appendix A). The calculation of *Streamflow* (m^3/s) would be:

Where:

A = 0.406 m^2
L = 7 m
C = 0.9 (coefficient for a smooth, muddy, sandy or bedrock bottom stream) or 0.8 (coefficient for rough, loose rock or coarse gravel bottom stream)
T = 15 seconds

Streamflow = ALC / T

Streamflow = (0.406 m^2) (7 m) (0.9) / 15 sec

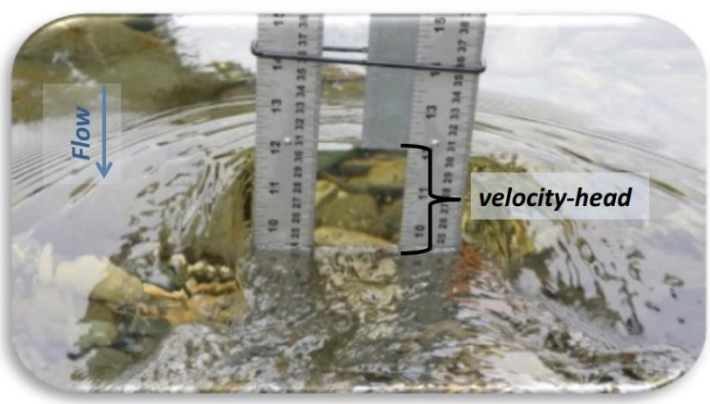
Streamflow = 2.59 m^3/ 15 sec

Streamflow = **0.16 m^3/sec**

2.2 Stream Velocity Board Method

The stream velocity board is a clear plastic board that measures water depth and is used to calculate stream velocity and discharge (Figure 4). The board is simple and inexpensive to construct or purchase and provides reliable discharge measurements under the right application conditions (Young et al., 2021).

Figure 4. Stream Velocity Board (Young et al., 2021).



How and Where to Measure Streamflow:

The metering section for the stream velocity board should have the following characteristics (RISC, 2018):

- a single channel as shown in Figure 2.
- a reasonably uniform depth and velocity, or flow, across the section.

- no aquatic growth or vegetation. Both the low flow and high flow measurement sections should be clear of aquatic growth.
- The stream must be wadable, with a maximum depth of 75 centimetres or 0.75 m.

Complete Appendix B – Recording the Information, as per your Water Licence or Letter.

Refer to Appendix C - User's Guide – for instructions on how to use and construct the board.

The board (also called a Transparent velocity-head rod) is also available for purchase from River Hydraulics, out of France, for ~$130 (Canadian dollars) excluding shipping and taxes. For more information on how to order the board or to watch instructional videos, visit the following website:

- https://riverhydraulics.inrae.fr/en/tools/instrumentation/discharge-measurements/transparent-velocity-head-rod/

2.3 Stream Depth

Stream depth may be measured, recorded, and submitted to represent streamflow if it is not practical or realistic to measure streamflow across the stream. If stream depth is to be measured, the location must be marked with a stake or something visible. The location of where to take the stream depth will be identified in the terms and conditions of the authorization and will typically be at or near the point of diversion. The location should be accessible from the stream's edge, where the water is flowing uniformly, free from plants or branches and along a straight stretch of the channel. Avoid measuring the stream depth in a pools or slow water where the sediment can accumulate. The measuring device should rest on the stream bottom and not sunk into soft substrate and read as close to the water level as practicable. The water depth should be measured to the closest centimeter (cm) or meter (m). For example, if the water depth is 1 m and 22.5 cm, the measurement may be recorded as 1.225 m. Be sure to take a picture of the stream where the depth is measured and include a photo showing the stream depth as measured.

If there is a bridge or stream crossing on your property, or near the point of diversion, that a ruler or measuring device can be attached to permanently, this may be a better place to measure the stream depth. A permanent structure may be attached to the bridge or road crossing such as a ruler or tape measure attached to a board. A staff gauge may also be purchased and installed as more permanent fixture at the bridge or in a protected area within the stream as shown below in

Figure 5.

Complete Appendix B – Recording the Information, as per your Water Licence or Letter.

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Figure 5. Staff gauge installed in stream and protected from ice and debris by rocks (photo credit – Suzan Lapp).

2.4 Timed Volume Method

This method is used to estimate the flow from streams where all the flow goes over a fall, or through pipe(s) or culvert(s), flowing full or partially, where the flow can be captured in a container.

For this method you will need a container to capture the water, such as a bucket (the larger the container the more accurate) and a stopwatch for timing.

Mark the level of the bucket indicating the volume of water which will be captured (use a container of known volume to do this). A "5-gallon" bucket may work well for low flow rates.

Take the average of three readings.

1. At the water discharge point (e.g., through a culvert or pipe or over a stream fall), move the bucket under the flow and at the same time start the stopwatch.
2. Stop the watch when the water reaches the marked level on the bucket and note the time.
3. Repeat two more times and average the readings of time to fill the container.
4. Convert the readings into a flow rate (discharge): Flow rate = volume / time.
    a. If you are using a 5-gallon bucket, the flow rate would be in gallons/second.
    b. To convert gallons/second to m3/s divide the value by 264.2.

For example, if it took 2 seconds to fill a 5-gallon bucket the discharge or flow rate would be:

Gallons/sec = 5 gallons / 2 sec

Flow rate or discharge = 2.5 gallons/sec

Flow rate or discharge = 2.5 gallons/sec / 264.2

Flow rate or discharge = **0.009 m^3/s**

Note: If you can measure streamflow using this method, it is likely that the water level is too low to withdraw water.

Complete Appendix B – Recording the Information, as per your Water Licence or Letter.

3 Safety and Equipment

3.1 Safety

Safety is critical when measuring streamflow. The following is a list of some basic common-sense rules (EPA, 2017):

- Always conduct a streamflow measurement with another person and let someone else know where you are, when you intend to return and what to do if you do not return as scheduled.
- Do not measure if severe weather is predicted or if a storm occurs while you are at the site.
- Never wade in swift or high water, or water that makes you feel uncomfortable. Do not measure if the stream is in a flood or during spring runoff or freshet.
- Wear a personal flotation device if necessary.
- Ensure your personal items such as wallet, phone and keys are in a safe place and/or waterproof bag.
- Do not walk on unstable stream banks. Disturb vegetation as little as possible.
- Be careful when walking in the stream itself. Rocky-bottom streams can be very slippery and can contain deep pools. Muddy-bottom streams might also prove treacherous in areas where mud, silt, or sand have accumulated in sink holes. If you must cross the stream, use a walking stick to steady yourself and to probe for deep water or muck. Your partner(s) should wait on dry land ready to assist you if you fall. Do not attempt to cross streams that are swift and above the knee in depth.
- Wear waders and rubber gloves in streams suspected of having significant pollution problems.
- If at any time you feel uncomfortable about the condition of the stream or your surroundings, stop measuring and leave the site at once. Your safety is more important.

If during periods of high flow or spring runoff (freshet), visual inspection may be sufficient to ensure streamflow is higher than the conditions stated in your authorization to withdraw water, a photo record is still required.

3.2 Basic Equipment

Listed below is some basic equipment for safety and to enhance effectiveness when conducting a streamflow measurement. This is not an exhaustive list.

- Rubber boots or waders
- Personal flotation device (e.g., Life jacket)
- Tape measure (~10m – 15m)
- Field data sheets
- Camera to document stream conditions
- Pencil
- Waterproof paper

4 References

California Water Boards. Information Paper 4.1: Flow. Guide for Citizens Monitors X. https://www.waterboards.ca.gov/water_issues/programs/swamp/docs/cwt/guidance/412.pdf accessed September 13, 2023.

EPA, 1997. https://www.epa.gov/sites/default/files/2015-04/documents/volunteer_stream_monitoring_a_methods_manual.pdf

Missouri Stream Team, 2022. Stream Discharge Data Sheet. https://www.mostreamteam.org/index.html

Othman, Affandy & Khairudin, Wan & Othman, Jamel & Ghani, Abd & Shakir, Ahmad & Mohd Saudi, Ahmad Shakir. (2017). Water flow measuring methods in small hydropower for streams and rivers-A study. International Journal of Applied Engineering Research. 12. 14484-14489.

Resources Information Standards Committee (RISC). 2018. Manual of British Columbia Hydrometric Standards. Version 2.0, December 2018. Knowledge Management Branch, B.C. Ministry of Environment and Climate Change Strategy, Victoria, B.C., 160pp. https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nr-laws-policy/risc/man_bc_hydrometric_stand_v2.pdf

WLRS, 2023. Decisions on Applications on Water Diversion and Use in the Blueberry, Upper Beatton, and Lower Sikanni Chief Watersheds: Phase Two. BC Ministry of Water, Land and Resource Stewardship. 20pp. https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/water-licensing-and-rights/water-policies/environmental-flow-needs/blueberry_pilot_op_final.pdf

Young, E.L., R.G. Pike and J.D. Goetz. 2021. Stream Velocity Board User's Guide. BC Ministry of Environment and Climate Change Strategy. 5pp. https://a100.gov.bc.ca/pub/acat/documents/r50525/SVB_Guide_Eng_2021_1632844892300_C54252B9EC.pdf

APPENDIX A - VELOCITY-AREA STREAM MEASURING DATA SHEET

Complete this data sheet as per the Water Licence or Letter.

Water Licence # ______________ Stream name ____

Latitude and Longitude____

Date _____/_____/_____ Time (Local) ____________

Streamflow Value for the week of (refer to your Water Licence) ________________________________

Site Description (e.g., rocky, vegetation, beaver activity, debris, straight stretch, etc.):

____

Weather ____

Participants

____

If discharge is unmeasurable due to conditions, please indicate: _____ Flow too low to measure _____ Flow too high to measure

If discharge is unmeasurable a photo must be taken. The rest of the form does not need to be completed.

Instructions for Calculation of Stream Discharge (Flow)

Step 1a: Determine stream width. Select a section of stream that is relatively straight, near your point of diversion, free from large objects such as logs or large boulders, with a noticeable current, and with a depth as uniform as possible. Stretch the tape measure across the stream. The "0" point should be anchored at the flowing edge of the stream. The end of the tape measure should be anchored at the opposite end so that it is tight and even with the other flowing edge. Do not measure nonflowing water.

Stream Width: __________ meters

Step 1b: Determine stream cross-sectional area. The first step in determining cross-sectional area is to measure and calculate the average stream depth. In the table below, for streams less than 7 meters wide, record depth measurements at every 0.50 meters (50 centimeters). For streams greater than 7 meters wide, record depth measurements every meter. The depth must be measured in **meters.**

Record Depth at 0.50 meter or 1 meter Intervals					
Interval Number	Depth in Meters	Interval Number	Depth in Meters	Interval Number	Depth in Meters
1		11		21	
2		12		22	
3		13		23	
4		14		24	
5		15		25	
6		16		26	
7		17		27	
8		18		28	
9		19		29	
10		20		30	
Sum		*Sum*		*Sum*	

The average depth is calculated by dividing the sum of the depth measurements by the number of intervals at which measurements were taken.

__________ ÷ __________ = __________

Sum of Depths (meters) Number of Intervals Average Depth (meters)

The final step in calculating the cross-sectional area is multiply the average depth (in meters) by the stream width (in meters) at the point where the tape measure is stretched across the stream.

__________ x __________ = __________

Average Depths (meters) Stream Width (meters) Cross Sectional Area (meters)²

Step 2: Determine the average velocity for the stream. A minimum of four velocity measurements should be taken from equal intervals across the stream's width. For example, if the stream is less than five (5) meters wide, then velocity measurements should be taken at approximately every 0.6 meters across the stream to derive four measurements. For a stream width of five (5) meters or greater, velocity measurements should be taken at approximately one (1) meter increments across the stream to derive four measurements. This method of measuring the stream velocity will ensure that velocity measurements are recorded for the slow and fast portions of the stream. For greater accuracy, more than four measurements are recommended for wider streams.

Put the float in the stream a few meters upstream of Transect 1. The clock starts when the float fully passes the upstream transect line (Transect 1) and stops when the float passes fully under the downstream transect line (Transect 2). Record the distance between Transect 1 and Transect 2 as Distance (L) in meters.

Distance (L): __________ meters

Count the number of seconds it takes the float to travel the distance between Transect 1 and Transect 2. Record this time (in seconds) in the table on the back of this page for each float trial you complete.

Velocity Float Trials	
Trial Number	Time (seconds)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
Sum	

The next step in calculating the surface velocity is to determine the average float time (T). Average float time is equal to the sum of the float times (in seconds) divided by the number of float trials.

________	÷	________	=	________
Sum of Float Trail Times (seconds)		Number of Trials		Average Float Time (T) (seconds)

The final step is to divide the distance floated (from the **Distance (L)** on the previous page) by the average float time.

________	÷	________	=	________
Distance Floated (L) (meters)		Average Float Time (T) (seconds)		Average surface velocity (meters per second (m/s))

Water in the stream does not all travel at the same speed. Water near the bottom travels slower than water at the surface because of friction (or drag) on the stream bottom. When calculating stream discharge, the water's velocity for the entire depth (surface to bottom) needs to be determined. Therefore, you must multiply the **average surface velocity** (from above) by a correction factor to make it represent the water velocity of the entire stream depth**.**

Choose the correction factor that best describes the bottom of your stream and multiply it by the average surface velocity to calculate the corrected average stream velocity.

Stream Bottom Type: Rough, loose rocks or coarse gravel: **correction value (C) = 0.8**
Smooth, mud, sand, or bedrock: **correction value (C) = 0.9**

________	x	________	=	________
Correction Value (C)		Average surface velocity (meters per second (m/s))		Corrected Average surface velocity (meters per second (m/s))

Step 3: Calculate the stream discharge. Multiply the cross-sectional area (meters)² from **Step 1** by the corrected average stream velocity (meters/Second) from **Step 2.**

________	x	________	=	________
Cross Sectional Area (meters)²		Corrected Average surface velocity (meters per second (m/s))		Streamflow Discharge (meters³ per second (m³/s))

Submit the Streamflow Discharge Information and photo of the stream as outlined by the Water Licence or Letter.

Contact the Ministry at northeastwaterstewardship@gov.bc.ca or 250-787-3415 for additional information or questions.

APPENDIX B – RECORDING THE INFORMATION

The following information should be recorded when collecting a streamflow measurement using the Depth, Stream Velocity Board, Timed Volume, or other methods:

Date:

Water licence number:

Latitude and Longitude:

Streamflow value for the week of:

Time of day:

Who took the measurements:

Description of the site (e.g., rocky, vegetation, beaver activity, debris, straight stretch, etc.):

Weather (sunny/windy/rainy/etc.):

Method used to estimate streamflow (circle one). If using the Stream Velocity Board be sure to include the field data collected as per Appendix C:

Depth / Stream Velocity Board / Time Volume / Other (explain below)

If streamflow is unmeasurable due to conditions, please indicate. A photo is still required:

Flow too low to measure/ Flow too high to measure / Other (explain below)

Estimated Depth (meters) or Streamflow (m^3/s):

Photos (ensure date is included on the photo):

Contact the Ministry at northeastwaterstewardship@gov.bc.ca or 250-787-3415 for additional information or questions.