Observed stream flow from seven small coastal watersheds in British Columbia between 2013 and 2019

Methods and metadata for discharge time-series version 5.0

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Introduction

The Watersheds program of the Hakai Institute analyzes and models the flow of materials from land to sea in the context of long-term environmental change - the origins, pathways, processes, and consequences for the food web. Stream flow, the conduit of these materials, is a fundamental component of this research.

Seven small watersheds (~3 to 13 km^2) in the coastal temperate rainforest of British Columbia, Canada (Fig. 1) are gauged for streamflow since 2013. This document outlines the metadata and the methods used to calculate discharge for these watersheds, between 2013 and 2019. For a more detailed description of the watersheds, please consult Oliver et al. (2017).

Version 5.0 includes time-series up to October the 1st, 2019. The methods and metadata outlined in this document are identical to those used in version 4.1.

With questions, please contact Bill Floyd (Bill.Floyd@viu.ca).

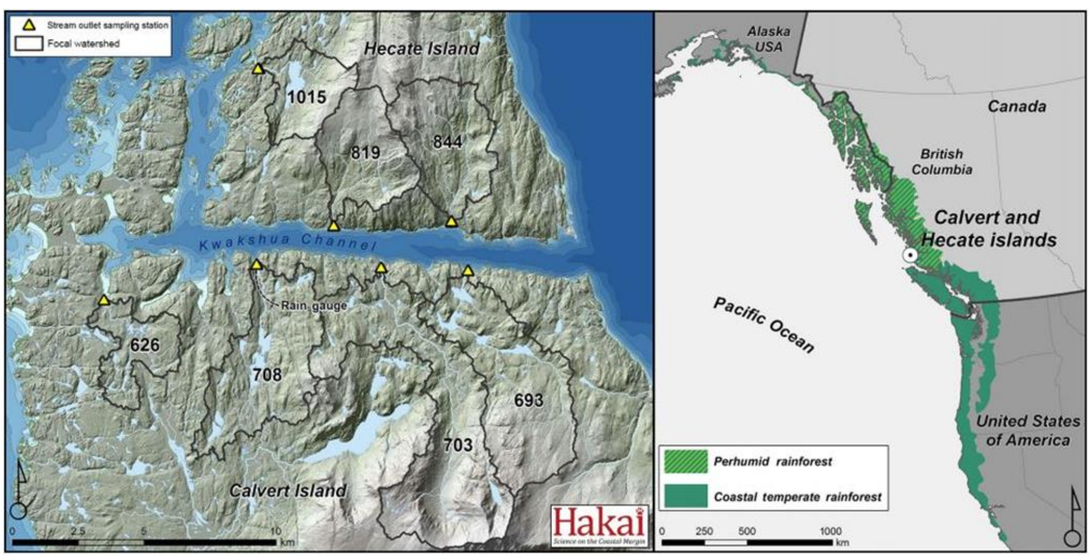

Figure 1: The location of Calvert Island, British Columbia, Canada, within the perhumid region of the coastal temperate rainforest (right) and the study area on Calvert and Hecate islands, including the seven study watersheds, corresponding stream outlet sampling stations (left). From Oliver et al. (2017).

Methods

General field methods

In natural streams it is not possible to continuously measure stream discharge, thus an indirect approach was used: river height (stage) was continuously measured at a gauging station using a pressure transducer and periodic discharge measurements were taken along the range of potential stages to develop a stage-discharge rating curve. Detailed description of the measurement methods outlined below can be found in the supplement section of Oliver et al. (2017).

Pressure transducers were installed in the fall of 2013 at watershed 708 and in the fall of 2014 at the other watersheds (Table 1). Low flows were manually measured using the velocity-area method, with either a Swoffer Current Velocimeter or a Sontek Acoustic Doppler Velocimeter. Stream flows, generally greater than 0.5 m^3/s, were measured using the salt dilution method, either manually (dry salt) or remotely (starting in the fall of 2015) using a fully automated system. The automated salt dilution (auto-salt) system releases pre-defined volumes of salt solution at pre-defined water stages, with two electrical conductivity sensors permanently located down-stream, to measure the salt wave passing through. Data are available in near real-time using the Hakai Telemetry Network (www.hakai.org/technology/#science-1). A calibration factor, required for the salt dilution method, was manually calculated at a minimum twice per barrel refill of salt solution, once at the initial fill and the other with the remaining solution before re-fill.

General data QC and analysis

Stage-discharge rating curves are not static but shift over time due to changes in the morphology of river channels, often associated with flood events. Therefore, rating curves are updated regularly. Korver et al. (2018) developed the first rating curves in 2015 and performed a detailed analysis of uncertainty of these rating curves. A concise description of rating curve plotting methods can be found in the supplement section of Oliver et al. (2017). However, this method has been substantially altered since and a summary of the current method used is described below.

All discharge measurements are assigned a relative uncertainty, based on fluctuations in the flow velocity profile (for area-velocity method), or based on the uncertainty in the volume of salt solution, the EC sensor resolution and the EC sensor calibration factor (for salt dilution method). Measurements with uncertainties higher than 20%, with noise or malfunctioning conductivity sensors, or with high uncertainties in stage monitoring are excluded from further analysis. The remaining stage-discharge measurements are plotted using a LOWESS regression that accounts for scatter in the stage-discharge data and multi-section rating curves. Uncertainty of derived discharge data is quantified by plotting confidence intervals (CI) around the rating curve. Following the methodology proposed by Coxon et al. (2015), these CI's are derived from 500 curve fitting results of LOWESS regressions on a randomized set of stage-discharge measurements and their maximum and minimum value of error. Using LOWESS regression is considered an improvement from using fixed power-law shaped functions (previously used method), as LOWESS has no defined shape and can therefore fit data more precise. Especially the determination of confidence intervals using LOWESS provides more realistic results as the previous CI algorithm is intended for linear functions and therefore needs to be log transformed. This results in unrealistic small CI's in the low flow end and unrealistic high CI's in the high flow end of the rating curve.

This discharge time-series was created using 5-minute average stage measurements that are Quality Controlled (QC), flagged and corrected where needed (Table 2). Generally, data gaps that were filled as well as noisy, faulty data that were corrected were assigned an 'EV' – Estimated Value flag. Suspicious data points that could not be corrected and estimated were assigned an 'SVC' – Suspicious Value Caution flag. All other data points were flagged 'AV' – Accepted Value. QC flags assigned to stage data were automatically copied to the corresponding 5-minute discharge calculations. Only flows greater than the highest measured discharge were assigned an additional 'SVC' flag, because the extrapolation of a rating curve beyond a set of measurements is usually highly uncertain and can greatly over or under estimate discharge.

Hourly, daily, monthly and yearly discharge rates, as well as hourly, daily, monthly and yearly discharge volumes are calculated from 5-minute discharge data as described in Table 3.

The R scripts used to calculate the rating curves as well as the hourly, daily, monthly and yearly discharge rates are available on Github:

- https://github.com/HakaiInstitute/RatingCurve
- https://github.com/HakaiInstitute/Discharge-editing

Table 1: detailed location information for the stage monitoring devices and discharge measurements at the seven studied watersheds.

Watershed	Site	Latitude	Longitude
WTS626	Stage monitoring device (pressure transducer)	51.64111	-128.12056
WTS626	Velocity-area method	51.64090	-128.12050
WTS626	Salt dilution method dump site	51.64081	-128.12065
WTS626	Salt dilution method sensor site	51.64167	-128.12028
WTS693	Stage monitoring device (pressure transducer)	51.64500	-127.99778
WTS693	Velocity-area method	51.64541	-127.99796
WTS693	Salt dilution method dump site	51.64500	-127.99778
WTS693	Salt dilution method sensor site	51.64750	-127.99639
WTS703	Stage monitoring device (pressure transducer)	51.64661	-128.02572
WTS703	Velocity-area method	51.64682	-128.02556
WTS703	Salt dilution method dump site	51.64661	-128.02572
WTS703	Salt dilution method sensor site	51.64829	-128.02607
WTS708	Stage monitoring device (pressure transducer)	51.64500	-127.99778
WTS708	Velocity-area method	51.64541	-127.99796
WTS708	Salt dilution method dump site	51.64500	-127.99778
WTS708	Salt dilution method sensor site	51.64750	-127.99639
WTS819	Stage monitoring device (pressure transducer)	51.66222	-128.04194
WTS819	Velocity-area method	51.66277	-128.04190
WTS819	Salt dilution method dump site	51.66222	-128.04194
WTS819	Salt dilution method sensor site	51.65817	-128.04242
WTS844	Stage monitoring device (pressure transducer)	51.66083	-128.00250
WTS844	Velocity-area method	51.66096	-128.00258
WTS844	Salt dilution method dump site	51.66083	-128.00250
WTS844	Salt dilution method sensor site	51.65827	-128.00208
WTS1015	Stage monitoring device (pressure transducer)	51.69056	-128.06528
WTS1015	Velocity-area method	51.69063	-128.06532
WTS1015	Salt dilution method dump site	51.69056	-128.06528
WTS1015	Salt dilution method sensor site	51.69078	-128.06718

Table 2: Description of data variables used in discharge time-series v3. This information can also be found in the 'Data Dictionary.csv'.

	Description and units	**5min**	**hourly**	**Daily**	**Monthly**	**Yearly**
Qrate	Discharge rate in m^3/s	Derived from 5 minute average 2 second stage data	The average of 12 five minute Qrate values of that hour	The average of 288 five minute Qrate values of that day	The average of five minute Qrate values	The average of five minute Qrate values
Qrate_min	Lower confidence interval (95%) of discharge rate in m^3/s	Derived from 5 minute average 2 second stage data	The average of 12 five minute Qrate_min values of that hour	The average of 288 five minute Qrate_min values of that day	The average of five minute Qrate_min values	The average of five minute Qrate_min values
Qrate_max	Higher confidence interval (95%) of discharge rate in m^3/s	Derived from 5 minute average 2 second stage data	The average of 12 five minute Qrate_max values of that hour	The average of 288 five minute Qrate_max values of that day	The average of five minute Qrate_max values	The average of five minute Qrate_max values
Qvol	Discharge volume in m^3	The 5 min Qrate value x 300	The sum of 12 five minute Qrate values x 300	The sum of 288 five minute Qrate values x 300	The sum of five minute Qrate values x 300	The sum of five minute Qrate values x 300
Qvol_min	Lower confidence interval (95%) of discharge volume in m^3	The 5 min Qrate_min value x 300	The sum of 12 five minute Qrate_min values x 300	The sum of 288 five minute Qrate_min values x 300	The sum of five minute Qrate_min values x 300	The sum of five minute Qrate_min values x 300
Qvol_max	Higher confidence interval (95%) of discharge volume in m^3	The 5 min Qrate_max value x 300	The sum of 12 five minute Qrate_max values x 300	The sum of 288 five minute Qrate_max values x 300	The sum of five minute Qrate_max values x 300	The sum of five minute Qrate_max values x 300
Qmm	Discharge volume in mm	The 5 min Qrate value x 300 divided by watershed area (km^2 x 1000)	The sum of 12 five minute Qrate values x 300 divided by watershed area (km^2 x 1000)	The sum of 288 five minute Qrate values x 300 divided by watershed area (km^2 x 1000)	The sum of five minute Qrate values x 300 divided by watershed area (km^2 x 1000)	The sum of five minute Qrate values x 300 divided by watershed area (km^2 x 1000)

Qmm_min	Lower confidence interval (95%) of discharge volume in mm	The 5 min Qrate_min value x 300 divided by watershed area (km^2 x 1000)	The sum of 12 five minute Qrate_min values x 300 divided by watershed area (km^2 x 1000)	The sum of 288 five minute Qrate_min values x 300 divided by watershed area (km^2 x 1000)	The sum of five minute Qrate_min values x 300 divided by watershed area (km^2 x 1000)	The sum of five minute Qrate_min values x 300 divided by watershed area (km^2 x 1000)
Qmm_max	Higher confidence interval (95%) of discharge volume in mm	The 5 min Qrate_max value x 300 divided by watershed area (km^2 x 1000)	The sum of 12 five minute Qrate_max values x 300 divided by watershed area (km^2 x 1000)	The sum of 288 five minute Qrate_max values x 300 divided by watershed area (km^2 x 1000)	The sum of five minute Qrate_max values x 300 divided by watershed area (km^2 x 1000)	The sum of five minute Qrate_max values x 300 divided by watershed area (km^2 x 1000)

Table 3: Description of data variables used in discharge time-series v3. This information can also be found in the 'Data Dictionary.csv'.

Datetime	Date and time. The end time of 5min and hourly time intervals is used for averaged and summed data.
Format	MM/DD/YYYY HH:MM
Timezone	Pacific Standard Time [PST]
Watershed	Name of the watershed
QC_flag	Quality Control flag
AV	Accepted Value
EV	Estimated Value
SVC	Suspicious Value Caution

Watershed specific comments

Please consult the 'Rating curves' folder which includes the rating curves of all seven watersheds, as well as a concise description of watershed specific issues and decisions that were made in the process of plotting rating curves.

References

Coxon, G., J. Freer, I. K. Westerberg, T. Wagener, R. Woods, and P. J. Smith.: A novel framework for discharge uncertainty quantification applied to 500 UK gauging stations, Water Resour. Res., 51, 5531–5546, doi:10.1002/2014WR016532, 2015.

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