White Paper - Discharge Calculation with HyQuant Q

The following is a brief description of the three typical methods used in hydrology to calculate discharge Q of a stream using a KISTERS HyQuant Q radar sensor. This white paper focuses on features available only on the HyQuant Q model. HyQuant Q builds on the HyQuant L+V, a sensor for simultaneous measurement of level and surface velocity, by incorporating discharge calculations, making it a comprehensive tool for hydrological monitoring without the need for additional sensors or housing modifications.

A brief tour of Q Calculation Methods

To calculate the discharge (Q) of a stream accurately, a cross-section profile of the stream is essential. This profile helps transform the measured surface velocity into the average velocity across the entire stream width. Here's a step-by-step overview:

Step 1: Establishing a Cross-Section Profile:

- A detailed measurement of the stream's cross-section is needed to understand the variations in depth and width of the riverbed.
- This involves dividing the stream into several sub-sections (or boxes) and measuring the depth at various points across the stream.

Step 2: Determining Sub-Section Areas:

- The area of each sub-section needs to be calculated. This is done by measuring the width and depth of each segment.
- These measurements help in understanding how much water each part of the stream can hold and contribute to the total discharge.

Step 3: Measuring Riverbed Variations:

- The height variations of the riverbed need to be determined accurately. Different methods such as manual surveying, ADCP, LiDAR, or echo sounding can be used to obtain this data.
- This information ensures that the cross-section profile reflects the actual shape and depth variations of the streambed.

Step 4: Applying the k-Factor:

- The k-factor is used to convert the measured surface velocity into the mean velocity across the cross-section.
- k is determined based on the cross-section data and is crucial for accurate discharge calculation.
- The k-factor may vary along the cross-section and needs to be interpolated between the measured levels to apply it accurately across all sub-sections.

By using a detailed cross-section profile and an appropriate k-factor, HyQuant Q will transform the measured surface velocity into mean velocities. This allows for a precise calculation of the stream's discharge, ensuring accurate hydrological assessments.

KISTERS' HyComm software enables the user to enter k-factors. The three distinct methods implemented in HyQuant Q are described in the following.

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Page 1 / 7

Constant *k*-Factor Method

- **Overview**: This method uses a constant value of the k-factor (or *alpha*) derived from textbooks or historical data for specific types of rivers or streams.
- **Procedure**:
  - Measure the surface flow velocity V_s
  - Apply the constant k-factor to convert V_s to the average flow velocity V_m: $V_m = k \times V_s$
  - Measure the cross-sectional area A of the stream.
  - Calculate discharge Q using the formula: $Q = V_m \times A$.
- **Advantages**: Simple and quick, useful for streams with stable characteristics.
- **Disadvantages**: May not be accurate for streams with variable flow conditions or irregular cross-sections.

Dynamic *k* using a Power Law profile

- **Overview**: This method utilizes the relationship between depth and velocity based on a power law profile to determine the k-factor.
- **Procedure**:
  - Measure the depth y and velocity *V(y)* at multiple points in the cross-section.
  - Fit the measured velocity data to a power law profile: $V(y) = V_{max} \left(\frac{y}{d}\right)^n$, where V_{max} is the maximum velocity at the surface, d is the total depth, and n is the exponent.
  - Calculate the k-factor from the power law parameters: $k = \frac{1}{1+n}$.
  - Measure the surface velocity V_s
  - Apply the k-factor to convert V_s to the average flow velocity V_m: $V_m = k \times V_s$
  - Measure the cross-sectional area A of the stream.
  - Calculate discharge Q using the formula: $Q = V_m \times A$.
- **Advantages**: Provides a tailored k-factor based on empirical data, can be more accurate than using a constant k-factor.
- **Disadvantages**: Requires detailed measurements and fitting to a power law, which can be complex and time-consuming.
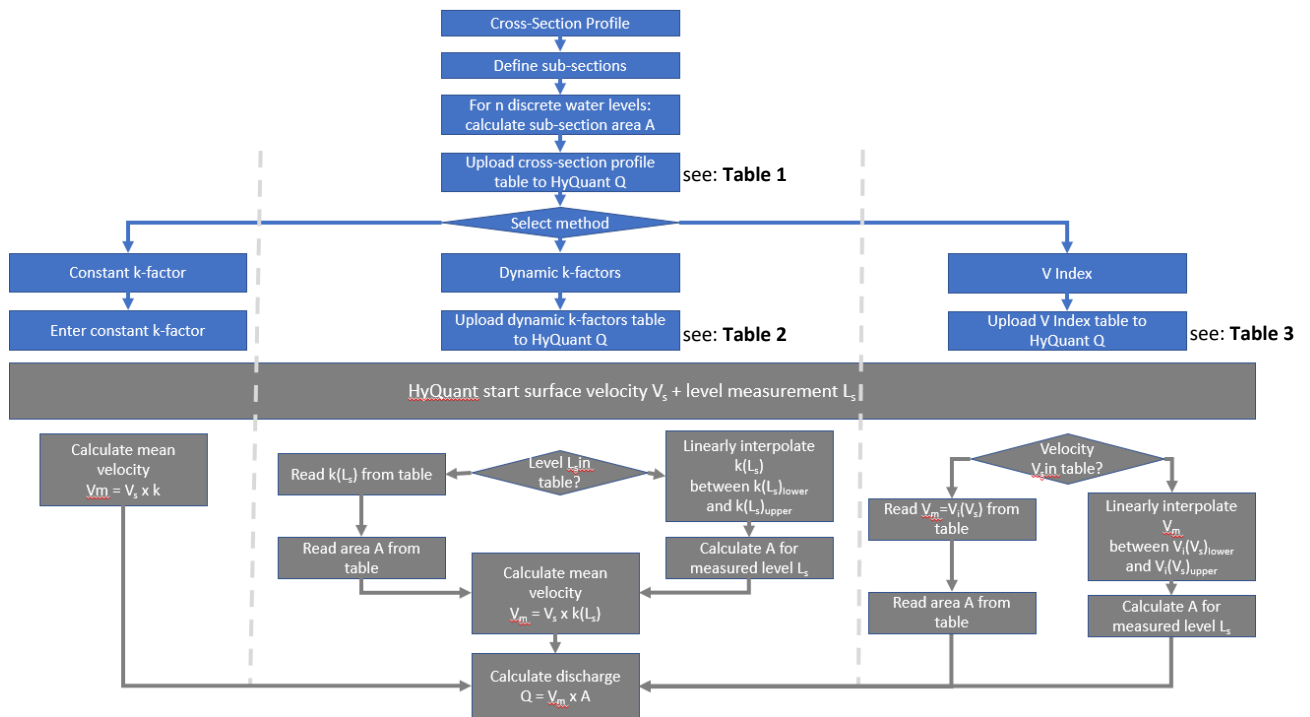
Index Velocity Method

- **Overview**: This method utilizes the relationship between measured surface or near-surface velocities and the average flow velocity in the cross-section.
- **Procedure**:
  - Measure the surface flow velocity V_{index}
  - Establish a calibration relationship between V_{index} and the average velocity V through detailed measurements and statistical analysis.
  - Measure the cross-sectional area A of the stream.
  - Calculate discharge Q using the calibrated relationship and the cross-sectional area: $Q = V_m \times A$.
- **Advantages**: More accurate for streams with variable conditions, uses real-time data.
- **Disadvantages**: Requires extensive initial calibration and continuous monitoring.

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Page 2 / 7

## Practical application of the three methods with HyQuant Q and HyComm

Each radar sensor needs to be configured. Level measurements must be adjusted to a reference water level or zero point. Q models require additional settings, in particular a correction factor to convert surface velocity to mean velocity, taking into account variations in river cross section at the monitoring point. The HyComm configuration software is designed for use with KISTERS' HyQuant radar sensors and allows local communication and configuration. To connect the HyQuant sensor to HyComm, users need to activate the mobile hotspot on the sensor and connect their computer or portable device to the sensor's Wi-Fi access point. This simple process ensures that users can quickly connect and begin configuring the sensor. The following describes how to use HyComm to configure a HyQuant Q sensor for Q measurements. Please note that these functions are only available for the HyQuant Q and not for the other models of the product family.

The following flow chart illustrates the path through HyComm for entering input values (constants or tables of numerical values) and selecting a Q calculation method. Blue boxes contain user actions, while HyQuant actions are described in grey boxes.

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Page 3 / 7

Q Settings in HyComm

For a HyQuant Q sensor, the user can select one of the three supported Q calculation methods. Select "Discharge" from the left menu bar. The following dialogue opens:
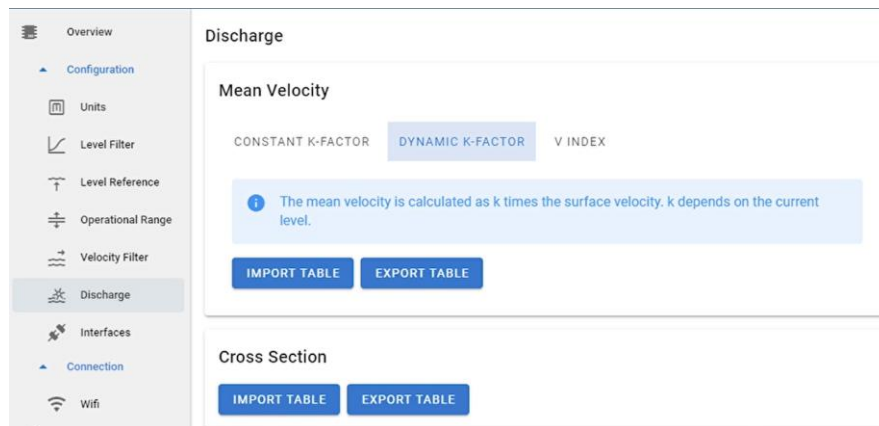
Preliminaries

The cross-section must be determined for all Q calculation methods. A table of section data must be provided. The table can be imported and exported. The cross-section table defines a relationship between water level and area. Level data is entered as discrete values. For measured levels between two specified levels, HyQuant Q uses linear interpolation to derive the correct value of *k*.
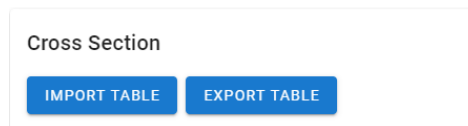

Table structure

Table 1 – Cross-Section Table

Table	Column 1			Column 2		
	Header	Description	Range	Header	Description	Range
cross-section	W [cm]	Level	0..2000	A [m²]	Cross-section	0..∞

Sample File

Constant *k*-Factor

k-factors are chosen to reflect characteristics of the chosen monitoring site. In hydrology, *k*-factors are essential for understanding the impact of stream conditions on flow.

Various studies suggest *k*-factors based on empirical data. For example, one approach for natural streams is to use a factor of *0.87*, while for engineered channels, it might be around *0.95*. It's essential to refer to specific hydrological studies or guidelines relevant to the geographical area and stream type for precise values.

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Page 4 / 7

Dynamic k-factor an V Index

Both methods rely on externally calculated values organized in tables. These tables can be imported and exported.

- **Dynamic k-factor**: relies on applying imported k-factors for improved accuracy. The k-factors have been calculated using a power law. The method is more accurate but requires more effort in providing solid input data for the power law model. Refer to "**Dynamic k using a Power Law profile**" for details.

- **V Index**: relies on k-factors calculated using statistical methods modelling the relationship between measured surface velocities and the mean velocity of a cross-section. The method is moderate complex and achieves good accuracy. Refer to "**Index Velocity Method**" for details.

HyComm interpolates the values and stores a value for each level step (cm or in) or velocity step (mm/s or in/s).

Table structure

Table 2 – Dynamic k-factor Table

Table	Column 1			Column 2		
	Header	**Description**	**Range**	**Header**	**Description**	**Range**
k-factor	W [cm]	Level	0..2000	k-factor	k-factor	0..1.0

Table 3 – V-Index Table

Table	Column 1			Column 2		
	Header	**Description**	**Range**	**Header**	**Description**	**Range**
v-index	v [m/s]	Surface velocity	0..15	v [m/s]	Mean velocity	0..∞

CAUTION: v-index table needs to start with *v_surface = 0*

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Page 5 / 7

Sample Table

k-factor:

	A	B	C
1	W [cm]	k-factor	
2	0	0,9	
3	100	0,95	
4			
5			

V-Index:

	A	B	C
1	v [m/s]	v [m/s]	
2	0	0	
3	0,5	0,45	
4			
5			

File structure

The best way to create a table is in Microsoft EXCEL®. Note that for all tables, only the first two columns are used. Additional columns will be ignored when the tables are imported.

- Create a table that follows the table structure information defined above
- The table and data values are typically exported from a cross section or rating curve editor or the corresponding module of your hydrological data management software. KISTERS software solutions WISKI, HYDSTRA and SKED all provide the required functionality.
- Ensure that the table structure, including headers, follows the specifications in the table structure definitions above. Additional formatting requirements:
  - o The decimal separator can be either ',' or '.'.
  - o A thousand separator is not allowed.
  - o Ensure that the table values are put in an ascending order from the first column.
- Save the data in a CSV UTF-8 file (Comma Separated Values) file:
  1. Select the "Save As" option in EXCEL.
  2. Check the file type settings in "Save file as".
  3. Select the file type: CSV UTF-8 (with delimiter) and specify ';' as a column delimiter.

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Page 6 / 7
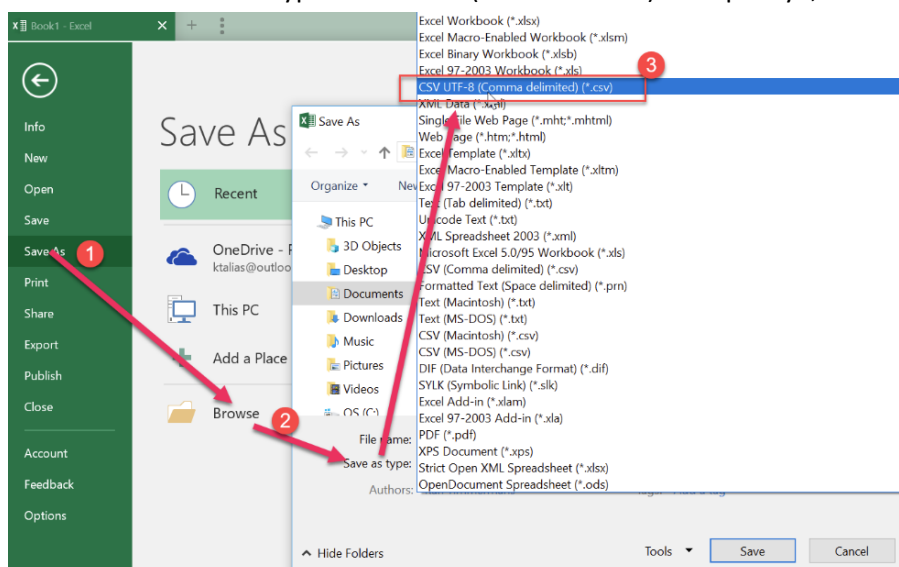
Conclusion

In summary, the KISTERS HyQuant Q radar sensor offers a comprehensive solution for accurately calculating the discharge (Q) of a stream by integrating both level and surface velocity measurements with advanced discharge calculation methods. Utilizing the cross-section profile of a stream is crucial for transforming surface velocities into mean velocities and ensuring precise discharge calculations.

The cross-section must be determined for all Q calculation methods, requiring detailed measurement of the stream's depth and width variations. The HyQuant Q model provides flexibility with three distinct methods for discharge calculation: the constant k-factor method, the dynamic k-factor using a power law profile, and the index velocity method. Each method offers unique advantages and suits different stream conditions.

It is important to note that k-factors must be calculated or modelled separately, as the HyComm software is only used to import this data and upload it to the HyQuant Q sensor. Similarly, HyComm does not provide functionality to actively manage cross-section data; it can only import and export tables defining the relationship between water level and cross-sectional area.

The HyComm software enhances the functionality of the HyQuant Q sensor, enabling users to configure the sensor, enter k-factors, and upload cross-section data efficiently. By leveraging the HyQuant Q sensor and HyComm software, hydrologists can perform accurate hydrological assessments with ease, making the HyQuant Q a vital tool in modern water monitoring and management.

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Page 7 / 7