BedloadWeb

https://en.bedloadweb.com/

User Manuel

CONTENTS

LEXIQUE

A: Wetted section area [m2]

d or H : flow depth [m]

D: Sediment diameter [m]

D_{50}: Median diamètre [m]

D_x: Grain diamètre (indice means % finer than x)

Fr: Froude number Fr=U/sqr(gH)

ω: flow power ω=τU

Φ: Dimensionless transport, Φ=qsv/sqrt(g*(s-1)*D^3)

Ψ: Geometric grain diameter, Ψ=LogD/Log2, D=2^Ψ

Q: Discharget [m3/s]

q: débit unitaire (q=Q/W) [m3/s/m]

Qs: Solid discharge [kg/s]

Qsv: Volumetric solid discharge [m3/s]

Qsapp: Apparent solid discharge, Qsapp=ρ/ρapp*Qs

qs: Unit solid discharge (qs=Qs/W) [kg/s/m]

qsv: Volumetric unit solid discharge (qs=Qsv/W) [m3/s/m]

R: Hydraulics radius [m]

Re: Reynolds number Re=UR/v

ρ: water density (kg/m3)

$ρ_s$: sediment density (kg/m3)

s: density ratio s=ρs/ρ

S: Slope [m/m]

τ: Shear stress (N/m2)

τ_c: Critical shear stress (N/m2)

τ^*: Shields number [ ]; $\tau^*=\tau/(g(\rho s-\rho)D)$ <=> $\tau^*=RS/((s-1)D)$

τ_c^*: Critical Shields number [ ]; $\tau_c^*=\tau_c/(g(\rho_s-\rho)D)$

U: Men velocity [m/s]

u*: shear velocity, u*=sqrt(τ/ρ)

W: bed width [m]

z: bed level [m]

1 ABSTRACT

This document presents the BedloadWeb program. Proposed for a wide audience (from non-specialists to confirmed scientists in sediment transport), the program has been designed to be as intuitive as possible. It could therefore be used (a priori) without a manual.

The program has two components:

- a database: it provides more than 11,000 data from the field or laboratory. These data can be downloaded. This tool also allows playing with the transport equations, to test their sensitivity to the different parameters.

- A toolbox component: this part of the program provides a series of tools to carry out a complete solid transport study, from granulometric measurement to the establishment of a sediment budget.

2 INTRODUCTION

Bedload transport is an essential contributor to the morphological evolution of rivers, and remains poorly known because the phenomena involved are complex and difficult to observe and measurable, this phenomenon occurring during flooding and at the bottom of the bed.

To overcome the difficulty of measuring, there have been numerous attempts to develop formulas for computing bedload transport in rivers. The problem is that today dozens of formulations are available for practitioners, whose condition of use sometimes remains unclear, and sometimes producing results far apart from each other. As a consequence, to the natural complexity of the phenomenon, was added a "conceptual" complexity related to the difficulty to choose between these different tools.

Developers and technicians in charge of rivers management are therefore often poor when facing bedload transport problems or more generally questions related to the river morphodynamics. To overcome this situation, we propose with BedloadWeb a pedagogical platform, but also a real tool for technicians and managers, allowing:

- "Database" tab: to manipulate data and test equations, including sensitivity to the different parameters. An important dataset (more than 1100 measurements collected in more than 130 streams) as well as a dozen equations are proposed.

- "Toolbox" tab: to build a sediment transport project. The interface allows you to define all the parameters of the calculation, including the geometry of the section, the grain size, the hydraulics and the solid transport

From a technical point of view, BedloadWeb was written in R-Shiny. It supports all browsers but iexplore. The data uploaded as text files must be in UTF8 format.

3 DATA BASE

3.1 Data

The current dataset includes 11,484 values (10,167 values from the field and collected from more than 100 rivers around the world, and 1317 values from the laboratory). It consists only of data published in the literature (official reports, articles) and having reached consensus. Unpublished confidential data (personal data) that do not give access to a critique of their measurement condition are not considered.

Any addition of new data respecting the above criteria is possible on request to the site manager.

The parameters entered in the different columns are:

N °: Mark the line in the global database

River: Name of the river or lab experiment

ID: Mark the line inside the selection

Date: date of measurement

Width: Flow width (in m)

Slope: Bed slope (in m / m)

Q: flow rate (in m3 / s)

U: Section averaged velocity (m / s)

H (or d): mean flow depth (m)

R: Hydraulic radius

D_{16}, D_{50}, D_{84}, D_{90}: the characteristic diameters (mm)

qs: transport rate per meter width (g / s / m)

Morphology: morphology of the section

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Nø	River	ID	Date	Largeur (m):	Pente (m/m):	Q(m3/s)	U(m/s)	H(m)	R(m)	D16(mm)	D50(mm)	D84(mm)	D90(mm)	qs(g/s/m)	Morphologie
2	41	Big wood	1	19/05/1999	12.76	0.0091	9.6	1.38	0.55	0.5	0.028	0.116	0.25	0.38	0.768	Plane Bed
3	42	Big wood	2	19/05/1999	12.76	0.0091	9.6	1.38	0.55	0.5	0.028	0.116	0.25	0.38	4.22	Plane Bed
4	43	Big wood	3	20/05/1999	12.76	0.0091	10.76	1.44	0.58	0.54	0.028	0.116	0.25	0.38	2.31	Plane Bed
5	44	Big wood	4	20/05/1999	12.76	0.0091	10.87	1.45	0.59	0.54	0.028	0.116	0.25	0.38	5.97	Plane Bed
6	45	Big wood	5	21/05/1999	12.77	0.0091	12.97	1.56	0.65	0.59	0.028	0.116	0.25	0.38	9.91	Plane Bed

Data is not always documented for all fields, but each data line comprises at least:

- Hydraulic: 1 flow or 1 water level
- Sediments: the D_{50} (when D_{84} is missing it is approximated by 2.1 * D50)
- Slope
- Transport rate

All these quantities are averaged over the wetted section.

The width is almost always indicated, except for some streams (wide rivers: Nile, Rhine) where the width is absent because the measurements correspond to local (on the vertical) and not cross averaged values.

For almost the entire dataset (with the exception of some streams such as Oak Creek), the hydraulic radius was not measured but calculated considering a rectangular section with the formulation:

$$R = \frac{dW}{2d + W} \tag{1}$$

The morphologies indicated are: braiding (braids), step-pool (stepped mountain morphology), plane bed, riffle-pool, sand bed, and channel for the laboratory. They are given as an indication.

3.2 Option « Select a river »

| Welcome | Data base | Tools box | Help |

| Select a river 🖼 | Multicriteria selection 🗐 |
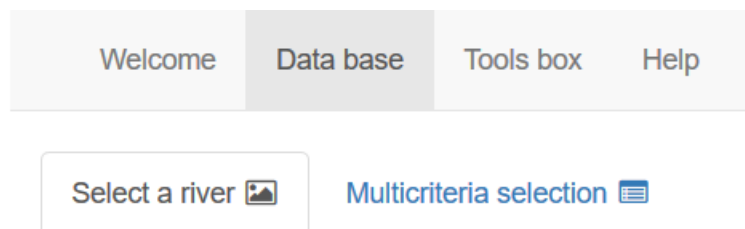
3.2.1 Goal of this tab

The Select River page displays only one dataset at a time.

It should be preferred when looking for a specific dataset, or for pedagogical purposes to test the equations and their sensitivity to different parameters.

It is advisable for beginners to start with this tab to get used of the tool and become familiar with the various features (the rest of the site is built according to the same principles).

3.2.2 Data selection
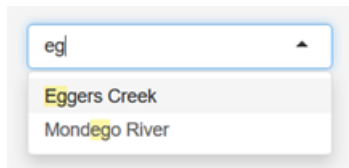
The Laboratory / Field button distinguishes the data from the laboratory with data from the field
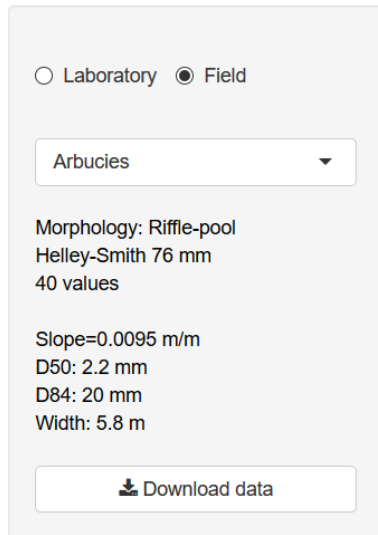
The drop-down tab allows you to choose the dataset.
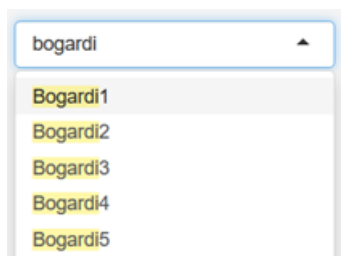
The text recalls metadata for the selected dataset

The button "export" allows as the name suggests to save the data on computer in text format.

To access a given dataset, you can write the beginning of the name directly in the drop-down tab.

The field data is unambiguous because each data set usually has a unique stream name. For laboratory data, the name used is that of the author who originated the data. However each laboratory data set had to be cut into homogeneous groups of slope and material diameter, which explains why for the same author the page will display several datasets.

Each laboratory data set was divided into homogeneous groups of slope and material diameters, otherwise it would have been impossible to graphically represent the models by a single Qs (Q) curves.

The exported data is saved in text form:

Big wood - Bloc-notes   —

Fichier Edition Format Affichage ?

```
"Nø"    "River"  "ID"    "Date"   "Largeur (m):"  "Pente (m/m):"  "Q(m3/s)"        "U(m/s)"        "H(m)"   "R(m)"   "D1(
.07     2.09     1.01    0.87     0.028    0.116   0.25     0.38     84       "Plane Bed"50   "Big wood"       "10"     "27.
76      0.0091   21.66   1.91     0.89     0.78    0.028    0.116    0.25     0.38     9.4      "Plane Bed"60   "Big wood"
d"      "29"     "08/06/1999"     12.76    0.0091  17.39    1.75     0.78     0.69     0.028    0.116    0.25     0.38     15.
ne Bed"79        "Big wood"       "39"     "17/06/1999"     12.76    0.0091  30.87    2.21     1.1      0.94     0.028    0.1
0.38    24.3     "Plane Bed"89    "Big wood"       "49"     "22/06/1999"     12.76    0.0091  22.03    1.93     0.9      0.7
57      0.028    0.116    0.25    0.38     1.87     "Plane Bed"99   "Big wood"       "59"     "31/05/2000"     12.76    0.0
0"      12.76    0.0091  11.41    1.48     0.61     0.55     0.028    0.116    0.25     0.38     1.3      "Plane Bed"109  "Bi;
"118    "Big wood"       "78"     "10/06/2000"     12.76    0.0091  10.36    1.42     0.57     0.52     0.028    0.116    0.2
0.38    1.58     "Plane Bed"128   "Big wood"       "88"     "14/06/2000"     12.76    0.0091  8.16     1.29     0.5      0.4
42      0.39     0.028    0.116    0.25    0.38     0.21     "Plane Bed"138   "Big wood"       "98"     "21/06/2000"     12.
```

The file can be opened and manipulate with Excel.

Assistant Importation de texte - Étape 2 sur 3   ?   ✕

Cette étape vous permet de choisir les séparateurs contenus dans vos données. Vous pouvez voir les changements sur votre texte dans l'aperçu ci-dessous.

Séparateurs

☑ Tabulation
☐ Point-virgule   ☐ Interpréter des séparateurs identiques consécutifs comme uniques
☐ Virgule
☐ Espace   Identificateur de texte : ["] [▾]
☐ Autre : [   ]

Aperçu de données

```
Nø    River     ID    Date         Largeur  (m):  Pente  (m/m):  Q(m3/s)  U(m/s)  H(m)   R(m)   D16(mm)  D50(mm)  D84(m ▲
41    Big wood  1     19/05/1999   12.76          0.0091         9.6      1.38    0.55   0.5    0.028    0.116    0.25
42    Big wood  2     19/05/1999   12.76          0.0091         9.6      1.38    0.55   0.5    0.028    0.116    0.25
43    Big wood  3     20/05/1999   12.76          0.0091         10.76    1.44    0.58   0.54   0.028    0.116    0.25
44    Big wood  4     20/05/1999   12.76          0.0091         10.87    1.45    0.59   0.54   0.028    0.116    0.25
45    Big wood  5     21/05/1999   12.77          0.0091         12.97    1.56    0.65   0.59   0.028    0.116    0.25 ▼
```

[Annuler]   [< Précédent]   [Suivant >]   [Terminer]

3.2.3 Display

Each time a stream is selected, an automatic update of the display is performed and the corresponding data is displayed graphically:
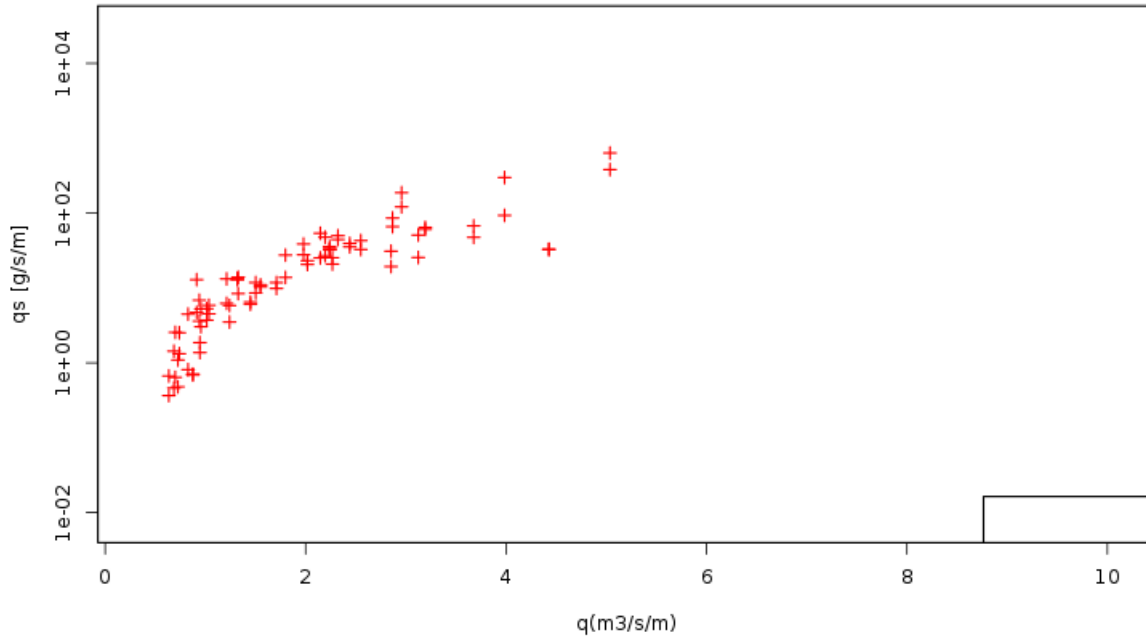
Plot options:

☑ Display legend

☐ X log

☑ Y log

Stretch X axes

Stretch Y axes

Plot X with:

⦿ q ◯ H ◯ τ ◯ τ* ◯ τ*/τ*c ◯ ω

Plot with τ*c=

*Default T*c=T*c(S)=0.032*

Plot Y with:

⦿ qs ◯ Φ

Percentile i for Di=

Default τ(D50) , Φ(D50)*

The user will note that whatever the data set, data never align on a single curve, but rather show a wide variability (in general within an envelope covering almost 2 orders of magnitude). This variability is often explained by measurement errors. Of course these errors (or inaccuracies) exist. But the variability results largely from natural fluctuations in the bedload process, related to the variability of the flow environment (turbulence, slope, granulometry) and to granular processes (grain sorting).

The panel below the figure changes the display options. The Xlog and Ylog, as well as the sliders "Stretch the axes" allow to improve the visibility for certain values too weak or too strong compared to the cloud of points

Plot X with: Plot Y with:

◉ q   ○ H   ○ τ   ○ τ*   ○ τ*/τ*c   ○ ω   ◉ qs   ○ Φ

The "Show in X" and "Show in Y" options allow you to choose the magnitudes to display on both axes. By default the display shows q (m3 / s / m) in X and qs (g / s / m) in Y.

T (N / m²) denotes the bed shear stress:

$$\tau = \rho g R S \tag{2}$$

T * is the bed shear stress made dimensionless with the grain diameter D (or Shields number):

$$\tau^* = \frac{\tau}{g(\rho_s - \rho)D} \tag{3}$$

By default the values are calculated with the median diameter D_{50}.

T * / T_c * is a ratio between the dimensionless shear stress and the critical Shields stress T_c * corresponding to the beginning of movement. ω (Watt / m²) is the specific power of the flow

$$\omega = \tau U \tag{4}$$

In Y, the transport rate qs (g / s / m) can also be displayed with the Einstein parameter Φ, which is a the transport rate made dimensionless with the grain diameter D:

$$\Phi = \frac{q_s}{\rho_s\sqrt{g(s-1)D^3}} \tag{5}$$

There is no consensus in the scientific community on the appropriate values for Tc *, and a wide variety of values between 0.03 and 0.06 have been proposed in the literature. By default, this number is recalculated here with a slope function [*Recking et al.*, 2008]:

$$\tau_c^* = 0.15 S^{0.275} \tag{6}$$

But the user has the possibility to change this value:

Plot with τ*c=   Percentile i for Di=

*Default T*c=T*c(S)=0.032*   *Default τ*(D50) , Φ(D50)*

Similar options exist for the reference diameter. For example, entering Di = 84 will imply that the Shields and Einstein numbers will be calculated with the D_{84} instead of D_{50}.

3.2.4 Test the equations

The page offers the possibility to display the transport equations with the data.

Choose equations

Bagnold
Camenen-Larson
Einstein-Brown
Engelund
Meyer-Peter Muller
Parker79
Parker90

To display an equation, just click on the "Choose Equations" window. The equations will be displayed in a drop-down menu and you just have to make a choice by clicking on the equation to display. To remove an equation from the figure, simply select its name and press the "Delete" key or « ← »

When the equation selection panel is changed, the figure is updated automatically.
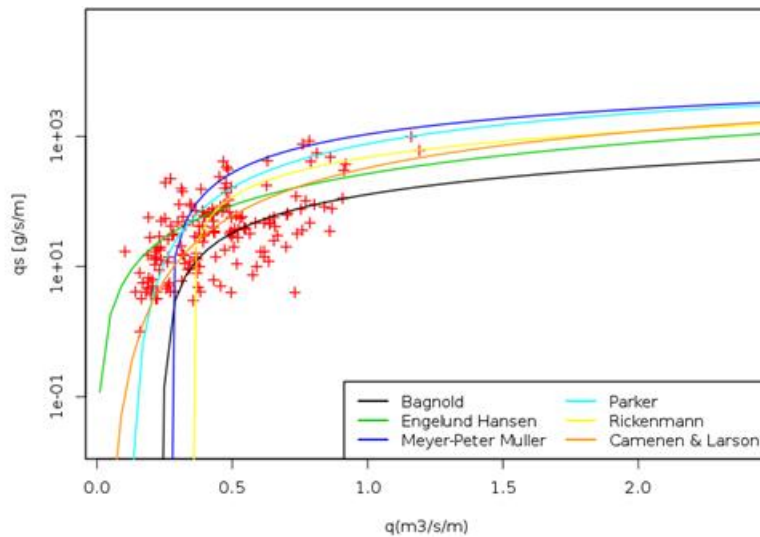
Bagnold Camenen-Larson Engelund
Meyer-Peter Muller Parker79
Rickenmann

This representation mode makes it possible to have an overview of the behavior of the models displayed as Qs(Q) curves; the disadvantage is that it required calculations are made for constant values of width, diameter and slope. This is usually the case for most datasets, but not all: in some datasets width, diameter, and slope values change for each qs value. A specific calculation is then needed, line by line (which is possible with the "Multicriteria Selection" tab).

Several options are available for calculation:

Calculation option   Help Equations

Compute with : ◉ Q   ○ H

☐ Correct the shear stress

☑ Correct wall effects in glass wall canal

☐ Suppress the sand fraction for calculation with Parker 90

The calculation can be done with the discharge Q or the water depth H.

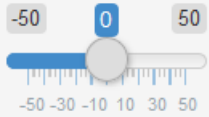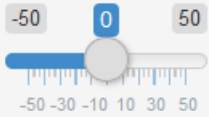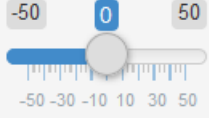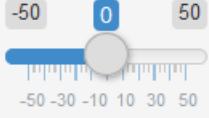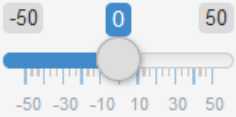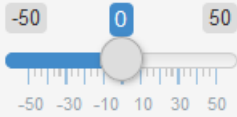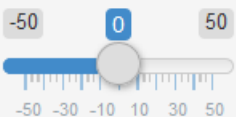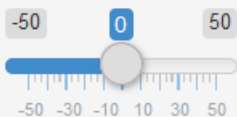The shear stress can be corrected to account for the bedforms roughness.

The correction of wall effects corrects friction against smooth glass walls that impact average velocities in flumes.

The Parker 90 equation is supposed to be used with particle size excluding sand.

When the calculations are made with discharge Q, the friction law of Ferguson [2007] is used to calculate the low parameters and the stress τ (Eq.2). This law was chosen because tests on large datasets [*Rickenmann and Recking*, 2011] have shown that it gives satisfactory results regardless of the morphology, and in particular for steep mountain streams with small relative depths.

Finally, users have the possibility to test the sensitivity of the equations to the different input parameters by moving the sliders of the "Test sensitivity to" panel. This tool has mainly an educational purpose, and makes the user aware of the equations sensitivity to input parameters.

Each slider can be moved between -50% and + 50% of the initial value.

For example + 30% applied to the slope parameter means that the slope associated with the dataset will be multiplied by a coefficient 1.3.

The parameter "Hydraulic" will be either discharge or flow depth depending on the chosen calculation option.

The "Threshold" parameter can be, depending on the equations, a critical shear stress or a critical discharge.

The parameters ρ and ρs are respectively the density of water (default 1000 kg / m3) and sediments (default 2650 kg / m3)

3.2.5 Bedload grain size distribution

The second part of the page "select a river" is devoted to the grain size transported

Grain size distribution (Arbucies)

Surface grain size distribution

% finer	Measured	Model
D5	NA	NA
D10	NA	NA
D16	0.42	NA
D25	0.58	NA
D50	2.40	2.20
D75	11.85	13.53
D84	21.38	20.00
D90	32.35	26.00
D95	73.60	41.00
D100	NA	100.00

⬇ Download

The model reconstructs a grain size distribution from the D50; it is used when the measured GSD is not available

Note: small differences may exist between the D50 and D84 extracted from the granulometric curves and those provided in the database

Bedload Gain Size Distribution

% finer	Bed	W&C	Parker	GTM
D5	NA	NA	NA	NA
D10	NA	NA	NA	NA
D16	NA	NA	0.35	0.37
D25	NA	0.42	0.52	0.53
D50	NA	0.99	1.55	1.60
D75	NA	2.77	7.45	6.42
D84	NA	4.01	13.71	12.04
D90	NA	5.61	21.32	15.78
D95	NA	11.73	30.06	24.20
D100	NA	73.60	73.60	30.70

⬇ Download

Note: Parker90 used here with sand fraction of the granulometric curve

Bedload grain size distribution ☑ Wilcock and Crowe ☑ Parker ☑ GTM

Discharge q (m3/s/m):

H= 0.13 m, R= 0.12 m, U= 0.81 m/s
T*/Tc*(pour D84)= 1.35 L/H= 45.14

options GTM ?

The left panel recalls the bed grain size distribution. This curve is used by some transport equations. When absent, it is modeled from the D_{50} [*Recking*, 2013].

Surface grain size distribution

% finer	Measured	Model
D5	NA	NA
D10	NA	NA
D16	0.42	NA
D25	0.58	NA
D50	2.40	2.20
D75	11.85	13.53
D84	21.38	20.00
D90	32.35	26.00
D95	73.60	41.00
D100	NA	100.00

The "measured" column provides information on the data as available in the original document.

The "model" column gives the modeled grain size curve. This model uses a similarity with a large database to reconstruct a realistic curve from the D_{50}.

The right panel gives the transported particle size calculated according to different methods.

Bedload Gain Size Distribution

% finer	Bed	W&C	Parker	GTM
D5	NA	NA	NA	NA
D10	NA	NA	NA	NA
D16	NA	NA	0.35	0.37
D25	NA	0.42	0.52	0.53
D50	NA	0.99	1.55	1.60
D75	NA	2.77	7.45	6.42
D84	NA	4.01	13.71	12.04
D90	NA	5.61	21.32	15.78
D95	NA	11.73	30.06	24.20
D100	NA	73.60	73.60	30.70

WC (Wilcock and Crowe) and Parker use the results of the solid transport calculation performed for each grain class to reconstruct a grain size curve.
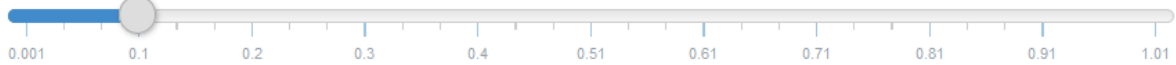
GTM is a model that extends the concept of beginning of transport to the whole grain size distribution present on the bed surface [*Recking*, 2016].

By moving the cursor, one can observe the impact of the flow on the transported curve. Again, this tool mainly has an educational purpose.

The "GTM Options" button gives the user the ability to calibrate the GTM model parameters. For more information the reader is invited to consult the appendices dedicated to the calculations.
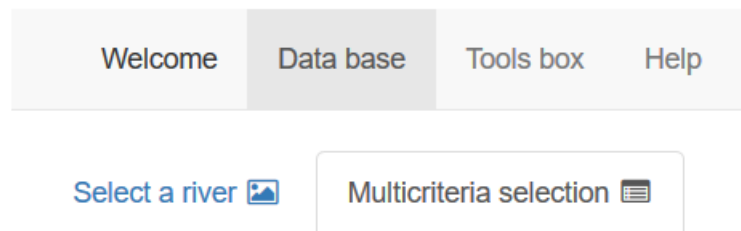
3.2.6   References

Finally, this page also displays all references related to the selection. Users are strongly encouraged to recall the associated references each time they use data from the website.
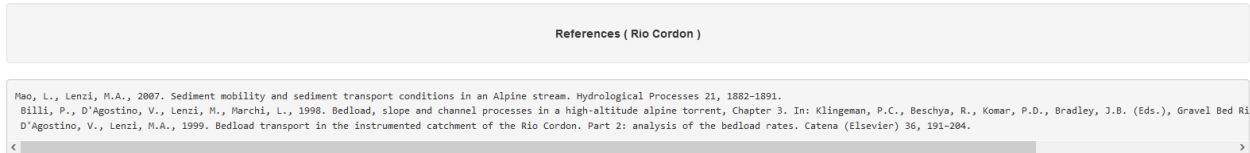
3.3 Option « Multicriteria selection »

| Welcome | Data base | Tools box | Help |

Select a river 🖼   Multicriteria selection ▤

3.3.1   Goal of this tab

Unlike the previous tab, this tab allows to select multiple streams that meet specific user-defined criteria.

Beyond the pedagogical aspect, this tool can be used for example as part of a study, to search bedload data on rivers with similar characteristics to the studied river.
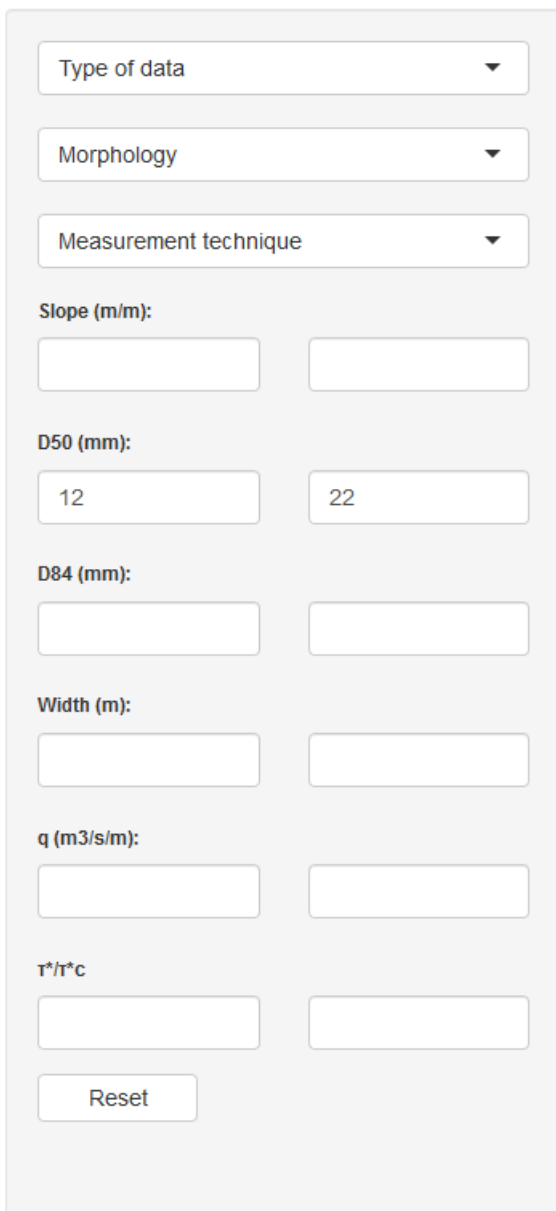
3.3.2   Data selection

The left panel of the page allows to select the data with several selection criteria.

The drop-down menus gives access to data by class: Lab / Field, Morphology, Measurement technique (refer to the Measurement manual for a description of the different techniques).

The input boxes associated with the Slope, D_{50}, D_{84}, Width, q, τ^* / τ^*_c parameters correspond to the desired minimum and maximum values.

This selection panel always remains visible and active regardless of the display mode, table or graph, as described below.

| Type of data ▼ |
| Morphology ▼ |
| Measurement technique ▼ |

Use this panel to make a data selection.

The drop-down menus give immediate access to data by class.

Slope (m/m):

D50 (mm):

12	22

The input boxes associated with each parameter are the minimum (left) and maximum (right) values for the search.

D84 (mm):

Width (m):

The criteria entered in this example will display all streams or laboratory data with a D_{50} between 12 and 22 mm.

q (m3/s/m):

τ*/τ*c

[Reset]

The reset button clears the entire entry and displays the complete database

3.3.3 Display

The data selection is displayed in the central table which recalls the name of the selection as well as the associated metadata. Note: You can also search for a stream by entering its name in the "Search" box.

Show [15 ∨] entries   Search: [   ]

|	River	Slope (m/m):	D50(mm)	D84(mm)	Width (m):	Morphology	Technique
10	Buffalo Fork	0.0025	18	52	45	Riffle-pool	Helley-Smith 76 mm
16	Chultinana River below canyon near Talkeetna	0.001	12	52	108	Braiding	Helley-Smith 76 mm
74	North Fork of Caspar Creek	0.013	15	50	4.4	Riffle-pool	Helley-Smith 76 mm
76	Pacific Cr	0.0035	20	45	43	Braiding	Toutle sampler TR2
111	Tanana River at Fairbanks, Alaska	0.0005	13	30	315	Braiding	Helley-Smith 76 mm
113	Tom McDonald Cr	0.006	19.8	58	6.125	Riffle-pool	Helley-Smith 76 mm
117	Torrent de Saint-Pierre	0.025	21	80	100	Braiding	Helley-Smith 150 mm
120	Trap Bay Cr	0.006	20	40	14	Riffle-pool	Helley-Smith 76 mm
122	Turkey Brook	0.00815	22	42	3	Riffle-pool	Pit trap (Birkbeck type)
123	Upper South Fork of Williams Fork near Leal	0.0096	22	56	10.5	Riffle-pool	Helley-Smith 76 mm
124	Urumqui	0.025	20	160	6.4	Braiding	Helley-Smith 150 mm
126	Versilia	0.002	22	50	32	Riffle-pool	Helley-Smith 76 mm
131	Wind river	0.001	14	50	40.9	Riffle-pool	Helley-Smith 76 mm
138	Bogardi5	0.01685	15.2	18.24	0.3	Canal	Laboratoire
177	Graf Suszka1	0.005	12.2	14.64	0.6	Canal	Laboratoire

Showing 1 to 15 of 22 entries   Previous [1] 2 Next

It is still possible to refine the selection by clicking on the lines.

113	Tom McDonald Cr	0.006	19.8	58	6.125	Riffle-pool	Helley-Smith 76 mm
117	Torrent de Saint-Pierre	0.025	21	80	100	Braiding	Helley-Smith 150 mm
120	Trap Bay Cr	0.006	20	40	14	Riffle-pool	Helley-Smith 76 mm
122	Turkey Brook	0.00815	22	42	3	Riffle-pool	Pit trap (Birkbeck type)

The [Table < > Graphe] button gives access to a graphical representation of the selection.
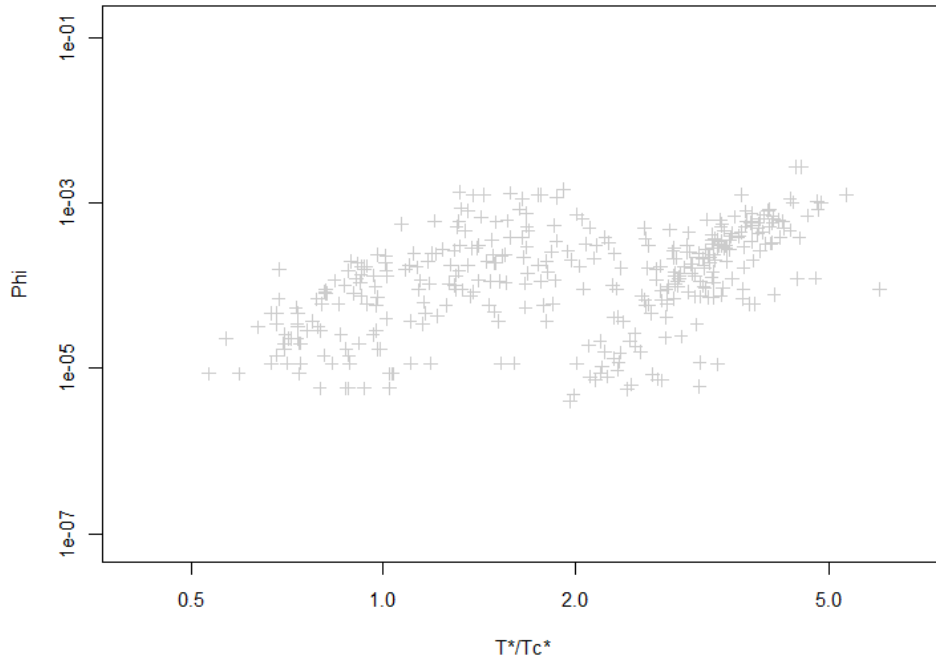
The graphic page offers several display options, as was already the case for the "Select a river" page.

The list of selected rivers is shown below the figure and the small table at the bottom right presents the meta-data of the selection. These values can hide a larve variability.

Selection: Arbucies, Big wood, Black River near Galesville, Blackmare, Blue riv

Variable	Min	Mediane	Max
S (m/m)	2.6e-03	1.56e-02	2.5e-02
D50 (mm)	20	22	22
D84 (mm)	42	42	160
L (m)	3	3	12.6

Data can be displayed according to whether they belong to a given morphology or according to the measurement technique.
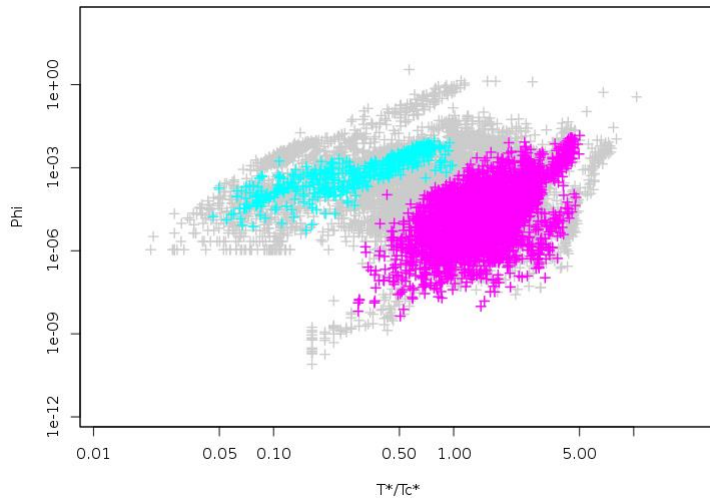
Plot with:

○ Measurement technique ◉ Morphology

Morphology

☑ Morphology ☐ Braiding ☐ Canal ☐ Plane Bed ☐ Riffle-pool
☐ Sand bed ☐ Step-pool
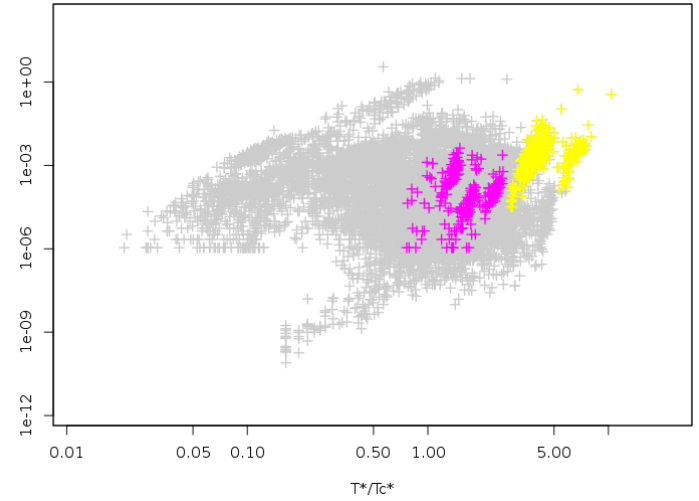
Plot with:

◉ Measurement technique ○ Morphology

Measurement technique

☑ Measurement technique ☐ Laboratoire ☐ Basket Sampler
☐ Elwha sampler ☐ Helley-Smith 150 mm ☐ Helley-Smith 76 mm
☐ Nozzle 99x55mm ☐ Pit trap (Birkbeck type) ☐ Sediment trap
☐ Settling basin ☐ Toutle sampler TR2 ☐ Trap with endless belt ☐ Vortex
☐ VuV Sampler

3.3.4 Test the equations

The second part of the page is dedicated to calculation

Choose equations

> Einstein-Brown Engelund
> Rickenmann

> Start calculation

To use this page you must select the equations to be tested, then click on the "Start calculation" button.

Compute with :

◉ Q ○ H

☐ Correct the shear stress

☑ Correct wall effects in glass wall canal

The calculation options are the same as those shown above for the Select River page.

☐ Suppress the sand fraction for calculation with Parker 90

The calculations take into account only the selected data and equations and the results are shown in the table on the left of the screen.

Equation	E2(%)	E5(%)	E10(%)
Einstein-Brown	61.1	88.1	93.8
Engelund-Hansen	61.9	84.9	91.9
Meyer-Peter & Muller	22.6	77.4	92.8
Schoklitsch	23.8	79.4	95.3

The results are presented as a percentage of values of the Qscal / Qsmes ratios that fall in the intervals:

E2: 0.5 <Qscal / Qsmes <2

E5: 0.2 <Qscal / Qsmes <5

E10: 0.1 <Qscal / Qsmes <10

E2 is an acceptable criterion for laboratory data, as the fluctuations in the measurements are quite moderate. On the other hand, E10 makes sense in the field where almost all datasets show a wide (natural) fluctuation around the median values.

Unlike the previous tab where each selection corresponded to a single river (thus a single D_{50}, a single slope …) the calculation must here be carried out line by line to take into account the wide variety of parameters in the selection. The models can no longer be represented by a single curve, which explains a different graphical display mode showing the computed data versus the measurement.

The following figure presents the results of calculations for sand rivers with the equations of Einstein-Brown, Engelund & Hansen, Meyer-Peter & Muller, Schoklitsch.
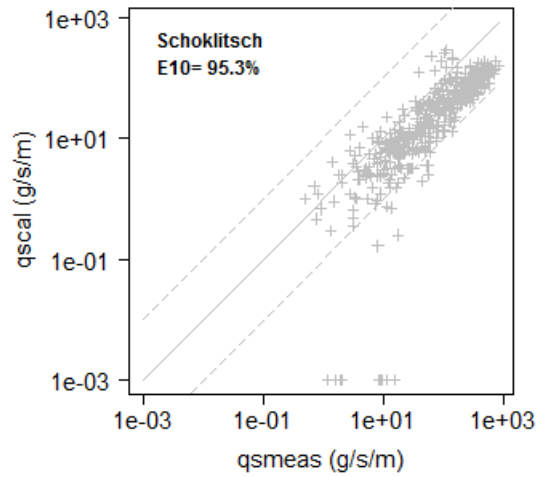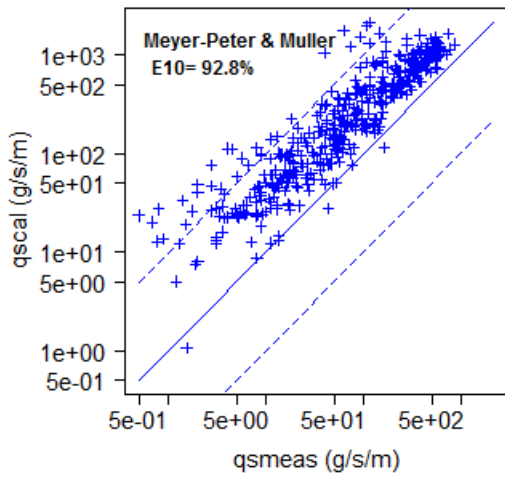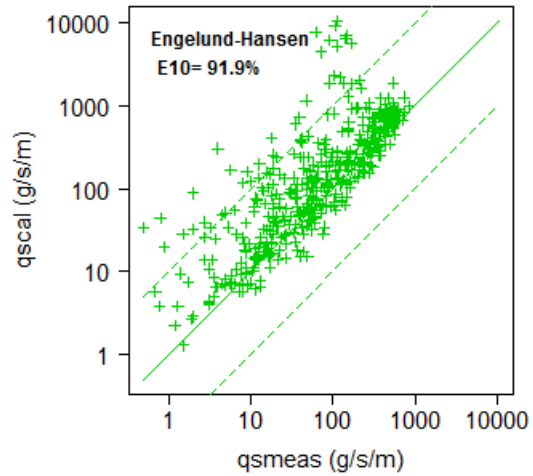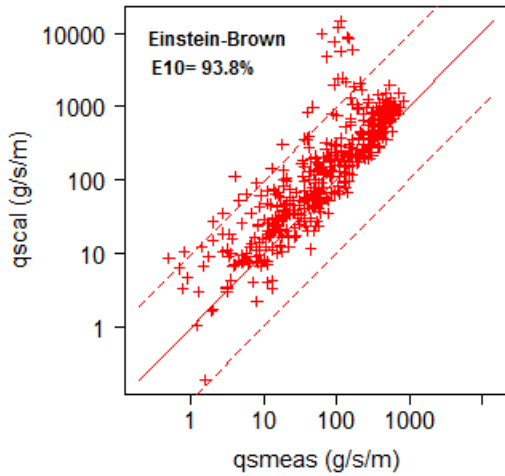
The axes can be adjusted with the slider:

Minimum to display:
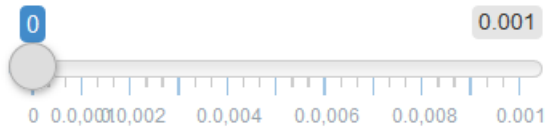
The button [⬇ Exporter les calculs] allows to edit the details of calculations.

When the Wilcock and Crowe or Parker 90 equations are used alone, the file details the fractional calculation (for each size class)

4 TOOLS BOX

This part is composed of a series of tools aiming to accompany the user in the elaboration of a sediment budget study. It comprises several tabs each of which representing an essential step for a serious study. The tabs are presented in a logical sequence, each producing useful input data for the following: (1) the tab 'Granulometry' allows to define the grain size distribution curves (2) the tab 'Section' allows to define (topography) and to dress (roughness ..) the flow section (3) the 'hydraulic' tab is used to calculate the main hydraulic parameters (4) the 'solid transport' tab calculates a bedload-discharge curve Qs(Q) for the granulometry, topography and hydraulics previously defined (5) the tab 'hydrology' allows to define a hydrology, (6) the tab 'Sediment budget' calculates volumes transported for the period considered, and finally (7) the tab 'Analysis' proposes a synthesis of the sediment budget computed for each section.

4.1 Start a project

Before starting a project on BedloadWeb it is recommended to question the objectives. If it's just to test section in order to get a first glimpse of its hydraulics and solid transport response, entering the project does not pose major difficulty.

If the objective is to understand the sedimentary behavior of a watershed, "stations" must be defined, where all the data necessary for the calculations will be collected: granulometry, cross section, slope, catchment area (to adapt the hydrology if necessary).

The following figure illustrates a hydrographic network and the positioning of several study sections where sedimentary budget can be made. The location of these sections is a major factor in the success of a sediment budget study. It is therefore advisable before any calculation, to study the functioning of the watershed, in order to collect the right data in the right places.
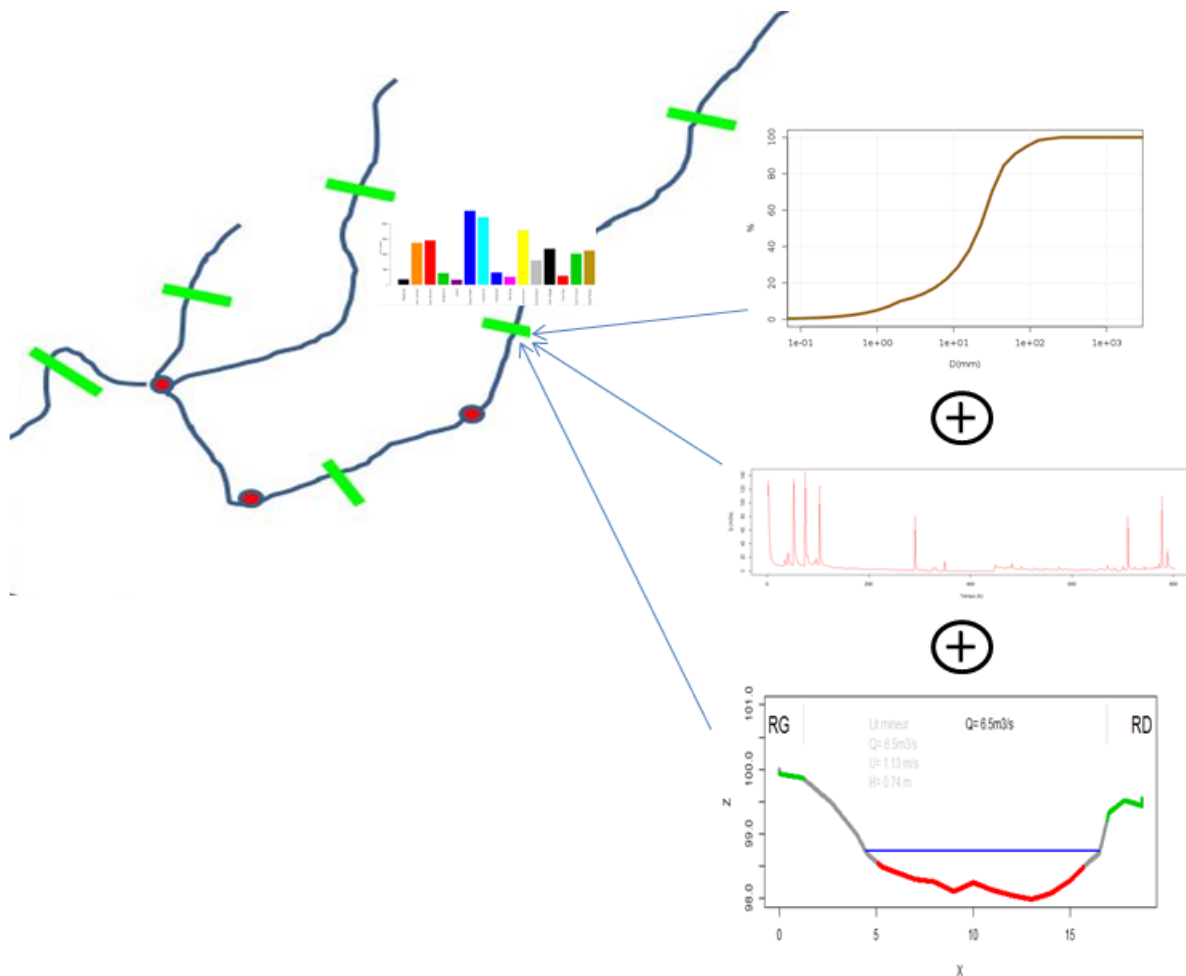
The first thing to keep in mind is that bedload transport equations only make sense if they are used on self-formed geometry: in other words, we will relate the geometry of the bed with the sediments that compose it and the hydraulics that shaped it through solid transport.

When the geometry of the section (width and slope) results from processes external to solid transport (man-made sections for example), where the today transport conditions are no longer those prevailing during the formation of the bed (Gravel transport on mountain block beds for example), relating the bed grain size, the hydrology and the geometry of the section will make sense for hydraulics but not for sediment transport.

Favorable conditions are generally present in the alluvial parts of rivers. For data collection, preference will therefore be given to sections with erodible banks (emergent or not), between which the minor bed has been built: wet threshold zones, alternate banks, etc. Sand beds in general are rather favorable to calculation. .

The most delicate areas are mountain streams where alluvial sections may be rare. It will therefore be necessary to take the time to read the landscape, taking care to distinguish:

- alluvial sections

- the "tubes": zones of effective transfer of the sediments coming from the upstream (traveling bedload) on a stable paved bed, with steep slope, and mobilized only for rare floods [Piton and Recking, 2017];

- the preferential zones of deposit, characterized by a sudden widening and a rupture of slope (as for example during the brutal transitions of morphology: step-pool -> braiding).
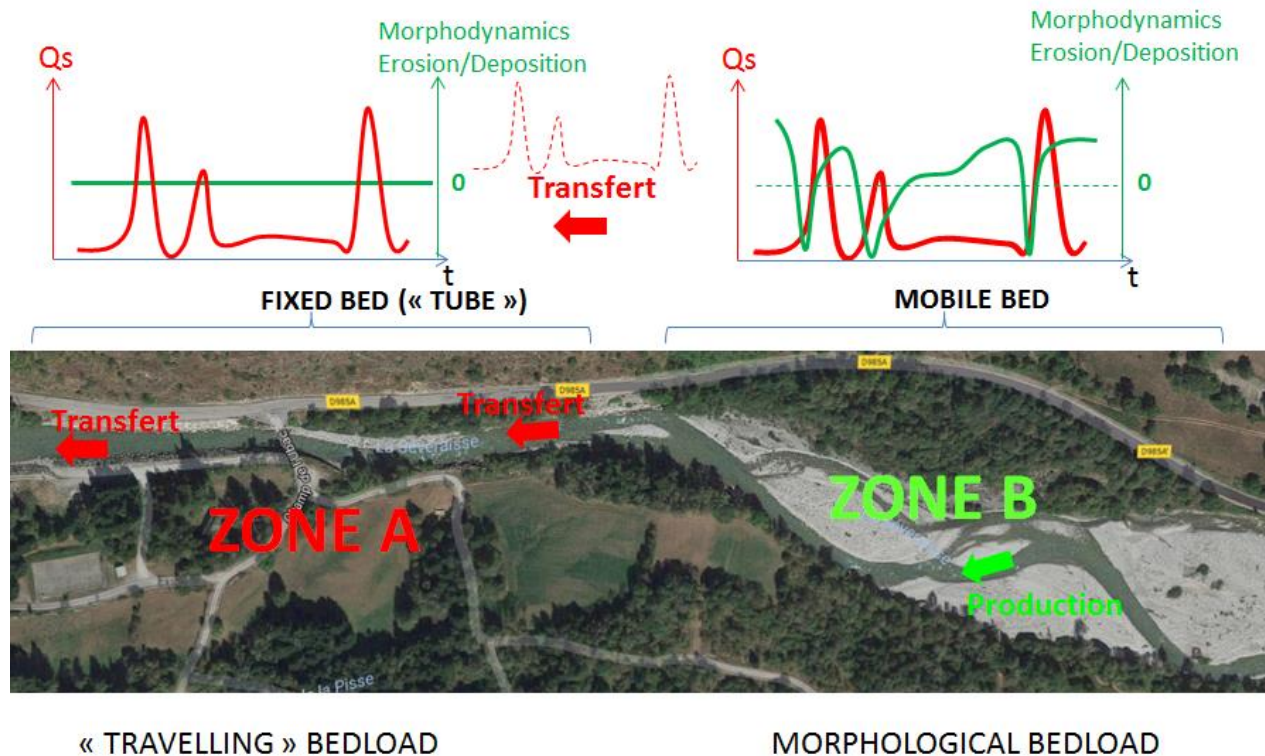
In the above figure, ZONE A is characterized by a paved and stable bed between lateral fixed embankments and is totally not appropriate for bedload computation, even though large quantities of sediments pass through it. However, this transport comes from the morphological changes of ZONE B where bed geometry is a direct result of solid transport: this area is favorable for calculations.

The selection of reaches for data collection should result from this preliminary analysis and will be decisive for the relevance of the calculations.

4.2 Management of profiles and projects

Welcome	Data base	Tools box	Help

Your project	> Granulometry	> Cross section	> Hydraulic	> Sediment transport	> Hydrology	> Sediment budget	> Analysis
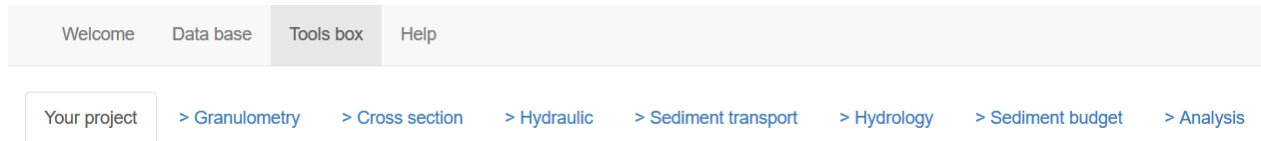
This tab allows to define the project but overall offers backup and sharing options.

A large amount of data can be entered on the site and it is very important to be able to save them. The site offers two backup options.

> Local Backup
>
> Connexion
>
> Reset the entry
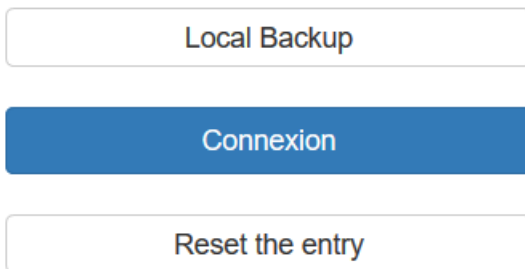
The data entered can be saved locally on your PC in text format.

They can be saved on the server which offers more options and makes sharing easier.

4.2.1 Local Backup

If you have defined small hydrographs they can be saved in a single file with the project. If, on the other hand, you have imported large files (and often one may have to test several hydrographs), it is preferable to save them separately using the proposed option in order not to increase the size of the files. In this case it will be imperative to import the two files (the Project + its hydrograph file) when opening a project. In order to know which option to choose, you can first test a single backup, then try to reimport it: the program will refuse if the file is too big.

This backup option allows data exchange because another user will be able to open your text files. However he will not have access to the photos.

Local Backup

Download saved data **?**

⬇ Download the project

☐ Download hydrographs
separately

IMPORTANT: ENSURE THAT THE
ENCODING OPTION IS UTF8
WHILE BACKING UP THE .TXT
FILE ON YOUR PC

Import a project

Browse... No file selected

☐ Import Hydrographs (if saved in
a different file)

The "Export project" button allows you to save your input on your PC in text format. This backup option does not require creating an account, however photos and text description of the project are not saved.
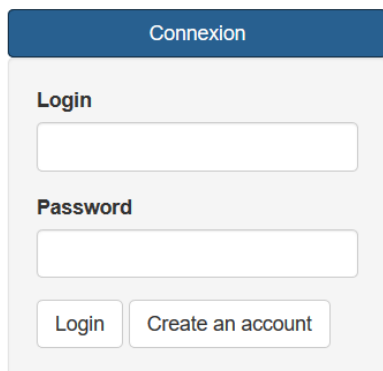
IMPORTANT: All text files must be in UTF8 format otherwise the program will crash when importing a previously saved file.

The "Import Project" button allows you to import a project previously saved in text format.

IMPORTANT: The text file must be in UTF8 format

4.2.2 Create an account
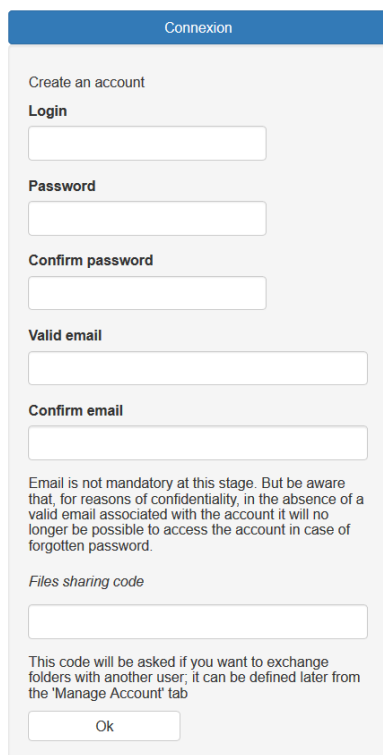
You can save your data entered on the server hosting the website. This option offers more comfort than the previous option because the project is saved in one click, and it can be accessed just as easily. Another important advantage is the ability to save photos.

Connexion

Login

Password

Login   Create an account

To log in, simply enter your username and password and click on the "login" button.

You must have previously created an account.

Connexion

Create an account
Login

Password

Confirm password

Valid email

Confirm email

Email is not mandatory at this stage. But be aware that, for reasons of confidentiality, in the absence of a valid email associated with the account it will no longer be possible to access the account in case of forgotten password.

Files sharing code

This code will be asked if you want to exchange folders with another user; it can be defined later from the 'Manage Account' tab

Ok

To create an account just choose a username and password.

The email is not mandatory but is strongly recommended. Indeed, the data entered on an account are confidential; if you lose your password, the email associated with the account will be used as a signature, allowing the webmaster to forward the forgotten password.

In the absence of email, an account with forgotten password can be considered lost.

The 'code share' is a code different from the login code. It will be used to exchange data with other accounts.

Once logged in, the user's name is displayed and the welcome panel changes to provide access to new options for project and account management.

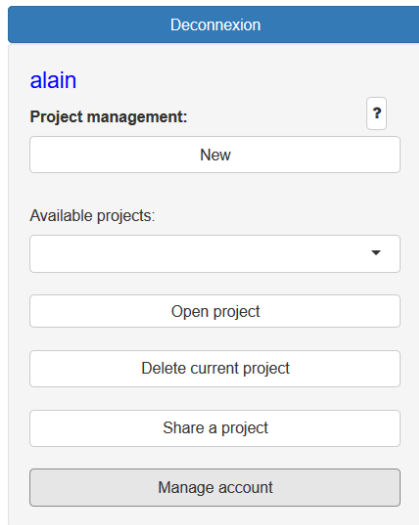The project management options are presented in the following paragraphs.

The "Manage account" button allows you to modify the information entered when creating the account.

For security reasons it is necessary to re-enter your password before accessing the changes.

It is then possible to modify the password, the e-mail address and the sharing code.

This option also gives access to the share code, if it has been forgotten.
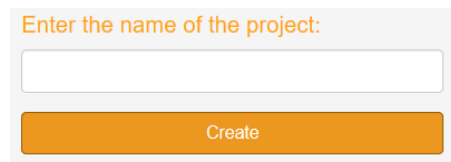
4.2.3 Manage projects

The connection gives access to several project management buttons

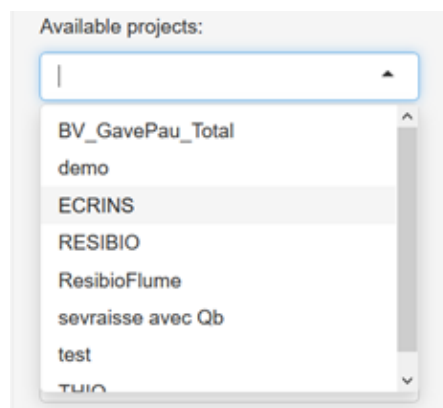'New' allows you to **create** a new project.

'Available Projects' gives access in the drop-down menu to all projects already entered.

'Delete open project' destroys the active project

'Share a project' allows you to interact with other users

When you press the 'New' button, just enter the name of the project and confirm. All data entered will be stored in a directory with the name of the project. You can press this key at any time to save an entry in progress

To **open** an existing project, simply select it from the list and then press the "Open project" button

To **copy** a project, you must open this project (the data are displayed). Then you create a new project, give a name, and save. All data are saved in the new project.

Delete current project

Do you confirm deletion of project 'BV_GavePau_Total' ?

YES	NO

Share a project

You have two options to transfer a project to another user: OPTION1 you export the project locally on your PC and you transfer the resulting text file, which can be open by the other user (warning: this option does not take into account the photos and the text 'project description'). OPTION2, you and your contact have a user account and you can use the function below: for this you need to know its identifier (pay attention to lower / upper case), and its share code (different from its password!)

Project to copy

BV_GavePau_Total ▼

Copy the project under:

BV_GavePau_Total

Enter the recipient:

Enter the sharing code

Share

Reset the entry

The '**delete** open project' button deletes the active project. The deletion is definitive (directory deleted) so a confirmation is requested.

The 'share project' button allows you to transfer one of your projects to another BedloadWeb user. This option can be very useful for example when collaborating remotely on a data collection, or if one needs an external look on a file.

To transfer a project you must:
1) choose the project from the list of available projects.
2) Give a name under which the project must be copied (name that will appear on the hosting account)
3) Enter a share code provided by the other user: it allows you to copy something on his account.
4) Click on the 'share' button: the entire file is copied.

The 'reset entry' button clears all the current entries. If a project is open, it will not be deleted, but completely empty.

When opening an existing project, the page displays the main information related to this project: number of sections, granulometries, hydrographs, sections.

THIO			

You defined 12 sections, 12 grain size distribution and 3 Hydrograph or flow duration curves. Open a section to visualize its content.

Code	Nom de la section	Granulometrie	Hydrologie
SEC1	Thio amont confluences	GSD1	HYD1
SEC2	amont Confluence Neburu	GSD2	HYD1
SEC3	aval confluence Neburu	GSD3	HYD1
SEC4	amont pont St Michel	GSD4	HYD1
SEC5	Pont Saint Michel	GSD5	HYD1
SEC6	Amont confluence Tomuru	GSD6	HYD1
SEC7	Confluence Tomuru	GSD7	HYD1
SEC8	Pont pétroglyphes	GSD8	HYD1
SEC9	confluence creek cimetiere	GSD9	HYD1
SEC10	amont Pont de Thio	GSD10	HYD1
SEC11	Nakale	GSD11	HYD1
SEC12	Neburu	GSD12	HYD1

Project description

Sediment budget of the THIO River

All pages of the site are updated.

4.2.4 Double backup concept

A very important aspect is recalled here.

Each modification in a page (for example an addition, deletion or modification of granulometry, section, hydrograph …) must be saved in the page in question.

The modification will be effective and taken into account by the program as long as the project remains open.

However, in order for this backup to become definitive, it is necessary to return to the management page to save the project by clicking on the 'save' button located under the name of the project.
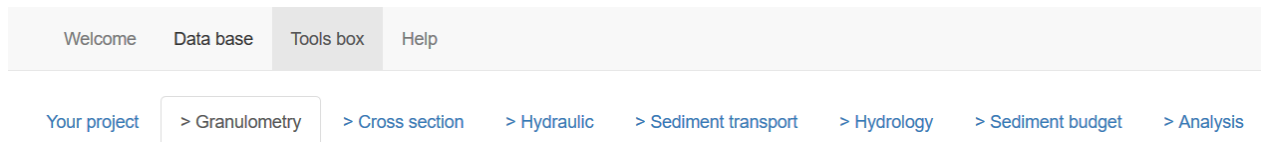
It is therefore advisable to save the project as often as possible!
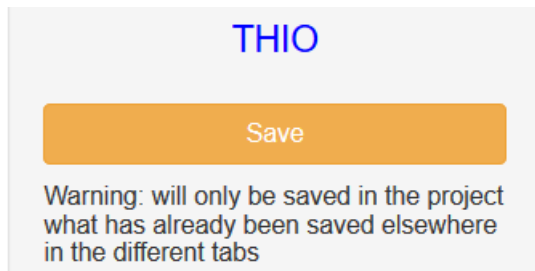
For each new backup in a page, a small label will appear at the bottom of the page to remind you of this requirement.
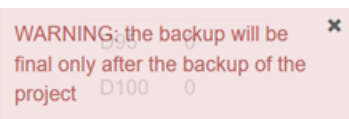
4.3 Granulometry

This tab makes it possible to manage the measured particle sizes, which will be used later for the calculations.

4.3.1 Why and how to define grain size ?

Particle size is essential for both hydraulics and sediment calculation:

- The hydraulics of the main channel is computed for the bed D_{84} deduced from your measurements.

- All transport equations use either the D_{50} or the D_{84} or the entire grain size curve (fractional calculation, ie for each grain class).

The calculations are very sensitive to this parameter, which must therefore be estimated as seriously as possible.

As already mentioned above, the local grain size will always be suitable for hydraulic calculation, whatever the location chosen on the watershed. On the other hand, for solid transport it is imperative that this particle size be measured on a self-formed section, where the sediments present are representative of what is transported by the current hydrological regime.

In general, for a given site, a single grain size will be used for hydraulic calculation and solid transport calculation. Only certain mountain contexts (where sediments produced by upstream sources propagate efficiently on a high energy fixed bed) may lead to a distinction (travelling bedload).

To find out more about sampling techniques and sampling strategy, readers are invited to refer to the guide dedicated to this issue on the BedloadWeb website or to other articles and guides available online [*Wolman*, 1954; *Bunte and Abt*, 2001].

4.3.2   Distinction between Sample and Grain size curve

When accessing this page, you will see that there are two 'Save' buttons.

When studying a river section, it will be necessary to associate a grain size curve to it. This curve will be built from combination of one or several samplings (such as Wolman type [1954]) made on this site.

The **right button** (in red) is the one that will ultimately record your GRAIN SIZE CURVE

The **left button** (in orange) will be used to add new SAMPLES to your grain size curve.

For example, the following figure shows two granulometries GSD1 and GSD2, composed respectively of 3 and 2 Wolman counts (GSD1 is the average of ECH1, ECH2, ECH3 site 1 and GSD2 is the average of ECH1, ECH2 site 2).
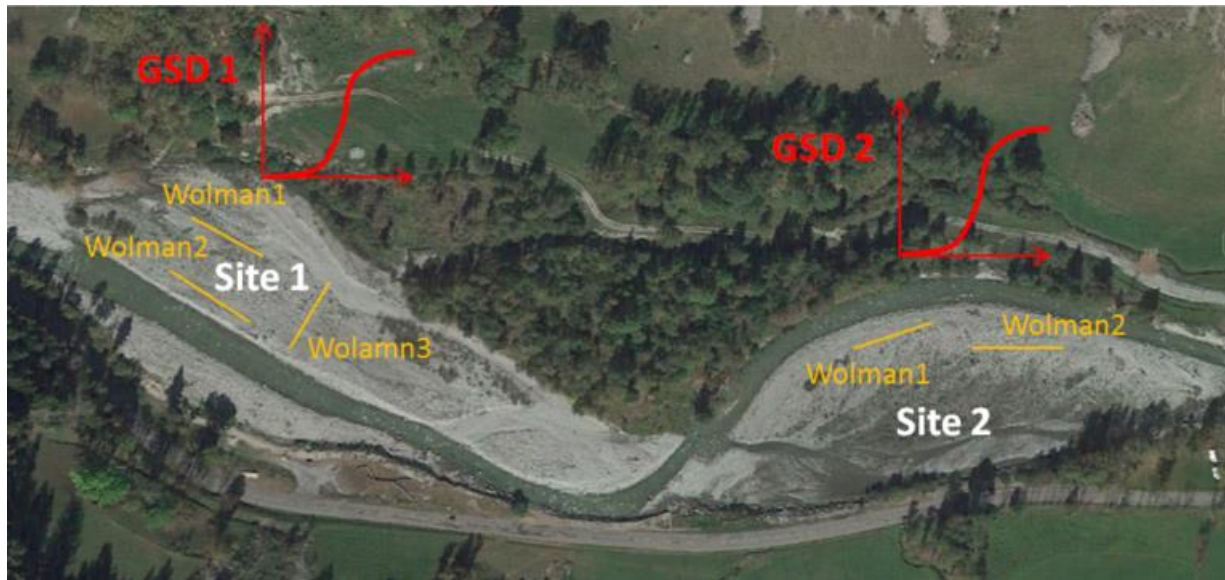
During the first entry, only one 'registered' button is active (red), so there is no ambiguity on which button to activate: the first backup automatically creates a granulometry (called GSD1) and a sample (called ECH1)

However, for the following entries, each grain size backup (red button) will only take into account the samples already saved. If for example you make a modification of the current entry, and you save the grain size curve without saving the sample, the change will not be taken into account.

4.3.3   Enter a grain size curve

As mentioned above, the first backup automatically creates a GSD1 curve and an ECH1 sample.

This sample must be completed, and several options are possible.

The 'Input' option displays a table where the user will be able to manually enter the data (Wolman count or% of a curve, for example). The 'Model' option allows to reconstruct a granulometric curve from the D_{50}.

When the 'input' option is chosen, the user can choose between three input modes: 0.5ψ, ψ and free.

Ψ	D(mm)	Nombre (ou %)
-5.00	0.03	
-4.50	0.04	
-4.00	0.06	
-3.50	0.09	
-3.00	0.13	
-2.50	0.18	
-2.00	0.25	
-1.50	0.35	
-1.00	0.50	
-0.50	0.71	
0.00	1.00	

Ψ	D(mm)	Nombre (ou %)
1	2	
2	4	
3	8	
4	16	
5	32	
6	64	
7	128	
8	256	
9	512	
10	1024	
11	2048	

Ψ	D(mm)	Nombre (ou %)

For memory ψ is :

$$\Psi = \frac{LN(D)}{LN(2)} \tag{7}$$

or :

$$D\ (mm) = 2^{\Psi} \tag{8}$$

These three options give great freedom of entry. For the first two options diameters are already entered. Option 2 (with ψ) proposes the diameters generally used in a Wolman count. The third option is completely free and the user must enter the diameters.

Let's take an example for a first entry. As you type, the curve is displayed and automatically updated. Since this is a first entry and nothing has been saved yet, no name is displayed, and the curve is green. The orange backup button is blocked.

For this first entry we have no choice but to save with the red button.

When saving, the curve turns red (the green is still there but below), and two names appear: GSD1 (in red) and ECH1 (in green).

Only Samples already saved are considered ✖

WARNING: the backup will be final only after the backup of the project ✖

At the time of the backup two small labels remind you to also save the project

The two tables at the bottom left and bottom right are updated. They give the percentiles calculated for the sample (on the left) and for the grain size curve (on the right).

At this point, the save button for samples (orange) is unlocked, and any changes to this entry must be saved with this button.

4.3.4 Add a sample

We will now add a sample to this grain size curve. The first step is to create this new sample with the 'New' button located under the orange button: a new sample ECH2 is created, the input area is erased, and the red curve becomes inconsistent as it considers empty (null) values in its calculation.

This time we will use the model to create the sample. The D_{50} alone is enough to create a curve, but we can also inform the other parameters:

At least the D_{50} must be completed; it must be greater than 2mm (limit sand / Gravel).

If not entered, the D_{84} is equal to 2.1 * D_{50}

By default the program considers that the lower class consists of sands. If this is not the case, the minimum diameter must be entered.

Entering the percentage of sand makes it possible to wedge the lower limit of the curve.

When entering a D_{50} a new green curve appears (the ECH1 is always displayed but in gray). At this stage, the values of the grain size curve are not updated yet.

You must save the entry (orange button) for the update to apply:

At this point, the grain size curve (in red) is the average of the two samples (in green).
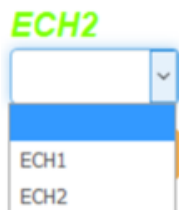
You can redisplay the data for each sample using the drop-down menu.

CAUTION 1: At this point you have not saved your particle size curve (red button), which means that if you create a new granulo the sample ECH2 will be lost. **You still have to click on the red button** (which will turn gray).

CAUTION 2: At this point the GSD1 grain size curve has not been saved in the project yet; for the entry to be final **you must save the project**.

4.3.5 Manage grain size curves
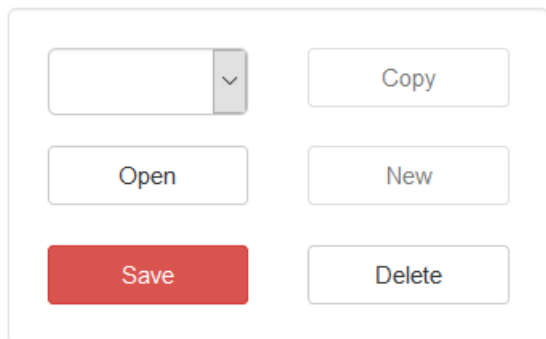
The menu on the right of the screen allows you to manage the grain size curves.

To open a curve, select it and click on "open"

Remember to save the current entry before creating a new curve with the "new" button.

CAUTION: the "Delete" button acts on the active curve and not the one you select from the drop-down menu (ie, you have to open a curve before deleting it).

4.3.6   Name the grain size curve

As you understood, each new sample and each new curve will automatically be assigned a code starting with the letters ECH and GSD, respectively, and incremented more and more.

However, when you have defined many curves, the name GSD15 for example will not be very explicit about the geographic location of sampling. A name such as "Downstream Red Bridge" for example will immediately associate the curve to a place.

This is why, in addition to the coding (necessary for the manipulation of the data in the program), it is advisable to name the curve:
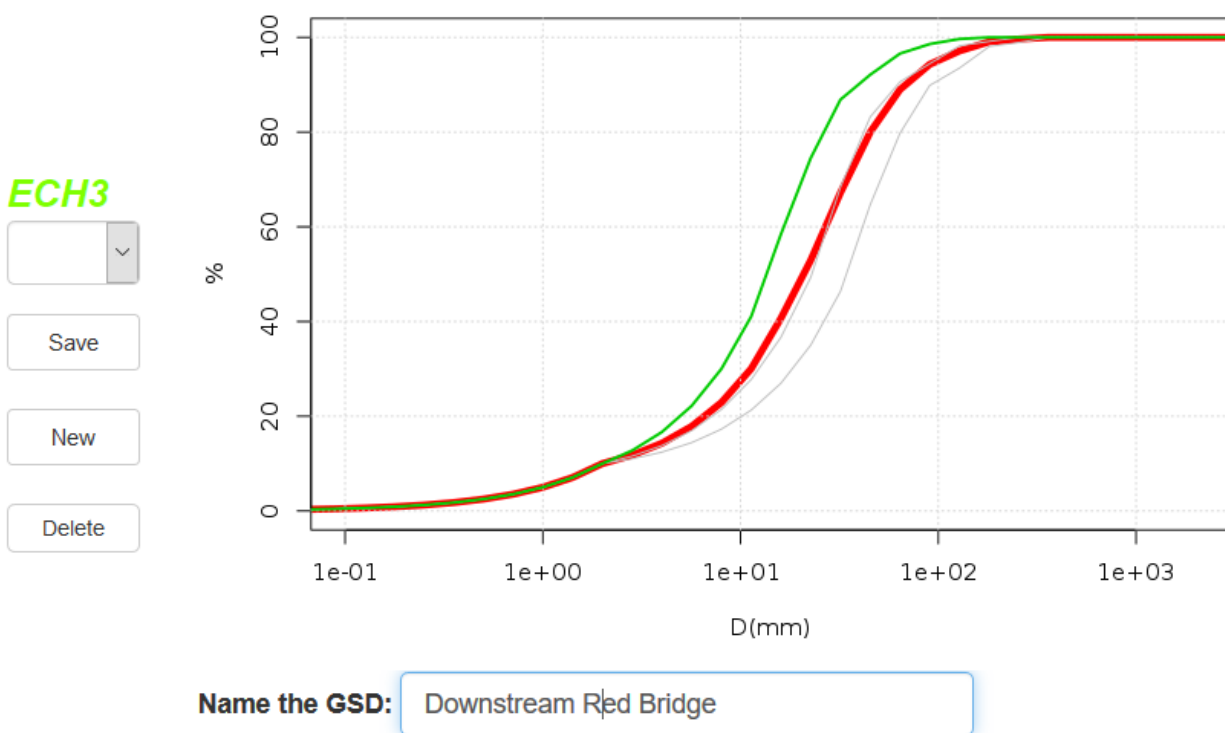
This name will be systematically be recalled with the grain size curve code.

4.3.7 Add a photo

In order for the description to be complete, you can add a photo of the sampling site. For example, you can locate sample collection locations on this photo.

This option is particularly interesting if you need to share your project with a remote contact who has not been on the site. Two examples are presented in the following figure.

4.3.8 Locate the measure

It is advisable to locate the measurement by its coordinates.

4.4 Section

4.4.1 Choosing the location of the section

Once again, it is important to emphasize that the choice of the location of the calculation section will be decisive in the relevance of the bedload transport calculation. The section must be self-formed in its alluvium (refer to the note on transport equations).

A section is defined by its geometry and the local slope.

By convention the sections are generally defined from the left bank to the right bank (but this does not affect the calculations).

Once the section entered, it must be "dressed", that is to say we will define the main flow zone (man channel), the overflow zone (flooding area), the active zone (where solid transport occurs), areas with special roughness (vegetation ...).

There are three ways to define a section:

- Manual entry in the input table
- Importing a text file
- Automatic entry by trapeze

4.4.2 Manual entry of a section

Manual entry consists of directly entering the X, Y values in the input table:

? Manual entry:		
X	**Z**	
0.00	3.00	
0.50	2.00	
0.50	2.00	
1.00	1.00	
1.63	1.00	
2.13	0.00	
6.13	0.35	

The data can be entered manually.

X is the distance from the origin of the entry (in m)

Z is the altitude (in m)

Describe the section by X increasing from the Left Bank to the Right Bank (by convention but it does not matter if all sections are all described in the same way).

As you type, the section is drawn in the center of the screen.

? Easy built with trapezes

[Trapeze modelling]
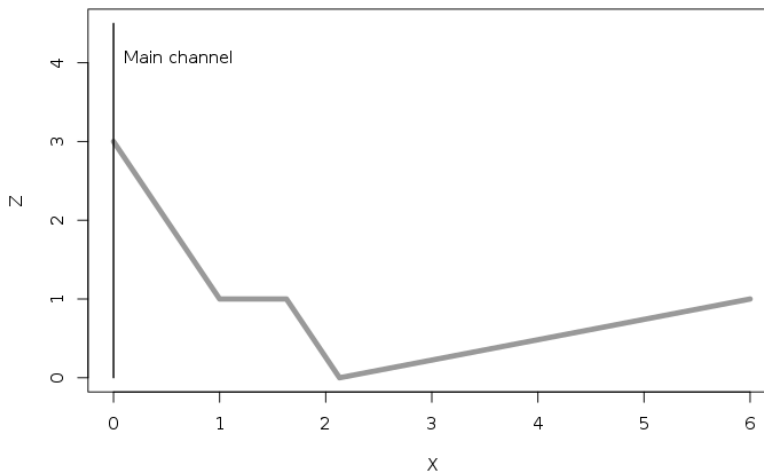
? Import a file

[Browse...] [No file selected]

? Manual entry:

X	Z
0.00	3.00
0.50	2.00
0.50	2.00
1.00	1.00
1.63	1.00
2.13	0.00
6.00	1.00

SEC1

[Save]

Slope (m/m):

[   ]

Select:

4.4.3   Importing a section from a text file

? Import a file

[Browse...] [No file selected]

This option imports the distance (X) / altitude (Z) data from text files. The data must be arranged in 2 columns separated by tabs and containing titles (for example X, Z). Describe the section by X increasing from the Left Bank to the Right Bank (by convention but it does not matter from the moment when the sections are all described in the same way). Check the quality of the data, for example by avoiding non-numeric characters or missing values.

Fichier Edition Format Affichage ?

X	Z
0	24
1	23
3.5	22.38
5.5	22.385
6.5	22.475
8.5	22.78

4.4.4 Definition of a section by trapezoidal modeling

? Easy built with trapezes

Trapeze modelling

This option makes it possible to build very quickly sections composed by juxtaposition of trapezes. It can be useful, for example, when there is a poorly documented field survey (bank height and channel width).

By clicking on the "Trapezoidal modeling" button the user is redirected to an input table allowing to define up to 3 superimposed trapezoids:

Each trapeze is defined by a top, a bottom and a height. It is clear from the above example that the base of a trapeze should be wider than the trapezoid top below.

The first two sliders of the right menu allow you to modify the relative position of the trapezoids (this does not impact the calculations but allows you to get closer to a more realistic description of the section).

The third slider changes the shape of the main channel.

It is possible to add a secondary channel by clicking on the checkbox on the right of the screen.

The sliders that appear in the menu allow to move and size this secondary channel.

To validate the section, click on the orange button "Return to the entry to validate". We are then brought back to the initial screen with the trapezoid data entered in the table. It is then possible to modify these data by writing directly in the table.

4.4.5 Define the slope

The slope is, with particle size, an extremely important parameter for calculations. It must therefore be defined with great attention.

4.4.6 Dress up the section

The menu on the right of the screen allows to "dress" the section, that is to say, to define the man channel, the active bed, the secondary channel, and any specific roughness areas. This step is indispensable and decisive for the calculation.

The main channel is the bed that transfers the current floods, and must be differentiated from the flood plain.

A secondary channel is channel generally active during flooding, but not considered active from the point of view of solid transport.

The active bed is the part of the bed where bedload transport and morphodynamic processes occur during floods. Main channel and active bed are generally identical. Only one active bed will be considered, whatever the morphology.

 Define the fixed bed left bank or bed fixed right bank if they are characterized by a particular roughness (vegetation ...). These areas can be the major bed (overflow plain).

The roughness zone is a zone associated to a particular roughness (vegetation, jams ...)

To set all these areas just move the associated sliders.
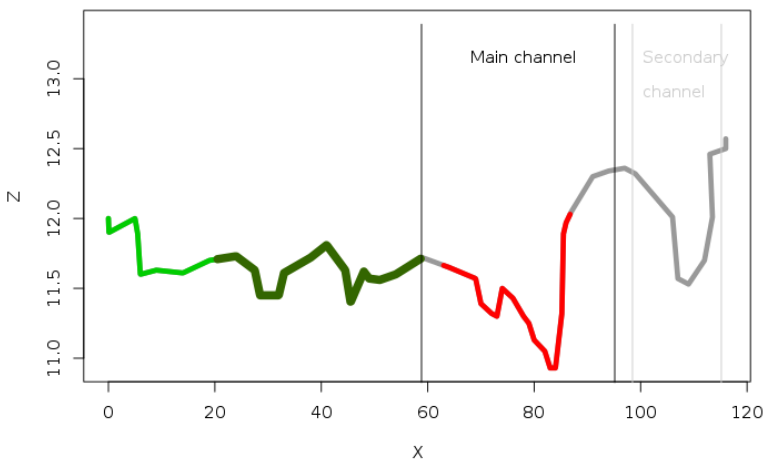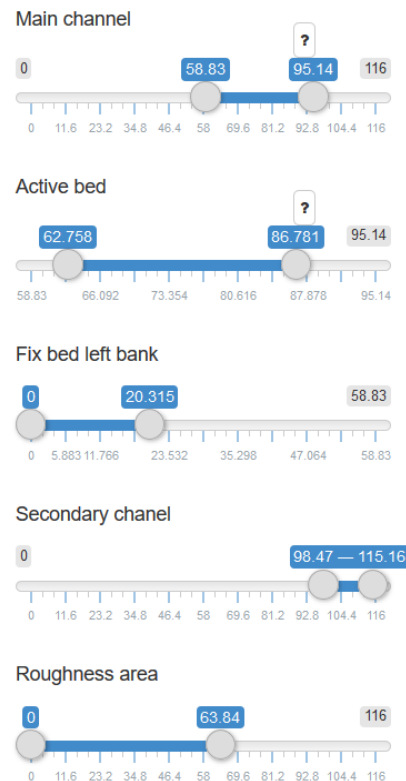
Several examples are presented in the online help.

Define the different part of the bed can be tricky for braided rivers, where the boundary between the different areas is not always clear. Even though the entire bed appears to be active, it is advisable to limit the active channel to the main channel because laboratory experiments [*Ashmore et al.*, 2011; *Leduc*, 2013] and field measurements [Misset et al 2019] suggest that, even during high flows, there is only one active channel (roughly the main channel visible at low flows) that migrates by sweeping the alluvial mattress laterally.
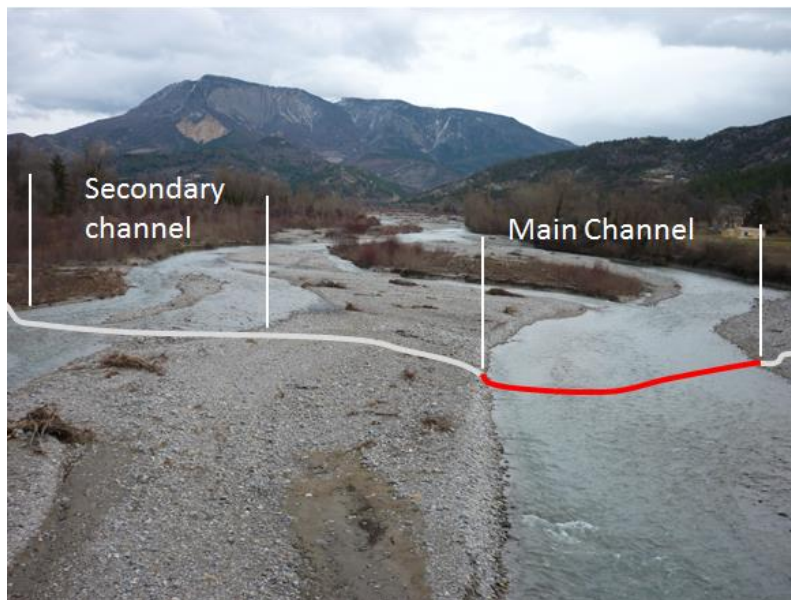
4.4.7 Define the morphology

Morphology:

○ Ro   ○ SP   ○ Pl   ○ Br   ○ Wa   ● RP   ○ BA   ○ Sa

Morphology must be defined for 2 reasons:

- The first reason is that this parameter is necessary for some equations.

- The second reason is that it will allow an outside user to better understand the calculation.

Abbreviations used care Ro (Rocky Bed), SP (Step-Pool), Pl (Flat Bed), Tr (Braid), Di (Wandering Bed), SM (Wet Threshold), BA (Alternate Bench), Sa (Sandy bed). Photographic illustrations are presented in the online help by clicking on "? ".

4.4.8 Name the section

Each new section will be assigned a code with the three letters SEC followed by a number. This code is necessary for data management but is not at all understandable for a user. As for particle size, it is therefore strongly advised to give an explicit name to the section.

Name the section: Red Bridge

4.4.9 Add a photo

Adding a photo of the site where the section was measured can be a real plus, especially for an outside user who does not know the site, and who can, this way, evaluate the alluvial nature or not of the section. This may be a photo taken on the spot, or an aerial view depicting the section.

Import an image

| Browse... | No file selected |

4.4.10 Save the entry

SEC1
Red Brige

Save

Once the section created, it must be saved. As mentioned above, a SEC + Number code will automatically be assigned to the section. The explicit name will be displayed under the code.

Think about double backup.

4.4.11 Manage sections

Select:

[▼]

[Open]

[Copy]

[New section]

[Delete]

[⬇ Download]

The menu allows you to select and open saved sections.

To open an existing section, select its name in the list and click on the "open" button.

Deletion affects the active section (ie, you must open a section before deleting it).

To create a new section, click on the "New section" button: a new code will be created and all the current entry will be erased.

4.5 Hydraulic

Welcome	Data base	Tools box	Help

| Your project | > Granulometry | > Cross section | > Hydraulic | > Sediment transport | > Hydrology | > Sediment budget | > Analysis |
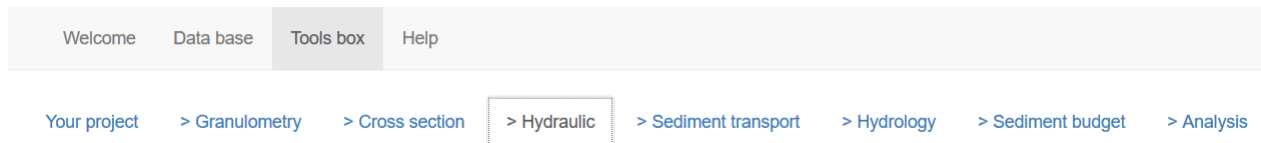
It should be kept in mind that the objective is not to reproduce a complex hydrodynamics, but rather to try to approach as closely as possible the average stress of a section for the different flow regimes, which parameter is necessary for the bedload calculation. Hydraulics is therefore calculated for the uniform regime by considering homogeneous sections.

When you open the "Hydraulic" tab, the active section (i.e. the one which is opened in 'Section' tab) is automatically displayed.
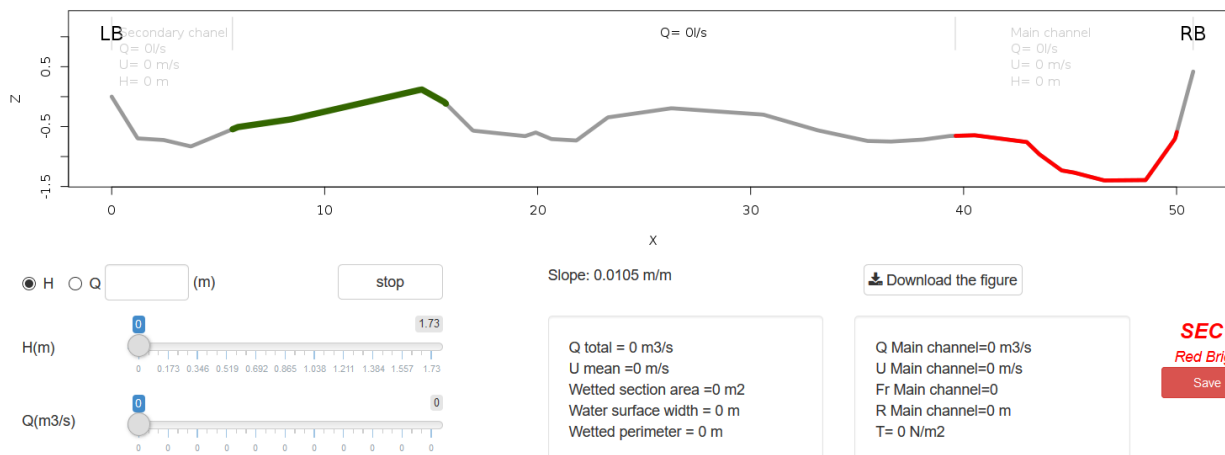
4.5.1 Set the hydraulic condition
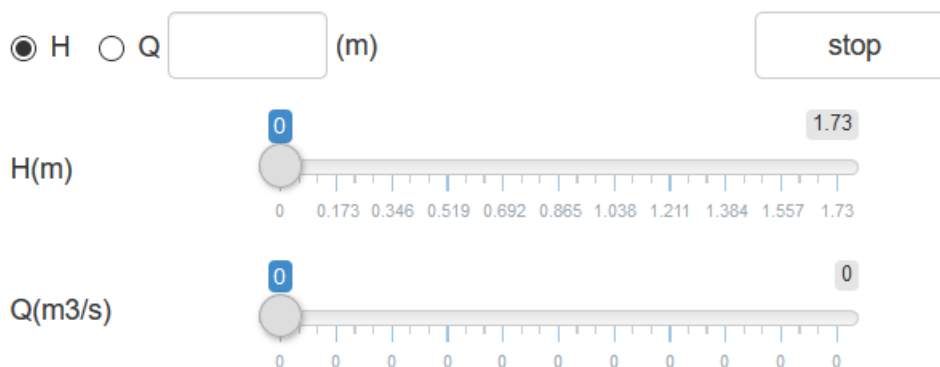
The menu on the left of the screen allows to set a hydraulic condition. This can be done in two ways:

- You can impose a value of water height H or flow Q by directly typing this value in the text box provided for this purpose

- You can vary the sliders H or Q

At this point, when you test a flow Q nothing happens. When testing a water depth H, a water line is drawn but the displayed discharge is 'zero'. This is normal: the correspondence between water velocity and discharge requires a friction law that must be defined.

What is the "STOP" button for?

When using one of the cursors H or Q, the program makes iterations to adjust the position of the two cursors (to a Q value corresponds to a single H value and vice versa). When the cursor movement is very small, it can happen that this iteration is racing and does not stop. While waiting to adjust this small BUG this option is proposed: by clicking on STOP a discharge value is imposed and the iteration stops. You must then remove this value to use the sliders again.

4.5.2 Define the friction law

The panel located at the bottom of the screen makes it possible to define the friction laws and roughness for each part of the bed. It is the friction law which defines the flow velocity and depth for a given discharge over a given slope and a bed roughness. Two laws are proposed to the user:

- The Manning-Strickler law: the roughness K must be entered by the user. This value can result from a calibration, or from a catalog.

- The Ferguson [2007] law: this law use D_{84} for the bed roughness.

For the sake of simplicity, the choice was limited to these two laws that cover all hydraulic conditions: the Ferguson law is valid over a wide range of conditions, including mountain streams with high roughness and low depths [*Rickenmann and Recking*, 2011]. It will be used for the main channel, and more generally for all parts of the bed devoid of vegetation, where the flow occurs over a sedimentary bed (gravel, pebbles, blocks) defined by its grain size curve. By the possibility of fixing a roughness K, the Manning-Strickler law will be particularly adapted for complex zones, like vegetation, log jams ...

To be available, the grain size distribution must have been previously entered and recorded in the Granulometry tab.

The active bed grain size distribution is not used in the hydraulic calculation but in the bedload transport calculation (Shields number, Eintein parameter). A priori the granulometry of the

active bed is the same as that of the main channel (except special cases, such as the 'traveling bedload' [*Piton and Recking*, 2017]).

4.5.3 Calculation

Once friction laws and roughness have been defined, the program prepares the section for hydraulic calculation. For the main and the secondary channels, a single calculation of the average velocity is made with the hydraulic radius U = U (R). For the rest of the bed, the calculation is made on each vertical with the water height U = U (H).
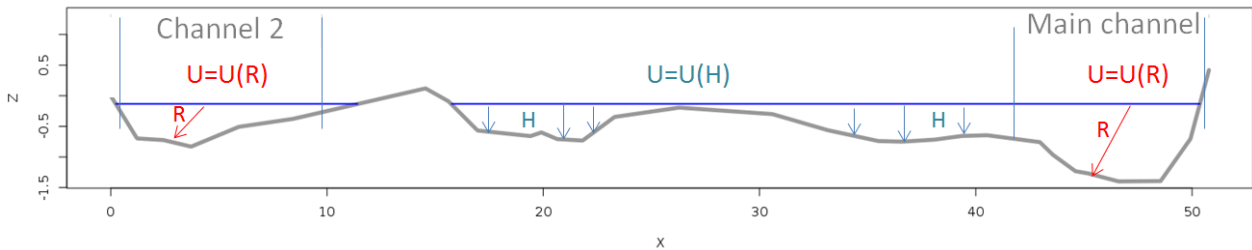
Finally, when the hydraulic condition (H or Q) is imposed by the user, the associated quantities (U, Fr.) and the figure are updated automatically.
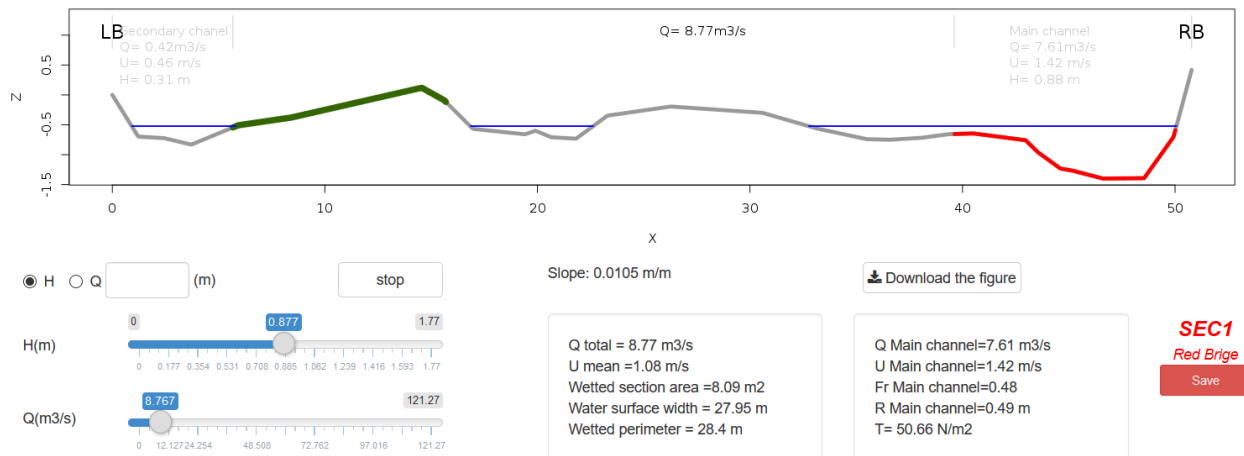
4.5.4 Rating curves

The rating curves associated with the section are available at the bottom of the screen: H(Q), R(H), U(H), U(Q).

Q(H):

[Download]
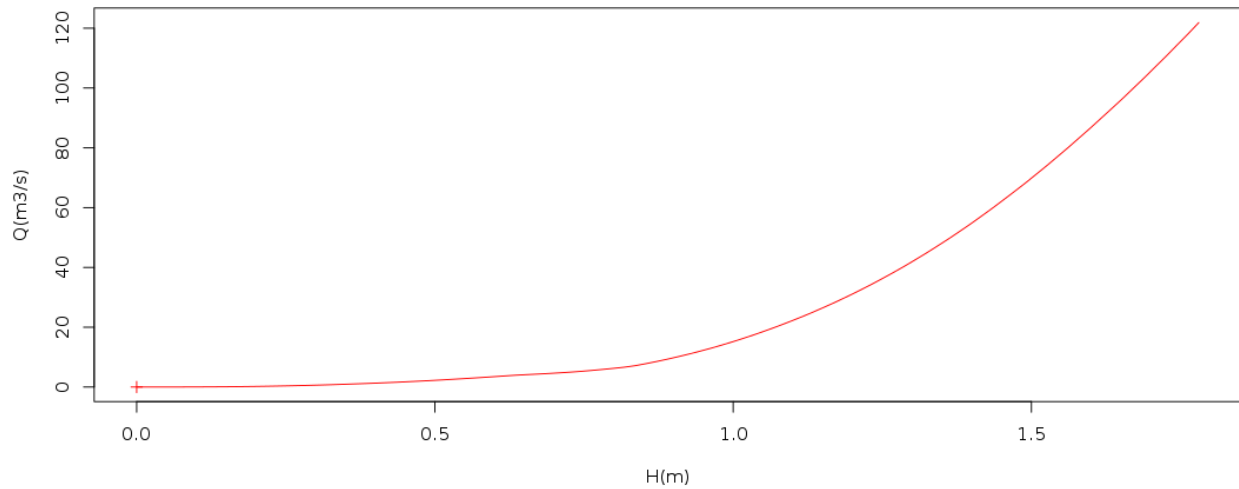
4.5.5 Validation data

This menu is used to enter measured Height / Flow values if available. The calculated calibration curve can thus be compared to the measurements, and adjusted if necessary (via the values of K or D_{84}).

Q(H):

[Download]
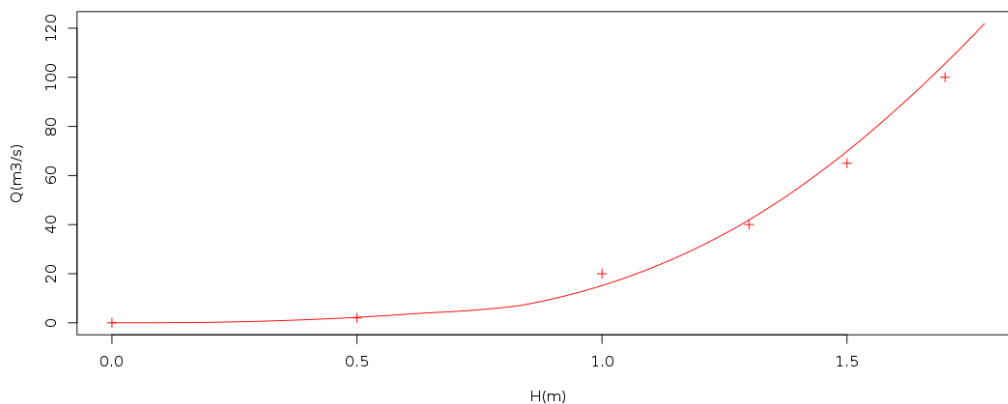
Validation data

H(m)	Q(m3/s)
0.00	0.00
0.50	2.00
1.00	20.00
1.30	40.00
1.50	65.00
1.70	100.00

Import

[Browse...] [No file]

The data can be uploaded from a text file.

4.5.6 Backup

All input (friction law, roughness and validation data) must be saved with the "save" button.

CAUTION: think of the double backup: as for all the other tabs, the backup will be final only after saving the project.

4.6 Sediment transport

Welcome	Data base	Tools box	Help

| Your project | > Granulometry | > Cross section | > Hydraulic | > Sediment transport | > Hydrology | > Sediment budget | > Analysis |

This page uses all data previously entered (granulometry, section, hydraulics) to calculate bedload transport, for each bedload equation.

4.6.1 Bedload calculation

There is no additional data to enter at this point to access the solid transport values: just move the water level or flow slider, or enter a value in the text box. As for the hydraulic page, **the STOP button makes it possible to stop an iteration** (see explanations in the section dedicated to "Hydraulics")

The computed bedload values are displayed graphically and in the table on the right.

4.6.2 Display

The panel is divided into 4 figures that represent:

- Bedload models Qs (Q) for equations selected by the user
- The computed bedload values for the given flow condition
- The active section
- The bedload grain size distribution
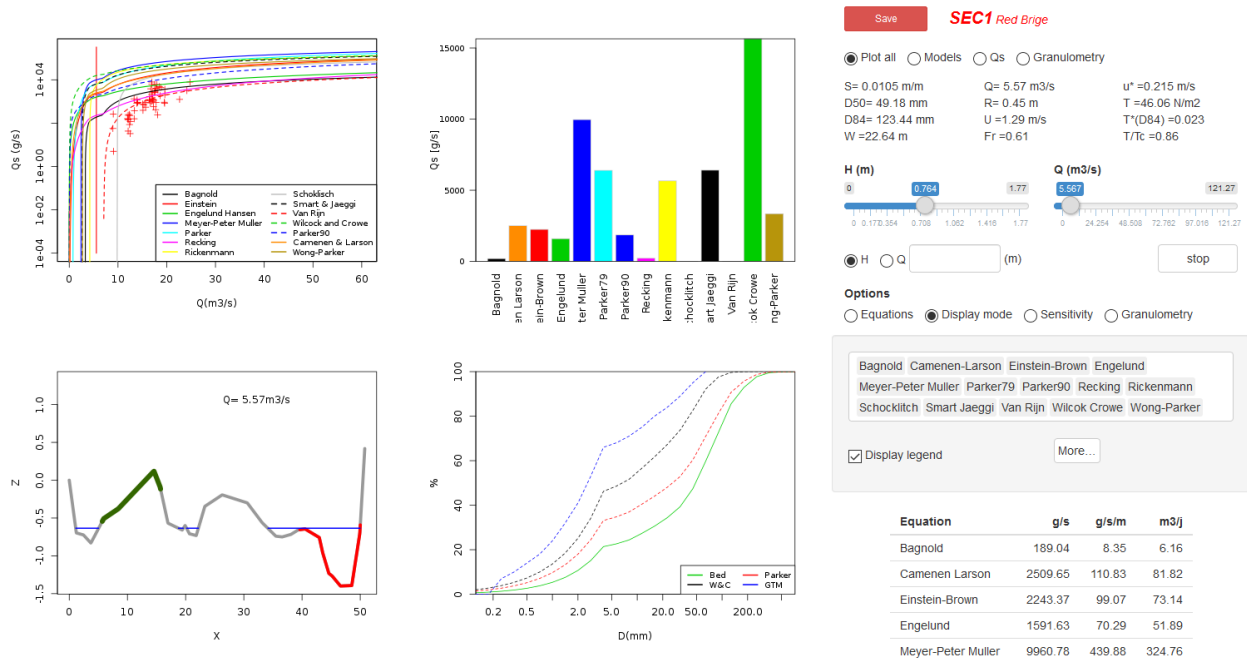
Click on the options on the top right to zoom in on one or the other of these figures

The associated hydraulic data are updated.

S= 0.0105 m/m   Q= 19.47 m3/s   u* =0.258 m/s
D50= 49.18 mm   R= 0.65 m   T =66.57 N/m2
D84= 161.71 mm   U =1.63 m/s   T*(D84) =0.025
L =34.87 m   Fr =0.65   T/Tc =0.95

4.6.3   Display and calculation options

The options menu allows to adjust the calculations and the display

The "Equations" button allows to adjust the critical stress or critical discharge values used in the equations (in other words, it permits to calibrate the transport equations). If there is no entry, the default values are displayed.

☐ Correct shear stress

Calibrate equations

Bagnold: ωc= [____] wc=[0-6.498]

Camenen & Larson: τc*= [____] Tc*=0.055

Lefort: q0= [____] q0=[1.236-18.115]

Meyer-Peter & Muller: τc*= [____] Tc*=0.047

Parker: τc*= [____] Tc*=0.03

Parker90: τr*= [____] Tr*=0.0386

Recking: τm*= [____] Tm*=0.049

Rickenmann: qc= [____] qc=0.843

Schocklitch: qc= [____] qc=1.33

Smart & Jaeggi: τc*= [____] Tc*=0.049

Van Rijn: uc*= [____] uc*=0.209

Wilcock & Crowe: τr*= [____] Tr*=0.023

Wong & Parker: τc*= [____] Tc*=0.0495

Water density ρ(kg/m3)= [1000]

Sediment density ρs(kg/m3)= [2650]

Apparent sediment density ρs_app(kg/m3)= [2000]

☑ Correct wall effects in glass wall canal

☐ Suppress the sand fraction for calculation with Parker 90

One can also correct the constraint to remove the effects of bedform roughness. The densities of water and sediments are also modifiable (but the same values will be used in all calculations for this section).

It is important to note that these adjustments will only be taken into account for the active section (which is opened in the 'section' tab).

Options

○ Equations   ◉ Display mode   ○ Sensitivity   ○ Granulometry

The display options are the same as those presented for the database

The "sensitivity" option permits to test equations sensitivity to the input parameters, as was already the case for the database.

The "granulometry" option gives access to the options for calculating the grain size transported, and in particular to adjust the calibration parameters of the GTM model [*Recking*, 2016].

4.6.4   Enter validation data

When the "Model" button is selected the bottom of the page displays a table where you can enter measured bedload values when available.

Calibration data

Q(m3/s)	Qs(g/s)
13.30	1327.00
9.03	264.00
8.96	57.00
9.08	5.00
17.56	2568.00
17.79	4098.00
18.19	3415.00
16.94	7897.00
18.79	4458.00
13.32	159.00
13.38	378.00
13.86	832.00
14.01	925.00

Solid flow rate / flow rate values can be manually entered directly into the table.

Note: Enter the section average values (m^3/s and g/s) and not the values per unit width (m^3/s/m and g/s/m).

The "import" button also allows to directly import data recorded in text format on two columns separated by tabs, with title (Q, Qs for example)

The values entered will be superimposed on the models, which is a good means of validation.
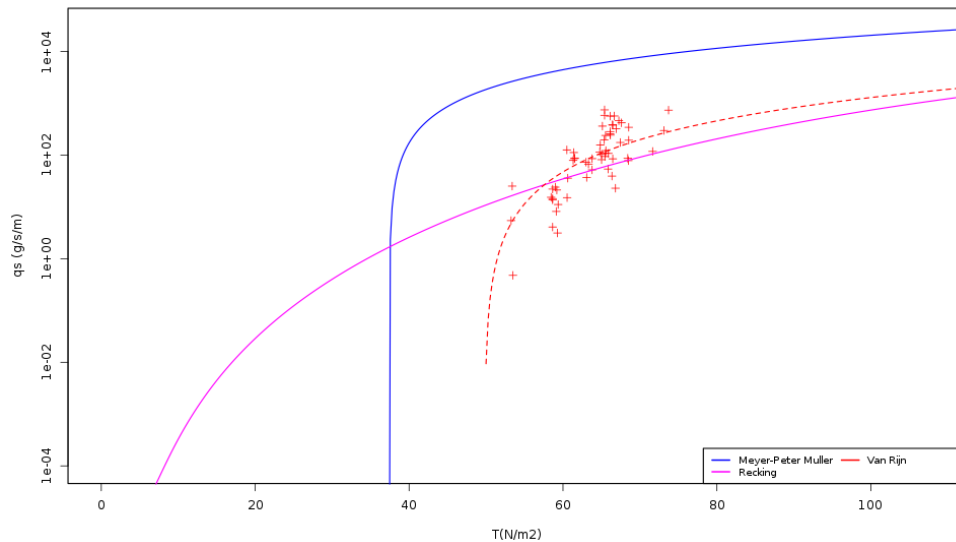
4.6.5 Entering validation data for the transported grain size

○ Plot all   ○ Models   ○ Qs   ◉ Granulometry

In the same way, when the "Granulometry" button is selected, the page displays a table where you can enter measured bedload grain size distributions, when available.

Bedload grain size distribution validation

A given bedload grain size distribution must of course be associated with a given discharge (because at zero flow rate the transported grain size is null). It is possible to enter several grain size curves and save them. A GTM + Number code is associated with the backup. These data can be used to calibrate the GTM model.

4.6.6 Backup

All input (template parameters and validation data) must be saved with the "save" button.

CAUTION: think of the double backup (as for all the other tabs, the backup will be final only after saving the project).

4.7 Hydrology

This tab allows to enter the hydrological data that will be associated with the sections to calculate sediment budgets. Two options are possible:

- Hydrographs Q (t): series of flow values Q as a function of time t

- Q (T): flows associated with their return period T

4.7.1 Enter an hydrograph

This option allows you to enter series of Q (t) values.
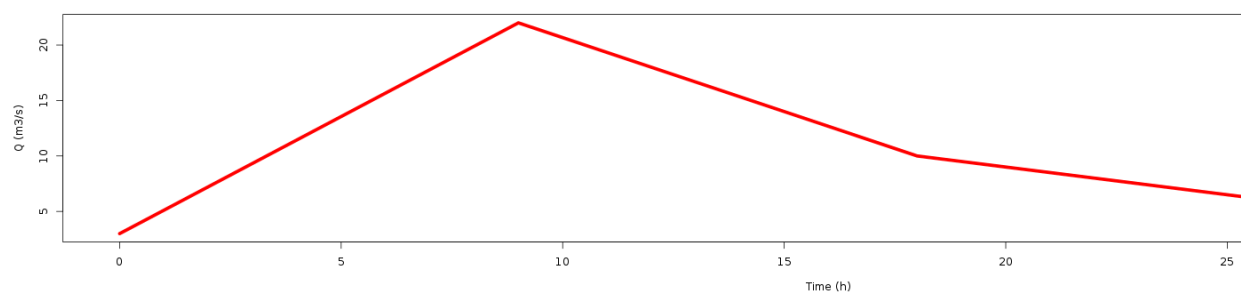
The page that is displayed allows several input options:

- The data can be entered directly into the input table.
- A file can be imported in text format (2 columns with title t , Q, separated by tabs)
- A small tool allows to quickly build a theoretical triangular hydrograph

When data is entered, the hydrograph is directly drawn.

Regardless of the input mode, it is important to define the units:

From the entered data, the program rebuilds a hydrograph for each calculation; for that :

1) the two time limits of the hydrograph (t_minimum and t_maximum) entered by the user are read
2) a matrix [t, Q] is discretized at the chosen unit time step (minute, hour or day) between these two extremes
3) discharge values are extrapolated from the hydrograph entered by the user

T	Q
42	16
43	12
53	2
54	5
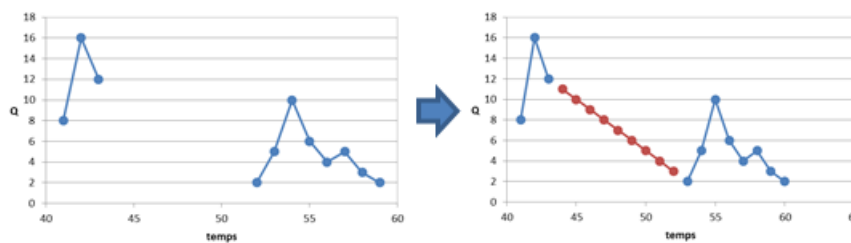
It is therefore very important to check the consistency of the hydrograph entered. If there are holes in the time series, they must be framed by '0' values so as not to cause an inappropriate calculation. In the previous example, this would imply inserting zero flows at times 44 and 52:

T	Q
43	12
44	0
52	0
53	2
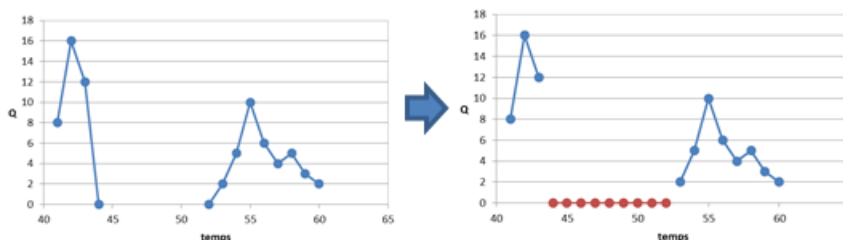
Empty (or NA) values must also be replaced by zero.

It will then belong to the user to take into account these shortcomings in the analysis of the sediment balances made.

4.7.2 Assistance to build a hydrograph

Hydrology input

? Built a hydrograph

Parameters	
T Rising (h)	Q peak (m3/s)
10	53.556374046802
Tbase (h)	Q Threshold (m3/s)
20	26.77818702340'
Duration (h)	Qmin (m3/s)
40	5.3556374046802

Apply

When you click on the "Build a hydrograph" option, an input window opens to define a theoretical triangular hydrograph. The proposed values can then be changed.

Although this hydrograph may be used with any section, the proposed Qmax is calculated to be compatible with the active section (open in the 'section' tab) at the time of entry.
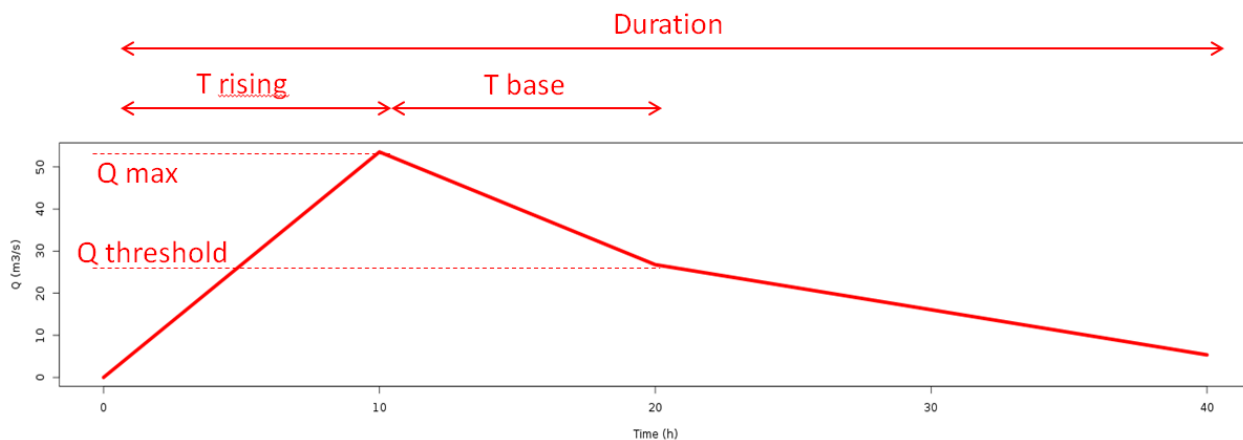
4.7.3 Enter flow duration curve

In this option, flow rates are derived from a statistical analysis of hydrological data at the station, which requires at least 30 years of data.

Frequency of non-exceedance x 100	Q(m3/s)
99.9945	120.00
99.9863	100.00
99.9726	90.00
99.9452	79.00
99.863	62.00
99	51.10
98	43.70
95	35.80
90	29.00
80	20.20
70	13.70
60	8.90
50	5.56
40	3.89
30	2.94
20	2.35
10	1.90
5	1.61
2	1.33
1	1.14

The data can be entered by hand in the table, in two columns:

- Column1: the frequencies of non exceedance FND x 100

- Column2: associated flows Q in m^3/s

The data can also be imported in text format in two columns with titles (eg F, Q) and separated by tabulation

The frequency of non-exceedance is related to the return period T and the frequency of exceedance FD by:

$$T=1/FD \qquad (9)$$

$$FD=1-FND \qquad (10)$$

The number of days where a discharge Q of non-exceedance frequency FND will be overpassed on average, in any year, is:

$$FD(j/an)=(1-FND)*365 \qquad (11)$$

FND100	FD	T	Duration	Q
0.999945	0.020075	49.8132005	0.020075	120
0.999863	0.050005	19.9980002	0.02993	100
0.999726	0.10001	9.9990001	0.050005	90
0.999452	0.20002	4.99950005	0.10001	79
0.99863	0.50005	1.99980002	0.30003	62
0.99	3.65	0.2739726	3.14995	51.1
0.98	7.3	0.1369863	3.65	43.7
0.95	18.25	0.05479452	10.95	35.8
0.9	36.5	0.02739726	18.25	29
0.8	73	0.01369863	36.5	20.2
0.7	109.5	0.00913242	36.5	13.7
0.6	146	0.00684932	36.5	8.9
0.5	182.5	0.00547945	36.5	5.56
0.4	219	0.00456621	36.5	3.89
0.3	255.5	0.00391389	36.5	2.94
0.2	292	0.00342466	36.5	2.35
0.1	328.5	0.00304414	36.5	1.9
0.05	346.75	0.00288392	18.25	1.61
0.02	357.7	0.00279564	10.95	1.33
0.01	361.35	0.0027674	3.65	1.14

The average duration of occurrence of a given discharge during a year is the difference of the FD values surrounding this discharge in the table: for line i, the duration of occurrence of Q (i) is FD(i) -FD(i- 1), in a day per year.

The graphical display shows on the abscissa the classified flows, and on the ordinate, the average number of days per year where each flow is exceeded.
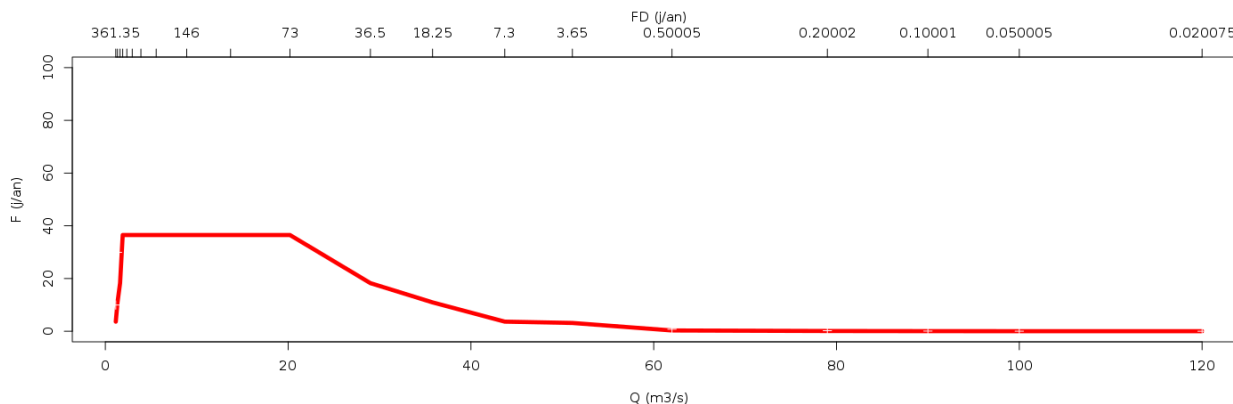
A second X-axis matches the flow rates with (optionally) FND, FD, or T.

Plot in X:

○ FND   ○ FD   ● T

We will see in the next part how these hydrological data are used in the establishment of a sediment budget.

4.7.4   Name the hydrology

Name of the data series

Analyse FREQ

Name of the station

Longitude

Latitude

Short comment

At each backup the program will automatically associate a code to the hydrological series.

However, as for the granulometry or for sections, it is advisable to give an explicit name to each series.

Additional information can also be entered such as the name of the hydrological station, its coordinates, and even a small commentary of a few words.

4.7.5   Save and manage hydrological data

Management of hydrological data

Select:

Open

Save

Copy

New

Delete

⬇ Download data

⬇ Download figure

Each new hydrological series must be saved. A code will be automatically associated with each series, with the letters HYD for the hydrographs and QCL for the classified flows.

Again we insist on the principle of double backup: a file will be permanently saved with the backup of the project.

The hydrological data management menu is identical to the previous menus.

The "deleted" or "replicate" buttons act on the open series.

4.8 Sediment budget

Welcome   Data base   Tools box   Help

Your project   > Granulometry   > Cross section   > Hydraulic   > Sediment transport   > Hydrology   > Sediment budget   > Analysis

The sediment balance will be computed for the active section (i.e. the one opened in the 'Section' tab) and use everything that has already been defined in the previous tabs.

At this point, the input work is almost done. The models for hydraulic calculation and bedload transport associated with the section have already been built.

4.8.1 Associate a hydrological series

Calculation option
◉ Hydrograph
◯ Flow duration curve

HYD1 (Hydro court)

Select:

HYD1 (Hydro court)

Open

The first thing to do is to associate a hydrological series with the section.

This series is to be chosen thanks to the drop-down menu among hydrographs or classified flows.

Then you must open the series to start the calculation.

Local hydrology [?]

Referent watershed (km2)   122

BV section (km2)   83

Myer coefficient   0.8

The second input zone makes it possible to adapt the hydrograph (measured at a reference station which is not necessarily located at the location of the calculation section) to the actual surface drained by the calculation section.

The correction of the pro-rata flows of the surfaces is done thanks to Myer formula which is written:

$$Q = Q_{Ref}\left(\frac{A}{A_{Ref}}\right)^{\alpha} \tag{12}$$

where :

- QRef is the reference flow as entered by the user in the 'hydrology' tab
- A_{Ref} ("Referent Watershed") is the catchment area that generated QRef
- A ("Actual Area") is the catchment area drained by the calculation section
- Q is the corrected rate that will be used for the calculation section

The Myer coefficient is a regional coefficient. It is usually set in the range 0.7-0.8, but can be estimated locally with a hydrological study.

The entire hydrograph is adapted to the calculation section according to this procedure.

4.8.2 Principle of calculation

For each time t_i the program calculates $Q_s(Q_i)$ and a volume V_i transported over time $dt=t_i-t_{i-1}$:

$$V_i = Qs(Q_i)*(t_i-t_{i-1}) \tag{13}$$

The total volume transported for the hydrological series is the sum of these elementary volumes:

$$V = \sum V_i \tag{14}$$

For classified flows the method is a little different. At each graded flow is associated an average number of days of annual exceedance ('Duration' in the table). The discharge values corresponding to the limits of the occurrence intervals, a median value Q_i is considered for the calculation. At this discharge Q_i is associated a transport rate Q_s and for each line a mean volume transported is calculated:

$$V(m^3) = Qs(m^3/j)*Duration(j) \tag{15}$$

FND100	FD	Tretour	Duration (j/an)	Q(m3/s)	Qi(m3/s)	Qs(g/s)	V(m3)
0.999945	0.020075	49.8132	0.020075	120	120	15120.0	303.5
0.999863	0.050005	19.9980	0.02993	100	110	11646.3	348.6
0.999726	0.10001	9.9990	0.050005	90	95	7502.0	375.1
0.999452	0.20002	4.9995	0.10001	79	84.5	5279.3	528.0
0.99863	0.50005	1.9998	0.30003	62	70.5	3066.0	919.9
0.99	3.65	0.2740	3.14995	51.1	56.55	1582.4	4984.4
0.98	7.3	0.1370	3.65	43.7	47.4	931.8	3401.2
0.95	18.25	0.0548	10.95	35.8	39.75	549.6	6017.7
0.9	36.5	0.0274	18.25	29	32.4	297.6	5431.3
0.8	73	0.0137	36.5	20.2	24.6	130.3	4754.5
0.7	109.5	0.0091	36.5	13.7	16.95	42.6	1555.3
0.6	146	0.0068	36.5	8.9	11.3	12.6	460.8
0.5	182.5	0.0055	36.5	5.56	7.23	3.31	120.7
0.4	219	0.0046	36.5	3.89	4.725	0.92	33.7
0.3	255.5	0.0039	36.5	2.94	3.415	0.35	12.7
0.2	292	0.0034	36.5	2.35	2.645	0.16	5.9
0.1	328.5	0.0030	36.5	1.9	2.125	0.08	3.1
0.05	346.75	0.0029	18.25	1.61	1.755	0.05	0.9
0.02	357.7	0.0028	10.95	1.33	1.47	0.03	0.3
0.01	361.35	0.0028	3.65	1.14	1.235	0.02	0.1

The total annual volume is the sum of the volumes calculated for each rated flow.

This method generally shows that extreme flows usually transport little volumes of sediment (large flows but short durations => low volumes). It is thus considered that they do not have a major morphological role in the long term. This does not mean that in the short term their effect on the morphology and the populations is not important.
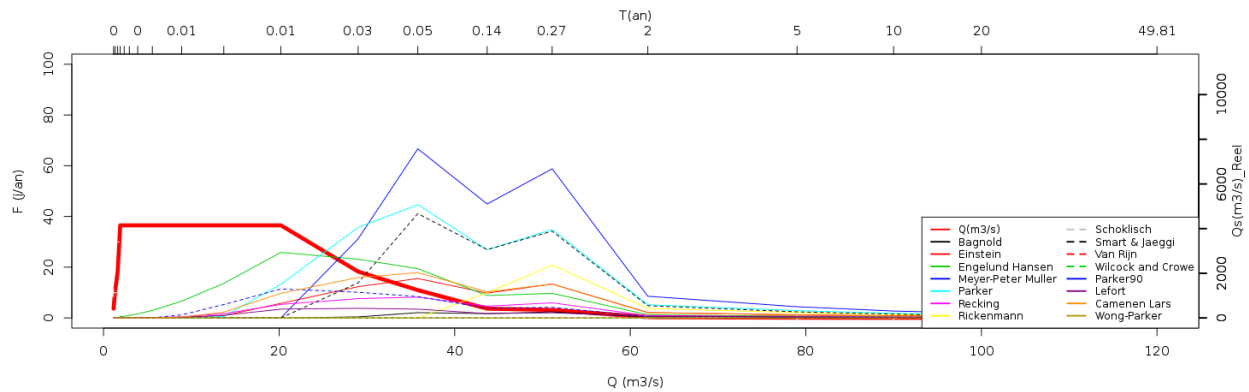
The more detailed the statistical analysis, the more precise the result will be. However, this approach is generally limited by the lack of data for reliable statistical processing, preventing access to rare frequencies.

4.8.3 Calculation options

At this stage all calculation options were set in the previous page and you no longer have access to the options concerning the transport equations.

☐ Allow calculation beyond the maximum dimension of the section

☐ Correct the shear stress

☐ Correct wall effects in glass wall canal

☑ Suppress the sand fraction for calculation with Parker 90

Parameters defined in the tab 'Solid Transport

Only the option "Allow calculation beyond the maximum dimension of the section" is editable.

The other calculation options have been entered in the "Sediment transport" tab

Avant calcul, le programme vérifie que les débits de l'hydrogramme sont compatibles avec la capacité hydraulique de la section. Si ce n'est pas le cas il vous propose d'étendre le calcul au-delà de la côte maximum de la section.

☑ Allow calculation beyond the maximum dimension of the section

When clicking on the option "Allow calculation beyond the maximum dimension of the section" you must define the height of the side walls.

Walls height   2

When allowing calculation beyond the maximum dimension of the section, the program considers two side walls at the left and right limits.
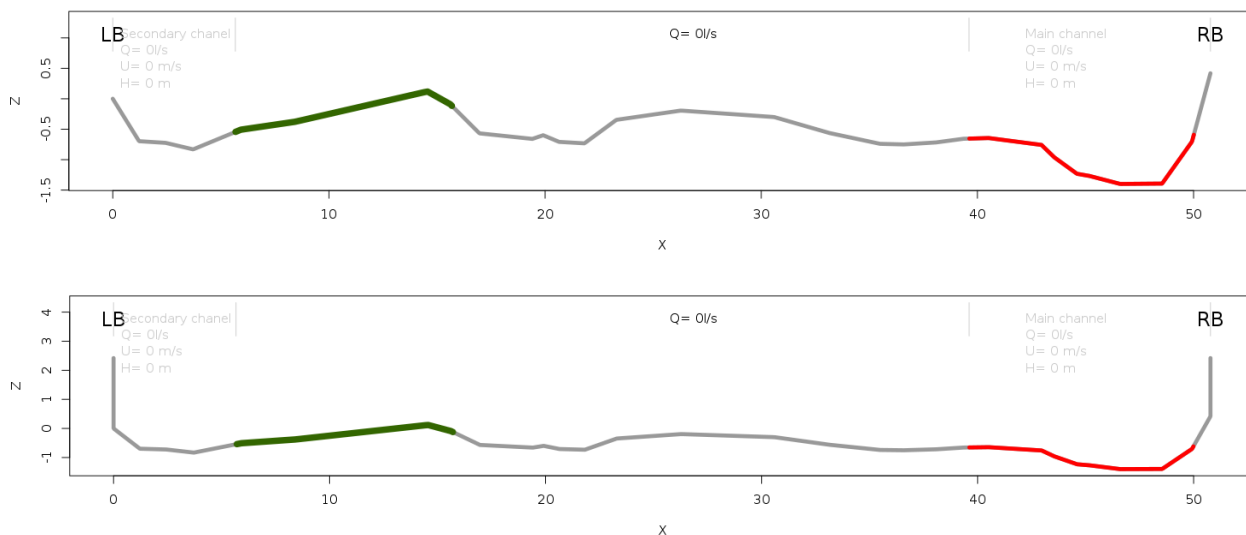
4.8.4 Display

It is possible to choose the display units for the results:

Sediment budget

◉ Volume real   ○ Apparent volume

○ g   ○ Kg   ◉ m3   ○ t

The transport equations calculate a "real" volume of pure material (density ρ_s = 2650 Kg/m^3), that is to say without taking into account the voids between the grains. In reality, the comparison with field measurements must take into account the space occupied by the pores of the sedimentary mixture (air + rock mixture with density ρ_{sa} = 2000kg/m^3). The conversion is done by:

$$Volume\ apparent = \frac{\rho_s}{\rho_{sa}} \text{x } Volume\ real \qquad (16)$$

With $\rho_s \approx 2650$ Kg/m^3 and $\rho_{sa} \approx 2000$kg/m^3, $V_{apparent} = 1.3V_{real}$.

The results are displayed in the table and can be downloaded.

The graphical display makes it possible to represent bedload as a function of time, or the cumulated volumes.
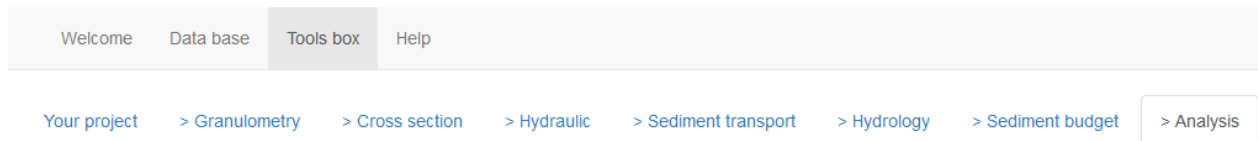
Plot options

⦿ Hydrograph ◯ Volume transported

4.8.5 Backup

The data entry, and in particular the section / hydrograph association, is saved with the "Save" button.

Double backup is necessary for a final backup in the project.

4.9 Analyse

Welcome	Data base	Tools box	Help

Your project	> Granulometry	> Cross section	> Hydraulic	> Sediment transport	> Hydrology	> Sediment budget	> Analysis

4.9.1 Goal

The goal is to assist the user towards a conclusion on the sediment budget study.

We can conclude a sediment budget analysis not on the basis of a single transport equation, but considering several equations that seem to be context-specific.

In addition, it is interesting when studying several sections, to compare the volumes transported from one section to another; we can then conclude:

- If the volumes are not significantly different: we are in the margin of error of the calculation and the sections have a similar behavior
- If volumes transported upstream are higher than volumes transported downstream, one can conclude an intermediate storage
- If the volumes transported upstream are lower than the volumes transported downstream, one can conclude an intermediate destocking

4.9.2 Use

At this stage, no further calculations are performed and only sediment budgets previously saved are taken into account.

Sections to consider	Equations to consider

If you have not saved any sediment budget, the selection box "Sections to consider" will be empty.

The page will display a series of graphs summarizing the results obtained for the selected sections and equations.
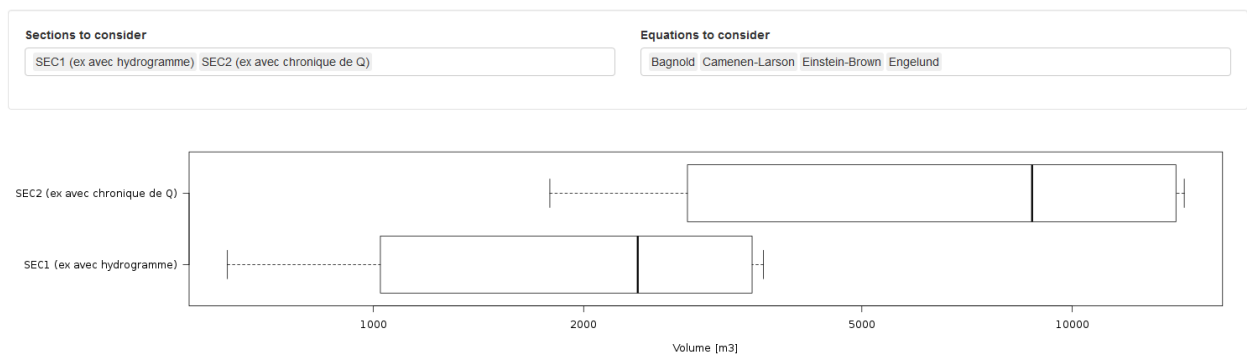
Several display options are available.

4.9.3 How to choose an equation ?

BedloadWeb build bedload models Qs (Q) for all equations. The great difficulty for the user is to make a choice among these equations. How to proceed?

A first method will be to consider the validity domain of each equation in question. However this is not trivial, because there is a real ambiguity on these validity domains, which often are not even defined.

A second method consists to use the database to select a set of data measured in streams with similar characteristics to the studied stream and then test the equations on that dataset.

	River	Slope (m/m):	D50(mm)	D84(mm)	Width (m):	Morphology	Technique
70	N Fork Toutle River near Kid Valley	0.0041	2.5	20	40.25	Riffle-pool	Helley-Smith 76 mm
78	Pony creek near Antero Res	0.005	2.5	6	1.1	Riffle-pool	Helley-Smith 76 mm

Showing 1 to 2 of 2 entries   Previous 1 Next

A third method consists in validating the equations on data measured on the studied river. These measurements may be either local instantaneous measurements (see the document on measurement methods) or deposited volumes.

Whatever the method chosen, the equations can possibly be adjusted (calibration).

4.9.4 Backup

This page is essential in the analysis and its conclusion, and the backup makes it possible to keep your choices (section + equations).

This can be useful if the project is to be shared with another user.

There is no need to recall at this stage the need for double safeguarding.

5 HELP

The help page provides a lexicon of the parameters used.

Various downloadable documents are proposed in pdf format. Links will be updated as documents become available.

Document to download

User manuel.pdf

Example.txt

An example file can also be downloaded in text format: save this file on your PC and open it with the button "Import a project" in the menu "Your project" >> "Local backup".

Import a project

Browse...   No file selected

6 REFERENCES

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