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Dye tracer / Salt dilution

Discharge measurements

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jingheng.huang@unifr.ch & eric.pohl@unifr.ch

we act

Find this document and all related material on github:
https://github.com/pohleric/mountain-hydrology-workshop-2026

READ THIS:

This tutorial uses variable injection and calibration amounts of Uranine.
A detailed description on how to prepare the calibration is in **"Documentation/EN(or RU)/05 – Preparation.docx"**

Overview – Measuring discharge with tracers

- What is the dye tracer/ salt dilution method?
  - Principles
- Where to apply it?
  - What creeks/rivers can I measure?
- How to apply it?
  - Color amount
  - Mixing length
  - Signal
    - Fluorometer
    - Electrical conductivity
- How to prepare it?
  - Fluoresceine
  - Dye preparation
  - Salt preparation

- What is the dye tracer method?
  - Principles

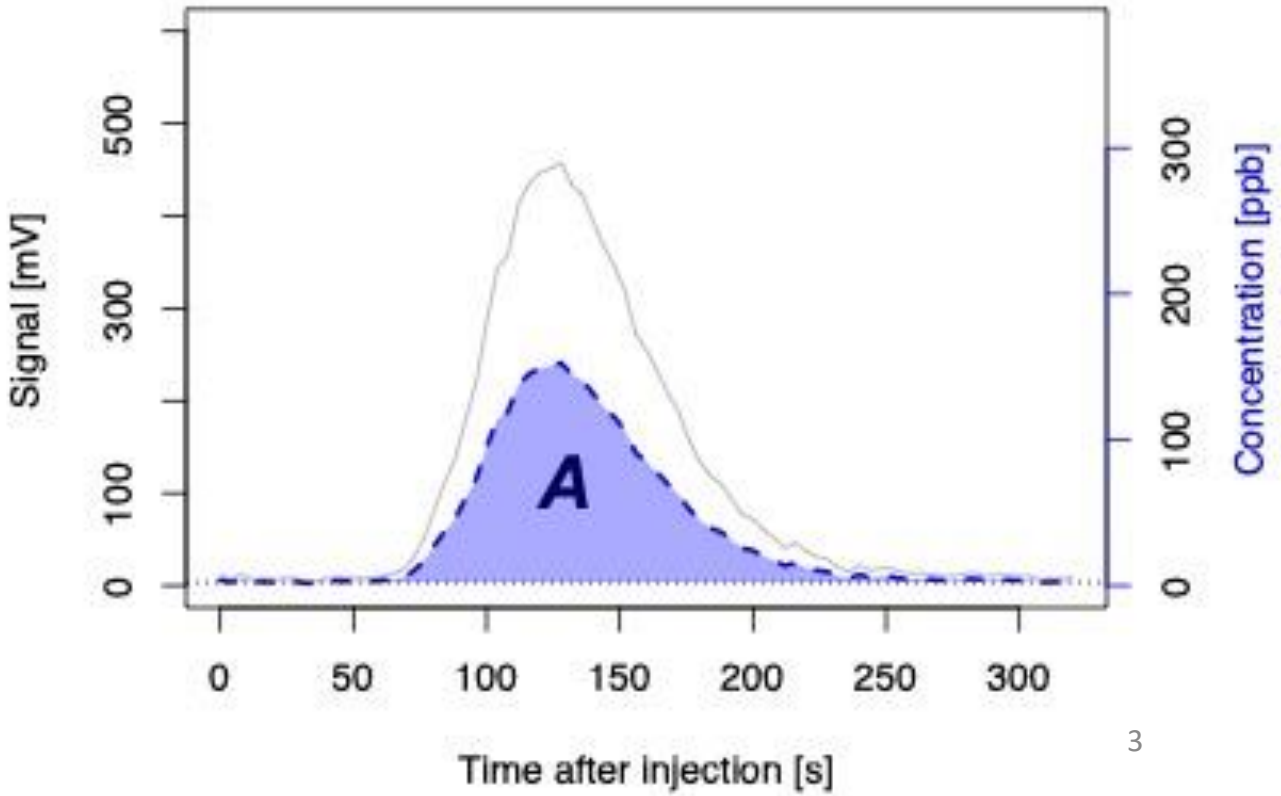
Discharge – dilution method (salt or color)

$$Q = \frac{M}{A},$$

Q – Discharge [m^3/s]
M – Tracer mass [**mg**]
A - [**µg***s /l]

$$A = \Sigma(c_t * t_{int}),$$

c_t – concentration at time t [µg/l = ppb]
t_{int} – time step increment

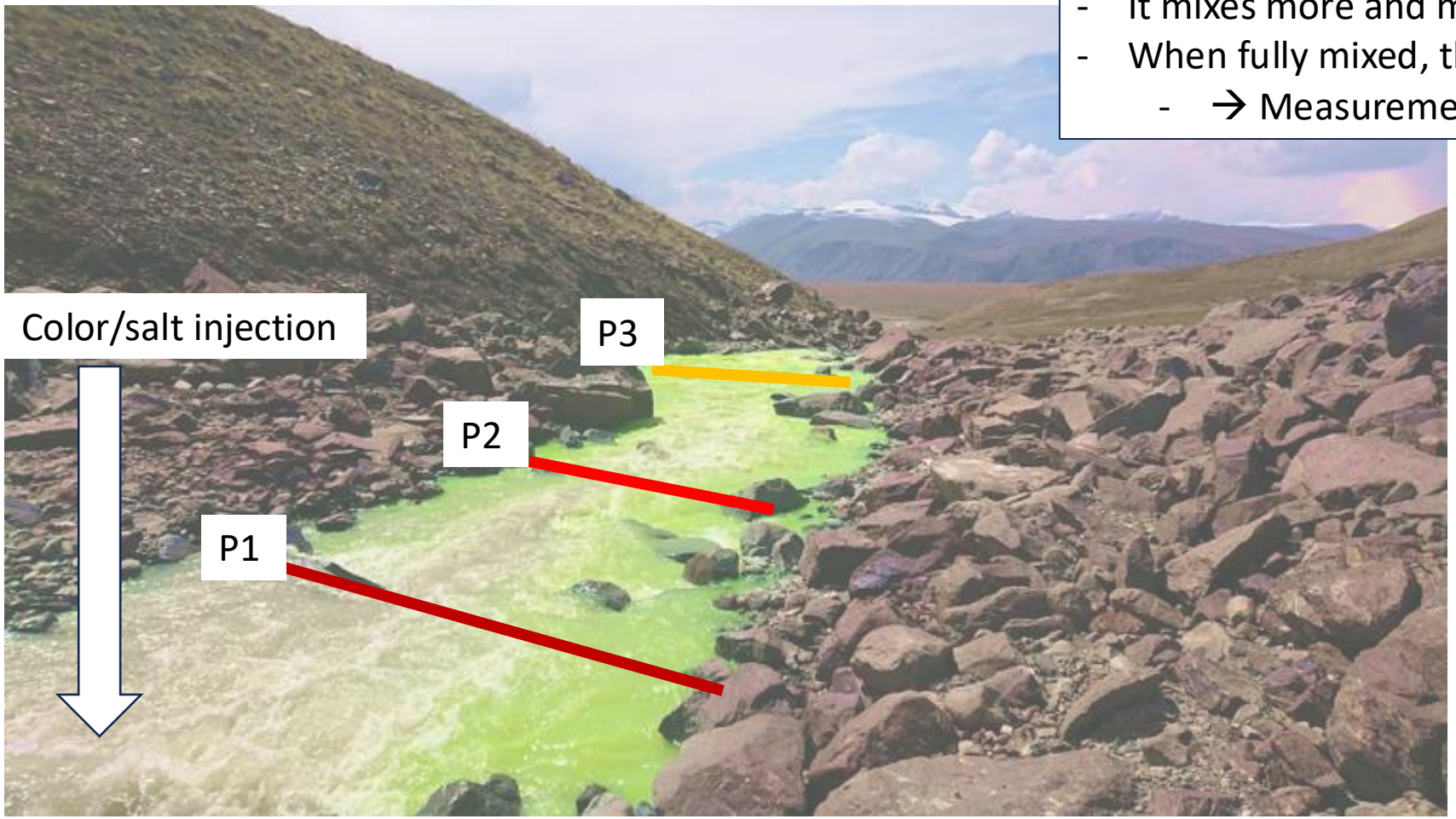


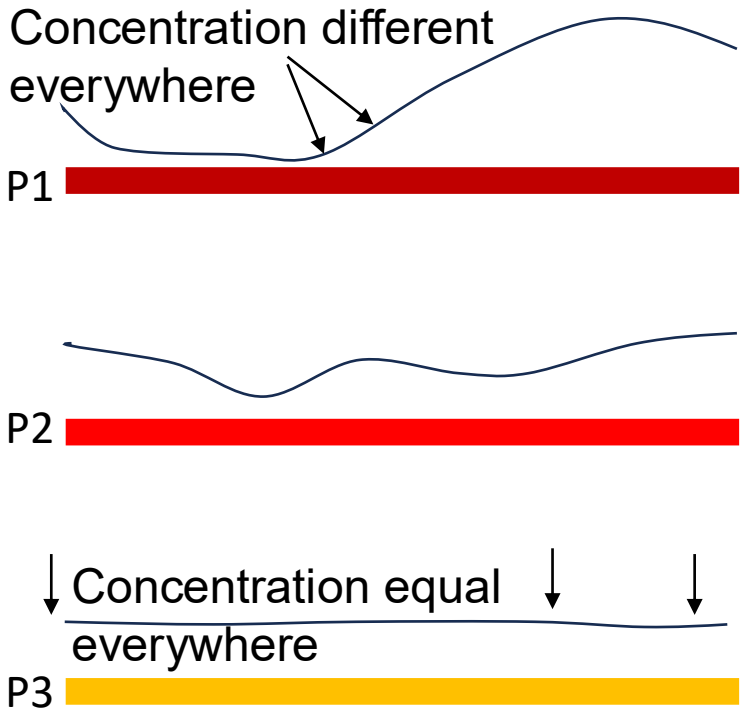
* 1 ppb = 1µg/l

- What is the dye tracer method?
  - Principles

Discharge – dilution method (salt or color)

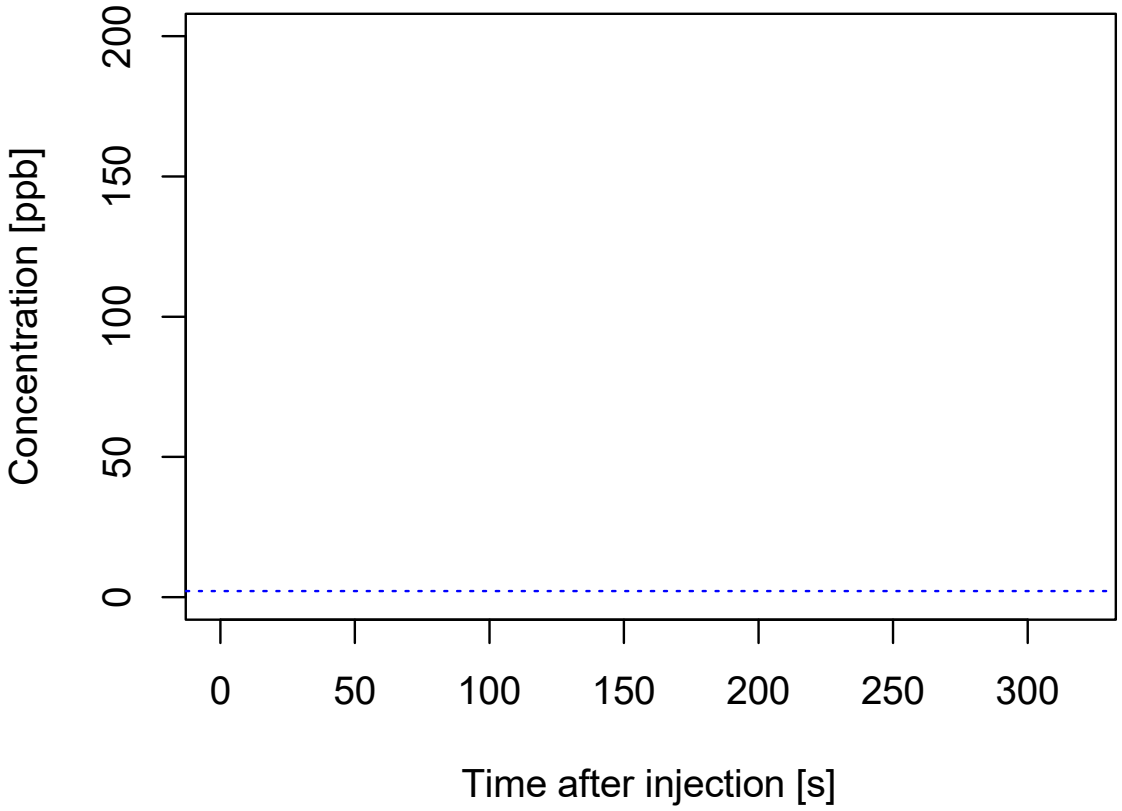
- Color/salt is injected at one point
- It mixes more and more the longer it travels downstream
- When fully mixed, the concentration is everywhere the same
  - → Measurement only at one point neccesary

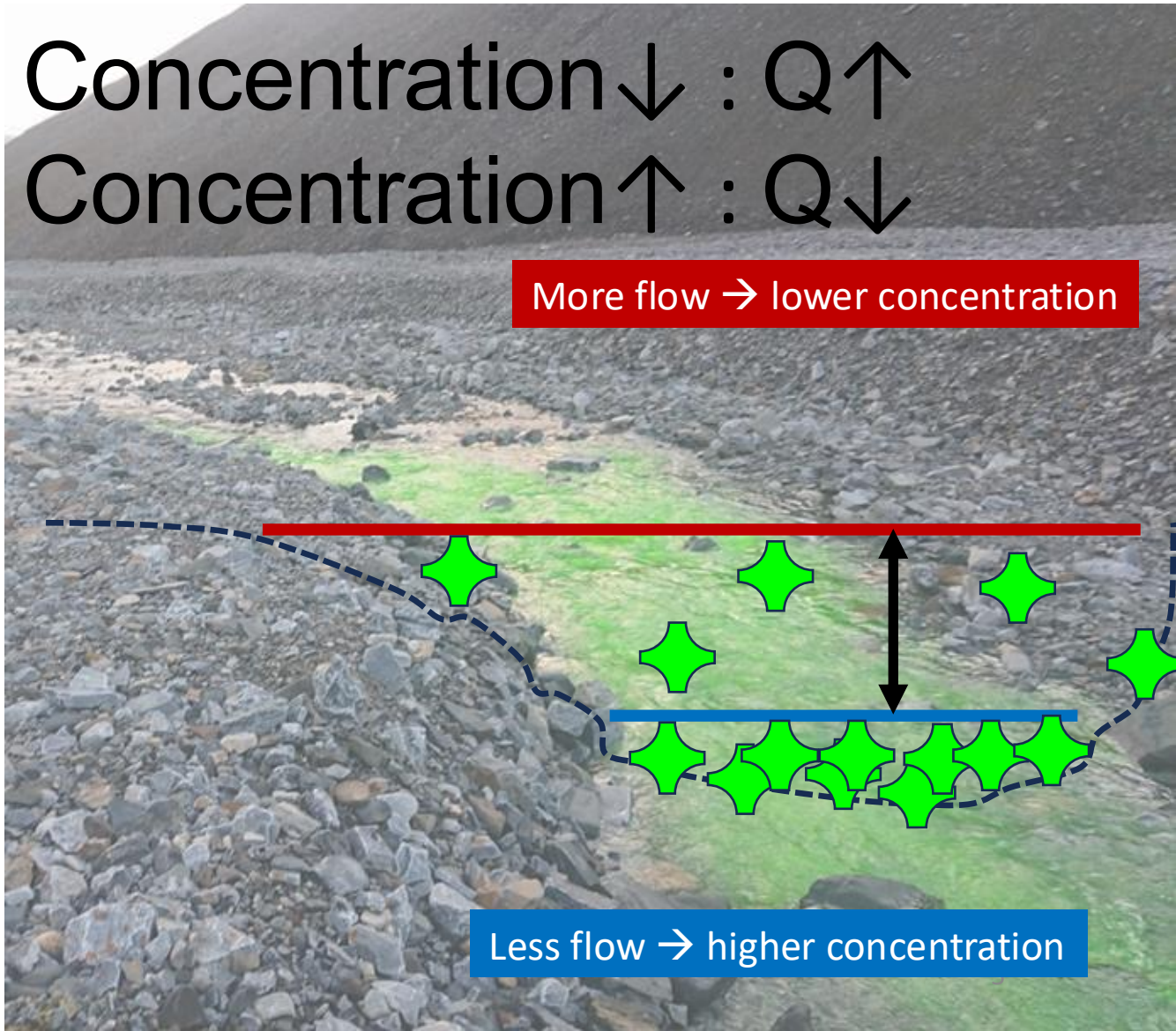




- What is the dye tracer method?
  - Principles

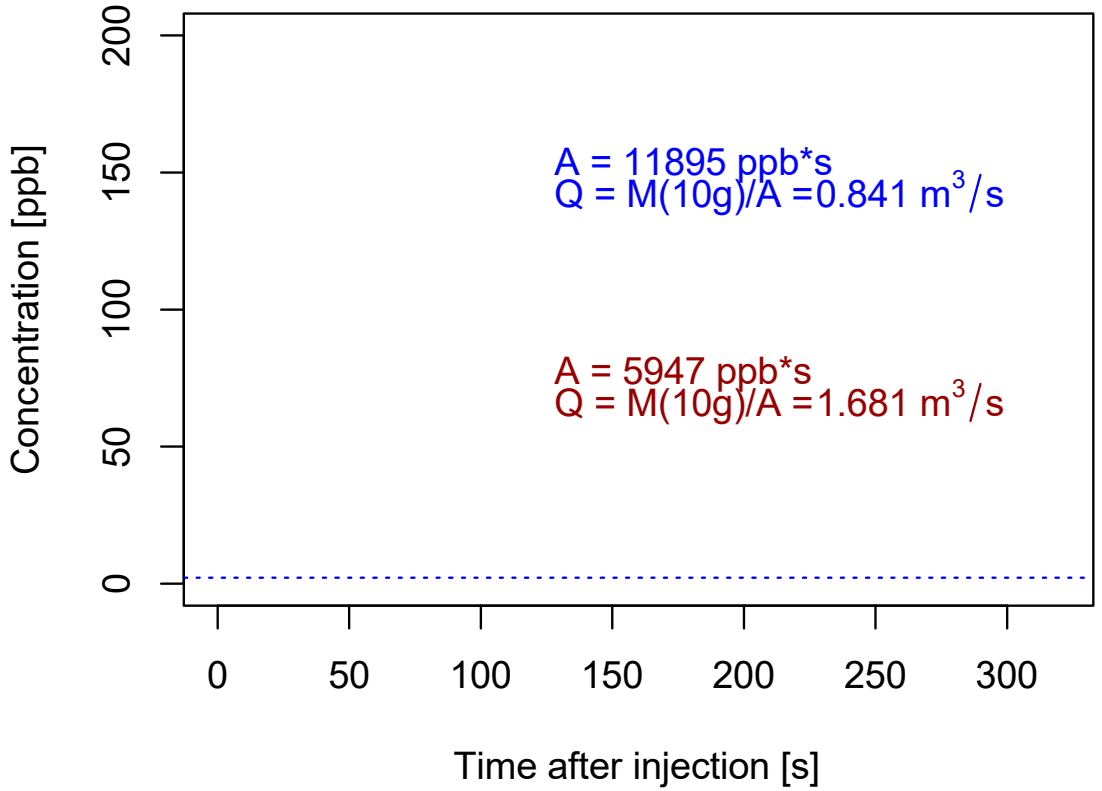
Discharge – dilution method (salt or color)





- What is the dye tracer method?
  - Principles

Discharge – dilution method (salt or color)



Example:
- 10 g of tracer mass

$$Q = \frac{M}{A},$$

Low flow:
- High concentration
- High A(rea under the curve)
- → M/A is small | Discharge is low

High flow:
- Low cocentration
- Small A(rea under the curve)
- → M/A is big | Discharge is high

Application – Where?

- Most rivers – size not so important
- Large river requires a lot of color/salt
- Color tests can be difficult if sediments are present
  - Better use salt in such cases
  - Color breaks down under sunlight
- Salt tests require a lot of salt (~1kg for $1m^3/s$)
  - But easy to conduct (only conductimeter needed)

Application – Color amount?

Total amount (how many grams and liters) depends on stream

Table 2: Amount of fluorescent dye needed to reach a peak concentration of 50–70 ppb during various discharge conditions. The amounts are listed for different types and concentrations of the dye tracers.

Discharge $m^3\ s^{-1}$	Tracer mass powder g	Tracer mass 20% solution ml	Tracer mass 40% solution ml	Salt [kg]
1	5	10	5	**1**
2	10	20	10	**2**
3	15	20	10	**3**
4	20	30	15	**4**
5	25	30	15	**5**
6	30	40	20	**6**
7	35	40	20	**7**
8	40	50	25	**8**
9	45	50	25	**9**
10	50	50	25	**10**
15	75	80	40	**15**
20	100	120	60	**20**

(from Dahlke 2014)

~ 0.5-3 m^3/s

~ 5-15 m^3/s

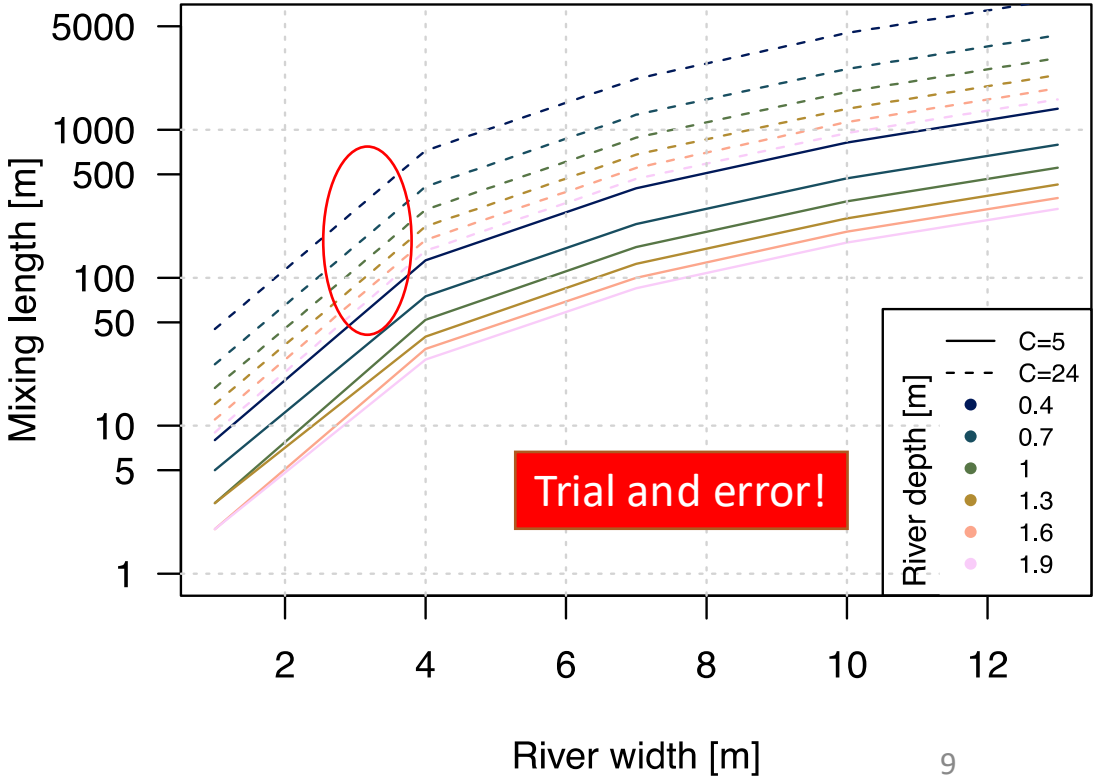
Application – Mixing length?

What distance is needed for good mixing?

- Injection point
- Measurement point
- Mixing length

The dye must be well-mixed in stream water!

Empirical estimation:
Example width=3m, depth=0.5m
→ At least 70m downstream
→ The further away, the better mixed
→ The further away the more tracer needed!

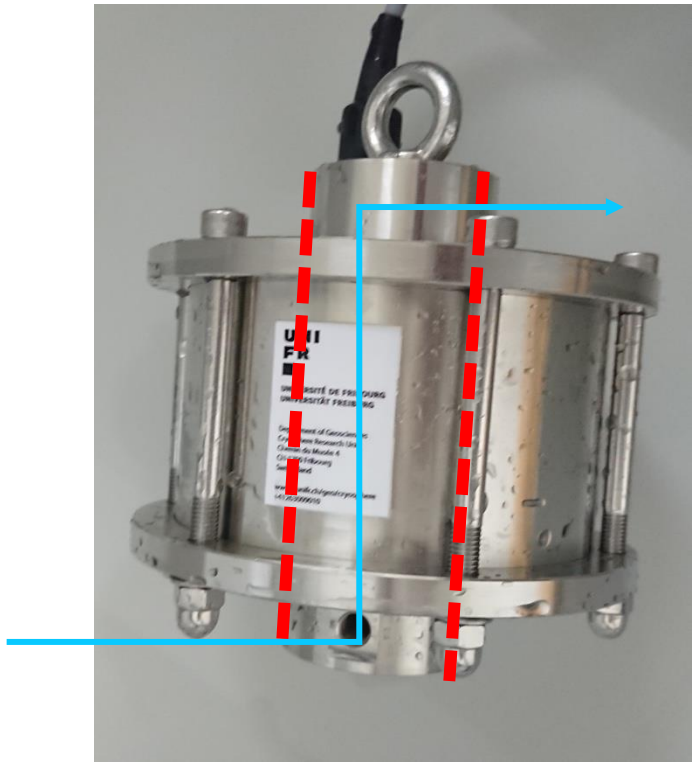


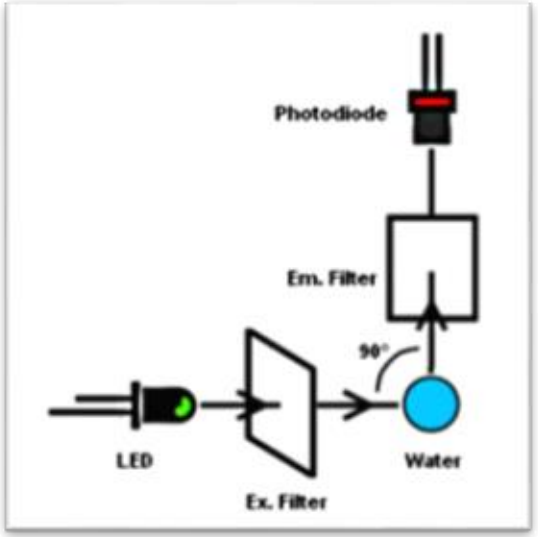
Application – Signal

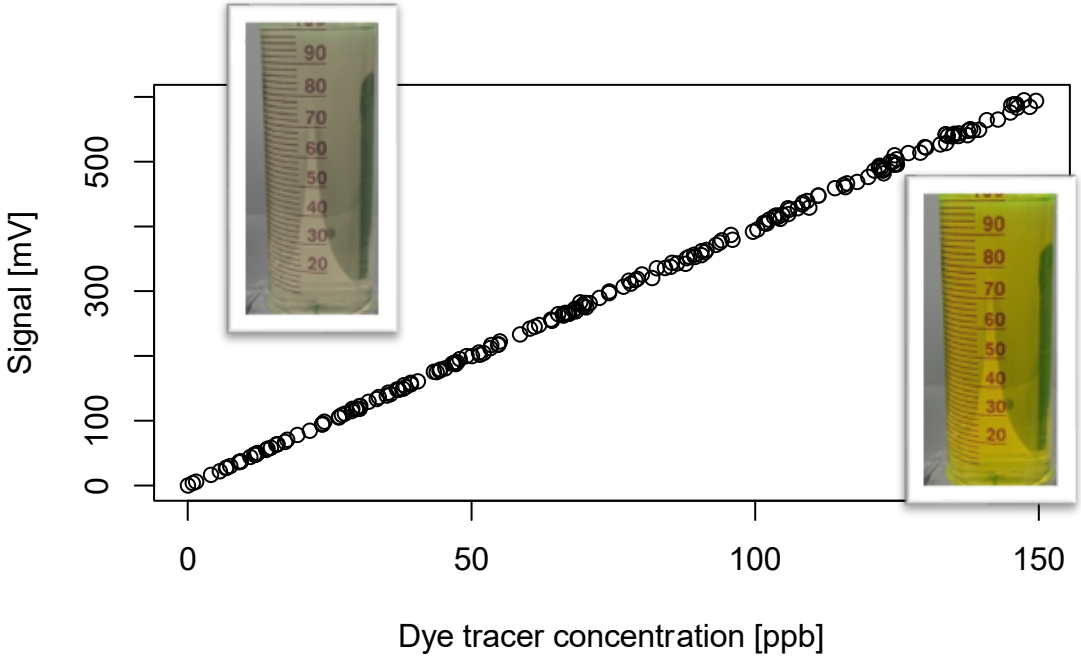
- Measure the concentration (salt/color)
- Instruments work electrically
  - → Electrical conductivity meter (salt)
  - → Photodiode Fluorometer (color)
  - The measured signal is **always relating to an electrical current: <u>conductivity</u> or <u>voltage</u>**
    - **→ Transform back into useable units !**
    - **→ Always calibration needed !**

Application - Fluorometer

- The dye tracer flows through the instrument
- Light (excitation wavelength) is emitted by a lamp and absorbed by the dye
- Light (emission wavelength) is emitted by the tracer and measured with photo diode
- The photo diode produces an electrical signal that is measured [mV]
- The more dye, the higher the signal (linear and proportional)

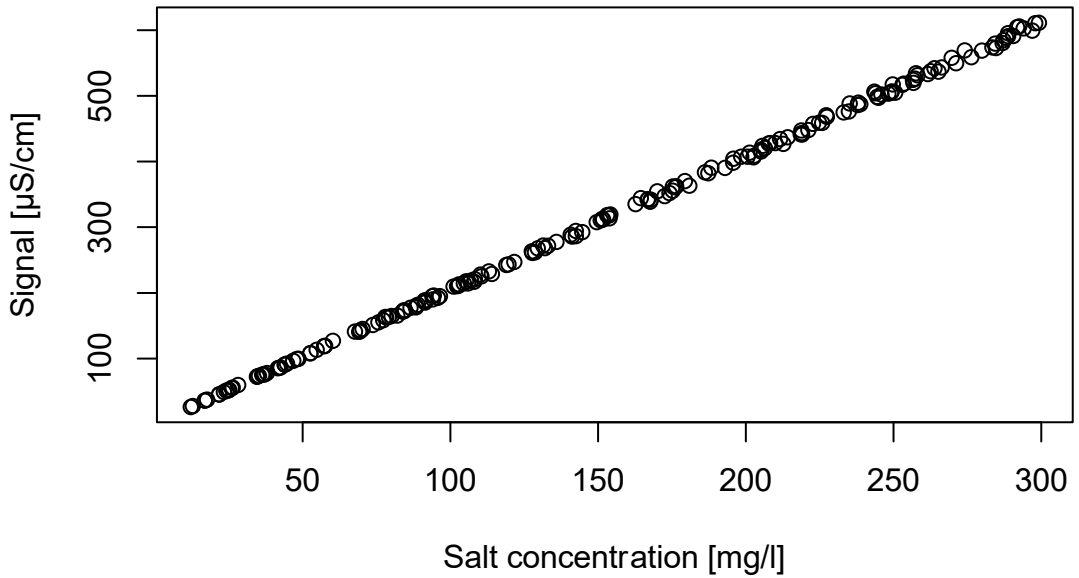






Application - Fluorometer

- The salt water flows pass the electrodes
- Electrical current flows between the electrodes – **conductivity [µS/cm]** is measured
- The more salt (ions), the more electrical current can flow (linear and proportional)
- Requires also calibration! (different salts, temperature and other environmental parameters affect conductivity)



Preparation - Fluorometer

- Dye tracer (**base solution**)
  - Industrially prepared solution (best but much heavier!)
    - Weighted mass solved in 1L of clean water
    - Total amount (how many liters) depends on streamflow
  - Powder (light-weight)
    - Weighted packs of e.g. 50 g (exact and precise amount not important)
  - Needed:
    - Scale
    - 1L cylinder
    - Lab tools (spatula,…)

50g/liter solution
(not yet in solution in this picture)

Preparation - Fluorometer

Write down all weights:
- Mixing flask
- Trace powder
- Final solution

- Dye tracer (**base solution**)
  - **From powder in the lab:**
    - Measure e.g. 50 g of powder using a lab scale:
      - Place 1L or 2L glass mixing flask on scale (lab scale)
      - Tare (set to 0)
      - Carefully add 50 g of powder using spatula and funnel (wear gloves)
    - Measure e.g. 50 g with precision scale:
      - Place small plastic vial on scale
      - Tare
      - Carefully add 50 g of powder to plastic vial using spatula
      - The powder needs to be transferred into the mixing flask
        - Add funnel to mixing flask
        - Pour powder into mixing flask
        - Rinse powder with water from plastic vial into mixing flask with squeeze bottle

50 ml plastic vial

Lab scale

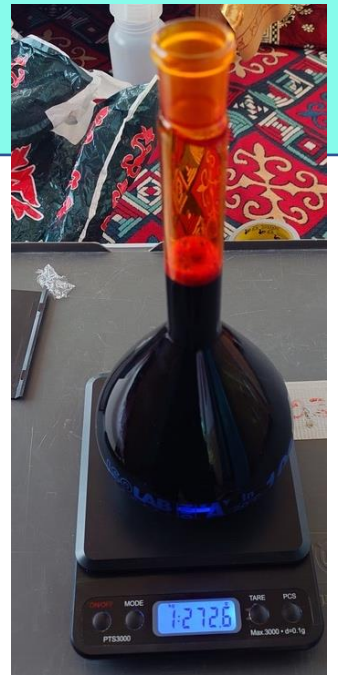
Adding 50 g of powder to mixing flask

Squeeze bottle (with water)

Mixing flask

Preparation - Fluorometer

Write down all weights:
- Mixing flask
- Trace powder
- Final solution

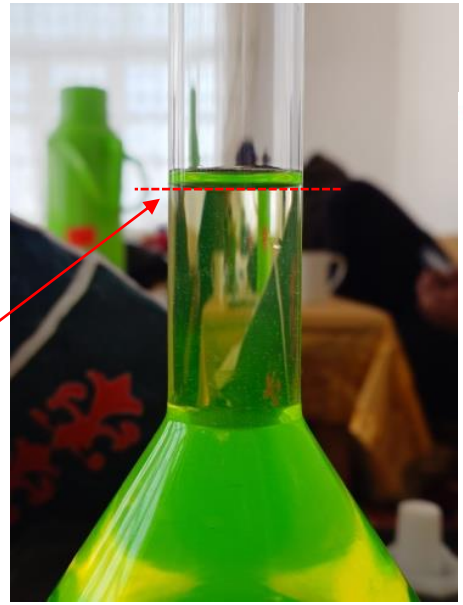


- Dye tracer (**base solution**)
  - **From powder in the lab:**
    - **Powder in the mixing flask:**
      - Add water to <u>solve</u> the Fluoresceine powder
      - Add water fast until ~2/3 full (use e.g. 1L cylinder)
      - Shake and stir until colour is <u>completely solved</u> (can take up to 30 minutes)
      - After it is solved, add water slowly to reach the 1L (or 2L) marker using squeeze bottle
        - Can be difficult to see because the solution is very dark red (see right side)
      - Write down all weights
      - Mix well !! (Stirring and shaking)

1L or 2L marker

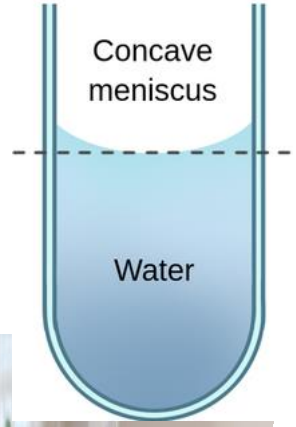
Solving before filling up

1L or 2L marker



Preparation - Fluorometer

- Dye tracer (**base solution**)
  - **From powder in the lab:**
    - **Powder in the mixing flask:**
      - **Base solution:**
        - Store in 1L PP bottle(s)



1L or 2L marker

Preparation – Fluorometer – Calibration liquid

Base solution = e.g. 50g/1L or 100g/1L

Using the Excel file: “05 - Lab preparation v 2025-07-15.xlsx”

Gravimetric preparation of calibration liquids

This sheet shall help you to calculate the correct amounts of tracer
Fill in the red marked cells with what you measure

Base solution/Standard concentration (g/L)	100.3	
Base solution/Standard density (kg/L)	1.0403	# measured
Bucket volume (L)	5	

Lab preparation	Dilution 1 (S1)		Dilution 2 (S2)		Dilution 3 (S3)		CALIBRATION FLUID 1		CALIBRATION FLUID 2		CALIBRATION FLUID 3		CALIBRATION FLUID 4		CALIBRATION FLUID 5	
Initial solution (to be collected)	*Volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***
	4.97	5.17	4.99	4.99	1000.00	1000		8		8		8		10		10
Final solution (mass in g)/size of mixing flask (ml)	1000		1000		1000		0.0000	µg (theoretical mass)	0.0000	µg (theoretical mass)	0.0000	µg (theoretical mass)	0.0000	µg (theoretical mass)	0.0000	µg (theoretical mass)
Dilution ratio	*Theoretical*	***Actual***	*Theoretical*	***Actual***	*Theoretical*	***Actual***	20.7006	µg (actual mass)	20.7006	µg (actual mass)	20.7006	µg (actual mass)	25.8757	µg (actual mass)	25.8757	µg (actual mass)
	4.97E-03	**4.9697E-03**	4.99E-03	**4.9900E-03**	1.00E+00	**1.0000E+00**										
Final dilution ratio	2.48E-05															
Concentration (mg/L)	518.5510		2.5876		2.5876											
Equipment used	10mL pipette/syringe & 2L(1L?) volumetric flask		10mL pipette/syringe & 2L(1L?) volumetric flask		10mL pipette/syringe & 2L(1L?) volumetric flask											
Production	Dilution of 10 mL base solution to 2L(1L?) water		Dilution of 10 mL of solution S1 with 2L(1L?) water		Dilution of 10 mL of solution S2 with 2L(1L?) water											
Current concentration of 50 ml in 5L. Transforming the g value of solution into g value of actual tracer powder - (µg/L) = ppb	5185.51		25.88		25.88											

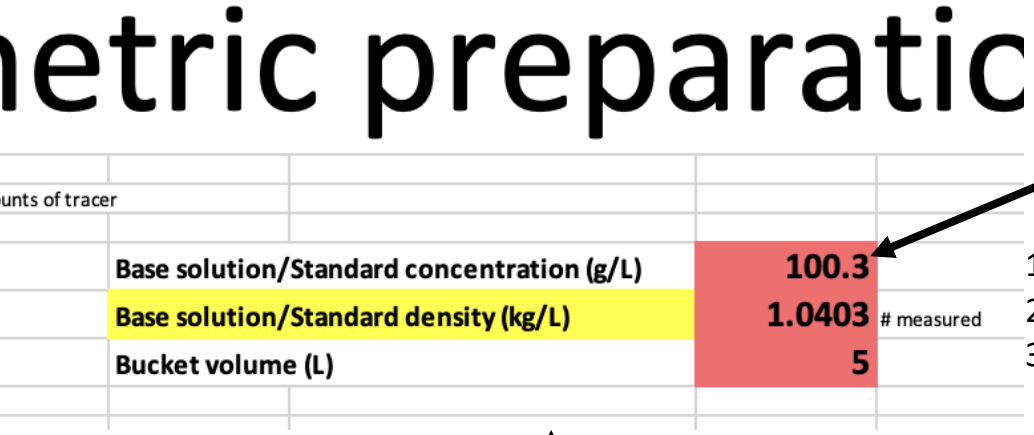
		Actual calibration [ppb]
Calibration series (final) in 5L bucket	1 step	4.13
	2 step	8.25
	3 step	12.36
	4 step	17.48
	5 step	22.57

Input values

Dilution concentration gravi | Help on injection preparation | +

Preparation – Fluorometer – Calibration & injection liquid

Using the Excel file: “05 - Lab preparation v 2025-07-15.xlsx”



Red fields need to be filled out!

1. : Concentration in g/l, e.g. 50 g/l
2. : Density = weight of the solution (weight Flask + solution – weight empty flask) / 1L
3. : How big is the bucket for calibration? Standard = 5L

Preparation – Fluorometer – Calibration & injection liquid

Formula Bar **lations based on discharge and time of travel hypothesis:**

Hypothesis	low	high
Discharge (m^3/s) :	0.25	2
Tracer time of travel (s) :	200	1800

Input values

Sample to prepare (ml) :	Estimated discharge (m^3/s)				
Estimated time of travel (s)	0.25	0.6875	1.125	1.5625	2
200	4.99	13.71	22.43	31.16	39.88
600	14.96	41.13	67.30	93.47	119.64
1000	24.93	68.54	112.16	155.78	199.40
1400	34.90	95.96	157.03	218.10	279.16
1800	44.87	123.38	201.89	280.41	358.92

How much color for injection?

Dilution concentration gravi | Help on injection preparation | +

Preparation – Fluorometer – Calibration & injection liquid

Formula Bar **lations based on discharge and time of travel hypothesis:**

Hypothesis	low	high
Discharge (m^3/s) :	0.25	2
Tracer time of travel (s) :	200	1800

How much discharge do we expect? (min and max)
How long is the color travelling from injection to measurement?

Sample to prepare (ml) :	Estimated discharge (m^3/s)				
Estimated time of travel (s)	0.25	0.6875	1.125	1.5625	2
200	4.99	13.71	22.43	31.16	39.88
600	14.96	41.13	67.30	93.47	119.64
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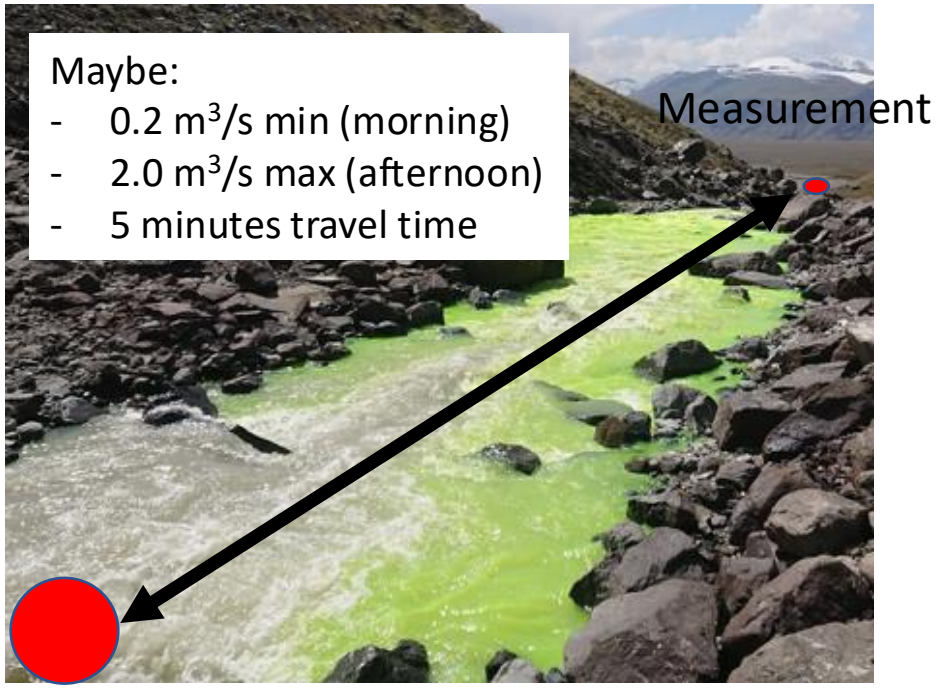

Dilution concentration gravi | Help on injection preparation | +

Preparation – Fluorometer – Calibration & injection liquid

Formula Bar **lations based on discharge and time of travel hypothesis:**

Hypothesis	low	high
Discharge (m^3/s) :	0.25	2
Tracer time of travel (s) :	200	1800

Input values

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e.g. 200 second travel time, 2 m^3/s Q → 40 g of base liquid

e.g. 1000 second travel time, 1.125 m^3/s Q → 112 g base liquid

e.g. 1800 second travel time, 0.25 m^3/s Q → 45 g base liquid

For each combination of discharge (Q) and travel time we get an estimate of how much color we need to inject

Dilution concentration gravi | Help on injection preparation | +

Preparation – Fluorometer – Calibration & injection liquid

Formula Bar **lations based on discharge and time of travel hypothesis:**

Hypothesis	low	high
Discharge (m^3/s) :	0.25	2
Tracer time of travel (s) :	200	1800

Input values

Sample to prepare (ml) :	Estimated discharge (m^3/s) 0.25	0.6875	1.125	1.5625	2
Estimated time of travel (s) 200	4.99	13.71	22.43	31.16	39.88
600	14.96				
1000	24.93				
1400	34.90				
1800	44.87				

$$m\ (g) = Q\ (m3/s) * T\ (s) * a / b$$

The estimates are for a final concentration at the measurement location in the water of 10 ppb (a=0.01); you can increase the value here, and all the base liquid estimates in the table will change automatically.

a = 0.01

b = 0.1003

a - target concentration in mg/L --> here 10 µg/L = 10 ppb

b - tracer liquid concentration [g(tracer)/g(water)]

a : base value : 0.003

Dilution concentration gravi | Help on injection preparation | +

Preparation – Fluorometer – Calibration & injection liquid

Formula Bar **lations based on discharge and time of travel hypothesis:**

Hypothesis	low	high
Discharge (m³/s) :	0.25	2
Tracer time of travel (s) :	200	1800

Input values

Sample to prepare (ml) :	Estimated discharge (m³/s) 0.25	0.6875	1.125	1.5625	2
Estimated time of travel (s) 200	4.99	13.71	22.43	31.16	39.88
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1800	44.87	123.38	201.89	280.41	358.92

$$m\ (g) = Q\ (m3/s) * T\ (s) * a / b$$

a = 0.01

b = 0.1003

a - target concentration in mg/L --> here 10 µg/L = 10 ppb

b - tracer liquid concentration [g(tracer)/g(water)]

a : base value : 0.003

The base liquid concentration (b) is automatically taken from the first sheet; no need to change anything. Here with 100.3 g/L base solution example.

Dilution concentration gravi | Help on injection preparation | +

Preparation – Fluorometer – Calibration & injection liquid

Formula Bar **lations based on discharge and time of travel hypothesis:**

Hypothesis	low	high
Discharge (m^3/s) :	0.25	2
Tracer time of travel (s) :	200	1800

Input values

Sample to prepare (ml) :	Estimated discharge (m^3/s) 0.25	0.6875	1.125	1.5625	2
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1400	34.90	95.96	157.03	218.10	279.16
1800	44.87	123.38	201.89	280.41	358.92

$$m\ (g) = Q\ (m3/s) * T\ (s) * a / b$$

a = 0.01

b = 0.1003

a - target concentration in mg/L --> here 10 µg/L = 10 ppb

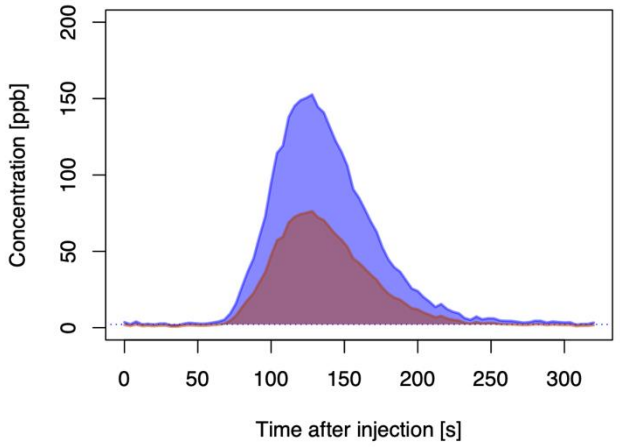
b - tracer liquid concentration [g(tracer)/g(water)]

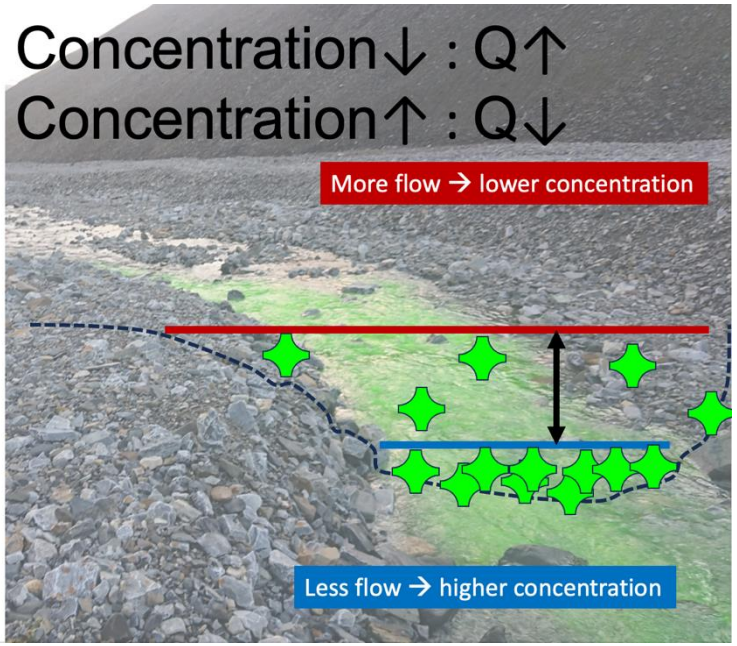
Example:

- We expect 1.5 m^3/s discharge, the travel time is 10 minutes (=600 seconds)
- To get a maximum concentration at the fluorometer of 10 ppb with a base liquid concentration of 100 g/L, we should **inject 93 g of the base liquid**!
- A bit more or less is perfectly fine: 80 and 120 g will both work perfectly fine!

Dilution concentration gravi | Help on injection preparation | +

Preparation – Fluorometer – Calibration & injection liquid





Sample to prepare (ml) :		Estimated discharge (m³/s)				
		0.25	0.6875	1.125	1.5625	2
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	600	14.96	41.13	67.30	93.47	119.64
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	1400	34.90	95.96	157.03	218.10	279.16
	1800	44.87	123.38	201.89	280.41	358.92

During the day, the water flow will change. E.g. low flow in the morning and high flow in the afternoon.

Example: Slow flow, low discharge in the morning → 35 g of base solution

Example: Fast flow, high discharge in the afternoon → 120 g of base solution

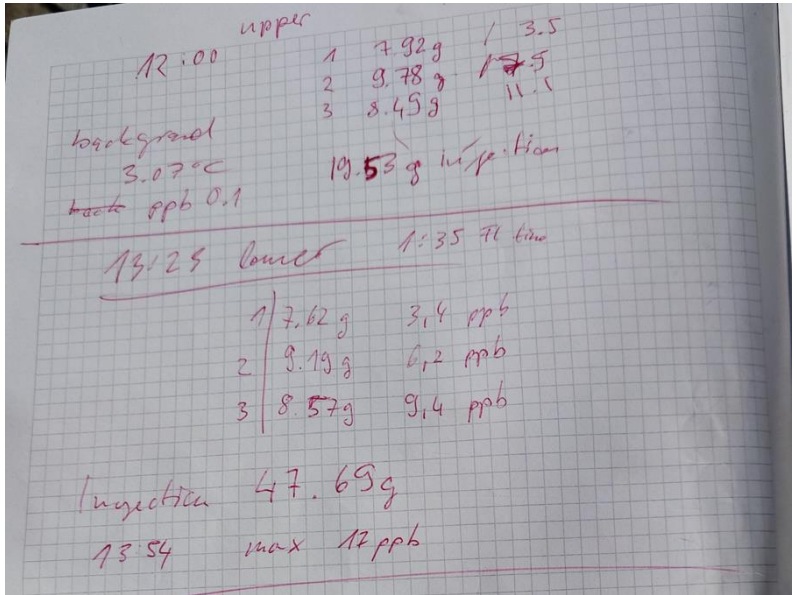
- → Some vials with 35 g and some with 120 g
- → Make **more small** amounts than high amounts:
  - → You can use multiple small amounts for injection
  - → You <u>cannot</u> split a high amount into smaller ones!!

Preparation – Fluorometer – Calibration & injection liquid

- → Prepare all injection vials before going into the field !
- → Write down the weight on the vials (see picture on the right)
- → Store all vials in an opaque plastic bag(s) (0 % sunlight)
- → Store the bag in a fridge
- → Transport the bag inside another opaque backpack

→ Avoid any exposure to sunlight !!!

Fieldbook notes on calibration and injection amounts, local time, travel time, and maximum recorded concentration by the fluorometer.



Injection vials just before measurement. Write down always the weights in your fieldbook!!! Here, two small ones (9.51 g and 10.00 g) were use for a single injection.

40.13 g injection vial

Preparation – Fluorometer – Calibration liquid

Using the Excel file: “05 - Lab preparation v 2025-07-15.xlsx”

Gravimetric preparation of calibration liquids

This sheet shall help you to calculate the correct amounts of tracer
Fill in the red marked cells with what you measure

Red fields need to be filled out!
The next slides show how to do this!

Base solution/Standard concentration (g/L)	100.3
Base solution/Standard density (kg/L)	1.0403 # measured
Bucket volume (L)	5

		Dilution 1 (S1)		Dilution 2 (S2)		Dilution 3 (S3)		CALIBRATION FLUID 1		CALIBRATION FLUID 2		CALIBRATION FLUID 3		CALIBRATION FLUID 4		CALIBRATION FLUID 5	
Lab preparation	Initial solution (to be collected)	*Volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***
		4.97	5.17	4.99	4.99	1000.00	1000		8		8		8		10		10
	Final solution (mass in g)/size of mixing flask (ml)	1000		1000		1000		0.0000	µg (theoretical mass)	0.0000	µg (theoretical mass)	0.0000	µg (theoretical mass)	0.0000	µg (theoretical mass)	0.0000	µg (theoretical mass)
	Dilution ratio	*Theoretical*	***Actual***	*Theoretical*	***Actual***	*Theoretical*	***Actual***	20.7006	µg (actual mass)	20.7006	µg (actual mass)	20.7006	µg (actual mass)	25.8757	µg (actual mass)	25.8757	µg (actual mass)
		4.97E-03	4.9697E-03	4.99E-03	4.9900E-03	1.00E+00	1.0000E+00										
	Final dilution ratio	2.48E-05															
	Concentration (mg/L)	518.5510		2.5876		2.5876											
	Equipment used	10mL pipette/syringe & 2L(1L?) volumetric flask		10mL pipette/syringe & 2L(1L?) volumetric flask		10mL pipette/syringe & 2L(1L?) volumetric flask											
	Production	Dilution of 10 mL base solution to 2L(1L?) water		Dilution of 10 mL of solution S1 with 2L(1L?) water		Dilution of 10 mL of solution S2 with 2L(1L?) water											
	Current concentration of 50 ml in 5L. Transforming the g value of solution into g value of actual tracer powder - (µg/L) = ppb	5185.51		25.88		25.88											

		Actual calibration [ppb]
Calibration series (final) in 5L bucket	1 step	4.13
	2 step	8.25
	3 step	12.36
	4 step	17.48
	5 step	22.57

Input values

Preparation – Fluorometer – Calibration liquid

Using the Excel file: “05 - Lab preparation v 2025-07-15.xlsx”

Gravimetric preparation of calibration liquids

Base solution/Standard concentration (g/L)	100.3
Base solution/Standard density (kg/L)	1.0403
Bucket volume (L)	5

The first three fields need to be filled out already at the start to determine how much injection liquid you need.

Lab preparation

	Dilution 1 (S1)		Dilution 2 (S2)		Dilution 3 (S3)	
	4.97	5.17	4.99	4.99	1000.00	1000
Final solution (mass in g)/size of mixing flask (ml)	1000		1000		1000	
Dilution ratio	Theoretical	Actual	Theoretical	Actual	Theoretical	Actual
	4.97E-03	4.9697E-03	4.99E-03	4.9900E-03	1.00E+00	1.0000E+00
Final dilution ratio	2.48E-05					
Concentration (mg/L)	518.5510		2.5876		2.5876	
Equipment used	10mL pipette/syringe & 2L(1L?) volumetric flask		10mL pipette/syringe & 2L(1L?) volumetric flask		10mL pipette/syringe & 2L(1L?) volumetric flask	
Production	Dilution of 10 mL base solution to 2L(1L?) water		Dilution of 10 mL of solution S1 with 2L(1L?) water		Dilution of 10 mL of solution S2 with 2L(1L?) water	
Current concentration of 50 ml in 5L. Transforming the g value of solution into g value of actual tracer powder - (µg/L) = ppb	5185.51		25.88		25.88	

Theoretical volume (mL)	Collected mass (g)	Theoretical volume (mL)	Collected mass (g)	Theoretical volume (mL)	Collected mass (g)	Theoretical volume (mL)	Collected mass (g)	Theoretical volume (mL)	Collected mass (g)
	8		8		8		10		10
0.0000	µg (theoretical mass)	0.0000	µg (theoretical mass)	0.0000	µg (theoretical mass)	0.0000	µg (theoretical mass)	0.0000	µg (theoretical mass)
20.7006	µg (actual mass)	20.7006	µg (actual mass)	20.7006	µg (actual mass)	25.8757	µg (actual mass)	25.8757	µg (actual mass)

Input values

Calibration series (final) in 5L bucket	Actual calibration [ppb]
1 step	4.13
2 step	8.25
3 step	12.36
4 step	17.48
5 step	22.57

Preparation – Fluorometer – Calibration liquid

Using the Excel file: “05 - Lab preparation v 2025-07-15.xlsx”

Gravimetric preparation of calibration liquids

This sheet shall help you to calculate the correct amounts of tracer
Fill in the red marked cells with what you measure

Base solution/Standard concentration (g/L)	100.3	
Base solution/Standard density (kg/L)	1.0403	# measured
Bucket volume (L)	5	

		Dilution 1 (S1)		Dilution 2 (S2)		Dilution 3 (S	
Lab preparation	Initial solution (to be collected)	Volume (mL)	Collected mass (g)	Theoretical volume (mL)	Collected mass (g)	Theoretical volume (mL)	Colle
		4.97	5.17	4.99	4.99	1000.00	
	Final solution (mass in g)/size of mixing flask (ml)	1000		1000		1000	
	Dilution ratio	Theoretical	Actual	Theoretical	Actual	Theoretical	
		4.97E-03	4.9697E-03	4.99E-03	4.9900E-03	1.00E+00	1.
	Final dilution ratio	2.48E-05					
	Concentration (mg/L)	518.5510		2.5876		2.5876	
	Equipment used	10mL pipette/syringe & 2L(1L?) volumetric flask		10mL pipette/syringe & 2L(1L?) volumetric flask		10mL pipette/syringe & 2L(1L?) volumetric flask	
	Production	Dilution of 10 mL base solution to 2L(1L?) water		Dilution of 10 mL of solution S1 with 2L(1L?) water		Dilution of 10 mL of solution S2 with 2L(1L?) water	
	Current concentration of 50 ml in 5L. Transforming the g value of solution into g value of actual tracer powder - (µg/L) = ppb	5185.51					

Input values

For the fluorometer calibration we need known concentrations of tracer. This allows to relate the mV signal of the fluorometer to the actual concentration. Aim for at least 3 calibration points (3 additions of calibration liquid to the 5L bucket).

		Actual calibration [ppb]
Calibration series (final) in 5L bucket	1 step	4.13
	2 step	8.25
	3 step	12.36
	4 step	17.48
	5 step	22.57

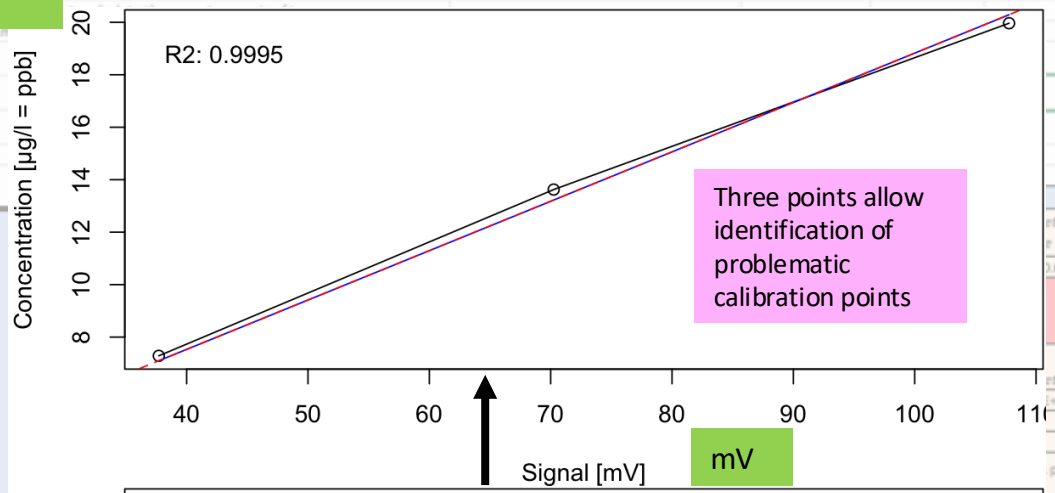
In sheet 2, we said we want to use around 10 ppb as maximum concentration. The calibration steps should therefore be around this value. Here between ~4 and ~12 ppb.

Preparation – Fluorometer – Calibration liquid

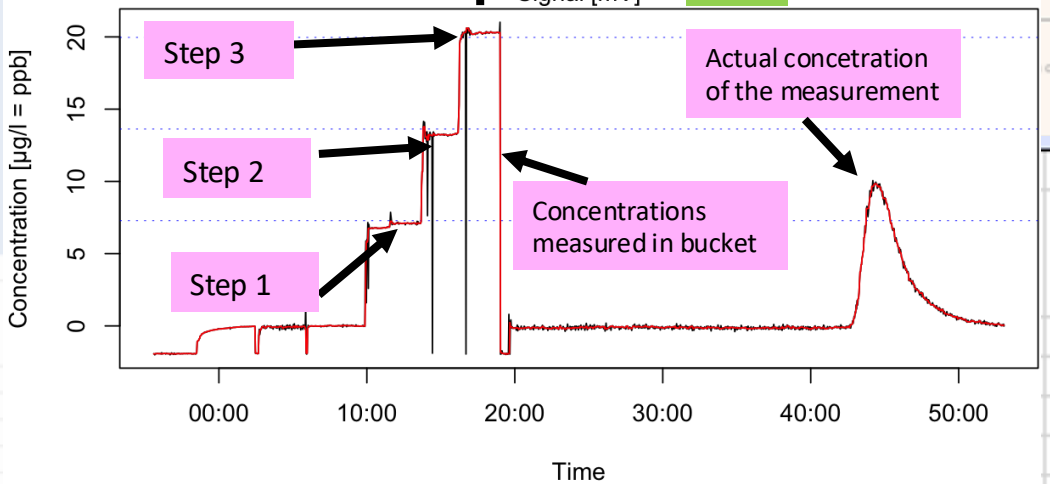
Using the Excel file: “05 - Lab preparation v 2025-07-15.xlsx”

Gravimetric preparation of calibration liquids

ppb or µg/L



mV



For the fluorometer calibration we need known concentrations of tracer. This allows to relate the mV signal of the fluorometer to the actual concentration. Aim for at least 3 calibration points (3 additions of calibration liquid to the 5L bucket).

	Actual calibration [ppb]
1 step	4.13
2 step	8.25
3 step	12.36
4 step	17.48
5 step	22.57

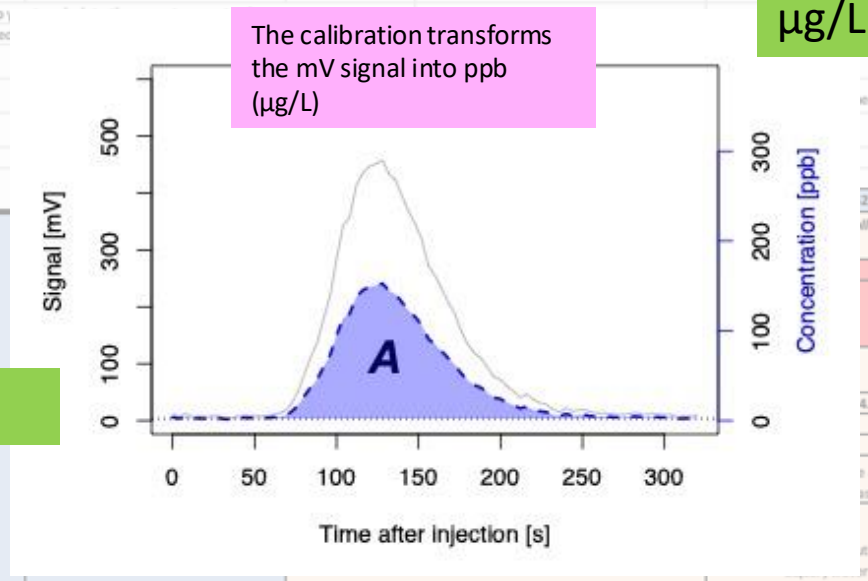
Preparation – Fluorometer – Calibration liquid

Using the Excel file: “05 - Lab preparation v 2025-07-15.xlsx”

Gravimetric preparation of calibration liquids

ppb = µg/L

The calibration transforms the mV signal into ppb (µg/L)



mV

For the fluorometer calibration we need known concentrations of tracer. This allows to relate the mV signal of the fluorometer to the actual concentration. Aim for at least 3 calibration points (3 additions of calibration liquid to the 5L bucket).

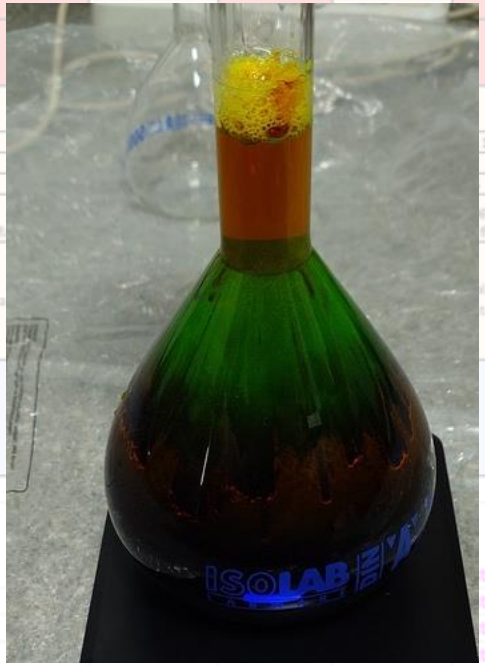
		Actual calibration [ppb]
Calibration series (final) in 5L bucket	1 step	4.13
	2 step	8.25
	3 step	12.36
	4 step	17.48
	5 step	22.57

Preparation – Fluorometer – Calibration liquid

How to get these calibration points?

- The base solution has a concetration of e.g. **50 g/l**
- We need calibration liquid that makes concentrations of around **5 ppb in a 5 L bucket**
- **50 g/l = 50’000 mg/l = 50’000’000 µg/l (ppb)** – this is much too high
- **We must dilute the liquid by more than 1/1’000’000 !**

dilute



dilute

Preparation – Fluorometer – Calibration liquid

How to get these calibration points?

Gravimetric preparation of calibration liquids

This sheet shall help you to calculate the correct amounts of tracer
Fill in the red marked cells with what you measure

Base solution/Standard concentration (g/L) 100.3

Dilution 1 (S1)	
Volume (mL)	*Collected mass (g)*
4.97	5.17
1000	

The fields show how much tracer (base solution) we would use to dilute the base in how much clear water. This solution is then called S1

Amount of base solution in [g]

Diluted in how much volume [ml]

Lab preparation			
Initial solution (to be			
Final solution (mass flask (ml)			
Dilution ratio			
Final dilution ratio			
Concentration (mg/L)	518.5510	2.5876	
Equipment used	10mL pipette/syringe & 2L(1L?) volumetric flask	10mL pipette/syringe & 2L(1L?) volumetric flask	
Production	Dilution of 10 mL base solution to 2L(1L?) water	Dilution of 10 mL of solution S1 with 2L(1L?) water	2L(1L?) water
Current concentration of 50 ml in 5L. Transforming the g value of solution into g value of actual tracer powder - (µg/L) = ppb	5185.51	25.88	25.88

CALIBRATION FLUID 5	
Theoretical volume (mL)	Collected mass (g)
	10
0.0000	µg (theoretical mass)
	µg (actual mass)

Theoretical	Actual				
20.7006 mass)	20.7006 mass)	20.7006 mass)	25.8757 mass)	25.8757	

Actual calibration [ppb]

Calibration series (final) in 5L bucket	
1 step	4.13
2 step	8.25
3 step	12.36
4 step	17.48
5 step	22.57

Input values

Preparation – Fluorometer – Calibration liquid

How to get these calibration points?

Gravimetric preparation of calibration liquids

This sheet shall help you to calculate the correct amounts of tracer
Fill in the red marked cells with what you measure

Base solution/Standard concentration (g/L) 100.3

Dilution 1 (S1)	
Volume (mL)	*Collected mass (g)*
4.97	5.17
1000	

	Dilution 3 (S3)		CALIBRATION FLUID 1		CALIBRATION FLUID 2		CALIBRATION FLUID 3		CALIBRATION FLUID 4		CALIBRATION FLUID 5	
	Theoretical volume (mL)	*Collected mass (g)*	*Theoretical volume (mL)*	*Collected mass (g)*	*Theoretical volume (mL)*	*Collected mass (g)*	*Theoretical volume (mL)*	*Collected mass (g)*	*Theoretical volume (mL)*	*Collected mass (g)*	*Theoretical volume (mL)*	*Collected mass (g)*
	1000.00	1000		8		8		8		10		10
	1000		0.0000	µg (theoretical mass)	0.0000	µg (theoretical mass)	0.0000	µg (theoretical mass)	0.0000	µg (theoretical mass)	0.0000	µg (theoretical mass)
	Theoretical	*Actual*	20.7006	µg (actual mass)	20.7006	µg (actual mass)	20.7006	µg (actual mass)	25.8757	µg (actual mass)	25.8757	µg (actual mass)

Initial solution (to be
Final solution (mass flask (ml)
Dilution ratio
Final dilution ratio 2.48E-05

	518.5510	2.5876
	10mL pipette/syringe & 2L(1L?) volumetric flask	10mL pipette/syringe & 2L(1L?) volumetric flask
	Dilution of 10 mL base solution to [illegible] water	Dilution of 10 mL of solution S1 with 2L(1L?) water
	5185.51	25.88

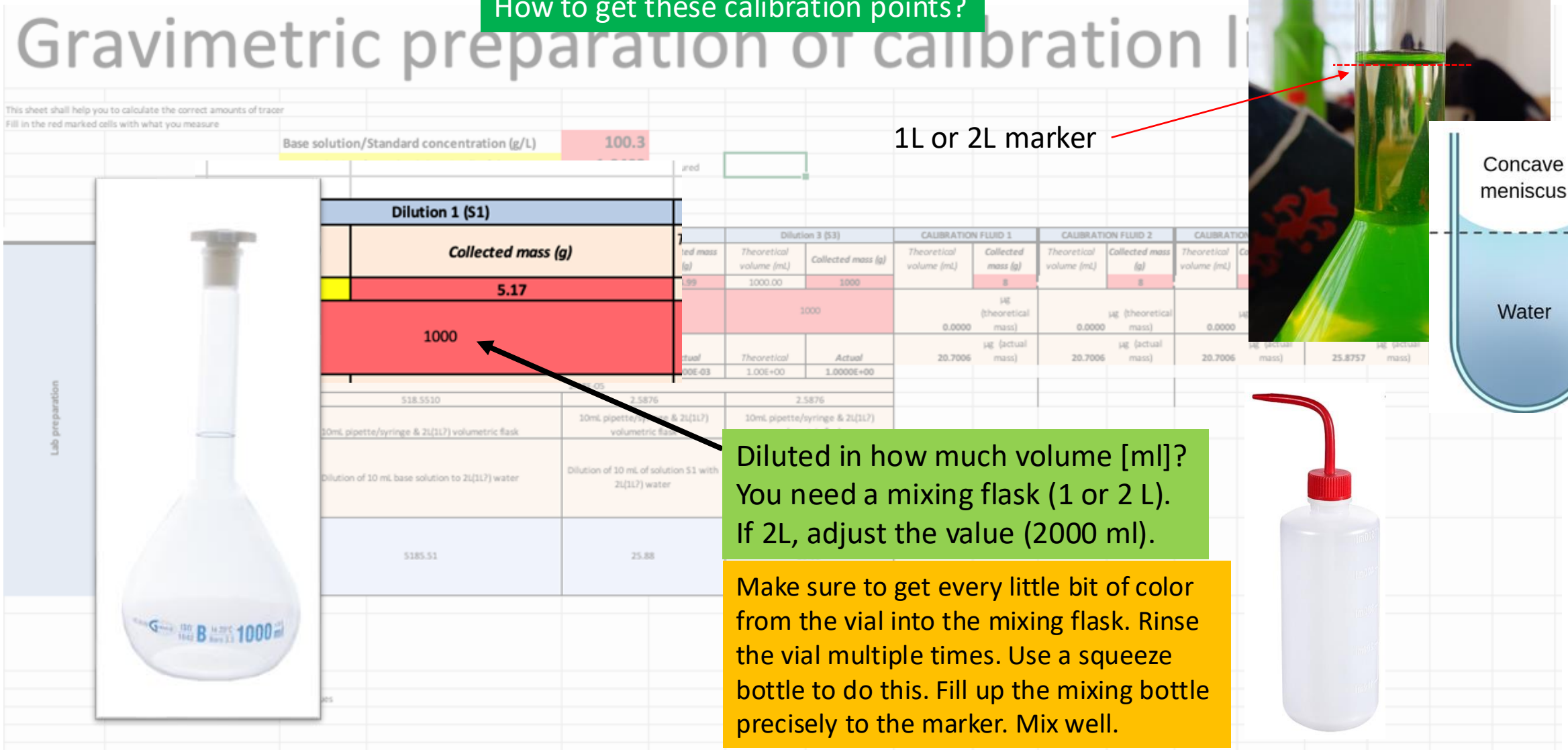
values

Amount of base solution in [g]? Measured with a precision scale (0.01 g precision with a Pesola 200g precision scale).

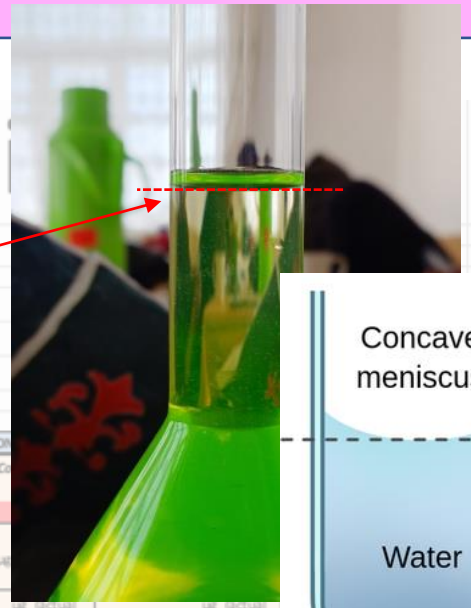
Make sure to calibrate the scale before using !!! There are calibration weights that come with the scale. Instructions are inside the scale lid.

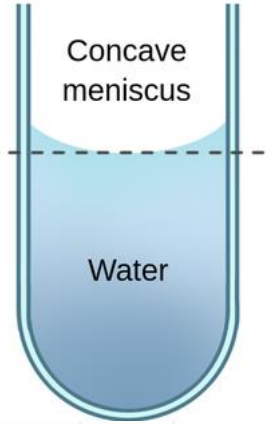
Preparation – Fluorometer – Calibration liquid

How to get these calibration points?



1L or 2L marker





Diluted in how much volume [ml]?
You need a mixing flask (1 or 2 L).
If 2L, adjust the value (2000 ml).

Make sure to get every little bit of color from the vial into the mixing flask. Rinse the vial multiple times. Use a squeeze bottle to do this. Fill up the mixing bottle precisely to the marker. Mix well.

Preparation – Fluorometer – Calibration liquid

How to get these calibration points?

Gravimetric preparation of calibration liquids

This sheet shall help you to calculate the correct amounts of tracer
Fill in the red marked cells with what you measure

Base solution/Standard concentration (g/L) 100.3

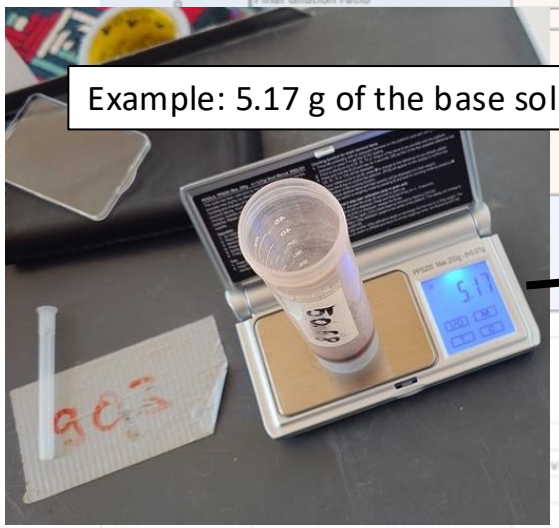
Dilution 1 (S1)	
Volume (mL)	*Collected mass (g)*
4.97	5.17
1000	

The fields show how much tracer (base solution) we would use to dilute the base in how much clear water.

Amount of base solution in [g]

Diluted in how much volume [ml]

Example: 5.17 g of the base solution diluted in 1L of water



Calibration series (final) in 5L bucket		Actual calibration [ppb]
	1 step	4.13
	2 step	8.25
	3 step	12.36
	4 step	17.48
	5 step	22.57

Preparation – Fluorometer – Calibration liquid

How to get these calibration points?

Dilution 1 (S1)		
Initial solution (to be collected)	*Volume (mL)*	***Collected mass (g)***
	4.97	5.17
Final solution (mass in g)/size of mixing flask (ml)	1000	
Dilution ratio	*Theoretical*	***Actual***
	4.97E-03	4.9697E-03
Final dilution ratio		
Concentration (mg/L)	518.5510	

Using 5.17 g of a 100.3 g/L base solution in 1L of water reduces the concentration to 518 mg/L

Change the "collected mass" in the Excel sheet to see how it affects the 3 calibration step concentrations.

Dilution 1 (S1)	
Volume (mL)	***Collected mass (g)***
9.61	10
1000	

Calibration series (final) in 5L bucket		Actual calibration [ppb]
	1 step	8.00
	2 step	15.96
	3 step	23.91
	4 step	33.80
	5 step	43.66

Dilution 1 (S1)	
Volume (mL)	***Collected mass (g)***
1.92	2
1000	

Calibration series (final) in 5L bucket		Actual calibration [ppb]
	1 step	1.60
	2 step	3.19
	3 step	4.78
	4 step	6.76
	5 step	8.73

Preparation – Fluorometer – Calibration liquid

How to get these calibration points?

Gravimetric preparation of calibration liquids

This sheet shall help you to calculate the correct amounts of tracer
Fill in the red marked cells with what you measure

Dilution 1 (S1)		Dilution 2 (S2)		Dilution 3 (S3)		CALIBRATION FLUID 1		CALIBRATION FLUID 2		CALIBRATION FLUID 3	
Volume (mL)	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***
4.97	5.17	4.99	4.99	1000.00	1000		8		8		8
1000		1000		1000		0.0000	µg (theoretical mass)	0.0000	µg (theoretical mass)	0.0000	µg (theoretical mass)
Theoretical	***Actual***	*Theoretical*	***Actual***	*Theoretical*	***Actual***	20.7006	µg (actual mass)	20.7006	µg (actual mass)	20.7006	µg (actual mass)
4.97E-03	4.9697E-03	4.99E-03	4.9900E-03	1.00E+00	1.0000E+00						
2.48E-05											
518.5510		2.5876		2.5876							

Production

Current concentration of 50 ml in 5L. Transforming the g value of solution into g value of actual tracer powder - (µg/L) = ppb

Input values

Actual calibration [ppb]

		Actual calibration [ppb]
Calibration series (final) in 5L bucket	1 step	1.60
	2 step	3.19
	3 step	4.78
	4 step	6.76
	5 step	8.73

Every choice in the dilution process will affect the resulting calibration concentration.

Rule of thumb:
- The less dilution steps, the better → Less mistakes
- The more mass to be diluted, the better → Less problems due to measurement precision

Preparation – Fluorometer – Calibration liquid

How to get these calibration points?

Gravimetric preparation of calibration liquids

This sheet shall help you to calculate the correct amounts of tracer
Fill in the red marked cells with what you measure

	Dilution 1 (S1)		Dilution 2 (S2)	
Initial solution (to be collected)	*Volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***
	4.97	5.17	4.99	4.99
Final solution (mass in g)/size of mixing flask (ml)	1000		1000	
Dilution ratio	*Theoretical*	***Actual***	*Theoretical*	***Actual***
	4.97E-03	4.9697E-03	4.99E-03	4.9900E-03
Final dilution ratio	2.48E-05			
Concentration (mg/L)	518.5510		2.5876	

Using 4.99 g of this diluted solution (S1) again in 1L, reduces the concentration to 2.59 mg/L

Using 5.17 g of a 100.3 g/L base solution in 1L of water reduces the concentration to 518 mg/L → S1

Use ~5 g of collected mass as minimum mass with the Pesola precision scale!

Preparation – Fluorometer – Calibration liquid

How to get these calibration points?

Gravimetric preparation of calibration liquids

Dilution 2 (S2)		Dilution 3 (S3)		CALIBRATION FLUID 1		CALIBRATION FLUID 2		CALIBRATION FLUID 3	
Theoretical volume (mL)	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***
4.99	**4.99**	1000.00	**1000**		**8**		**8**		**8**
1000		1000		**0.0000**	µg (theoretical mass)	**0.0000**	µg (theoretical mass)	**0.0000**	µg (theoretical mass)
Theoretical	***Actual***	*Theoretical*	***Actual***	**20.7006**	µg (actual mass)	**20.7006**	µg (actual mass)	**20.7006**	µg (actual mass)
4.99E-03	**4.9900E-03**	1.00E+00	**1.0000E+00**						
2.48E-05									
2.5876		2.5876							

If we would take now 8 g of this solution S2 …

… and dilute it in the 5L bucket, we get this concentration (4.13 ppb)

		Actual calibration [ppb]
Calibration series (final) in 5L bucket	1 step	4.13
	2 step	8.25
	3 step	12.36
	4 step	17.48

Preparation – Fluorometer – Calibration liquid

How to get these calibration points?

Gravimetric preparation of calibration liquids

Dilution 2 (S2)		Dilution 3 (S3)		CALIBRATION FLUID 1		CALIBRATION FLUID 2		CALIBRATION FLUID 3	
Theoretical volume (mL)	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***
4.99	**4.99**	1000.00	**1000**		**8**		**8**		**8**
1000		1000		**0.0000**	µg (theoretical mass)	**0.0000**	µg (theoretical mass)	**0.0000**	µg (theoretical mass)
Theoretical	***Actual***	*Theoretical*	***Actual***	**20.7006**	µg (actual mass)	**20.7006**	µg (actual mass)	**20.7006**	µg (actual mass)
4.99E-03	**4.9900E-03**	1.00E+00	**1.0000E+00**						
2.48E-05									
2.5876									

Dilution Step 3 is optional. Only needed

- If you have a high concentration base solution >100g/l
- If you aim for lower peak concentrations (in low sediment rivers, < 5 pbb work very well; fluorometers often have 0.1 ppb precision)

If not needed → use same value for collected mass and final mass (in the example 1000 and 1000 → no dilution)

Preparation – Fluorometer – Calibration liquid

How to get these calibration points?

Gravimetric preparation of calibration liquids

Dilution 2 (S2)		Dilution 3 (S3)		CALIBRATION FLUID 1		CALIBRATION FLUID 2		CALIBRATION FLUID 3	
Theoretical volume (mL)	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***
4.99	**4.99**	1000.00	**1000**		**8**		**8**		**8**
1000		1000		**0.0000**	µg (theoretical mass)	**0.0000**	µg (theoretical mass)	**0.0000**	µg (theoretical mass)
Theoretical	***Actual***	*Theoretical*	***Actual***	**20.7006**	µg (actual mass)	**20.7006**	µg (actual mass)	**20.7006**	µg (actual mass)
4.99E-03	**4.9900E-03**	1.00E+00	**1.0000E+00**						
2.48E-05									
2.5876									

For the calibration liquid and injection liquid, the more is better.

Equipment used	10mL pipette/syringe & 2L(1L?) volumetric flask	volumetric flask	volumetric flask
Production	Dilution of 10 mL base solution to 2L(1L?) water	Dilution of 10 mL of solution S1 with 2L(1L?) water	Dilution of 10 mL of solution S2 with 2L(1L?) water
Current concentration of 50 ml in 5L. Transforming the g value of solution into g value of actual tracer powder - (µg/L) = ppb	5185.51	25.88	25.88

Calibration series (final) in 5L bucket		Actual calibration [ppb]
	1 step	4.13
	2 step	8.25
Input values	3 step	12.36
	4 step	17.48
	5 step	22.57

Preparation – Fluorometer – Calibration liquid

WARNING

Gravimetri on of calibration liquids

Dilution 1 (S1)		Dilution 2 (S2)		Dilution 3 (S3)	
Volume (mL)	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***	*Theoretical volume (mL)*	***Collected mass (g)***
0.03	**0.03**	1000.00	**1000**	1000.00	**1000**
1000		1000		1000	
Theoretical	***Actual***	*Theoretical*	***Actual***	*Theoretical*	***Actual***
2.88E-05	**2.8838E-05**	1.00E+00	**1.0000E+00**	1.00E+00	**1.0000E+00**
2.88E-05					
3.0090		3.0090		3.0090	

Theoretically, you could directly take a very low amount from the base solution and don't dilute in the next steps (S2, S3)

But the measurement error (precision scale) increases too much for small masses ! 💀 **Use ~5 g mass from any previous solution as minimum when using the Pesola precision scale!**

Preparation – Fluorometer – Calibration

- Prepare the calibration liquid <u>always</u> from the same base solution that you use for measurements
- Prepare at best 3 calibration liquids for each measurement (e.g. **10 measurements → 30 calibration** vials)
- Keep the liquids (base, injection, calibration) **ALWAYS protected from sunlight**
  - Use plastic bags to keep the vials together
  - Keep the plastic bag within a backpack that is protecting 100% from sunlight
  - Only take out any of the liquids just before you use them in the field
- You can prepare all liquids before the fieldwork (fridge)
- **Attention: If you prepare the liquid at low altitude and travel to high altitude, it increases the pressure in the tubes. You can release some pressure in that case or else the vials might <u>leak!!!!</u>**
- **<u>Do not use leaked vials – difficult to tell which one leaked in the bag. Better to release the pressure. Close vials very tight.</u>**

Setup

- Discharge measurement
- Fluorescine sodium /Uranine

FL30 Fluorometer

Outflow (downstream) on top

low (upstream) at bottom

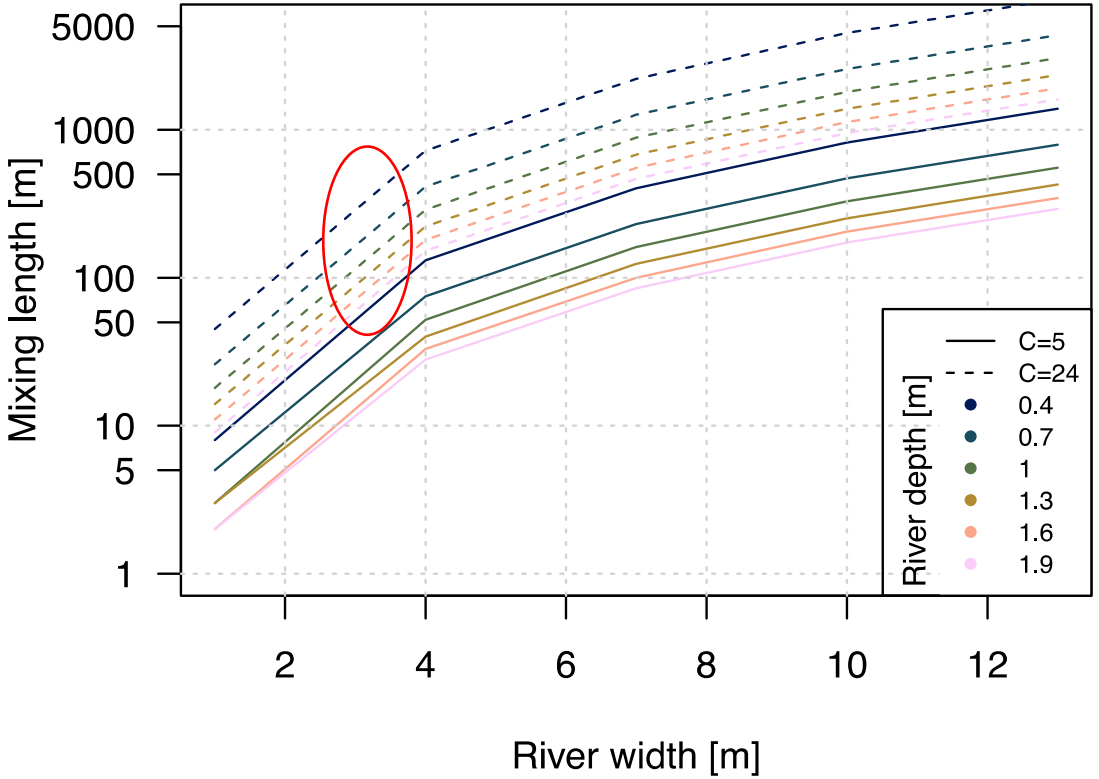
If there is a lot of sediments, you can change the direction: top=inlet, bottom=outlet

Setup

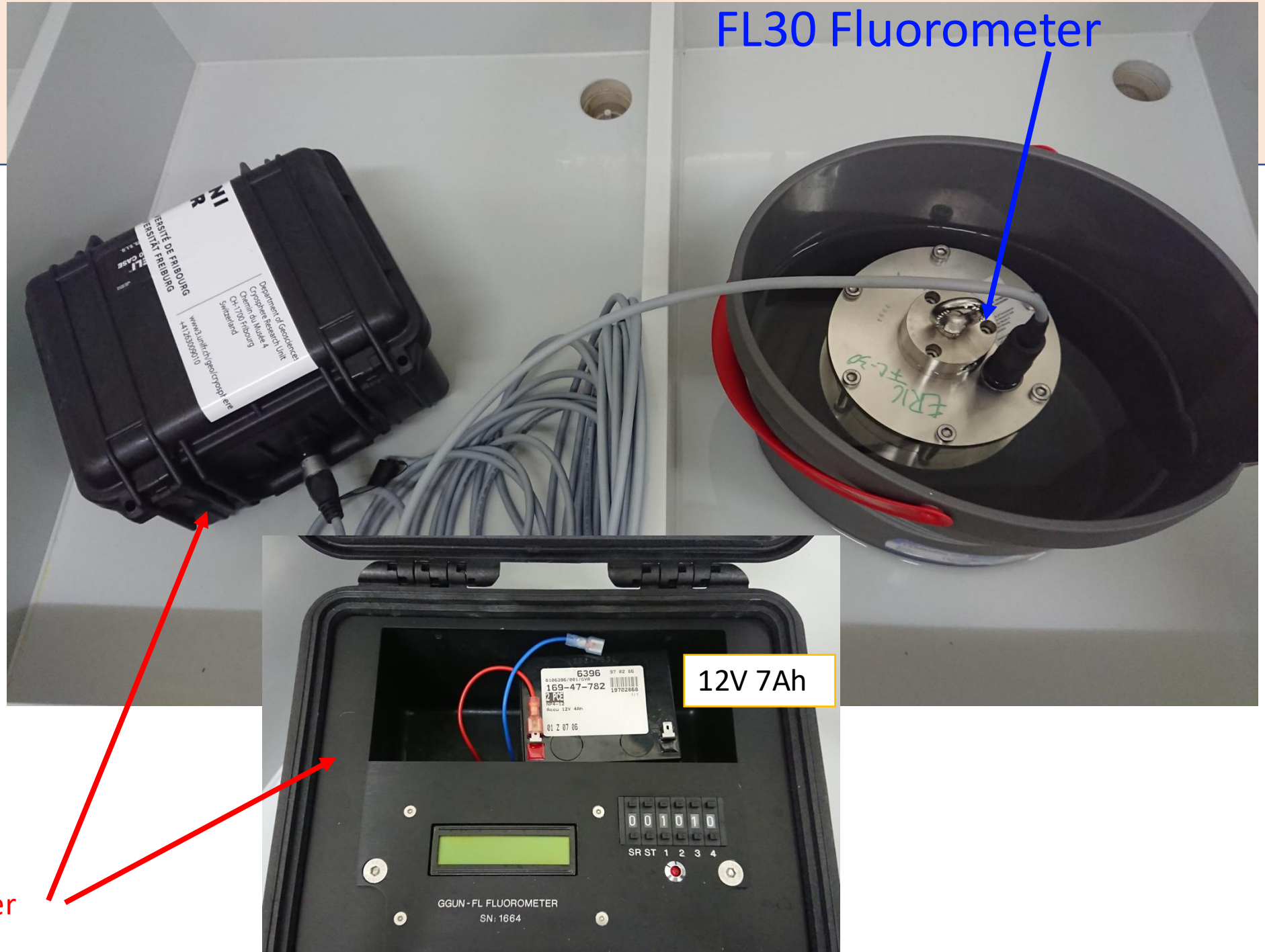
- Injection point
- Measurement point
- Mixing length

The dye must be well-mixed in stream water!

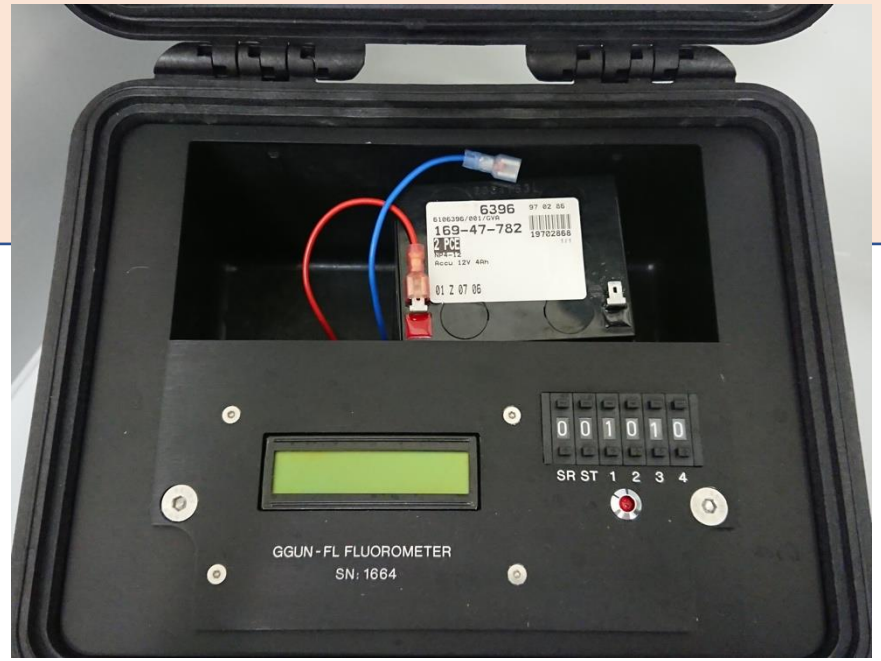
Empirical estimation:
Example width=3m, depth=0.5m
→ At least 70m downstream
→ The further away, the better mixed
→ The further away the more tracer needed!

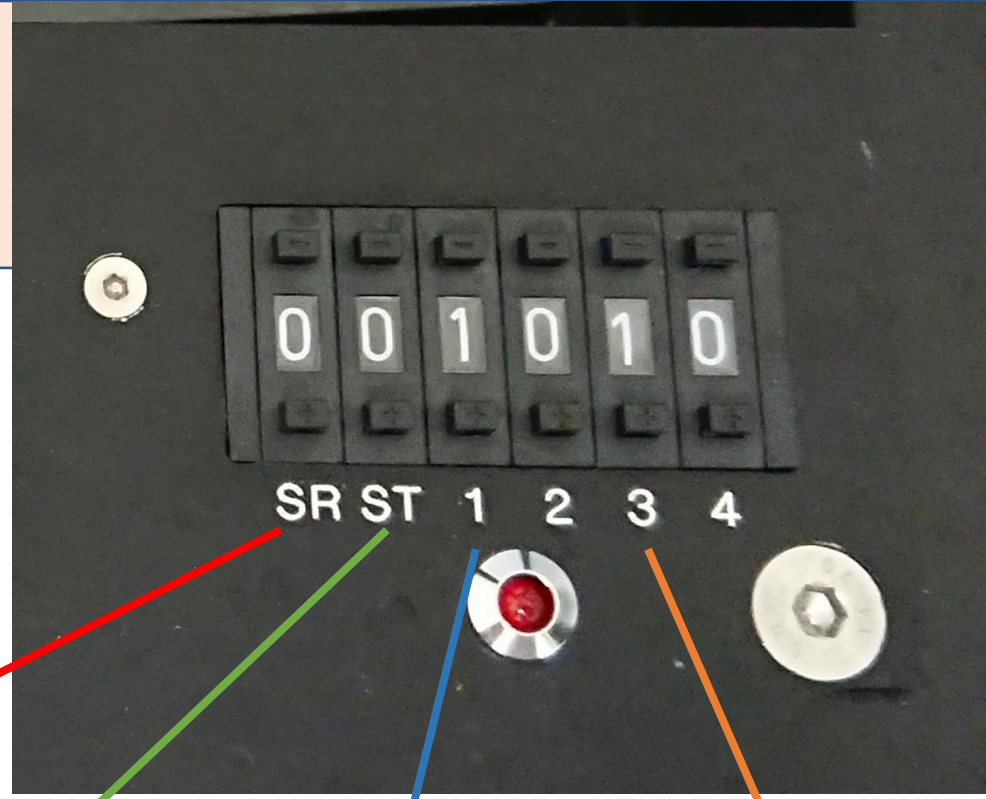


Setup


FL30 Fluorometer
12V 7Ah
GGUN-FL FLUOROMETER
SN: 1664
SR ST 1 2 3 4
Data logger

Setup





SR: Sampling rate; “0” is 2 second interval

ST: Stop; must be “0” to run

Tracer:
“1” – Fluorescine/Uranine
“2” – Rhodamine
“3” – Type III/IV

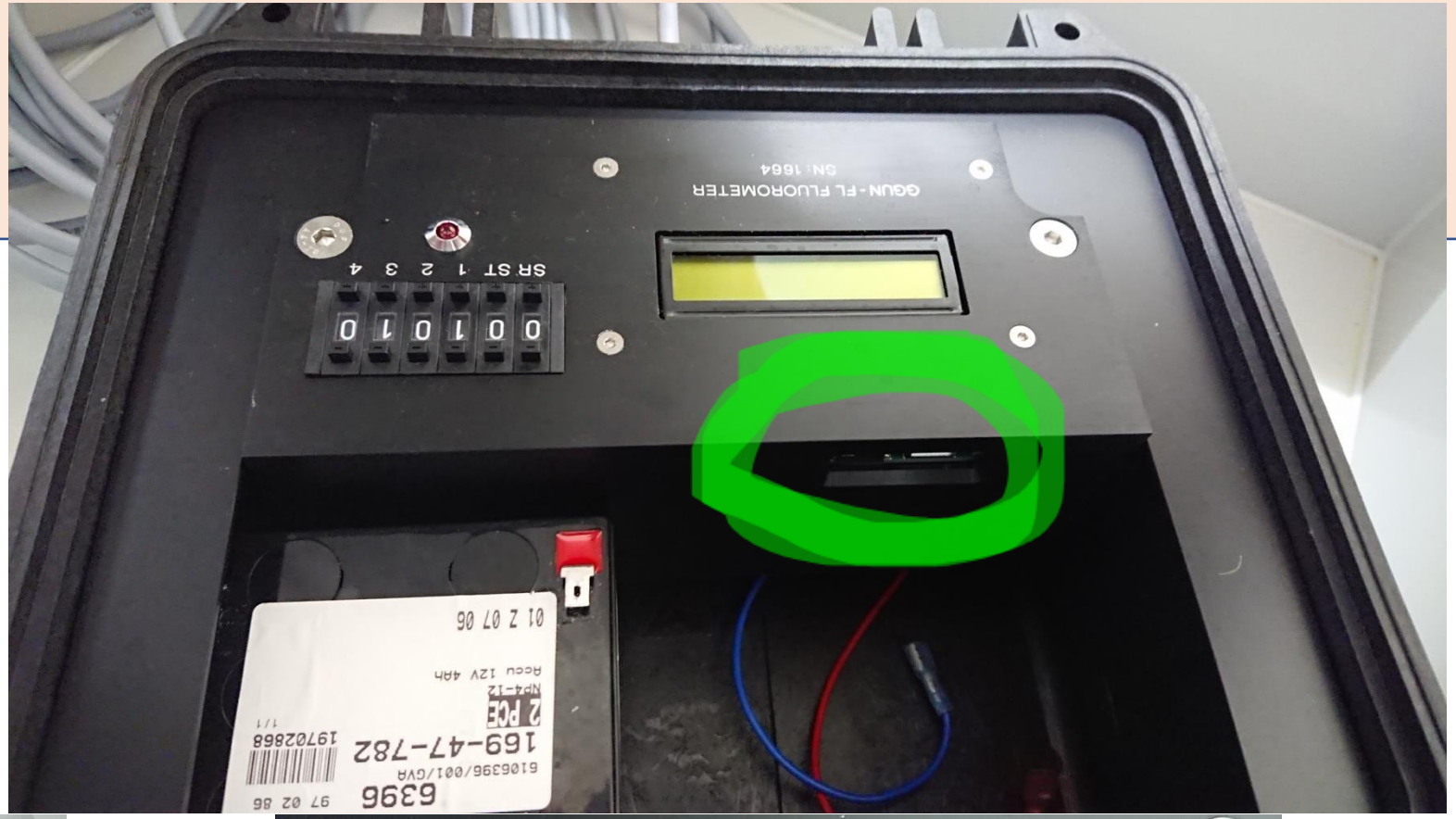
Display:
“0” – mV
“1” – ppb

- Keep these settings for Uranine/Fluorescine

Setup

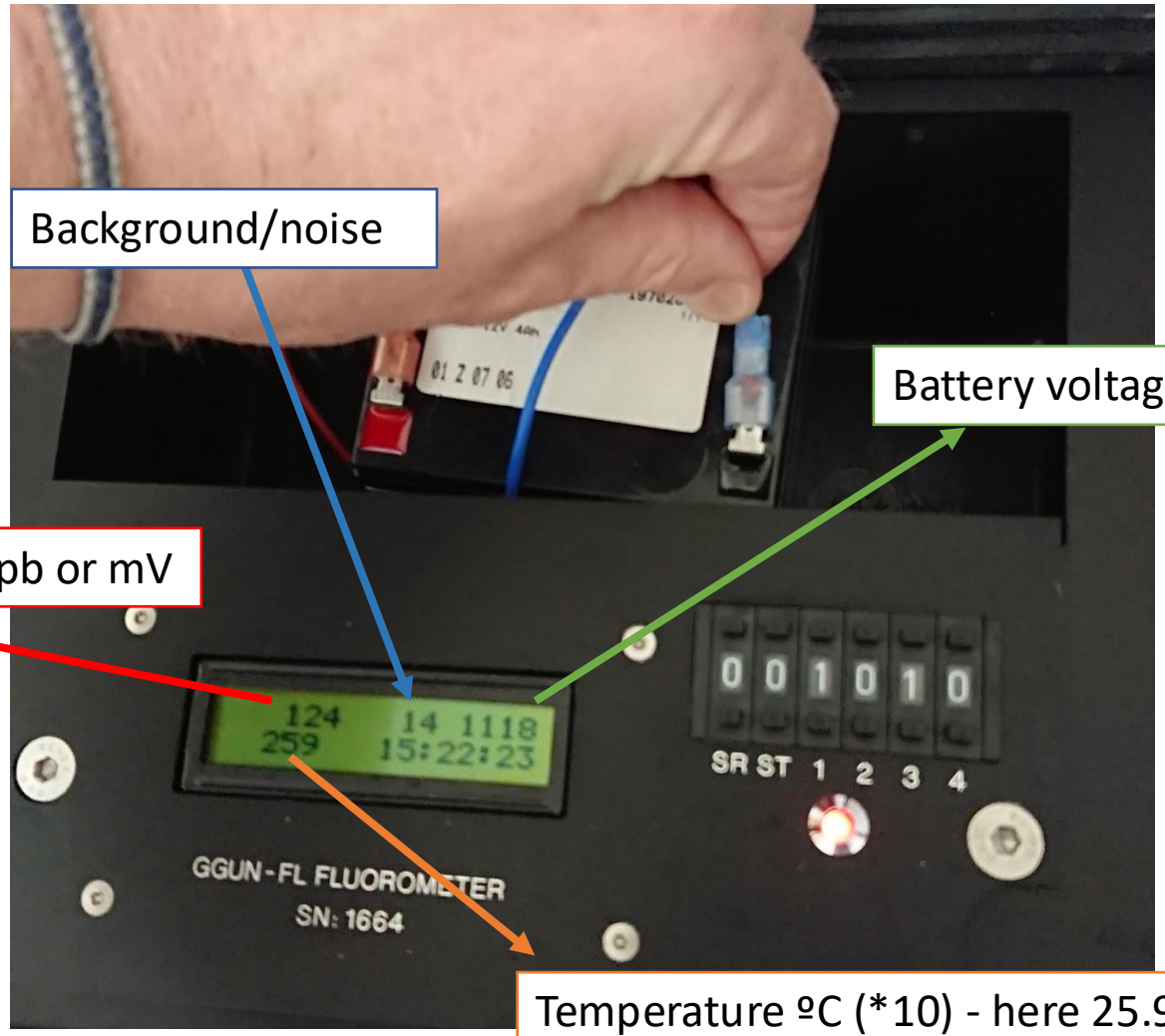
Micro SD card (prepared)

- with **Calibrat.dat**
- with **cal.dat**



Setup

- Micro SD card (needs to be inserted)
- Cables need to be attached and secured (bayonets on the FL30)
- Setting to **001010**
- Attach battery (1. red, 2. blue/black) when ready to start



Background/noise

Battery voltage V (*100) – here 11.18V

Dye concentration in ppb or mV

Temperature ºC (*10) - here 25.9ºC

Calibration

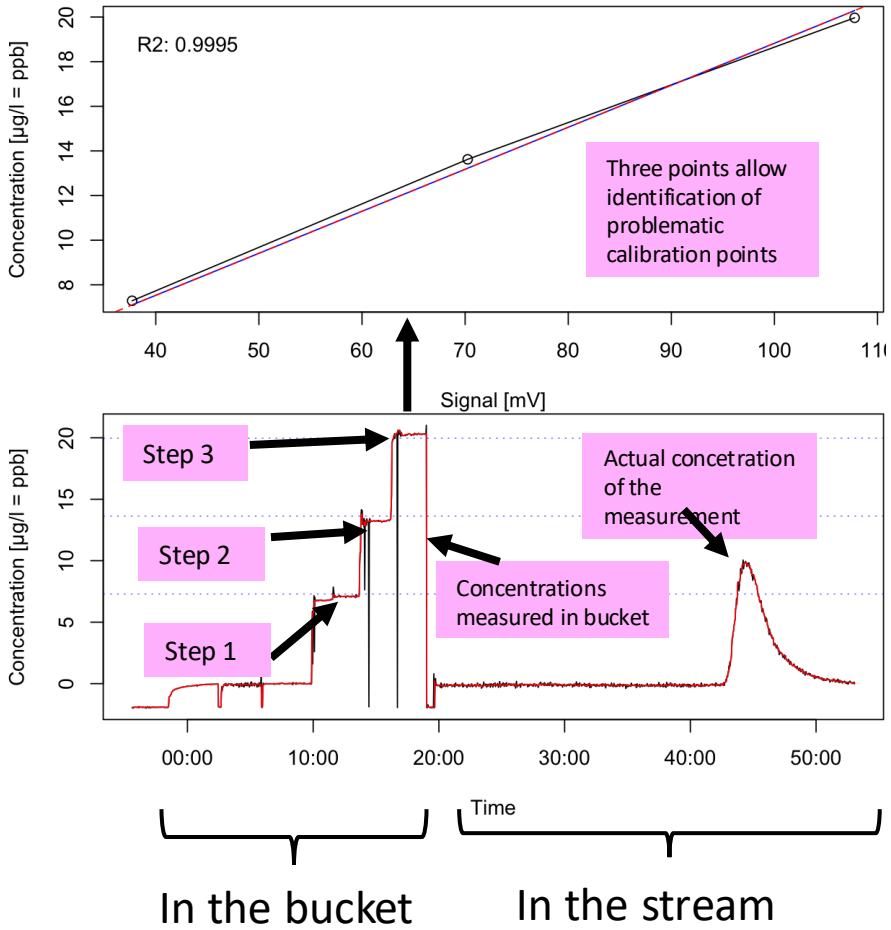
- Exact water volume in bucket (e.g. 10L or 5L)
  - measured with 1L cylinder
  - Stream water !
  - Instrument must have ± same temperature as the stream water
    - If not:
      - Pour only 1L over instrument, wait 2 minutes
      - add again 1L, wait 2 minutes and continue like this until 10 or 5L are reached
    - Best if instrument can slowly adjust (e.g. overnight) in ambient air
    - If instrument is warm and you directly submerge it into cold water, the glass tube inside can break !!!!
    - **Otherwise instrument can be damaged inside**

Calibration – in the field

Adding calibration vials into the bucket to get three calibration steps (see right-hand side figure):

- Add 5 L stream water to bucket
- Place clean (no color contamination) and temperature adjusted (cooled down) FL30 into bucket
- Check if signal is 0 (or near 0 or the same as in the stream → no contamination)
- STEP 1:
- Add 1 vial (write down the mass in your notebook)
    - Make sure your hands are clean (no color)
    - Clean the vial (in the stream) before
    - Open the vial (over the bucket) and pour into bucket
    - Rinse the vial and the lid with water from the bucket (at least 3 x)
- Mix:
    - Grab the cable of the FL30
    - Gently lift (but keep in bucket)
    - Make circular movements to mix the color in the bucket water (10 x)
    - Dip and raise out of water (5 x)
    - Check if the signal is stable
    - Each calibration step should increase the signal by the amount determined in the Excel sheet (roughly); can be slightly more or less.

		Actual calibration [ppb]
Calibration series (final) in 5L bucket	1 step	4.13
	2 step	8.25
	3 step	12.36
	4 step	17.48
	5 step	22.57



Calibration – in the field

- After adding a calibration vial:

e.g. expected increase by ~4 ppb

…

Mix well:
- Stir
- Dip out and in 5 times

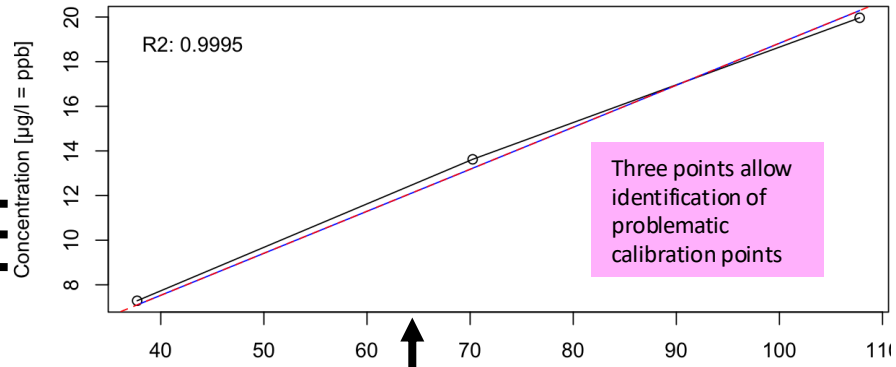
- ppb value should be close to (not necessarily exact) **4 ppb** !
- Sediments reduce the signal strongly (so it can be lower)
- A higher amount of calibration liquid leads to a stronger signal

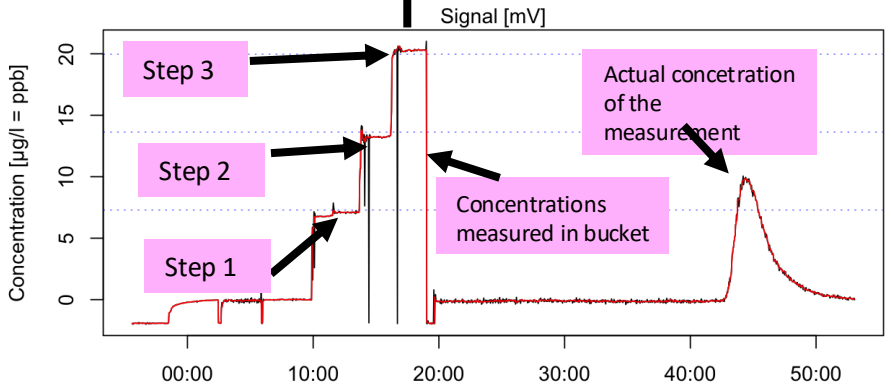
Calibration – in the field

Adding calibration vials into the bucket to get three calibration steps (see right-hand side figure):

- STEP 2 & STEP3
- Repeat simply the steps from STEP 1
- You should roughly see an increase according to the determined concentrations (Excel table)

		Actual calibration [ppb]
Calibration series (final) in 5L bucket	1 step	4.13
	2 step	8.25
	3 step	12.36
	4 step	17.48
	5 step	22.57





In the bucket

In the stream

Calibration – in the field

- Try to do 3 calibration steps for each measurement
- If you do not have enough calibration liquid:
  - Most important is the calibration if the sediment load (turbidity) is changing
- You **MUST** write down each calibration liquid mass you added into your notebook
  - Without this information, you **CANNOT** calculate the discharge

Write down temperature and background signal (ppb)

Write down local time

You MUST write down how much calibration liquid was added

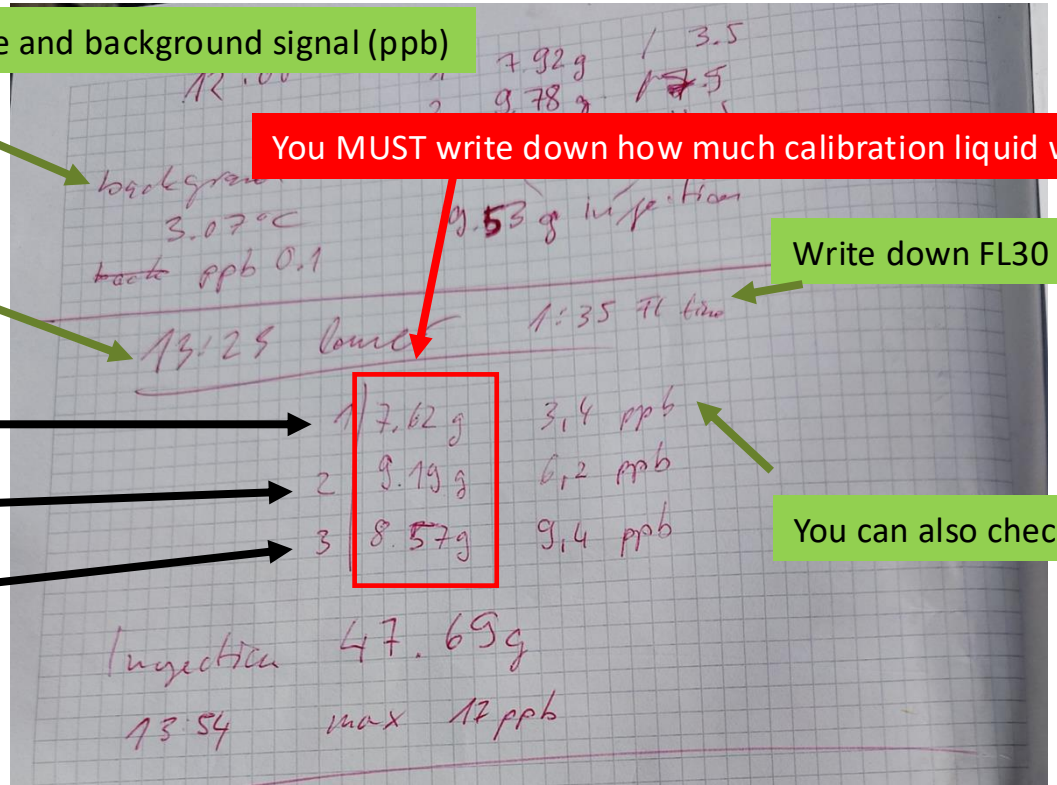
Write down FL30 time

Step 1

Step 1

Step 1

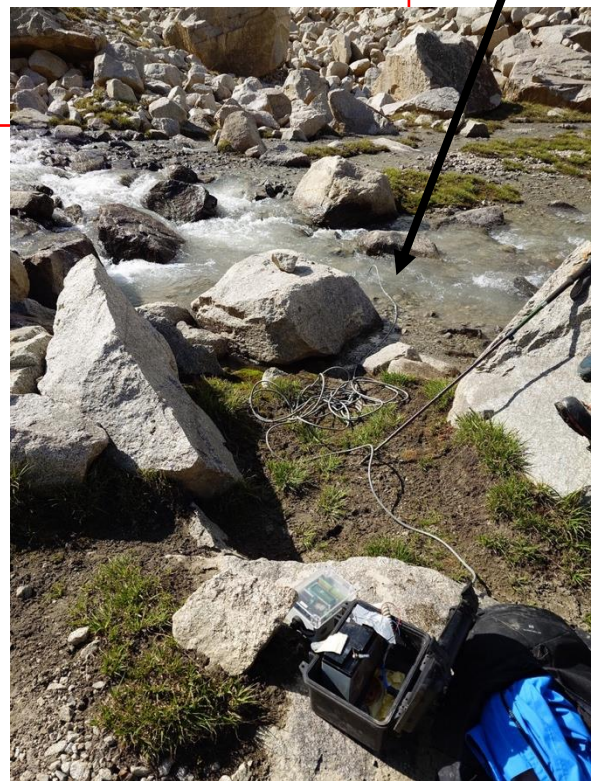
You can also check if the increase is as expected (compare to Excel file)

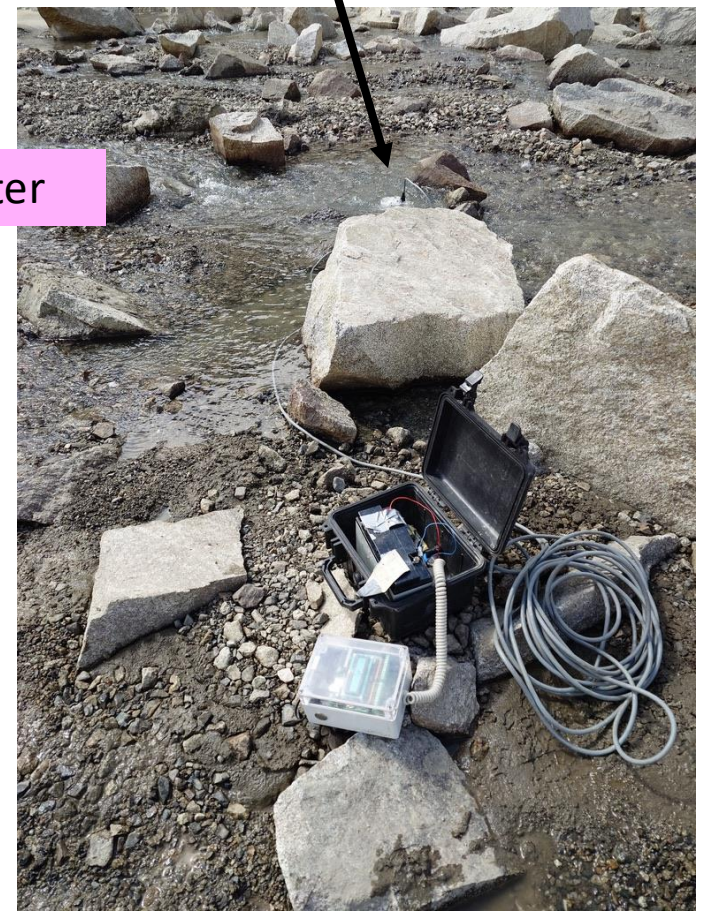


Measurement – in the field

After calibration, place the fluorometer into the stream:

- Safe position (don't risk ever falling into the stream)
- Stable position (choose a place where the fluorometer cannot be swept away)
- Low sediments
  - if you notice lots of sediments →
    - Normal signal and background signal is jumping (high, low, high, …)
    - → try to find a stone plateau under water to place fluorometer on top
    - → change fluorometer direction (inlet on top)
    - A jumping signal can destroy the measurement !!!

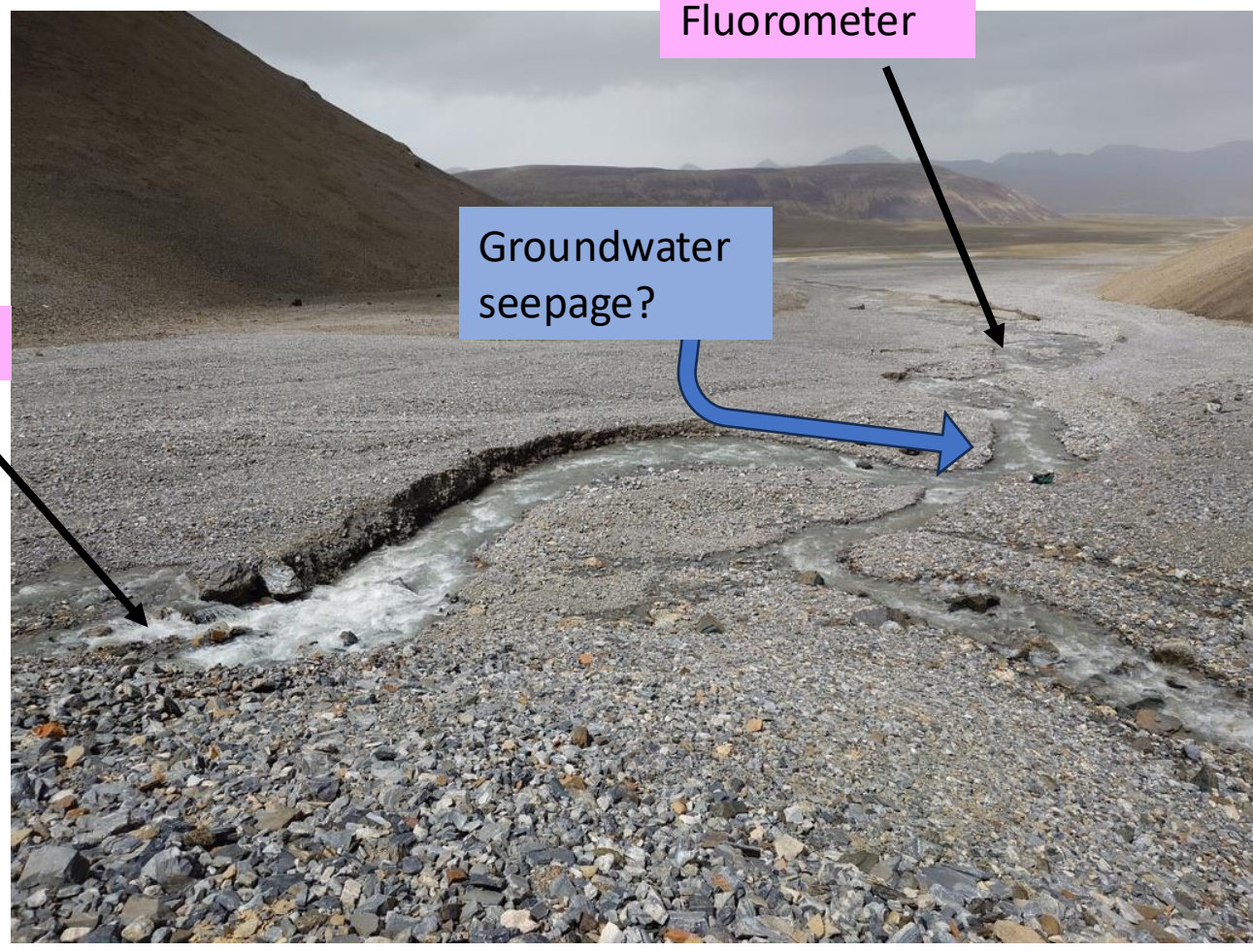




Measurement – in the field

Injection:

- The longer the mixing distance, the better (but the concentration also decreases)
- Warning:
  - Make sure there is no groundwater flowing in just before the fluorometer (this will dilute the concentration artificially and result in wrong and too high discharge estimation)



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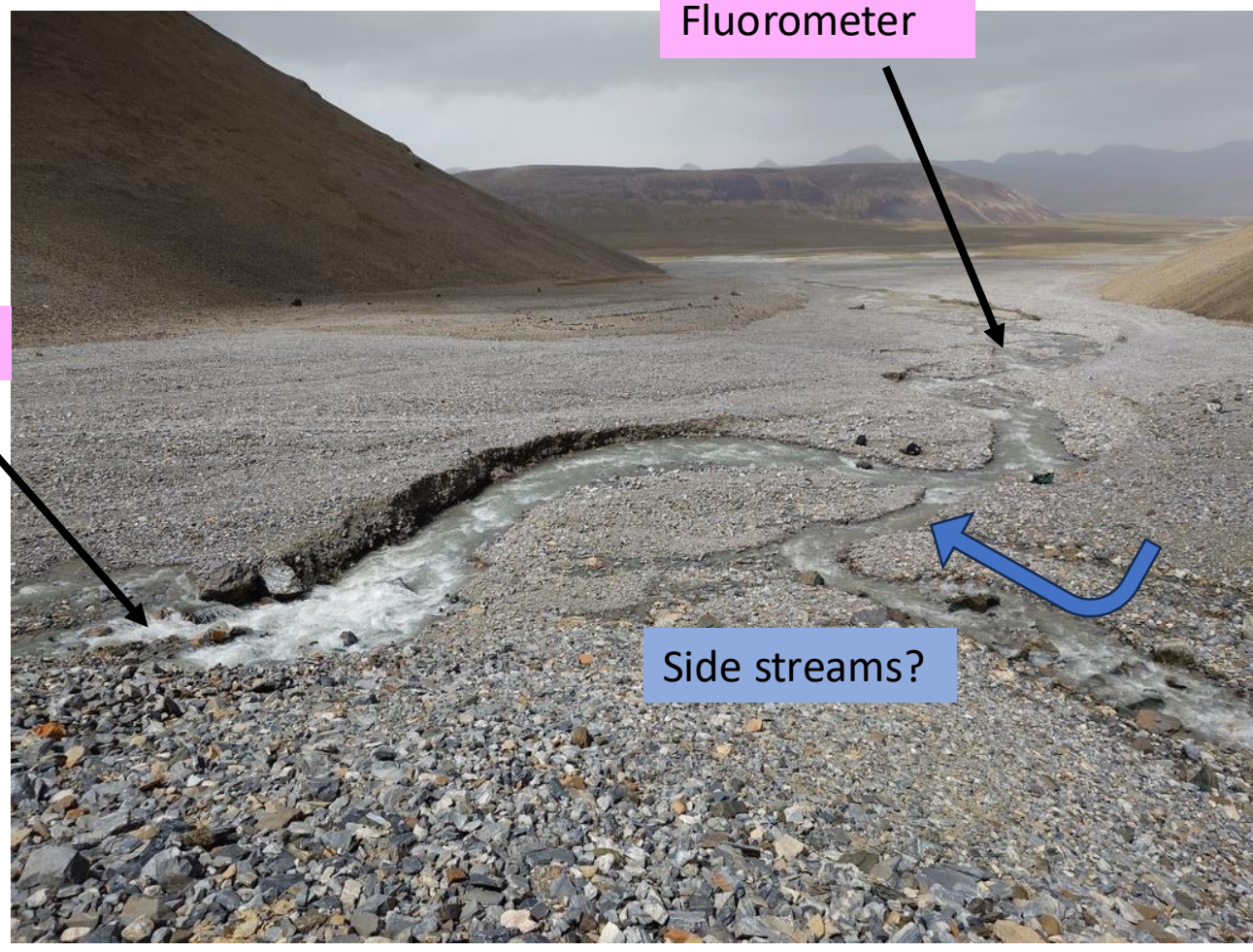
  - Side streams are fine BUT there must be enough distance behind to get full mixing again



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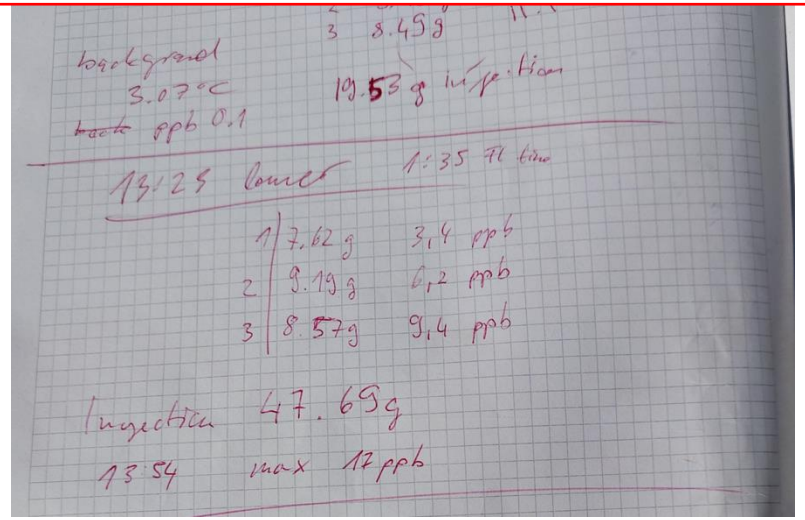
- The longer the mixing distance, the better (but the concentration also decreases)
- Warning:
  - Make sure there is no groundwater flowing in just before the fluorometer (this will dilute the concentration artificially and result in wrong and too high discharge estimation)
  - Side streams are fine BUT there must be enough distance behind to get full mixing again
- Injection close to rapid water for good mixing
- Always be safe ! Choose spot where you cannot fall into water.

Safe spots

Rapid water for good mixing from the start

Measurement – in the field

- PREPARE injection:
  - 1 L cylinder
  - 10 L bucket
  - Injection vials
- Place bucket safely so it cannot flip
- Fill 1L cylinder (stream water)
- Open injection vials over bucket (write down how much you inject!!!!)
- Pour color into bucket (over the bucket so if it spills, it spills into the bucket)
- Rinse all color into the bucket (simply pour from the 1L cylinder into the vials and let it overflow)
- Rinse the cap into the bucket
- Fill bucket around half full (no need to measure how much water you add)
- Mix (you can use the cylinder upside down – see picture)



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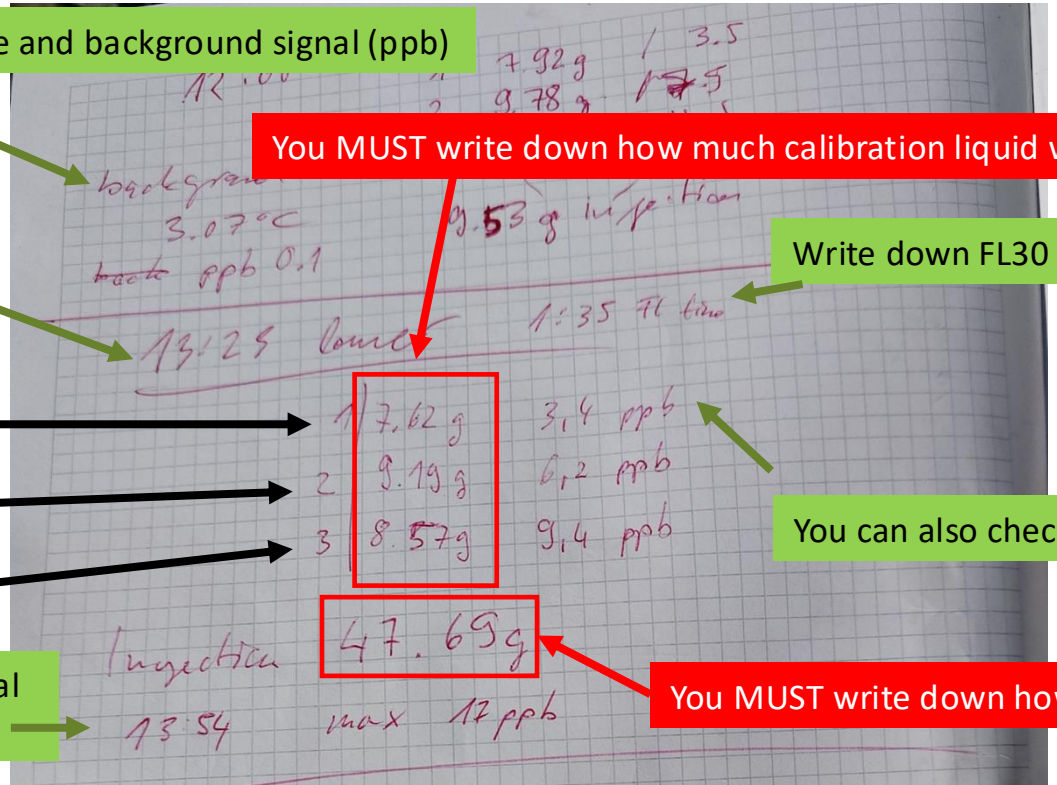
- Rinse the cap into the bucket
- Fill bucket around half full (no need to measure how much water you add)
- Mix (you can use the cylinder upside down – see picture)
- Inject:
  - Pour the mix (water+color) as centered as possible and in one go (fast) into the stream
  - Quickly rinse the bucket
  - This should be very quick (the color should move in one cloud)
- Write down the time of injection into your field notebook

Measurement – in the field

- Move back to your colleague at the fluorometer
- If color arrived before you, note at what time it arrived
- Observe the concertation on the fluorometer (the person at the fluorometer)
  - Does it jump ? → BAD, you will have to do the measurement again
  - Is it smooth (slow increase, plateau, slower decrease)? → GOOD
- Write down all information !!



Write down temperature and background signal (ppb)

Write down local time

You MUST write down how much calibration liquid was added

Write down FL30 time

Step 1

Step 1

Step 1

You can also check if the increase is as expected (compare to Excel file)

Write down when signal arrived

You MUST write down how much injection liquid