



arpav

# Tecniche innovative di misura dei livelli delle portate

**Zasso Marco**

**Arpav – U.O. Supporto alla Protezione Civile**

Padova, 30 maggio 2024

- 
- Importanza delle misure idrologiche livello - portata;
  - Misure puntuali di portata:
    - sistemi Doppler: profilatori e misure puntuali radar;
    - tecniche di analisi video;
  - Applicazioni per misure di livello-portata in continuo: esempi di recenti installazioni;

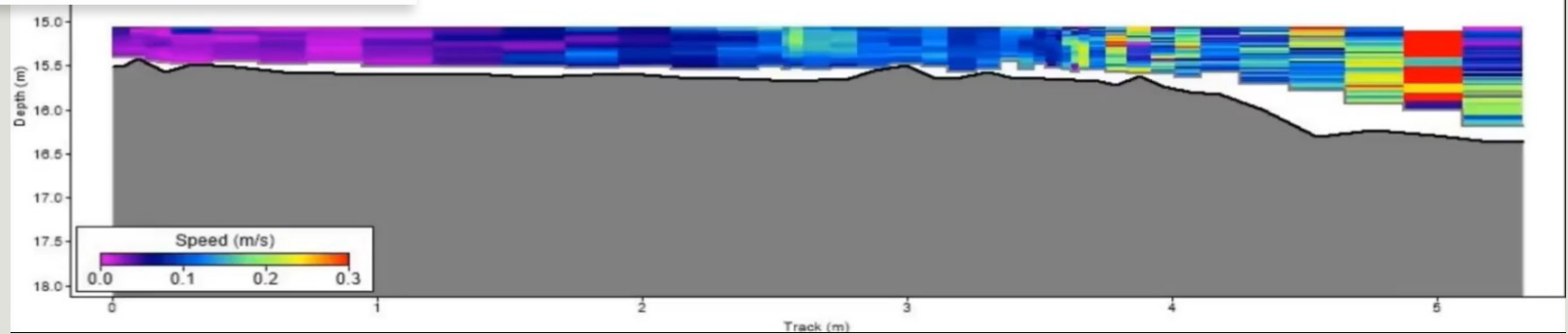


# Misure con profilatori Doppler



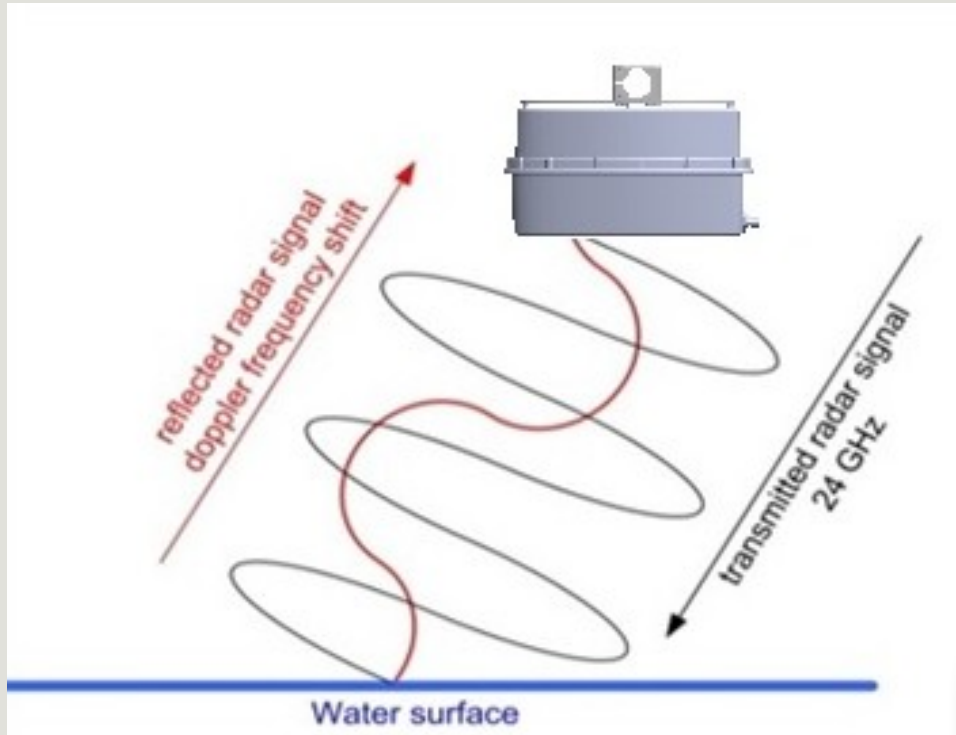


# Misure con profilatori Doppler





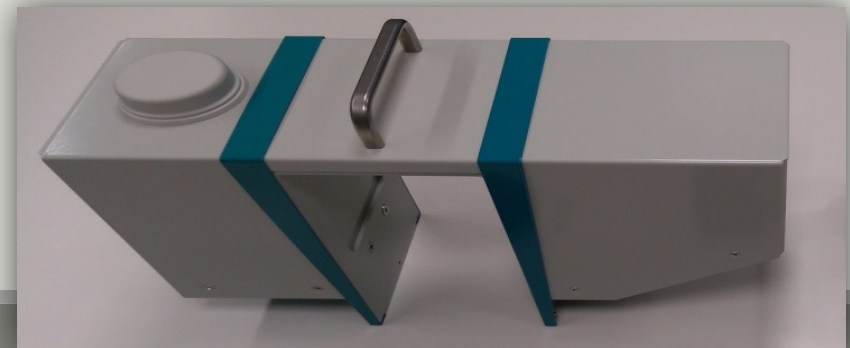
# Misuratori radar Doppler non a contatto



Sfruttano il principio Doppler per la misura della velocità superficiale.

Altezza onda 0.3-0.5 cm

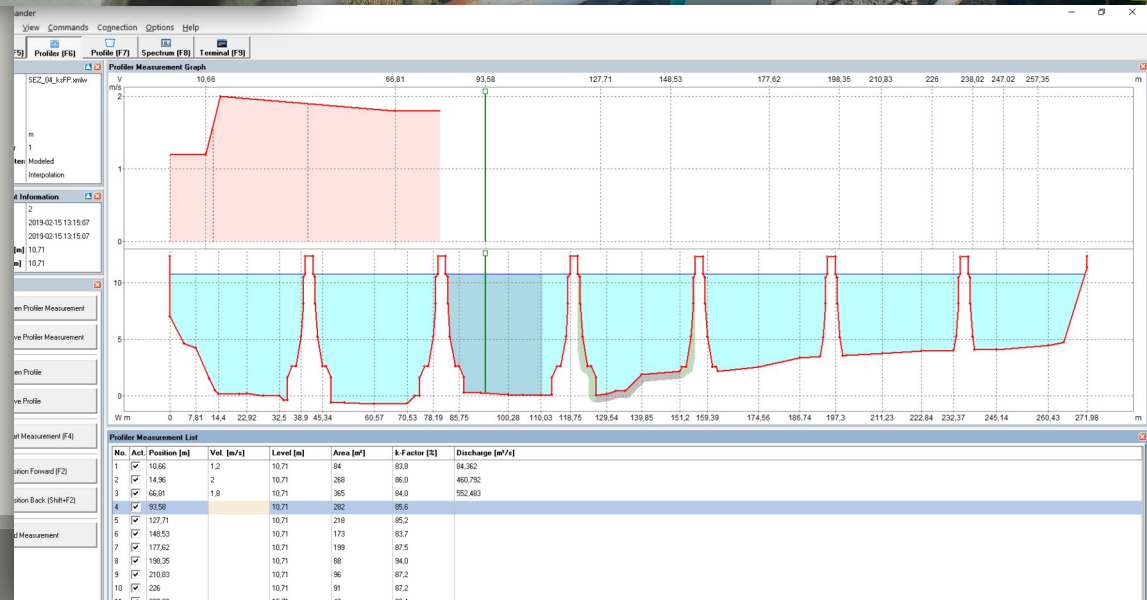
Inclinometro



# Misure con sensori radar Doppler

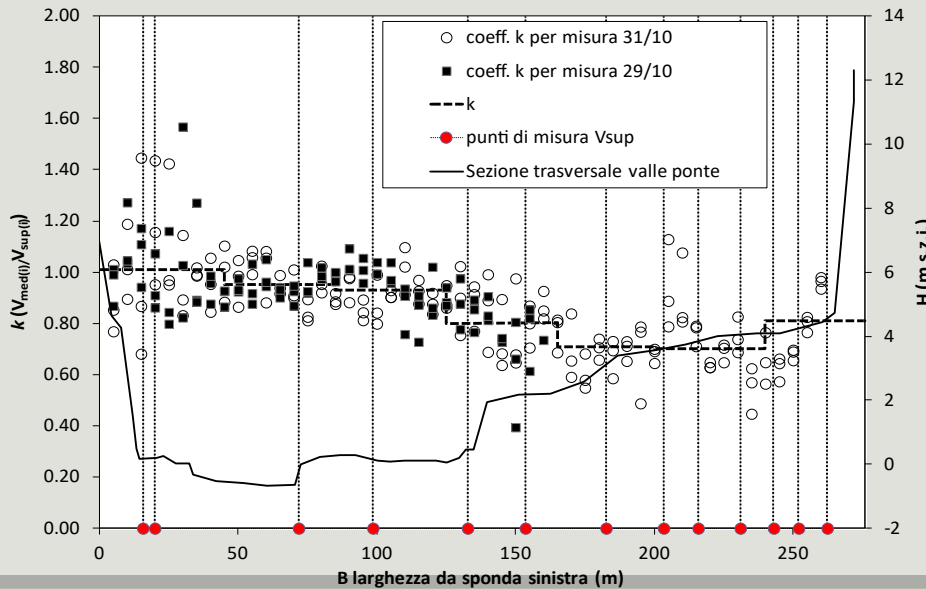
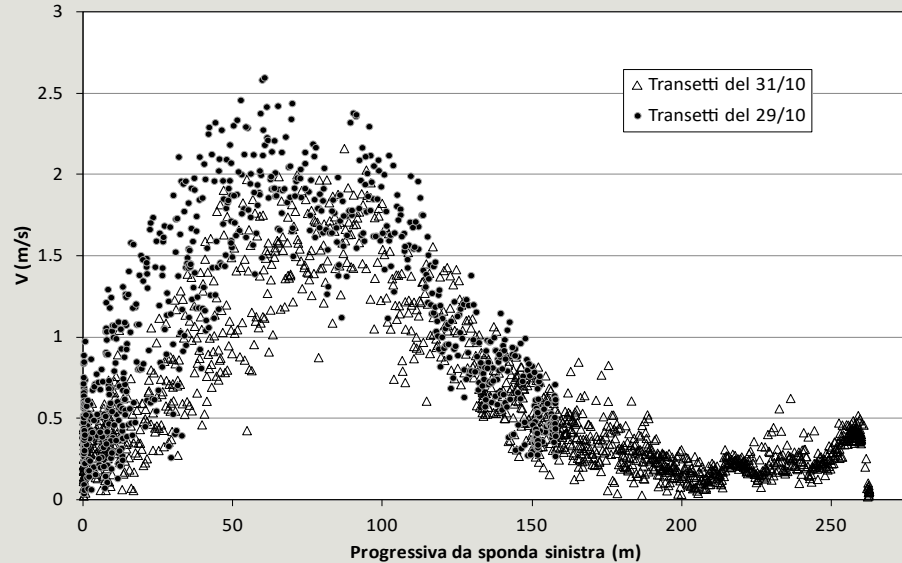


$$V_{med} = k * V_{sup}$$





# Integrazione di metodologie diverse



## ADCP:

1. Estrazione da dati ADCP di valori velocità superficiali e medie sulle verticali;
2. Stima e valutazione variabilità trasversale del rapporto  $v_{sup}/v_{med}$ .

## RADAR:

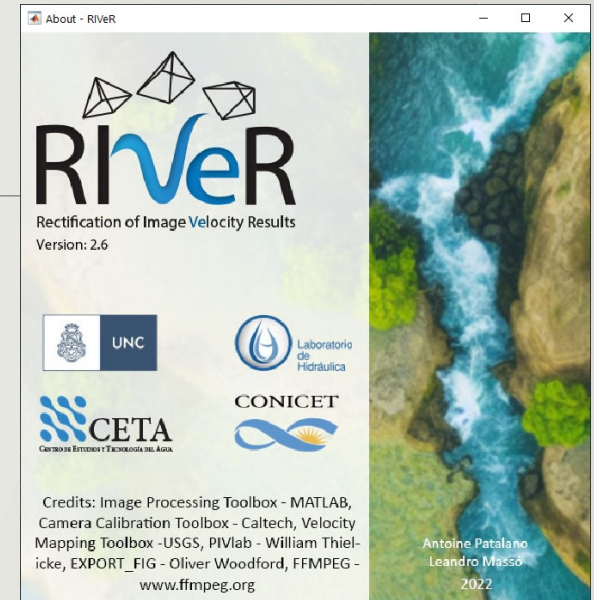
3. Utilizzo di un coefficiente di proporzionalità tra  $v_{sup}/v_{med}$  sito specifico.

# Tecniche di analisi video

DOI: [10.1016/j.cageo.2017.07.009](https://doi.org/10.1016/j.cageo.2017.07.009) Computers & Geosciences (2017)

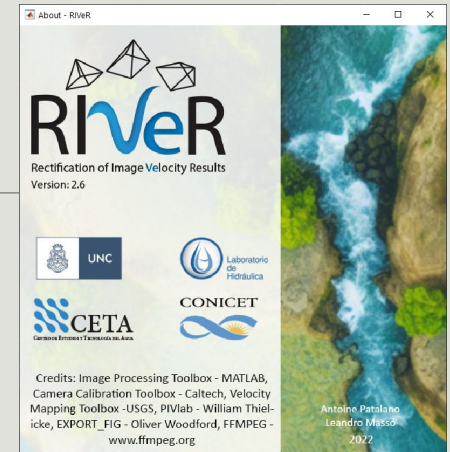
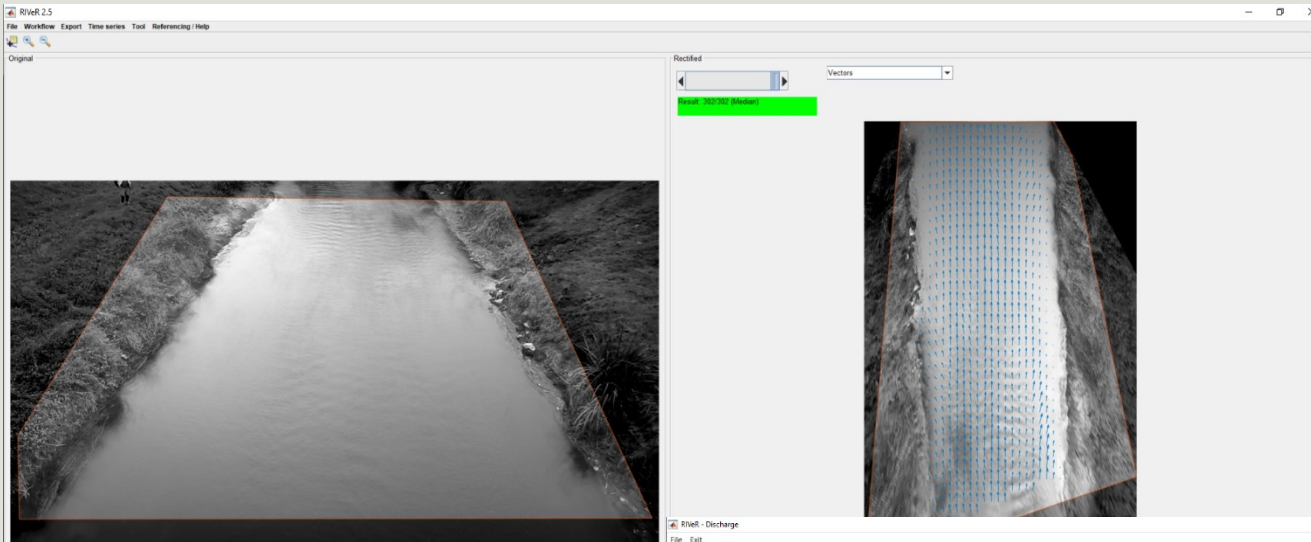
LSPIV (Large Scale Particle Image Velocimetry)

LSPTV (Large Scale Particle Tracking Velocimetry)





# Tecniche di analisi video



### RiVeR - Discharge

File Exit

#### Stage Profile (from AreaComp2 V1.07 - Lant and Mueller)

Station and Stage Table

Station	Stage (Dist. from left bank)
1	0
2	0.9868 -0.2388
3	1.3000 -0.4500
4	2.5500 -0.9200
5	3.3600 -1.0700
6	4.6100 -1.0100
7	5.2400 -0.9800
8	6.7000 -0.9100
9	8.1500 -0.7600
10	8.2000 -0.7400
11	8.7000 -0.6900
12	9.4300 -0.6200
13	10.1000 -0.5600
14	10.2600 -0.5800
15	11.0000 -0.4000
16	11.6200 -0.2800
17	11.9200 -0.1200
18	12.6300 0

ADCP: File: Starting Station: 0

CSV: File: Sezione\_02.csv Starting Station: 0

#### Discharge Computation

Interp. half:

Mean Velocity coefficient: 0.87

Mean Section Method:  Mid Section Method:

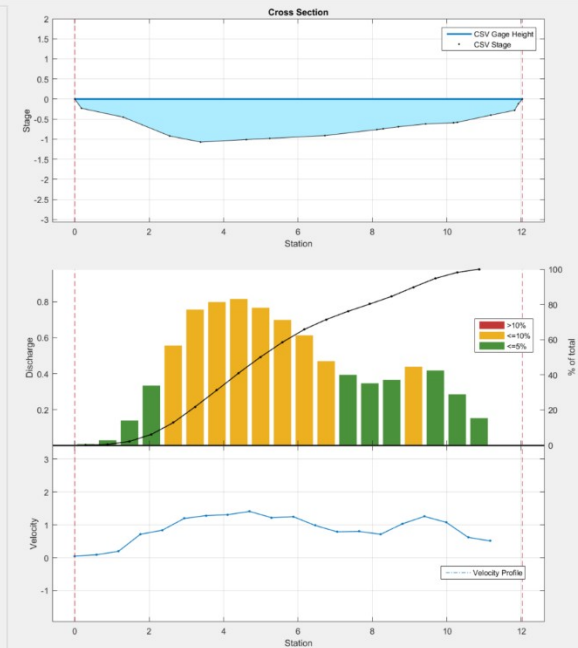
Computed Discharge: 7.29

Measured 100%  
Interpolated 0%

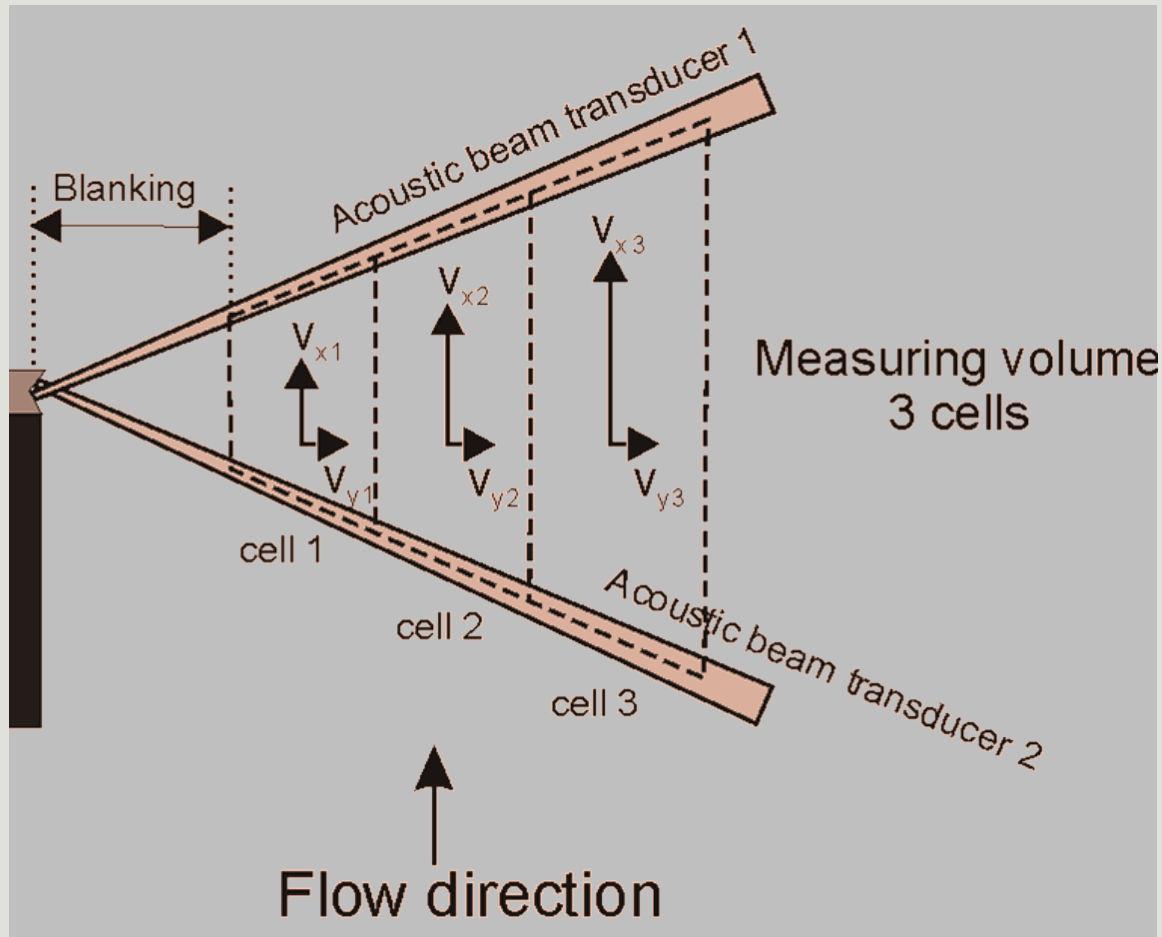
#### Velocity Profile

Station and Velocity Table

Station	Velocity
1	0.0188
2	0.0874 0.0888
3	1.1147 0.1343
4	1.7621 0.1712
5	2.3495 0.8361
6	2.3368 1.1058
7	3.5242 1.2820
8	4.1116 1.3091
9	4.6889 1.4086
10	5.2663 1.2188
11	6.8727 1.2481
12	6.4811 0.9813
13	7.0464 0.7185
14	7.6588 0.7996
15	8.2232 0.7138
16	8.8105 1.0543
17	9.3879 1.0270
18	9.9853 1.0752
19	10.5726 0.6188



# Misure di livello-portata in continuo profilatori Doppler

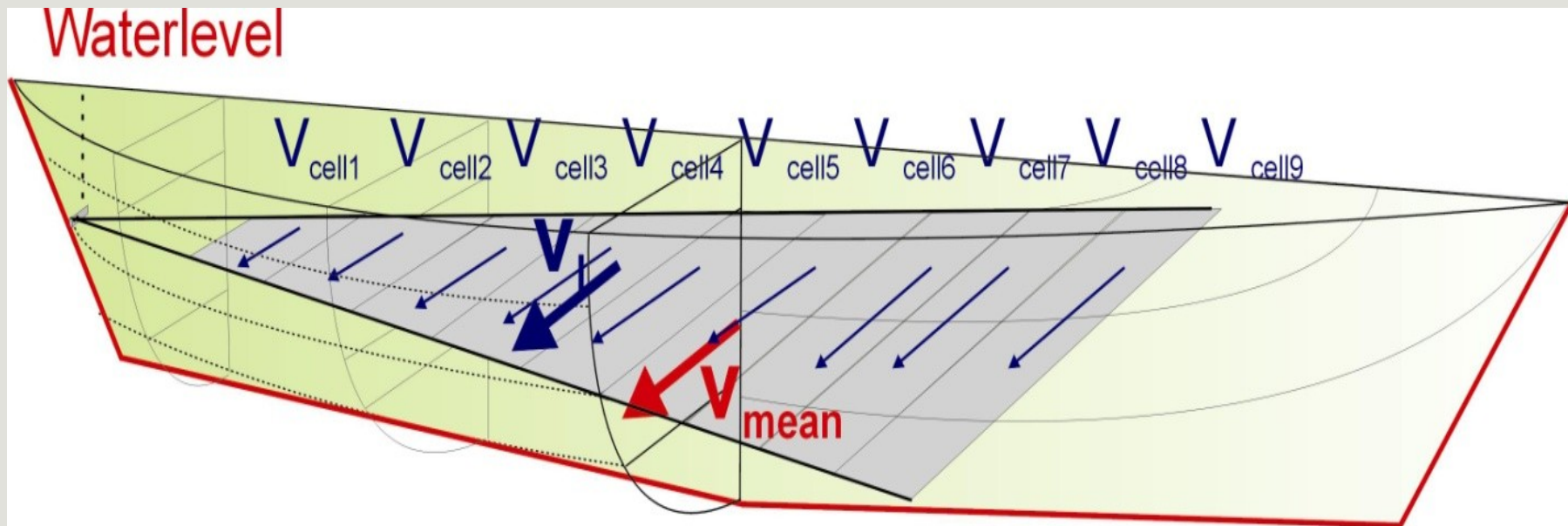




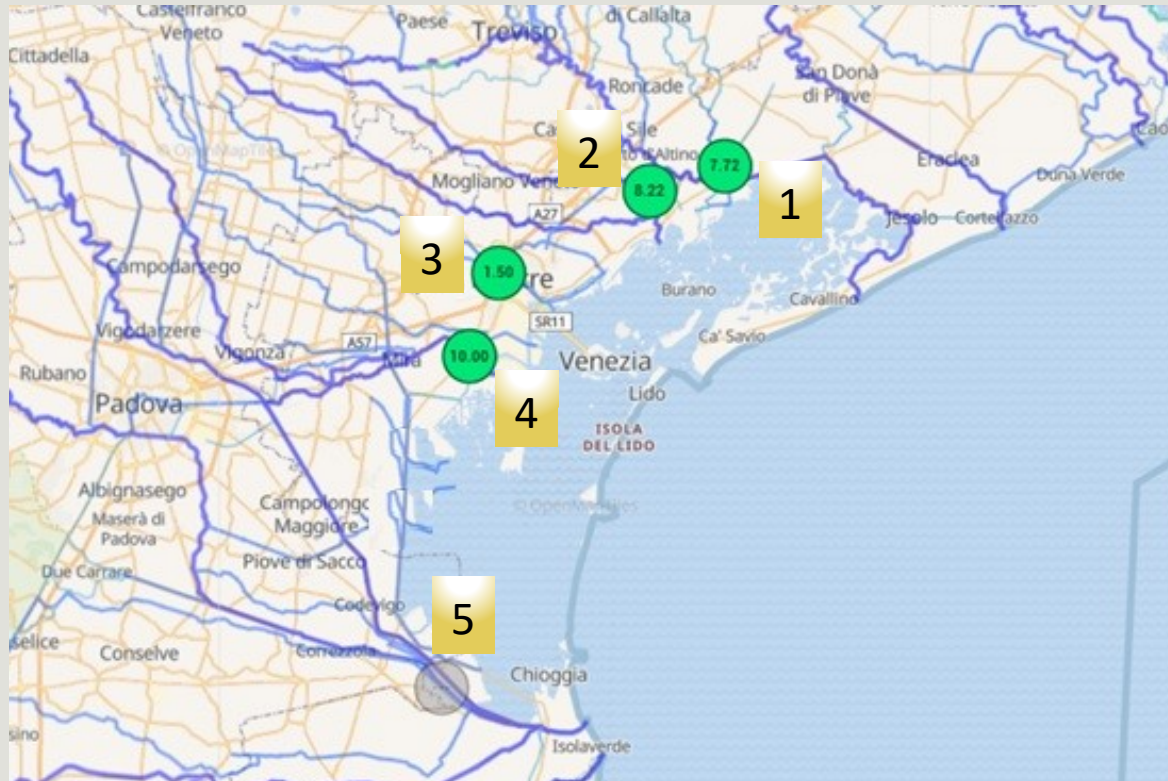
# Misure di livello-portata in continuo profilatori Doppler

In una determinata sezione viene effettuata contemporaneamente:

- **Misura del Livello**
- **Misura della Velocità** di 9 celle orizzontali

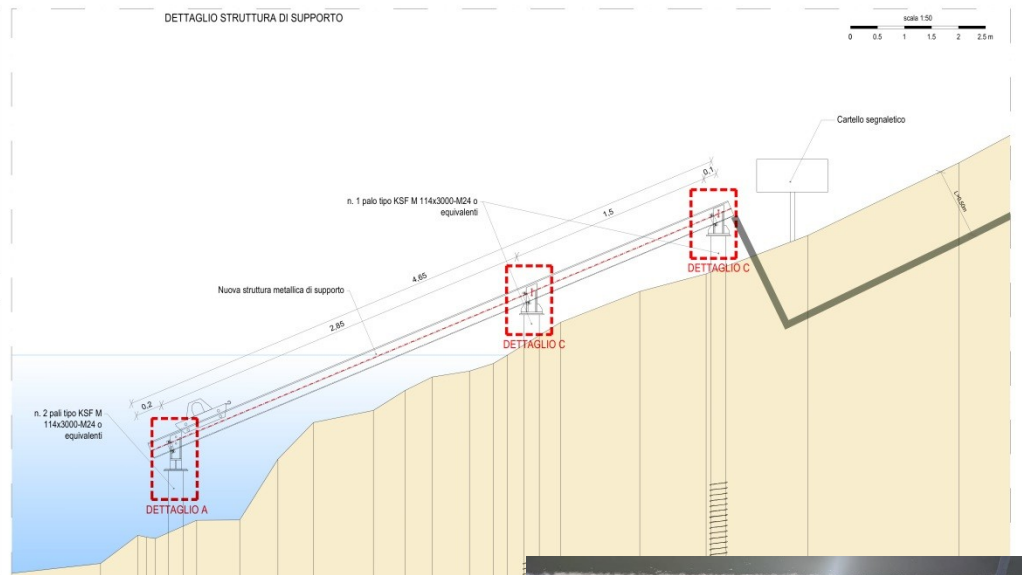
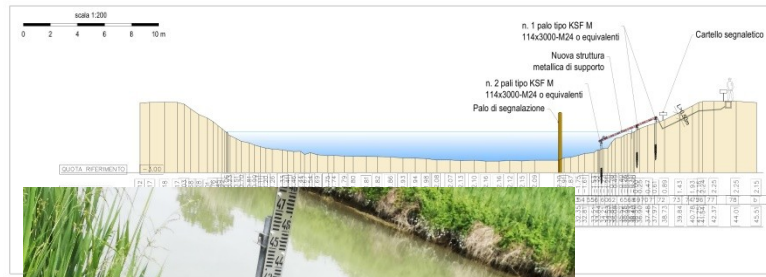
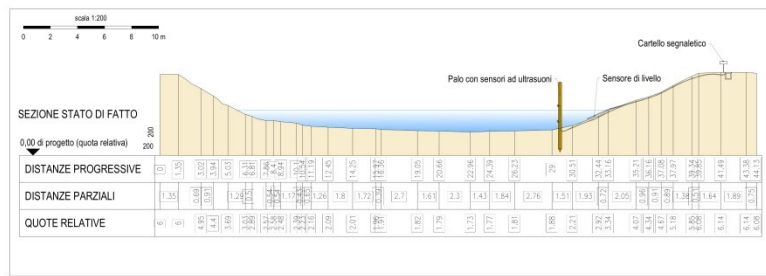


# Misure di livello-portata in continuo profilatori Doppler



1. Canale Vela a Ponte Vela
2. Zero a Carmason
3. Marzenego a Mestre
4. Naviglio Brenta a Malcontenta
5. Canal Morto a Sostegno Priula

# Misure in continuo - profilatori Doppler





# Misure in continuo - profilatori Doppler

FASE DI CALIBRAZIONE:

Misure dirette di portata  $\rightarrow$   $V_{med}$

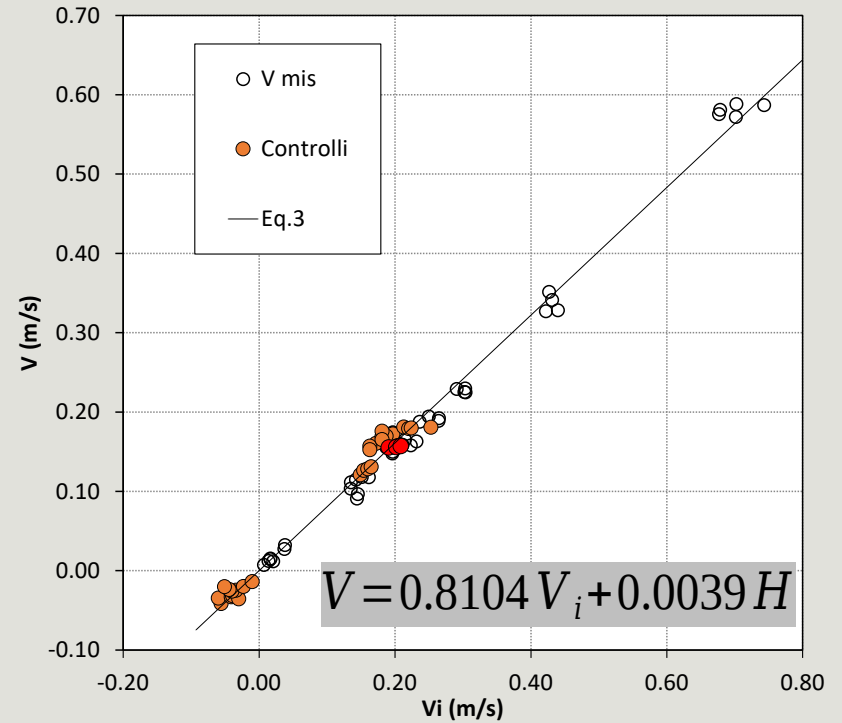
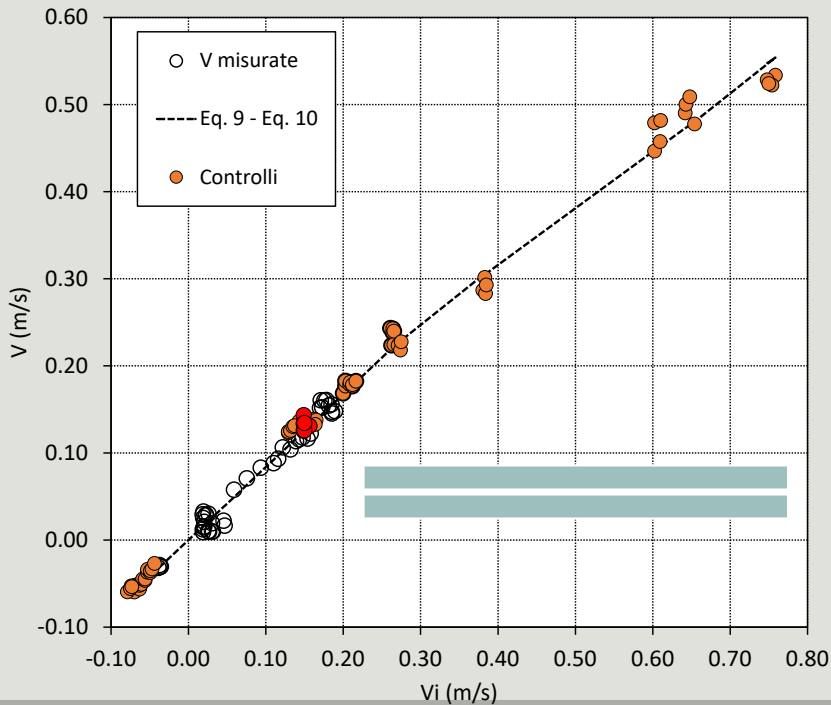
Dati stazioni  $\rightarrow$   $V_i, H$

Regressione lineare multipla

$V_{med} = f(H, V_{ind})$

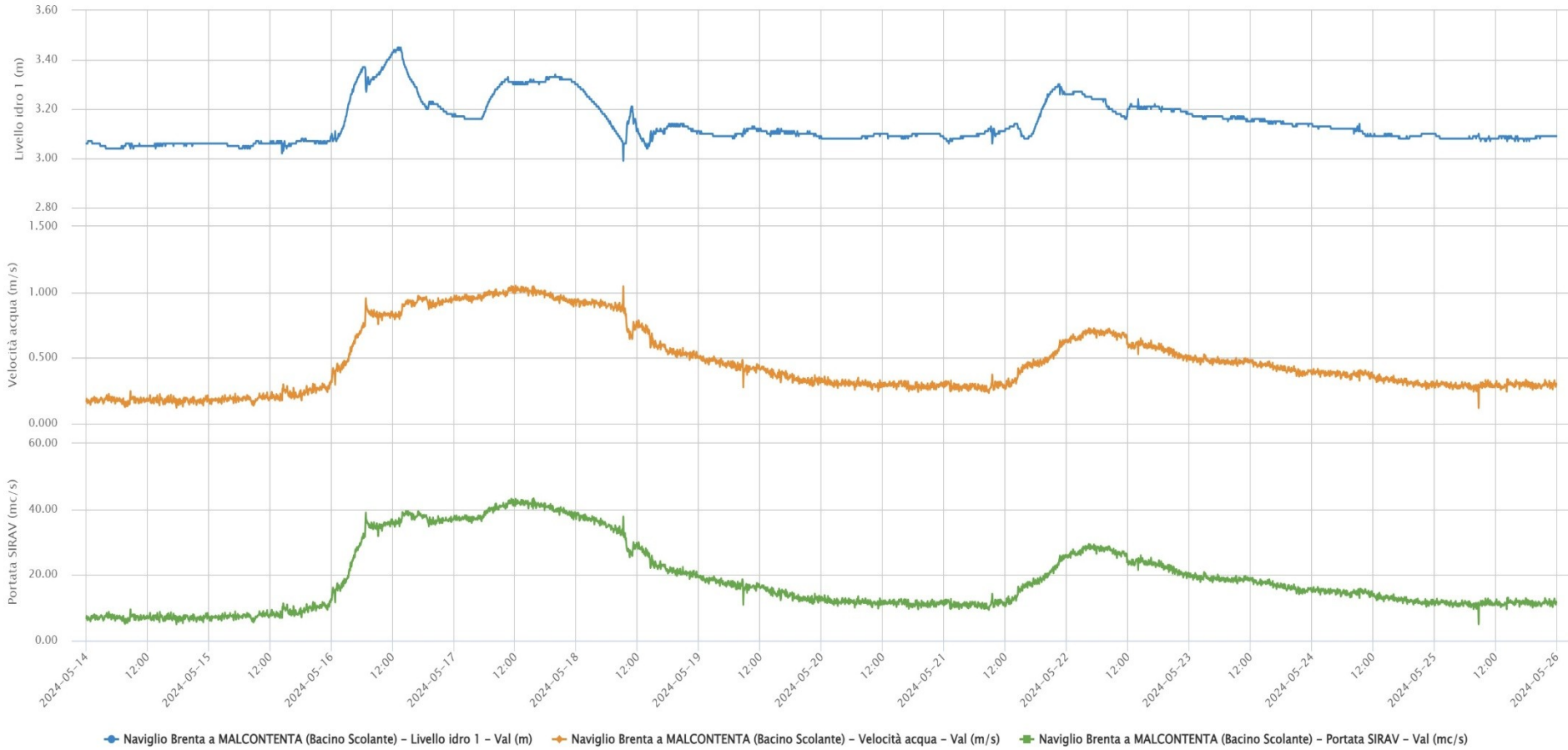
$Y = V_{med}$

$X = (H, V_{ind})$



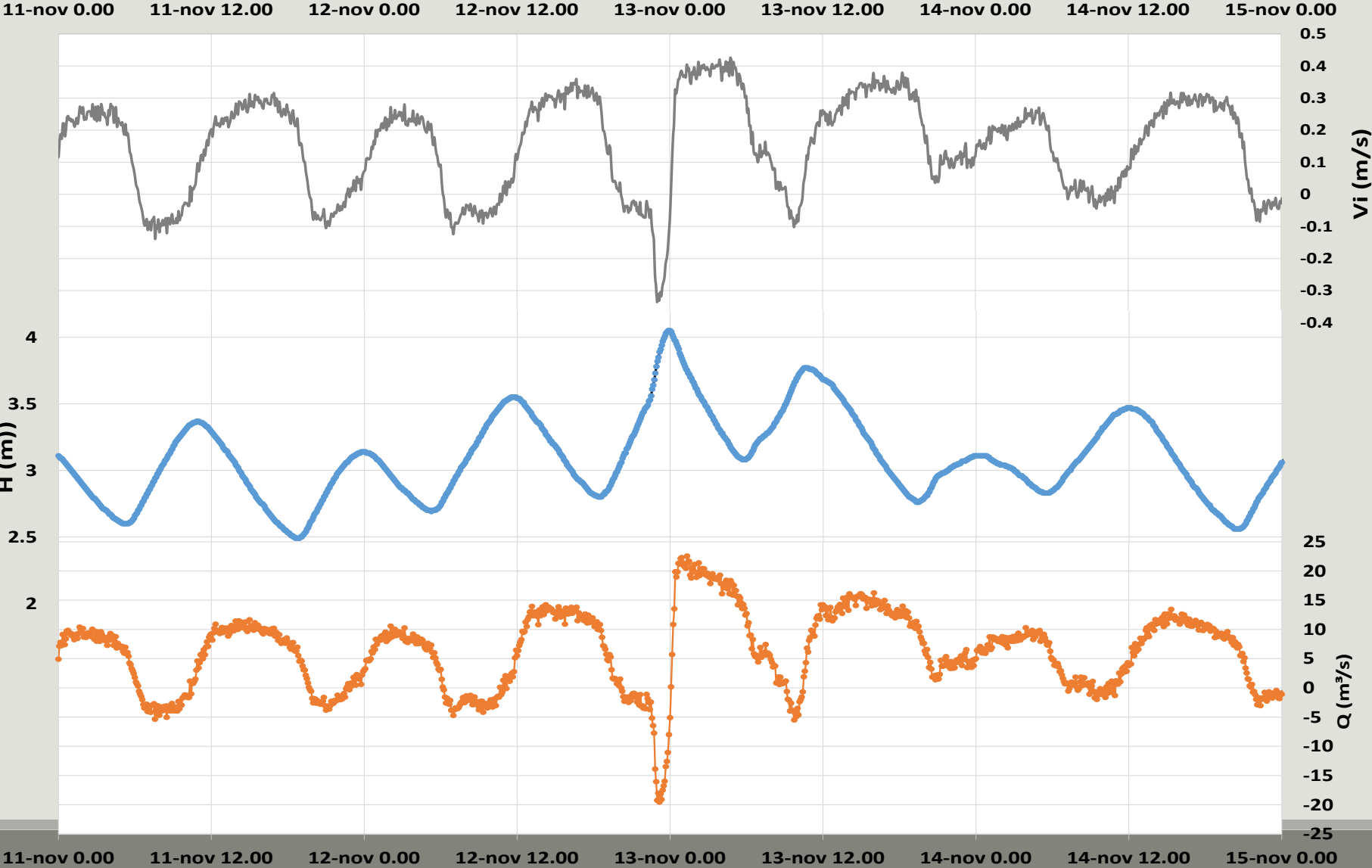
# Misure in continuo - profilatori Doppler

## Naviglio Brenta a Malcontenta – maggio 2024



# Misure in continuo - profilatori Doppler

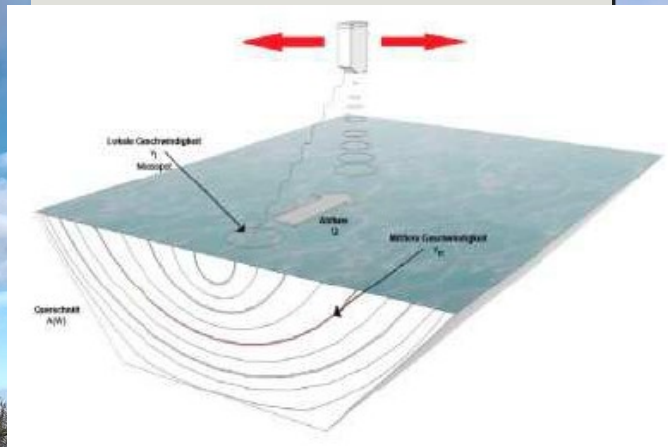
## Zero a Carmason- novembre 2019





# Misure in continuo - radar Doppler

V sup + H + topografia  $\longrightarrow$  Vmed + A  $\longrightarrow$  Q





# Misure in continuo - radar Doppler

**Boite a Cancia**



**Brenta a Primolano**



**Meschio a Cordignano**

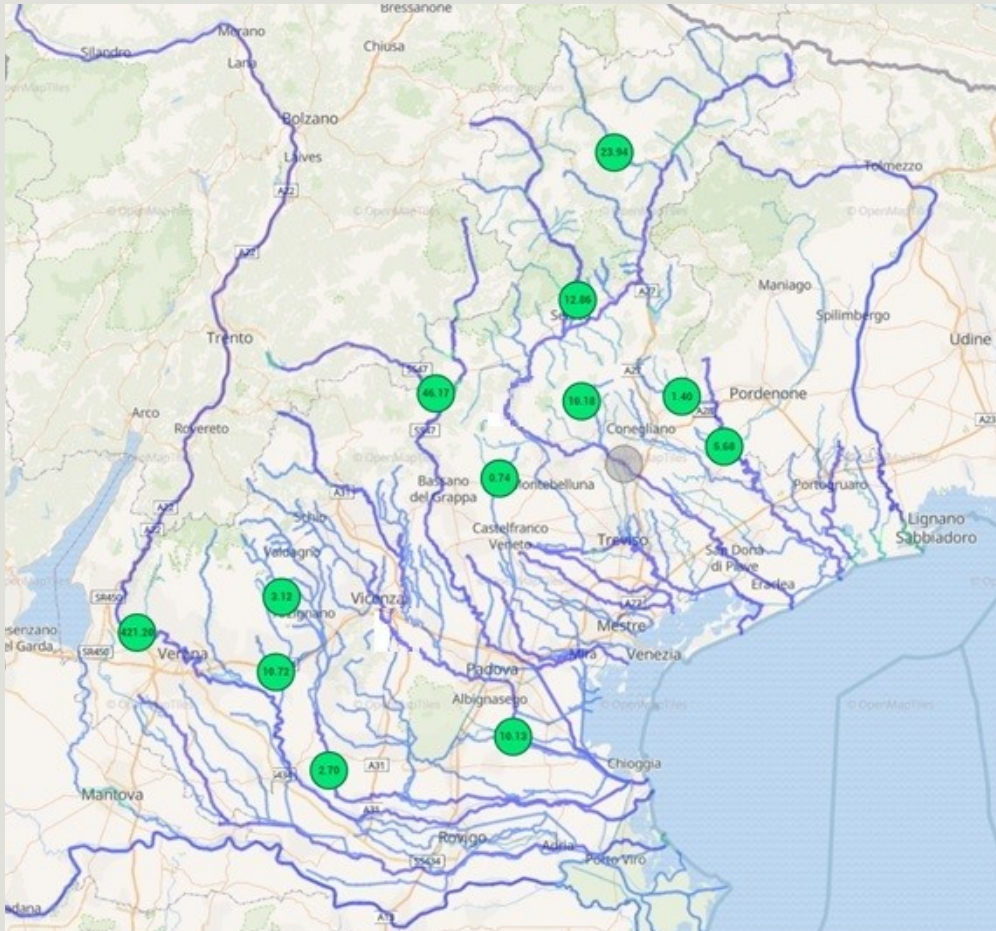


**Alpone a San Bonifacio**





# Misure in continuo - radar Doppler



1. Boite a Cancia
2. Cordevole a Sass Muss
3. Brenta a Primolano
4. Soligo a Pramaor
5. Muson a Asolo
6. Meschio a Cordignano
7. Livenza a Portobuffolè
8. Chiampo a Chiampo
9. Alpone a San Bonifacio
10. Adige a Pescantina
11. Fratta a San Salvaro
12. Cagnola a Bovolenta
13. Piave a Ponte della Priula??

Variabilità di condizioni!!



# Misure in continuo - radar Doppler

FASE DI CALIBRAZIONE:

Misure dirette di portata  $\longrightarrow$   $V_{med}$

Dati stazioni  $\longrightarrow$   $V_i, H$

Regressione lineare multipla

$V_{med} = f(H, V_{ind})$

$Y = V_{med}$

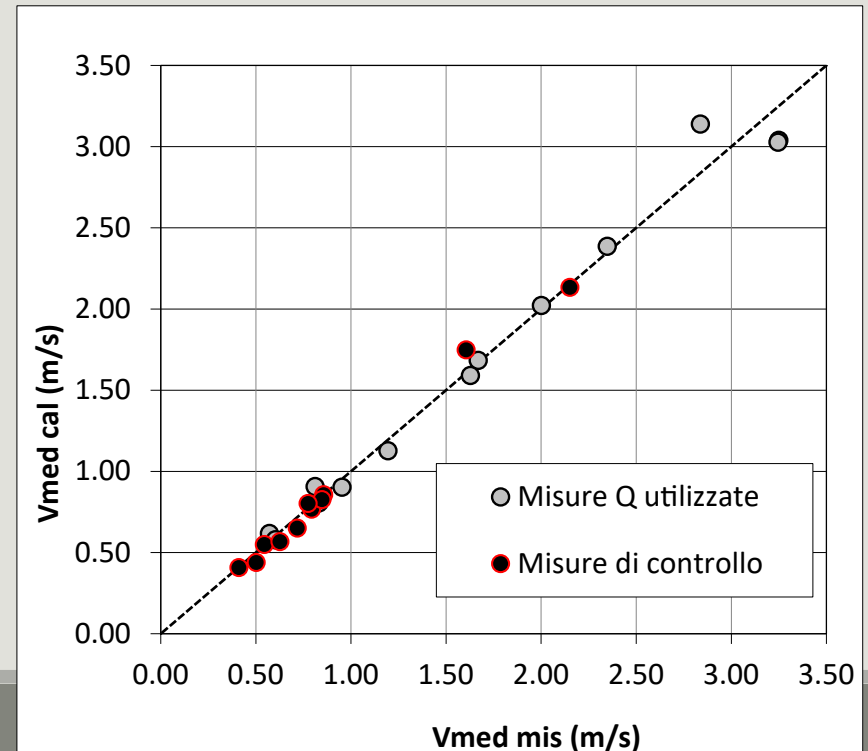
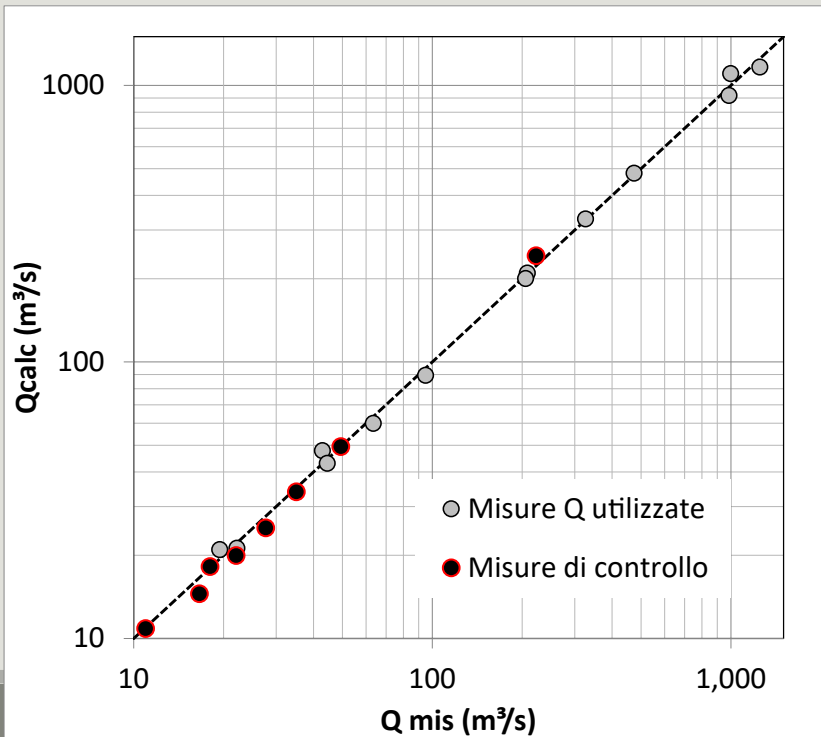
$X = (H, V_{ind})$

Adige a Pescantina (2019):

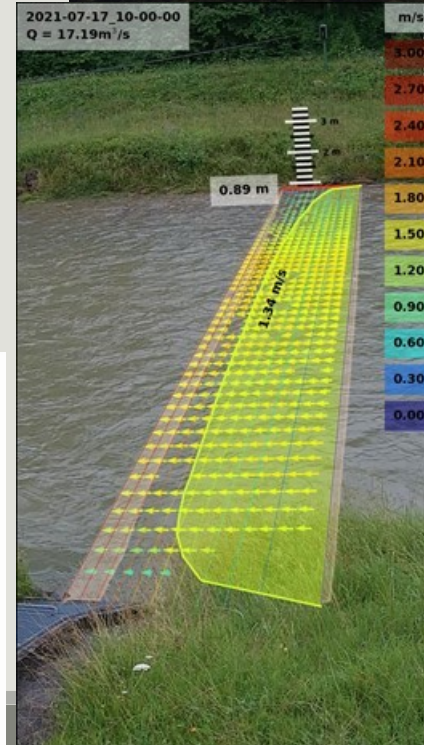
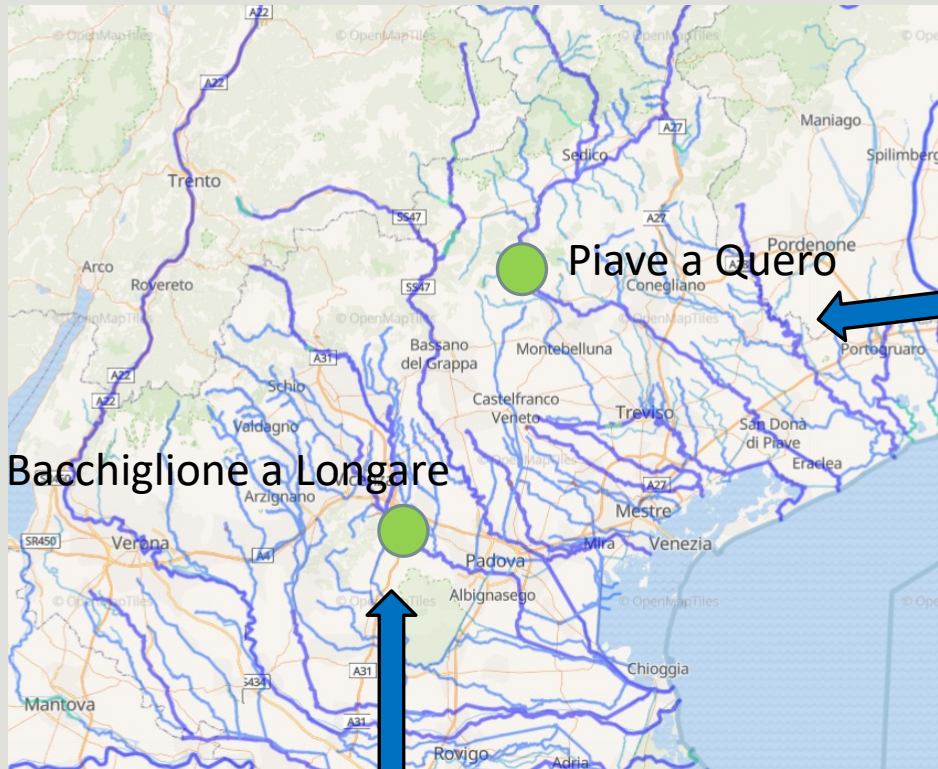
$$1. Q = A * (0.826 * V_i + 0.0912 * H)$$

$$\text{Se } V_i \leq ((0.945 + 0.190 * H) / 0.314)$$

$$2. Q = A * (0.945 + 0.512 * V_i + 0.281 * H)$$



# Misure in continuo - analisi video



Vmedia su verticale

$$V_{medv} = k \cdot V_{sup}$$

$$V_{medv} = f(k_s, y)$$





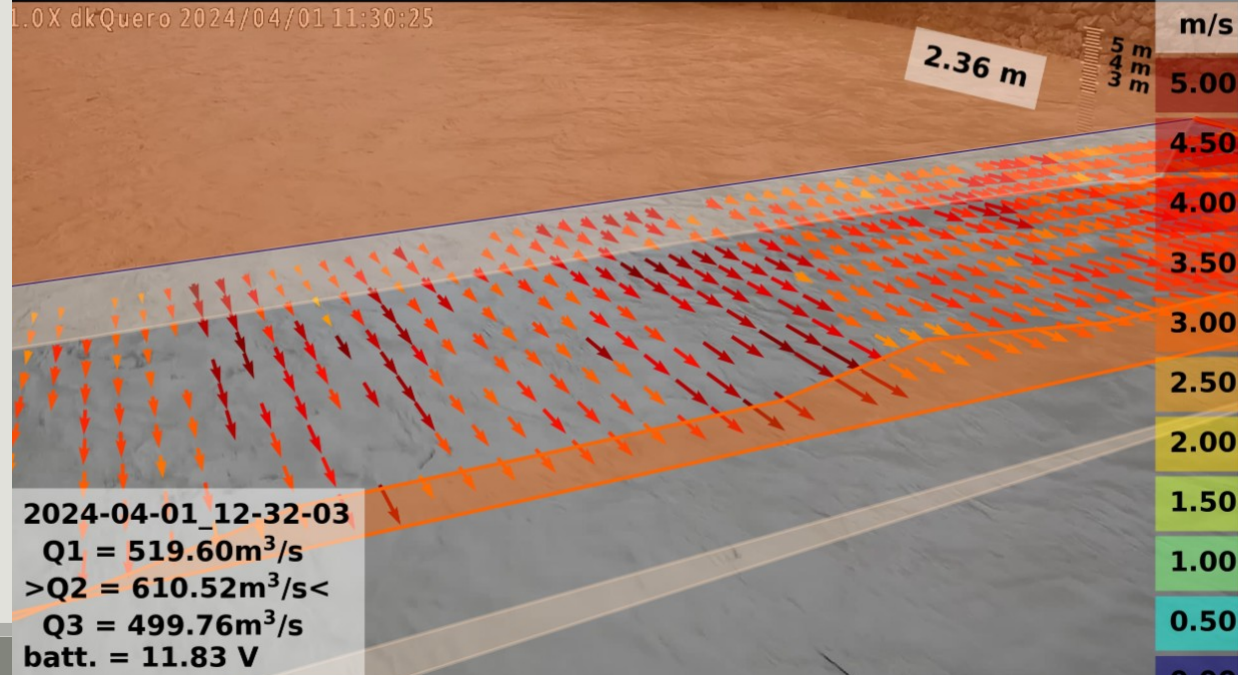
# Misure in continuo - analisi video

## Piave a Quero



Measurement image

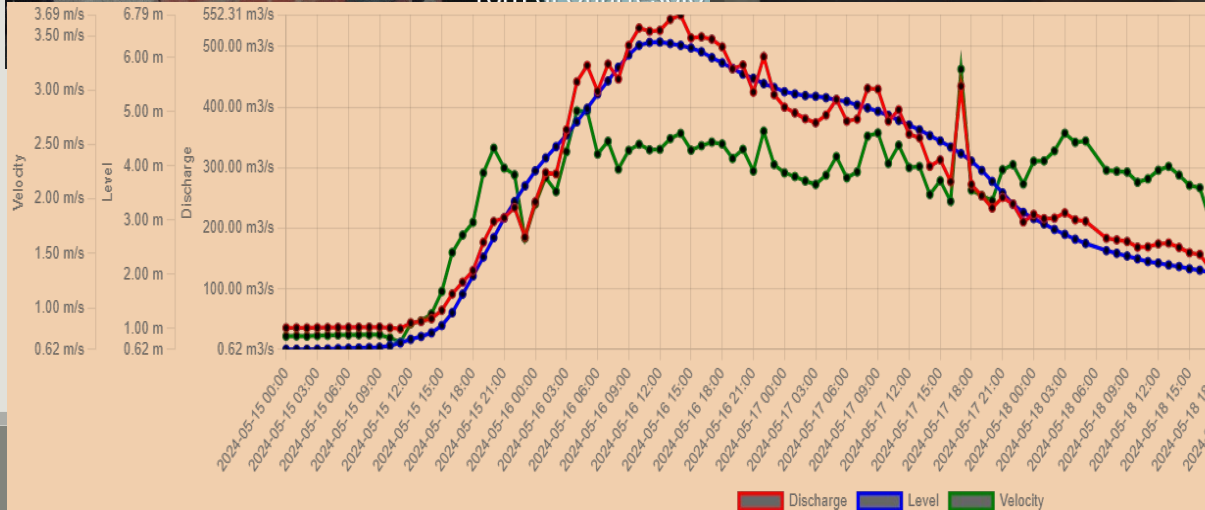
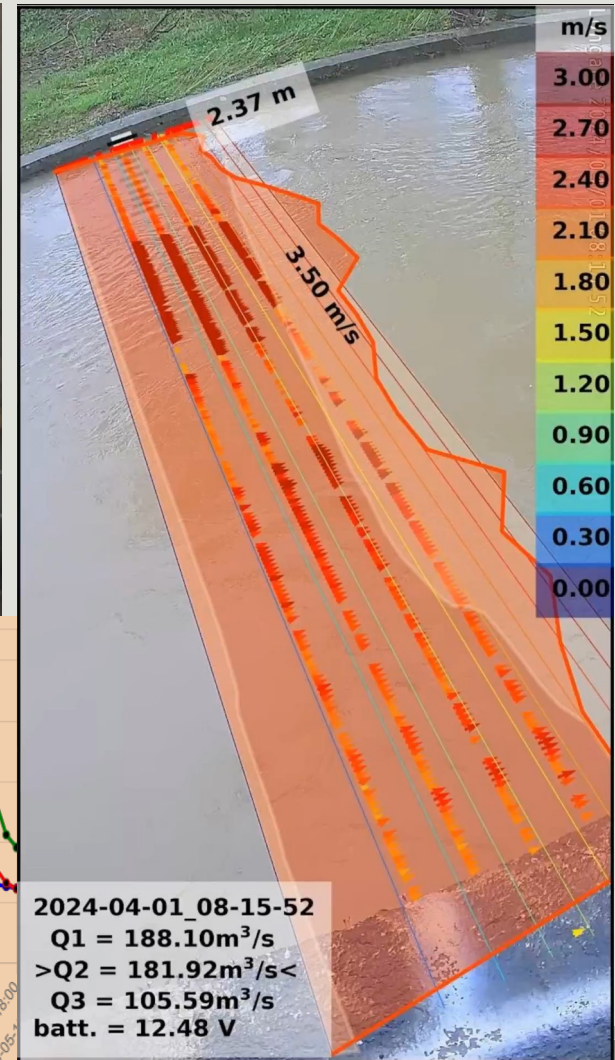
L.0X dkQuero 2024/04/01 11:30:25





# Misure in continuo - analisi video

## Bacchiglione a Longare





GRAZIE