دانشگاه فردوسی مشهد

عملیات مبانی و روشهای آبیاری

WATER MEASUREMENT MANUAL

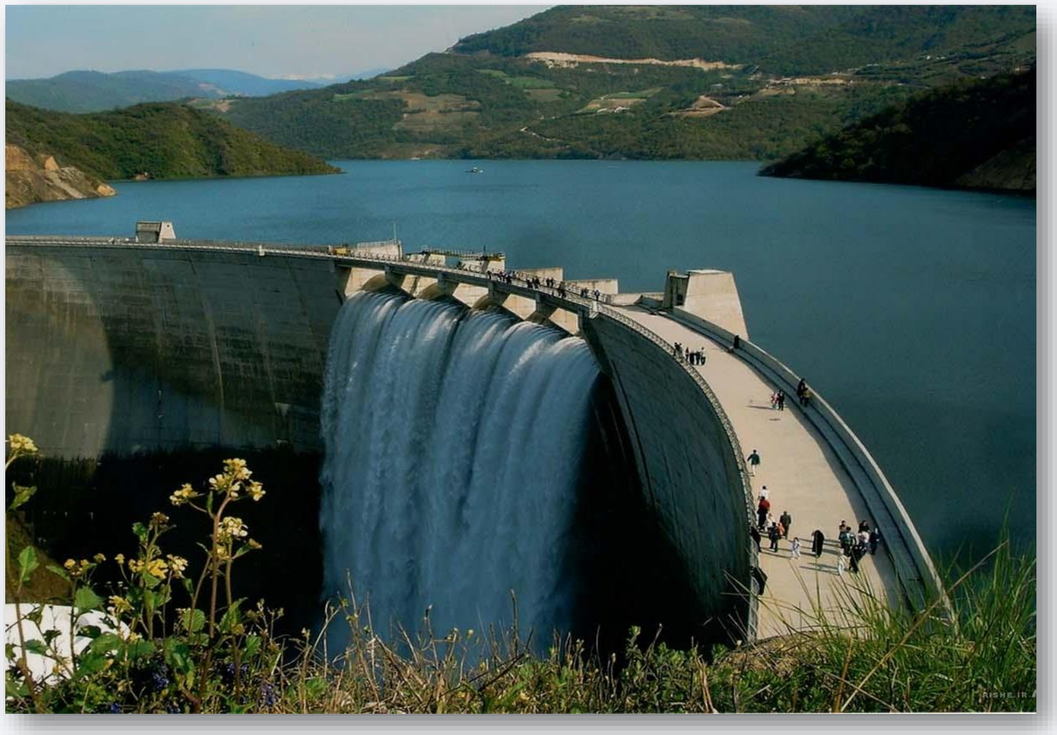
A WATER RESOURCES
TECHNICAL PUBLICATION

A guide to effective water measurement
practices for better water management

U.S. Department of the Interior
Bureau of Reclamation
Third edition

USDA
United States
Department of Agriculture

Theory



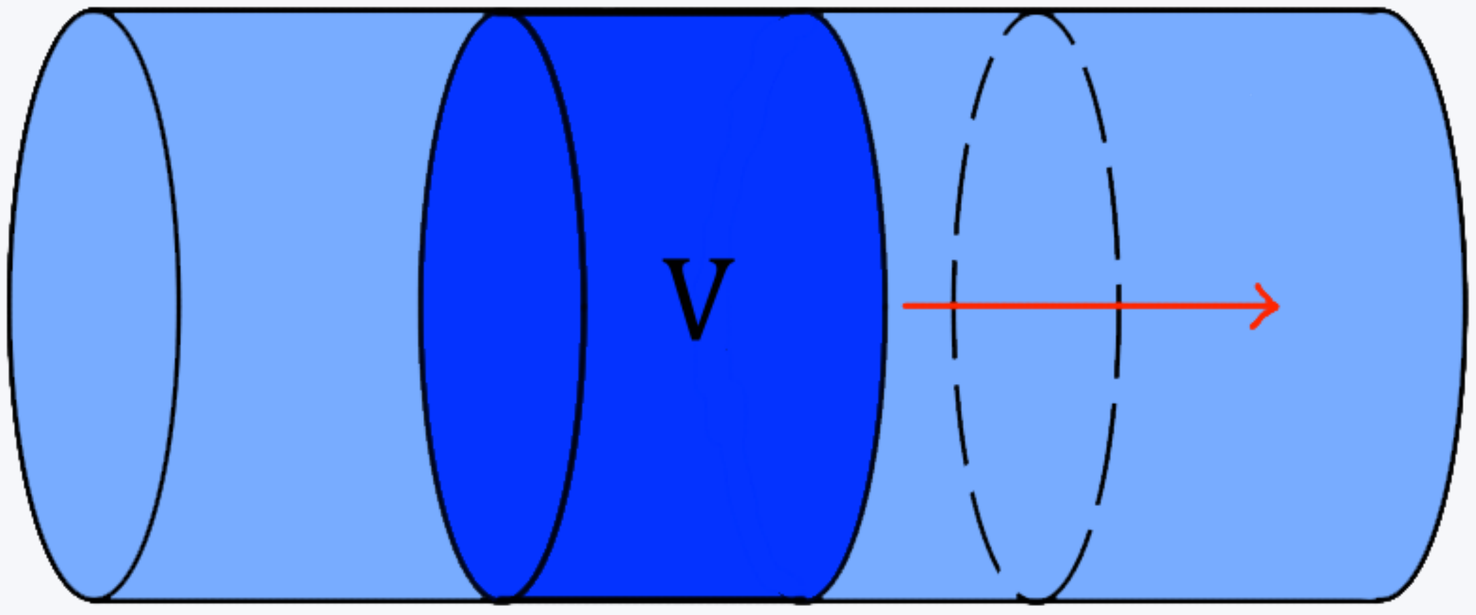
Theory

دبی یا آبده یا بده:

به حجم آب جابجاشده از یک مقطع مشخص (رودخانه، کانال آب، دریچه سد، لوله یا هر سازه دیگر) در مدت زمان مشخص بـده یا دبی گفته می‌شود.

Theory

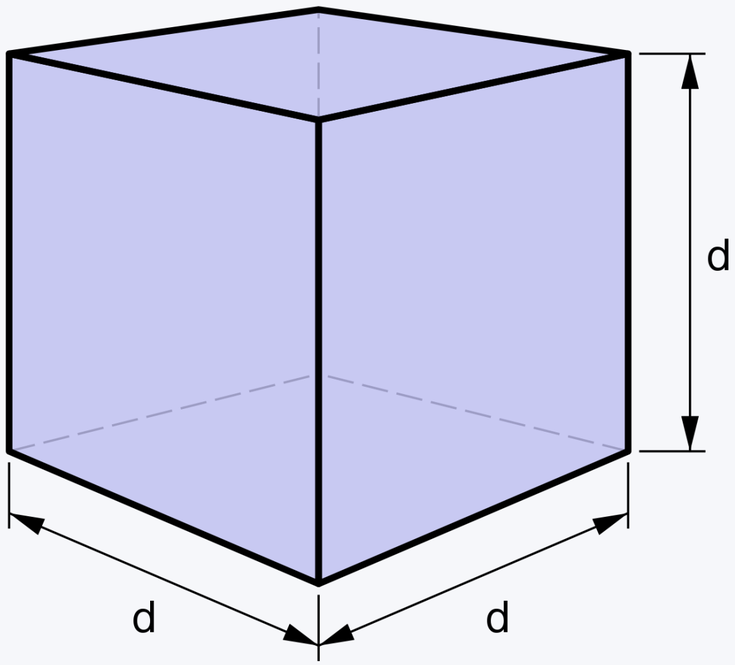
Volumetric **F**low **R**ate:



$$\boldsymbol{Q} = \lim_{\Delta t \to 0} \frac{\Delta \boldsymbol{V}}{\Delta \boldsymbol{t}} = \frac{\boldsymbol{dV}}{\boldsymbol{dt}}$$

Measure The Flow Rate Using Bucket Method

Experimental Method



$$Q = \frac{V}{t}$$

Q: Volumetric Flow Rate (L^3/T)
V: Volume of the Bucket (L^3)
T: Average Time (T)

Equipment


MODE
SPLIT RESET
START STOP
ACCUSPLIT
STOPWATCH
10:5323
MIN. SEC. 1/100
PRO SURVIVOR
601X
3V.1

Results

Trial Number	Time (Seconds)	Bucket Volume (Gallons)
1	13.2	5
2	14	5
3	14.5	5
4	13	5
5	13.4	5
6	13.1	5

$$t_{Ave} = \frac{13.2s + 14s + 14.5s + 13s + 13.4s + 13.1s}{6\ trial} = 13.5s$$

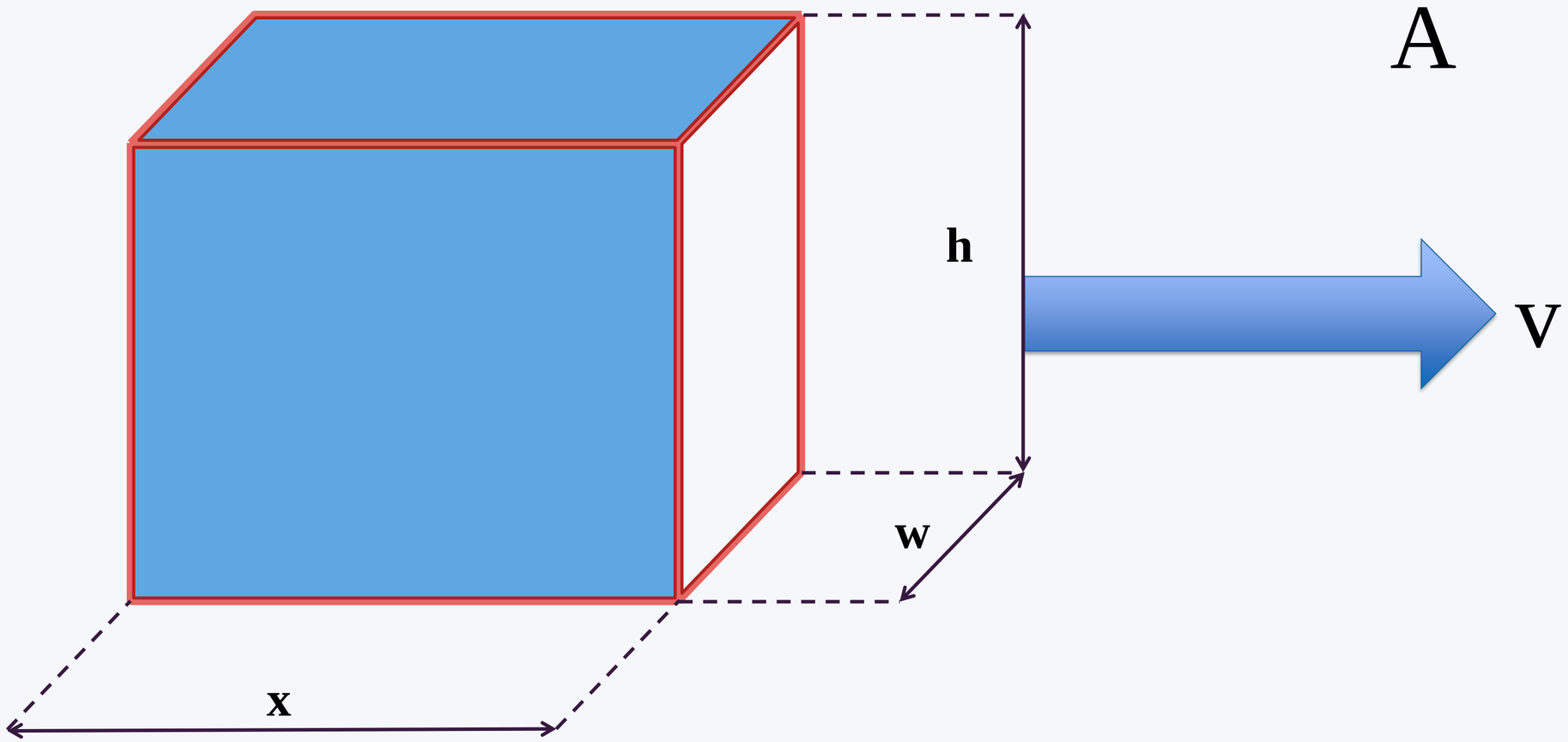
Q: Volumetric Flow Rate
V: Volume of the Bucket
T: Average Time

$$\boldsymbol{Q = \frac{V}{t} = \frac{5\ Gallons}{13.5\ Seconds} = 0.37\ \frac{Gallons}{Seconds}}$$

Float Method to Measure the Flow Rate

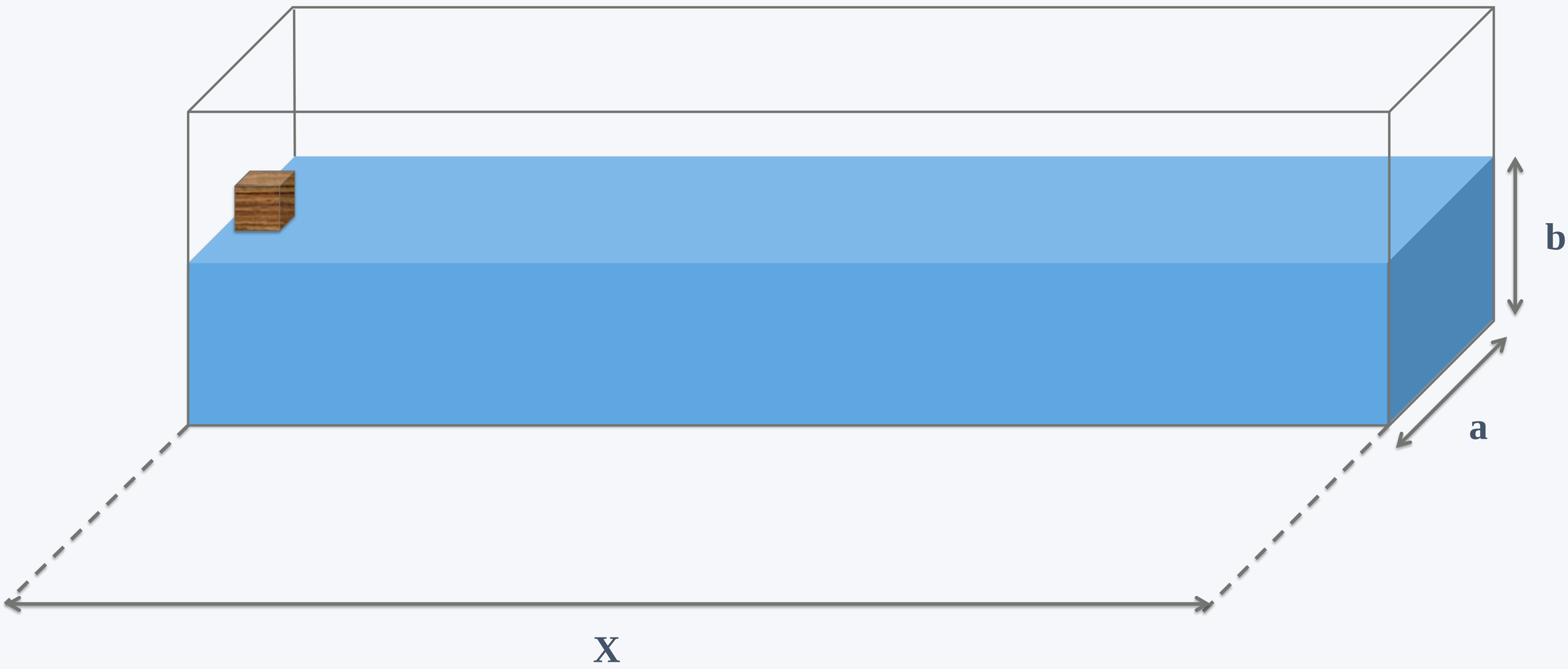
Theory

The **Volume of Water** Passing Through a **Channel Section** Per **Unit Time** Is Called The Flow Rate Or **Discharge**.

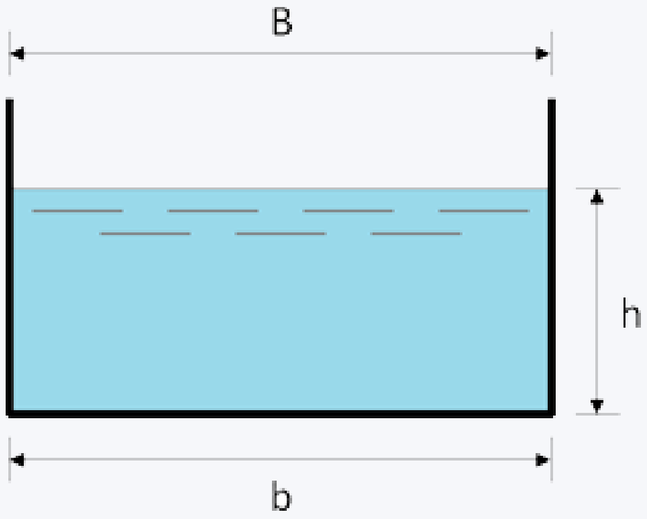


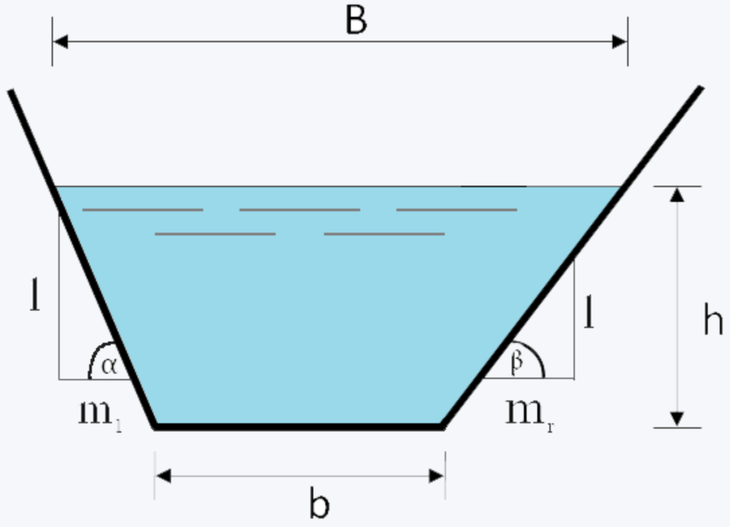
$$Q = \frac{V}{t} = \frac{x \times w \times h}{\cancel{v} \times \cancel{A}} = \frac{x}{t} \times (w \times h)$$

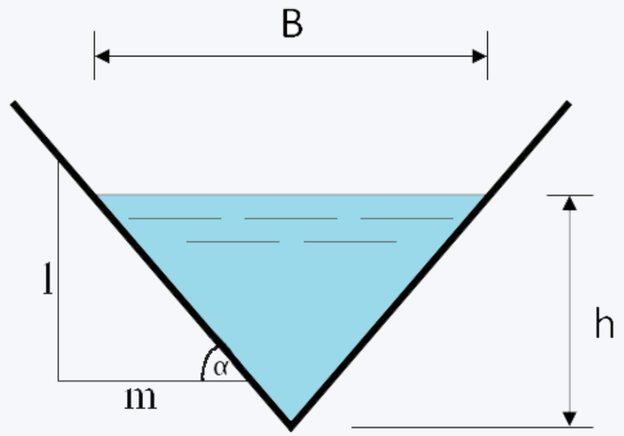
Experimental Method

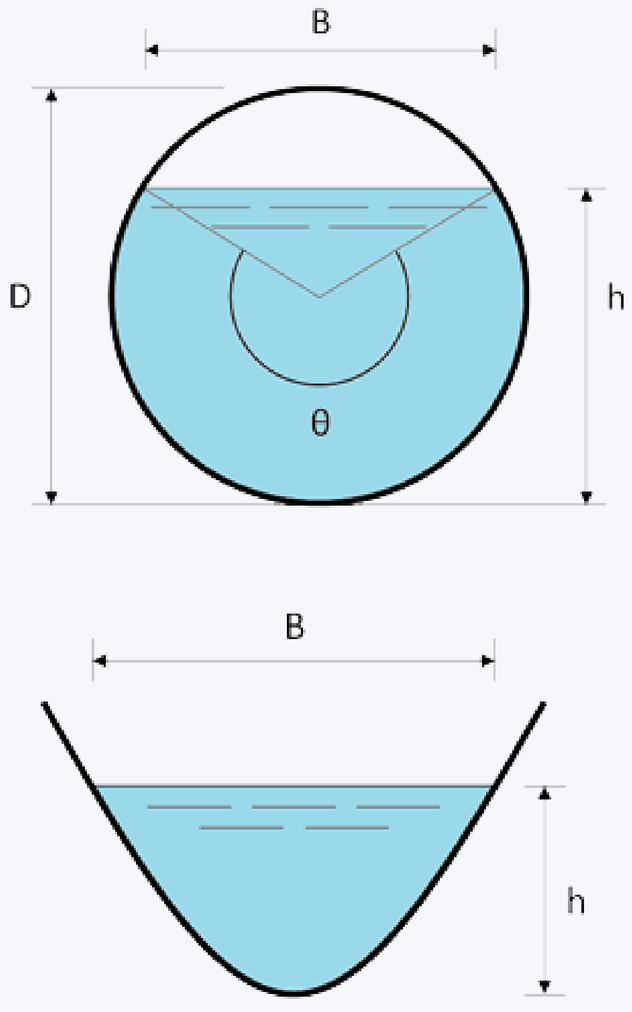


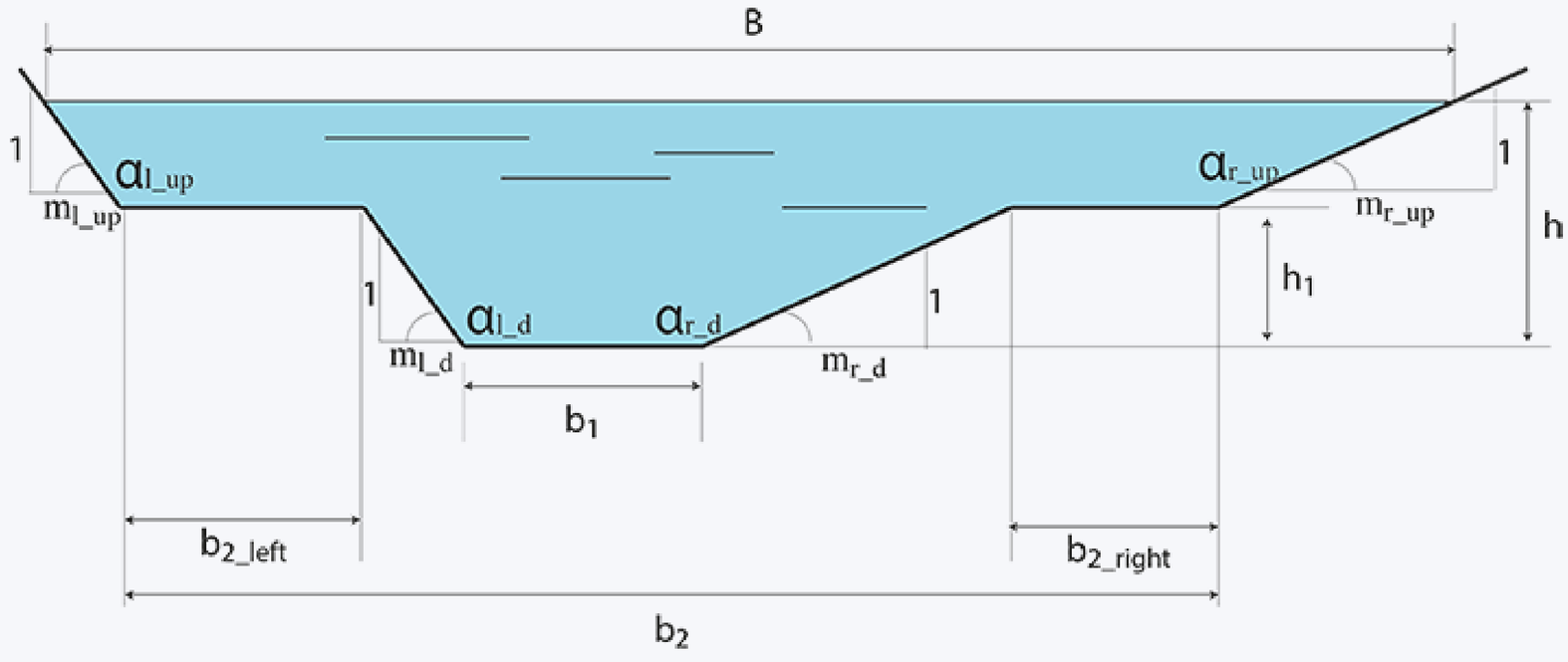
Experimental Method



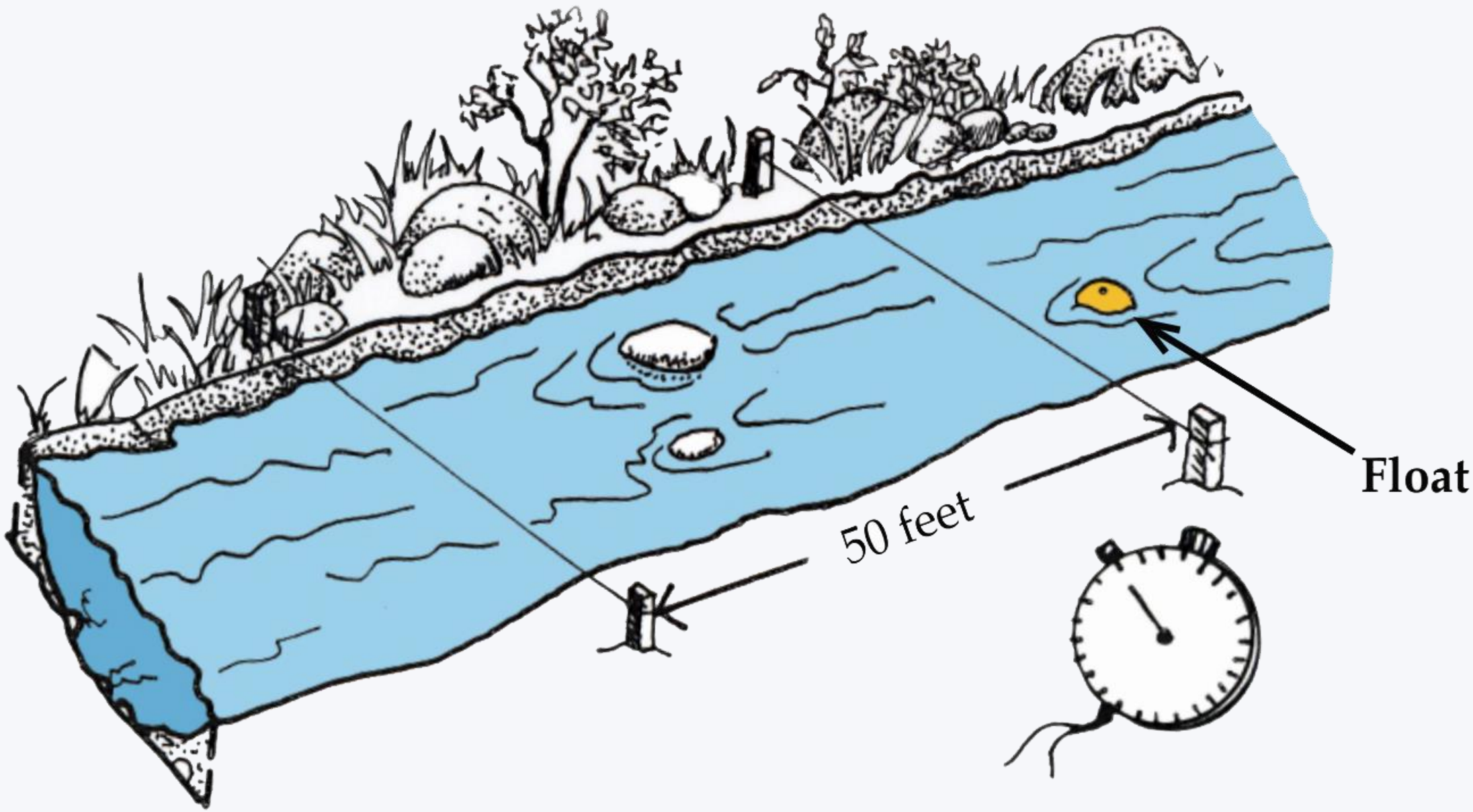




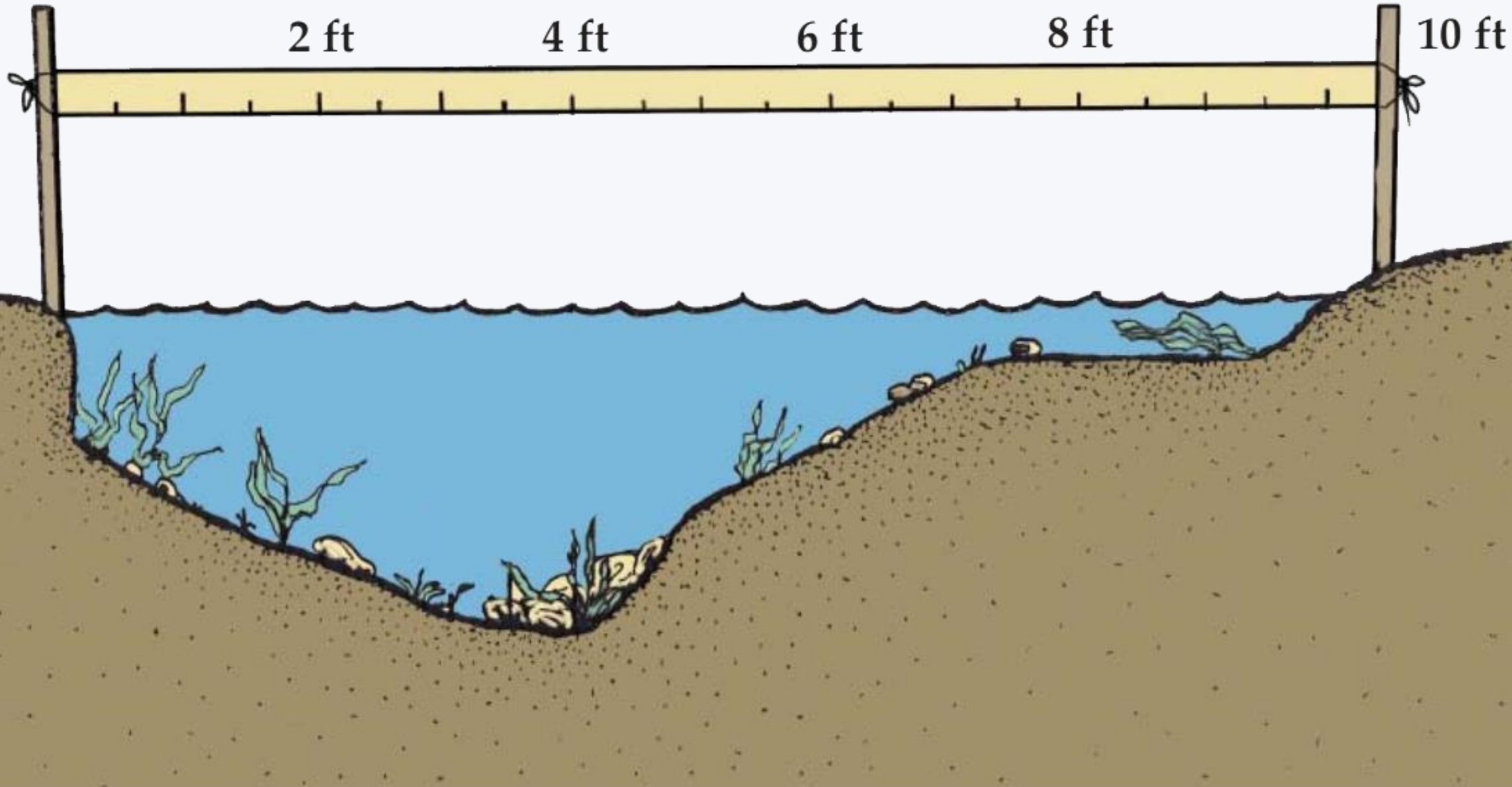




Experimental Method



Experimental Method

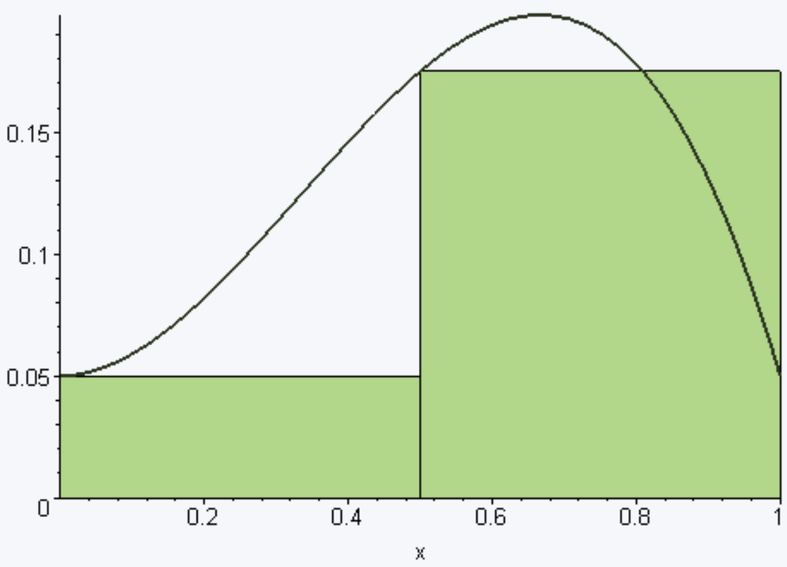


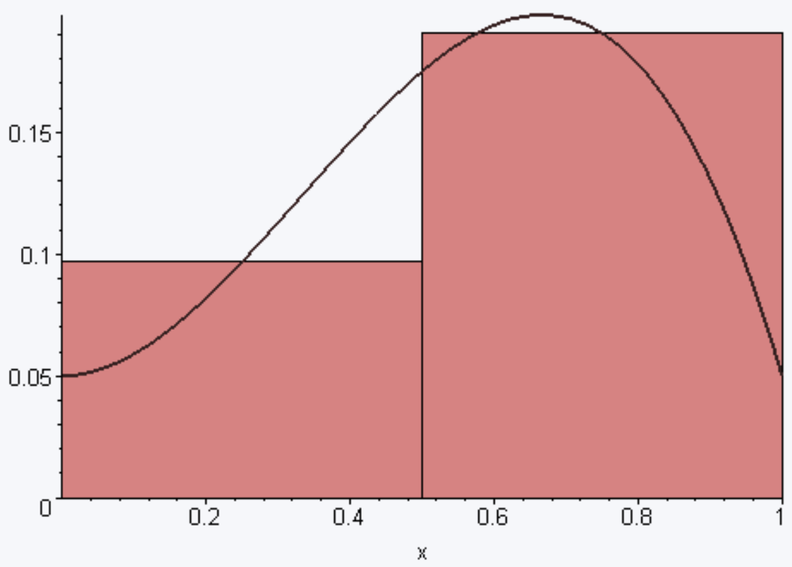
Experimental Method

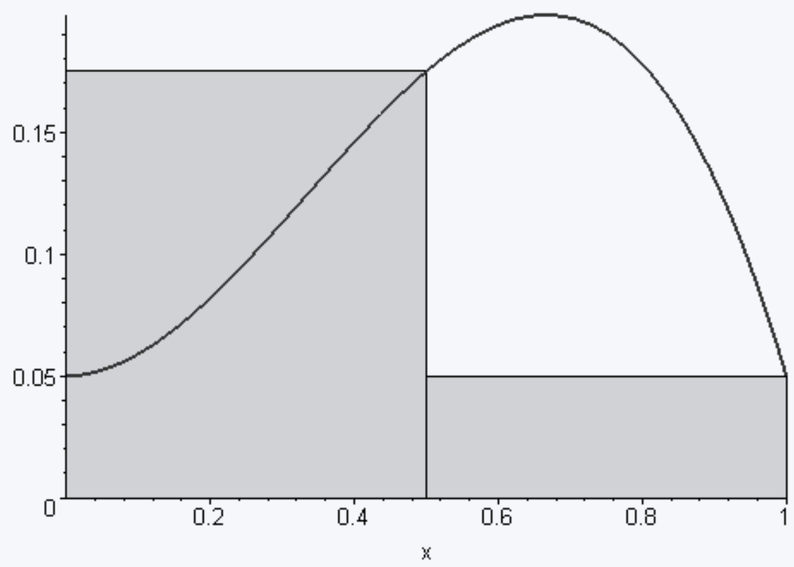
Riemann Sum

$$S = \sum_{i=1}^{n} f(x_i^*)\,\Delta x_i \qquad \Delta x = \frac{b-a}{n}$$

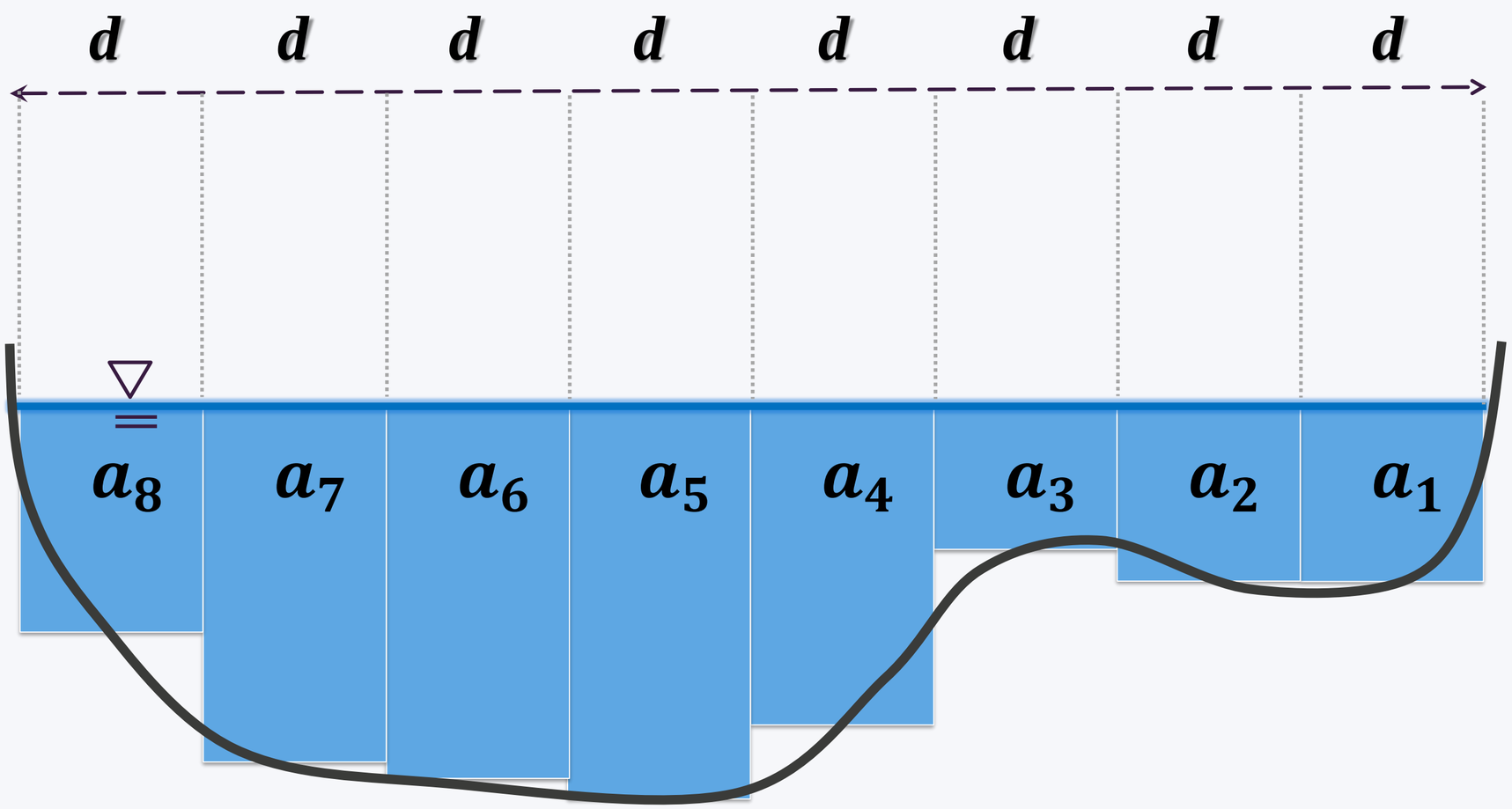
$$\Delta x \left[f(a + \frac{\Delta x}{2}) + f(a + \frac{3\,\Delta x}{2}) + \cdots + f(b - \frac{\Delta x}{2}) \right]$$





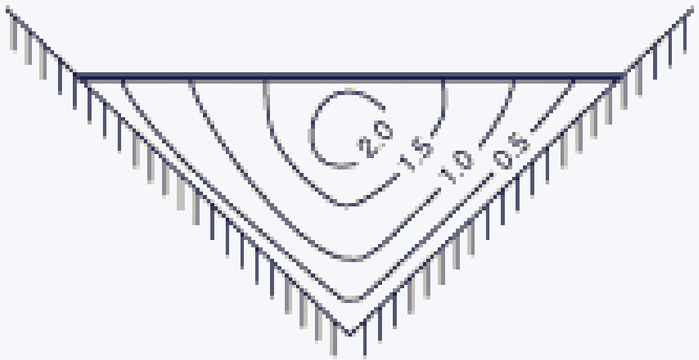


Experimental Method

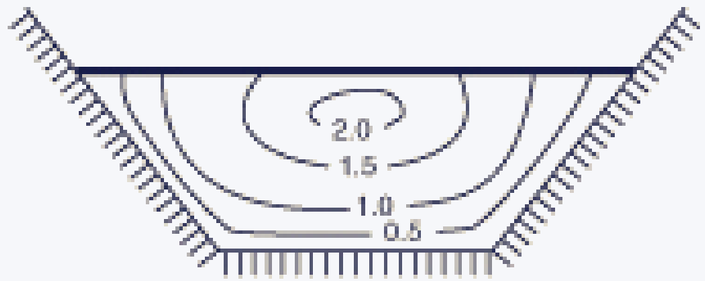


$$A = \sum_{1}^{8} a_i = a_1 + a_2 + a_3 + a_4 + a_5 + a_6 + a_7 + a_8$$

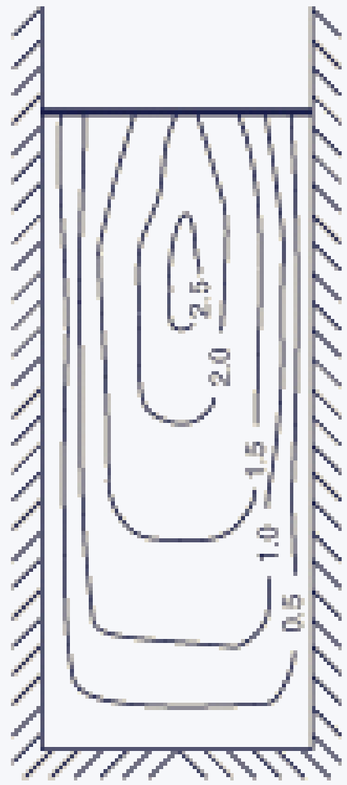
Experimental Method



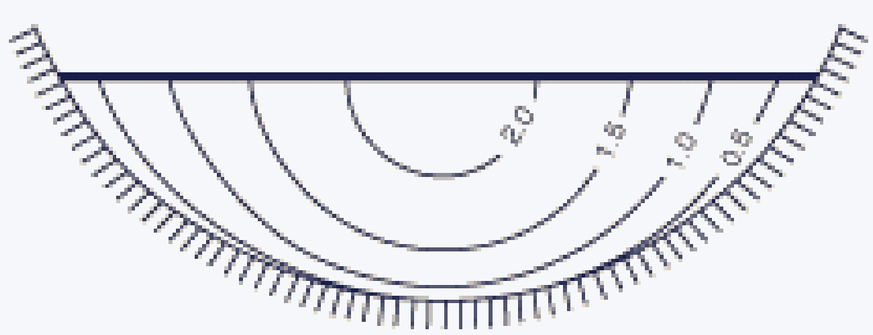
Triangular channel



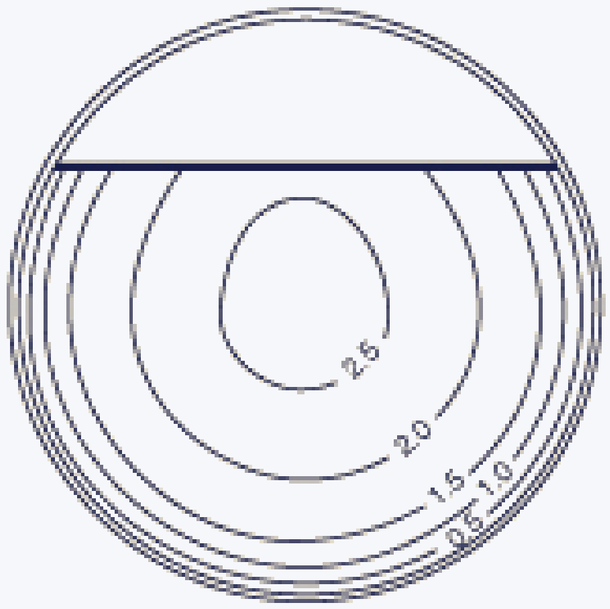
Trapezoidal channel



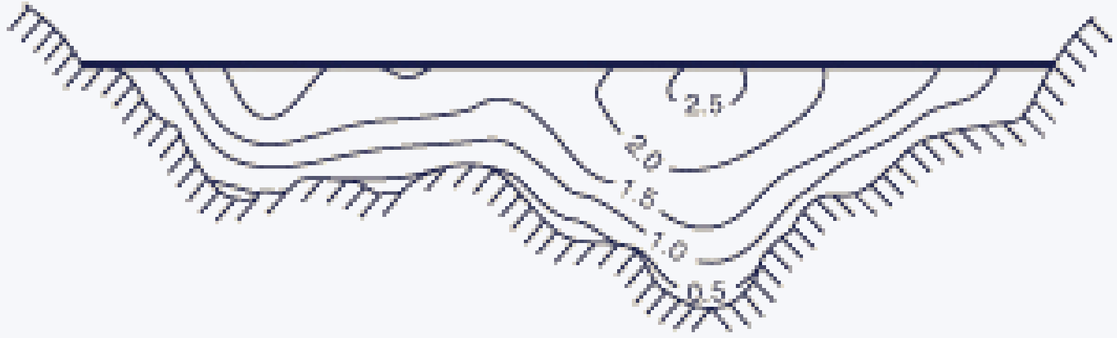
Narrow rectangular section



Shallow ditch

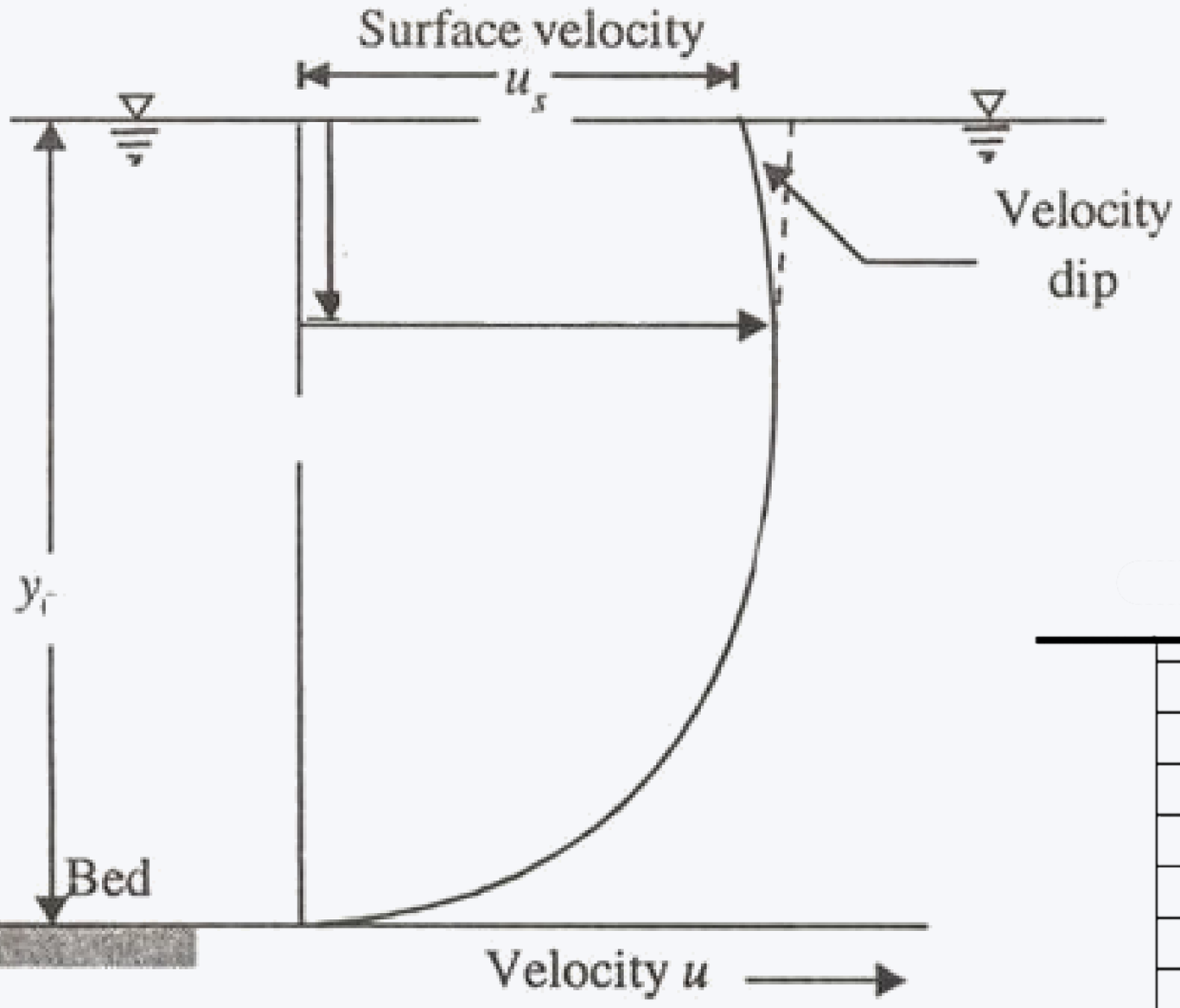


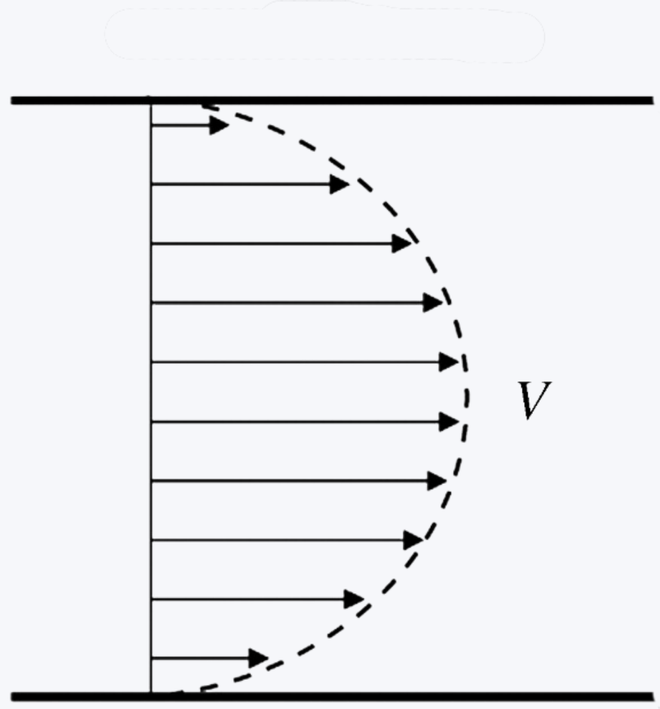
Pipe



Natural irregular channel

Experimental Method





flow direciton

Experimental Method

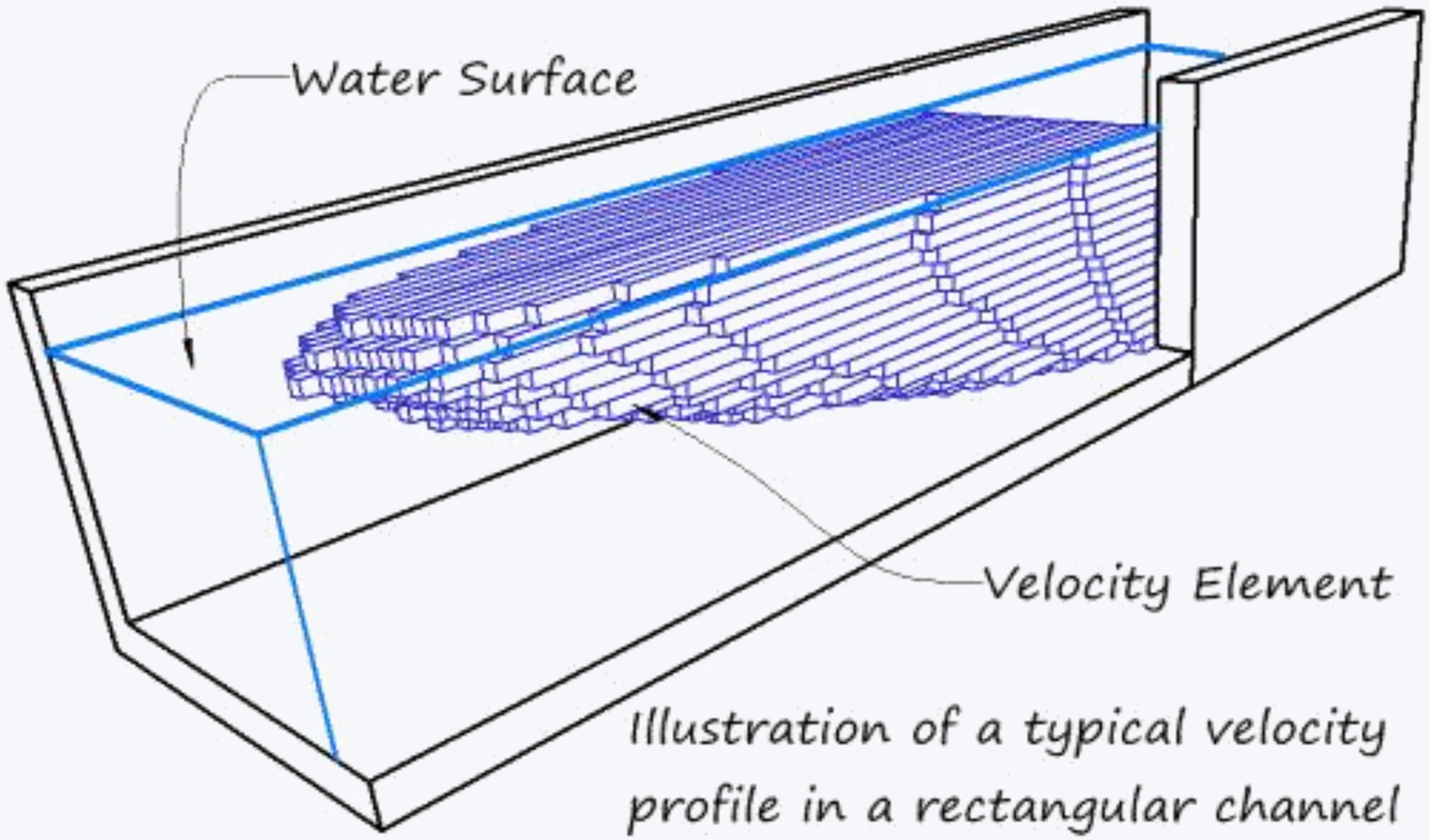


Illustration of a typical velocity profile in a rectangular channel

Experimental Method

Table 13-1. Coefficients to correct surface float velocities to mean channel velocities	
Average depth in reach (ft)	Coefficient
1	0.66
2	0.68
3	0.70
4	0.72
5	0.74
6	0.76
9	0.77
12	0.78
15	0.79
>20	0.80

Experimental Method

Trial	Time (s)	Distance (m)	Area (m^2)
1	10.25	2	0.032
2	10.63	2	0.032
3	11.02	2	0.032

$$\overline{T} = \frac{10.25 + 10.63 + 11.02}{3} = 10.63s$$

$$Q = \frac{2}{10.63} \times 0.032 = 0.006\ {}^{m^3}/_{s}$$

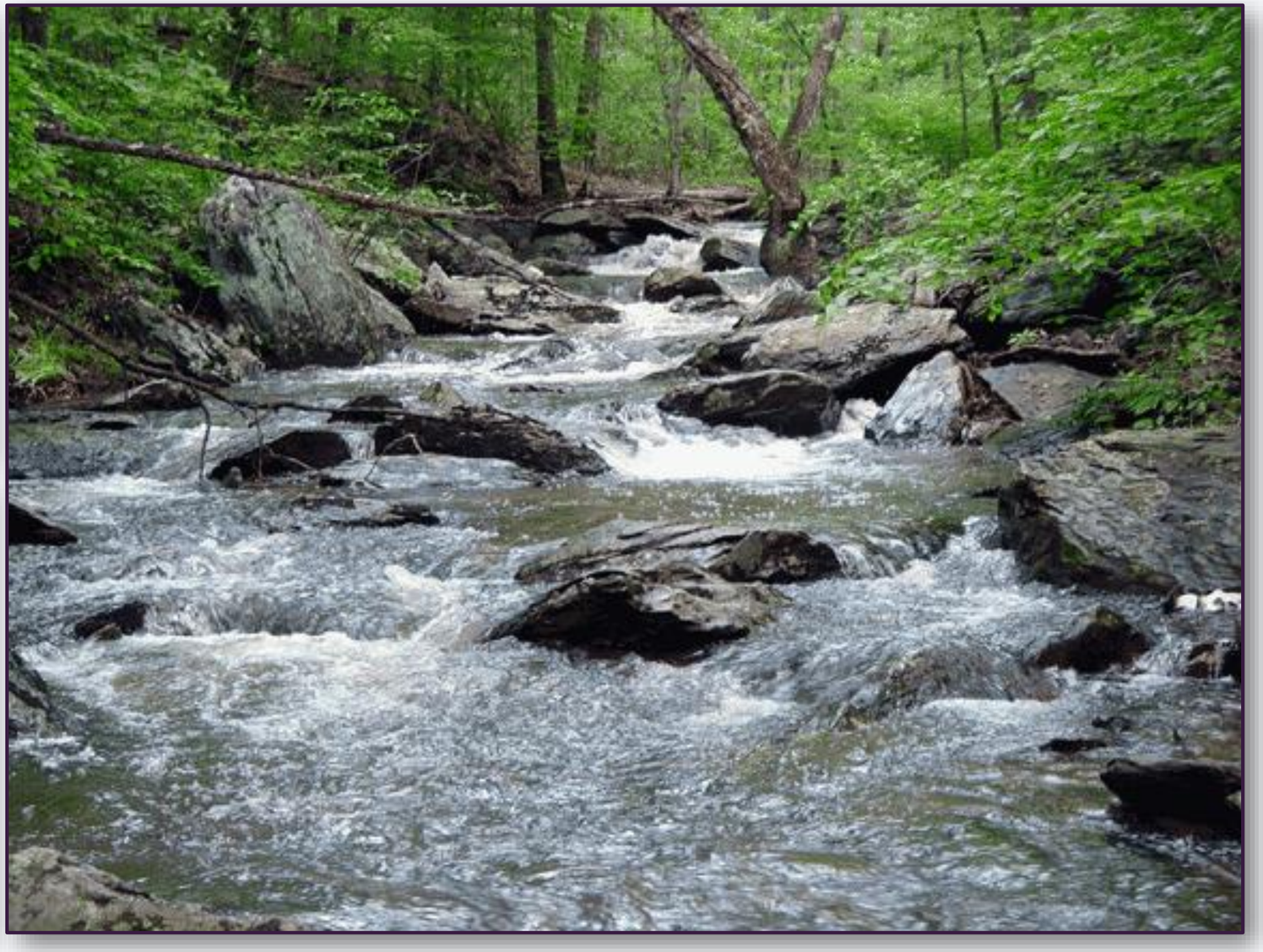
Equipment


MODE
SPLIT RESET
START STOP
ACCUSPLIT
STOPWATCH
10:5323
MIN. SEC. 1/100
PRO SURVIVOR
601X
3V.1


STAINLESS
FitMin
3m

Discharge **M**easurements **U**sing **T**racers

Theory



Theory

Kinds of **T**racers **U**sed

ردیاب‌ها انواعی از ماده یا انرژی هستند که به منظور تعیین توزیع زمانی و مکانی آب و مواد آلاینده آن در منابع آب به کار میروند

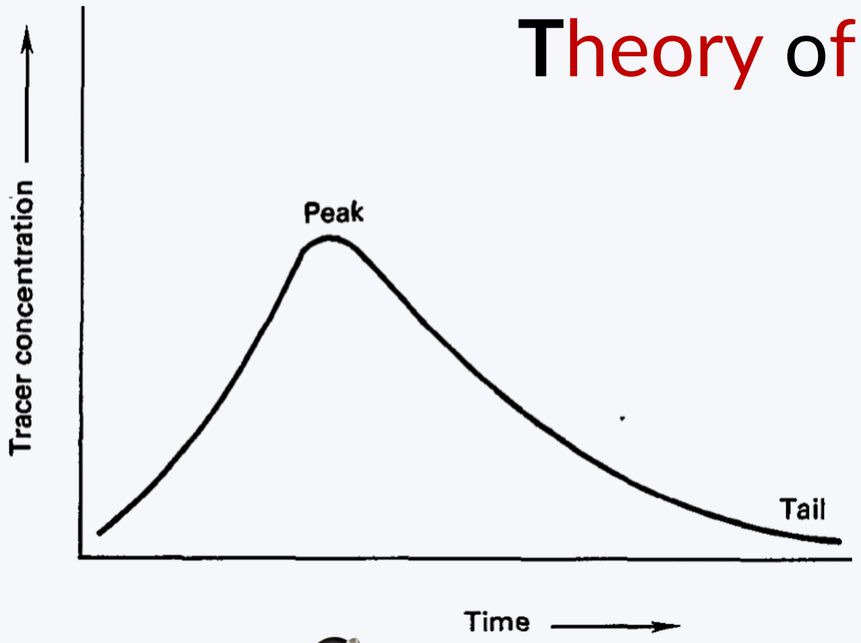
ویژگی‌های ردیاب‌ها:

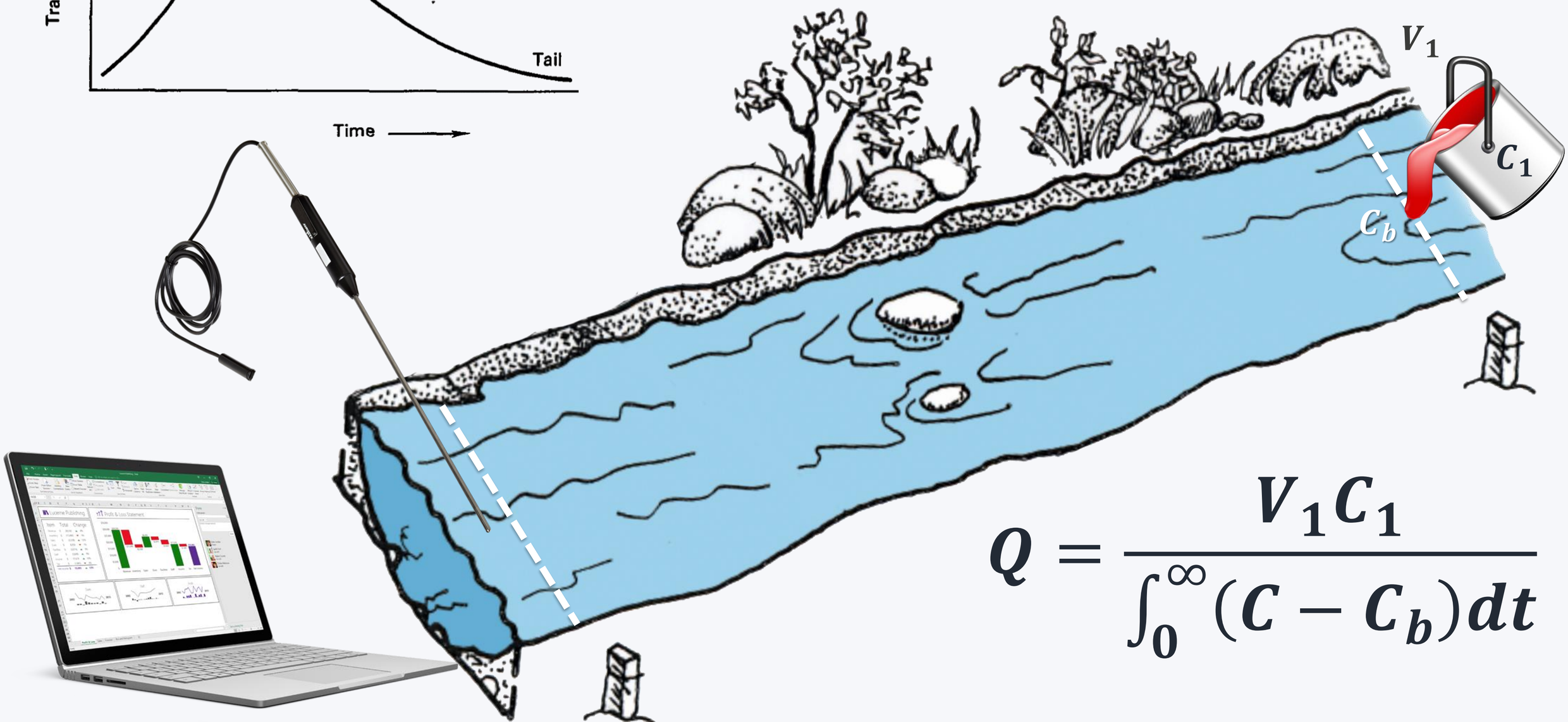
- پایداری ردیاب در طول مدت عملیات ردیابی
- بی خطر بودن برای محیط زیست حتی در غلظت کم
- امکان استفاده توام از ردیابهای مختلف
- امکان آشکارسازی با دقت بالا در غلظت کم
- انحلالپذیری در آب
- قابلیت جدایش از محیط زیست

Theory

Dilution Method

Theory of the Sudden Injection Method



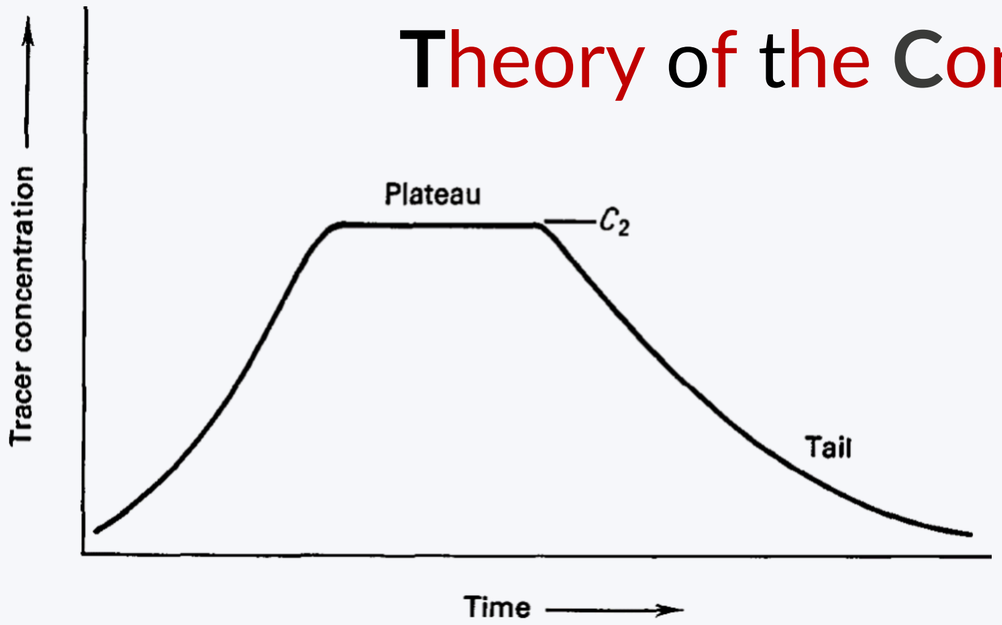


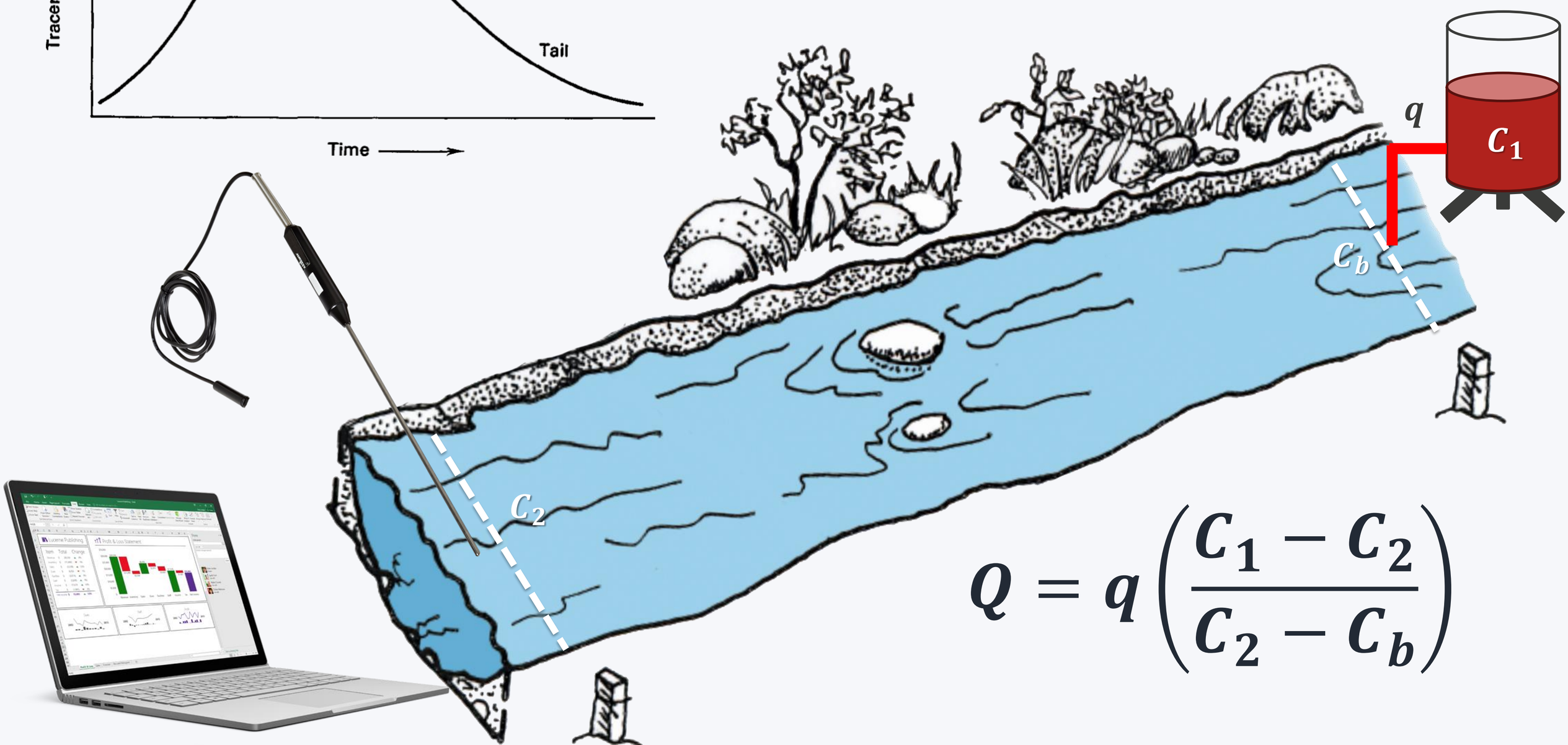
$$Q = \frac{V_1 C_1}{\int_0^\infty (C - C_b)dt}$$

Theory

Dilution Method

Theory of the Constant Rate Injection Method



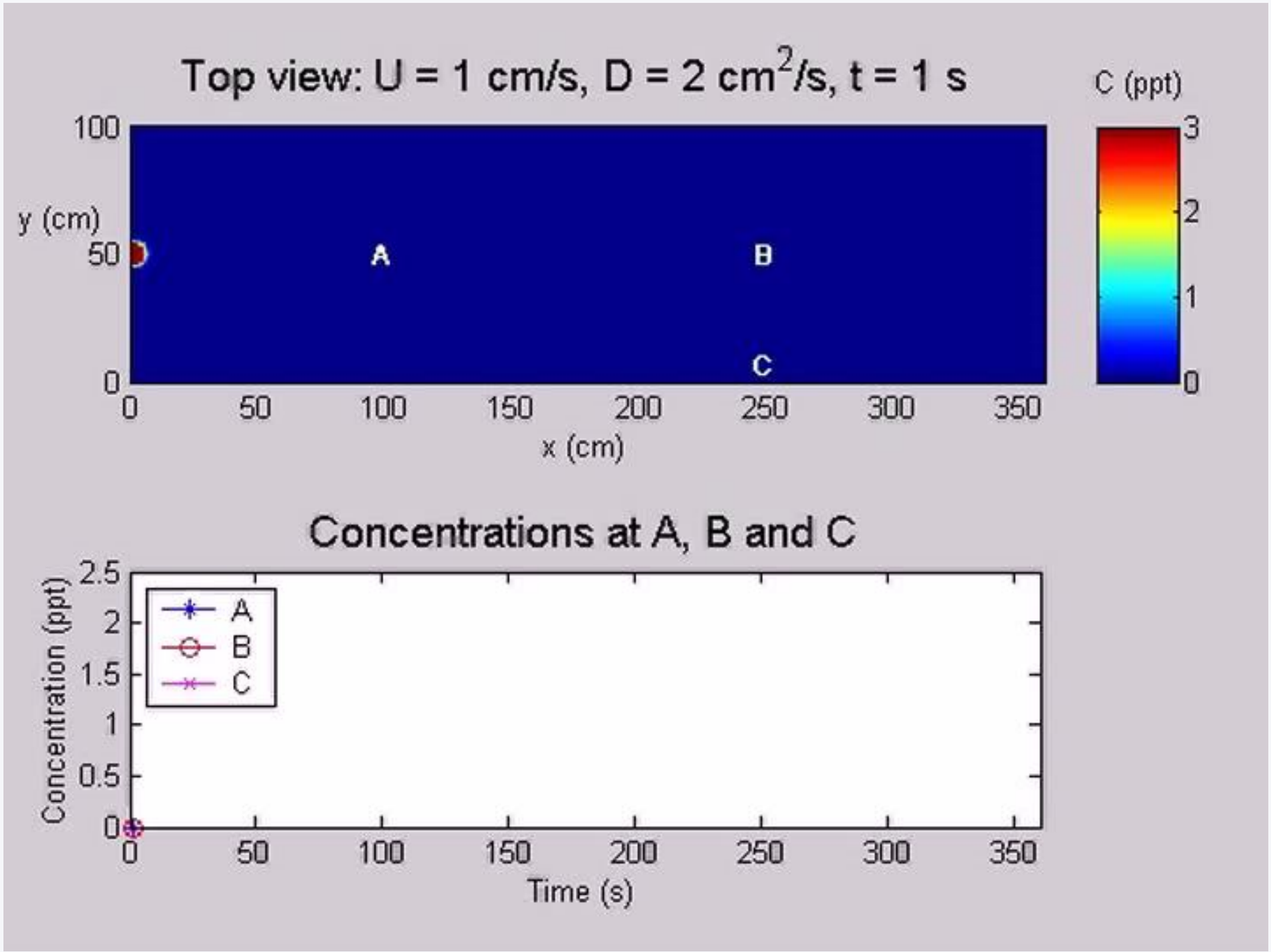


$$Q = q\left(\frac{C_1 - C_2}{C_2 - C_b}\right)$$

Theory

Dilution Method

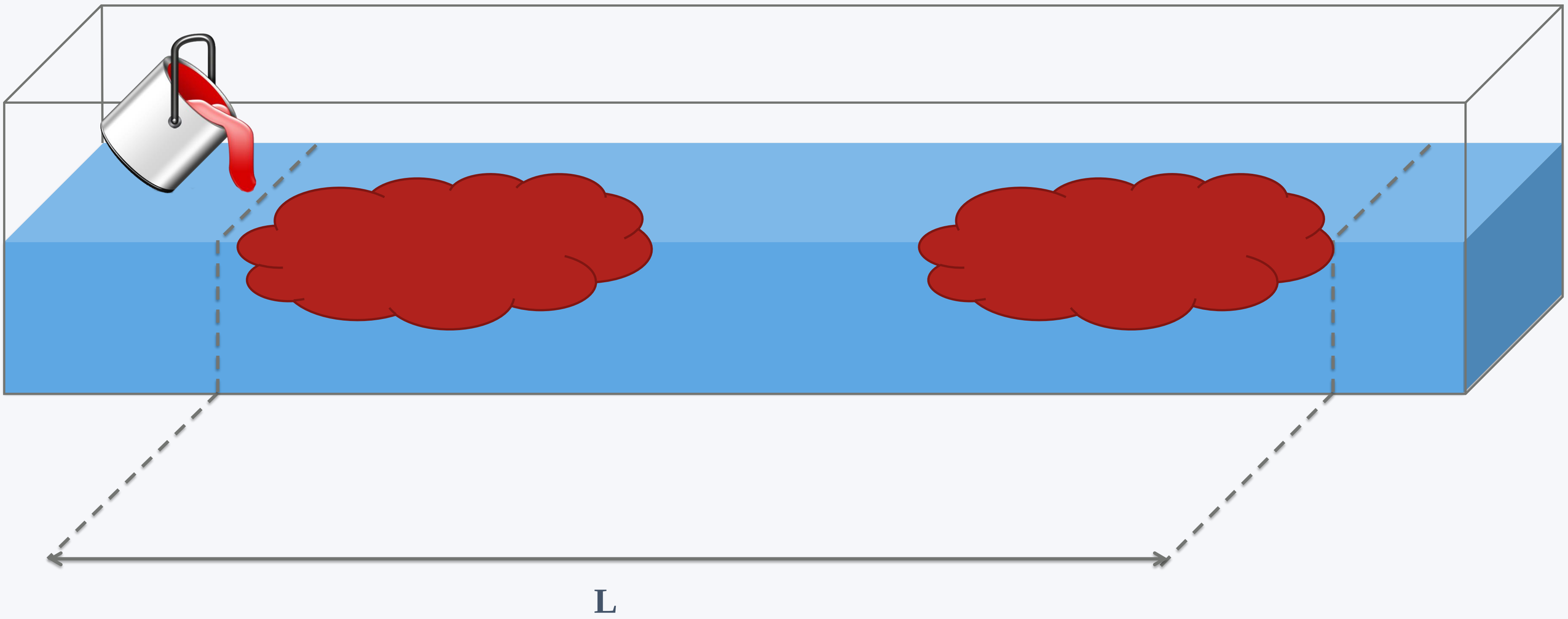
Theory of the Constant Rate Injection Method



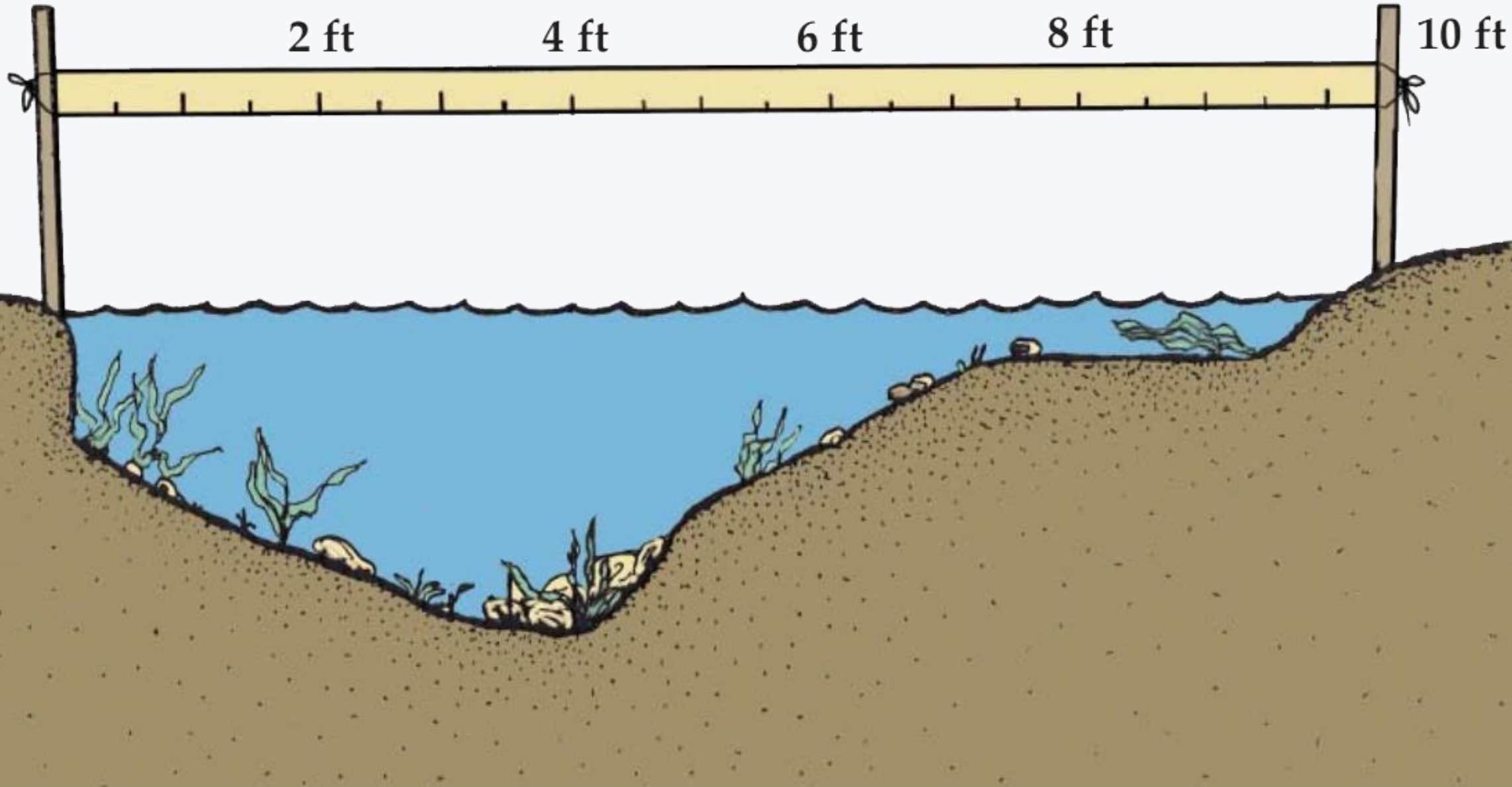
Experimental Method

$$t = \frac{t_1 + t_2}{2}$$

t_2
t_1

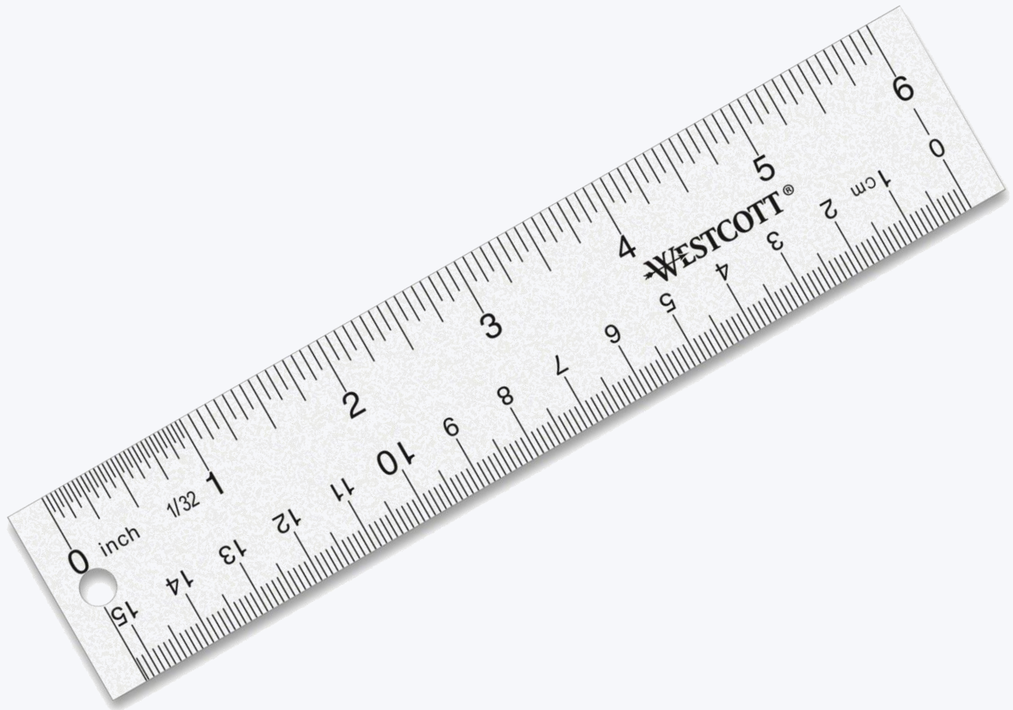


Experimental Method



Equipment

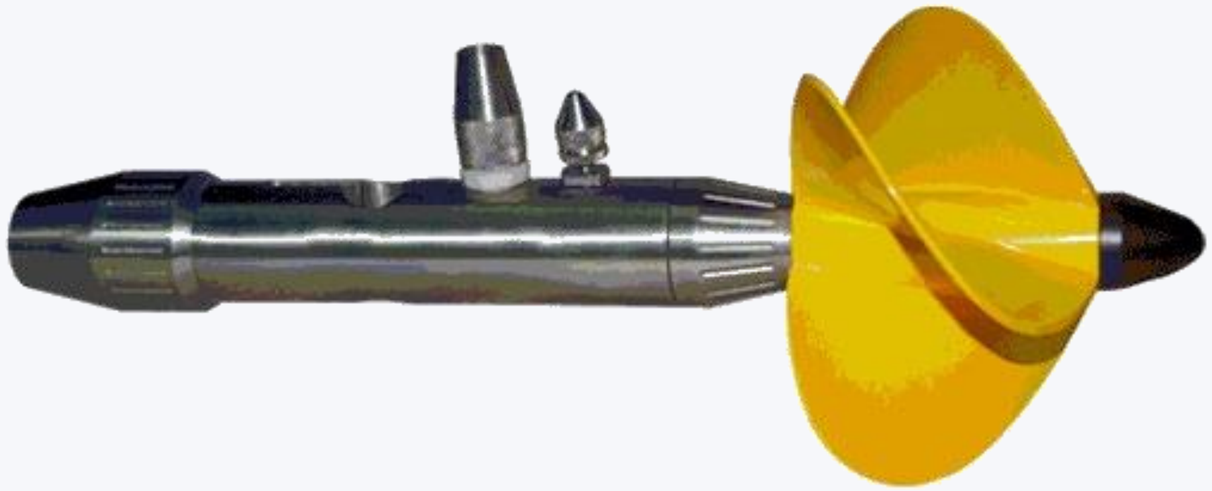

STAINLESS
FitMin
3m

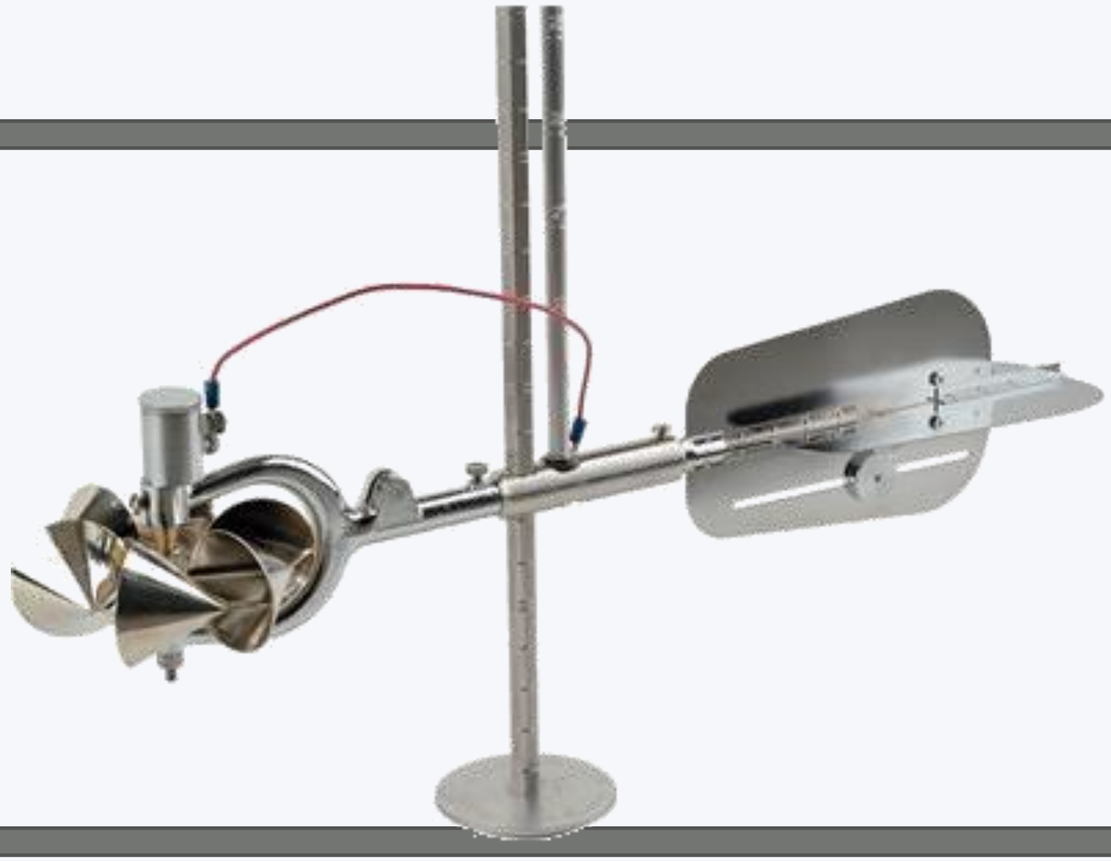

WESTCOTT®
inch
cm


MODE
SPLIT RESET
START STOP
ACCUSPLIT
STOPWATCH
10:5323
MIN. SEC. 1/100
PRO SURVIVOR
601X
3V.1

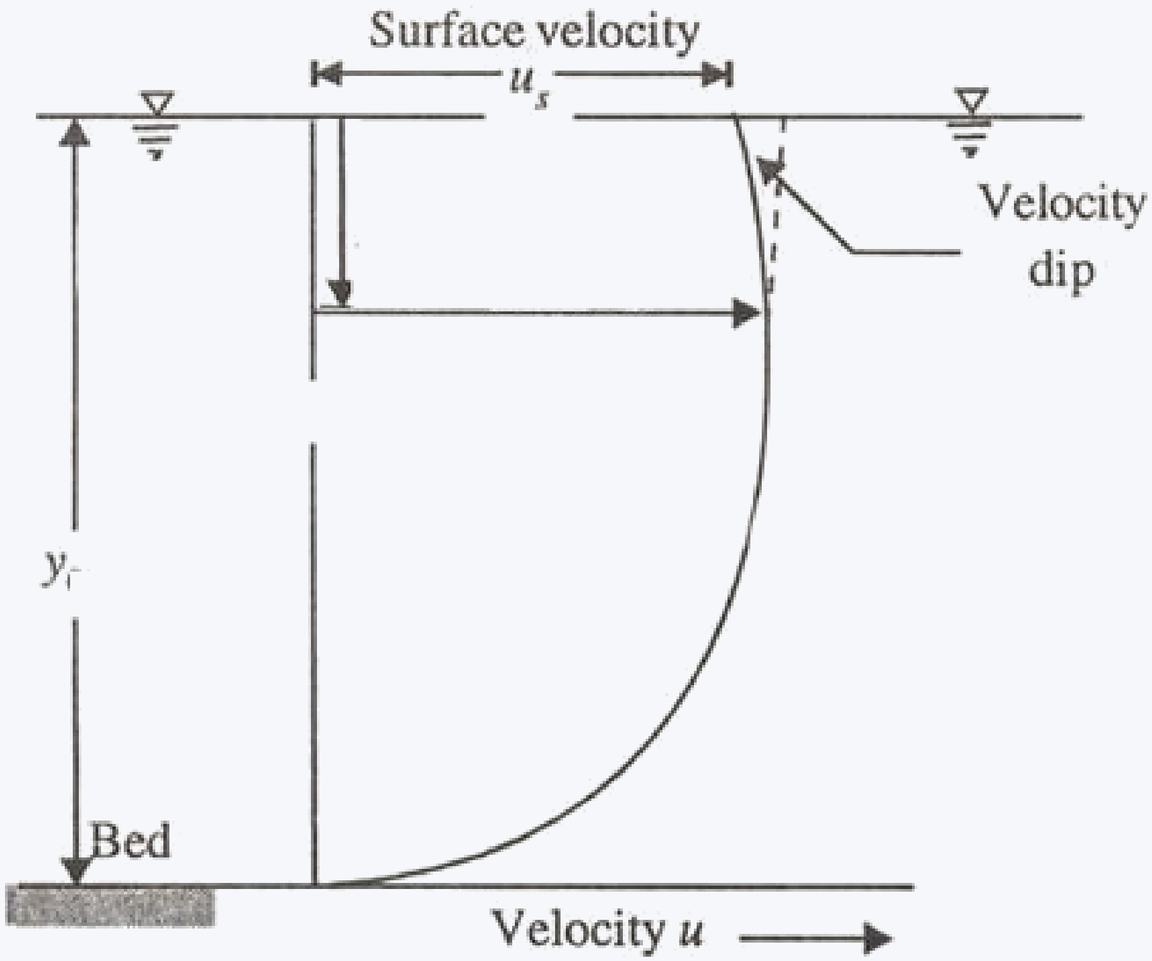

BOMEX
100ml
APPROX

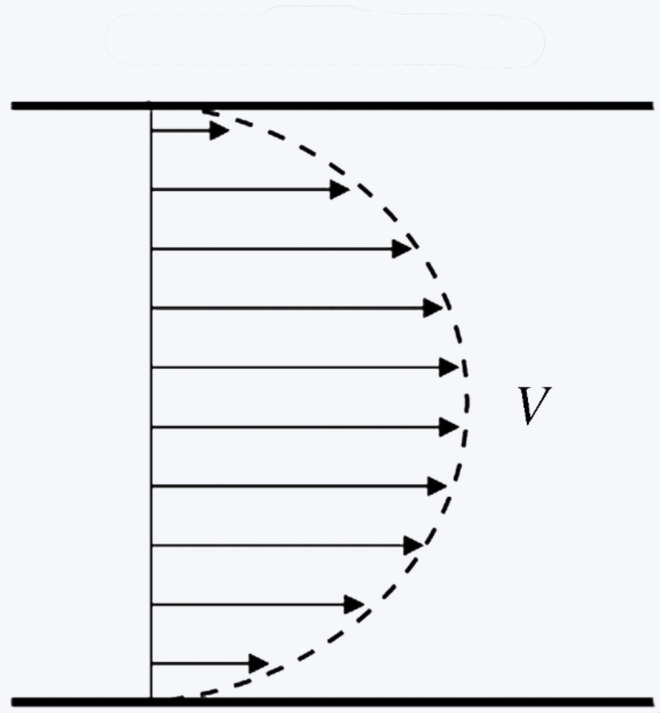
Discharge Measurements Using Current Meter

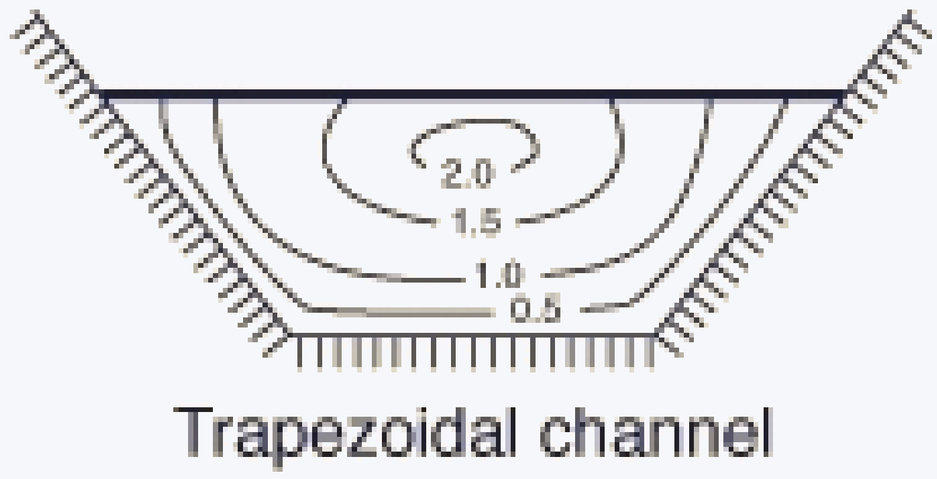




Theory







Trapezoidal channel

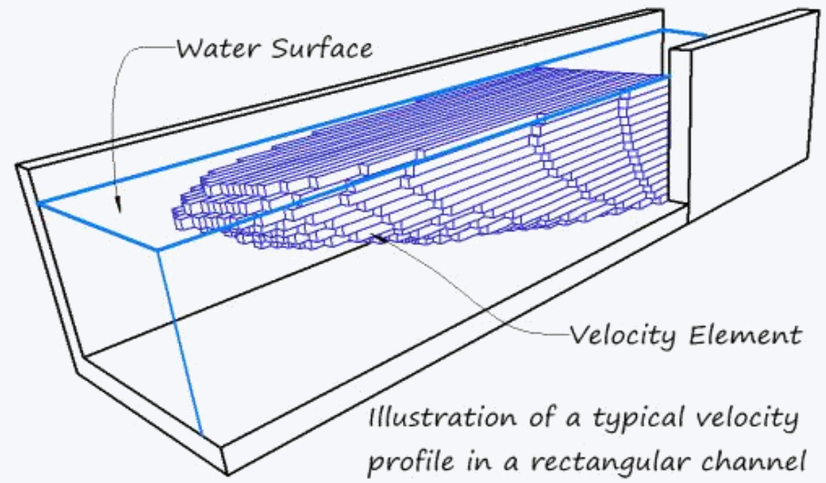


Illustration of a typical velocity profile in a rectangular channel

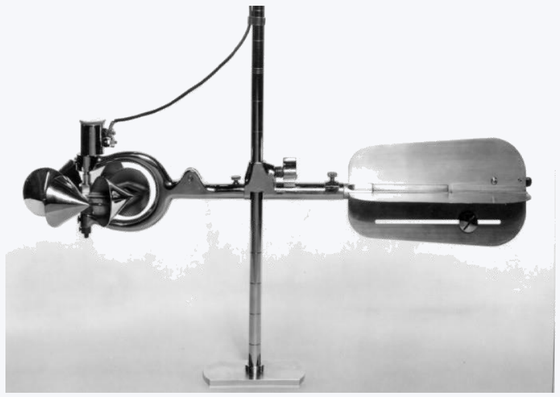
Theory

Classes of **C**urrent **M**eters

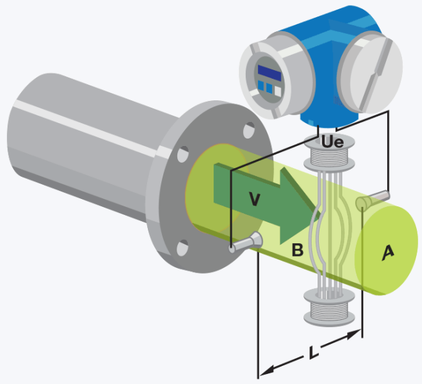
Doppler **Velocity Meters**

Optical Strobe **Velocity Meters**

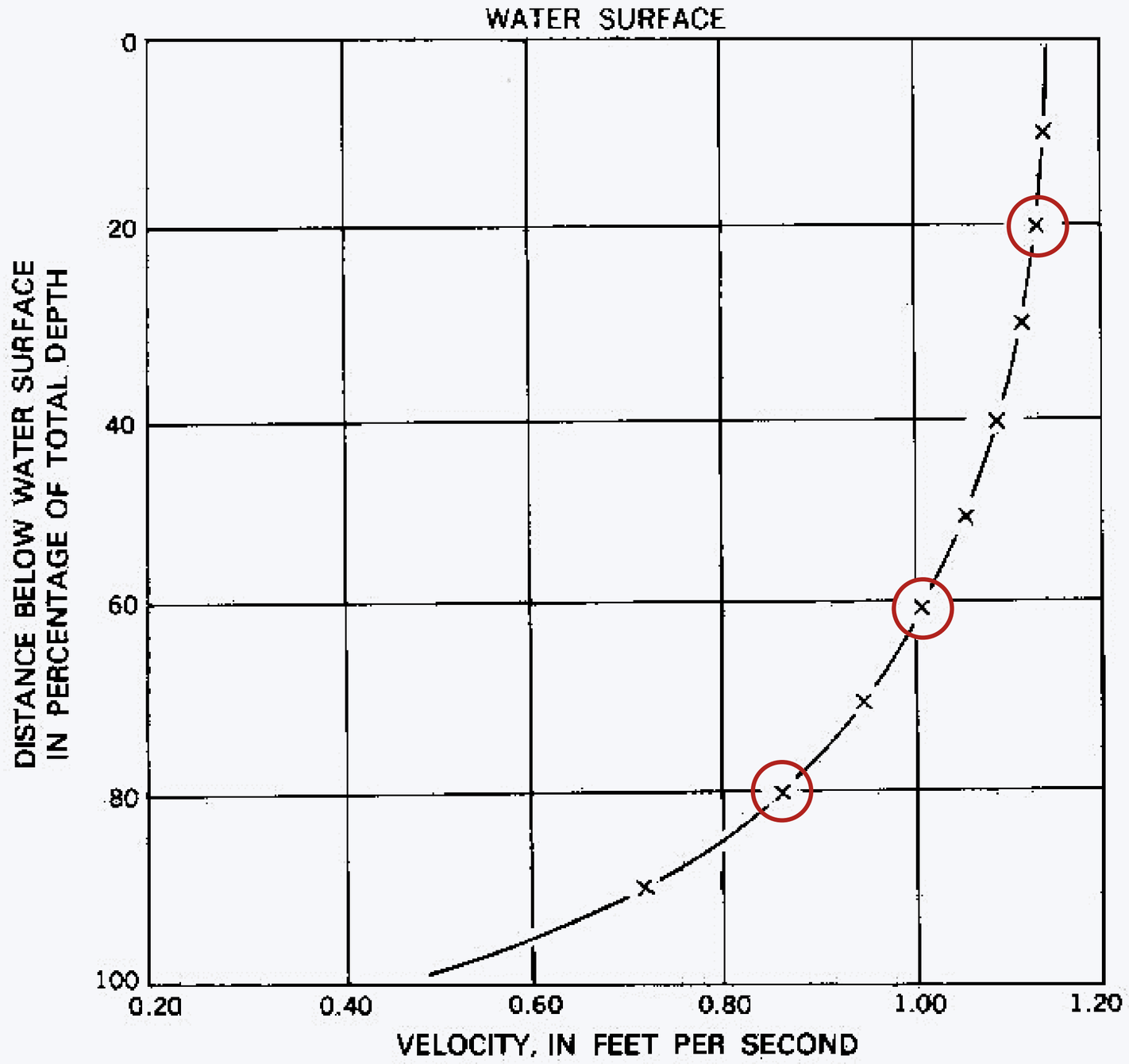
Anemometer And Propeller **Velocity Meter**



Electromagnetic **Velocity Meters**



Methods of Determining Mean Velocities



Methods of Determining Mean Velocities

- Two-point method
- Six-tenths-depth method
- Vertical velocity-curve method
- Subsurface method
- Depth integration method

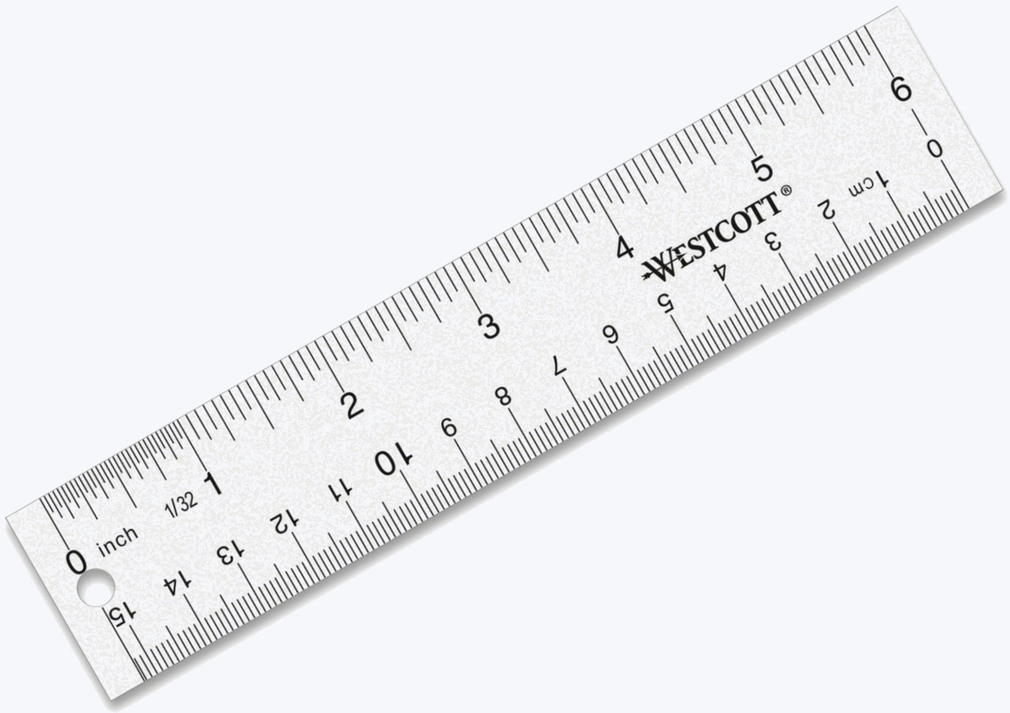
✓Consists of measuring the velocity at **0.6** of the depth from the water surface.

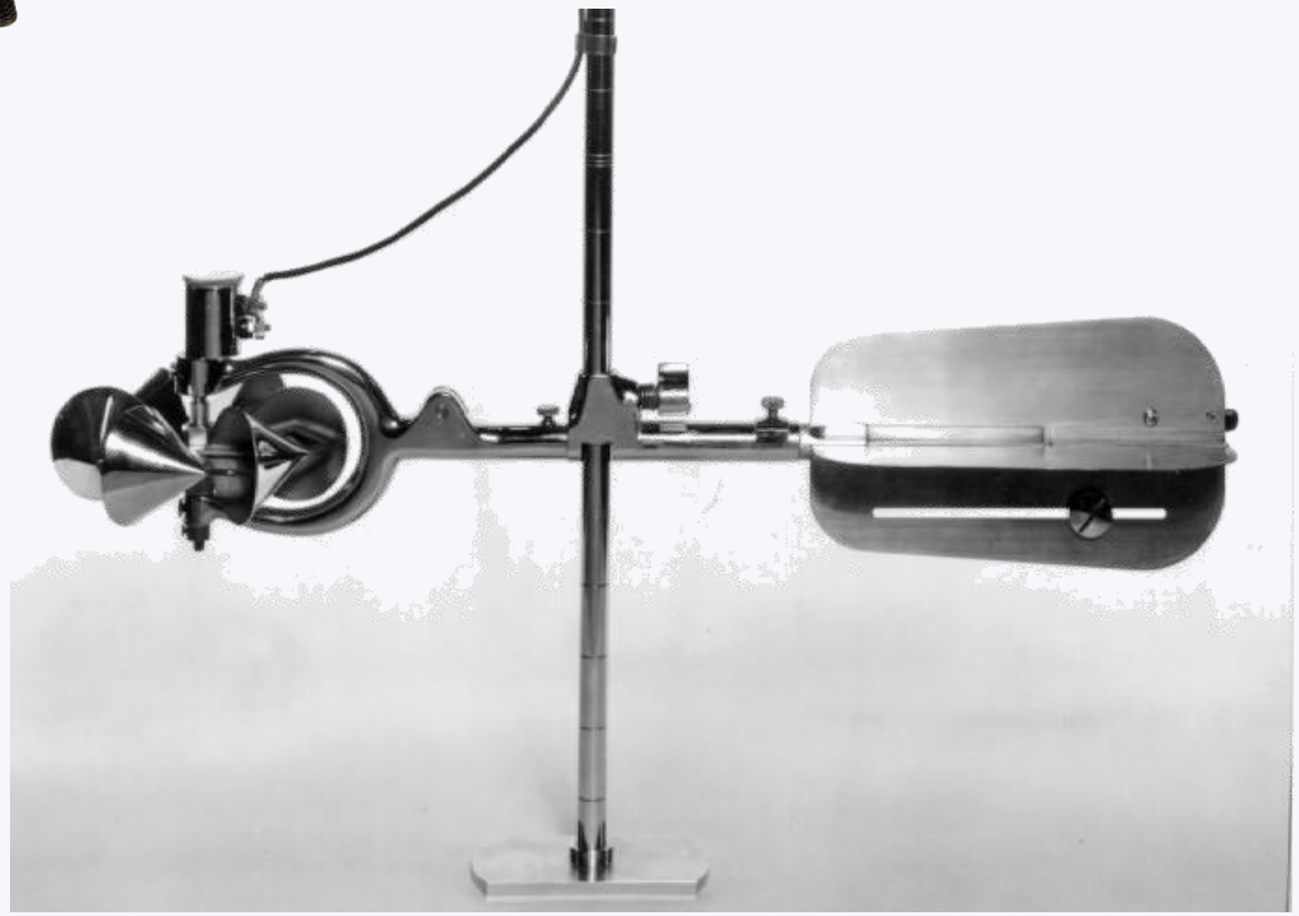
✓Generally used for **shallow flows** where the two-point method is not applicable.

✓The method gives **satisfactory** results.

Equipment

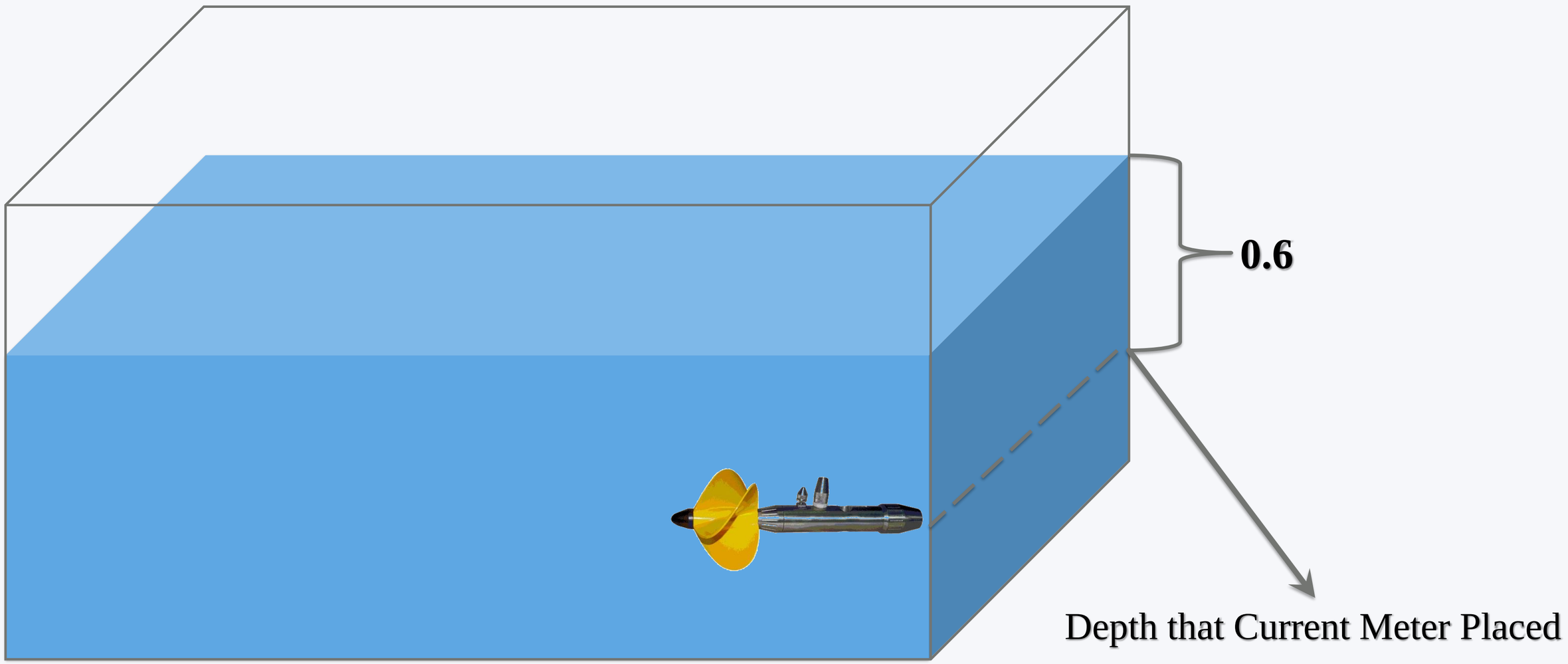

MODE
SPLIT RESET
START STOP
ACCUSPLIT
STOPWATCH
10:5323
MIN. SEC. 1/100
PRO SURVIVOR
601X
3V.1


WESTCOTT®
inch
cm

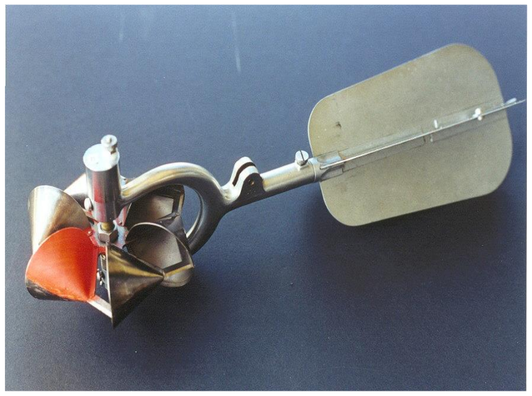


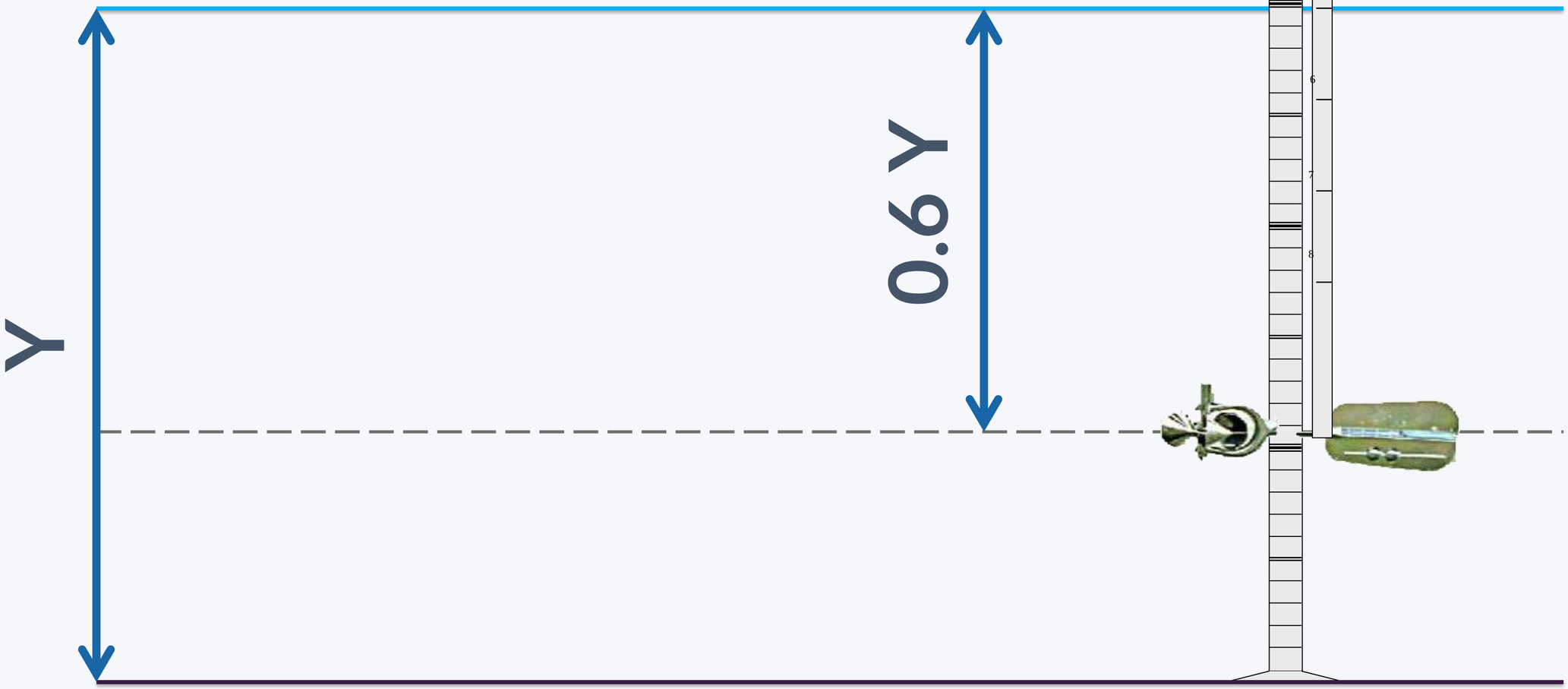
Experimental Method

$$\boldsymbol{Q = A \times V}$$



Experimental Method





Experimental Method

METRIC RATING TABLE FOR No. 622 CURRENT METER

VELOCITY IN METERS PER SECOND

Time in Secs	1 Rev	2 Rev	3 Rev	5 Rev	10 Rev	20 Rev	30 Rev	40 Rev	50 Rev	60 Rev	70 Rev	80 Rev	90 Rev	100 Rev	150 Rev	200 Rev	Time in Secs
40	0 027	0 046	0 064	0 094	0 177	0 344	0 5.2	0 680	0 84"	1 018	1 189	1 356	1 527	1 695	2 542	3 389	40
41	0 027	0 046	0 061	0 091	0 174	0 335	0 500	0 664	0 826	0 994	1 161	1 323	1 490	1 655	2 481	3 307	41
42	0.027	0 043	0 061	0 091	0 171	0 326	0 488	0 649	0 808	0 969	1 134	1 292	1 454	1 615	2 423	3 228	42
43	0 027	0 043	0 061	0 088	0 165	0.320	0 475	0 634	0 789	0 948	1 106	1 262	1 420	1 579	2 368	3 152	43
44	0 027	0 043	0 058	0 085	0 162	0 314	0 466	0 619	0 771	0 927	1 082	1 231	1 387	1 542	2 313	3 078	44
45	0 027	0 043	0 058	0 085	0 158	0 308	0 457	0 607	0 756	0 905	1 058	1 204	1 356	1 509	2 262	3 008	45
46	0 027	0 043	0 058	0 085	0 155	0.302	0 448	0 594	0 741	0 884	1 033	1 190	1 325	1 475	2.213	2 941	46
47	0 024	0 043	0 055	0 082	0 152	0 296	0 439	0 582	0 725	0 866	1 012	1 155	1 298	1 445	2 167	2 880	47
48	0 024	0 043	0 055	0 079	0 149	0.290	0 430	0 570	0 710	0 847	0 991	1 131	1 271	1 414	2 121	2 819	48
49	0 024	0 040	0 055	0 079	0 146	0 283	0 421	0 558	0 695	0 829	0 969	1 106	1 247	1 384	2 076	2 761	49
50	0.024	0 040	0 052	0 079	0 143	0 277	0 411	0 546	0 680	0 814	0 951	1 085	1 222	1 356	2 033	2 710	50
51		0 040	0 052	0 076	0 140	0 274	0 402	0.533	0 668	0 799	0 933	1 064	1 198	1 329	1 993	2 658	51
52		0 040	0 052	0 076	0 140	0 268	0 393	0.524	0 655	0 783	0 914	1 042	1 173	1 305	1 957	2 609	52
53		0 040	0.049	0 073	0 137	0 262	0 387	0.515	0 643	0 768	0 896	1 024	1 152	1 280	1 920	2 560	53
54		0 040	0 049	0 073	0 134	0 259	0 381	0.506	0 631	0 753	0 878	1 006	1 131	1 256	1 884	2 512	54
55		0 040	0.049	0 073	0.131	0 253	0 375	0.497	0.619	0 741	0 863	0 988	1 109	1 234	1 850	2 466	55
56		0.037	0.049	0.070	0 131	0.250	0 369	0 488	0 607	0 728	0 947	0 969	1 091	1 213	1 817	2 423	56
57		0 037	0.049	0.070	0 128	0 244	0 363	0.479	0 597	0 716	0 832	0 951	1 073	1 192	1 786	2 360	57
58		0.037	0.046	0.067	0.125	0.241	0 357	0.469	0 588	0 704	0 817	0 936	1 055	1 170	1 756	2.341	58
59		0 037	0.046	0 067	0 125	0.238	0 351	0 460	0 579	0 692	0 802	0 920	1 036	1 149	1 725	2 301	59
60		0.037	0.046	0.067	0.122	0.235	0 344	0.451	0.570	0 680	0 789	0 905	1 018	1 131	1 693	2 252	60
61		0.037	0.046	0.067	0.119	0.229	0 338	0.445	0.561	0 668	0.777	0 890	1 003	1.113	1.667	2 225	61
62		0.034	0.046	0.064	0.119	0.226	0 332	0.439	0.552	0.658	0 765	0.875	0 988	1.094	1.640	2 188	62
63		0.034	0.043	0 064	0.116	0 223	0 326	0.433	0.543	0 649	0 753	0 860	0 972	1 076	1 615	2 155	63
64		0.034	0.043	0.064	0 116	0.219	0 320	0.427	0 533	0 640	0 741	0 844	0 957	1 061	1.591	2 121	64
65		0.034	0.043	0 061	0 113	0.216	0 314	0.421	0.524	0 631	0 728	0.832	0.942	1 045	1 567	2 088	65
66		0.034	0 043	0 061	0.113	0.213	0 311	0.415	0 515	0 622	0 716	0 820	0.927	1.030	1.542	2 057	66
67		0.034	0.043	0.061	0 110	0.210	0 308	0 408	0.506	0 613	0.707	0 808	0.911	1.015	1.518	2 027	67
68		0.034	0.043	0.061	0.110	0.207	0 305	0.402	0.500	0 604	0 698	0 796	0.899	1.000	1 497	1 996	68
69		0.034	0.040	0.058	0 107	0 204	0 302	0 396	0 494	0 594	0 689	0 783	0 887	0.985	1 475	1 966	69
70		0.034	0.040	0.058	0 107	0 201	0 299	0 390	0 488	0 585	0 680	0.771	0 875	0 969	1 454	1 939	70

This table applies when measurements are made with meter suspended by cable When measurements are made with meter suspended by rod, reduce the tabular velocities by 2 per cent

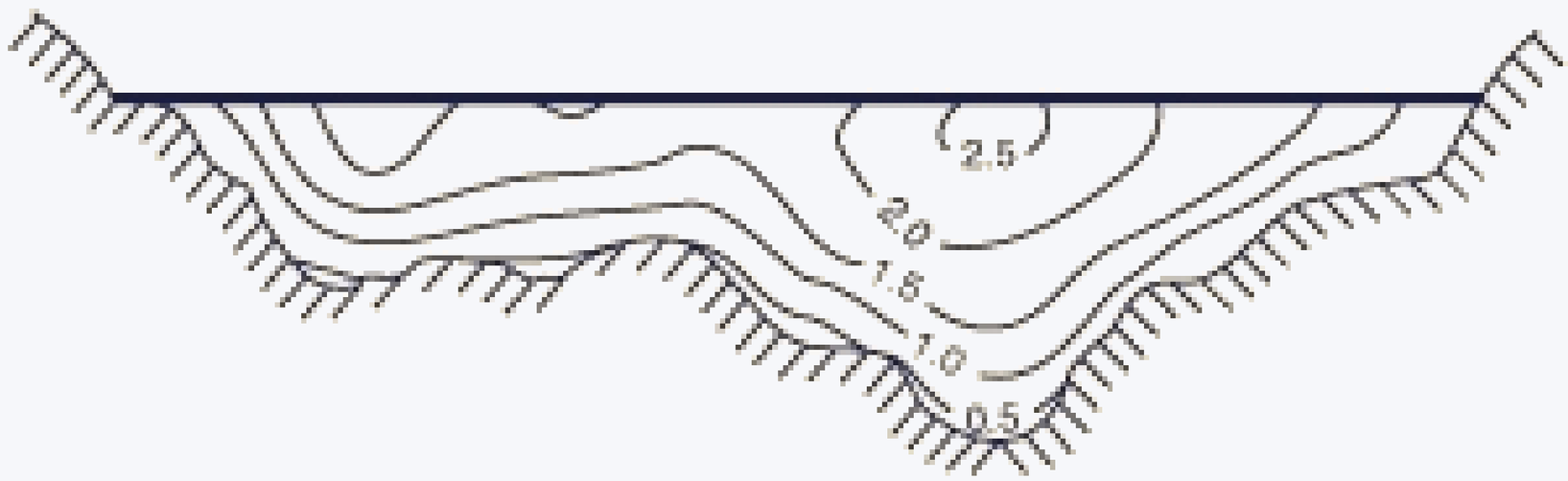
Experimental Method

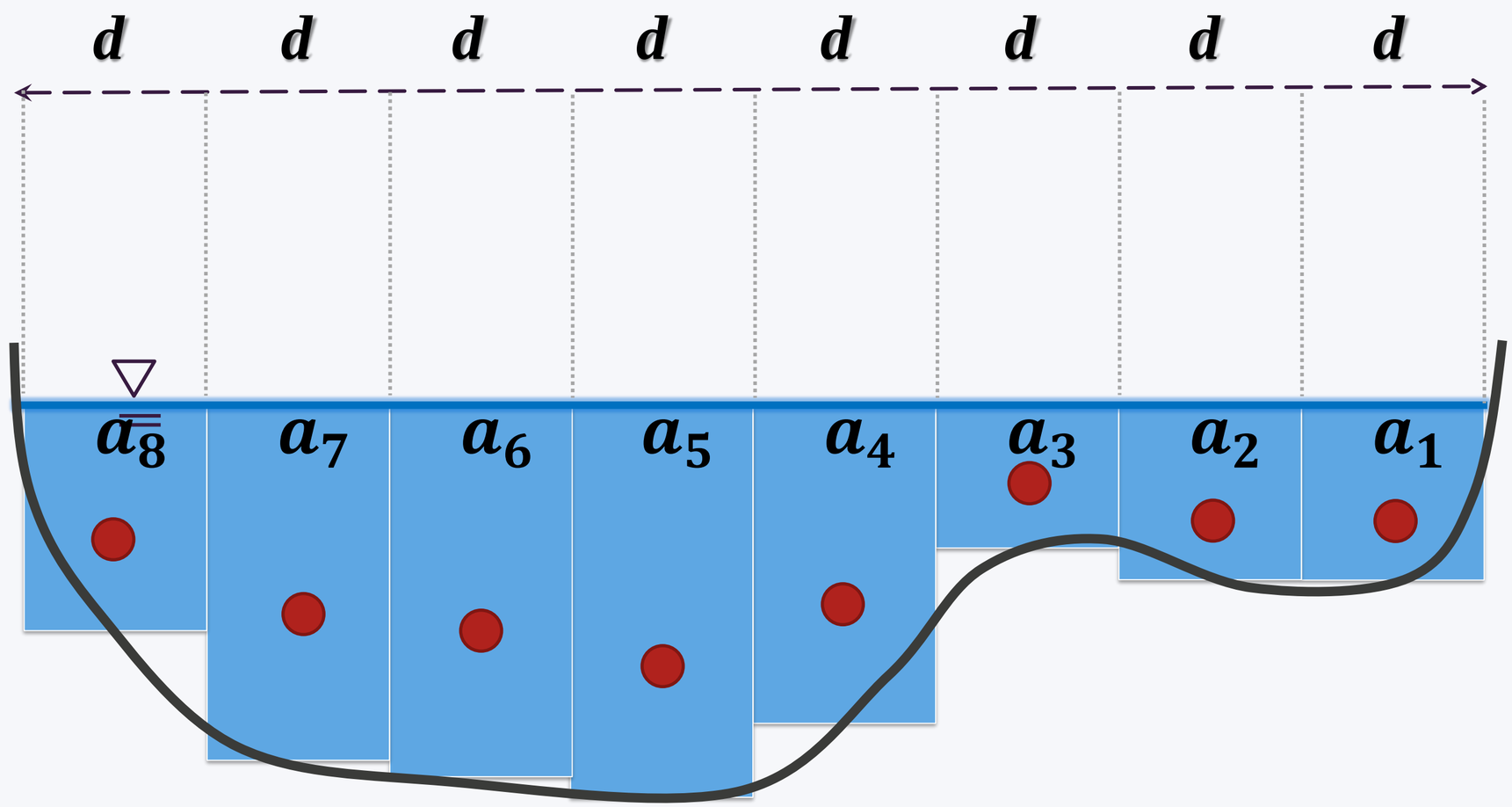
Equations for Standard Rating Tables

$$V = aR + b$$

R = **R**evolutions **p**er **S**econd

Experimental Method





Any Questions?