Principles of Hydrometry

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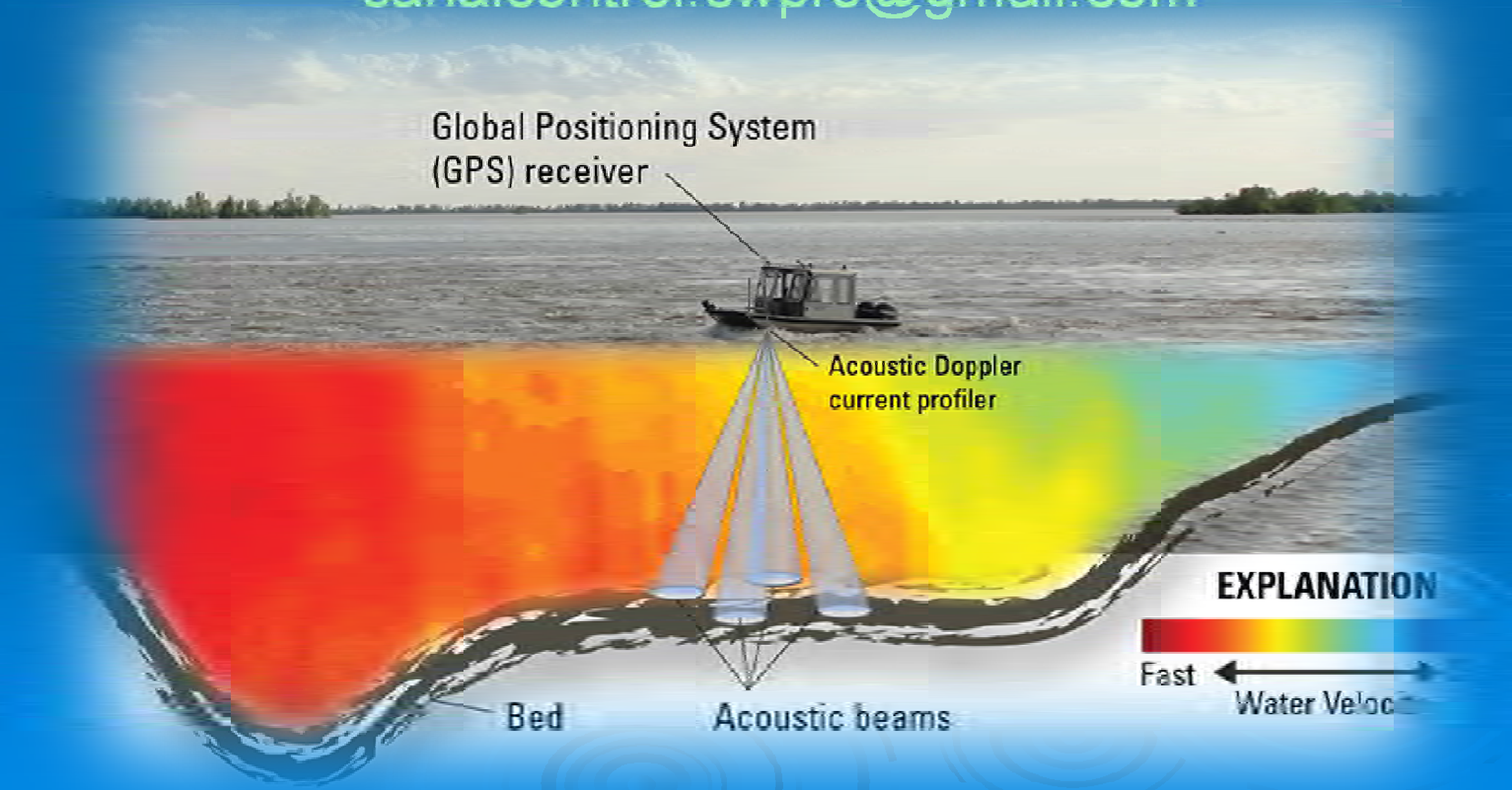
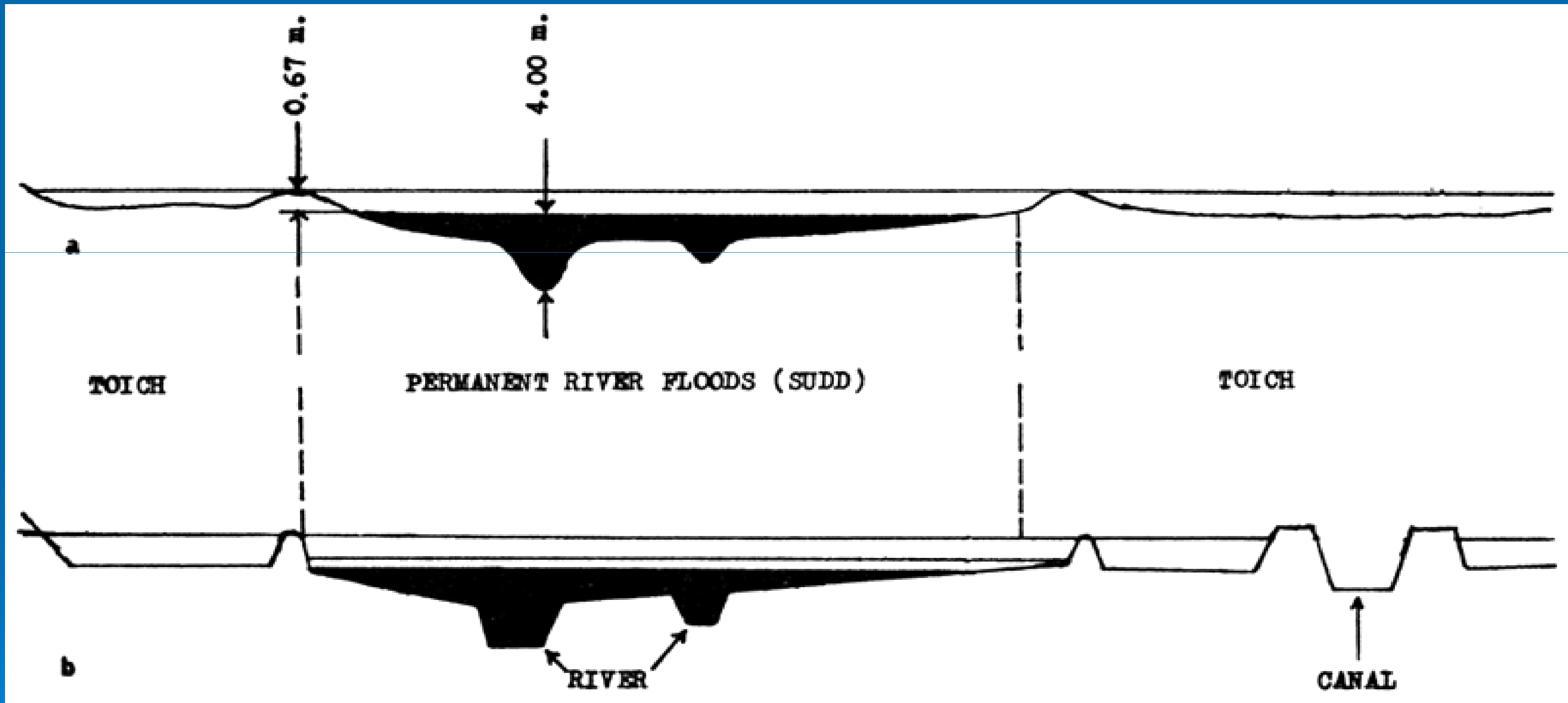


Stream Flow Measurement

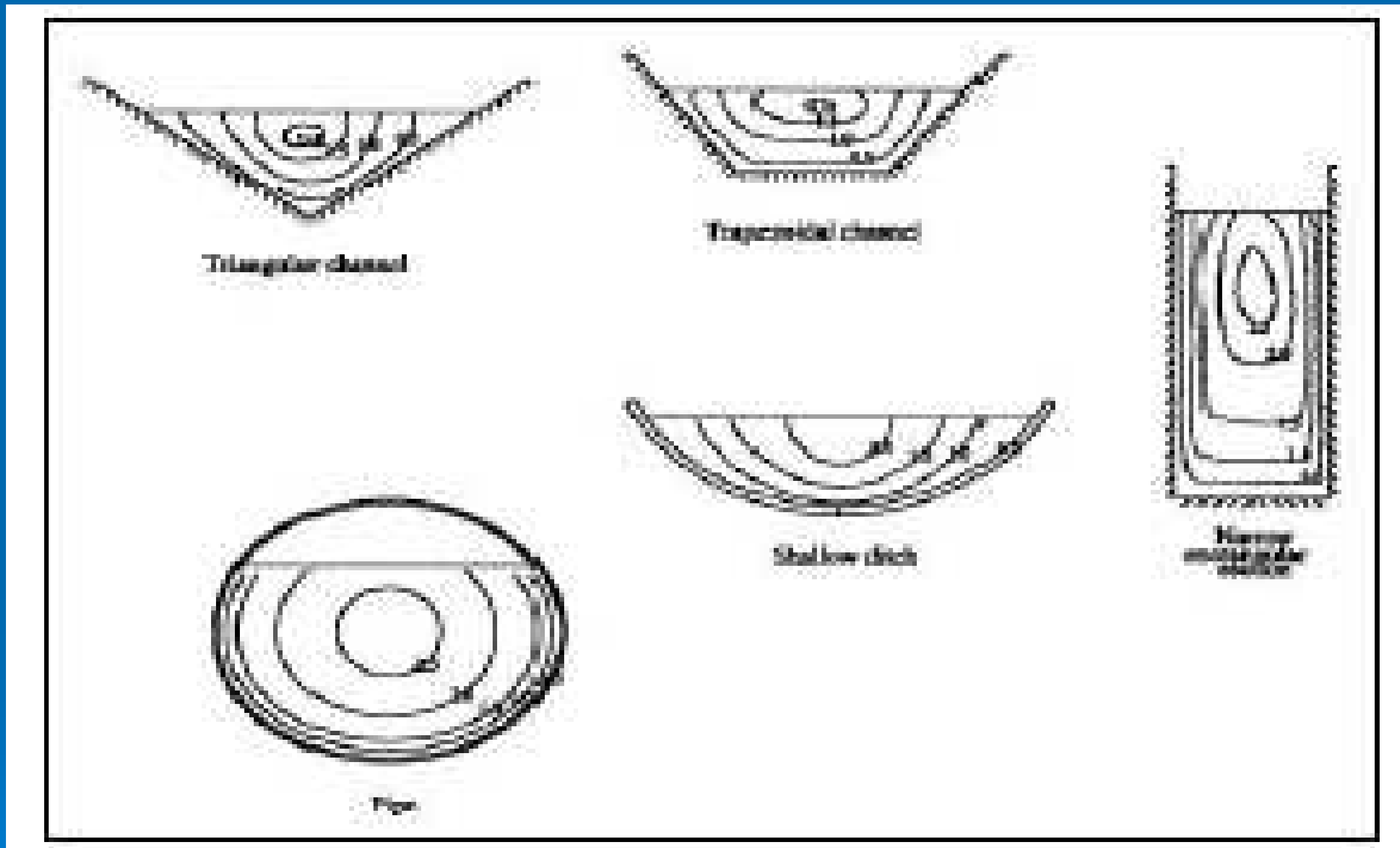
- Flood Forecasting – hydrological data
- WR planning – basic data for reliable designs
- Hydrologic Research – calibrating flow data
- Operation of WR projects– flow variability in time & space
- Irrigation Management – availability
- River Engineering – basis for design of bridges, culverts, dams and flood control reservoirs, for flood plain delineation and flood warning systems

River Floodplain



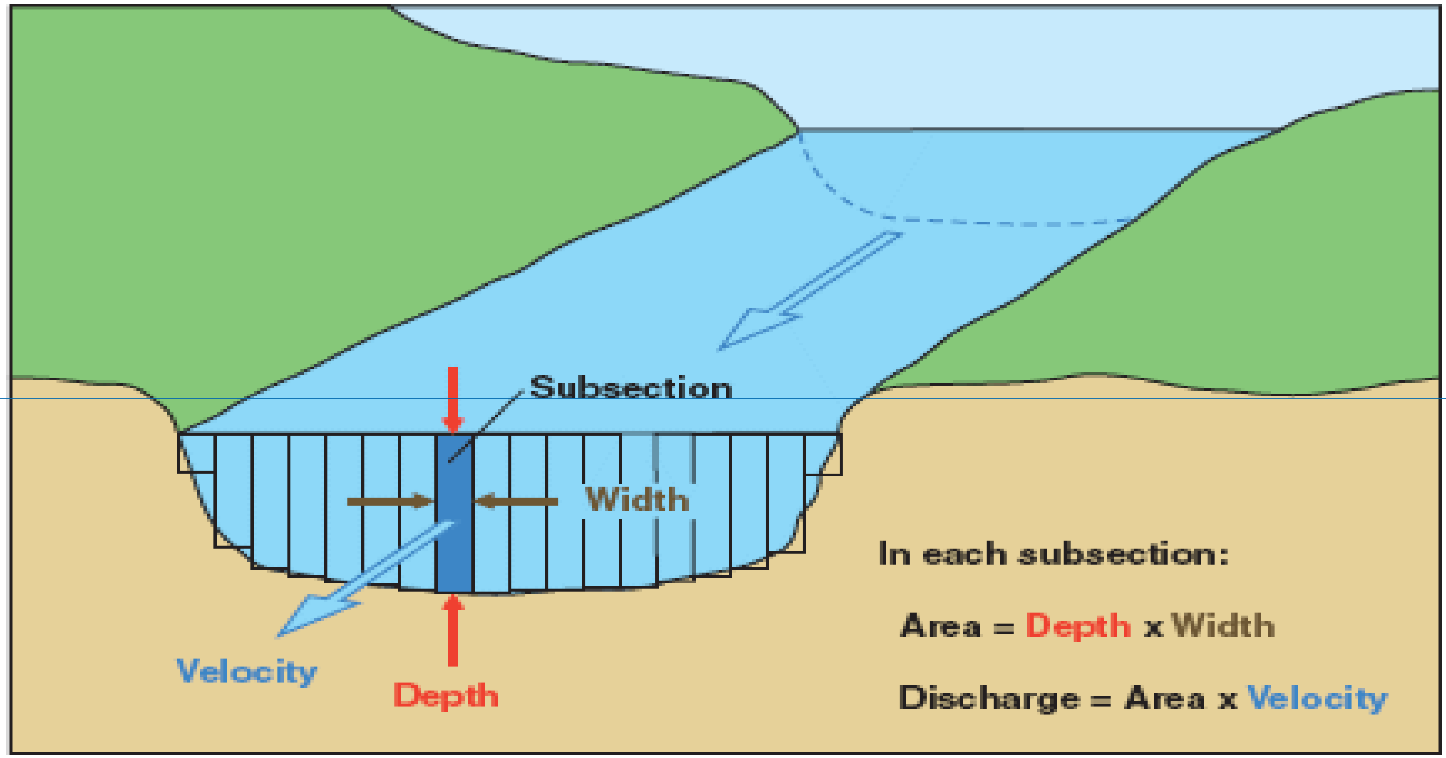
Velocity distribution

Isovels in various channel sections



Velocity of stream is controlled by surrounding channel conditions

Stream Gauging



Current-meter discharge measurements are made by determining the discharge in each subsection of a channel cross section and summing the subsection discharges to obtain a total discharge.

Discharge Measurements
Average velocity

Velocity-Area station Method

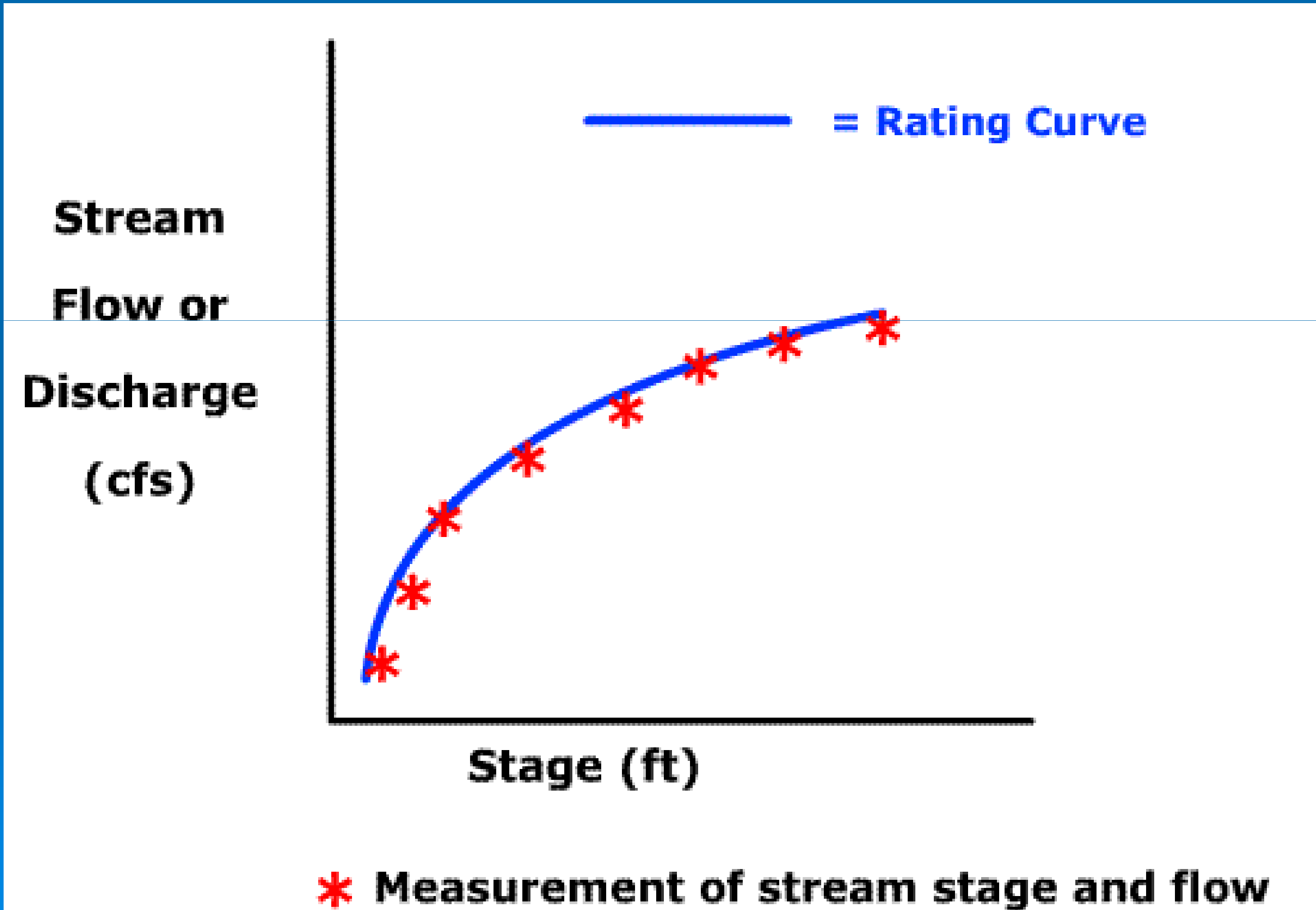
$Q = V_{av} * A$

$V_{av} = V_{0.6}$ for shallow stream ; depth < 3 m

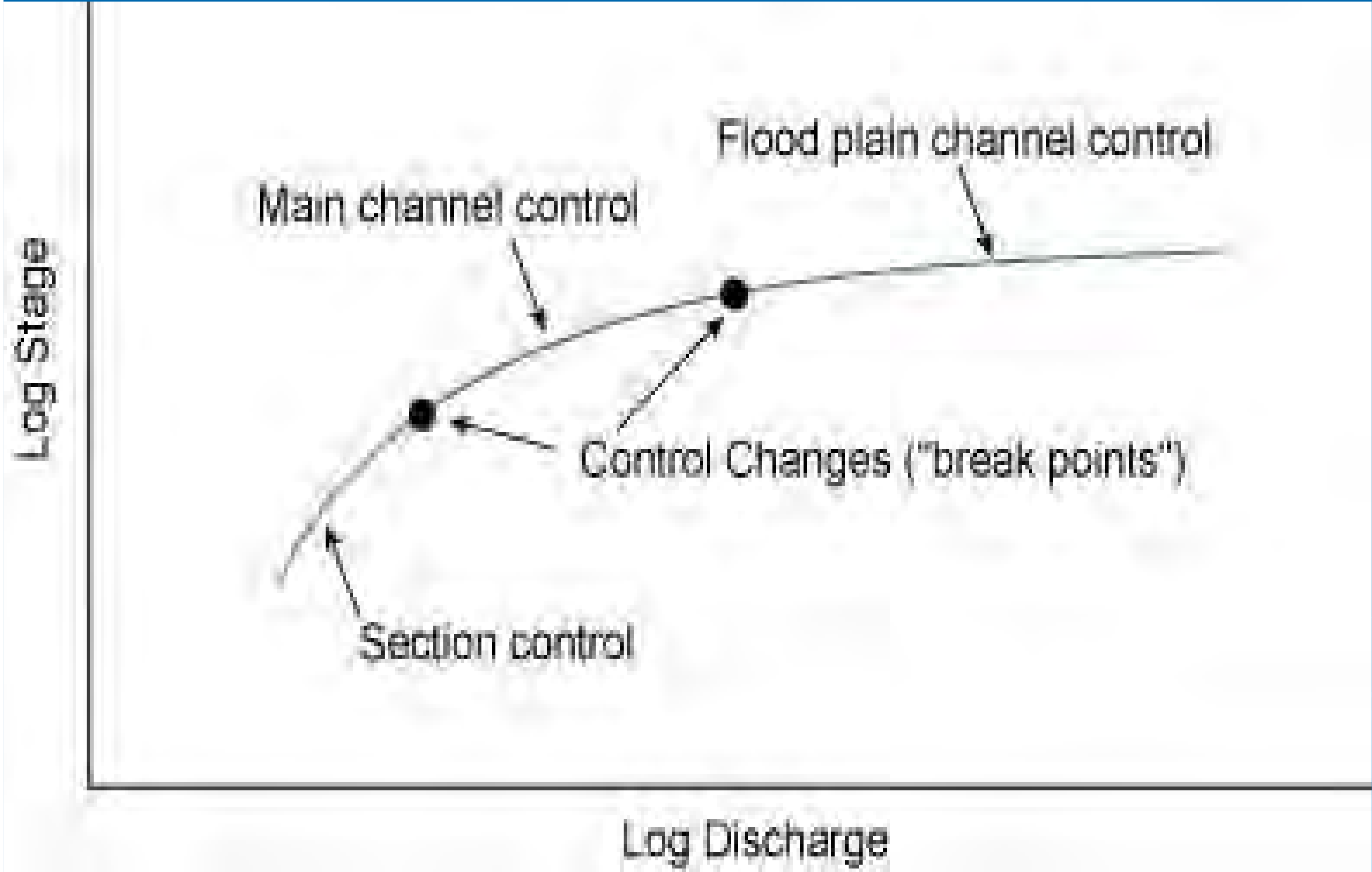
$V_{av} = (V_{0.8} + V_{0.2})/2$ for moderate stream

$V_{av} = C\, V_{0.5}$ for deep stream –flood flow

Rating Curve - Channel



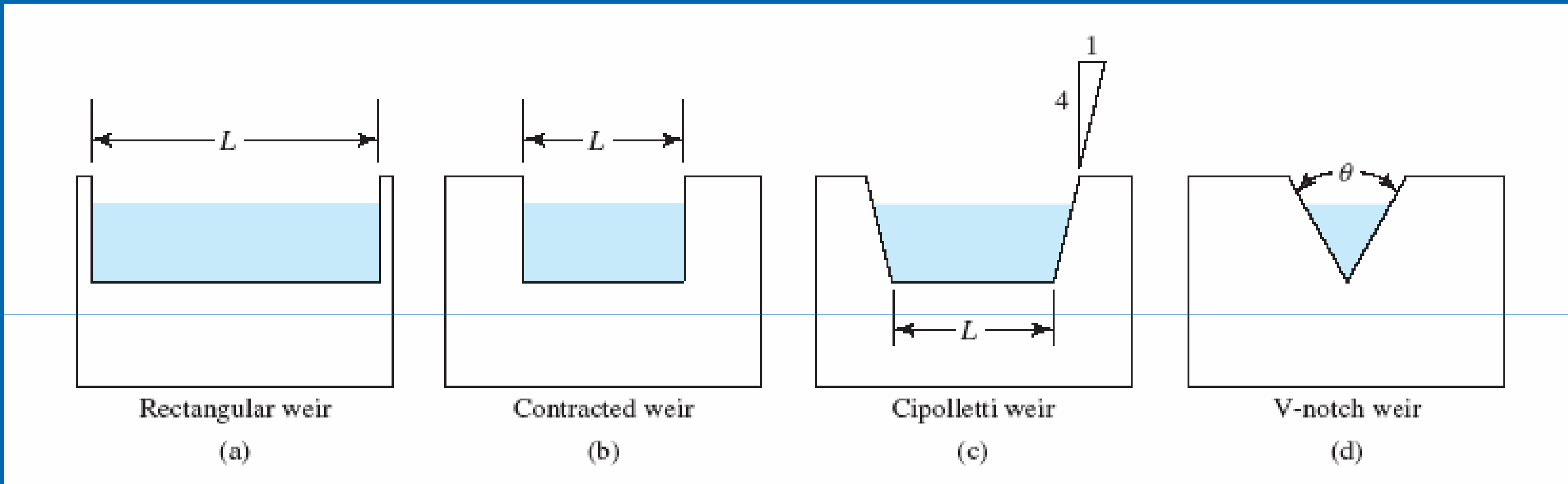
Rating curve - River Floodplain



Gauging Site Selection

- Ideal site characteristics:
  - Straight channel
  - Channel constriction (not expansion)
  - Stable bed and banks
  - Little or no overbank flow
  - Single channel
  - No backwater influence
  - Little flow turbulence
- Ideal site for operating a gauging station is weir (but costly)
- Look for Natural Weirs !

Sharp Crested Flow Measurement Devices



Four common shapes for sharp crested weirs for which discharge equations have been developed

Q = f (dimensions of the weir, H)

Sharp Crested Weir

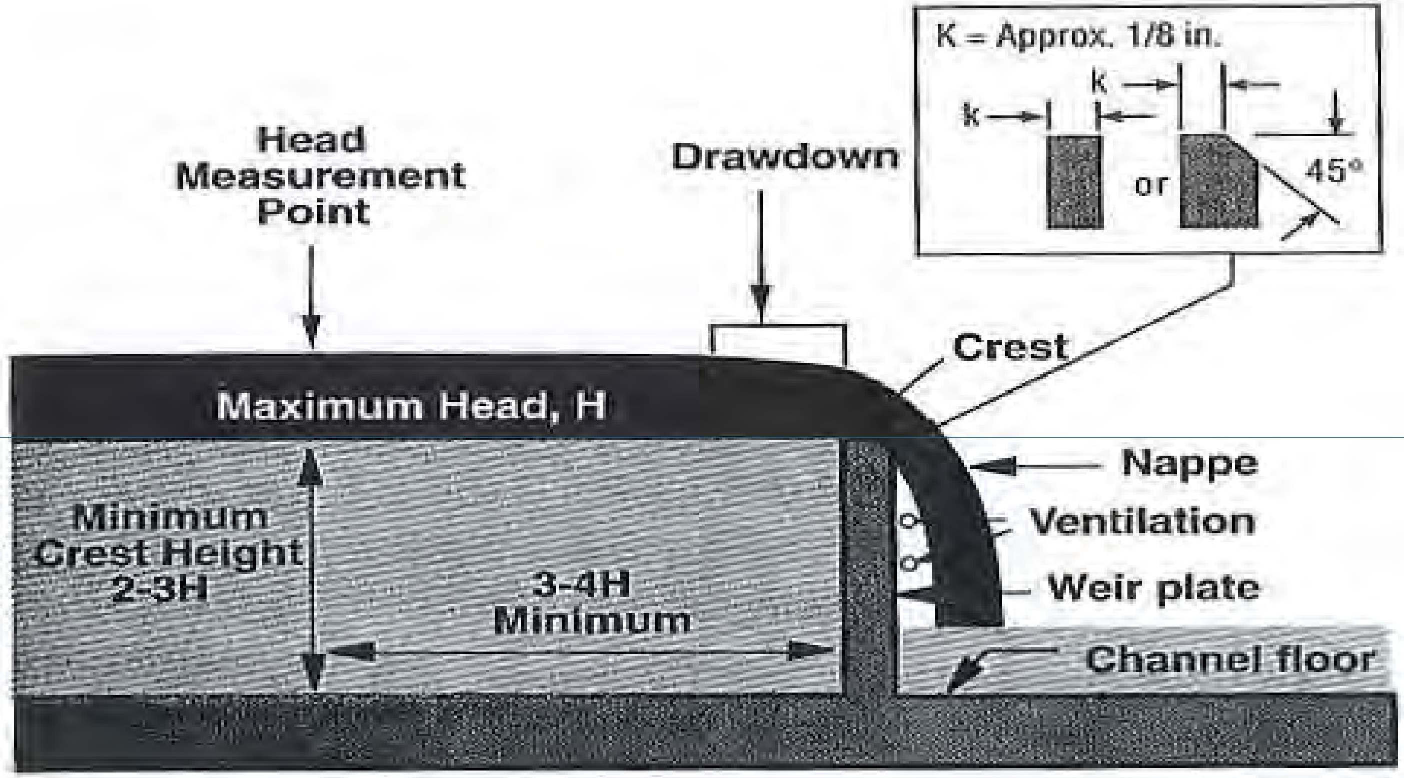
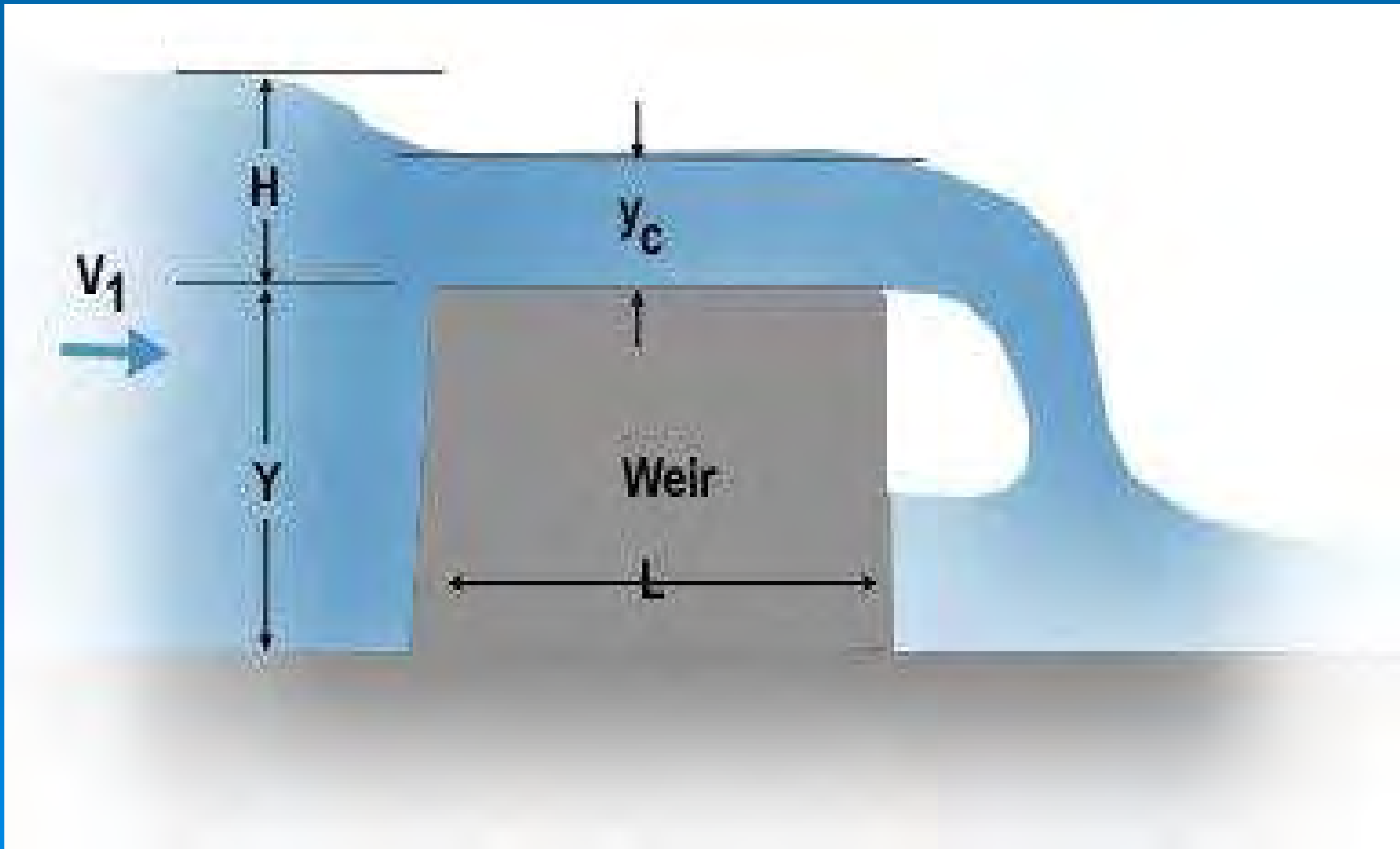
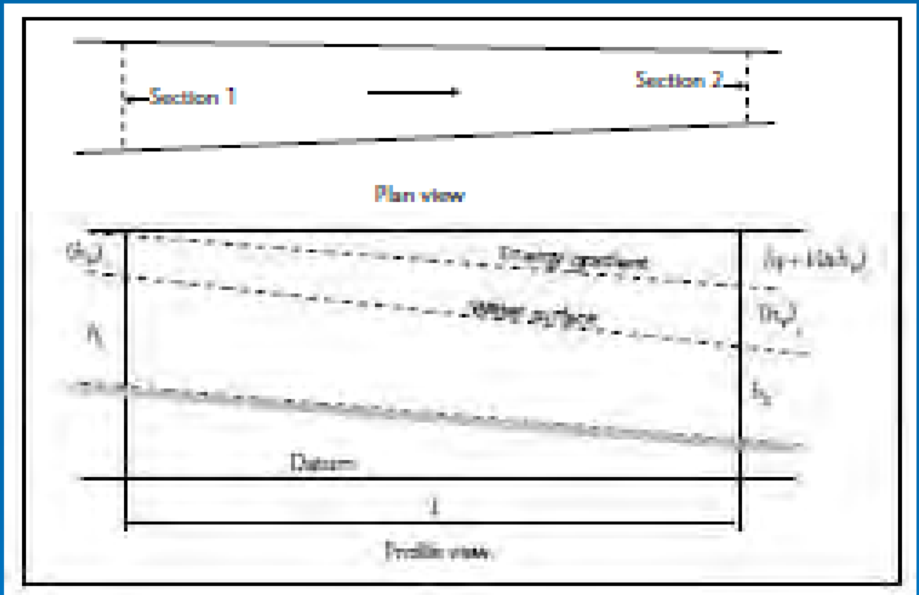


Figure 3-2: Sharp-crested Weir

Broad crested weir



INDIRECT DETERMINATION OF PEAK RIVER DISCHARGE



$$Q = \frac{1}{n} A R^{2/3} S^{1/3}$$

UNIFORM FLOW

- Uniform flow formula $V = C R^x S^y$

- THE CHEZY FORMULA $V = C\sqrt{R_h S}$

- THE MANNING FORMULA $V = \frac{1.49}{n} R^{2/3} S^{1/2}$

Doppler's Effect

- Frequency of sound is changed by motion of sound-source relative to listener.

- Example -
  - Car moving towards you, you hear horn of higher frequency
  - Car moving away from you, you hear horn of lower frequency
  - Though car transmitted same frequency, but you hear higher/lower frequency because of movement of car w.r.t. you.

Acoustic Doppler Current Profiler (ADCP)

- Discharge measurement by Acoustic Doppler Current Profiler (ADCP) is a modern method of discharge measurement. Doppler ultrasonics technology is used to measure flow velocity.

- Discharge calculation involve measuring flow area of stream at a certain point multiplied by average flow velocity in the cross-section.

- Typically, flow area is determined by measuring WLs through pressure transducers and calculating area based on the size and shape of channel.

ACOUSTIC FLOW MEASUREMENTS

- ADCP measurements derive flow velocity from the Doppler shift of the measured return of an emitted acoustic signal that is reflected off suspended matter in the water column.

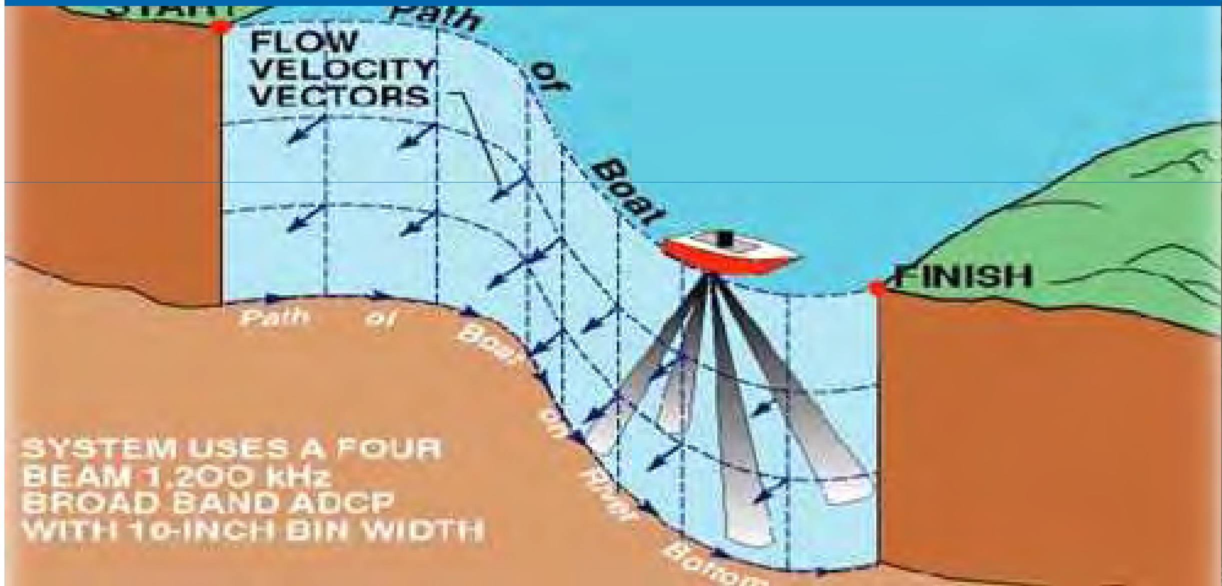
- The information from a combination of several (usually 3 or 4) acoustic beams is used to calculate the mean velocity and flow direction, based on the assumption that the acoustic scatterers move at the same speed as the water and that flow is homogeneous over the area covered by the beams.

Advantages of ADCP

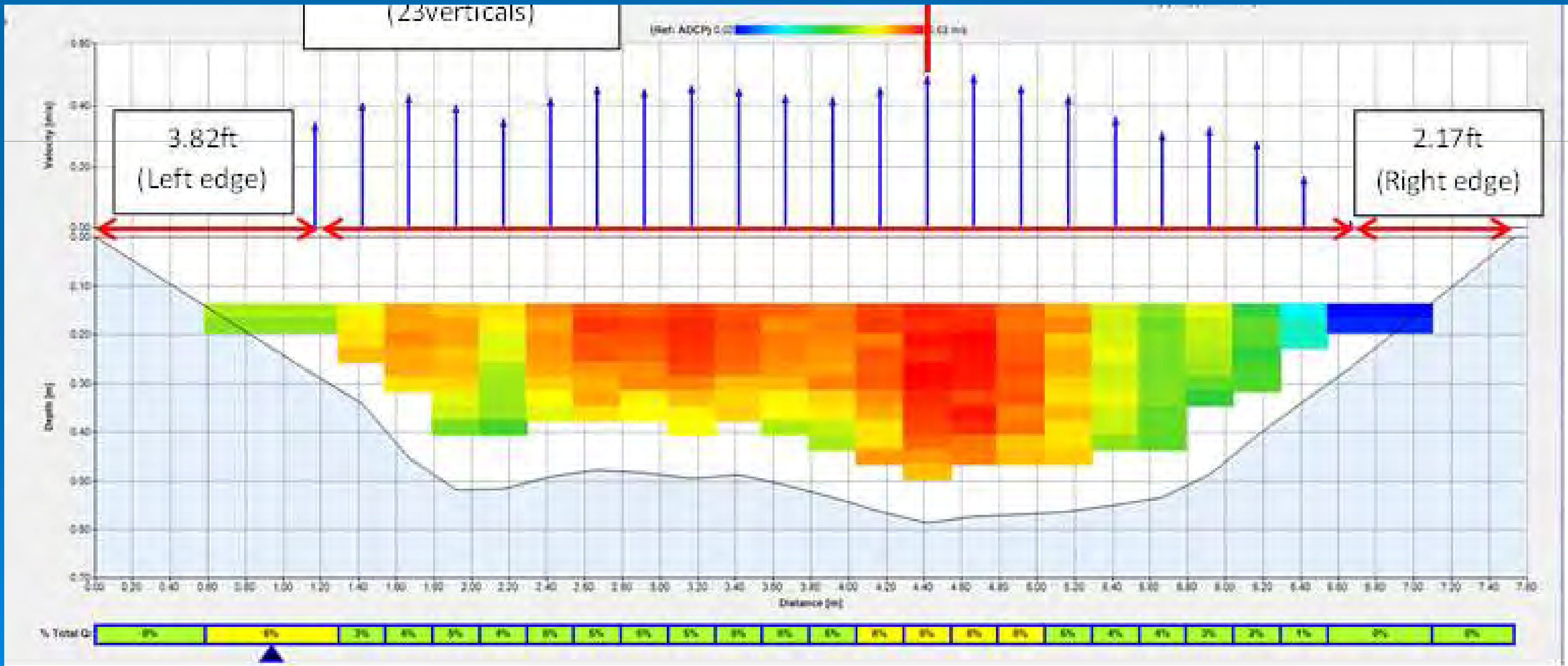
- Rapidly replacing conventional flow measurement techniques.
- Simple maintenance, no moving parts
- Ease and economy with improved performance, relatively high spatial and temporal sampling resolution and require fewer calibrations.
- Other applications - Surrogate for suspended sediment concentration.
- Stable instrument calibration provided components are not damaged
- Velocity accuracies upto 0.3 mm/s (0.01 ft/s) attainable

Velocity measurements: instrument deployment

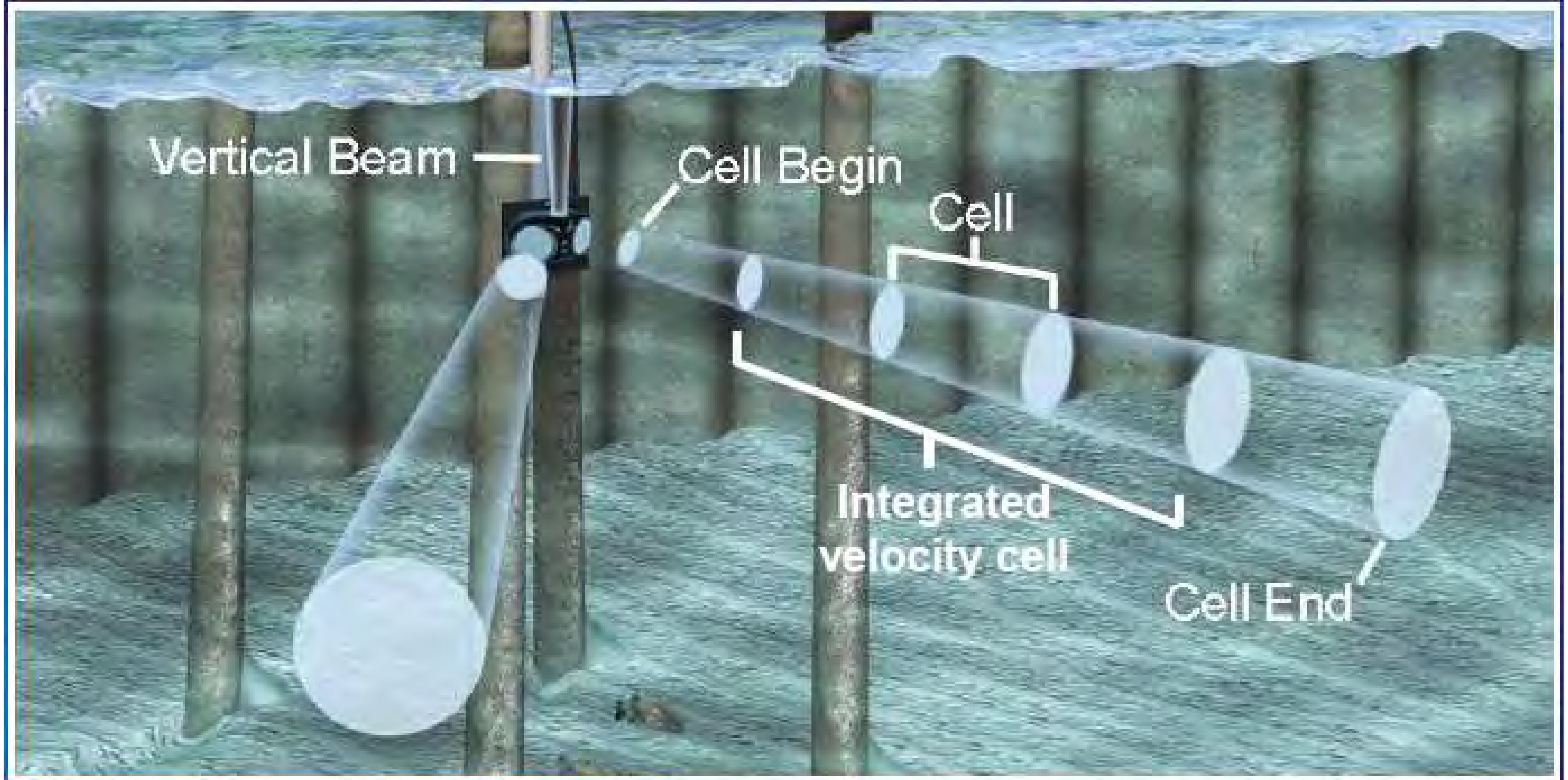
ADCP Moving boats



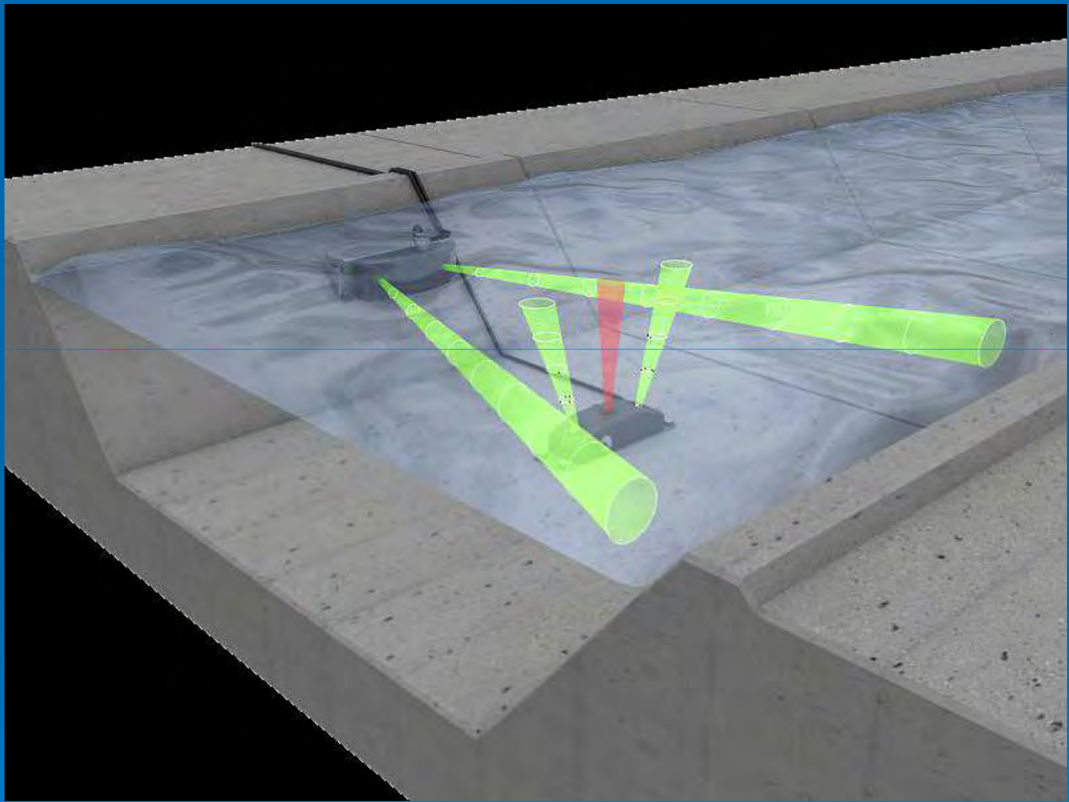
ADCPs measurements for hydrometry: instantaneous discharge measurements

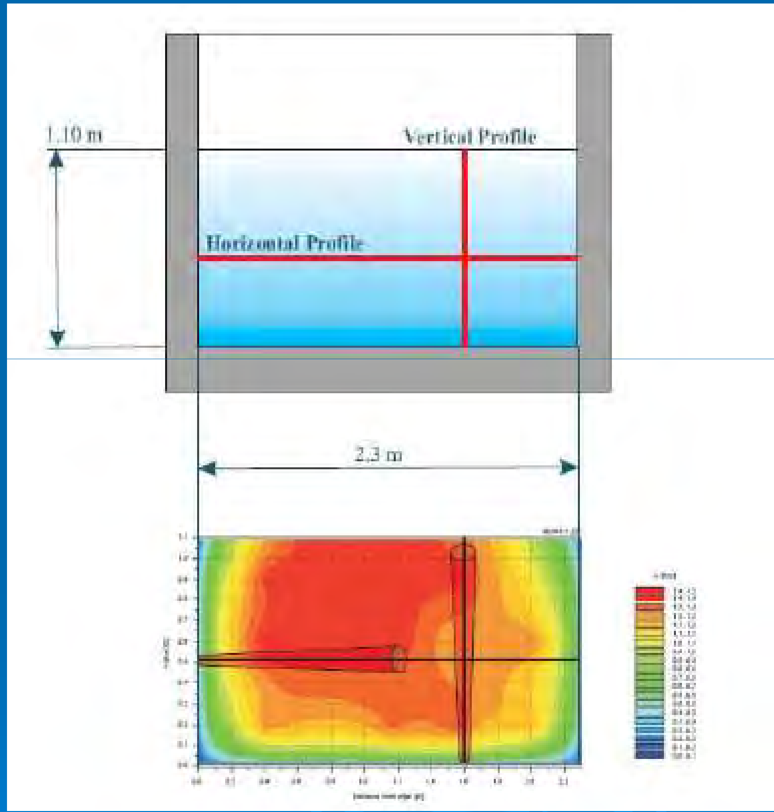


Side-Looking Doppler Profiler



2-d Flow profile

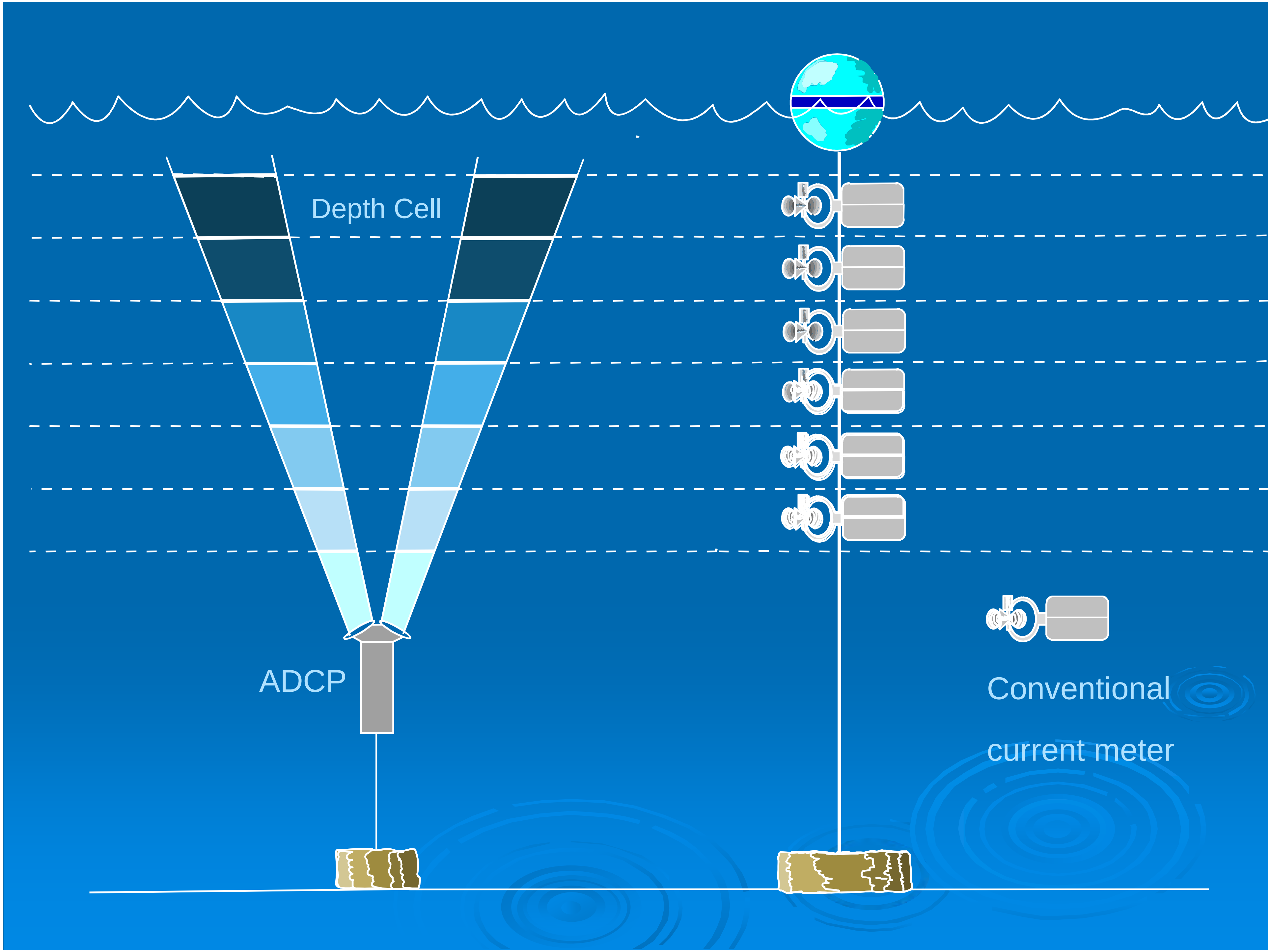




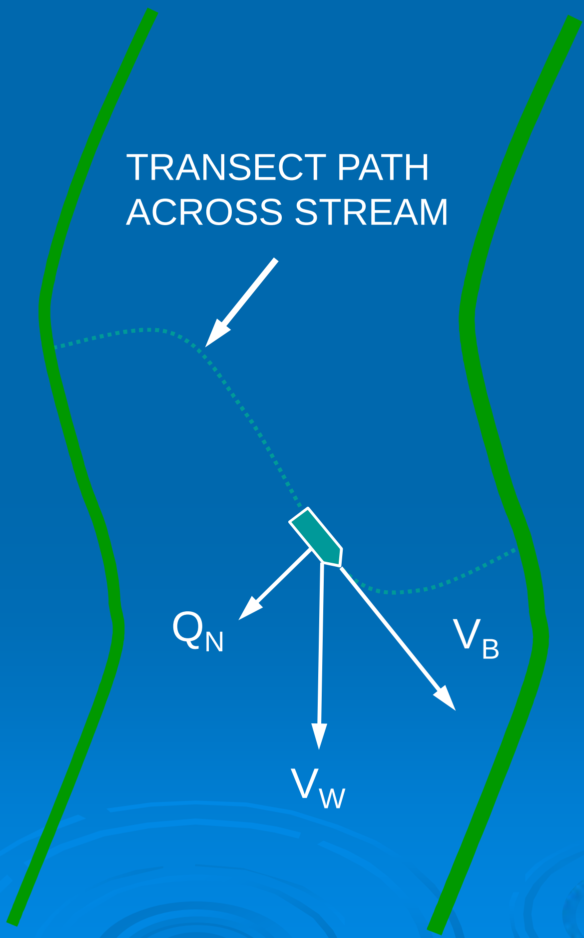
Hydro-acoustic Technology

- Sound from the outgoing pulse is reflected/scattered in all directions by particulate matter or “backscatterers” in the water.

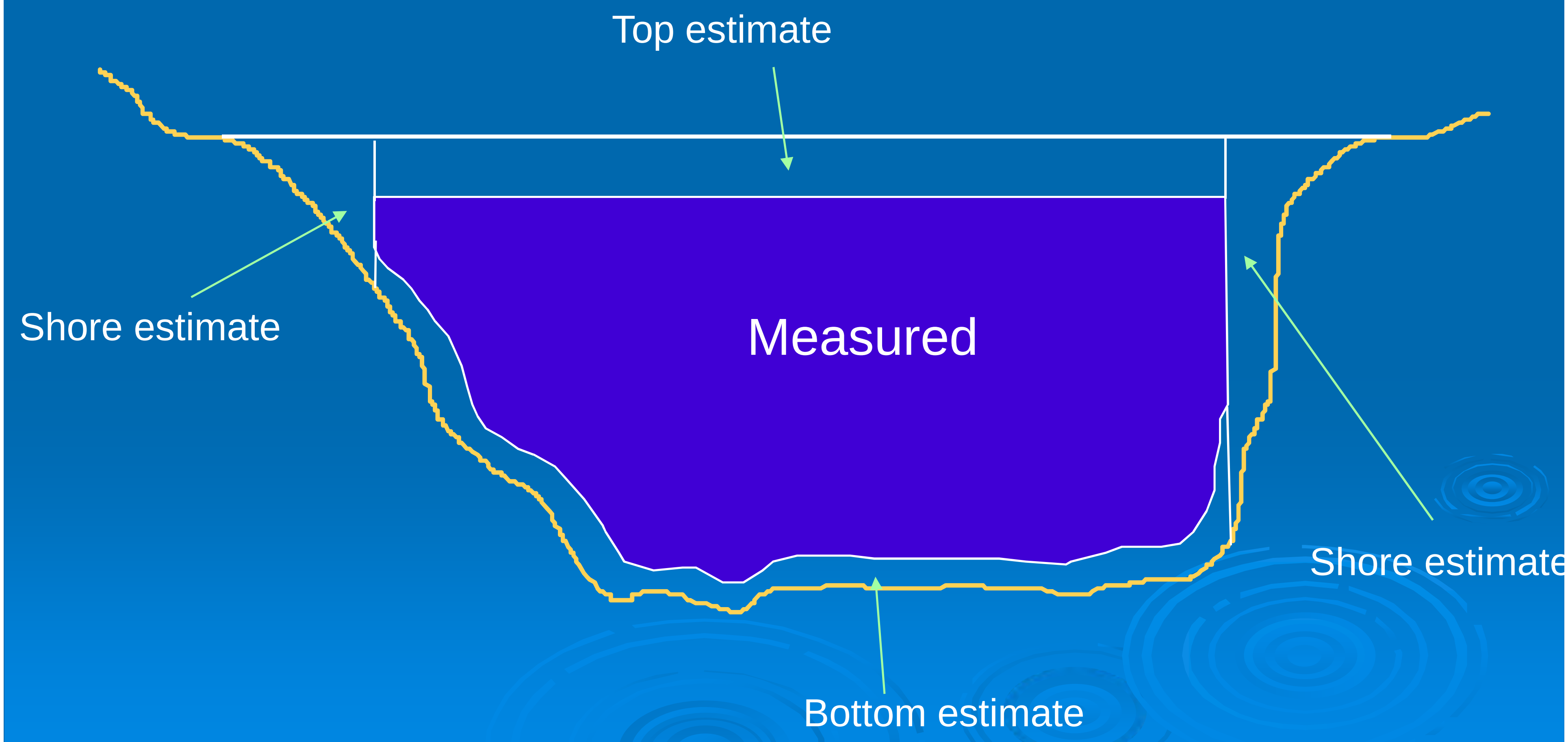
- Some portion of this scattered energy travels back along the acoustic beam axis to the transducer. This return signal has a frequency shift proportional to the velocity of the scattering material.


Depth Cell
ADCP
Conventional
current meter

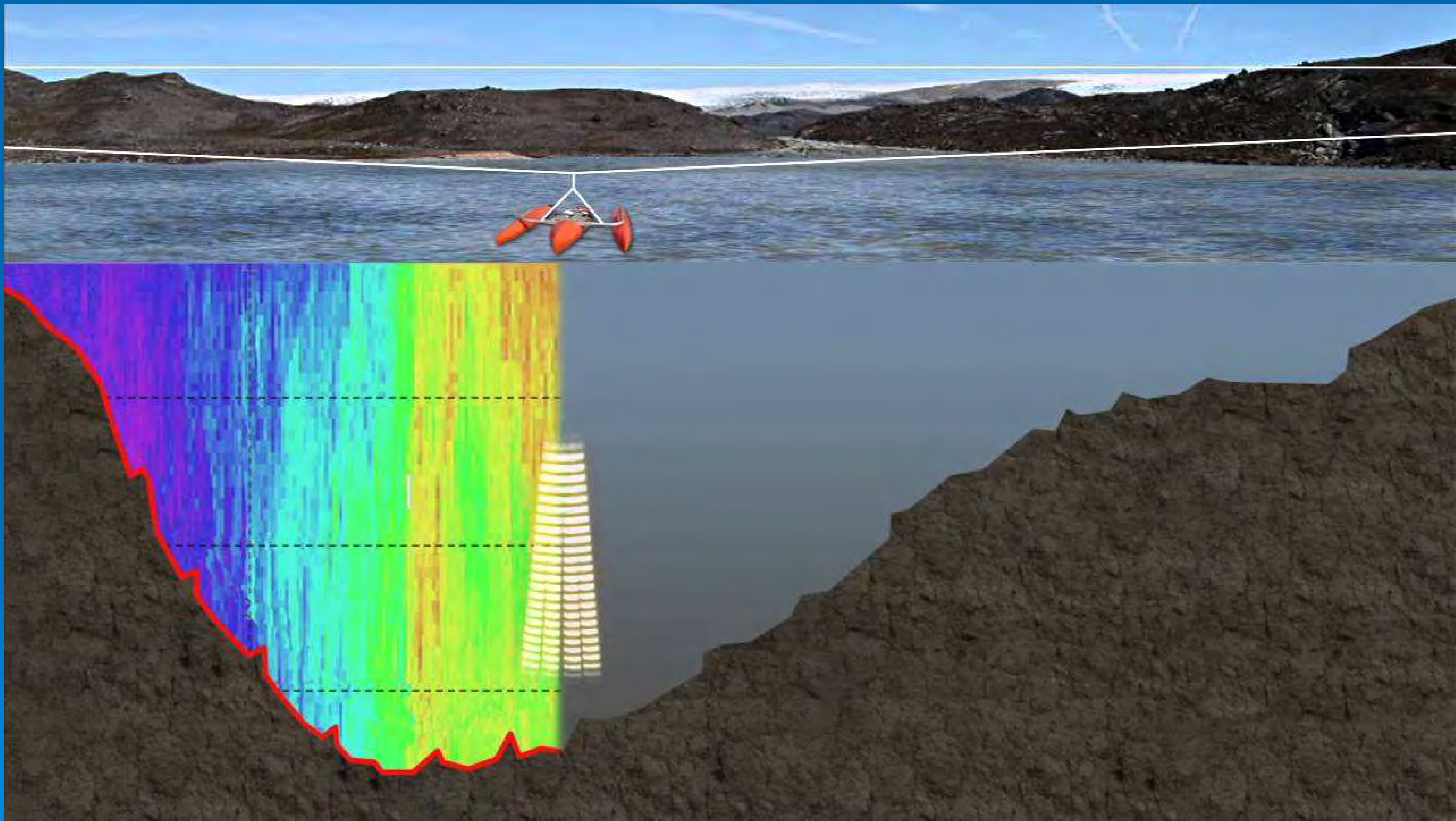
ADCP Discharge Measurement



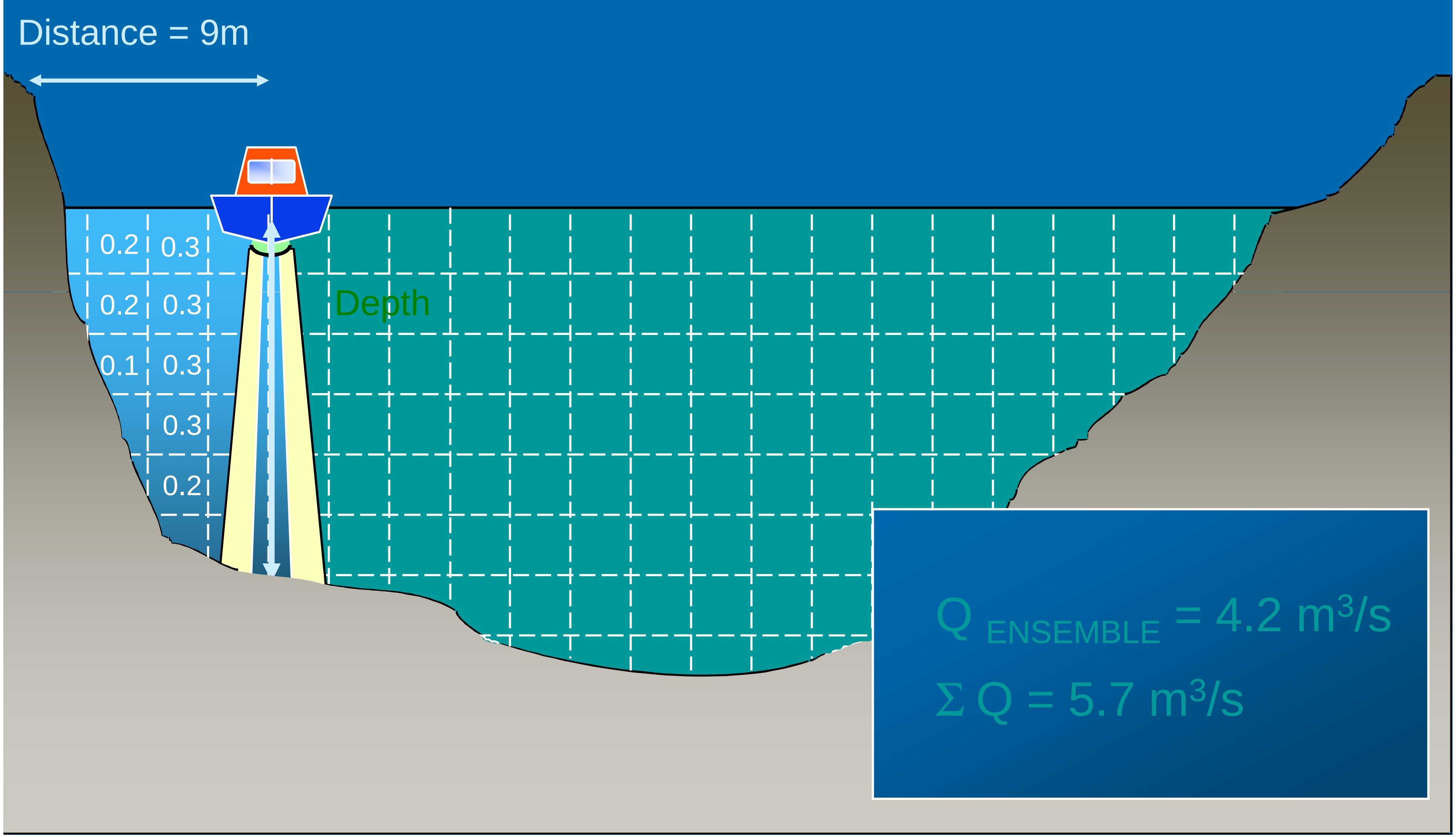
Measured and Unmeasured Areas



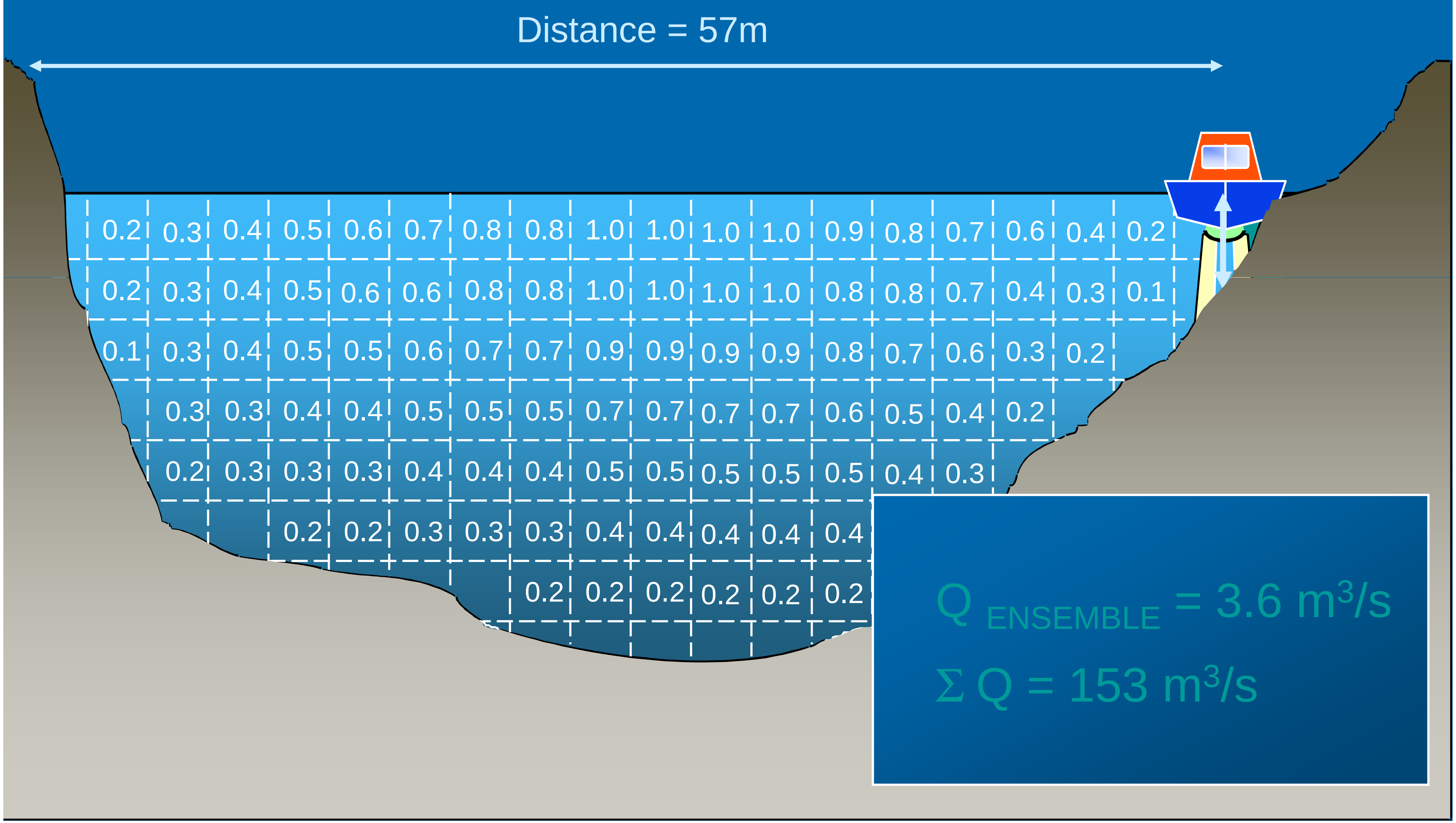
ADCP Discharge Measurement



Discharge Measurement



Discharge Measurement

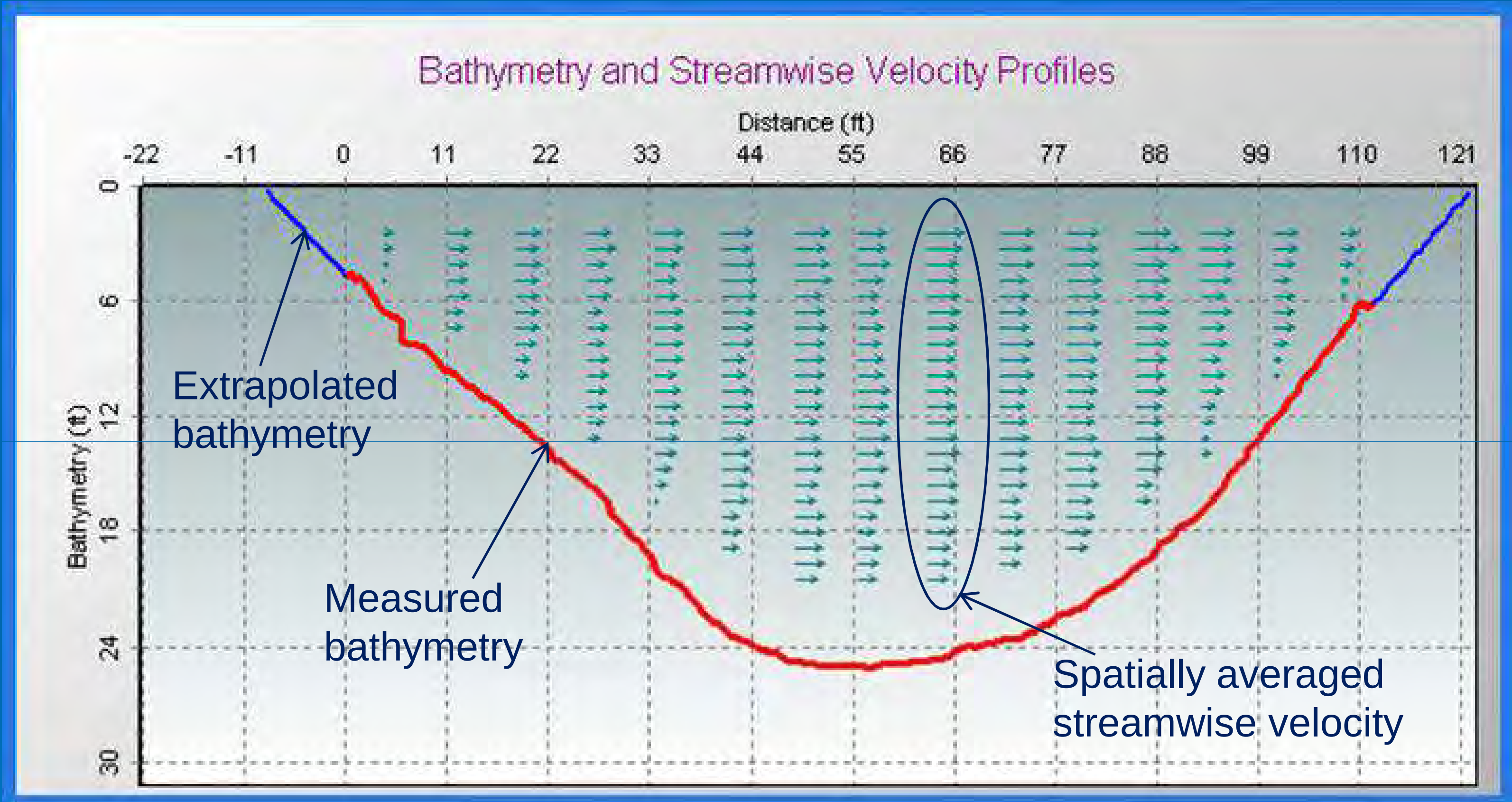


Acoustic Doppler Current Profiler (ADCP)

- ADCP instrument transmits sound pulses at a fixed frequency in the column of water and receives returning echoes to produce successive segments, called depth cell.

- Velocities that are measured by the ADCP are assigned to individual depth cells constitute the center weighted mean of velocities measured throughout the sample window.

ADCP – velocity profile



ADCP result contains information about the bathymetry and spatially averaged stream-wise velocity profiles. This provide a general idea of the velocity distribution in the cross section. Extrapolated edge bathymetry (blue lines) based on the depths near the river bank.

Some Commonly Used ADCP’s

RDI StreamPro

RDI Rio Grande ADCP

SonTek ADP

SonTek Mini-ADP

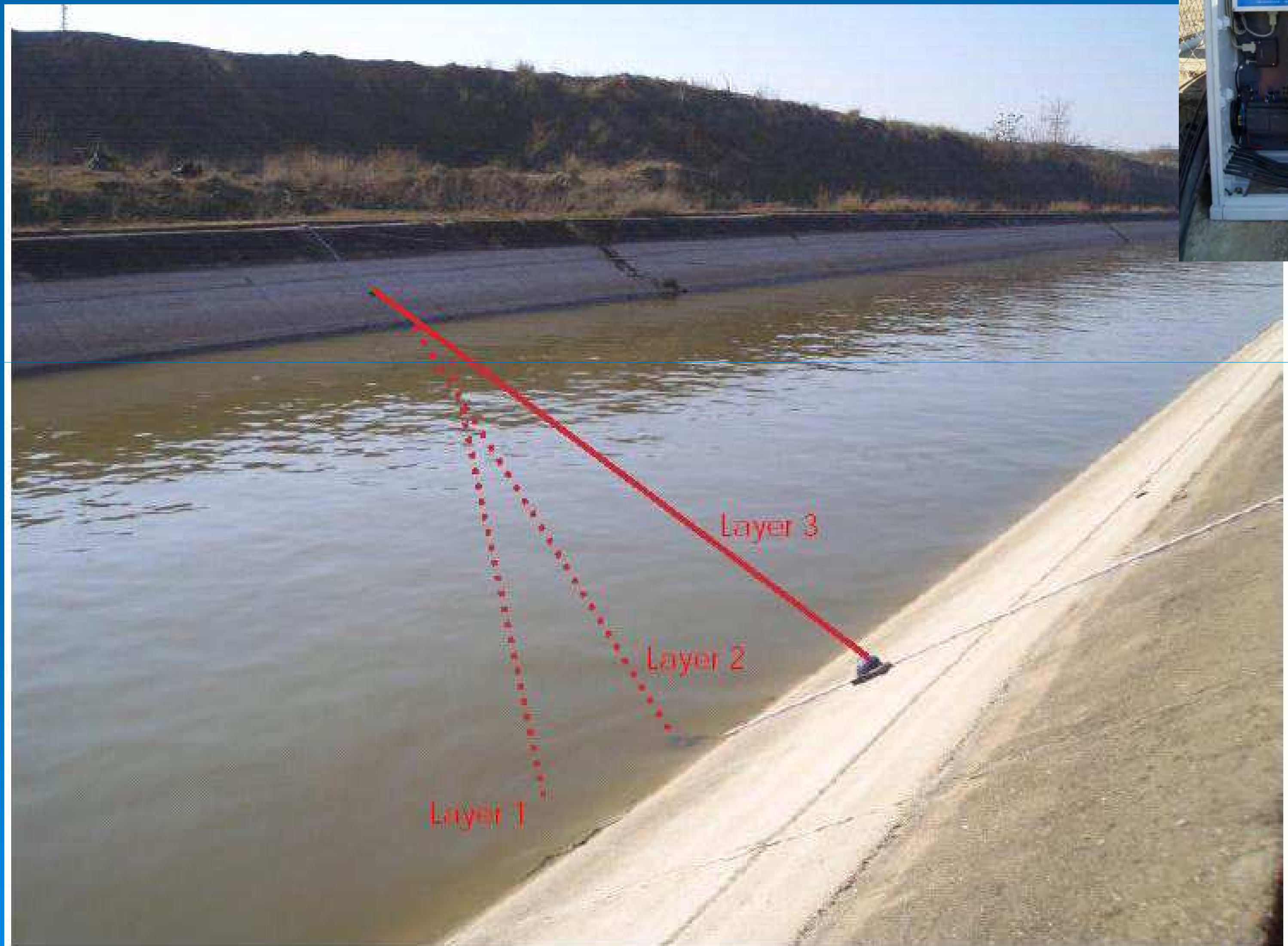
Transit Time Flow meter

- TT method of discharge measurement entails that the propagation velocity of an acoustic wave and the flow velocity are summed vectorially. Acoustic pulse in u/s direction is slower than in d/s. The difference in transit time in both direction is determined.

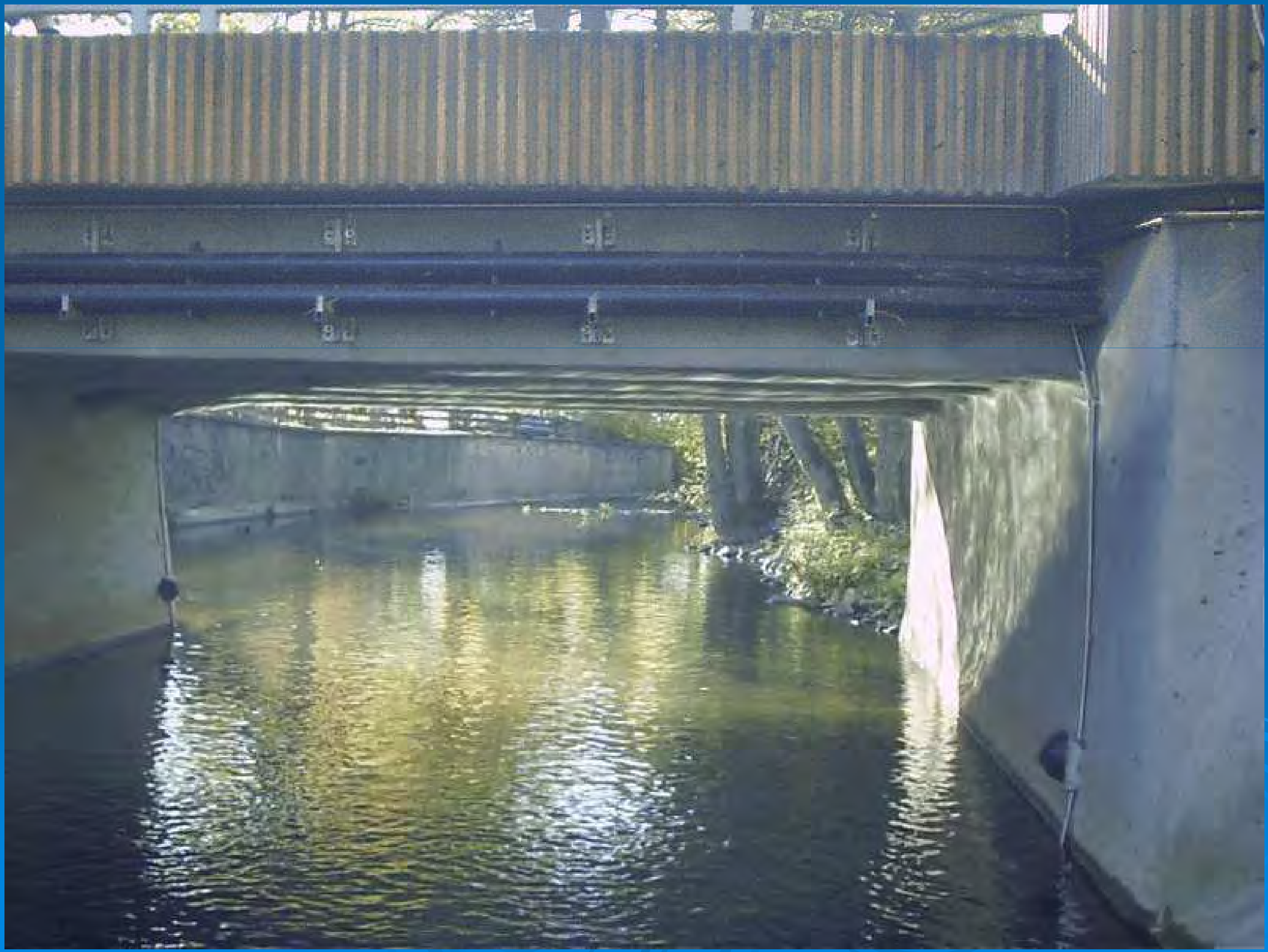
- All piezo-ceramics have at least one series resonant frequency at which they vibrate most easily. This is dependent on the ceramic material, shape and dimensions.

- Attenuation of sound in water increases with frequency. Because there is less attenuation of lower frequency signals, lower frequencies are used to achieve longer path lengths.

Ultrasonic Transit Time



Ultrasonic Transit Time



Ultrasonic Transit Time

Test of equipment

3D point cloud containing surface points, flow velocity and direction points in the water column and river bed elevation points

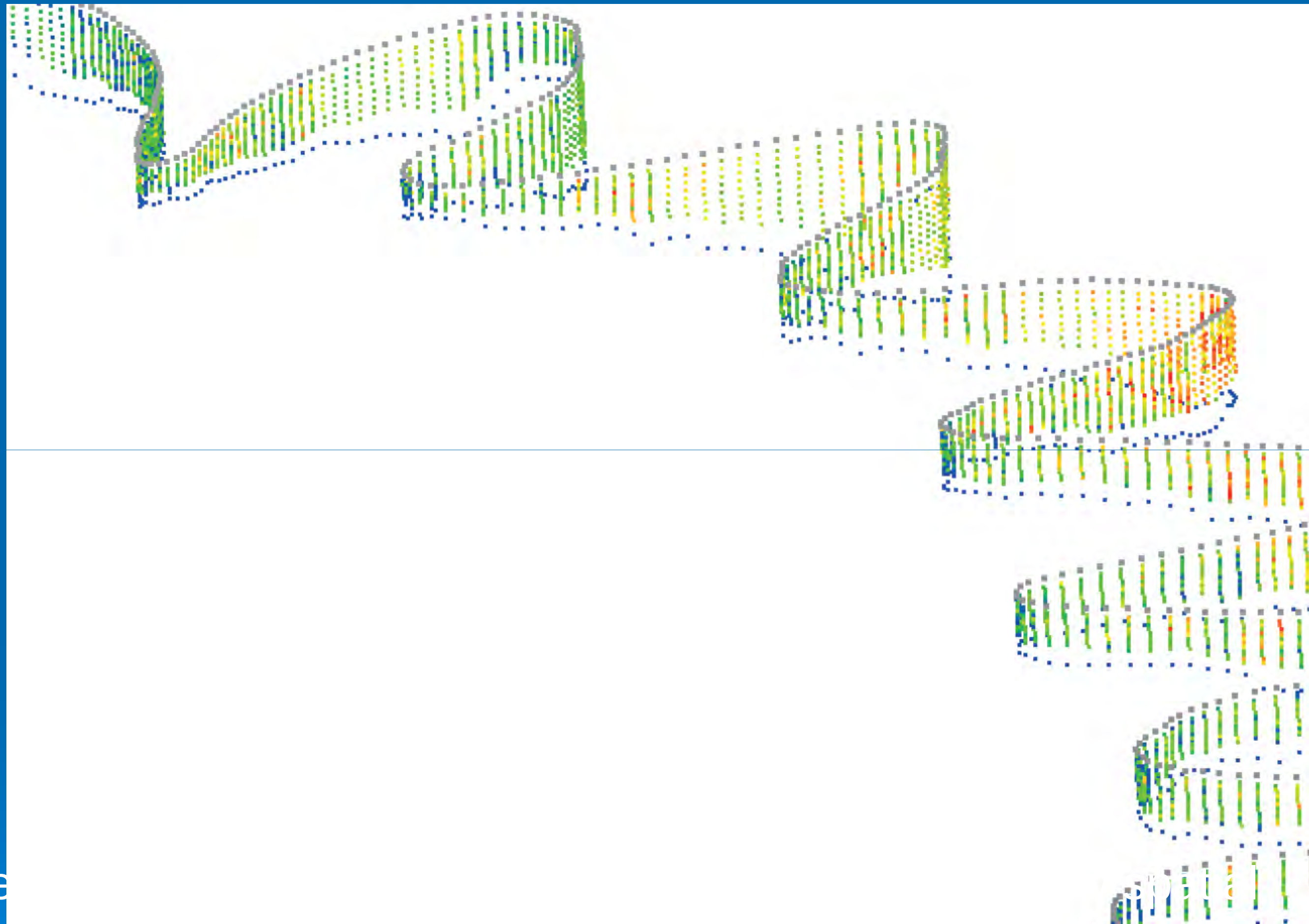


Diagram of the

modeling of flow vectors as a 3D point cloud containing surface points, flow velocity and

direction points in the water column and river bed elevation points; (B) This subfigure contrasts the more traditional method of representing flow as a series of transects.

Most updated and well documented resource:
http://hydroacoustics.usgs.gov

Thank you for your attention

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