River Morphology Problems and Mitigation (Sediment Transport, Bank Erosion, Flood)

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Workshop of Modelling Tools for River Engineering:
“Applications on River Morphology for the Nile Basin”

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- Streams stability and sediment transport
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- flood

Introduction

- **Realizing that the behavior of fluid and sediments is an important aspect of our engineering works, the understanding of the physical processes involved will be the focus of this presentation.**
- **Impacts can be short or long term, localized or far-reaching, predictable or unpredictable.**

There are many morphological problems such as:

- **Sedimentation in front of intake structures. (e.g. water treatment, power station, …)**
- **Scour around bridge piers.**
- **Bank erosion.**
- **Flood hazards.**

… etc.

Stream Stability

- It is the tendency of a stream to maintain its cross-section and profile geometry over time, effectively transporting its water and sediment supply without aggrading (building up), degrading (down-cutting) or adjusting laterally (eroding its banks)

- Stability concepts apply to all parts of a stream:
  bed, banks, floodplain, valley and watershed

Stream Stability (continue)

- Stability is an expression of a dynamic equilibrium: stream processes in balance to maintain or adjust channel form over time in response to environmental variables.
- The stream bed is mobile: sediment is transported and deposited regularly, even in a “stable” stream.
- Flood waters occupy different areas of the stream, from bed to valley.
- Sediment, flow and vegetation interactions define relative stability.

Unstable Stream?

- An “unstable” stream cannot effectively transport its water and sediment supply without aggrading (building up), degrading (down-cutting) or adjusting laterally (eroding its banks).
- Unstable streams are not “adjusted” to the landscape, they exhibit dramatic change in morphology.
- Unstable streams are the focus of attention because instability most often results in habitat, water quality, infrastructure and other management problems.

Sediment Transport

Sediments

- Are fragmental materials, formed by the physical and chemical disintegration of rocks from earth's crust.
- Range in size from large boulders to colloidal size.
- Sediment transported by water is called fluvial sediment transport.

Types of Sediment

- Cohesive Sediment:
Physical-chemical interaction between particles.

- Non-Cohesive Sediment:
No physical-chemical interaction between particles.

Sediment Transport

- It is the science or discipline which deals with the flow-sediment interaction in rivers.

- It is very important to determine the sediment to be transported by the river and to predict the effect of river training works on the bed morphology.

Sediment Transport

Total Load

Wash Load

Important in places which have very low velocity that the fine particles are able to settle; (for instance upstream of dams and in river ports).

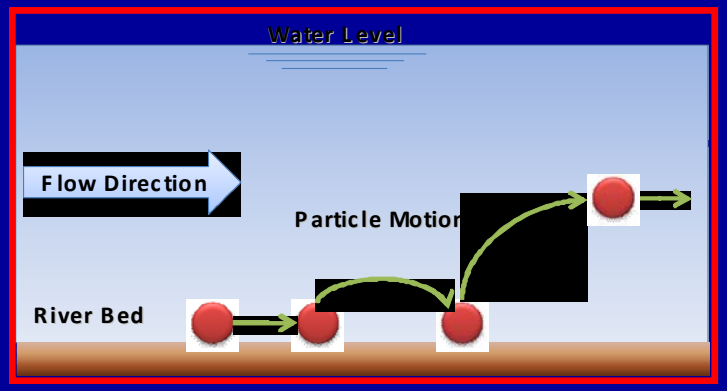
Bed Material Load

Important for description and prediction of erosion and sedimentation.

- Bed Load
- Suspended Load

(depending on the particle motion)

The Particle Motion Can Be Classified Into Three Modes As:



1- Rolling or sliding

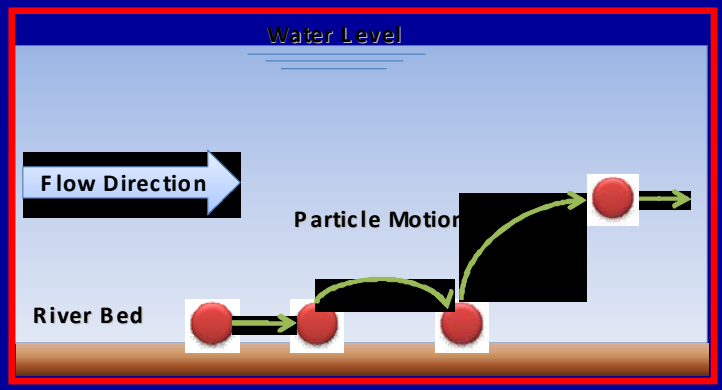
The type of movement depends on the bed shear velocity [$u_* = (ghi)^{0.5}$].

When the value of the bed shear velocity just exceeds the critical value for initiation of motion, the particle will be rolling, sliding or both, in continuous contact with the bed.

Particle motion (Continue)

2-Saltation (Jumping)

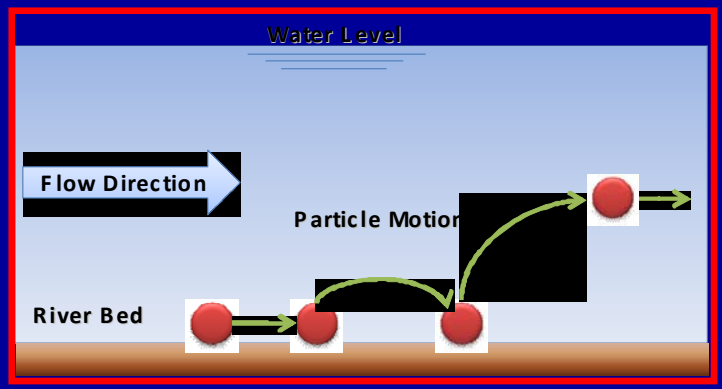
For increasing value of bed shear velocity, the particles will be moving along the bed by more or less regular jumps, which are called saltation.



Particle motion (Continue)

3- Suspended particle motion

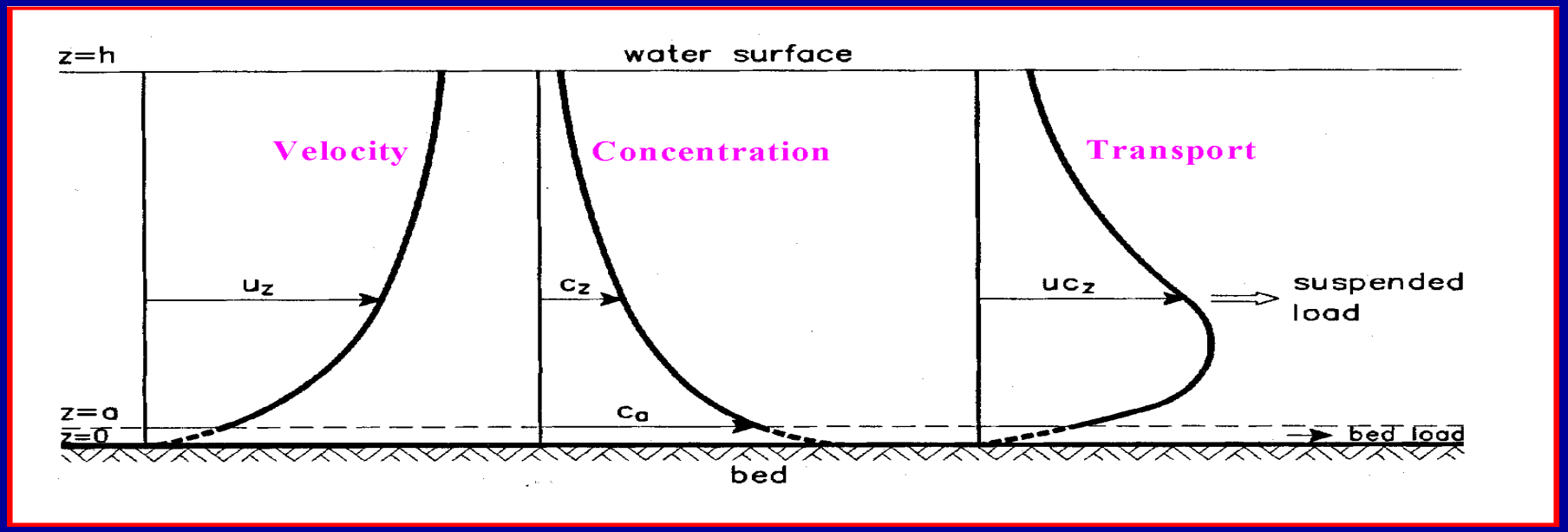
When the value of bed shear velocity exceeds the fall velocity of particles, the sediment particles can be lifted to a level at which the upward turbulent forces will be comparable with or of higher order than the submerged weight of the particles and as a result the particles go in suspension.



Bed load transport rate
is defined as the transport of particles by rolling, sliding and saltating.

Suspended load transport rates
is defined as the transport of particles by suspension.

Total load transport rates
is the sum of the bed load and suspended load.



Definition sketch of velocity, concentration and transport profile

Sediment Sampling Techniques

Field measurements are essential to determine the local morphological variables such as:

Bed material size
Fall velocity
Bed load
Suspended load, ...etc.

Sediment Sampling Techniques (continue):

Selection of the most suitable instruments depends on:

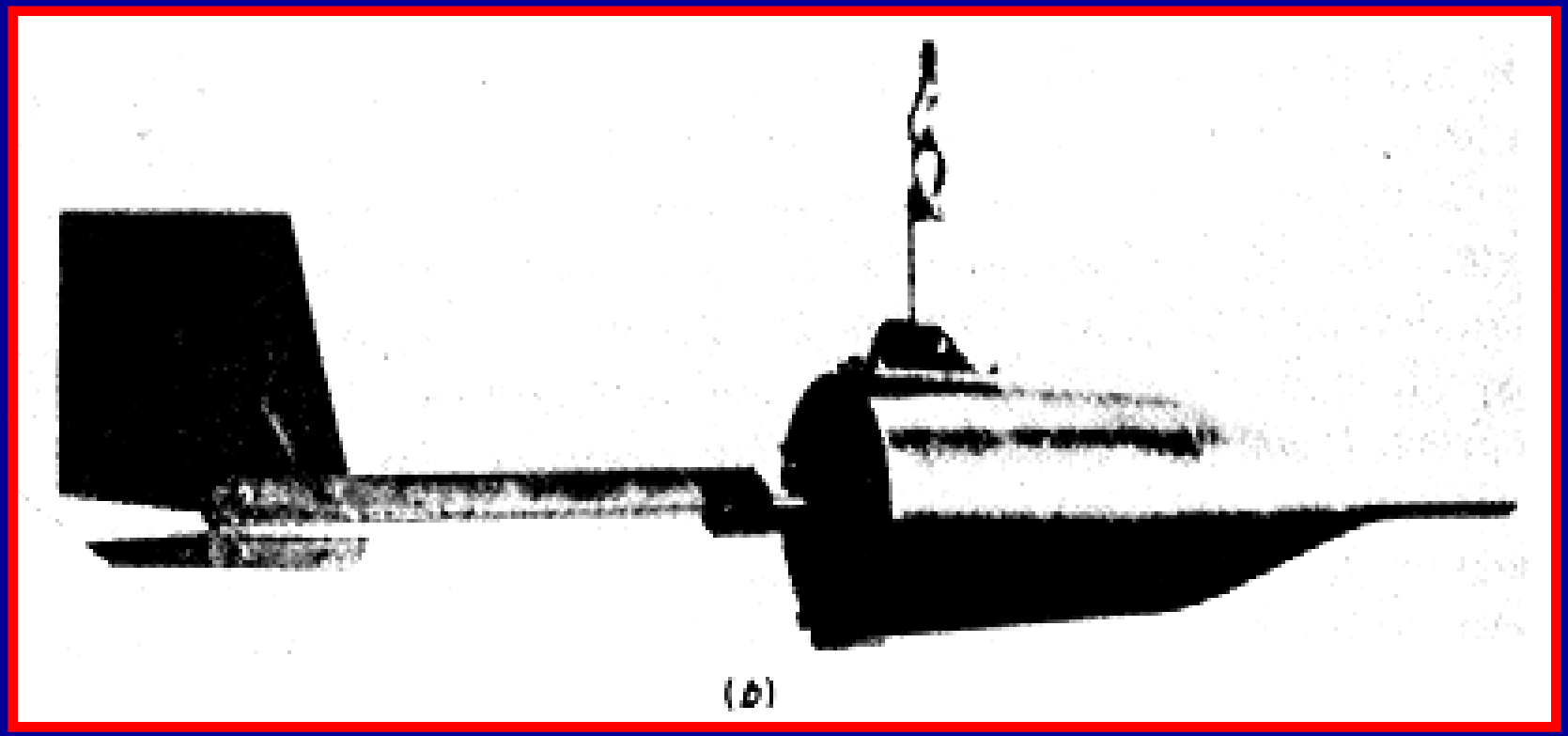
- There is a wide range from simple mechanical samplers to sophisticated samplers.
- Variables to be measured.
- Available facilities (boat, winch, ...etc.).
- Required accuracy (observation study or basic research study).

Suspended Load Sampling

Direct method

Direct measurements of the time-averaged sediment transport in a certain point or over a certain depth range.

The sampler has a vertical movement at a uniform speed over the depth.
(such as the delft Bottle)



Delft Bottle (depth-integrating)

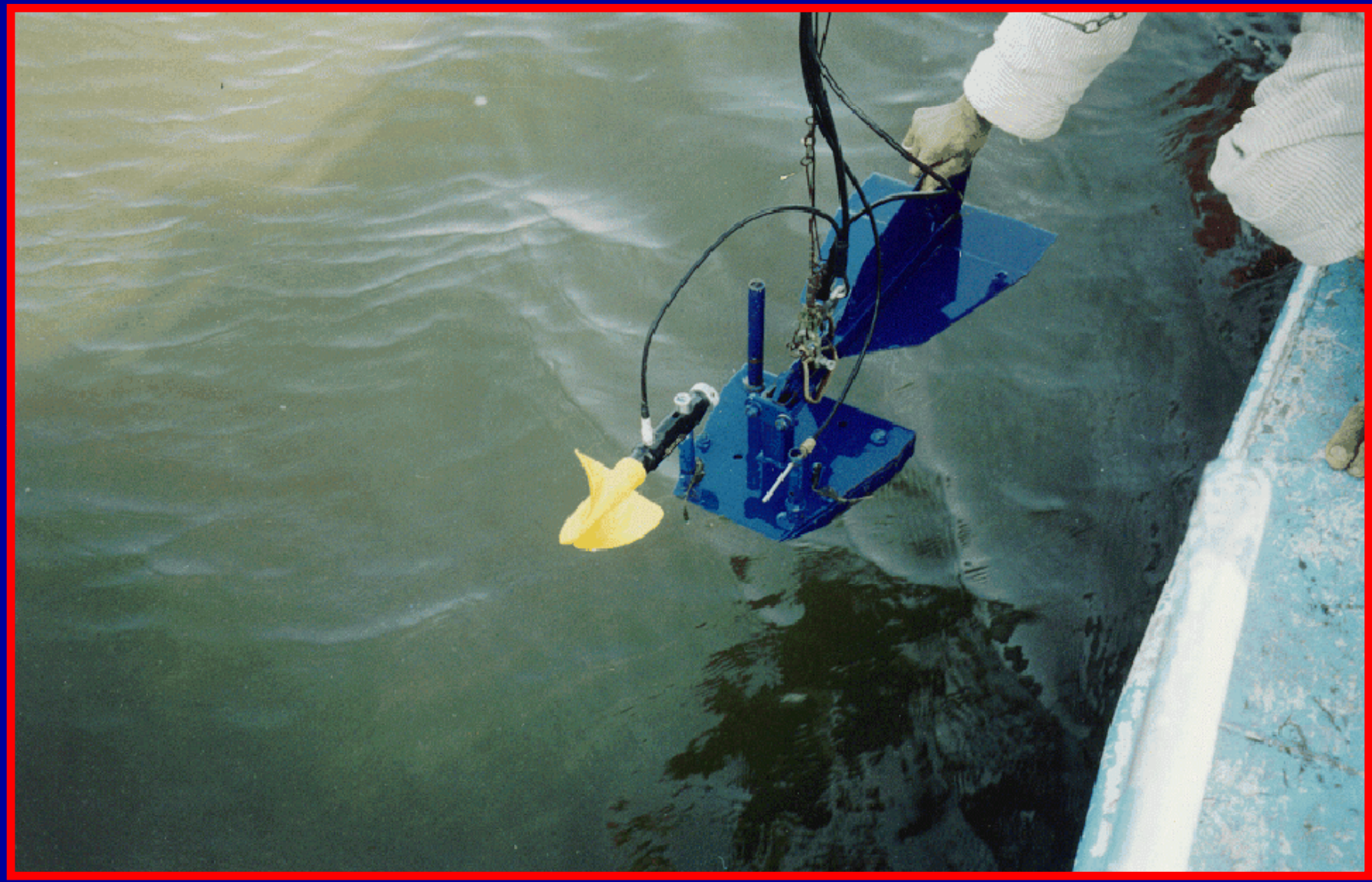
Suspended Load Sampling

Indirect method

simultaneous measurements of fluid velocity

and sediment concentration.

(such as the Delft Fish).



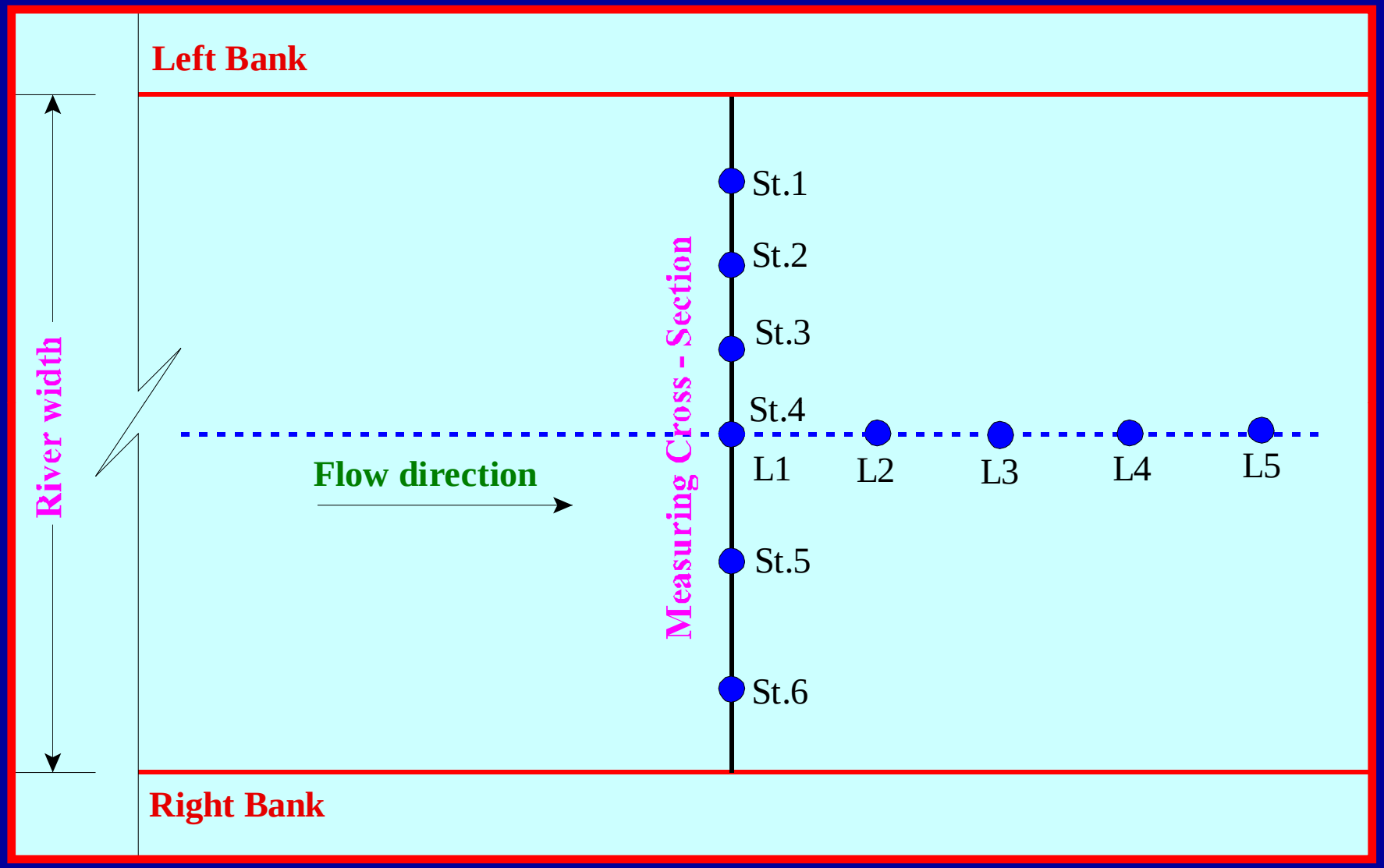
The Delft Fish Used for Velocity Measurements and Suspended Sediment Sampling

Bed Load Sampling

Sampling should be taken in each vertical in which sediment transport is measured.
Selection of bed load sampling depends on the actual circumstances:

- Shallow or deep water.
  (Sampler forced by hand into stream or an instrument depends on weight and shape)
- Flow velocity should preferably not exceed 1.5 m/s during sampling.
  Increase the weight of sampler for higher flow velocity.

Survey boat equipped with digital echo-sounding, positioning system and the Delft Nile Sampler



Layout of the measuring Stations and locations

The numbers of locations and stations were determined based on statistical analysis.

The Delft Nile Sampler and the Underwater Video Camera

Nylon Bag

Set of Pulsation Pumps Used for Suspended Sediment Sampling

Suspended Load Sample


764
789
751
851
7 23:20

BED MATERIAL SAMPLING

Position during lowering the sample

Position during raising the sample

Van Veen Grab Sampler

Analysis of Bed and Suspended Sediment Samples


7 21:15

Bank Erosion

How and Why Does Bank Erosion Occur?

- Bank erosion is a natural fluvial process, is directly or indirectly influenced by:

➢ Strength of bank materials
  - Bank height
  - Surface protection
  - Bank angle
  - Cohesiveness (how well it sticks together)

➢ Force of flowing water
  - Depth over bank materials
  - Velocity
  - Direction of flow

Large and rapid drop of the water levels and the high velocities are the main reasons for bank erosion of the Nile near Khartoum

Blue Nile Eroded Bank

White Nile Eroded Bank

Bank Erosion on Eastern Bank Upstream of Aldaba bridge, North Sudan

Typical Bank Erosion At Luxer, Egypt

Bank Erosion Mitigation

Main Nile Eroded and Protected Banks near Khartoum

North Qena Drain Protection Project, Egypt, Using Gabions

Before drain development

After drain development

Good maintenance is needed

Bio Geo Material Technology:

- One of its applications is the Smart Soil in which sand bars can be changed into sand-stone. The soil is injected by certain kind of bacteria.
- This can be used in coastal protection works and protection of inlets and outfalls of pump stations especially in the north of delta.

Earth Reinforcement

A flexible armoring system that controls erosion, reinforces vegetation and stabilizes the earth in the extreme situations.

Floods

Floods

Floods occur in rivers, when flow exceeds the capacity of the river channel, particularly at bends or meanders.

Floods often cause damage to homes and businesses if they are placed in natural flood plains of rivers.

While flood damage can be virtually eliminated by moving away from rivers and other bodies of water.

people have lived and worked by the water to seek sustenance and capitalize on the gains of cheap and easy travel and commerce by being near water.

Principal types and causes

- **Riverine**

  Slow kinds: Runoff from sustained rainfall or rapid snow melt exceeding the capacity of a river's channel. Causes include heavy rains, hurricanes and tropical depressions.

  Fast kinds: include flash floods resulting from convective precipitation or sudden release from an upstream impoundment created behind a dam, or landslide.

- **Estuarine**

  Commonly caused by a combination of sea tidal surges caused by storm-force winds.

- **Coastal**

  Caused by severe sea storms, or as a result of another hazard (e.g. tsunami or hurricane).

- **Catastrophic**
  Caused by a significant and unexpected event e.g. dam breakage, or as a result of another hazard (e.g. earthquake or volcanic eruption).

- **Human-induced**
  Accidental damage by workmen to tunnels or pipes.

- **Muddy**
  is produced by an accumulation of runoff generated on cropland. Sediments are then detached by runoff and carried as suspended matter or bed load. Muddy runoff is more likely detected when it reaches inhabited areas.

Flood Effects

Primary effects

- *Physical damage:* Can damage any type of structure, including bridges, cars, buildings, canals and roadways.

Secondary effects

- *Water supplies*: Contamination of water. Clean drinking water becomes scarce.
- *Diseases*: Spread of water-borne diseases.
- *Crops and food supplies*: Shortage of food crops can be caused due to loss of entire harvest.
- *Transport*: Transport links destroyed, so hard to get emergency aid to those who need it.

Flash flood

- is a rapid flooding of geomorphic low-lying areas ، rivers ،dry lakes and basins .
- It may be caused by heavy rain associated with a storm ،hurricane ،or tropical storm or melt-water from ice or snow flowing over ice sheets or snowfields.
- Flash floods may occur after the collapse of a natural ice or debris dam ،or a human structure such as a man-made dam.

- Flash flooding occurs when precipitation falls too quickly on saturated soil or dry soil that has poor absorption ability.

- The runoff collects in low-lying areas and rapidly flows downhill .

Flooding of the Ewaso Ng'iro River destroyed the research camp of Africa's wild elephants located in Samburu National Reserve, Kenya

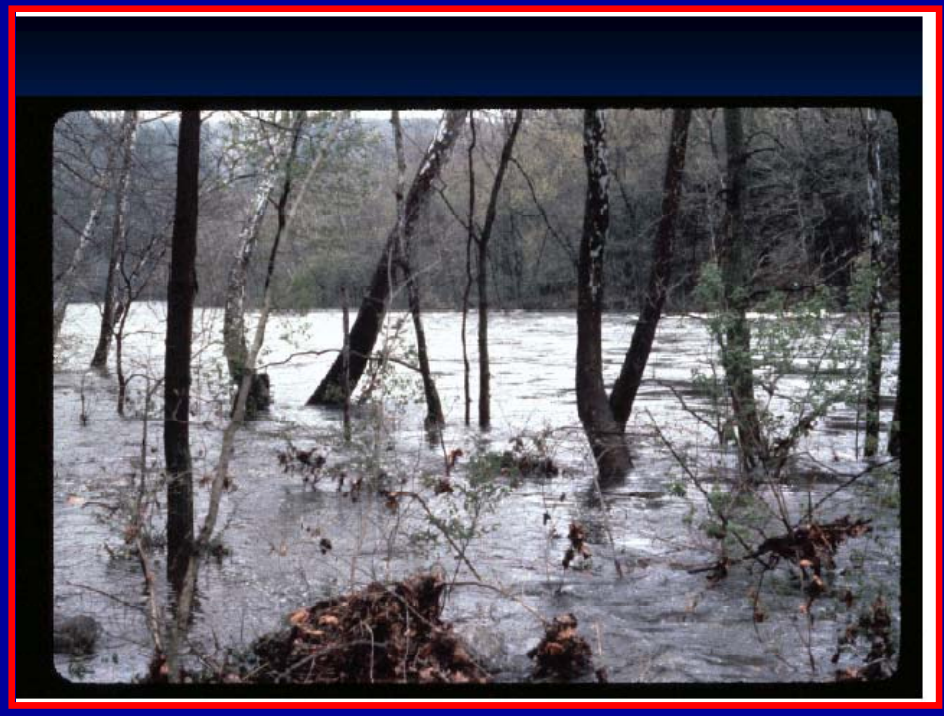
Vehicle was swept away in flash floods in Turkana County, north western Kenya and a number of people were killed

Flood mitigation:

- Flood control structures such as: berms, levees, dams
- Infrastructure management (roads, bridges, culverts)
- Proper design and management to minimize infrastructure or property damages.

Floodplain Function

- Energy dissipation during flooding events
- Lowers flood peaks: storage and infiltration
- Trap for fine sediments: keeps that material out of the bed, and provides a growth medium



Floodplain Function (continue)

- Vegetation slows water velocity allowing sediment deposition and storage, and groundwater recharge
- Live vegetation root mass stabilizes stream banks

Thank you for your attention