



DHV CONSULTANTS &
DELFT HYDRAULICS with
HALCROW, TAHAL, CES,
ORG & JPS

VOLUME 5
SEDIMENT TRANSPORT MEASUREMENTS

FIELD MANUAL
SUSPENDED LOAD MEASUREMENT,
BED MATERIAL SAMPLING,
SEDIMENT ANALYSIS

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1 OBSERVATION PRACTICE

The routine sediment observations made in the Indian Peninsula - at the National and at the State levels – include the measurements of suspended load and of bed material. No bed load is measured routinely. Suspended sediment samples are analysed routinely in the laboratories for particle size determination, limited however to the determination of the percentage of fine, medium and coarse fractions (respectively below, between and above 0.75 and 210 microns). The particle size distribution of bed material, where sampled, is analysed routinely.

This chapter on observation practices contains general instructions for operation and maintenance of samplers and instruments for sediment measurement. For the samplers and instruments presently utilised in India, more detailed instructions and recommendations are given, also for those manufactured locally but not yet used in the hydrological services in the Peninsula. Some detailed instructions are also given for those samplers likely to be used in India, in the future.

As a matter of fact, many difficulties and questions may arise during implementation of sediment measurement methods, techniques and instruments; those may be so specific to the river or site that they have to be appraised separately for each site by qualified personnel. The routine procedures are making the operators/observers losing alertness for basic details. The field checking procedures would therefore be given due importance; they will be discussed in some detail in this chapter.

The sediment samplers and instruments available in India are either locally designed or of US design. The US instruments were introduced in India through an UNDP project and are presently manufactured in India, by the Central Water & Power Research Station (CW&PRS) in Pune and, more recently, by private manufacturers. The list of the suspended sediment samplers and instruments, locally made, either used or tested in India, includes the following (not all are listed below):

1. Bottle-type point samplers
 - Punjab bottle
 - RRI bottle
 - Fish-weight contained bottle
2. Depth-integrating samplers
 - Wading, hand-held type, rod mounted US DH-48
 - Wading or hand-line type US DHS-48
 - Hand-line US DH-59
 - Cable suspended US D-74
3. Point-integrating samplers
 - Cable suspended US P-61
 - Cable suspended US P-63
 - Cable suspended US P-50

For bed material sampling in flowing channels, the scoop-type Ekman dredge is used by CWC, while samples from the dry bed are taken by hand after eventually removing the vegetation cover. CW&PRS manufactures the Peterson grab-type sampler, not appropriate for most stations. The US BM-54 is well suited for most sites.

2 SUSPENDED LOAD

2.1 INTRODUCTION

The methods for suspended load observations are described in earlier in this report. The most widely utilised principle for suspended load measurement is to determine the concentration of a water catch under water. Samplers of different types and makes are available on the market, sub-divided into two main groups

- the point sampler
- the depth-integrating sampler

A point-integrating sampler is equipped with a device for opening and closing the sampler nozzle or mouth - for controlling the sampling time - while the depth-integrating sampler remains open, catching sediment particles during the entire transit time in the flow. The point-integrating sampler is usually more sophisticated than the depth-integrating one, most of these samplers requiring electric power to operate the valve. It is also more versatile, as it can be utilised as a depth-integrating sampler too; the opposite is not possible.

In India, the methods and instruments for suspended load measurements have been kept as simple as possible:

- samples from a large number of verticals
- total number of composite samples has to be as small as possible
- sampling at one level only (0.6 of the depth) or depth-integrated
- Punjab bottle sample used in most stations
- US DH-48 and US P-61 used in some states (e.g. in Gujarat)

The Punjab (bottle sampler), the US DH-48 (depth-integrating suspended-sediment wading-type sampler) and the US P-61 (point-integrating suspended-sediment suspended-type sampler) are in use in the Indian Peninsula.

2.2 BOTTLE-TYPE SAMPLER (E.G. PUNJAB SAMPLER)

2.2.1 GENERAL DESCRIPTION

The bottle sampler is a point-integrating device. The current practice in most states of the Indian Peninsula is to use the "Punjab" bottle sampler for measuring suspended load. The sampler is appropriate for rivers with suspended load almost exclusively composed of wash load, with no or little coarse and medium particle size fractions. The measurement procedure with this instrument is described in several documents.

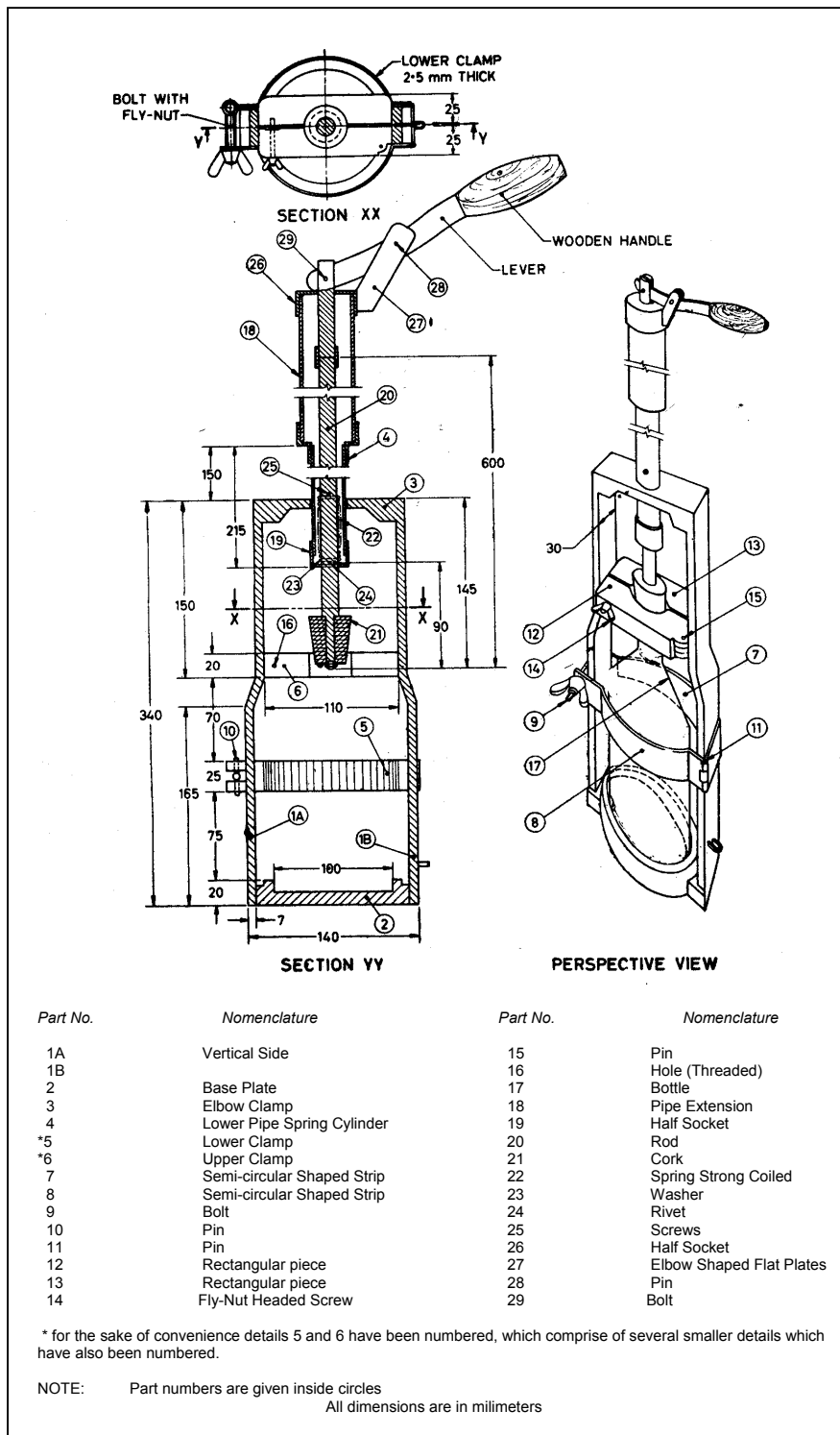
1. Principal advantages, limitations of bottle samplers; alternatives or corrections

- Bottle samplers are very simple and easy to use; they can be appropriate for operation in rivers containing only wash load in suspension, the coarse and medium particle size fractions being very limited in concentration
- The Punjab bottle sampler was designed in India in 1935 for slow flowing, shallow rivers and canals, and does not work efficiently at large depths (Figure 2.1)
- The Punjab-type bottle sampler does not work efficiently at high velocities, mainly due to the difficulty to keep it vertical, also when suspended or hung from a line with a fish-weight

The water does not enter the bottle with the velocity and direction of the surrounding stream velocity (not iso-kinetic sampling)

- When operated from a survey vessel, a special device can be used to keep the rod-mounted bottle vertical (Figure 2.2)
- A redesigned Punjab-type bottle sampler (1951-1952) was placed in a fish-weight for use in 8m depths with velocities of 3 m/s, however with poor results; it is not in use anymore
- Over- or under-filling may be avoided by equipping the bottle with an electrical bell design

Air exhaust and pressure equalising device may reduce the disturbance of sampling caused by sudden inrush of water when opening the bottle for sampling (Figure 2.3)



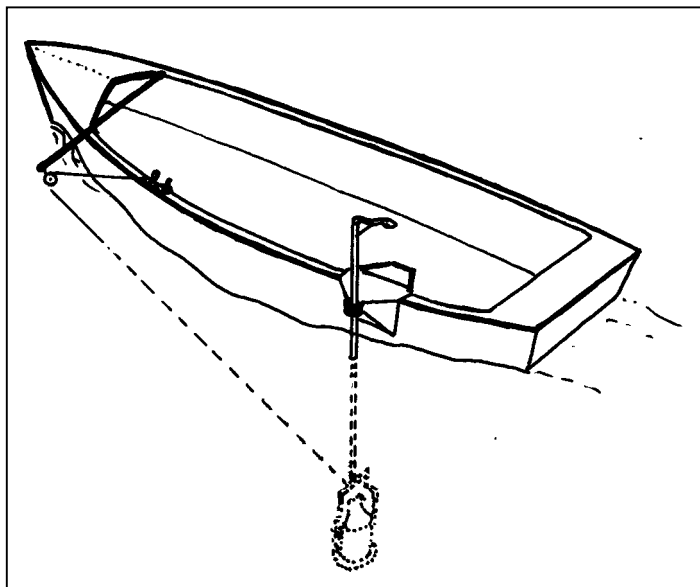


Figure 2.2
The Punjab bottle sampler mounting
when operated from a boat

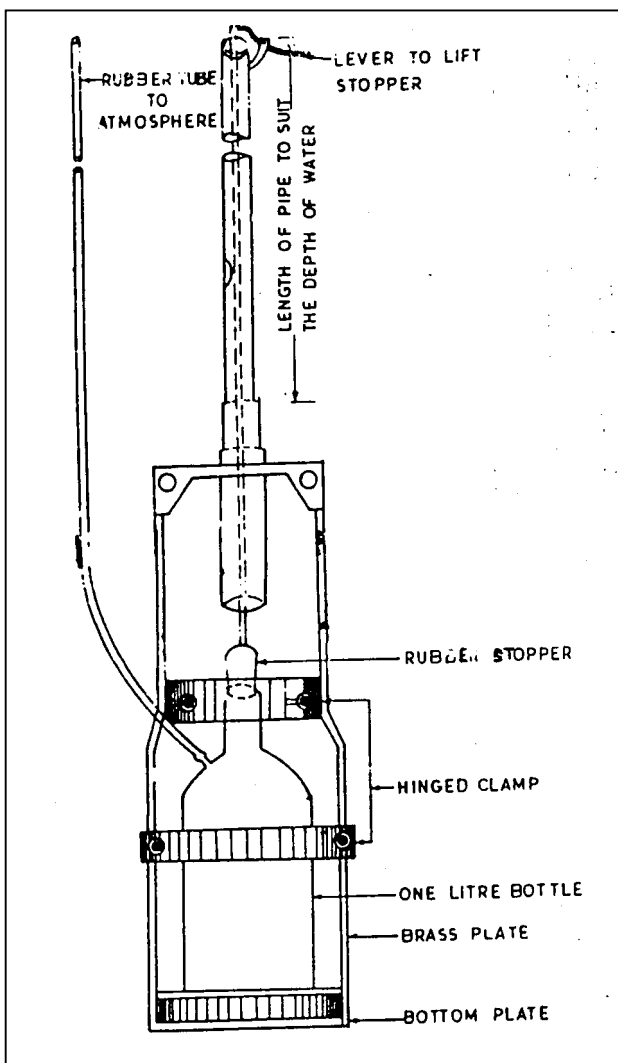


Figure 2.3
The Punjab bottle sampler equipped with
pressure equalising system

2.2.2 ESSENTIAL INSTRUCTIONS AND PRECAUTIONS WHILE SAMPLING - FOR ALL THE BOTTLE SAMPLERS

- The sampler must be kept vertical while sampling
- The mouth of the bottle must be opened only when the instrument has reached the required depth, not earlier
- The bottle may not leak; leakage would result in a catch before the actual sampling starts
- The mouth must be kept open with a sufficient water passage and for a minimum time span so as to fill enough, though overfilling should be avoided
- The exact volume of the collected sediment sample must be measured and recorded

2.2.3 INSTRUCTIONS FOR PUNJAB SAMPLER O&M (CHECK LIST, INSTRUCTIONS AND PRECAUTIONS)

Before sampling, check

Sampling bottle

- A metallic bottle, if deformed (out of shape) or damaged (especially its mouth) has to be replaced by a spare one
- A glass bottle, if breached, has to be replaced by a spare one

Bottle cork

- Must close tightly to avoid leaking
- May never be painted
- Damaged corks must be replaced
- Cork must be suitably tapered to enter 0.5 to 1 cm in bottle mouth
- Eventually, rub smoothly lower end of cork with emery paper if cork does not enter far enough into the bottle mouth

Bottle holder (frame)

- Clamps at neck and mid-portion may not be damaged and should hold tightly the bottle with the cork seating perfectly axial in the mouth
- Fly nuts for locking must operate easily; they should be replaced if they don't lock gently
- Socket thread may not be damaged

Pipe, rod, spring and lever

- Brass rod and pipe may not be bending
- Spring must be checked and dead springs replaced

Sampler leakage

- The sampler must be tested for possible leakage by holding it tightly closed under water for 5 minutes and collected sample needs to be less than 5 cc.
- In case of leakage, do not try to repair on the spot and use spare sampler

During sampling, instructions and precautions***In general***

- The sampler must be oriented with the vertical frame perpendicular to the flow so that it does not disturb the flow at the mouth
- The time required to fill the sampling bottle must be checked by trial and error, so that sampled volume would total between 80 and 90 % of the bottle volume (i.e. 0.4 l to 0.45 l for a 0.5 l bottle)
- Samples from partially or fully filled bottles must be rejected and a new sample taken
- Sampler may never touch the stream bed
- The distance between sampler bottom and the streambed must always be larger than 20 cm

When sampling from a survey vessel

- If flow permits, the survey vessel should be kept stationary to hold the sampler vertical
- In high flows, use a fitting to the hull and a line for keeping the sampler vertical whenever possible (Figure 8.2-3)
- In flows too strong for keeping the sampler vertical, drifting from the vessel may be allowed exceptionally to reduce the drag on the sampler as to keep it vertical, this only if sampling can be performed in the selected vertical (this procedure should be first tested in presence of the assistant research officer and/or junior officer)

When sampling while wading

- During sampling, keep the bottle upstream and well in front of you
- Avoid sampling when the product of flow velocity (in m/sec) with depth (in m) exceeds 1

When sampling from a bridge

- The bottle sampler should not be used if it can not be kept vertical in the flow
- When flow is too strong for measuring at 60 % of the depth (0.6 d), a water surface sample may be taken, but with the bottle mouth at least 0.5 m under water
- Operation of the bottle sampler with a fish weight should be avoided if this is not specifically designed to contain the bottle
- When operated with a suitable fish, the drift angle measured at the protractor should not exceed 15 degrees

After sampling, instructions and precautions

- Reject the sample if there is any floating debris hanging to the sampler or trapped between bottle mouth and cork
- The sample must be collected carefully, without spilling any water
- The volume of the collected sample must be measured precisely before rinsing, even if sediment remains in the bottle, to be rinsed later with clean water
- If water or sediment is spilled during collection of sample, this must be rejected and a new sample taken
- The rinsing water with its sediment must be added to the collected sample

2.3 HAND-HELD ROD-MOUNTED STREAMLINED DEPTH-INTEGRATING SAMPLER (FIXED VOLUME, E.G. US DH-48)

2.3.1 GENERAL DESCRIPTION

Several hand-held, streamlined, depth-integrating samplers are available on the market, the best known being the US DH-48. This lightweight sampler has a aluminium casting body, originally designed for use with a round pint milk bottle sample container. An intake nozzle extends horizontally from the nose of the sampler body. While sampling, the air present in the bottle escapes through a streamlined exhaust mounted on the side of the sampler head. The sampler is easy to operate and to maintain. In India, a tin bottle replaces the glass one.

The original US DH-48 exists in several versions available in the US. It is also manufactured in India, though the original design was most often slightly adapted. Some local makes were however badly copied and/or some basic features were not respected, such as the 70° angle between the axis of the streamlined body and the wading rod or the fitting (alignment) of the bottle in the body. Also, the sampler has been used in India suspended at a hand-line, set up for which it is not suited at all; the US DHS-48 (Figure 2.4) or the US DH-59 (Figure 2.5) (further described) are especially designed for attachment at a hand-line.

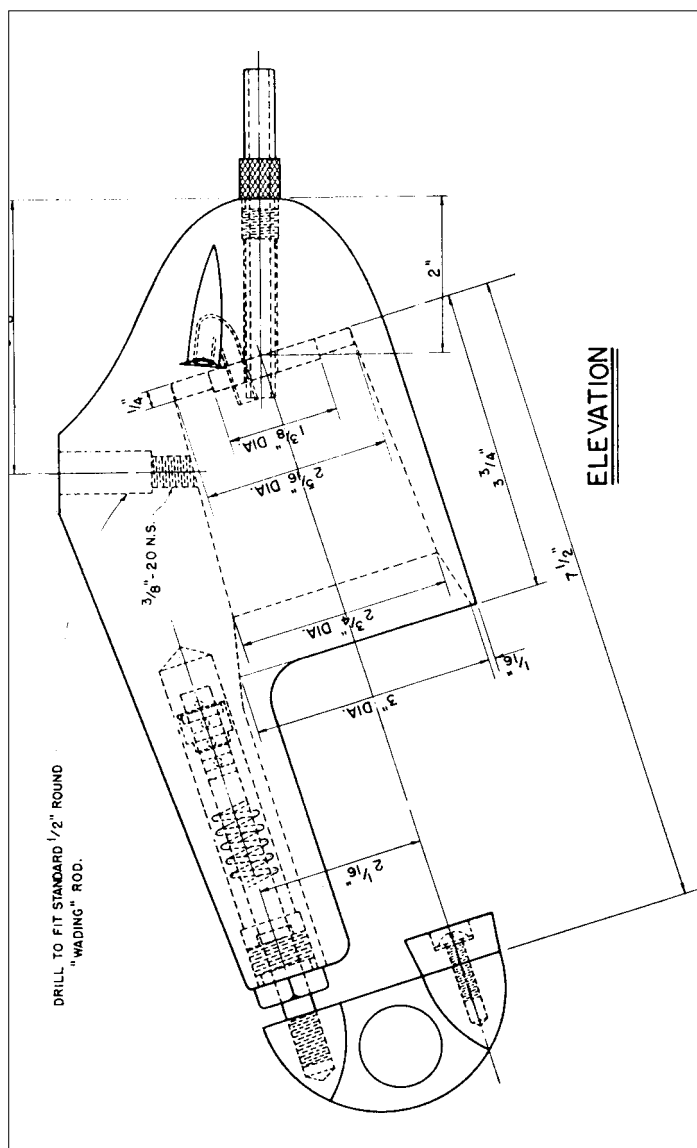


Figure 2.4
US DH-48

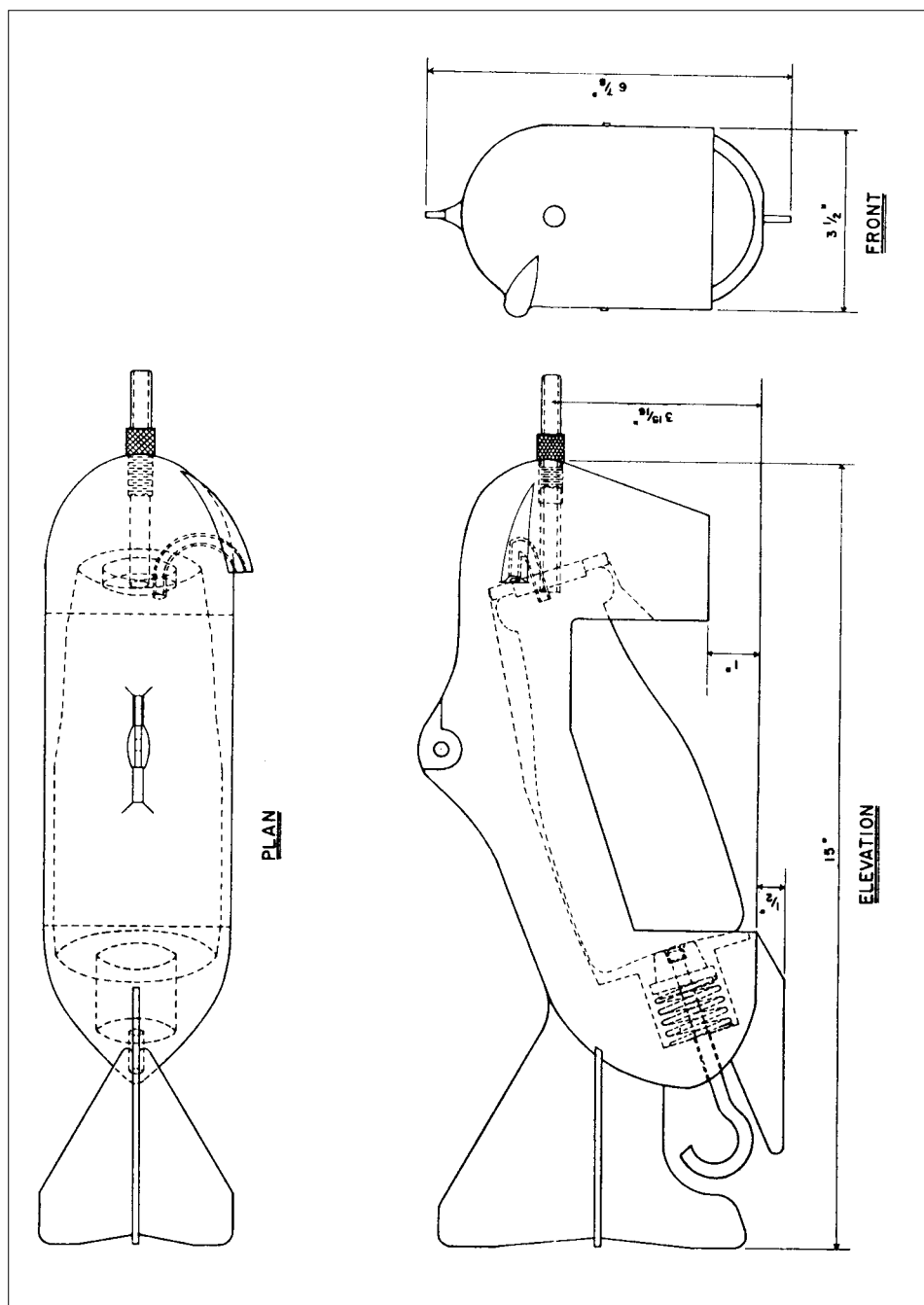


Figure 2.5 US DH-59

2.3.2 PRINCIPAL ADVANTAGES, LIMITATIONS OF HAND-HELD SAMPLERS; ALTERNATIVES OR CORRECTIONS

- Simple and easy to operate
- Use restricted to wadable rivers with low velocities
- May never be used as a hand-line suspended sampler and may not be adapted for use as such
- Rate of filling must be found by experience
- Small bottle volume, requiring to take several samples if concentration of suspended load is too small

2.3.3 ESSENTIAL INSTRUCTIONS AND PRECAUTIONS WHILE SAMPLING - FOR ALL HAND-HELD STREAMLINED DEPTH-INTEGRATING SAMPLERS

- The mounting rod must be kept vertical during the duration of the sampling
- A standard rod of 3-foot (0.9 m) rod with plastic grip can be used for most site situations, but additional length can be added with separate 1-foot or 3-foot sections
- The sampler body must be kept well aligned in the flow during the entire transit between water surface and stream bottom
- The transit rate must be kept constant and the same when lowering and hoisting
- The lowering and hoisting speed during sampling may not exceed 0.4 times the maximum flow velocity in the sampling vertical, to be measured before sampling
- The lowering and hoisting speed shall be adjusted to fill the bottle at $\frac{3}{4}$ th of its capacity
- The total volume needed to get a representative catch will determine the number of individual samples to be taken
- Reject all overfilled samples (bottle full)
- Reverse instantly from lowering to hoisting when sampler touches the stream bottom

2.3.4 INSTRUCTIONS FOR THE US DH-48 SAMPLER O&M (CHECK LIST, INSTRUCTIONS AND PRECAUTIONS)

Before sampling, check

- Check overall status of the sampler's body for possible damage and replace when needed
- Check the bottle for possible damage and replace when needed
- Check the nozzle for possible damage and replace when needed
- Check the assembly parts (gasket, spring-operated clamp) for possible damage and replace by spare parts if needed
- Place suitable nozzle for the prevailing depth of flow and bottle size
- Check the mounting rod for possible damage and mount it on the sampler; if rod does not fit correctly on the sampler, do not try to repair on site and use the spare one
- Verify that all sample bottles and/or containers are clean and properly labelled

During sampling, instructions and precautions

- Place yourself downstream of the sampler and keep it well in front of you
- Keep the rod always vertical during sampling
- Keep the lowering and hoisting speed constant, never higher than 0.4 times the maximum velocity and sufficient to fill the bottle at least at $\frac{3}{4}$ th of its capacity
- Reverse instantly from lowering to hoisting when sampler touches the stream bottom
- Avoid sampling when the product of flow velocity (in m/sec) times depth (in m) exceeds 1

After sampling, instructions and precautions

- Reject the sample if there is any floating debris hanging to the sampler body or nozzle
- The sample must be collected carefully, without spilling any water
- The volume of the collected sample must be measured precisely before rinsing, even if sediment remains in the bottle, to be rinsed later with clean water
- If water or sediment is spilled during its collection, this sample must be rejected and a new sample taken
- The rinsing water with its sediment must be added to the collected sample

2.4 LIGHT- AND MEDIUM-WEIGHT, STREAMLINED, HAND-LINE SAMPLERS (FIXED VOLUME, E.G. US DHS-48, D-59, D-76)

2.4.1 GENERAL DESCRIPTION

Several hand-line, streamlined, depth-integrating samplers are available on the international market, for use suspended from a bridge or boat, possibly from a manned cableway. This type of sampler is not yet manufactured in India. The US DHS-48 (Figure 2.6), D-59 (Figure 2.7) and D-76 are suitable for most low and medium flow situations. These samplers have an aluminium or bronze casting body, originally designed for use with a round pint milk bottle sample container. An intake nozzle extends horizontally from the nose of the sampler body. While sampling, the air present in the bottle escapes through a streamlined exhaust mounted on the side of the sampler head. The sampler is very easy to operate and to maintain.

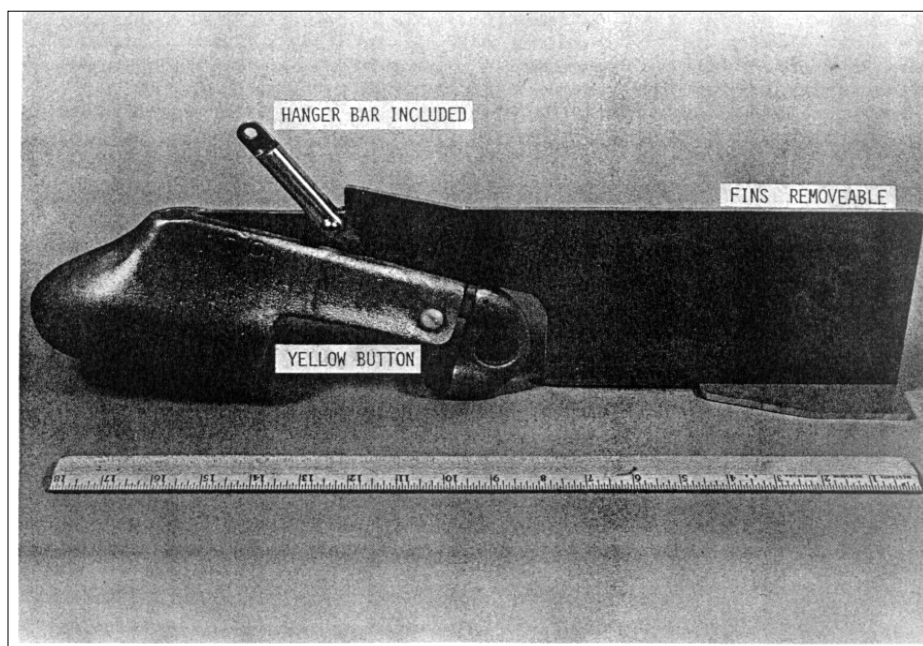


Figure 2.6
US DHS-48

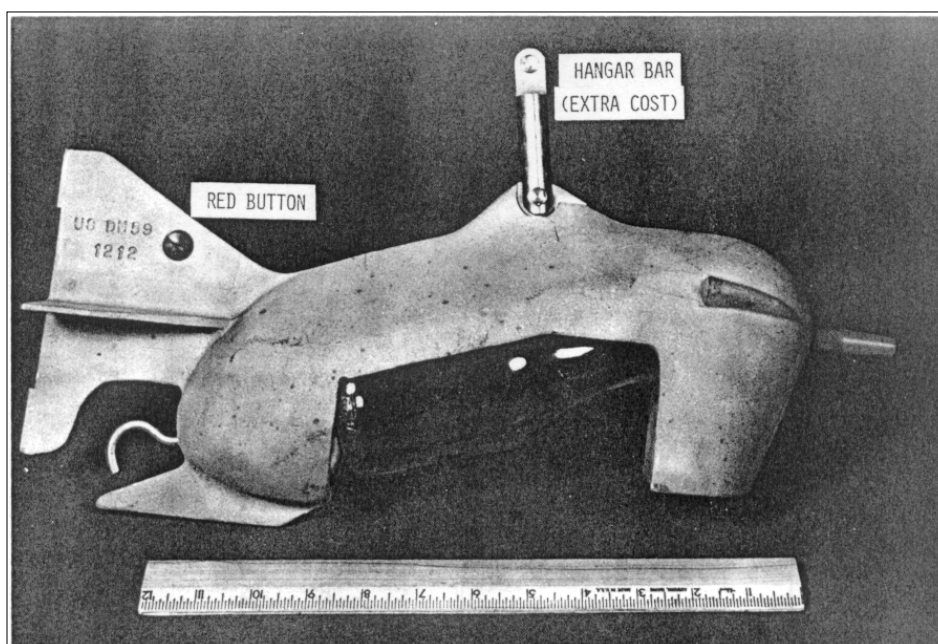


Figure 2.7
US DH-59

2.4.2 PRINCIPAL ADVANTAGES, LIMITATIONS OF HAND-LINE SAMPLERS; ALTERNATIVES OR CORRECTIONS

- Simple and easy to use sampler
- Use restricted to shallow water in low to medium velocities
- May never be used for deeper water and/or higher velocities by adding fish-weight
- Never use an additional line to refrain the sampler from drifting as this could bring the sampler out of balance
- Rate of filling must be found by experience
- The rather small bottle volume requires to take several samples if the concentration of the suspended load is too small

2.4.3 ESSENTIAL INSTRUCTIONS AND PRECAUTIONS WHILE SAMPLING - FOR ALL HAND-LINE SUSPENDED, STREAMLINED, DEPTH-INTEGRATING SAMPLERS

- The transit rate must be kept constant, the same when lowering as when hoisting
- The lowering and hoisting speed during sampling may not exceed 0.4 times the maximum velocity in the sampling vertical, to be measured before sampling
- The lowering and hoisting speed shall be adjusted to fill the bottle at $\frac{3}{4}$ th of its capacity
- The total volume needed to get a representative catch will determine the number of individual samples to be taken
- Reject all overfilled samples (bottle full)
- Reverse instantly from lowering to hoisting when sampler touches the stream bottom
- When velocities become too large, the drag force on the sampler may become too high and the drifting angle increase too much:
 - If the sampler drift reduces close to the stream bottom because of the lower velocities found there, the sampler may hit the streambed and the sampling may become disturbed
 - The sampler may have to be replaced by a heavier one
- Do not release the hand-line more when the sampler touches the bed, as otherwise the latter would fall aside on the stream bed with the nozzle too close to it, or in the zone of bed load transport

2.4.4 INSTRUCTIONS FOR THE US DHS-48, D-59 OR D-76 SAMPLERS O&M (CHECK LIST, INSTRUCTIONS AND PRECAUTIONS)

Before sampling, check

- Check overall status of the sampler's body for possible damage and replace when needed
- Check the bottle for possible damage and replace when needed
- Check the nozzle for possible damage and replace when needed
- Check the assembly parts (gasket, spring-operated clamp) for possible damage and replace by spare parts if needed
- Place suitable nozzle for the prevailing depth of flow and bottle size
- Check the hanger bar and pin for possible damage or weakness and mount them on the sampler
- Verify that all sample bottles and/or containers are clean and properly labelled

During sampling, instructions and precautions

- Operate the sampler smoothly; lower it quickly to the water surface, avoiding too much swinging of the device
- Keep the lowering and hoisting speed in the water constant, never higher than 0.4 times the maximum velocity and sufficient to fill the bottle at least at $\frac{3}{4}$ th of its capacity
- Reverse instantly from lowering to hoisting when sampler touches the stream bottom

After sampling, instructions and precautions

- Reject the sample if there is any floating debris hanging to the sampler body or nozzle
- The sample must be collected carefully, without spilling any water
- The volume of the collected sample must be measured precisely before rinsing, even if sediment remains in the bottle, to be rinsed later with clean water
- If water or sediment is spilled during its collection, this sample must be rejected and a new sample taken
- The rinsing water with its sediment must be added to the collected sample

2.5 MEDIUM- AND HEAVY-WEIGHT, STREAMLINED, CABLE-SUSPENDED SAMPLER - DEPTH-INTEGRATING (FIXED VOLUME, E.G. US D-74)

2.5.1 GENERAL DESCRIPTION

Several streamlined, cable-suspended, depth-integrating samplers are available on the market for use from a boat, from a bridge or from a cableway. The US D-74 (Figure 2.8) is suitable for many low and medium flow situations. This medium-weight sampler has a cast bronze body, originally designed for use with a round pint milk bottle sample container. The head of the sampler is hinged to permit access to the sample container. Tail vanes orient the instrument into the stream flow. A reel with a 3 mm cable is needed for safe operation. An intake nozzle extends horizontally from the nose of the sampler body. While sampling, the air present in the bottle escapes through a streamlined exhaust mounted on the side of the sampler head. The sampler is quite easy to operate and to maintain. This sampler was tested in India in the early 70's.

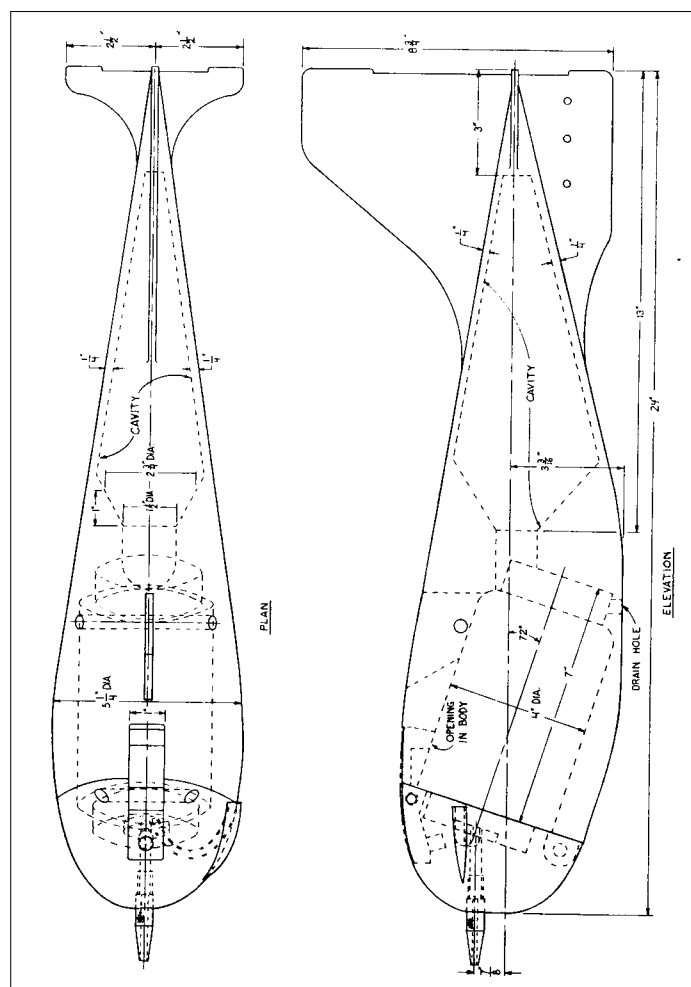


Figure 2.8
US D-74

2.5.2 PRINCIPAL ADVANTAGES, LIMITATIONS OF STREAMLINED SAMPLERS DEPTH-INTEGRATING, ALTERNATIVES OR CORRECTIONS

- Quite simple and easy to use sampler
- Never use for depths and flow velocities higher than given in the specifications
- May never be used for deeper water and/or higher velocities by adding fish-weight
- Never use an additional line to refrain the sampler from drifting as this could bring the sampler out of balance
- Rate of filling must be found by experience
- The rather small bottle volume requires to take several samples if the concentration of the suspended load is too small

2.5.3 ESSENTIAL INSTRUCTIONS AND PRECAUTIONS WHILE SAMPLING - FOR ALL STREAMLINED, DEPTH-INTEGRATING SAMPLERS, CABLE-SUSPENDED

- The transit rate must be kept constant and the same when lowering and hoisting
- The lowering and hoisting speed during sampling may not exceed 0.4 times the maximum velocity in the sampling vertical, to be measured before sampling
- The lowering and hoisting speed shall be adjusted to fill the bottle at $\frac{3}{4}$ th of its capacity
- The total volume needed to get a representative catch will determine the number of individual samples to be taken
- Reject all overfilled samples (bottle full)
- Reverse instantly from lowering to hoisting when sampler touches the stream bottom
- When velocities become too large, the drag force on the sampler may become too high and the drifting angle may increase too much:
 - If the sampler drift reduces close to the stream bottom, because of the lower velocities found there, the sampler may hit the streambed and the sampling may become disturbed
 - The sample may have to be replaced by a heavier one
- Do not release the suspension cable more when the sampler touches the bed, as otherwise the latter would fall aside on the stream bed with the nozzle too close to it, or in the zone of bed load transport

2.5.4 INSTRUCTIONS FOR THE US D-74 SAMPLERS O&M (CHECK LIST, INSTRUCTIONS AND PRECAUTIONS)

Before sampling, check

- Check overall status of the sampler's body for possible damage and replace when needed
- Check the bottle for possible damage and replace when needed
- Check the nozzle for possible damage and replace when needed
- Check the assembly parts (hinged sampler head) for possible damage and replace by spare parts if needed
- Place suitable nozzle for the prevailing depth of flow and bottle size
- Check the hanger bar and pin for possible damage or weakness and mount them on the sampler
- Verify that all sample bottles and/or containers are clean and properly labelled

During sampling, instructions and precautions

- Operate the sampler smoothly; lower it quickly to the water surface, avoiding too much swinging of the device
- Keep constant the lowering and hoisting speed in the water, never higher than 0.4 times the maximum velocity and sufficient to fill the bottle at least at $\frac{3}{4}$ th of its capacity
- Reverse instantly from lowering to hoisting when sampler touches the stream bottom

After sampling, instructions and precautions

- Reject the sample if there is any floating debris hanging to the sampler body or nozzle
- The sample must be collected carefully, without spilling any water
- The volume of the collected sample must be measured precisely before rinsing, even if sediment remains in the bottle, to be rinsed later with clean water
- If water or sediment is spilled during its collection, this sample must be rejected and a new sample taken
- The rinsing water with its sediment must be added to the collected sample

2.6 MEDIUM- AND HEAVY-WEIGHT STREAMLINED, CABLE SUSPENDED SAMPLER - POINT-INTEGRATING (FIXED VOLUME, E.G. US P-50, P-61, P-63)**2.6.1 GENERAL DESCRIPTION**

Several streamlined, cable-suspended, point-integrating samplers are available on the market for use from a survey vessel, from a boat, from a bridge or from a cableway. Operation of these medium- or heavy-weight samplers require special reels with depth indication. Sometimes, depth is measured directly on the cable, but this technique is not adequate because too much unreliable. The 50 kg heavy US P-61 (Figure 2.9(a) and 2.9(b)) is widely considered as a standard suspended sediment sampler; it is suitable for most flow conditions. This medium-weight sampler has a cast bronze body, originally designed for use with a round, pint milk-bottle sample container. The head of the sampler is hinged to permit access to the sample container. Tail vanes orient the instrument into the stream flow. A reel with a 3mm cable is needed for safe operation. An intake nozzle extends horizontally from the nose of the sampler body. A valve mechanism enclosed in the head is electrically activated to start and stop the sampling. The valve-operating switch is located at the observer's station on the vessel, bridge or cableway. While sampling, the air present in the bottle escapes through a streamlined exhaust mounted on the side of the sampler head.

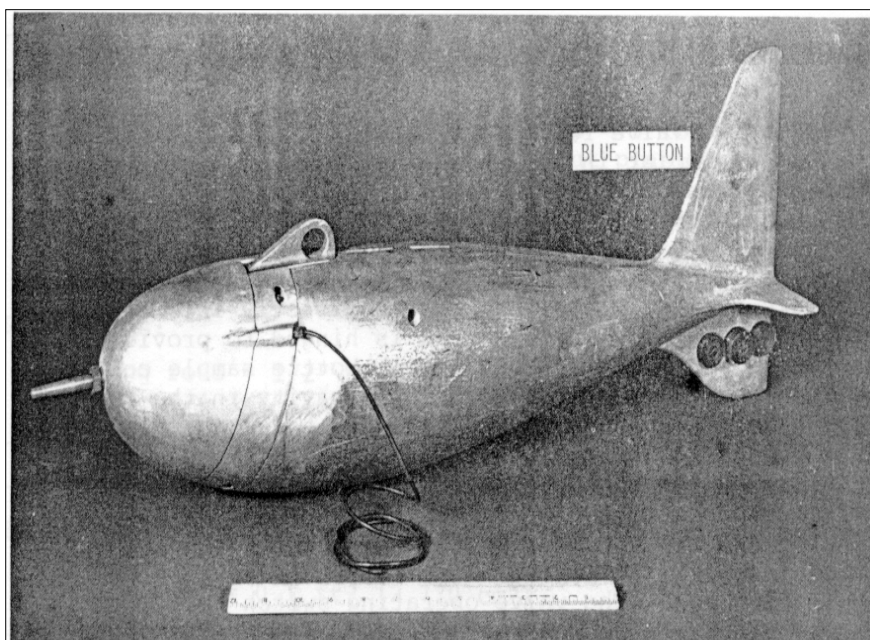


figure 2.9(a)
US P-61

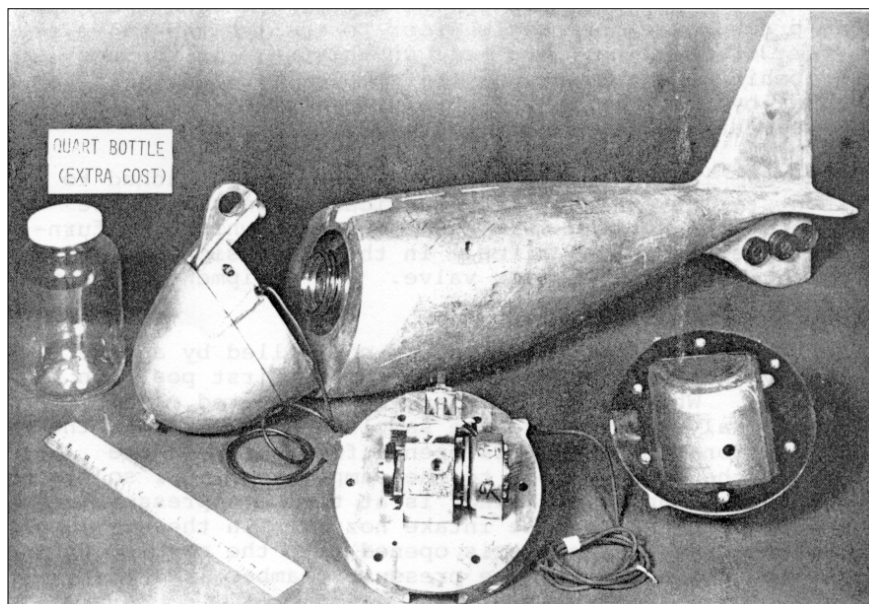


Figure 2.9(a)
US P-61

The sampler is supported by a hanger bar attached to a 3 mm steel two-conductor electrical cable, wound on a reel, mounted on a crane, which protrator point must be high enough above vessel or bridge deck to allow an easy handling of the instrument when removing the sample bottle.

The point-integration samplers may be used to take depth-integrated samples:

- As for the depth-integrating samplers, if the depth is not over 5m with moderate flow velocity (see instructions for the US D-74)
- When the stream is between 5m and 9m and/or has a high velocity ($>2\text{m/s}$), the sampler may be used to depth-integrate in one direction, i.e. from the stream bottom to the water surface, over part of the vertical only

The sampler is quite easy to operate and to maintain. This sampler was tested in India in the early 70's.

2.6.2 PRINCIPAL ADVANTAGES, LIMITATIONS OF STREAMLINED SAMPLERS DEPTH-INTEGRATING, ALTERNATIVES OR CORRECTIONS

- Appropriate sampler for medium size and large size rivers
- Never use for depths and flow velocities higher than given in the specifications
- Never use an additional line to refrain the sampler from drifting as this could bring the sampler out of balance
- Rate of filling is controlled
- The rather small bottle volume requires to take several samples if the concentration of the suspended load is too small

2.6.3 ESSENTIAL INSTRUCTIONS AND PRECAUTIONS WHILE SAMPLING - FOR ALL STREAMLINED, POINT-INTEGRATING SAMPLERS, CABLE-SUSPENDED

At fixed depth

- Lower the sampler to the desired depth using the depth counter on the reel
- While lowering the sample, keep the valve in the equalising and closed position
- At the sampling point, open the valve in the sampling position
- At the end of the experimentally predetermined sampling time, the valve is closed

- Hoist the sampler out of the water
- Remove the sample container

Depth-integrating

- The transit rate must be kept constant and the same when lowering and hoisting
- The lowering and hoisting speed during sampling may not exceed 0.4 times the maximum velocity in the sampling vertical, to be measured before sampling
- The lowering and hoisting speed shall be adjusted to fill the bottle at $\frac{3}{4}$ th of its capacity
- The total volume needed to get a representative catch will determine the number of individual samples to be taken
- Reject all overfilled samples (bottle full)
- When integrating from water surface to bed and again to water surface, the lowering of the sampler must be reversed to hoisting as soon as the stream bottom is touched
- When integrating from stream bottom to water surface only, the sampler must be lowered to the stream bed with closed valve, touching the stream bottom and opening the valve when the sampler leaves the bed for hoisting
- When velocities become too large, the drag force on the sampler may become too strong and the drifting angle increasing too much:
 - If the sampler drift reduces close to the stream bottom because of the lower velocities found there, the sampler may hit the streambed and the sampling may become disturbed
 - The sampler may have to be replaced by a heavier one (e.g. US P-63)
- Do not release the suspension cable more when the sampler touches the bed, as otherwise the latter would fall aside on the stream bed with the nozzle too close to it, or in the zone of bed load transport

2.6.4 INSTRUCTIONS FOR THE US P-61 SAMPLERS O&M (CHECK LIST, INSTRUCTIONS AND PRECAUTIONS)

Before sampling, check

- Check overall status of the sampler's body for possible damage and replace when needed
- Check the bottle for possible damage and replace when needed
- Check the nozzle for possible damage and replace when needed
- Check the assembly parts (hinged sampler head) for possible damage and replace by spare parts if needed
- Place suitable nozzle for the prevailing depth of flow and bottle size
- Check the hanger bar and pin for possible damage or weakness and mount them on the sampler
- Check the functioning of the valve operating mechanism
- Verify that all sample bottles and/or containers are clean and properly labelled

During sampling, instructions and precautions

At fixed depth

- No special instructions

Depth-integrating

- Operate the sampler smoothly; lower it quickly to the water surface, avoiding too much swinging of the device
- Keep constant the lowering and hoisting speed in the water, never higher than 0.4 times the maximum velocity and sufficient to fill the bottle at least at $\frac{3}{4}$ th of its capacity
- Reverse instantly from lowering to hoisting when sampler touches the stream bottom

After sampling, instructions and precautions

- Reject the sample if there is any floating debris hanging to the sampler body or nozzle
- The sample must be collected carefully, without spilling any water
- The volume of the collected sample must be measured precisely before rinsing, even if sediment remains in the bottle, to be rinsed later with clean water
- If water or sediment is spilled during its collection, this sample must be rejected and a new sample taken
- The rinsing water with its sediment must be added to the collected sample

3 BED MATERIAL

3.1 INTRODUCTION

Bed material sampling in India needs to be improved for collecting representative and meaningful data, mainly in rivers having a heterogeneous bed composition, variable in space and time, also in nature and particle size. In many sites, the simplest devices may continue to be utilised. More sophisticated samplers and sampling procedures may be recommended or even required in other places. Not all bed material samplers or sampling procedures are presented in the manual; only those presently in use in India and those recommendable for future use are presented and discussed.

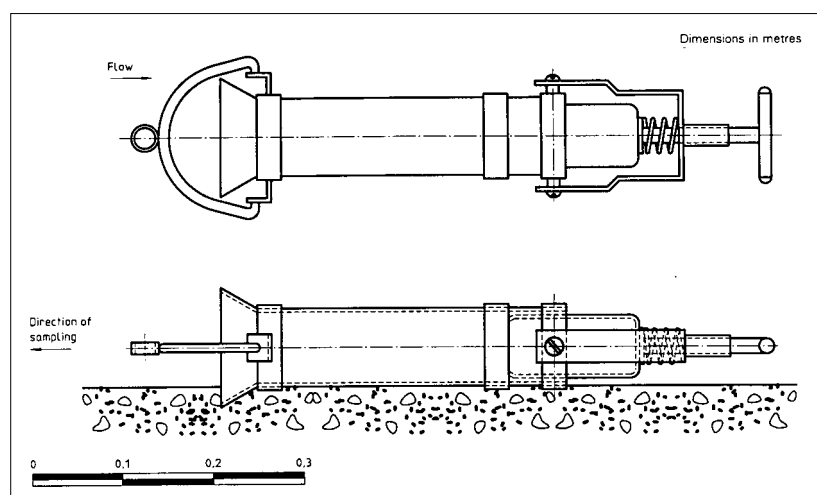
3.2 DREDGE-TYPE OR DRAG BUCKET-TYPE

3.2.1 GENERAL DESCRIPTION

The dredge-type or drag-bucket type samplers (Figure 3.1), as described in the ISO/DIS 4364 are composed of a weighed bucket or cylinder with a flared cutting edge at one end and a sample collecting receptacle at the other. A drag rope is attached to a pivoting bridle towards the cutting end of the cylinder.

3.2.2 OPERATION, PRINCIPAL ADVANTAGES AND LIMITATIONS; ALTERNATIVES OR CORRECTIONS

It is a very simple, easy-to-use device, but liable to be affected by washing out of the material. It requires a movement of the dredge relatively to the bottom, what makes it difficult to apply from a bridge or cableway. Sampling while wading does not make any problem.



*Figure 3.1
Drag bucket sampler*

When operated from a boat in flowing water, the traditional way to use it is to have the device lowered to the bed and dragged along it when sailing slowly in upstream direction. With this procedure, the boat must sail at high speed if the flow is too strong. The sampler will be dragged away by the current. This may be partially prevented by attaching a streamlined weight to the rope, just above the sampler. However, if the weight touches the bed in front of the sampler, this may result in stirring up the bed material and in a more disturbed sample. With this procedure, the high turbulence of the flow around the mouth of the sampler makes that the sample is very much disturbed.

Another procedure consists sampling while drifting. The boatsman sails into the current up to a point upstream of the sampling station. He then let the vessel drift with the current while the sampler is lowered to the bed, without any drift. When the sampler touches the bottom, some more line is released before holding and dredging the sampler over the bed. If dredging is performed while letting escape the line with a speed slightly less than the flow velocity, the relative speed of the sampler to the bed will be small and the flow comes from the back of the sampler. The dredge will take thus the sample with little disturbance. This procedure can only be applied with well-trained operators.

A practical drag-or bucket-dredge is composed of two parts, with lower part of the cylinder being a removable contained. When correctly operated, the sample in the contained is almost undisturbed.

3.2.3 ESSENTIAL INSTRUCTIONS AND PRECAUTIONS FOR OPERATION

Before sampling

- Verify if the sample collecting receptacle is tightly fitted on the bucket or cylinder
- Verify if the bridle is freely pivoting
- Check if the velocities are below 2.5 m/s for safe operation; if not, delay the sampling or use another more appropriate sampler

While sampling from the boat (recommended method)

- Starting from the predefined sampling station, sail upstream of it along a flow line
- Stop the engines at a point distant by at least three times the water depth (more in case of strong currents)
- Reverse the engines as the stop the boat and let it drift with the flow towards the sampling position
- When the sampling position is reached, let the sampler drop rapidly to the stream bottom
- Slacken the cable by several metres when the stream bottom is reached
- Hold the rope so that the sampler is dragged over the bed for sampling
- Manoeuvre the boat upstream to stop the dredging and pull the sampler out of the water
- Keep the sampler well vertical while handling before removing the sample

After sampling

- Remove the sample-collecting receptacle from the sampler bucket above a clean recipient
- Empty the receptacle with a spoon-shaped device, possibly rinsing the remaining particles with clean water
- Drain carefully the water from the sample, avoiding loss of fines
- If needed, reduce the sample to the required quantity by the cone and quartering technique
- Collect the sample in a polyethylene bag
- Place the polyethylene bag in thick and resistant cloth bags and label it
- Store the sample to be sent to the laboratory for analysis

3.3 GRAB SAMPLER, 90° CLOSURE

3.3.1 GENERAL DESCRIPTION

The 90° closure grab sampler is probably the most used bed sampler (see Figure 3.2). The Van Veen and the Peterson grab samplers are well known, the latter manufactured by the CW&PRS in Pune. Two quarter-cylinder buckets are hinged to each other and kept in open position by means of a hook. When closed, the two buckets form a semi-cylinder in which the sample is held. Arms are attached to each bucket, with pulleys at their end, through which a looped rope or cable is passed and attached to a rope or cable line. The latching system holds the bucket open until the grab reaches the stream bottom. The slackening of the grab rope releases the latch. The sample is retrieved by tightening the rope before pulling it to the water surface.

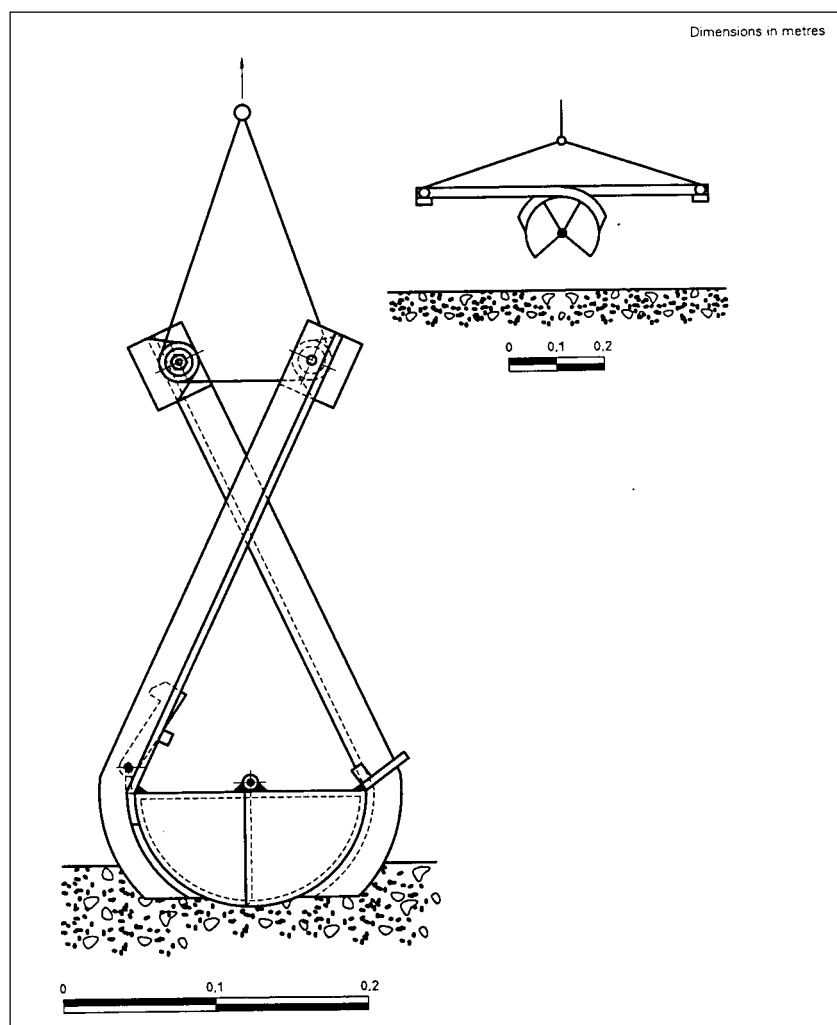


Figure 3.2
Grab-bucket sampler, 90°
closure

3.3.2 OPERATION, PRINCIPAL ADVANTAGES AND LIMITATIONS; ALTERNATIVES OR CORRECTIONS

- The device is usually operated from a boat. It is lowered to the bed, latched open. When the sampler reaches the stream bottom, the cable or rope is slackened momentarily, then pulled to close the sampler. It is then further pulled out of the water and retrieved.
- In low flow velocities, the boat is maintained stationary, either with the engines or anchored. In somewhat higher flow velocities, the boatman may leave the vessel drift, possibly limiting the drift with the engines. It is not suited for operation in strong currents.
- The 90° grab sampler can be operated from a bridge when the flow velocities are low.

- The main advantage of the device is its elementary design, making it easy to manufacture; its operation and maintenance are also very simple. The catch is usually large, giving a representative sample for the station.
- The major disadvantage is the high risk to have the sample washed out, losing mainly the fines. This is due to the closing mechanism, as the two jaws, in the lowest position, may be prevented from joining tightly by some coarser particles.
- The sampler is not operating or difficult to use in water velocities above 1 m/s.

3.3.3 ESSENTIAL INSTRUCTIONS AND PRECAUTIONS FOR OPERATION

Before sampling

- Verify if the jaws are perfectly joining when sample is in closed position
- Do not operate the sampler if there is any damage at the cutting edge of the jaws
- Check physically the closure mechanism: loop rope or -cable, pulleys, suspension rope/cable, latching system
- Check if the velocities are below 1 m/s for safe operation; if not, delay the sampling or use another more appropriate sampler

While sampling

- Lower the sampler quite rapidly but smoothly to the stream bottom
- Slacken somewhat the cable when the stream bottom is reached
- Pull the suspension rope/cable for sampling
- Pull quickly but steadily the grab sampler out of the water and keep it well closed while handling before removing the sample
- Check if the sampler jaws are tightly closed
- Reject the sample if sediment escapes from the jaws

From a boat

- Keep the boat stationary with the engines if the velocities are small
- Let the boat drift slightly in medium velocities, below 1 m/s

From a bridge

- Do not allow the sampler to swing in the air while lowering and hoisting
- Do not sample from a bridge if the flow velocity exceeds 1 m/s

After sampling

- Keep a constant pull at the handling rope as to keep the sampler's jaws tightly closed
- Open the sampler above a clean recipient
- Reduce to the required quantity by the cone and quartering technique
- Collect the sample in a polyethylene bag
- Place the polyethylene bag in thick and resistant cloth bags and label it
- Store the sample to be sent to the laboratory for analysis

3.4 GRAB SAMPLER, 180° CLOSURE

3.4.1 GENERAL DESCRIPTION

The 180° closure grab sampler is a widely used bed sampler. The US BM-54 sampler (Figure 3.3) is well known and manufacturing started in India. A semi-cylindrical bucket is housed within a 45 kg

streamlined, cast-iron fish-weight with tail fins. The bucket rotates from a position totally inside the fish till it surrounds and encloses the sample in such a way that it is not washed out when the device is raised to and out of the water surface. The sample is collected from the top 5 cm of the streambed. When suspended at the steel cable, the bucket may be cocked by means of a wrench - i.e. set in open position – for taking the bed sediment. The bucket is freed and snap-shuts when the tension on the cable is released. The shutting mechanism is operated by a spring which tension can be adjusted so that the bucket can scoop the bed material.

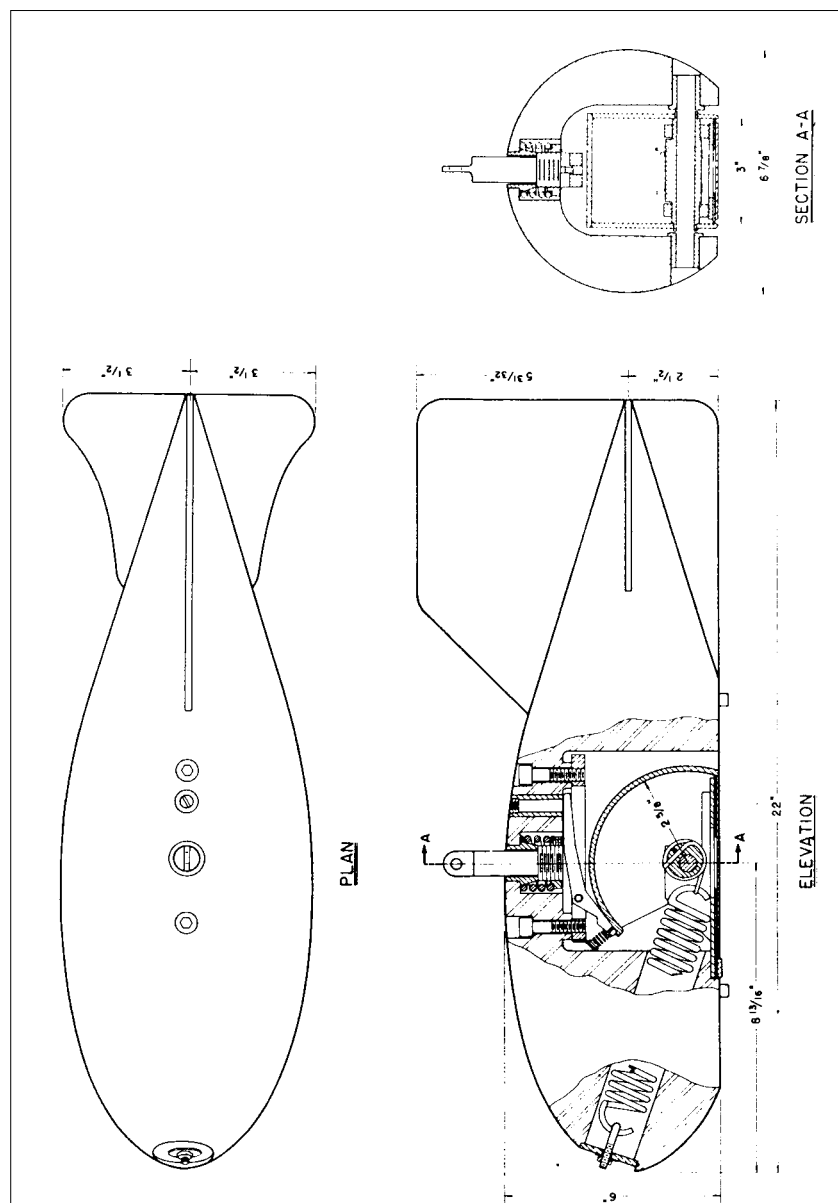


Figure 3.3
Bed-material sampler US
BM-54

Besides the US BM-54, other US makes are available for different working conditions.

3.4.2 OPERATION, PRINCIPAL ADVANTAGES AND LIMITATIONS; ALTERNATIVES OR CORRECTIONS

The device can be operated from a boat, from a bridge and eventually from a cableway. It is suited for use in flow velocities up to 2.5 or 3 m/s. The sampler is lowered to the stream bottom in open position and the catch is taken when the suspension steel cable is slackened momentarily. The sampler is then hoisted out of the water and the sample retrieved.

When operated from a boat, this must be maintained stationary, either with the engines or anchored. Drifting of the vessel is not allowed, as it would not be possible to control if the sampler would land correctly on the bed.

The main advantages of the device are:

- secure operation, even in relatively strong currents
- sample quite undisturbed and not washed out when sampler is properly closed
- bucket penetrates in all kind of bed material, except in rocks and when sediment contains large pebbles or cobbles
- the strength of the spring can be adjusted to penetrate to all kind of bed material

The disadvantages are:

- bucket may close by accident during handling and hurt the operator
- heavy equipment, necessitating heavy handling equipment
- rather small catch

The sampler is not easy to manufacture, especially the mechanism operating the closure of the bucket, as only drawings are available but no details such as spring characteristics.

3.4.3 ESSENTIAL INSTRUCTIONS AND PRECAUTIONS FOR OPERATION FOR US BM-54

Before sampling

- Verify if the bucket jaw's edge is not damaged and replace it eventually
- Check physically the closure mechanism: free rotation of the bucket, spring, spring loaded cocking device, suspension rope/cable

While sampling

- Lower the sampler quite rapidly but smoothly to the stream bottom
- Slacken somewhat the cable when the stream bottom is reached
- Pull the grab sampler out of the water and keep it well closed while handling before removing the sample

From a boat

- Keep the boat stationary preferably with anchoring
- Keep the boat stationary with the engines only if anchoring is absolutely not possible
- Never let the boat drift

From a bridge

- No special instructions

After sampling

- Keep the bucket perfectly horizontal when releasing it from the sampler
- Reject the sample if sediment surface looks disturbed
- Empty the sampler above a clean recipient
- Collect the entire sample in a polyethylene bag
- Place the polyethylene bag in thick and resistant cloth bags and label it
- Store the sample to be sent to the laboratory for analysis

3.5 PISTON-TYPE BED MATERIAL HAND-HELD CORE SAMPLER

3.5.1 GENERAL DESCRIPTION

In shallow, wadable channels, the piston-type sampler is an easy-to-handle and appropriate instrument for all kind of bed material, except very coarse sand and gravel. It operates on the vacuum principle to retain the sample in the core.

The sampler is composed of a cylinder equipped with a piston. The operator presses the cylinder into the stream bed with the handle while retaining the piston by the other handle. The suction created by the piston keeps the sample in the cylinder. The sampler is pushed out of the cylinder by the piston.

Several makes are available on the market. The corer is easy to manufacture. The US BMH-53 (Figure 3.4) is a very popular and can be taken as prototype for use in India.

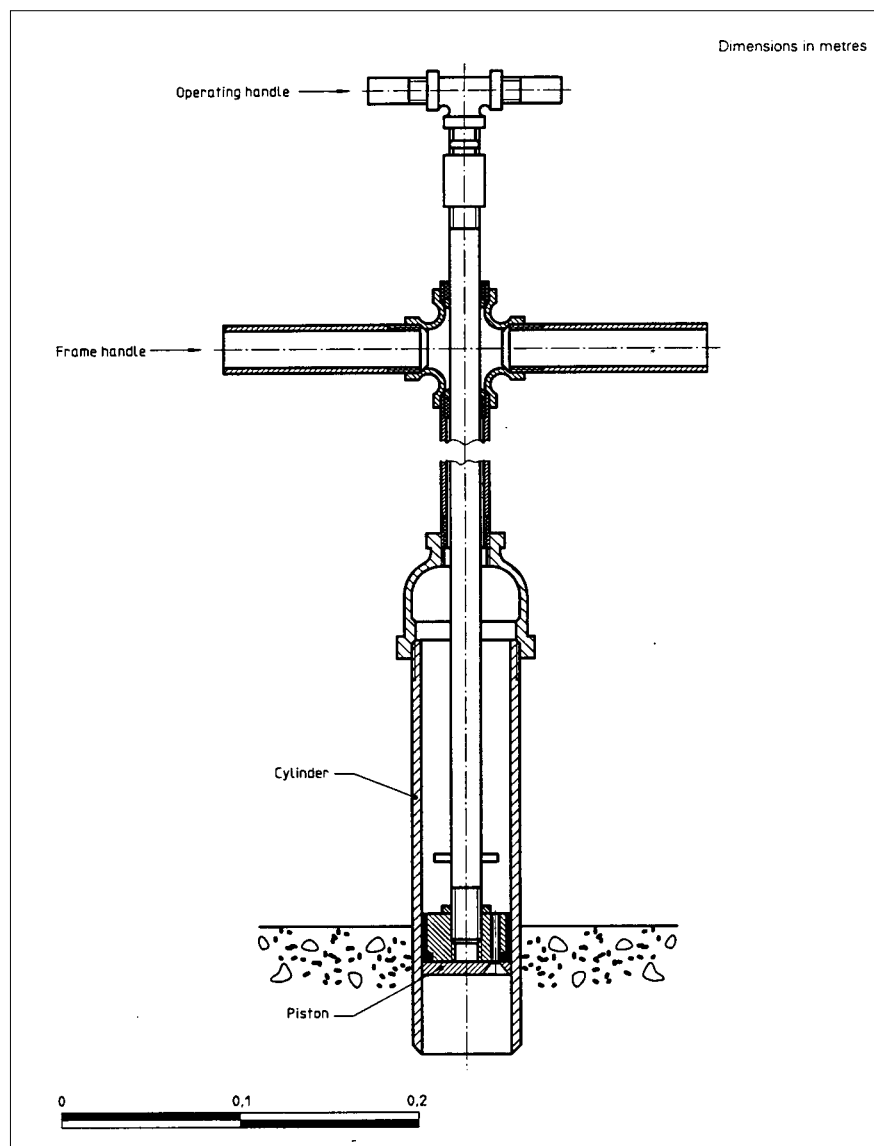


Figure 3.4
Piston-type bed-material
hand sampler, US BMH-
53

3.5.2 OPERATION, PRINCIPAL ADVANTAGES AND LIMITATIONS; ALTERNATIVES OR CORRECTIONS

The operation of the sampler is very simple. A few elementary precautions must be taken into account, such as to bring the piston in low position before starting the sampling.

One major advantage of corers is to have a sample over a certain depth, while other samplers like the 180° closure grab samplers take only material from the bed surface. In the lean season, this is quite important as the coarser active river bed material of the monsoon season may be covered with a layer of finer suspended load that settles during the falling phase of the flood.

The core sampler can be used for very fine material, such as clay or even mud, as long as the soil's relative density exceeds 1.3. Sampling becomes problematic for coarse sand and gravel. The sample is more or less disturbed, more in very soft and in very coarse bed material, less in fine to medium size sands; it will also be less disturbed if the sample is better graded.

3.5.3 ESSENTIAL INSTRUCTIONS AND PRECAUTIONS FOR OPERATION FOR US BMH-53

Before sampling

- Verify if the corer's cutting edge is not damaged and replace eventually the corer cylinder
- Check physically the piston mechanism

While sampling

- Keep the corer well vertical during the entire sampling
- Push the corer smoothly into the stream bottom while keeping the piston handle at constant level
- Pull the corer out of the stream bed and preferably obstruct the lower end while handling before removing the sample

After sampling

- Remove the sample by pushing the piston out of the corer, horizontally on a flat and clean surface
- Collect the entire sample in a polyethylene bag
- If layers are visible, they may be divided and collected in separate bags
- Place the polyethylene bag in thick and resistant cloth bags and label it
- Store the sample to be sent to the laboratory for analysis

4 SEDIMENT ANALYSIS

4.1 INTRODUCTION

The sediment analysis methods, techniques and instruments in use in India are described in the technical literature:

- Analysis using sieves and a hydrometer for C, M and F fractions
- Dry sieving for the medium and coarse fractions
- Bottom-withdrawal tube

Reference is made to IS: 6339-1971 for a description of "Methods of analysis of concentration, particle size distribution and specific gravity of sediment in streams and canals".

For bed material, the complete sediment size distribution is determined, while for suspended load, only the percentage of coarse, medium and fine grades are measured.

The sediment size information is quite limited for the transported material as the volume of the catch is usually very small. It would therefore be advised to introduce new methods for particle size determination.

The choice of the method and equipment needed for determining sediment particle size distributions would depend on:

- The kind in information requested (what do we want to know?, for what purpose?)
- The skills of the personnel in the laboratory
- The need for particle size analysis of the complete sample, or only of part of it (e.g. do we need the size distribution of the sand/silt/clay fractions?)
- The number of samples to be analysed per day
- The sample volumes
- The kind of “size” needed

When dealing with suspended- and bed-load, data may be required for various purposes, among which sediment transport computations. In this case, more detailed information is needed, such as:

- Complete size distribution
- Particle's densities
- Particle's shapes or angularities
- Particle's fall velocities

The sediment size methods are based on the determination of one or several characteristic dimensions or properties of a given sediment particle:

- The sieve measures a particle length
- The settling tubes or sedimentation balances measure a particle settling velocity
- The Coulter-Counter (originally a blood cell counter) measures a particle volume
- Some light extinction methods measure particle surfaces etc.

When the sample catch is small and when the particle sizes range between 0.62mm and 2mm, the visual-accumulation-tube size analyser, such as the US VATSA-58 is a recommendable instrument. It has even been used for sediment fractions down to 0.025mm.

4.2 ROUTINE ANALYSIS FOR COARSE, MEDIUM AND FINE FRACTIONS

4.2.1 ANALYSIS FOR ESTIMATION OF COARSE AND MEDIUM GRADE FRACTIONS

From the samples of water and sediment mixture collected in the enamelled buckets normally about 5 litres, the same is allowed to settle for about a minute. The supernatant water is carefully decanted off. The residue is passed into a numbered beaker for further analysis of coarse and medium fractions of sediment

Each sample in the beaker is then passed through a IS – 212 micron sieve placed over a beaker marked upto 10 cm height. The sediment retained by the sieve is washed thoroughly with a jet of clean water till all the coarse grade particles are separated and particles of medium and fine-grained size have passed through, into the beaker. The particles retained by the sieve after washing and removing organic matter is transferred to silt measuring tubes. Its volume in cubic centimetres (cc) is noted after tapping on a rubber pad. This can later be expressed as cubic centimetres per litre.

The sediment and water passing IS – 212-micron sieve collected in the beaker is made up upto 10-cm height. The mixture is stirred in 8 – wise direction for a few seconds and allowed to stand for the required interval of time given in table below, according to the temperature of water in the beaker.

Time taken for particles above 0.075 mm to fall through 10 cm column of water at different temperature:

| Water temp. in ° Celsius | Time of fall for particles of 0.075 mm to fall 10 cm in seconds |
|--------------------------|---|
| 5 | 31 |
| 6 - 10 | 28.5 |
| 11 - 15 | 25 |
| 16 - 20 | 22 |
| 21 - 25 | 20 |
| 26 – 30 | 18 |
| 31 - 35 | 16.5 |

Table 4.1: Time taken for particles above 0.075 mm to fall through 10 cm column of water at different temperature

The supernatant water is poured off. This process of separation of medium grade sediment by decantation of supernatant liquid, followed by filling the beaker upto the marked height is repeated, till the supernatant water is rendered clear. The medium grade sediment settled in beaker after the final washing and decantation process is transferred to a measuring tube and the volume is measured in cc as in the earlier case. The material is also washed down on to a pre-weighed filter paper, initially drained of all water, and then subjected to drying in an oven. It is allowed to cool in a dessicator and then weighed along with the collected dried sediment for obtaining its weight. This gives the concentration of medium fraction in gms per litre.

The concentrations together with the observed water level and discharge are put in the “Record of suspended sediment summary data”, see Annex III.

4.2.2 ESTIMATION OF FINE-GRAINED FRACTION OF SEDIMENT BY HYDROMETER METHOD

The fine grained sediment fraction can be estimated with the help of a sensitive calibrated hydrometer, see Figure 4.1. A hydrometer calibrated initially in distilled water is to be used. The hydrometer is to be placed for about five minutes in a separate sample of sediment and water to allow it to attain the water temperature. This helps also to eliminate effect of temperature change due to sudden placing of the hydrometer. The hydrometer is then taken out of the sample water. The water is stirred vigorously to put the sediment entirely into suspension and later poured into a double jacket metallic cylinder. The hydrometer is then immersed into the water in the cylinder and stopwatch started simultaneously. The level of immersion of the hydrometer in the cylinder is read after lapse of time intervals given in table below, depending on water temperature in the cylinder.

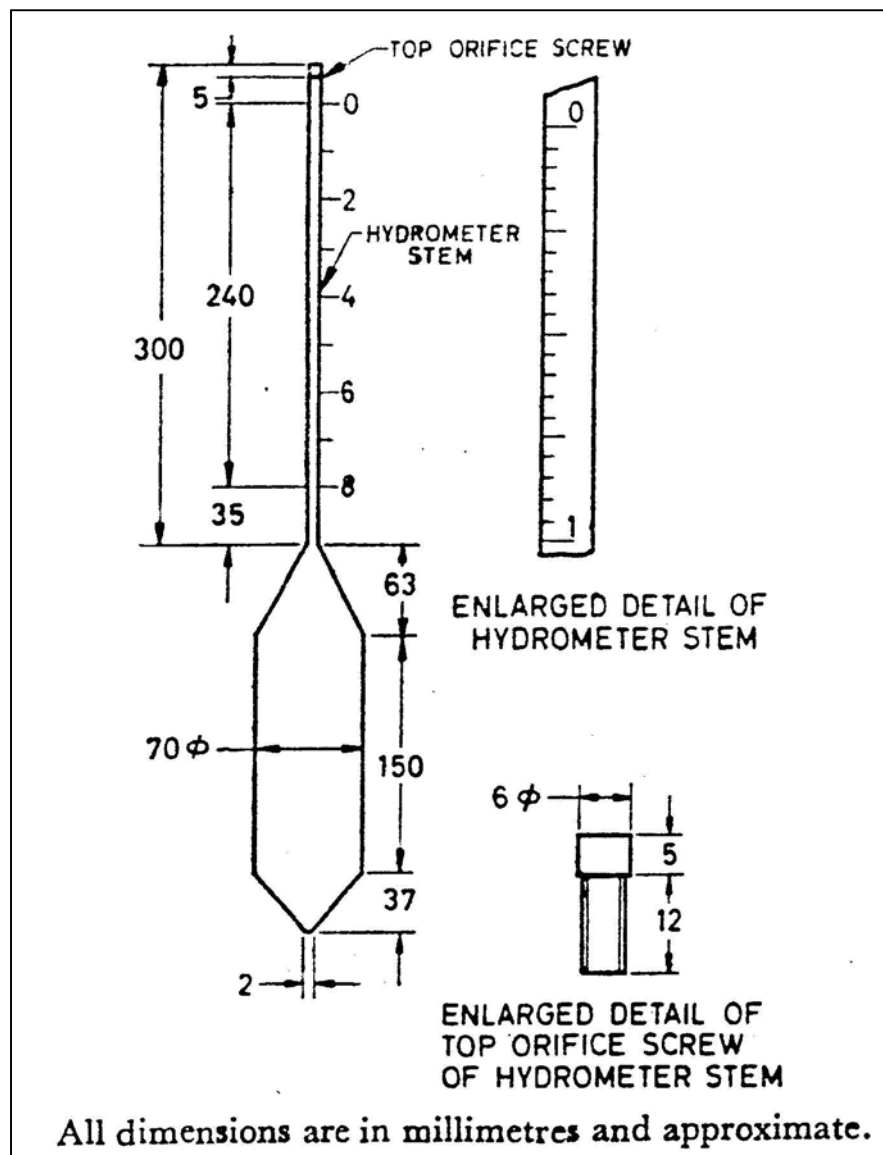


Figure 4.1: Hydrometer

A time interval after which hydrometer is to be read for estimating fine sediment, versus water temperatures:

| Water temperature ° Celsius | Time interval in seconds after which hydrometer to be read |
|-----------------------------|--|
| 5 | 105 |
| 6 – 10 | 100 |
| 11 – 15 | 87 |
| 16 – 20 | 77 |
| 21 – 25 | 70 |
| 26 – 30 | 63 |
| 31 – 35 | 58 |

Table 4.2: A time interval after which hydrometer is to be read

The point upto which the hydrometer is immersed can be used to derive the concentration of fine grained material and dissolved material in gms per litre as given below:

$$F + D = (R^1 - R) K$$

where: F = Concentration of fine sediment in gms per litre

D = Concentration of dissolved material in gms per litre

R¹ = Hydrometer reading taken in the cylinder water as described

R = Hydrometer reading in distilled water at the same temperature

K = Factor for the hydrometer for converting to value in gms per litre

Next filter the water containing the sediment through filter paper and take readings of hydrometer in filtered river water for obtaining the concentration of dissolved material as below:

Thus: $D = (r^1 - r) K$

Where: r¹ = Hydrometer reading for the filtered water

r = Hydrometer reading in distilled water

For arriving at value of F = (F+D) – D is to be evaluated in gms per litre

Precautions

1. The water sample should be at room temperature
2. The hydrometer should be kept immersed in the water sample for about 5 minutes so that it attains the water temperature.
3. The water sample should be thoroughly stirred before pouring into the jacket cylinder
4. No air bubbles should be sticking to the hydrometer stem and hydrometer should not touch the cylinder sides

4.3 THE VISUAL-ACCUMULATION-TUBE SIZE ANALYSER (VAT-SA)

4.3.1 INTRODUCTION

The visual-accumulation-tube sediment-size-analyser is widely used in the USA, but not well known in Europe in particular or in other countries all over the world. It is a very reliable instrument, well suited for particle size determination of fluvial sediment. It is sometimes confused with a simpler sedimentation tube device.

The VAT-SA (Figure 4.2) consists of a vertical transparent tube - usually glass, may be perspex - through which the sediment sample is settling. The tubes are of several lengths (1.2m and 1.8m) and diameters. At the lower end, the diameter reduces through a conical funnel down to a cylinder with various sizes (inside diameter of 2.1, 3.4, 5.0 or 7.0 mm).

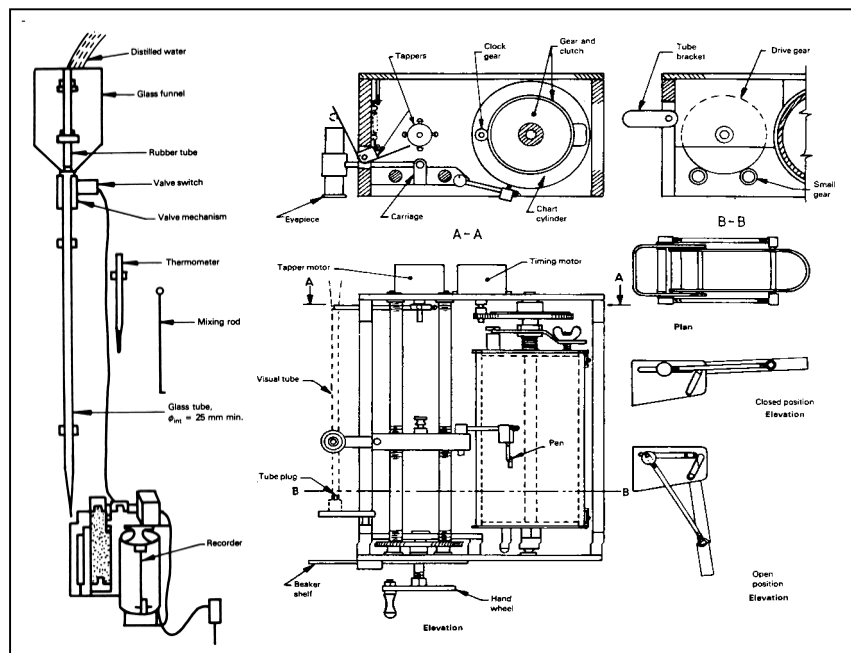


Figure 4.2: Visual-Accumulation-Tube size analyser US VATSA-58

The measurement principle is based on two hypotheses:

- Having little interaction with the surrounding particles, the individual particles settle with a terminal fall velocity, that can be related to an equivalent particle diameter through a simple formula
- The volume of particles settled in the lower and narrow end of the tube is considered to be linearly related to the weight of accumulated solids

This makes it best suited for uniform, sphere-shaped particles with uniform density.

The device is mainly used for determination of the particle sizes or fall velocity's distribution of sand composed of mainly quartz with a shape close to a sphere, what is quite acceptable in most sand-bed rivers.

The analysis is made by introducing the sample - which volume is usually very small, only a few cc's - in a glass funnel on top of the tube and recording the height of the accumulated sediment on the bottom of the tube. The top glass funnel is connected to the settling tube by a closure rubber funnel/tube with same diameter, equipped with a valve mechanism. The accumulation of the settled sediment is recorded versus time on a chart recorder.

In the hypothesis that the particles are all spherical, the measure of the bed height is linearly proportional to the accumulated sediment volume. This is based on the mathematical law of the sphere, that says that the total volume of spheres with a given diameter contained in a recipient is independent of the diameter of the spheres.

For small size particles, compaction of the settled layer will vary with time. Therefore, a special tapping device is used to have the sediment particles well compacted as soon as they have settled.

The VATSA-58 can be purchased in the USA, but it can easily be manufactured locally, making it possibly more appropriate for use in India.

4.3.2 OPERATION, PRINCIPAL ADVANTAGES AND LIMITATIONS; ALTERNATIVES OR CORRECTIONS

The sample is first wet-sieved to remove the sizes coarser than 2 mm and finer than 0.062 mm. An experienced operator may use the VAT-SA for a wider range of sediment particles, between 3 mm and 0.025 mm. The fraction coarser than 2 mm may be further sieved if sufficient sample volume is available. For small volumes, optical particle counting under a microscope may be feasible. If needed, the size distribution of the fraction finer than 0.62 mm may be determined with other methods such as sedimentation balance or Adreassen pipettes. This is however not necessary if the finer fraction is less than 20 % of the total.

Volumes as little as 1 cc can be analysed in the VAT-SA. This may be suited for the very small suspended sediment catches. For analysing bed load or bed material samples, cone and quartering technique should be applied to reduce the amount of sample to the optimum volume required for the sediment size analysis. Too much is not good as the fall velocities will not be the terminal ones (particles influencing each other), while too small a volume may not be representative.

A major advantage is the speed by which a size analysis can be performed with the VATSA: about 6 minutes only are required for a skilled VAT-SA operator.

A limitation of the VAT-SA is due to possible heterogeneous composition of the sample. When rounded quartz particles and mica flakes happen to occur in the same range of settling velocities, then the ratio height/volume of the accumulated deposit is not anymore linearly related. Best is to take a large and representative sample in a given gauging site and to split it into size fractions by sieving. Each fraction may be sieved and measured separately in the VATSA to establish the experimental height/volume relationship, instead of using the theoretical one delivered with the instrument or by formulas.

The settling velocities are function of temperature. Therefore, the temperature must be measured at each size analysis. The temperature of the water in the VATSA should be kept as constant as possible. The tube must not necessarily be emptied entirely after each analysis, if finer fraction is removed prior to it. Water from a container kept in the same room may be used to refill the tube as this water would have almost the same temperature.

4.3.3 ESSENTIAL INSTRUCTIONS AND PRECAUTIONS FOR OPERATION OF THE VAT-SA

Before operation of the analyser

- Prepare the sample by removing the size fractions >2mm and <0.062mm
- Place the sample in a clean bucket with clean water
- Chose the suited tube length and diameter on the basis of the sample volume and apparent particle size
- Check if the tube is perfectly clean and fix it in the tube holder
- Check the functioning of the tapping device
- Verify the functioning of the valve mechanism and the status of the rubber tube, especially to check whether there are no particles left from a previous analysis
- Place a new paper on the recorder after having filled all data related to the analysis
- Stir the sample in the bucket and pour it as a suspension in the funnel

- Keep stirring in the funnel till opening the valve

During operation of the analyser

- Start the analysis by opening the valve, initiating the registration of the settling height
- Watch carefully the first particles reaching the bed and start the registration by following precisely the elevation of the deposit
- While operating, check the functioning of the tapping device
- The analysis is ended after a time corresponding to the settling of the slowest particle (about 0.062 mm), taking into account the possibility of lower settling velocity due to flat-shaped particles; this time depends on the length of the tube and should preferably be determined experimentally

After the analysis

- Remove the recording paper and note all necessary and useful information
- Close the valve
- Place a clean bucket under the tube and remove the tap so that the sediment sample is recovered from the tube, but without emptying it entirely (most of the water would be retained in the tube due to suction, if upper valve is well closed)
- Replace the tap and open the valve
- Store the sample if required, possibly for repeated size determination
- Enter a long, clean stick in the tube and stir to detach particles that might remain attached to tube, funnel and upper sample container
- Let the detached sediment settle and repeat the operation
- Refill the tube with clean water, preferably from a tank stored in the same room in the laboratory, having the same temperature
- Having closed the valve, the instrument is ready for a new analysis

4.4 SILTOMETER

The siltometer according to Puri works on the principle of different settling velocities of particles in a column of water. Puri's siltometer method determines directly the rate of accumulation of the material by measuring the deposited sediment at the bottom of the tube. In the operation of the siltometer assumptions are made that the particles to be measured are evenly distributed at the start of the test and they have the same relative density. Furthermore, there is the implicit assumption that the fall velocity of each particle is independent of the others, a condition which is considered applicable if the concentration of the particles is not high (say up to 2 percent, although up to 5 percent such methods may be used). The particles of the different sizes fall through the column of water at different velocities. The size distribution of the particles varies throughout the suspension and the concentration decreases as the sedimentation continues.

Puri's siltometer is a rugged instrument and is widely used. Sediment in suspension should be allowed to settle for a time sufficient to allow all particles over a certain selected size to fall to the bottom of the long column of water and the different fractions should be collected in separate bores that move into position under the column of water at predetermined intervals of time. Figure 4.3 shows the essential features of the siltometer, which consists of the following four main parts:

- 1) **Sedimentation tube.** It is made of brass tubing, about a 6 cm inside diameter, 200 cm long. It is attached to lever B so that, by actuating this lever, the entire tube may be raised to a distance of about 1cm.
- 2) **Sediment dropping device.** The device is made of two funnels and is used to introduce the sediment under water. The funnels fit tightly together allowing the sediment to be introduced without entering the sedimentation tube straightaway. At the desired time, the inside funnel is lifted and the sediment enters the main tube.

- 3) **Sediment collecting device.** This device consists of a circular aluminum trough C, divided around its circumference into twenty individual pockets. The apparatus is so constructed that this collection trough may be moved $1/20^{\text{th}}$ of its circumference by operating a lever manually at any desired time.
- 4) **Silt measuring tube or container D.** It has a slender, graduated stem, used when a volumetric measurement of the sediment collected in each pocket is desired.

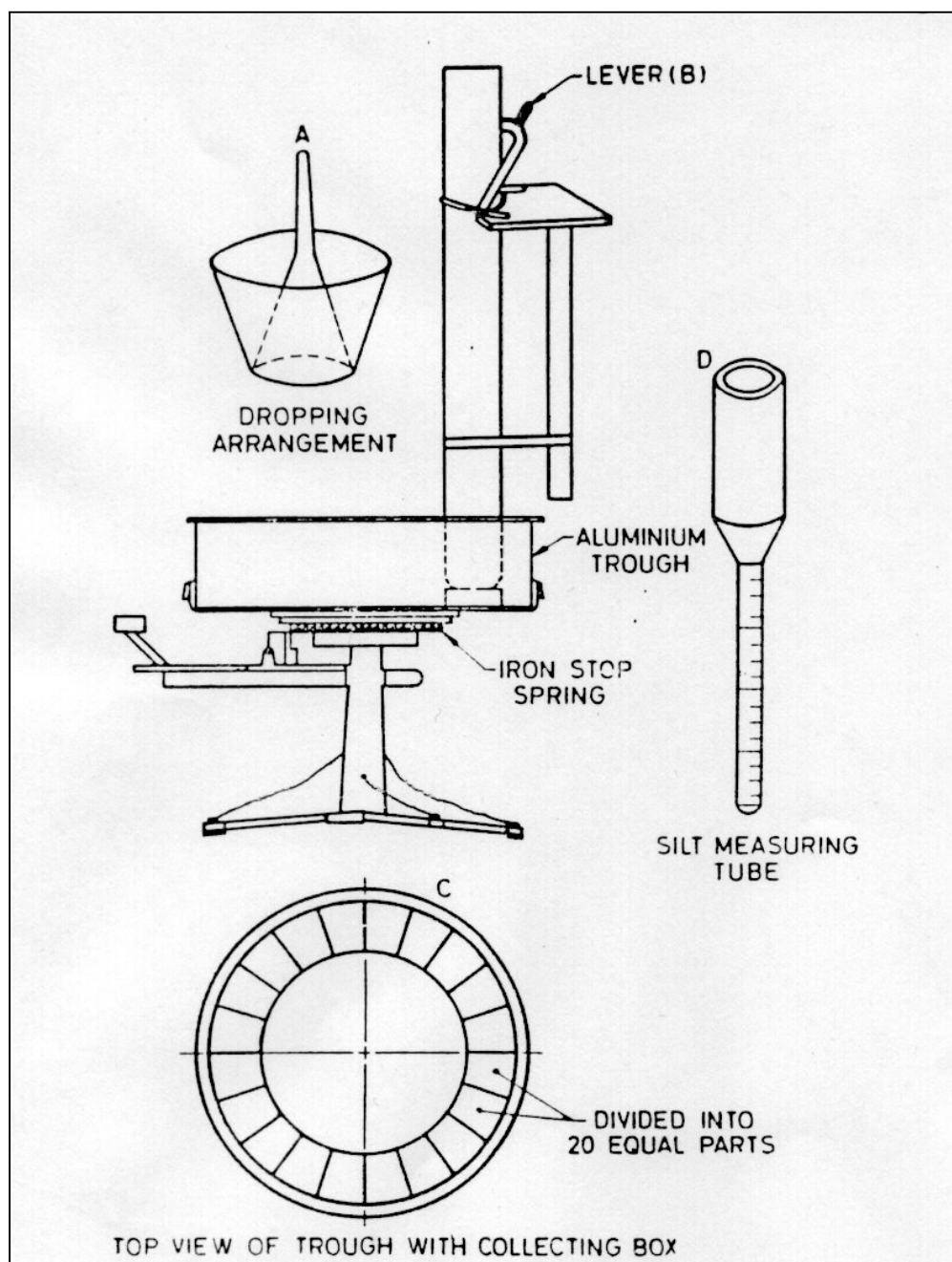


Figure 4.3: Essential features of Siltometer

The procedure in conducting an analysis by Puri's siltometer is as follows:

- The circular trough is filled with water to a depth of 10 cm. A rubber stopper is placed in the pocket immediately below the sedimentation tube (this should be pocket 20) and the tube is lowered by lever B, so that the stopper fits tightly in the end of the tube. The sedimentation tube is then filled with water and the inner funnel is then inserted snugly.

- The temperature of water in the tube should be measured. A sample of about 10 g of sediment is placed in the dropping device and covered with water. The actual separation into fractions by size may now be made. The inverted funnel is removed quickly and a stop-watch is started simultaneously. The remaining funnel section is removed as rapidly as possible and a rubber stopper inserted tightly into the top of the sedimentation tube. As soon as the rubber stopper is inserted tightly into the top of the sedimentation tube and the tube is raised by actuating the lever B, the trough should immediately be rotated with the help of lever so that the next pocket, that is, No. 1 may come below the tube to collect the sediment. The sedimentation into this first cup is allowed to continue until a period of 26 s has elapsed, by this time the trough is rotated one division, placing the second cup in position. Rotation of the trough continues at 4 s intervals up to 66 s, then at 10 s intervals up to 106 s and then after 136, 166, 196, 376 and 556 s. When the separation has been completed, which takes less than 10 min, the material in each compartment is filtered, dried and weighed.

This technique is suitable only for sediments with particle sizes between about 0.6 and 0.06 mm.

Table 4.3 gives the deduced diameter of sediment particles settling through a vertical water column of 200 cm length in various times and at different temperatures

| Temp °C | Time (sec) | | | | | | | | | | | | | | | | | | | |
|------------|------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| | 26 | 30 | 34 | 38 | 42 | 46 | 50 | 54 | 58 | 62 | 66 | 70 | 86 | 96 | 106 | 136 | 166 | 196 | 376 | 556 |
| 10 | 618 | 541 | 483 | 438 | 401 | 371 | 346 | 325 | 307 | 291 | 277 | 249 | 227 | 209 | 195 | 165 | 146 | 131 | 91 | 74 |
| 11 | 612 | 536 | 478 | 433 | 397 | 367 | 342 | 322 | 303 | 287 | 274 | 246 | 224 | 207 | 193 | 163 | 144 | 130 | 90 | 73 |
| 12 | 606 | 530 | 473 | 429 | 393 | 363 | 339 | 317 | 300 | 284 | 271 | 243 | 221 | 204 | 190 | 161 | 142 | 128 | 88 | 72 |
| 13 | 600 | 525 | 468 | 427 | 389 | 360 | 335 | 314 | 297 | 281 | 268 | 240 | 219 | 202 | 188 | 159 | 140 | 126 | 87 | 71 |
| 14 | 594 | 520 | 464 | 421 | 385 | 356 | 332 | 311 | 294 | 278 | 265 | 237 | 217 | 200 | 186 | 157 | 138 | 125 | 86 | 70 |
| 15 | 588 | 515 | 459 | 416 | 381 | 352 | 328 | 308 | 290 | 275 | 262 | 235 | 214 | 198 | 184 | 155 | 137 | 123 | 85 | 69 |
| 16 | 583 | 510 | 455 | 412 | 378 | 349 | 325 | 305 | 287 | 272 | 259 | 232 | 212 | 196 | 182 | 153 | 135 | 122 | 84 | 68 |
| 17 | 577 | 505 | 451 | 408 | 374 | 346 | 322 | 302 | 285 | 270 | 256 | 230 | 209 | 193 | 180 | 152 | 134 | 120 | 83 | 67 |
| 18 | 572 | 501 | 446 | 404 | 370 | 342 | 319 | 299 | 282 | 267 | 254 | 228 | 207 | 191 | 178 | 150 | 132 | 119 | 82 | 66 |
| 19 | 567 | 496 | 443 | 400 | 367 | 339 | 315 | 296 | 279 | 264 | 251 | 225 | 205 | 189 | 176 | 148 | 130 | 118 | 81 | 66 |
| 20 | 562 | 492 | 438 | 397 | 363 | 336 | 312 | 293 | 276 | 262 | 249 | 223 | 203 | 187 | 174 | 147 | 129 | 116 | 80 | 65 |
| 21 | 557 | 487 | 435 | 393 | 360 | 333 | 310 | 290 | 274 | 259 | 246 | 221 | 201 | 185 | 172 | 145 | 127 | 115 | 79 | 64 |
| 22 | 553 | 484 | 431 | 390 | 357 | 330 | 307 | 288 | 271 | 257 | 244 | 219 | 199 | 183 | 171 | 144 | 126 | 114 | 78 | 63 |
| 23 | 548 | 480 | 428 | 386 | 354 | 327 | 304 | 285 | 268 | 254 | 242 | 217 | 197 | 182 | 169 | 142 | 125 | 113 | 77 | 63 |
| 24 | 544 | 476 | 424 | 383 | 351 | 324 | 302 | 282 | 266 | 252 | 240 | 215 | 195 | 180 | 167 | 141 | 124 | 112 | 76 | 62 |
| 25 | 540 | 472 | 421 | 380 | 348 | 321 | 299 | 280 | 264 | 250 | 237 | 213 | 193 | 178 | 166 | 139 | 122 | 110 | 76 | 61 |
| 26 | 535 | 468 | 417 | 377 | 345 | 319 | 296 | 278 | 261 | 247 | 235 | 211 | 192 | 177 | 164 | 138 | 121 | 109 | 75 | 60 |
| 27 | 531 | 465 | 414 | 374 | 342 | 316 | 294 | 275 | 259 | 245 | 233 | 209 | 190 | 175 | 163 | 136 | 120 | 108 | 74 | 60 |
| 28 | 527 | 461 | 411 | 371 | 339 | 313 | 291 | 273 | 257 | 243 | 231 | 207 | 188 | 173 | 161 | 135 | 119 | 107 | 73 | 59 |
| 29 | 522 | 458 | 407 | 368 | 337 | 311 | 289 | 271 | 255 | 241 | 229 | 205 | 186 | 172 | 160 | 134 | 118 | 106 | 72 | 59 |
| 30 | 518 | 454 | 404 | 365 | 334 | 308 | 287 | 268 | 253 | 239 | 227 | 203 | 185 | 170 | 158 | 133 | 116 | 105 | 72 | 58 |
| 31 | 515 | 451 | 401 | 362 | 331 | 306 | 284 | 266 | 251 | 237 | 225 | 202 | 183 | 169 | 157 | 131 | 115 | 104 | 71 | 57 |
| 32 | 511 | 447 | 398 | 359 | 329 | 304 | 282 | 264 | 249 | 235 | 224 | 200 | 182 | 167 | 156 | 130 | 114 | 103 | 70 | 57 |
| 33 | 507 | 444 | 395 | 357 | 326 | 301 | 280 | 262 | 247 | 233 | 222 | 198 | 180 | 166 | 154 | 129 | 113 | 102 | 70 | 56 |
| 34 | 503 | 441 | 392 | 354 | 324 | 299 | 278 | 260 | 245 | 231 | 220 | 197 | 179 | 164 | 153 | 128 | 112 | 101 | 69 | 56 |
| 35 | 500 | 437 | 389 | 351 | 321 | 297 | 276 | 258 | 243 | 230 | 218 | 195 | 177 | 163 | 151 | 127 | 111 | 100 | 68 | 55 |

5 FIELD INSPECTION AND AUDITS

Field and laboratory inspections should be carried out according to the time schedule presented in Volume 4, Hydrometry, Field Manual, Part VII: Field Inspection and Audits.

The inspection form entries are to be extended with entries on sediment samplers:

- Suspended sediment samplers:
 - Equipment: Serial/reference number, sampler type, make, date of last calibration, and remarks
 - Associated equipment: type, amount, condition
 - Quality checks on maintenance of sediment samplers
 - General observations on sediment sampling practice
- Bed material samplers
 - Equipment: Serial/reference number, sampler type, make, and remarks
 - Associated equipment: type, amount, condition
 - Quality checks on maintenance of bed material samplers
 - General observations on bed material sampling practice

In the sediment laboratories the equipment availability and condition should be inventorised based on the list in Annex 1. Also the analysis and data entry practices should be reviewed.

6 MAINTENANCE AND CALIBRATION

6.1 GENERAL

Regular maintenance of the equipment and instruments is essential if the continued collection of good quality sediment data is to be assured.

Many maintenance and calibration routines are site and equipment specific. The overall maintenance of the measuring station has been discussed in Volume 4, Hydrometry, Field Manual, Part VIII: Maintenance and Calibration. In the following additional guidelines are given for a GD site where also sediment transport is being measured.

6.2 SPAREPARTS AND EQUIPMENTS

It is very essential to maintain an adequate stock of back-up equipment and spare parts at each Divisional office. The number of spare instruments and parts to keep in stock will be a function of the number and type of equipment used in the field and in the laboratory. It is advised to have one full set of equipment and consumables available as spare for every 5 sites. The requirement per site and laboratory is given in Annex 1 and 2.

6.3 MAINTENANCE NORMS

The maintenance cost of a station/laboratory comprises the following components:

1. Maintenance cost of civil works
2. Maintenance cost of equipment
3. Cost of consumables

4. Payments to staff
5. Miscellaneous expenditure

The annual maintenance costs of a sediment laboratory at a GD site is estimated at Rs. 1,04,000/-. The details are provided in following table.

| Item No. | Item | Qty | Rate (Rs.) | Unit | Amount (Rs.) |
|----------|--|----------|------------|----------|-----------------|
| | <i>Part A: Cost of Sediment Sampling and Analysis</i> | | | | |
| 1 | Cost of Establishment @ Rs 6000/- for 12 months | | | | 72,000 |
| 2. | Cost of repairs to sampler's, glassware etc. @ 15% of capital cost (Rs 70,000 plus Rs 80,000 – provided separately, see Annexures I & II) | | | | 22,500 |
| 3 | Cost of other lab consumables | Job/year | 1,000 | Job/year | 1,000 |
| 4 | Cost of registers, stationery | 5 | 100 | No. | 500 |
| | Total for Sampling and Analysis | | | | 96,000 |
| | <i>Part B: Maintenance of building</i> | | | | |
| 6.. | Provision for cleaning powder, brushes, brooms, napkins, etc. | Job/year | 1,000 | Job/year | 1,000 |
| 7. | Repairs to sanitary/electrical fittings | Job/year | 1,000 | Job/year | 1,000 |
| 8. | General maintenance of building | Job/year | 1,000 | Job/year | 1,000 |
| 9. | Electrical charges @ Rs. 1000.00/month | | | | 5,000 |
| | Total for Lab maintenance | | | | 8,000 |
| | GRAND TOTAL | | | | 1,04,000 |

Table 6.1: Annual maintenance cost of a sediment laboratory at a GD site

N.B.:

- a) The HIS network covers Peninsular India. Thus to provide uniform costs may not be appropriate. Costs are recommended amounts, and may be adjusted.
- b) The cost on account of deployment of staff is the main component of running cost. It is necessary that some of the staff performing multiple activities have to be considered only once.

6.4 CALIBRATION

If suspended sediment is sampled with a bottle sampler, calibration of the equipment itself is not required. However, an inter-comparison of the data obtained with the instrument with results of other sampling equipment will be required for interpretation purposes.

**ANNEX I: EQUIPMENT FOR SEDIMENT SAMPLING AND
SEDIMENT LABORATORY**

| S. No | Item | Quantity | Rate | Amount |
|-------|---------------------------|----------|------|--------------------|
| 1 | Bottle type Samplers | 2 | | |
| 2 | Metallic 1 Litre bottle | 2 | | |
| 3 | Metallic Conical Flask | 2 | | |
| 4 | Metallic Beaker 500 ml. | 12 | | |
| 5 | Double Jacketted cylinder | 1 | | |
| 6 | Filtering apparatus | 1 | | |
| 7 | Hydrometer | 1 | | |
| 8 | Set of 3 sieves (4" dia) | 1 | | |
| 9 | Bed Material Scoop | 1 | | |
| 10 | Oven | 1 | | |
| 12 | Other Sundry items | | | |
| | Total Cost | | | Rs.70,000/- |

ANNEX II: ORDINARY EQUIPMENT REQUIRED IN SEDIMENT LABORATORIES

| S. No | Item | Quantity | Rate | Amount |
|-------|--|----------|------|--------|
| 1 | Brass Tongs | 3 | | |
| 2 | Stop watches | 1 | | |
| 3 | Analytical Balance | 1 | | |
| 4 | Enamel or Stainless steel (SS) trough 28cmx7cms | 1 | | |
| 5 | Buckets S S or Enamel | 6 | | |
| 6 | Plates | 6 | | |
| 7 | Jug 2 litres | 1 | | |
| 8 | Bowls 500 ml | 2 | | |
| 9 | Funnel 8 cm dia | 2 | | |
| 10 | Funnel 16 cm dia | 2 | | |
| 12 | Funnel stand single | 2 | | |
| 13 | Funnel stand double | 1 | | |
| 14 | Bucket stand with hooks | 1 | | |
| 15 | Tripod stand | 1 | | |
| 16 | GI Bucket 30 cms | 1 | | |
| 17 | Tape metallic 50 mtrs | 1 | | |
| 18 | Pipe wrench 35 cms | 1 | | |
| 19 | Pliers 20 cm long | 1 | | |
| 20 | Pipette stand | 1 | | |
| 21 | Triangular file 15 cms | 1 | | |
| 22 | Physical Balance in a case | 1 | | |
| 23 | Beakers glass 500 ml | 6 | | |
| | Measuring cylinders 1 lit. | 2 | | |
| | Measuring cylinders 500 ml | 2 | | |
| | Desiccator 20 cms dia | 1 | | |
| 24 | Rubber cork Flat Bottom flask | 6 | | |
| 25 | Funnel glass 100 cms | 6 | | |
| 26 | Pipette glass 100 ml | 1 | | |
| 27 | Porcelain basin 9 cms | 3 | | |
| 28 | Porcelain basin 10 cms | 3 | | |
| 29 | Thermometer 110 deg C | 2 | | |
| 30 | Thermometer 50 deg C | 2 | | |
| 31 | Rubber pad 15 cm dia x 6mm thick | 2 | | |
| 32 | Bottle glass 500 ml | 12 | | |
| 33 | Rubber Corks assorted | 12 | | |
| 34 | Filter Paper assorted | 2 | | |
| 35 | Glass tubing assorted | 1 kg | | |
| 36 | Pressure rubber tubing | 10 mtrs | | |
| 37 | Glass marking pencil | 6 | | |
| 38 | Glass rod assorted | 1 kg | | |
| 39 | Watch glass 10 cm dia | 6 | | |

| S. No | Item | Quantity | Rate | Amount |
|-------|--------------------------|----------|------|--------------------|
| 40 | Pinch corks | 2 | | |
| 41 | Meter rod | 1 | | |
| 42 | Wash bottle polythene | 2 sets | | |
| 43 | Steel Scales | 1 | | |
| 44 | Jets and delivery tubes | 6 sets | | |
| 45 | Cleaning brushes | 1 | | |
| 46 | Wire gauge with asbestos | 6 | | |
| 47 | Cork borer set | 1 set | | |
| 48 | Hammer 1 kg | 1 | | |
| 49 | Rechargeable lamps | 1 | | |
| 50 | Graph pads 30x20 cms | 3 | | |
| 51 | Calcium chloride | 500 gms | | |
| 52 | Alum | 500 gms | | |
| | Sundries | | | |
| | Total cost | | | Rs 80,000/- |

ANNEX III: RECORD OF SUSPENDED SEDIMENT SUMMARY DATA

Agency: Central Water Commission, C&SR, Coimbatore

Sub-Division:

Division:

Name :

Station Code :

Independent River :

Local River :

District :

Latitude :°'

Longitude :°'

R.L. of Gauge Zero : (m+m.s.l.)

Year : **Month** :

| Date | Time of observation | Gauge Reading (m) | Water Level (m) | Total Discharge (cusec) | Suspended sediment concentration (g/l) | | | | Remarks |
|------|---------------------|-------------------|-----------------|-------------------------|--|-----------------|---------------|-------|---------|
| | | | | | Coarse Fraction | Medium Fraction | Fine Fraction | Total | |
| 1 | | | | | | | | | |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
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Observer's remarks:

Form filled by: _____ Manuscript checked: _____ Data entered & checked by: _____ Primary validation done by: _____

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