INSTRUMENTATION FOR COASTAL HYDROLOGICAL STUDIES-STATE OF ART

B.K. PURANDARA, P.K. MAJUMDAR AND P.R. RAO

Hard Rock Regional Centre, National Institute of Hydrology, Belgaum-590 001

ABSTRACT

Coastal zones of our country have become the most densely populated areas due to the availability of flat land, good soils, transportation facilities and high productivity. Coastal areas undergo severe and complex issues than most other land and water resources and must be viewed as an important component of a water resources system. It is a fact that the major portion of biological production are from coastal resources (12–24 percent).

However, hydrological studies of the coastal areas have not been given adequate importance. To understand the various hydrological phenomena, it is essential to conduct field and laboratory studies which require modern instruments and techniques.

The main objective of this chapter is to give theoretical and practical aspects of various types of hydrological instruments involved in sampling (watersediments) and laboratory analysis. However, here only a brief outline on the use and limitations of the instruments are discussed to draw attention of the engineers and scientists to come up with modern techniques.

1. INTRODUCTION

Environmental pollution is a result of our industrial revolution. Hydraulic civililizations evidently got into major difficulties through the onset of salinisation of soil and silting of irrigation works. But pollution (mainly air and water) on a massive scale has been concommitant with the industrial revolution due to increase in the mining activity for minerals and materials, more and more use of fertilizers and also due to many other anthropogenic activities.

In India, our attention towards environmental hazards has been drawn only recently, that too only about water pollution. However, it is a fact that the study of sediments is all the more important because, on the one hand, the sediments are potential carriers of organic compounds and metals from watersheds to the receiving body of water, and on the other, they play a significant role in the attenuation of toxic elements in a polluted aquatic environment.

With regard to these effluents, in our country so far major attention has been concentrated only on analysis of stream water. Such analytical studies are important but do not give a complete picture and must be supplemented by sediment sample study. The main reasons for taking up sedimentalogical studies are the following:

(1) The water samples represent a limited time period/interval during which they have been collected. Analysis of such data do not give an overall picture of the condition of water body, whether a river or lake or sea. On the other hand stream sedimentary layers correspond to different depositional conditions, the coarse layers to strong currents, while the fine layers represent weak currents.

(2) Determination of heavy metal concentration in surface water samples from rivers, collected at short interval reveal fluctuation of several orders of magnitudes. While in the case of sediments systematic relationships between metal concentration, particle size and distance down stream have been generally noted.

(3) Exchange processes between interstitial and surface water affect fluctuations along the river course. These processes depend on pH and Eh conditions, the type and quantity of complexing agents, salinity, temperature and biological activity. No relationship exists between heavy metal distribution in surface and bottom water.

(4) Many heavy metals are not readily soluble but become rapidly fixed to particulate matter in the receiving body of water.

(5) Trace elements in particulate matter is 1,000 to 1,00,000 times higher than the corresponding metal content in the associated aquatic phase. The presence of all large proportions of heavy minerals results in characteristic enrichment of trace metals, particularly in fine sand-silt fractions. On the other hand the high proportions of minerals like quartz, feldspars etc. tend to have the opposite effect on the sedimentary heavy metal budget.

Therefore environmental study requires mainly sedimentological analysis in addition to water chemistry. However in the present chapter the scope is limited only to sampling and analytical techniques, various instruments used for sampling in lakes, estuaries, oceans and also for rivers. Though some of these techniques may be used in any water resources systems, it is very important in the case of coastal hydrology because monitoring the coastal environment is quite essential as these regions are highly populated and people mainly depend on these coastal environments for their lively hood.

2. METHODOLOGY AND INSTRUMENTATION

In general, for any environmental understanding, we should follow systematic procedures and this can be done in two stages:

(A) Field investigations

(B) Laboratory analysis

(A) Field Investigations

Procedures recommended for sampling depend on the type of substances under study. For mineral micropollutants it is preferable to use a plastic sampler and hard-lined polyethylene bottles for storage. For organic micropollutants plastic devices should be avoided in all operations, from sampling to the laboratory analysis. The sampler should be metallic and rinsed with hexane or other organic solvent free of chlorinate hydrocarbons. For organic carbon and nutrients, the sampling and filtering apparatus can be metallic or plastic, cleaned and rinsed normally. Storage vessels are better made of glass.

Three types of sampling are very important for tackling any environmental problems:

1. Bottom sediments,
2. Suspended sediments,
3. Water samples.

1. Bottom Sediments

Samples of bottom sediment to be analyzed for contaminants should be taken from the inner part of the original sample. Those to be analyzed for trace metals should be kept in plastic bags and those to be analyzed for toxic substances kept in glass vessels.

A large number of samplers have been designed for specific purposes and for sampling in different environments. Sediment samplers can be classified as grab samplers (fig.1) and core samplers. Some of the commonly used samplers are described as follows:

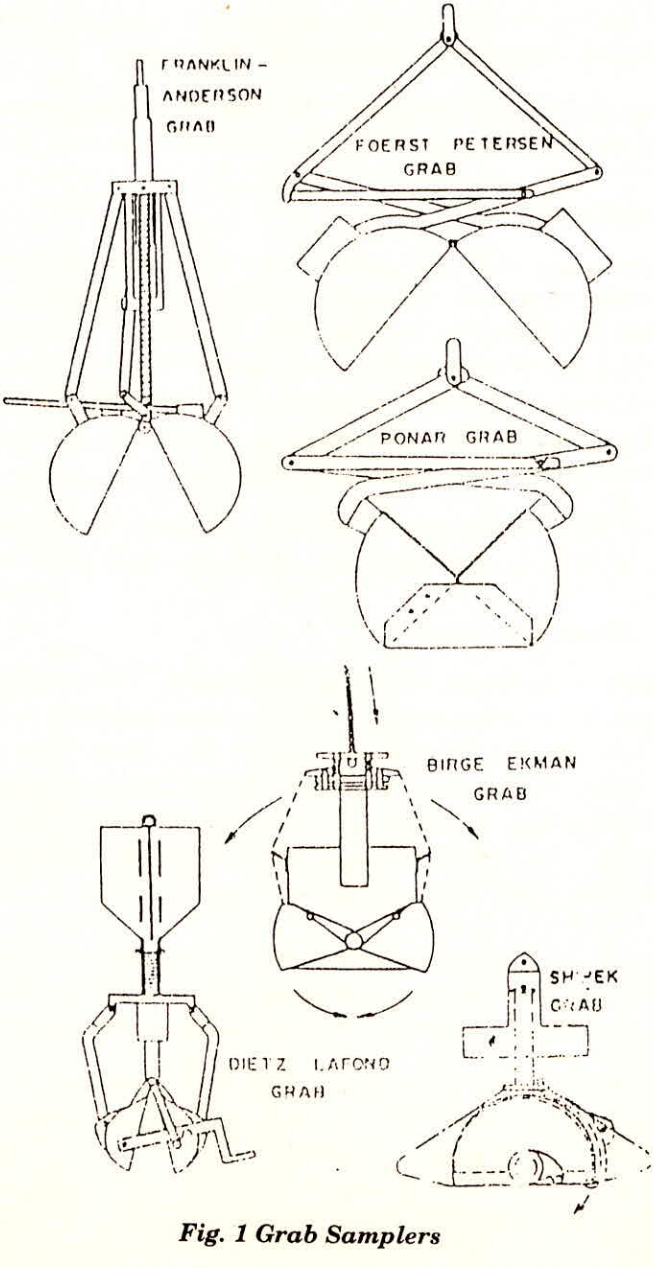

Fig. 1 Grab Samplers

(a) Van Veen Grab

This is a light sea sampler which can be used to collect samples of bottom deposits from shallow regions. It consists of two metallic jaws hinged together along a central axis. Jaws can be held open by the catching lever and a long bar arrangement. The grab is sent to the sea bottom in an open position. As it hits the bottom the "catching mechanism" releases and the jaws bite a sample from the bottom and come closer to form a closed container entrapping the sample.

If the grab entraps shells or stones the jaws may not get properly closed; in that case the sample may get washed out during the ascent.

(b) Petterson Grab

It consists of a pair of heavy metal jaws and chain and catch arrangements by means of which the grab is kept open during its descent and is closed when it strikes the bottom. The instrument is lowered vertically in the open position from a stationary vessel. When it strikes the bottom the slackened chain releases the catch and when the cable is tightened, the material including the organism is caught in the grab. The jaws close by their own weight and is hauled up.

Advantages of this instrument is that it is heavy, so the rope angle will be less and also a larger quantity of the sample can be collected.

(c) Lafond - Dietz Snapper

The instrument is lowered in an open position. The jaws are kept apart by a catch and lever arrangement. In the open position a short rod fixed to one jaw falls in the 'V' shaped cut in the lever. The spring is in a compressed state in the open position. When the instrument strikes the bottom the trigger is activated and the rod is released. The bottom trigger is activated and the rod is released. The compressed spring is released and it closes the jaws entrapping sediments in it.

The amount of sediment collected in this snapper is very small. It operates effectively on a sandy bottom. On muddy bottoms the instrument may get buried and the trigger mechanism may not work.

Suitable apparatus for collecting disturbed samples of bed material including deposits in reservoirs or river reaches, is shown in fig.2. This is mainly useful for sandy bottoms.

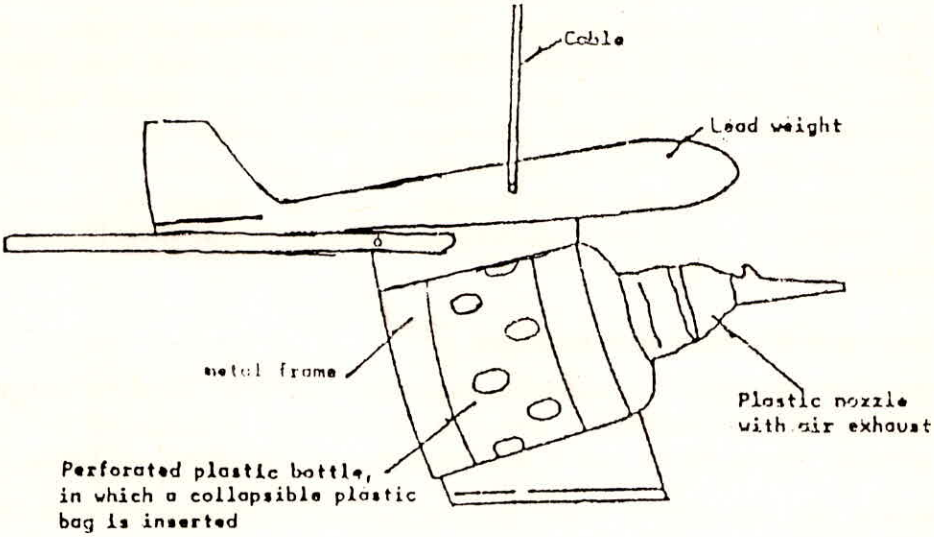

Fig. 2 Three litre collapsible-bag sampler mounted below a sounding weight

(d) Core Samplers

Apparatus used for taking undisturbed samples, ranging from simple to complicated equipment, are the axle type, revolving type, gravity core type, piston type, vibration type etc. Two of these are represented in fig. 3A,B,C.

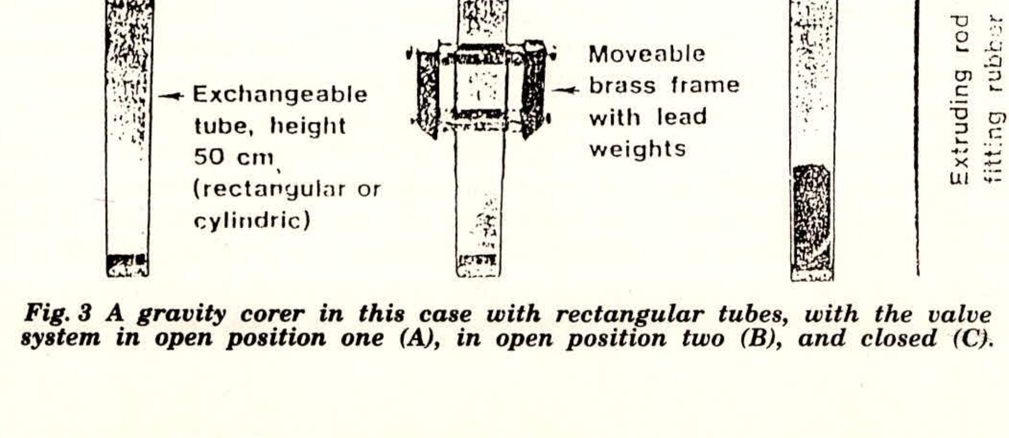

Fig. 3 A gravity corer in this case with rectangular tubes, with the valve system in open position one (A), in open position two (B), and closed (C).

All the particulate and bottom samples collected should be carefully stored in dry form before analysis. The drying temperature varies with the type of pollutant or nutrient: 20°C for organochlorines and hydrocarbons; 50°C for nutrients, total organic carbon and volatile mineral compounds of As, Hg, Pb. For determining trace metals and nutrients, samples should be stored in plastic bags in a refrigerator. For determining hydrocarbons and other organics, samples should be placed in glass containers sealed with aluminium foil and stored in a freezer at a temperature of –20°C.

2. Suspended Sediment Samplers

Devices for suspended - sediment sampling currently used in various countries may be classified into two categories: instantaneous and integration types. Basic types of samplers are classified in Table 1.

Samplers are selected to meet data collection requirements with due consideration of suitable measuring methods. More than one type of sampling device is sometimes installed at key hydrometric stations to meet various flow conditions. Comparisons of results with different samplers should be made if consistent data are to be obtained. Sometimes it may be necessary to make small modifications to samplers to cope with local river conditions, without sacrificing their basic properties.

Samplers designed on the basis of time integration have been widely adopted all over the world. Random errors due to fluctuations may be eliminated to a certain degree, improving the reliability of the results. Instantaneous samplers are also used extensively. These are simple and easy to operate; however, errors due to fluctuations in velocity and sediment concentration are inevitable and should be compensated for by repetitive samplings.

Basic requirements for an ideal sampler may be summarized as follows:

(a) Intake velocity of the nozzle for a time-integration sampler should be made equal or close to the ambient velocity. Experiments show that the coarser the particle size, the greater the error of concentration induced by the difference in intake velocity and the ambient velocity. To ensure sampling accuracy, it is better to calibrate the intake velocity of the nozzle. It has been proven by experiment that errors in the measurement of sediment concentration are less than 5 percent if the ratio of intake velocity to the ambient velocity is kept within 0.8 to 1.2 (USGS, 1976). For flow with a hyper concentration of sediment, no appreciable differences have been observed even if the ratio falls far below the above range (HU Jingxing, 1981);

(b) The sampler should be able to collect samples close to the bed so that the unsampled zone is as small as possible. The distance from the centre line of the nozzle to the bottom of the sampler is 10 cm to 12 cm for USP or USD series samplers;

(c) Disturbances created by the sampler, particularly near the nozzle intake, should be minimized;

(d) Enough weight should be available for the sampler to maintain its stability under water. Ease of operation and maintenance are essential;

(e) Sampling volume should be sufficient to fulfill minimum requirements for determining concentration as well as size gradation. Repetitive sampling may be necessary to fulfill minimum requirements for sample quantity.

In the design of a time-integration sampler, the intake velocity is adjusted by pressure equalization in the sampler container. Limitations as to the depth within which the adjustment is effective should be strictly observed. For instance, present US point-integration samplers can be operated to a depth of 23m to 37m with a maximum of 55m, while the US depth-integration sampler series can be used to a flow depth of less than 4.5m for a round trip operation (USGS, 1976).

Recently collapsible-bag samplers have been studied in the United States and China. The US bag sampler system, which consists of the D–77 sampler with a prefabricated plastic cap incorporated with intake and air vent nozzle, is attached to a plastic bottle within which a light weight plastic food storage bag is inserted as a collapsible bag. With a newly developed solenoid valve, it can be used either as a depth-integration or point-integration sampler. The Chinese version uses a specially made rubber bag as a collapsible bag. They perform similarly and a concentration of samples taken by both samplers corresponded closely from 0.7 to 3.0 m/s and concentrations ranging from 4 to 90 kg/cu.m. It seems that this type of sampler has potential for use in the field. A sketch of a collapsible bag sampler is shown in Fig 4.

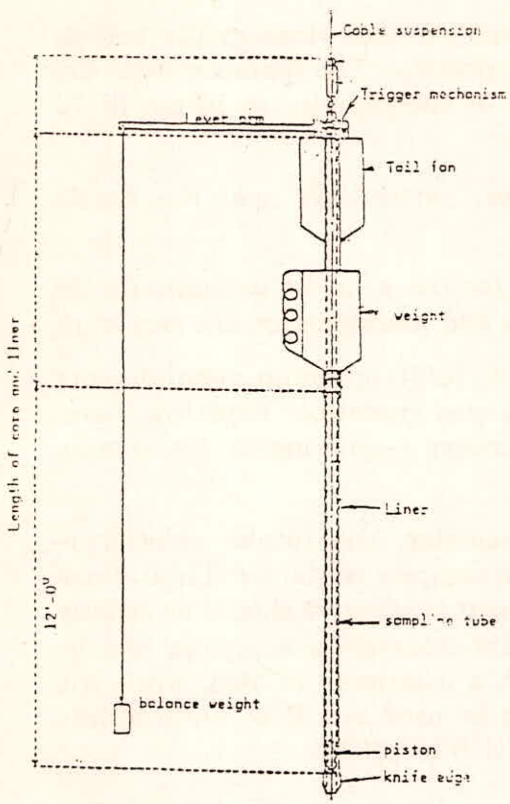

Fig. 4a Sketch of gravity core sample (Vanoni, 1975)

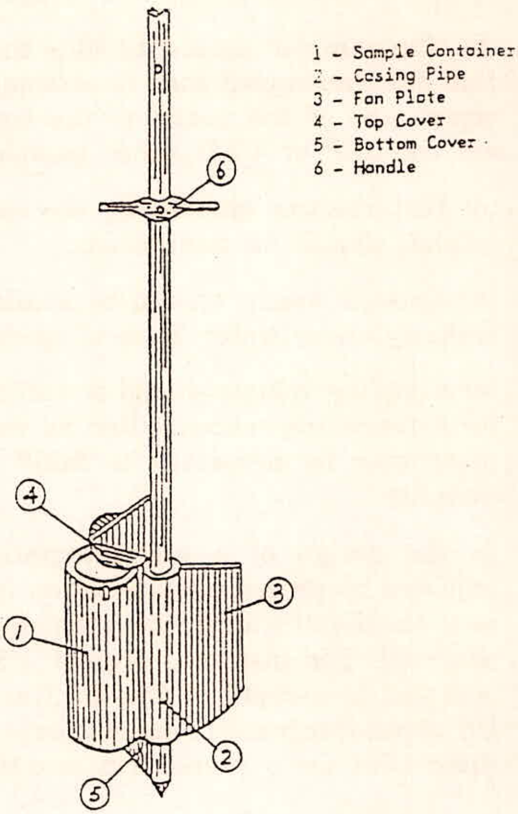

Fig. 4b Sample for taking undisurbed samples in unconsolidated deposits (revolving type) (Bajiazui Reservoir Experimental Station 1980)

In recent years automatic pumping devices have been used in small rivers, canals, experimental basin outlets, etc. One of the characteristics of this type of sampler is its ability to collect samples at predetermined intervals at a defined point in the river. The entire variation in sediment concentration of a flash flood may be followed. Sufficient samples can be obtained automatically to define the variations in the sediment concentration during a flood. It is particularly useful for stations located in remote areas. A simple pumping sampler developed by the USGS is shown schematically in Fig 5.

In order for the concentration obtained by a pumping sampler to represent the variation in concentration in a cross-section, the relationship between the concentration observed at a point and the cross-sectional average should be obtained for conversion purposes. Good relations usually exist during flash floods in mountain creeks and small tributaries.

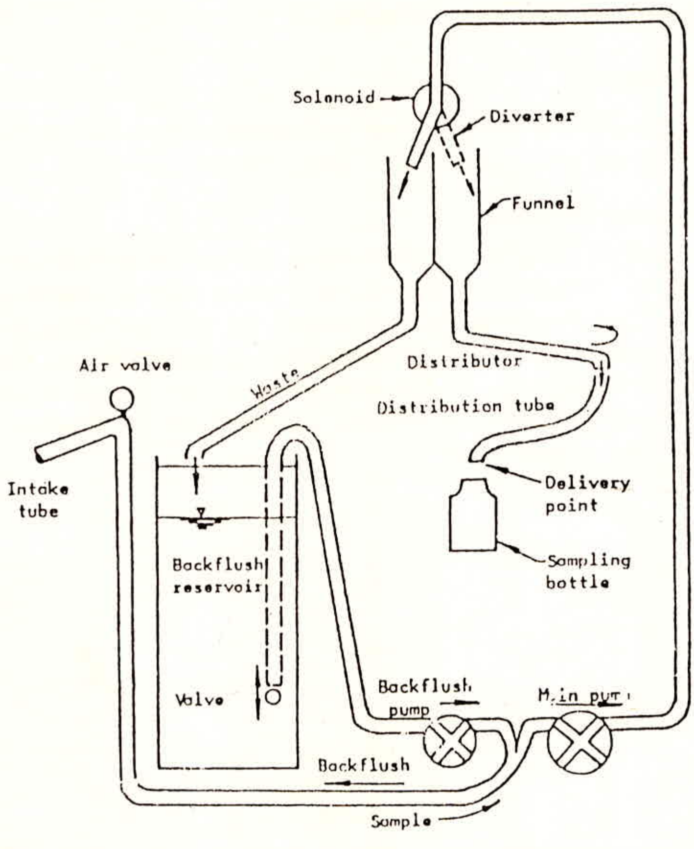

Fig. 5 Schematic diagram of hydraulic system for PS–4 pumping sampler (Skinner et. al., 1981)

A portable pumping sampler may be used for taking point-integrated or depth-integrated samples at any point or vertical in a cross-section. A sampling nozzle may be mounted on the streamlined sounding weight, together with velocity of depth measuring devices such as a propeller meter, echo sounder transducer etc. A device for measuring sediment and velocity distributions in rivers and estuaries has been reported. A pumping sampler with an attached filtering device has also been developed and used in Pakistan.

3. INSTRUMENTATION FOR COASTAL ZONE AND DEEP WATERS

For understanding the various problems of coastal zones and deep waters it is necessary to evaluate various oceanographic parameters especially waves, currents, tides, wind speed and direction, air pressure, bathymetry etc. It is also important to collect and monitor water quality of the coastal zone for which various instruments are used for collecting water samples from different depths.

3. Water Samples

The following are the commonly used techniques for water sampling from the coastal regions and also from deep waters.

(a) Nansen water bottles

Nansen water bottle (Fig.6) is a reversing water bottle having a capacity of 1200 ml. It is fitted with two plug valves one at each end of the brass cylinder. These valves are connected by a connecting rod and are operated simultaneously. The connecting rod is fastened to a clamp which is used to secure the bottle. In the set position the clamp is at the lower end and valves are opened. It is held in position by the bottle release mechanism at the upper end.

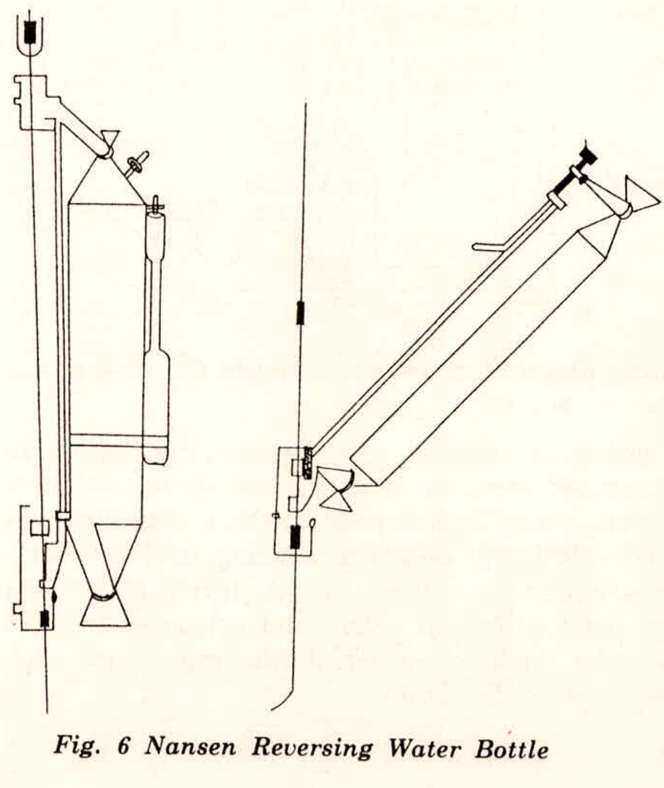

Fig. 6 Nansen Reversing Water Bottle

When a messenger from above hits the bottle release mechanism, the bottle falls over and turns through 180 degrees, and as it does so is automatically closed filled with water at that depth. The valves are then closed by a locking device.

The clamp is provided with a messenger release mechanism. The messenger held in position by a small rod. The messenger from above after reversing the bottle, slicks down the wire rope and hits the mechanism releasing the messenger fitted there. The messenger slides down to operate the next water bottle. Usually a series of twelve or more water bottles are placed on wires at various intervals so that water from different depths can be collected.

The water chamber is provided at the top with an "air vent" and at the lower end with a tap. The air oven has to be operated for drawing water through the tap.

Two hollow perforated cylinders are fitted in the front side of the bottle. The reversing thermometer (one protected and another unprotected) are kept in these hollows and held tightly with the help of rubber washers and screw disc. When the bottle is reversed the thermometers are also reversed, recording the temperature at that particular depth.

Temperature noted with depth has to be corrected with a correction factor. The correction factor is determined as follows:

Correction For Protected Thermometer

There are two important corrections to be made to obtain the exact temperature. The first correction is necessary because there is difference between the temperature at the reversal and the thermometer which is read. The second correction is for calculation errors. These two corrections are given by the equation

$$\Delta t = \frac{(T'-t)(T'+V_0)}{K}\left[1 + \frac{(T' - t) + (T' + V_0}{K}\right]$$

Where Δt is the correction to be added algebraically to the uncorrected reading of the reversing thermometer. T is the uncorrected reading of the reversing thermometer, t is the temperature at which the instrument is ready. V is the volume of the small bulb and of the capillary upto the zero mark expressed in terms of the cc units of the capillary and

K is a constant which depends on the relative thermal expansion of the mercury and glass used in the thermometer and I is the calibration correction which depends on the value T'. The values of V_0, K and **I** are supplied with the instrument.

Correction For Unprotected Thermometer

To obtain Tu from the observed temperature Tu$'$, a correction has to be applied which is given by

$$Tu = \frac{(Tw - Tu)(Tu' + Vo}{K}$$

Where Tu$'$ and Tu are the readings of the unprotected thermometer and its auxiliary thermometer. **Iu** is the calibration correction, K is a constant, Vo is the volume of the small bulb and the capillary upto zero mark. Δ Tu is to be added algebraically with Tu.

The Bathy Thermograph

The bathy thermograph is used to obtain a continuous record of the temperature against depth on smoked glass slick of size $1'' \times 1\frac{3}{4}$. This can be used upto a maximum depth of 450ft.

Echo sounders are commonly used to understand the bottom topography of the sea floor.

For coastal hydrological studies a lot of information about physical parameters such as waves, currents, tides and meteorological data are required and these parameters may be determined by using the following instruments.

Determination of various physical parameters are given as follows:

(a) Waves

There are mainly two methods to measure waves (Fig. 7).

(1) Non-directional wave measurement : To measure non-directional wave measurement datawell waverider buoy and wave and tide gauges.

(2) Directional wave measurement, commonly datawell directional waverider buoys, Wavec, Interocean S_4 Current meters are some of the instruments to measure wave height as well as wave direction.

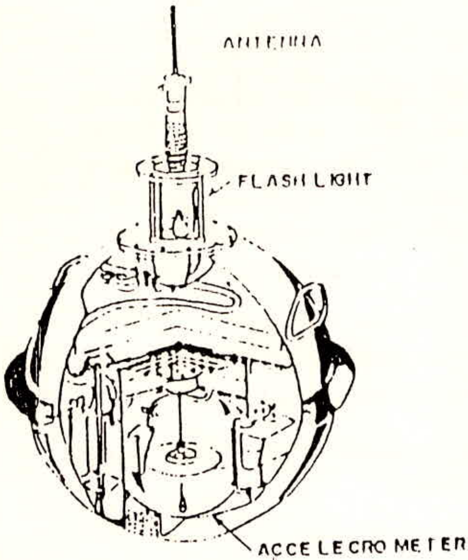

Fig.7A Waverlder Buoy

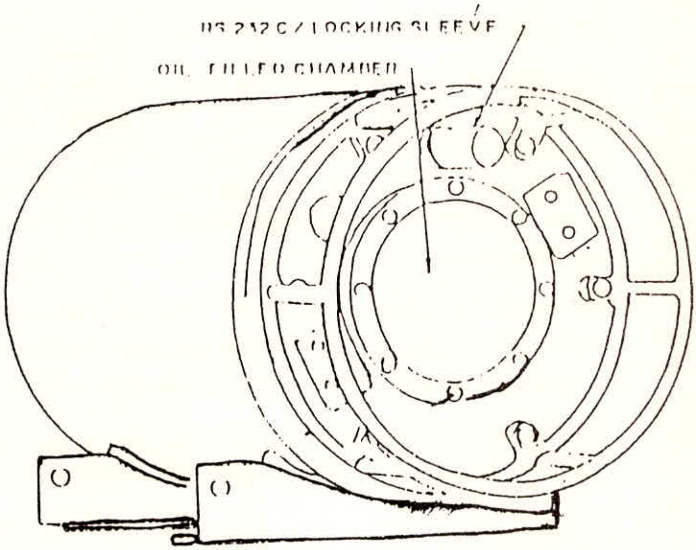

Fig.7B Wave and Tide gauge-WTGS 4

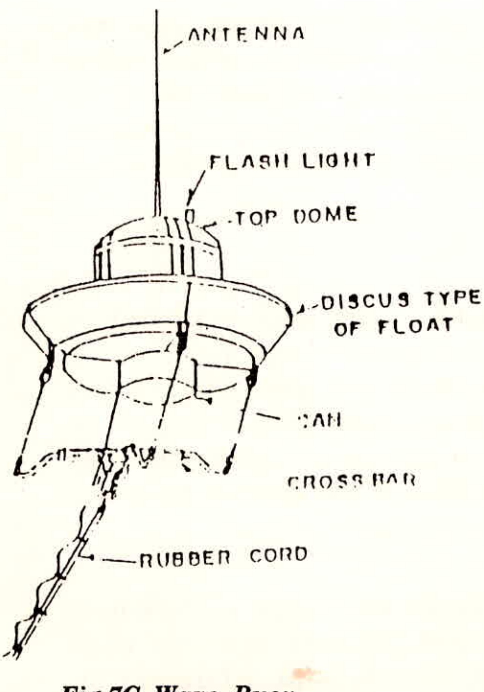

Fig.7C Wave Buoy

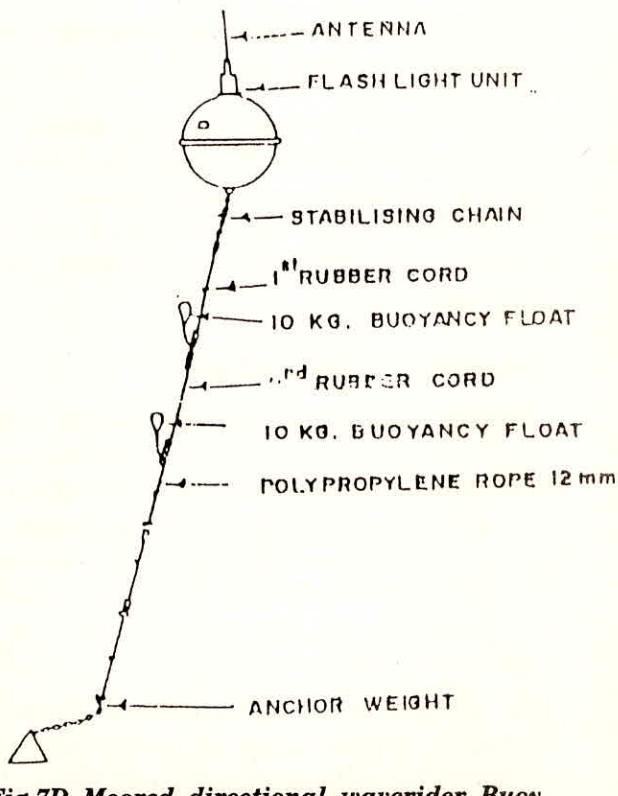

Fig.7D Moored directional waverider Buoy

(b) Currents

The speed and direction of the current at any depth can be determined by using current meters. In the ocean there exist currents of almost constant direction and speed throughout the year. They are mainly generated by wind and classified as drift currents and gradient currents, density currents and compensation currents according to their generation mechanisms.

To measure these currents, Ekman current meters, Aanderaa RCM-4/ RCM-5, Simrad UCM-30, Interocean S4 current meters are among some of the current meters widely used by oceanographers.

For small rivers and canals the flow can be measured by using pigmy current meters or digital portable current meters.

(c) Tides

Numerous kinds of long waves in the sea, such as tides, storm surges, tsunamis, and harbour oscillations would exist apart from ocean waves.

The tide level measurement instruments are basically classified into two categories, (1) The Float Type, and (2) The Pressure Type.

Measurement of weather parameters are observed by using Aanderaa Automatic Weather Station DL-2700 (Fig 8) is self recording twelve channel data logger which contains 9 volts battery, magnetic spool for recording various parameters such as wind speed, wind direction, relative humidity, air temperature, rainfall, air pressure, ground temperature, radiation etc.

Laboratory Procedures

After the field investigations, samples should be put to various laboratory studies for the determination of sediment concentration and particle size. Evaporation, filtration or displacement methods are generally used in laboratories to determine the sediment concentration of the sample. An optical method has been used in Zimbabve under specific conditions. Any one of the methods may be chosen on the basis of the desired accuracy.

Size Analysis

Size gradation is an important parameter in the study of sediment problems. The sources of supply and the mode of movement are quite different for different sediment sizes. It is necessary to determine the size distribution together with the total quantity of sediment.

Quality Monitoring

There are many other physical and chemical properties of sediments which have to be monitored continuously. However it requires well established laboratories with sophisticated instruments such as ICP (Integrated Coupled Plasma), AAS(Atomic Absorption Spectrophotometer), XRD (Xray Diffraction Technique), XRF (Xray Fluorocence), etc.

In general, sediments, particulate matter and water are the important constituents of nature which have to be monitored for environmental quality studies as they are considered as pollutant carriers. Heavy metals and organic micropollutants are mostly carried on the particulate matter. When deposited, the contaminated particles constitute a potential pollutant source available to contaminate the biota through direct contact or by release of pollutants into the water body. The level of contaminants in sediments can be used as indicators in the detection of environmental contamination. In general, the concentration of an element is inversely proportional to the grain size of the sediment.

A systematic monitoring of the quality of the sediment in rivers, lakes, reservoirs and in the coastal zones should be major components of water quality monitoring. The monitoring should include studies of flow regime, variation in suspended sediment discharge, location of pollutant sources and the types of pollutants should be investigated.

4. SUMMARY

Proper understanding of sediment yield, sediment transport and erosion or deposition, water quality are of vital concern for all coastal engineers and scientists engaged in the planning and development of environmental systems. Proper selection of operational methods for sediment and water quality sampling relies mainly on the basic knowledge of sediment movement in rivers or in reservoirs and coastal water bodies but also on the accuracy required for data acquisition. Therefore it is a must to call attention from instrumentation engineers and scientists to give serious thoughts in modifying the available techniques for getting accurate data from various environments.

References

1. Yuqian. L, 1989, Manual operational methods for the measurement of sediment transport.
2. Jansson, L.H.M, 1983, Lake Sedimentalogy.
3. Kumar, K.A., 1993, Instrumentation for Coastal Zone Management, Regional Course on Hydrology of Humid Tropics and Coastal Zone Management.

TABLE: 1 CLASSIFICATION OF SUSPENDED-SEDIMENT SAMPLERS

Classi fication	Operation for	Basic feature	Sample volume	Description	Depth limitation
Instant-aneous	Point Sampling	Horizontal	0. 5 1. 0 2. 0	May be opened or closed by spring Dropping hammer or electromagnetic switch; operated by rod suspended by cable	None
		Vertical	1. 0	Bottle sampler; cork opened and closed by spring and lever system	None
Inte-gration	Depth inte-gration	Presure adjus. by chamber	1pior 0.4713	USD or USDH series with nozzles in different sizes; used at depths of round trip less than about 5 m	4.5 m
			0.5	Bottle sampler with intake nozzle round pointing to the flow and air exhaust; trip used at depths of less than 5m	4.5 m
		Pressure adjusted by collapsible bag	1.0-2.0	Plastic nozzle exchangeable; while in deep water the volume of sample may be increased by using large plastic bags	None
	Point inte-gration	Pressure adju--1 stable; open and close by valve	quartor 0.941 1.0 2.0	USD series with nozzles in 3 different sizes; used under 55 m JS of JLC series with exchangeable able nozzles	25-40; max 55 m
		Pressure adju-sted by colla-psing bag;	1.0-3.0	Plastic nozzle exchangeable uses plastic food storage bag	None
		open and close by valve	1.0-2.0	Rubber bag spocially mode; nozzle exchangeable	None
		Intake velo-city may be adjusted	practically no limita-tion	Vacuum chamber used for adjusting pressure; may be used near bed surface	None
				Intake velocity adjusted by varying pump speed; may be used near bed surface	None
			1 pint or 0.471	Single-stage sampler; used in flashy streams	
Accum-ulation of sedi-ment	Direct acc-umulation of sediment.	Water flows out of while sed-iment retained		Delft bottle or Neyrpic type for mea-suring suspended bed material; disch-arge correction factor should be applied	
		Small fractions of flow are diverted into chamber where sedi-ment deposits	Enough for sampling in runoff period from small watershed	Various methods are adopted to extract small fraction of flow: mostly in experimental basins for soil conservation research	