CHAPTER 119

MEASUREMENT OF SUSPENDED SEDIMENT IN THE SURF ZONE

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1. Introduction

The sea is an important source of water for cooling and other industrial purposes. From practical considerations, the water is usually drawn from a zone close to the shore, perhaps within one or two kilometres of the shore line through an intake structure such as a tunnel, pipeline or harbour or some combination of these. If the coast is exposed to strong wave action and the local sea bed is of a sandy nature, sediment will be lifted into suspension by the oscillatory motion induced by the waves, and thus any sea water transported to the shore will contain a sediment load.

This sediment content may have an adverse effect on the operation of the intake structure in various ways. If the water velocity is maintained at a high enough value throughout to avoid deposition, then the sand water mixture will tend to abrade the surface with which it is in contact. If however the water velocity is permitted to fall below the deposition value, sediment accumulation will occur which may be intentional as in a settling basin (requiring regular dredging or other removal) or inadvertent as in a pipe conduit (leading to partial blockage of the pipe).

The writer has been associated with two sea water intake schemes, one on the western coast of South Africa, being a cooling water supply for a nuclear power station with a water consumption of about 100 m^3/s; the other an intake for the recovery plant of a mining company in Namibia, water capacity about 1 m^3/s. In both cases, information was needed concerning the variation of sediment concentration with distance above the sea bed, this distribution being measured at selected distances from the shore line. This led to a review of available techniques for determining the sediment content of sea water, and thence to development of new procedures and instruments. The details of these developments are presented in this paper.

2. Laboratory measurements of sediment concentration

There are established methods of measuring sediment concentrations in laboratory channels, either directly by withdrawing a sample of water under conditions of minimum disturbance of the local flow, (with subsequent analysis of the withdrawn sample) or indirectly by measuring the optical, electrical or acoustic properties of a localised water volume, the changes in these properties being related to sediment concentration by calibration.

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For example the electro-optical sediment concentration meter, which senses electrically the loss of light transmission due to the presence of sediments, was first described by Hom-ma and his associates in the period 1962 to 1965 [3, 4 and 5] and subsequently further refined and developed by Kennedy and co-workers in the period 1969 to date, [7, 8, 9 and 15]. In 1969 Hattori [6] introduced a sensor system in which the electrical conductivity of a sediment laden zone enabled the number of grains to be effectively counted. Basinski and Lewandowski [13] introduced a radiation sensor which made use of the principle that the concentration of suspended sediment in water is related to the absorption of gamma radiation. Wenzel [14] described acoustic methods of sediment concentration determination in which either the change in acoustic velocity or the extent of sound absorption could be related to the quantity of solids present.

Such inferential methods for assessing the sediment concentration imply that the instrument is sensitive only to the mass of the sediment in the zone explored. However in most cases it appears that other factors may influence the measurement obtained, for example the size and translucency of the particles and even the speed with which they are moving, thus a series of calibrations may be required.

In uni-directional flow, much attention is paid to the withdrawal of sediment laden water at the rate appropriate to the local flow velocity of the water. However, in wave action, where the velocity vector varies in magnitude and direction, it seems practically impossible to synchronise the rate of water withdrawal with the local velocity. In a laboratory of course, there is at least no difficulty in locating the instrument in the desired sampling position.

3. Field measurement of sediment concentration

There are surprisingly few field measurements of this type, although it is here necessary to distinguish between comparative samplers, such as bamboo tubes which give relative concentrations only [2], and quantitative samplers which give an absolute measurement of sand content in (say) ppm (parts per million by mass). In this latter category Watts [1] made a major contribution by measuring sand concentration at a site on the California coast, using a pump-filter-meter system all components of which appeared to be submersible. His measurements were taken at six stations between 100 and 300 m from the shore line (largely in the surf zone) and sampled mainly within 1 m of the sea bed. These tests identified the concentrations as being of the order hundreds to thousands ppm, and as the sand content was retained in the instrument, size distributions of the sediment could be obtained. The field tests were preceded by laboratory experiments to identify the optimum conditions for water withdrawal which appeared to be a vertical nozzle drawing at a high water speed (about 5 m/s); the resulting quantity of water withdrawn was about 200 litres, over about 5 minutes. The equipment required a power supply, made use of a convenient pier, and the paper concluded with the comment that "no satisfactory operational procedure has been developed for this sampler which would facilitate the procurement of samples other than from a fixed structure".

Fairchild [10] made use of a similar pier mounted sampler, but modified the system in that only the nozzle was submerged, the pump and receiving tank being tractor mounted to make the system more manoeuvrable. He also used a slightly higher intake velocity, greater than 6 m/s, which could have caused some entrainment with the nozzle positioned at its lowest position of 75 mm from the sea bed.

Hom-ma and Horikawa [3] make reference to an instantaneous horizontal sampler (Fujiki type) as used on tests on the coast of Japan, but give no details of how the sampler operated or was positioned.

Jensen and Sorensen [12] described measurements made in the entrance channel to the port of Karachi in water 11 m deep. They used a steel tripod frame resting on the sea bed, with nozzles attached at various elevations, and water samples were lifted by suction to an anchored surface vessel for subsequent concentration determination. The samples appeared small (2 litres at a time) and as the wave heights were less than 3 m, the zone explored was outside the breaker line.

4. Design criteria

The literature review led to tentative specifications for a versatile sediment sampler for determination of offshore concentrations as follows:-

a) Indirect sampling methods were rejected for use in the sea on the grounds that organic content and small marine organisms could give spurious information. In addition, the calibration of indirect instruments may be affected by the nature of the sediment as distinct from its mass. Direct sampling implies positive withdrawal of a water sediment mixture.

b) The water volume sampled should be as large as possible (minimum 100 litres) in order to handle as large a sediment quantity as possible (for example 100 litres of water yields only about 10 g of sediment at 100 ppm concentration). This sampling will take several minutes.

c) Following from (b) above, the sediment must be extracted and the water rejected (returned to the sea) otherwise the storage capacity required for the instrument would be excessive. This procedure has the added advantage that the sediment load may be examined in detail.

d) As far as possible, a field test should not involve personnel in or on the sea, otherwise zones of particular interest, such as a breaker line, and occasions of particular interest, such as a period of unusually strong wave action, may in themselves inhibit sampling activity.

5. Pneumatic samplers

From the outset, it was decided to use pneumatic power for any sampler design, based on the ready availability of portable vacuum and compressor equipment.

An elementary form of sampler was used initially, employing commercially available preserving jars, of 2 litre capacity, which are able to withstand a total internal vacuum. When equipped with a modified screw lid, containing a quick release manual valve, it could be used as a hand held sampler, suitable for relatively high concentrations in wading depths. Auxiliary equipment consisted of a portable generator and vacuum pump, which enabled as many bottles as desired to be vacuumised on the beach: when opened under water, a pressure head of about 10 metres is available immediately to fill the bottle, a process which takes about 2 seconds. Although only accurate when concentrations are of the order thousands of ppm, this procedure remains convenient for work close inshore.

For deeper water two compressed air samplers have been designed to fulfill the criteria outlined in paragraph 4, both using conventional 7 litre, 200 atmosphere compressed air cylinders for power supply. Sampler I has been in use for some months, and has proved effective, but requires a helicopter to insert and retrieve it. Sampler II is under development, and attempts to avoid a support vehicle entirely, rather making use of an offshore anchor.

The basic operational component of both these samplers consists of a compressed air cylinder connected to an air motor through a trigger valve. In sampler I this valve is actuated by water inflow into a compartment when the sampler is resting on the sea bed. The air motor has a common shaft with a centrifugal pump which draws sea water through an inlet tube positioned at the desired sampling height above the sea bed. The pump drives the water sample through a water filter and meter and back to the sea. The air cylinder capacity is such that the quantity of water sampled is about 100 litres and takes about 5 minutes to flow through the instrument, although the quantity could be increased easily by using higher pressure cylinders. The complete unit is weighted by a base plate, which also has three radial support arms to permit the sampler to remain stably on the sea bed under wave action. The function of the helicopter is restricted to lifting the prepared sampler off the beach, transporting it to the desired offshore station, lowering it into the water until slack rope indicates the device is on the sea bed, and then hovering until the sampling is complete, when the sampler is lifted clear of the water and returned to the beach. Once onshore, the empty cylinder is replaced, the water meter reading is taken as a measure of sample size, the nylon mesh filter is removed and replaced, and the process repeated. If desired, the position of the inlet pipe may also be changed. The cycle time for one reading is of the order of 15 minutes, but the strain on the helicopter pilot is considerable, and in practice not more than eight readings have been taken in one day.

Sampler II is designed to avoid the use of the helicopter, which is replaced in effect by an endless rope between the shore line and a heavy offshore anchor, the sampler being attached to the rope and in this way moved into desired station. In this development the sampler is basically buoyant, but when in position an air chamber is flooded by radio signal from the shore, causing the sampler to sink into position and initiate the sample pumping as described above. By means of time switches the air chamber is blown free of water at the end of sampling, the device surfaces and is pulled back to shore again.

The figures and photographs on following pages show the two compressed air samplers in outline and under operating conditions.

6. Conclusion

Subject to the successful operation of sampler II, surf zone sampling may now be accomplished by a shore-based party subject only to the retention of an offshore anchor buoy and sheave to accommodate an endless rope link to the shore. This permits sampling under any conditions of wave action. For isolated samples required from different areas, the helicopter may still be useful for sampler positioning.

Measurements of sediment concentration have been obtained inside and just outside the surf zone under local wave heights up to about 6 metres. Viewed from a helicopter under these conditions, the magnitude of vorticity about a vertical axis occurring naturally appears to outweigh the local vorticity generated by the presence of the instrument, thus it is assumed that the sediment measurement is not being exaggerated by the presence of the device. Further support for this view is not possible, as it is believed that this is the first time sampling has been achieved at all under these wave conditions, and thus comparative measurements are not available. However, very broadly the concentration magnitudes obtained in the present series of tests seem rather low when compared with tests conducted from fixed pier platforms.

7. Acknowledgements

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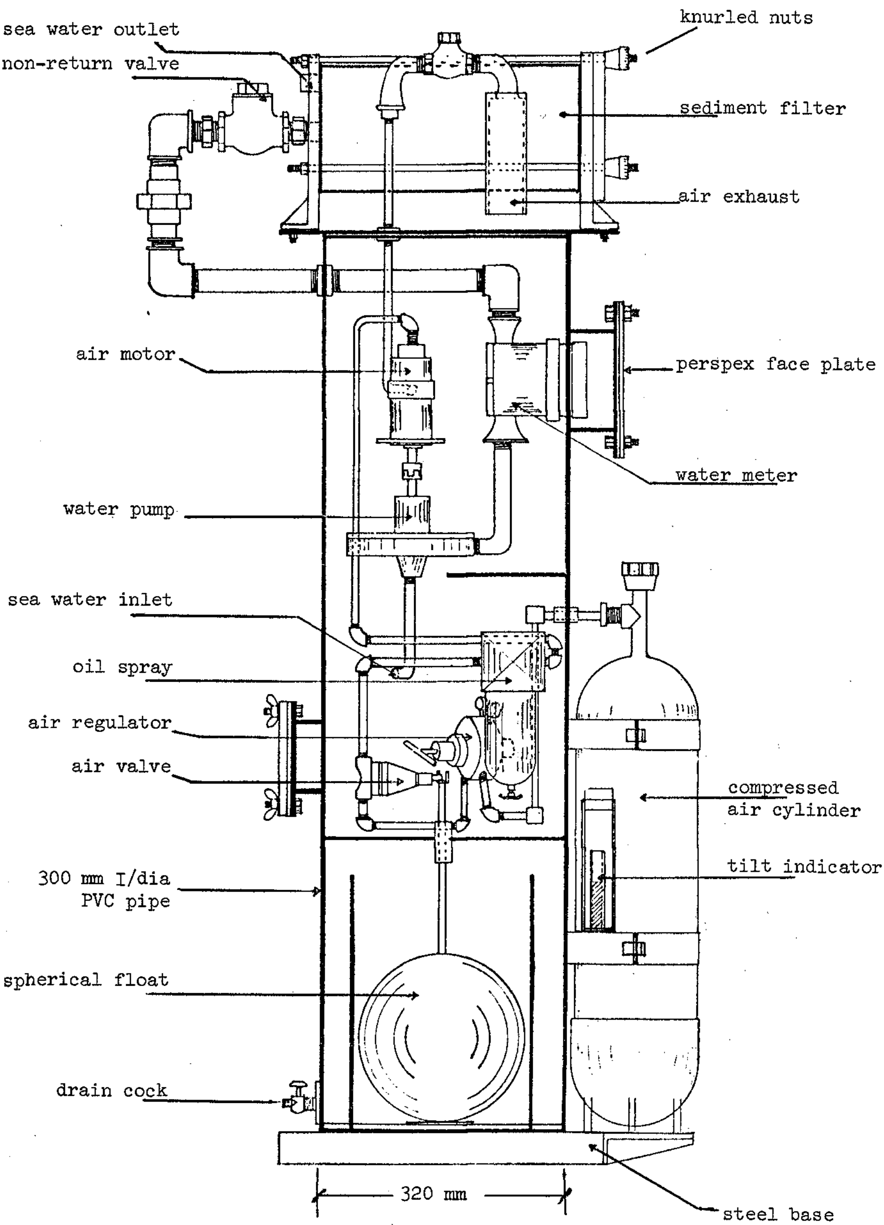
Vacuum sampler system

Helicopter sampler (no I) on beach

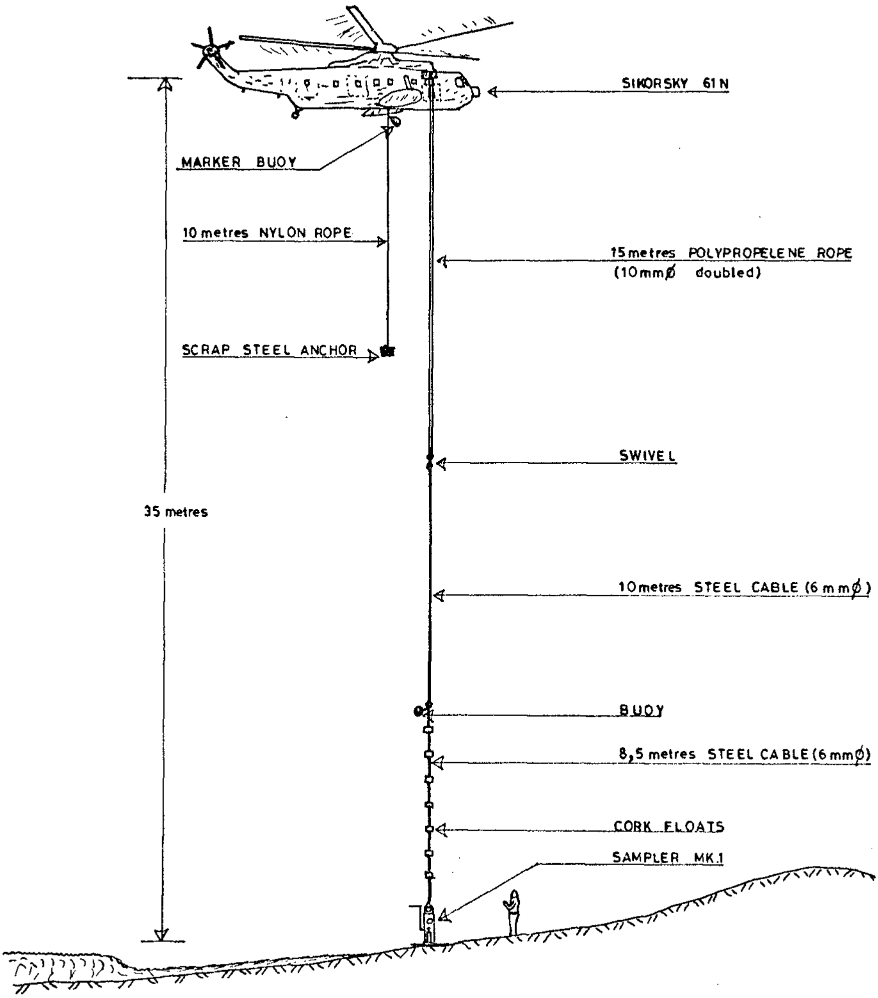
Sampler I

Helicopter supported

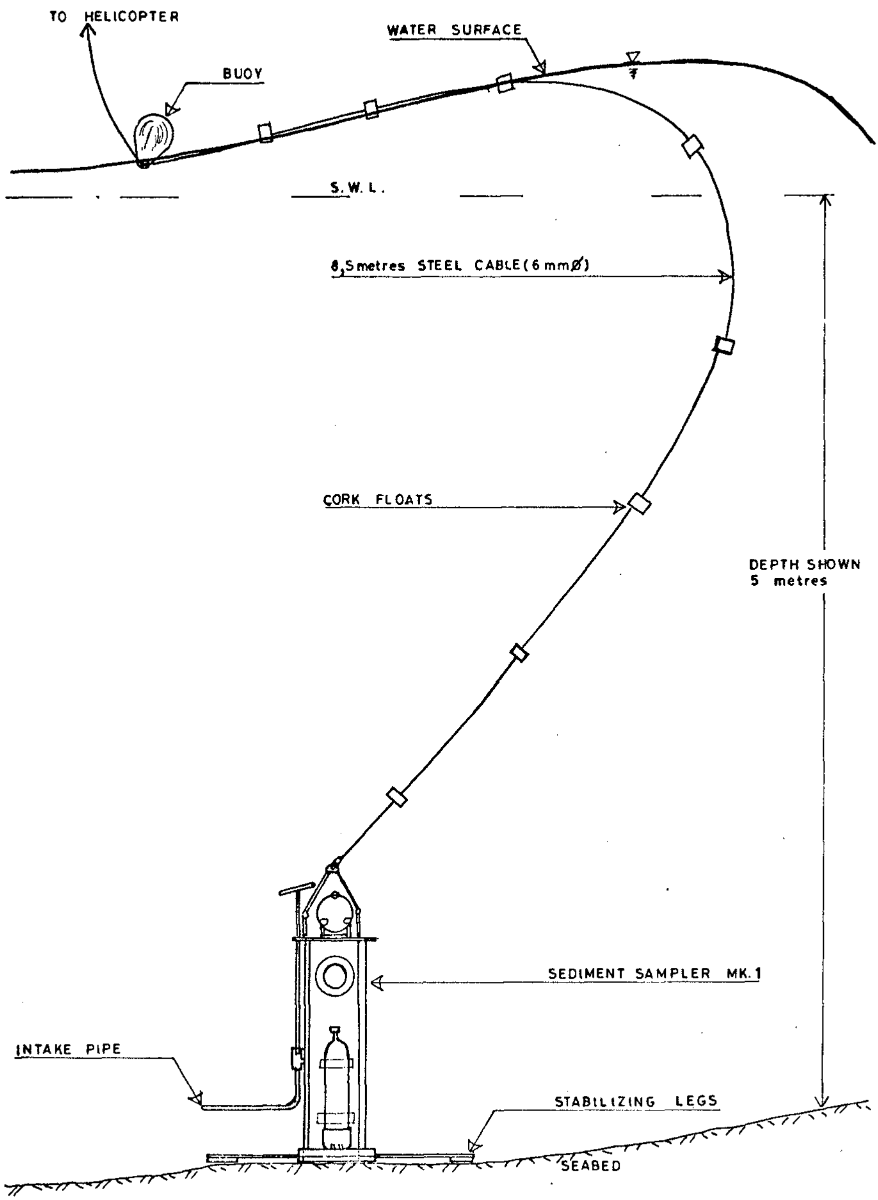
Overall height 1,4 m



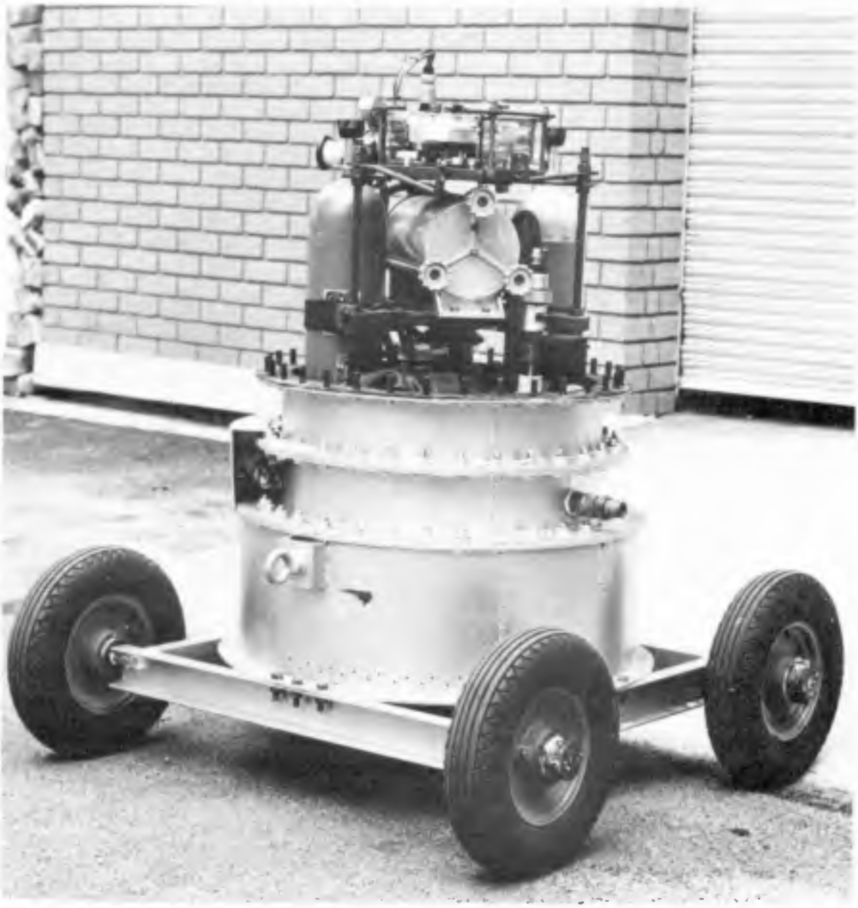
Helicopter sampler (no I)
being prepared on the beach



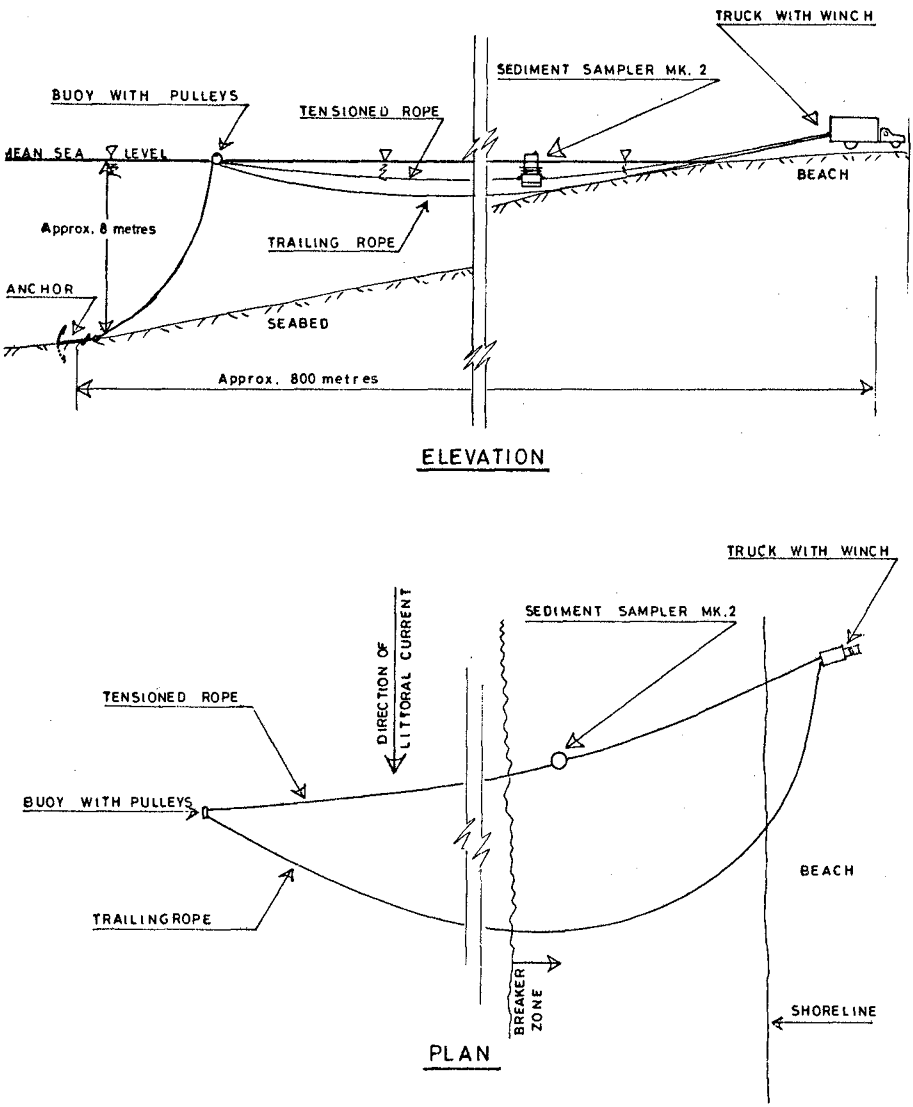
Helicopter sampler (no I)
on sea bed



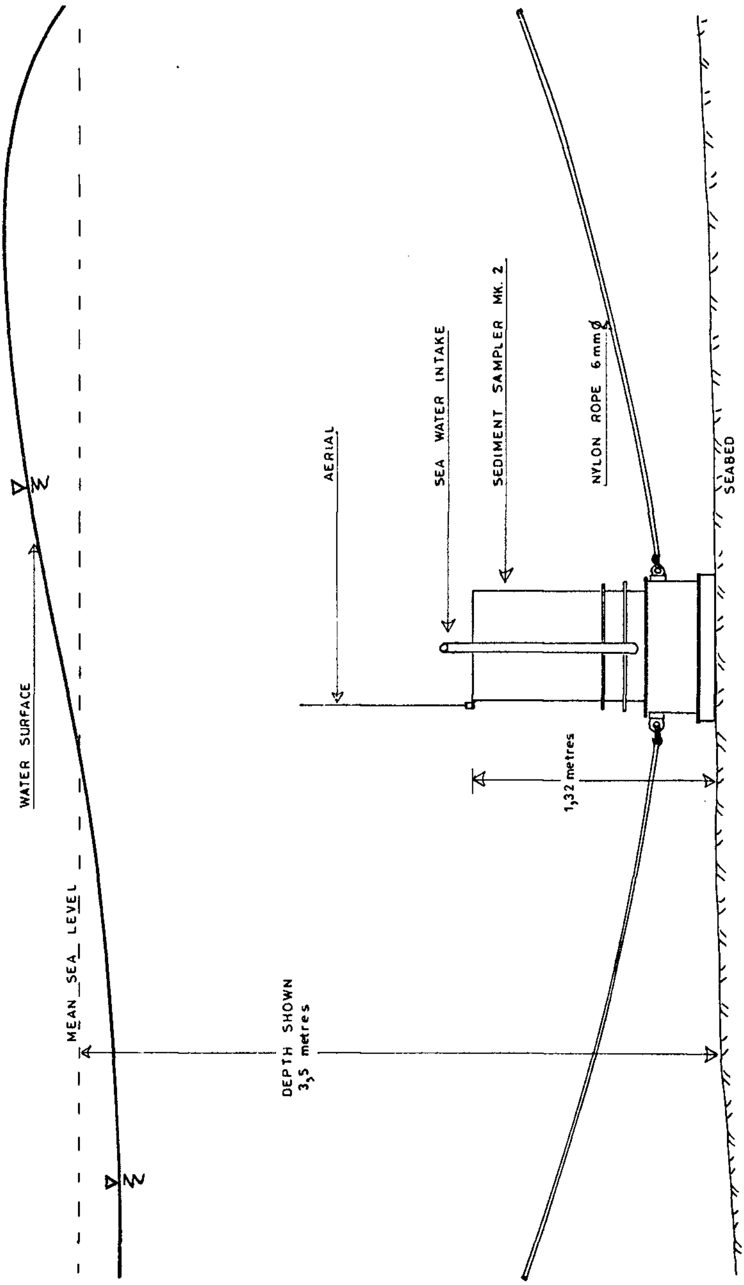
Sediment sampler no II



Operational configuration
for sampler no II



Sediment sampler no II on sea bed



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