CHAPTER 4

BUOYANT MONITORING STATIONS

4.1 INTRODUCTION

Buoyant monitoring stations platforms are those in which the monitoring sensors have certain degree of spatial mobility: vertically (*e.g*. by tides), and/or horizontally (*e.g*. by currents). Many different buoyant monitoring stations platforms exist for a wide range of near-shore, coastal and offshore applications. For shallow waters, buoyant systems can be subdivided into:

- **Surface Buoy**: one or several surface buoys are used as the monitoring sensors holding systems. These systems can be also used for profiling.
- **Subsurface**: subsurface buoys are used to maintain the monitoring sensor beneath the water surface at a distance much greater than what is achieved with a surface buoy.
- **Stationary Structure**: an existing structure or a specially constructed one is used to hold a floating device where the monitoring sensor is placed. The monitoring sensor has a restricted vertical movement.

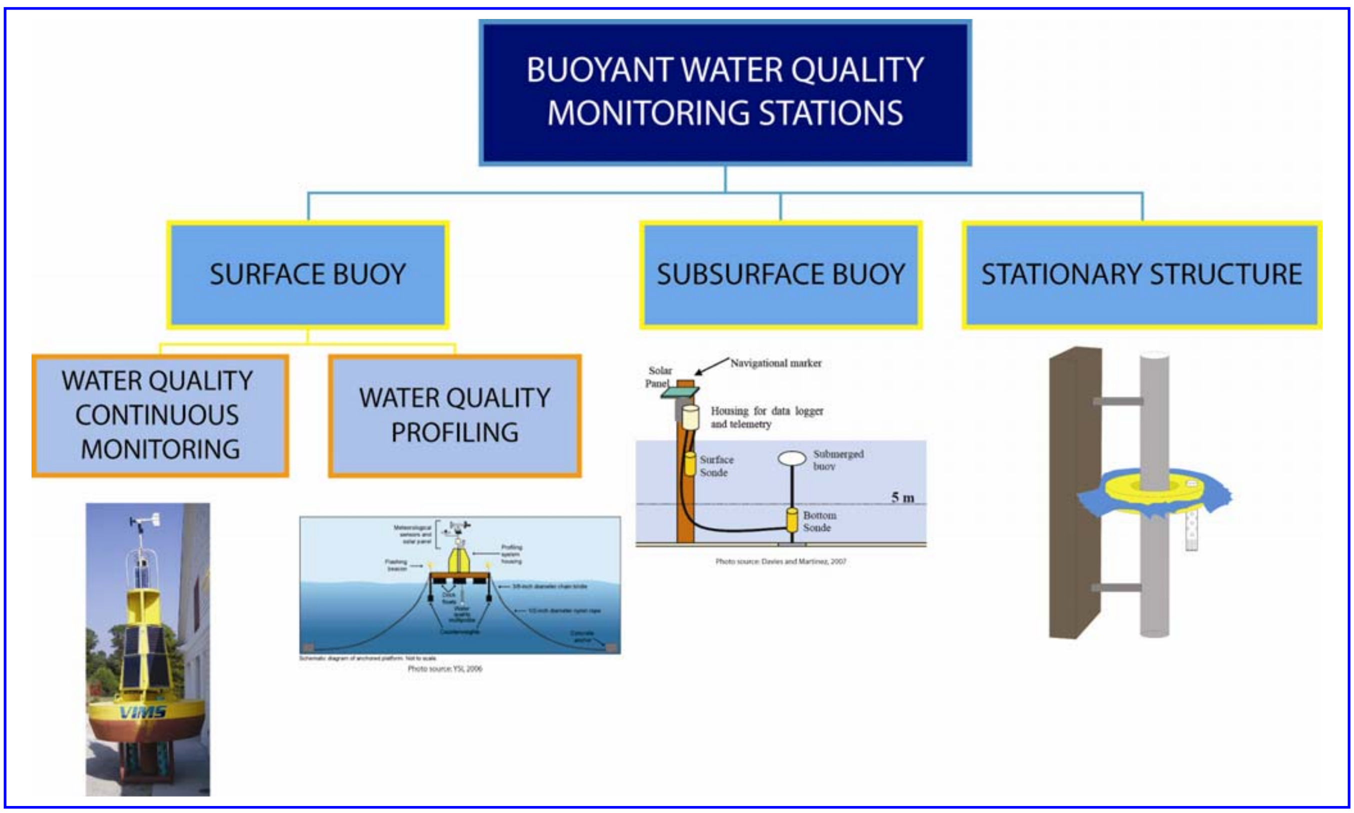

Figure 4.1 Types of near shore buoyant monitoring stations

It is not the intent of this section to provide design guidelines, or description of advantages or disadvantages of each type of buoy or mooring system. The main purpose of this chapter is to present the reader with a brief insight of three types of shallow water buoyant systems to enhance the decision-making process.

4.2 SURFACE BUOY

In its most simple configuration; a surface buoy system can be seen as one float, one line, one anchor and possibility some ancillary equipment (Berteaux, 1976). A great variety of buoys for near-shore, coastal and offshore applications have been designed; the shape, the dimension of the float, and the type of anchoring depend on the system purpose or performance requirements, as well as the characteristics of the environment where the buoy is going to be deployed.

For continuous water quality monitoring in shallow waters, a surface buoy is a good alternative to use when:

- Local regulations prohibit installation of a permanent structure
- Water is too deep to use a fixed station.
- Vandalism has high probabilities to occur at fixed structures.

Berteaux (1976), subdivides the surface buoy systems into: single point and multileg moored systems.

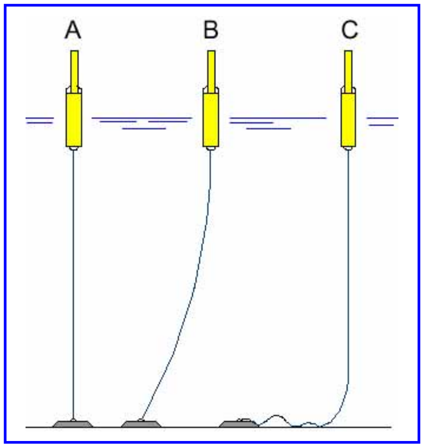

Figure 4.2 Mooring systems types (Soruce: CCG, 2001)

Single point moored surface buoy systems: systems that have only one anchoring point. These are subdivided depending in the ratio of the mooring line length to the water depth. A small ratio results in a taut moor, and a large scope in a slack moor.

The CCG (2001) subdivides the ratio into three categories (Figure 4.2):

(A) Taut: recommended where there is minimal variance of water level, low currents, and small waves; requires a larger size anchor than semi-taut or catenary.
(B) Semi-taut: provides just a little more movement for the buoy than the previous category.
(C) Catenary: employs longer lengths of mooring line which allows absorbing better the energy than the other two categories.

Multileg surface buoy systems: systems that have two or more anchoring points. Even though these systems are more expensive, they have certain advantages: reduced horizontal motion, allows for small-scale studies, and increased reliability; thus increasing life expectancy (Figure 4.3).

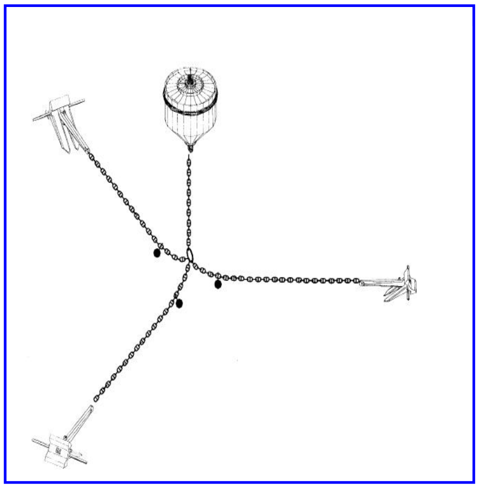

Figure 4.3 Single point mooring with drag anchors
(Sorce: U.S. Army Corps of Engineers *et. al.*,2005)

The first step in deciding whether to purchase or design a surface buoy monitoring station is to define the design characteristics that the system must have. For this goal in mind, the following flowchart may be of help (Berteaux, 1976).

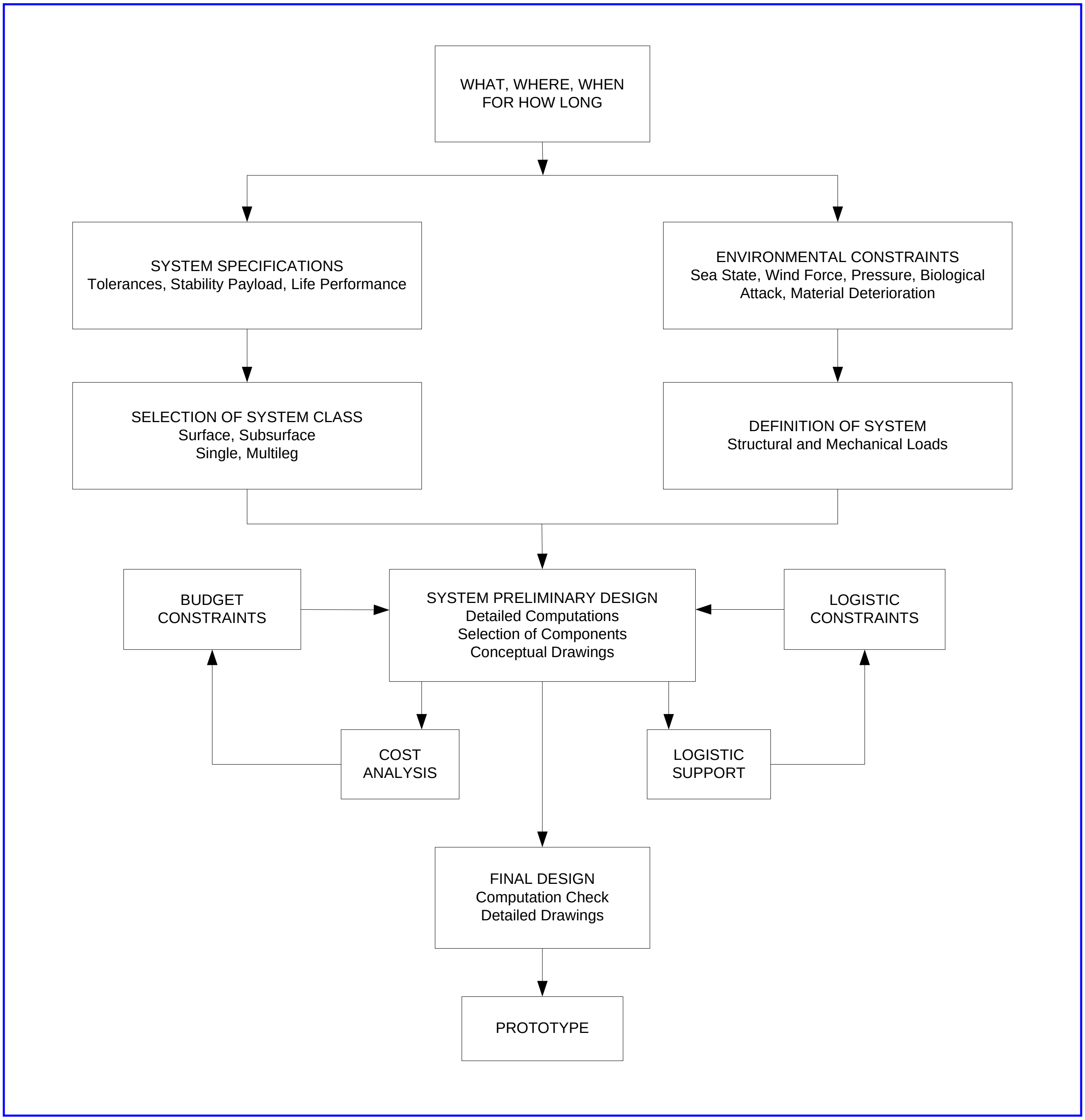

Figure 4.4 Buoy design flowchart (Soruce: Berteaux, 1976)

Most commonly, surface buoys are purchased directly from manufacturers or suppliers. This option provides a high reliability if the interested party does not have the qualified professional experience in building buoys and mooring systems. A list of various buoy manufactures can be found in
http://www.dbcp.noaa.gov/dbcp/1lobm.html

If construction is being considered, certain design characteristics must be considered to determine if the decision is viable or not. Among them, the most important are:

- Construction material: Common materials are steel, rigid plastic foam, rigid molded plastics, rubber or wood. Each material has its advantages and disadvantages.

- Mooring system: The mooring system must be reliable and effective to withstand all the forces that exert on the buoy (*e.g*. wind, currents, waves, and/or ice), and ensure the monitoring buoy stays in position to comply with the monitoring objectives.

  In order to design an appropriate buoy mooring, the following design characteristics must be assessed (CCG, 2001): buoyancy, system type, mooring length (scope), mooring material and mooring anchor.

> It is a good practice that the mooring systems be designed by a qualified professional.

Paul *et al.* (1999) describe, in detail, certain mooring concerns in shallow waters

> "*The vertical displacement of a surface platform in waves, is about equal to the wave height for most buoy types. With decreasing water depth, the wave height and heave become an increasing fraction of the water depth. In order to anchor a buoy safely in shallower water, the demands on the mooring link increase dramatically. A 15-m storm wave requires a taut mooring tether with an elastic stretch of <1 percent in 2,000 m of water, 8 percent in 200 m of water, 46 percent in 40 m or water, and 120 percent in 20 m of water.*
>
> *When anchored with a taut mooring, a surface buoy's "uphill" heave movement, forced by a passing wave crest, requires a rapid extension of the mooring link. This extension is required to prevent the buoy being pulled under by the passing wave peak. The buoy's subsequent "downhill" fall into the wave trough requires rapid retraction of the mooring link in order to avoid slack mooring conditions with subsequent snap loading when the buoy descends into the wave trough and subsequently raises again.*
>
> *The severe wave effects in exposed, shallow water sites, limit mooring configurations that can endure service without early fatigue failure or dynamic overloading. Workable configurations for surface buoy moorings with a minimum water depth of 20 to 30 meters are*:

TYPES OF MOORING	PRACTICAL WATER DEPTH
Elastomeric Tension Member (ETM) moorings	*Practical minimum water depth of 20 meters*
Chain catenary moorings	*Practical maximum depth is limited to about 300-900 meters depending on the chain quality*
S-Tether moorings	*From 30 meters to full ocean depth*
Medium and high stretch rubber hose moorings	*For minimum water depth of 20 meters (currently under development at WHOI)*

CCG (2001) emphasize the importance of the choice of the mooring material and provide a good summary of recommended mooring materials (Table 4.1). For example, chain is a good option to use with certain types of buoys, but not with others, given the added chain weight.

		Material	Type
Synthetic Rope	Has the advantage of being light. Prone to wear in the thrash area (the length near the bottom that rubs the sea floor) and is easily vandalized or cut. Recommended for small buoys in sheltered locations.	**Nylon**: High strength and elasticity; Good abrasion resistance; Can maintain heavy loads; Relatively low cost. **Polyester**: High strength and elasticity; Heaver weight. **Polypropylene**: Most popular material; Good strength; Elongation and seawater; Performance; May deteriorate if in direct sunlight. **Polyethylene**: Not as strong or as buoyant as polypropylene; Recommended for non critical applications only.	**Twisted**: Offer good strength; Easy handling; Tend to "unravel" when placed under load; may cause failure. **Plaited**: Resists rotation and will not kink or twist; Good strength, weight and elongation. **Braided**: Higher in strength / durability and lower in elongation; Very pliable and easy to handle; More difficult to splice; Higher cost; Single and solid-braided types are more reliable than double-braided.
Wire Rope	Stronger than synthetic rope and not as prone to wear will rust and fray, therefore; Most difficult to handle and maintain.		
Chain	Coast Guard's preferred choice for most buoys; Not as prone to wear nor can it be cut or vandalized; Due to its weight, chain enhances upright stability; Allows for use of smaller sinkers; Energy absorbing due to weight.	**Steel Alloy**: Most common; **Carbon Steel**: Highest strength and durability; **Multiple or Chromium / Nickel Alloys**: May fail due to stress, cracking, corrosion and fatigue.	**Open Link Chain**: Most common type used for mooring; **Stud Link Chain**: Provides for extra strength; Heavier than open link.

Table 4.1 CCG recommended mooring materials (extracted directly from CCG, 2001)

There is plenty of literature that explains different mooring technology, *i.e*. Tupper, *et al.*, 2000; Berteaux, 1976; Cuetara *et al.*, 2001, among many others. Schematic drawings can be found in many publications, for example Bosart and Sprigg (1998) show six standard moored buoy hull types used by NOAA-NDBC.

The reader can consult Cluney and Kinner (2000) to get some design guidelines to construct a simple buoy for very low energy sites that employs a multi-parameter monitoring sonde.

Given the high costs of buoy purchase or construction, an alternative is to use existing navigation aid buoys to place the monitoring sensors if permission is granted.

4.2.1 Profiling

If water quality measurements for the entire water column are needed in a continuous basis, a vertical profiling system may be used. Reynolds-Fleming *et al.* (2002) describe the design and implementation of a portable autonomous vertical profiler. Private companies, such as YSI Inc., provide profiling turn-key systems. For example, YSI has a line of vertical profiling systems that come in two deployment configurations:

- Fixed: ideal for mounting on piers, dams, and bridges
- Buoy: for deployment in lakes, reservoirs, and coastal environments

An example of profiling monitoring can be found in

http://nevada.usgs.gov/lmqw/profiling_system.htm

where the USGS use a profiling system to monitor water quality in Lake Mead. The system automatically performs water quality profiles at user defined time intervals and depths.

4.3 SUBSURFACE

Berteaux (1976) mentions that subsurface buoys are used when measurements at or near the surface are not required. Given that the buoy is under water, dynamic loads and sensor movement due to wave actions are suppressed. Berteaux identifies two types of subsurface buoys systems: simple point moored and multileg moored system.

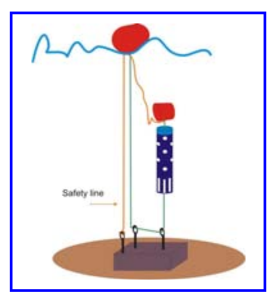

Figure 4.5 Sketch of a subsurface system

In shallow waters, many possible subsurface monitoring systems can be designed. A sketch of a simple subsurface system is shown in Figure 4.5. This system employs two buoys; a subsurface buoy to keep the multiparameter sonde in a vertical position, and a surface buoy as the site marker (Figure 4.6).

Figure 4.6 Subsurface buoy at Lynnhaven, VA

Another example of a subsurface buoy application is displayed in Figure 4.7. A subsurface buoy was employed at New Bedford Harbor Superfund Site for water quality monitoring to provide field reconnaissance information to the United States Army Corps of Engineers and the United States Environmental Protection Agency. The monitoring site was subject to tidal fluctuations ranging from 2 to 7 feet. Due to this tidal fluctuation and the relatively shallow water, a subsurface buoy was the preferred for characterization of the entire water column.

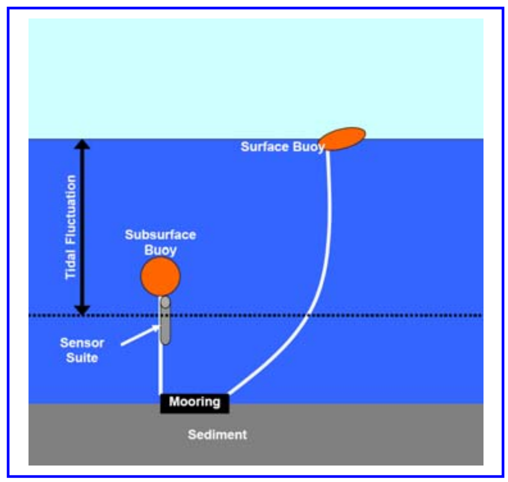

Figure 4.7 Application of subsurface buoy at New Bedford Harbor
(Soruce: Battelle, 2007)

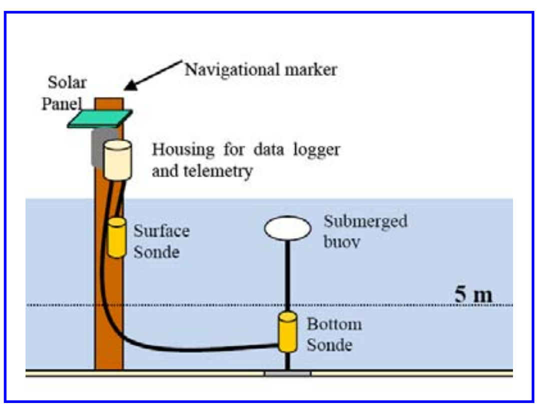

Figure 4.8 Application of subsurface buoy at Lakes King and Lake Victoria
(Source: Davies and Martinez, 2007)

Figure 4.8 shows another example of a submerged buoy application. Here two datasondes were employed to monitor water quality at Lake King and Lake Victoria, part of the Gippsland Lakes, a series of large estuarine lakes situated in the south-eastern corner of Australia. A subsurface buoy was employed to place a datasonde below depths of 5 m where a strong halocline generally occurred.

Subsurface monitoring has some advantages:

- Can minimize vandalism
- Can be used to continuously measure water quality at various water depths. For example, two or more sensors can be set at different water depth (*i.e.*, in the same vertical line).
- These types of systems can be used when water quality monitoring is needed close to the bottom in areas where fixed stations cannot be built. For example, Figure 4.9 shows a subsurface system in a very sensitive area (coral reef).

Figure 4.9 View of subsurface sensor
(Source: Y S I Environmental Pure Data for a Healthy Planet)

4.4 STATIONARY STRUCTURE

In a stationary structure buoyant system, an existing or a special designed structure is used to hold the floating device where the monitoring sensor is placed.

A floating dock is an existing stationary structure that can be used to secure the guard-pipe (Figure 4.10).

Figure 4.10 Water quality monitoring station at Norwalk Harbor.
(Source: University of Connecticut)

Structures to hold a floating device can be easily constructed; for example, existing pilings, such as navigation aids pilings, or PVC pipes can be used for this purpose. Figure 4.11 shows a sketch of a stationary structure on a pier, where a pile is used to hold in place ring type buoy.

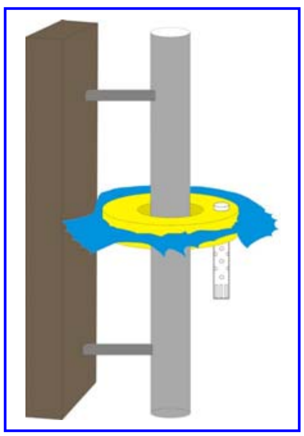

Figure 4.11 Sketch of a designed stationary structure buoyant system

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4.5.1 Photo Reference

Figure 4.1

YSI Photo – YSI Inc, 2006. **Monitoring and Protecting Water Quality in Lake Mead, Nevada**. Application Notes. 0506 A539. Photo originally from US Geological Service Water Resource of Nevada. Water Quality Monitoring at Lake Mead. http://nevada.usgs.gov/lmqw/instrumentation.htm

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Figure 4.2 - Canadian Coast Guard. 2001. An Owner's Guide to Private Aids to Navigation.

Figure 4.3 - U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Support Agency (AFCESA). 2005. DESIGN: MOORINGS. Unified Facilities Criteria (UFC) . UFC 4-159-03.

Figure 4.7 - Battelle. 2007. Final Water Quality Monitoring Summary Report. 2006 Remedial Dredging. Environmental Monitoring, Sampling, and Analysis. New Bedford Harbor Superfund Site. Contract Number: DACW33-03-D-0004.

Figure 4.8 - Davies, W.R. and Martinez, G., 2007. An Integrated Observation Network for Gippsland Lakes: Balancing the Needs of Science and Management. Journal of Coastal Research. Edited by C.J. Lemckert.. Special Issue No. 50. Proceedings of the 9th International Coastal Symposium. Pp. 57-61Griffith School of Engineering. Gold Coast, Queensland, Australia.

Figure 4.9 – Robert H. Richmond . University of Hawaii Kewalo Marine Laboratory. Photo in Integrating Coral Reef Ecosystem Management with Watershed-based Activities. YSI Inc. Application Notes.

Figure 4.10 - LISCOS **-**- The Long Island Sound Integrated Coastal Observing System. Norwalk Harbor Station. Department of Marine Science. University of Connecticut. http://lisicos.uconn.edu/about_nwkh.php

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