Chesapeake Bay
National Estuarine
Research Reserve
in Virginia

GUIDELINES

SHALLOW WATER QUALITY MONITORING

CONTINUOUS MONITORING STATION: SELECTION, ASSEMBLY & CONSTRUCTION

Eduardo J. Miles
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CHESAPEAKE BAY
NATIONAL ESTUARINE RESEARCH RESERVE
IN VIRGINIA

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By Eduardo J. Miles

Contributing Authors:

The following people collaborated in this document by providing construction and assembly ideas and guidelines, expert advice and by reviewing and editing the document.

William Reay, Director - CBNERRVA
Jim Goins, Field Manager - CBNERRVA
Voight Hogge, Laboratory and Field Specialist - CBNERRVA

In addition, this document reflects the collaborative efforts of the whole CBNERRVA group: Ken Moore, Betty Berry Neikirk, Joy Austin, Amber Knowles, Alynda Miller and Steve Snyder.

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PREFACE

Multi-parameter sondes are becoming the standard instrument to assess water quality in shallow waters. Their ability to measure a number of different water quality parameters in situ, unattended, and in short time intervals, makes them the ideal monitoring equipment to characterize water quality variability in of various types of water bodies.

In order for the multi-parameter sonde to fulfill its capabilities, site and station configuration selection must be properly addressed. The monitoring and data quality objectives provide the basic information for site selection. Once the site is selected, the station configuration can be defined.

Research has shown that most of the project's life-cycle quality and cost are committed by the decisions taken by the end of the planning and design stages. One of the best practices employed to improve quality, prevent errors, and minimize cost during the planning and design stages is by adapting, or reviewing, known techniques or processes that have shown through experience to achieve the desired results in a reliable, efficient, and effective way.

CBNERRVA has been performing continuous shallow water quality monitoring for more than ten years. During this time, several monitoring platforms have been developed that take into account certain design characteristics that are considered important when a proper balance between cost and operational performance is desired.

The purpose of this manual is to provide monitoring teams with guidelines to enable them maximize the effectiveness and efficiency of the station configuration selection process. Based on experience gathered at CBNERRVA, it is a good practice to review, at the beginning of the station selection process, the different types of platform configurations, and assess which configuration can work best in the specific monitoring environment. The manual provides basic information on monitoring platforms that can either be used to select a specific configuration or to define new design features to meet the particular needs of the monitoring program.

Reference in this manual to a specific multiparameter sonde is for the purpose of illustration only and should not be regarded as an endorsement of a particular brand.

About the author

Eduardo Miles

Mr. Miles is a Marine Scientist at Chesapeake Bay National Estuarine Research Reserve in Virginia (CBNERRVA). Prior to this position he worked in Uruguay doing consulting work in diverse areas, such as reengineering, processes design and improvement and project evaluation. He is in charge of the quality issues in PROFAUMA (Protection of Marine Fauna) an Uruguayan non-profit non-governmental organization. Mr. Miles holds a B.S. degree in Electrical and Industrial Engineering from the Republic University of Uruguay, a M.S. degree in Environmental Engineering and a M.E. degree in Industrial and Systems Engineering from Virginia Polytechnic Institute and State University.

The author is welcome to provide additional information or answer any inquiries in regard to these guidelines. Please contact at (804) 684-7135 or emiles@vims.edu.

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INTRODUCTION

i. WATER QUALITY MONITORING: PURPOSE

Water quality monitoring projects are executed to answer a variety of questions, or address concerns, that managers, researchers, policy makers, and other stakeholders have with regard to biological or physical interactions, water usage, recreation and aesthetics, or status of water bodies among many other water issues or concerns.

As any other type of monitoring project, there are some critical success factors that must be properly addressed for a water quality-monitoring project to be successful. A clear understanding of the monitoring purpose by the monitoring team is one of these critical factors (*i.e.*, what is or are the problems to be analyzed? and what are the questions to be answered?). It is crucial to understand that the monitoring objectives are defined by the monitoring purpose. The entire water quality monitoring effort may be unsuccessful if the objectives are not clearly defined, or understood by those conducting the project and those receiving the final results (Spooner and Mallard, 2003).

One problem facing the water monitoring community is the lack of consensus among the different agencies, institutions and organizations on the definition of the different types and terminology of water quality monitoring (Ward2 *et al*.). In this regard, the Intergovernmental Task Force on Monitoring Water Quality (ITFM) carried out a review of water-quality monitoring activities from 1992 to 1997, recommending several improvements concerning water quality monitoring terminology, process and methodology. In 1997, the ITFM was reconstituted with representatives of both public and private sectors, as the National Water Quality Monitoring Council, with the objective to provide a national forum for the coordination of consistent and scientifically defensible methods and strategies to improve water quality monitoring, assessment and reporting. This endeavor will have positive results in the near future. Meanwhile, there are some terms being used that are worthy of mention:

> *The International Organization for Standardization (ISO) defines monitoring as "the programmed process of sampling, measurement and subsequent recording or signaling, or both, of various water characteristics, often with the aim of assessing conformity to specified objectives".*
>
> *Water-quality monitoring is defined by the Intergovernmental Task Force on Monitoring Water Quality (ITFM) as "an integrated activity for evaluating the physical, chemical, and biological character of water in relation to human health, ecological conditions, and designated water uses".*

The Intergovernmental Task Force on Monitoring Water Quality (ITFM) (1995), as well as the Environmental Protection Agency (USEPA), defines five major monitoring purposes:

1. *Characterize waters and identify changes or trends in water quality over time.*

2. *Identify specific existing or emerging water quality problems.*

3. *Gather information to design specific pollution prevention or remediation programs.*

4. *Determine whether program goals, such as compliance with pollution regulations or implementation of effective pollution control actions, are being met.*

5. *Respond to emergencies, such as spills and floods.*

These major monitoring purposes are not mutually exclusive and some monitoring endeavors can meet more than one of these purposes at the same time.

The European Union (Working Group 2.7 – Monitoring, under the Water Framework Directive, 2003) describe three types of monitoring for surface waters: surveillance, operational and investigative monitoring. Ward *et al.* (2003) summarizes very well these three types of monitoring "*Surveillance monitoring is done to supplement and validate impact assessment procedures, for the design of future monitoring programmes, and for the assessment of long-term changes both in natural conditions and changes resulting from anthropogenic activities. This monitoring is done to keep track of changes in the water body. Operational monitoring is carried out for all those bodies of water, which on the basis of either the impact assessment or surveillance monitoring, are identified as being at risk of failing to meet their environmental objectives and for those bodies of water into which priority list substances are identified as being discharged. Investigative monitoring, finally, is carried out when the reason for any exceedance of standards is unknown, when surveillance monitoring indicates that the environmental objectives for a body of water are not likely to be achieved in order to ascertain the causes of the failing, or to ascertain the magnitude and impacts of accidental*".

Another classification is given by Cavanagh *et al*. (1998) who classify the purposes of the monitoring programs into four broad categories: compliance, trend, impact assessment, and survey. Each monitoring program involves a series of water quality measurements intended to detect short, or long-term variability of the water body studied (see appendix i).

The California Rangelands Research and Information Center (1995) gives another classification defining seven types of monitoring according to the parameters being measured, the frequency and duration of monitoring, and the data analysis. The seven types are: trend, baseline, implementation, effectiveness, project, validation, and compliance. It is emphasized that the seven types of monitoring are not mutually exclusive and the difference between them is due to the monitoring goal rather than the intensity, or type of measurements. In general, a water quality-monitoring project would involve a mixture of these seven types of monitoring. Thus, the same measurements can be used to comply with different monitoring goals (see appendix i).

ii. WATER QUALITY MONITORING: PROCESS

Even though is not the purpose of this manual to address all the necessary steps to design an effective water quality monitoring program, it is important to outline certain points that must be considered in order to collect data that consistently represent the existing environmental conditions.

In general, water quality monitoring is performed to answer a question that is linked, in one way or another, to a management concern (*e.g.* policy formulation, environmental protection, compliance, development concerns). Therefore, one of the main objectives of a water quality-monitoring endeavor is to provide the necessary information to answer specific questions in decision-making. In order to achieve this objective, a systematic process must be followed to address the monitoring project. The systematic process will ensure that the data collected can answer the questions with the degree of confidence required.

There are several systematic processes that have being designed for water quality monitoring projects, among them, the following processes are worth to mention:

1. The National Water Quality Monitoring Council (2003) proposed a framework for water quality monitoring programs composed of six phases considered critical to the establishment of a reliable water quality monitoring program: develop monitoring objectives; design monitoring program; collect field and lab data; compile and manage data; assess and interpret data; convey results and findings. In addition, the framework contains 3C's: collaborate, communicate, and coordinate; which are an integral part to each of the elements of the framework (appendix ii).

2. The EPA (2003) recommends ten basic elements of a State water monitoring and assessment program which serves also as a tool to help EPA and the States determine whether a monitoring program meets the prerequisites of CWA Section 106(e)(1). The ten elements are: monitoring program strategy; monitoring objectives; monitoring design; core and supplemental water quality indicators; quality assurance; data management; data analysis/assessment; reporting; programmatic evaluation; and general support and infrastructure planning.

3. The UN/ECE Task Force on Monitoring & Assessment (2000) proposes a monitoring cycle composed of: water management; information needs; assessment strategies; monitoring programmes; data collection; data handling; data analysis; assessment and reporting and information utilisation (appendix ii).

4. The Australian and New Zealand Environment and Conservation Council and the Agriculture and Resource Management Council of Australia and New Zealand (2000) propose monitoring guidelines, which lay out the framework and general principles for a water quality-monitoring program. The guidelines have the following elements: determining the primary management aims; setting monitoring program objectives; study design; field sampling program; laboratory analyses; data analysis and interpretation; reporting and information dissemination (appendix ii).

It is crucial that a systematic planning process is followed in the development of any type of water quality monitoring program. By executing a systematic planning process, the interested party will ensure that the data collected is of the appropriate type and quality for the intended use, and will accurately represent the water body. In addition, it will ensure that the appropriate monitoring and analysis technologies are used to yield unbiased and reproducible results (EPA, 2000).

The four systematic processes highlighted in this manual can be used to ensure a sound monitoring project.

Additional information in how to design a water quality-monitoring program can be found in:

- National Water Quality Monitoring Council (2003)
  http://water.usgs.gov/wicp/acwi/monitoring

- UN/ECE Task Force on Monitoring & Assessment (2000)
  www.unece.org/env/water/publications/ documents/guidelinestransrivers2000.pdf

- The Australian and New Zealand Environment and Conservation Council and the Agriculture and Resource Management Council of Australia and New Zealand (2000).
  http://www.deh.gov.au/water/quality/nwqms

- U.S. Environmental Protection Agency (2003).
  http://www.epa.gov/owow/monitoring/elements

- MacDonald *et al*. (1991), MacDonald (1994), Sanders *et al*. (1983), DEQ (2003), White (1999). Ward, R.C., and Peters, C.A. (2003).

iii. CONTINUOUS WATER QUALITY MONITORING

There are many types of water sampling methods that can be used to collect water quality data. For example: collection by hand, automatic sampler, remote sensing, or direct field observations. The nature of the required information and the parameters to be measured will determine the best method to apply.

Continuous monitoring is becoming a standard to determine shallow water quality. Multiparameter sondes are increasingly being used to monitor water quality at fixed monitoring sites, to carry out vertical profiling, or to perform water quality mapping (dataflow).

Continuous monitoring is the sampling method of choice when water quality variations are to be characterized over time. Some characteristics of automated water quality monitoring are:

- → Capability of measuring a number of different water quality parameters in situ, unattended, and in short time intervals.
- → Provide continuous water quality data that can be accessible in a timely basis, be transmitted directly by telemetry, and be published on the web in real time.
- → The information can be used to track real time environmental events, *i.e.* algal blooms or hurricanes.
- → The sampling intervals can be set to detect water quality variations specific to the study site.
- → The data can be used in conjunction with remote sensing, *i.e.* atmospheric corrections.

Continuous water quality monitoring has certain critical factors that must be properly addressed in order to assure the quality of the data collected. Two of these critical factors are: site and station configuration selection.

Site selection is not a straightforward task. The monitoring sites must be selected to comply with the monitoring and data quality objectives. Given that it is not possible to sample the whole target area, it is essential that the stations be placed where representative samples can be obtained, and where the data measured represents accurately and precisely the water body.

One activity that is closely linked to site selection is the determination of the type of monitoring station to be used. Once a monitoring site is selected, certain station designs will be more suitable than others to achieve the monitoring and data quality objectives.

There are a great variety of continuous monitoring station configurations with different designs and construction methods to be considered during the monitoring platform

selection process. Even though no universal design, assembly and construction procedure can be recommended, there are some stations configurations that are becoming the standard in shallow water monitoring. This document provides an overview of these shallow water quality monitoring platforms. Most of the configurations described here are based on the experience gathered over more than ten years of conducting continuous shallow water quality monitoring projects at the Chesapeake Bay National Estuarine Research Reserve in Virginia (CBNERRVA).

iv. REFERENCE

Bartram, J. and Ballance, R. [Eds]. 1996. **Water Quality Monitoring; A Practical Guide to the Design and Implementation of Fresh Water Quality Studies and Monitoring Programmes**. Chapman & Hall, London.

California Rangelands Research and Information Center. 1995. **Types of Monitoring. Agronomy and Range Science**. Monitoring Series No. 1. University of California at Davis.

Cavanagh, N., R.N. Nordin, L.W. Pommen and L.G. Swain. 1998. **Guidelines for Designing and Implementing a Water Quality Monitoring Program in British Columbia**. Ministry of Environment, Lands and Parks. Province of British Columbia.

Chapman, D. 1996. **Water Quality Assessments. A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring**. 2nd edition (edited by D. Chapman and published on behalf of UNESCO, WHO and UNEP by Chapman & Hall, London, 1996)

DEQ (2003). Virginia Department of Environmental Quality. **Virginia Citizen Water Quality Monitoring Program - Methods Manual**.

Intergovernmental Task Force on Monitoring Water Quality. 1995. **The Strategy for Improving Water-Quality Monitoring in the United States**. Final Report of the Intergovernmental Task Force on Monitoring Water Quality. Open File Report 95-742, U.S. Geological Survey, Reston, Virginia. Available at http://water.usgs.gov/wicp/itfm.html

MacDonald, L.H. 1994. **Developing a monitoring project**. Journal of Soil and Water Conservation. 49(3): 221-227.

MacDonald, L.H., Smart, A.W. and Wissmar, R.C. 1991. **Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska**. Center for Streamside Studies (CSS). United States Environmental Protection Agency. Water Division.

National Water Quality Monitoring Council (NWQMC). 2003. **Seeking a Common Framework for Water Quality Monitoring**. Water Resources IMPACT. September. Volume 5, Number 5. American Water Resources Association. Virginia.

Sanders, T.G., Ward, R.C., Loftis, J.C., Steele, T.D., Adrian, D.D. and Yevjevich, V. 1983. **Design of Networks for Monitoring Water Quality**. Water Resources Publications, Littleton, Colorado.

Spooner, C.S. and Gail E. Mallard. 2003. **Identify Monitoring Objectives**. Water Resources IMPACT. September, Volume 5, Number 5, pp 11-13. American Water Resource Association.

The Australian and New Zealand Environment and Conservation Council and the Agriculture and Resource Management Council of Australia and New Zealand (2000). **Australian Guidelines for Water Quality Monitoring and Reporting**. Australian and New Zealand Environment and Conservation Council, and the Agriculture and Resource Management Council of Australia and New Zealand

UN/ECE Task Force on Monitoring & Assessment. 2000. **Guidelines on Monitoring and Assessment of Transboundary Rivers**. Institute for Inland Water Management and Waste Water Treatment. Lelystad, Netherlands.

U.S. Environmental Protection Agency. 2003. **Elements of a State Water Monitoring and Assessment Program**. EPA 841-B-03-003. Assessment and Watershed Protection Division. Office of Wetlands, Oceans and Watershed.

U.S. Environmental Protection Agency. 2000. **Guidance for the Data Quality Objectives Process**. EPA QA/G-4

Wagner Richard J., Harold C. Mattraw, George F. Ritz, and Brett A. Smith. 2006. **Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation, and Reporting**. USGS. Techniques and Methods 1–D3.

Ward, R.C., and Peters, C.A. 2003. **Seeking a Common Framework for Water Quality Monitoring**. Water Resources IMPACT. American Water Resources Association. Vol 5, no. 5, Sept. 2003.

Ward, Robert C., Jos G. Timmerman, Charlie A. Peters and Martin Adriaanse. 2003. **In Search of A Common Water Quality Monitoring Framework and Terminology**. Proceedings of the Monitoring Tailor-Made IV Conference. Netherlands.

Ward, Robert C2., Charles A. Peters, Thomas G. Sanders, Jos G. Timmerman and Gared Grube. **In Search of a Common Water Quality Monitoring Glossary**. National Water Quality Monitoring Council Paper
http://water.usgs.gov/wicp/acwi/monitoring/glossary_paper1.1.pdf

Waterwatch Australia - Michael Cassidy. 2003. **Reference Manual: A guide for community water quality monitoring groups in Tasmania**. Waterwatch Tasmania. ISBN 072466748.

White, T.T. 1999. **Automated Water Quality Monitoring**. Field Manual. Water Quality Branch, Environmental Protection Department, British Columbia Ministry of Environment, Lands and Parks.

Working Group 7. **Monitoring under the Water Framework Directive**. European Union. 2003. Common Implementation Strategy for the Water Framework Directive (2000/60/EC). Office for Official Publications of the European Communities. Luxembourg.

APPENDIX i

Cavanagh *et al.* (1998) classification of the monitoring programs purposes

1. Compliance

USGS defines compliance monitoring as a type of monitoring done to ensure the meeting of immediate statutory requirements, the control of long-term water quality, the quality of receiving waters as determined by testing effluents, or the maintenance of standards during and after construction of a project (modified from Resh, D. M., and Rosenberg, V.H., eds., 1993, Freshwater Biomonitoring and Benthic Macroinvertebrates: New York, Chapman and Hall, 488 p)

2. Trend

"*Tend monitoring is used to detect subtle changes over time that may result from a potential long-term problem. Measurements are made at regular time intervals to determine if long-term trends are occurring for a particular variable. Trend monitoring is a commitment that extends over a long period (i.e., usually 10 years or more) to ensure that true trends are detected. It is essential that the program minimizes variability through time. Therefore, as much as possible, the program should remain consistent in terms of frequency, location, time of day samples are collected, and the collection and analytical techniques that are used*."

3. Impact Assessment

"*Impact assessment monitoring measures the effects on water quality of a particular project (anthropogenic) or event (natural). Projects, in this case, refer to anything associated with industrial activities, resource extractive activities, impoundments (dams), agricultural activities, and urban or recreational developments. Events refer to fires, floods, landslides, volcanic activity, etc.*

An ideal impact assessment monitoring program is one that has both test and control sites, is initiated prior to project start-up, continues while the project is operational, and extends for a defined post-project time period. In the case of anthropogenic impacts, it is ideal that the monitoring program be initiated prior to the start-up date of the proposed project. In this case, a baseline (pre-operation/treatment) assessment is carried out which can provide data to which post-treatment data can be compared, and allow for better estimates of the limits of normal variation. The baseline or pilot information should include an inventory of the existing ecosystem components (aquatic and terrestrial flora and fauna) and water uses in the project area. "

4. Survey

"*Survey monitoring is used to characterize existing water quality conditions over a specified geographic area. As such, it is more of an inventory rather than a true monitoring process because it does not address changes over time. It is often conducted within watersheds that have not been previously sampled and which are so remote that there exists little or no direct anthropogenic activity. It is generally carried out in a limited manner (once or twice per lake or river) unless the resulting data promote cause for concern. Consequently, this type of inventory occasionally serves as the first step towards establishing one of the above, more extensive monitoring programs*."

The California Rangelands Research and Information Center (1995) classification

1. Trend monitoring

   "*In view of the definition of monitoring, this term is redundant. Use of the adjective "trend" implies that measurements will be made at regular, well-spaced time intervals in order to determine the long-term trend in a particular parameter. Typically the observations are not taken specifically to evaluate management practices (as in effectiveness monitoring), management activities (as in project monitoring), water quality models (as in validation monitoring), or water quality standards (as in compliance monitoring), although trend data may be utilized for one or all of these other purposes*."

2. Baseline monitoring

   "*Baseline monitoring is used to characterize existing water quality conditions, and to establish a data base for planning or future comparisons. The intent of baseline monitoring is to capture much of the temporal variability of the constituent(s) of interest, but there is no explicit end point at which continued baseline monitoring becomes trend monitoring. Those who prefer the terms "inventory monitoring" and "assessment monitoring" often define them such that they are essentially synonymous with baseline monitoring. Others use baseline monitoring to refer to long-term trend monitoring on major streams*."

3. Implementation monitoring

   "*This type of monitoring assesses whether activities were carried out as planned. The most common use of implementation monitoring is to determine whether Best Management Practices (BMP'S) were implemented as specified in an environmental assessment, environmental impact statement, other planning document, or contract. Typically this carried out as an administrative review and does not involve any water quality measurements. Implementation monitoring is one of the few terms which has a relatively widespread and consistent definition. Many believe that implementation monitoring is the most cost-effective means to reduce nonpoint source pollution because it provides immediate feedback to the managers on whether the BMP process is being carried out as intended. On its own, however, implementation monitoring cannot directly link management activities to water quality, as no water quality measurements are being made*."

4. Effectiveness monitoring.

   "*While implementation monitoring is used to assess whether a particular activity was carried out as planned, effectiveness monitoring is used to evaluate whether the specified activities had the desired effect. Confusion arises over whether effectiveness monitoring should be limited to evaluating individual BMPs, or whether it also can be used to evaluate the total effect of an entire set of practices. The problem with this broader definition is that the distinction between effectiveness monitoring and other terms, such as project or compliance monitoring, becomes blurred*.

   Monitoring the effectiveness of individual BMPs, such as the spacing of water bars on skid trails, is an important part of the overall process of controlling nonpoint source pollution. However, in most cases the monitoring of individual BMPs is quite different

from monitoring to determine whether the cumulative effect of all the BMPs results in adequate water quality protection. Evaluating individual BMPs may require detailed and specialized measurements best made at the site of, or immediately adjacent to, the management practice. Thus effectiveness monitoring often occurs outside of the stream channel and riparian area, even though the objective of a particular practice is intended to protect the designated uses of a water body. In contrast, monitoring the overall effectiveness of BMPs usually is done in the stream channel, and it may be difficult to relate these measurements to the effectiveness of individual BMPs."

5. Project monitoring

"*This type of monitoring assesses the impact of a particular activity or project, such as a timber sale or construction of a ski run on water quality. Often this assessment is done by comparing data taken upstream and downstream of the particular project, although in some cases, such as a fish habitat improvement project, the comparison may be on a before and after basis. Because such comparisons may, in part, indicate the overall effectiveness of the BMPs and other mitigation measures associated with the project, some agencies consider project monitoring to be a subset of effectiveness monitoring. Again, the problem is that water quality is a function of more than the effectiveness of the BMPs associated with the project*."

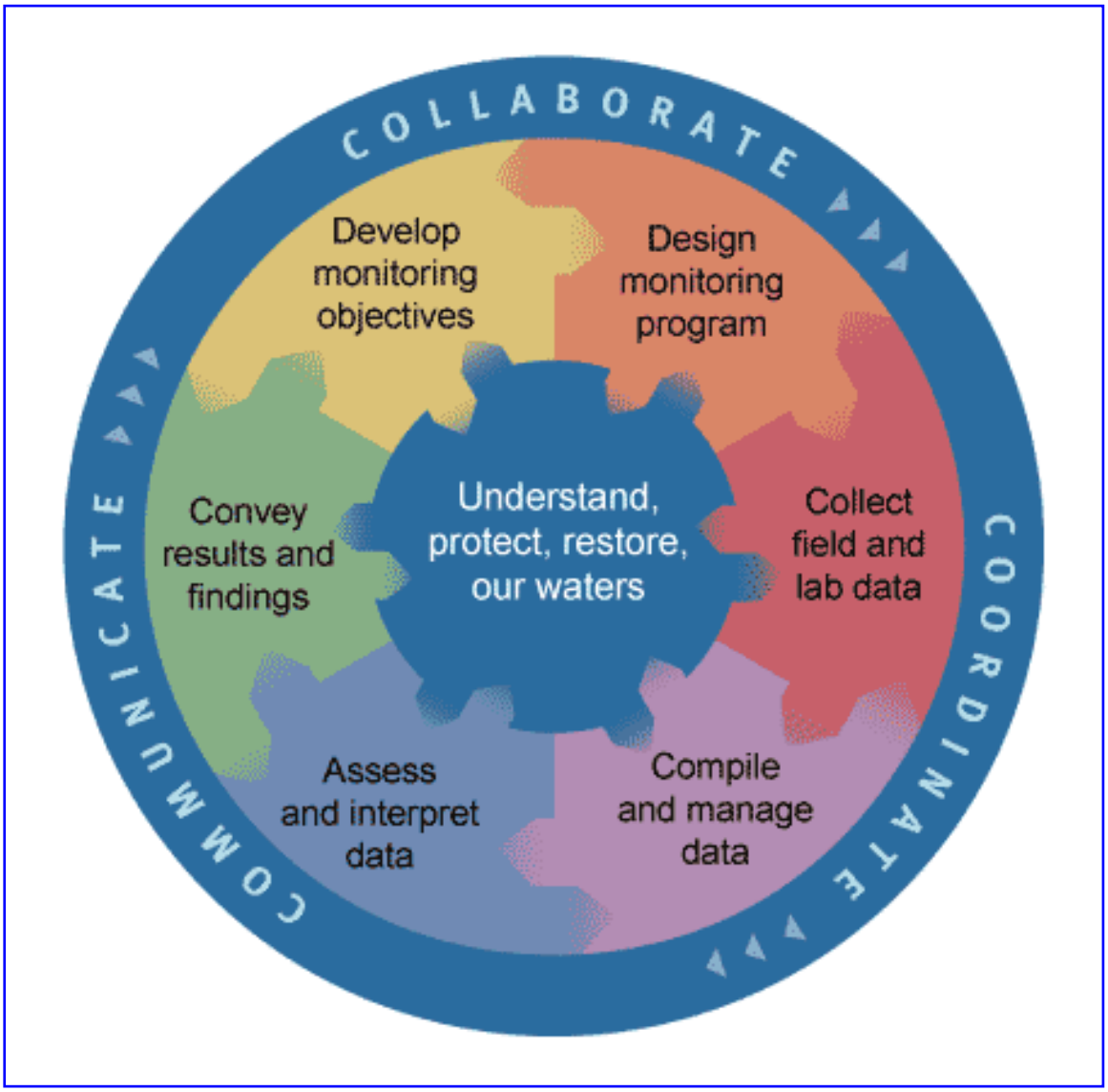
6. Validation monitoring.

"*This refers to the quantitative evaluation of proposed water quality model. The data set used for validation should be different from the data set used to construct and calibrate the model. This separation helps ensure that the validation data will provide an unbiased evaluation of the overall performance of the model. The intensity and type of sampling for validation monitoring should be consistent with the output of the model being validated*."

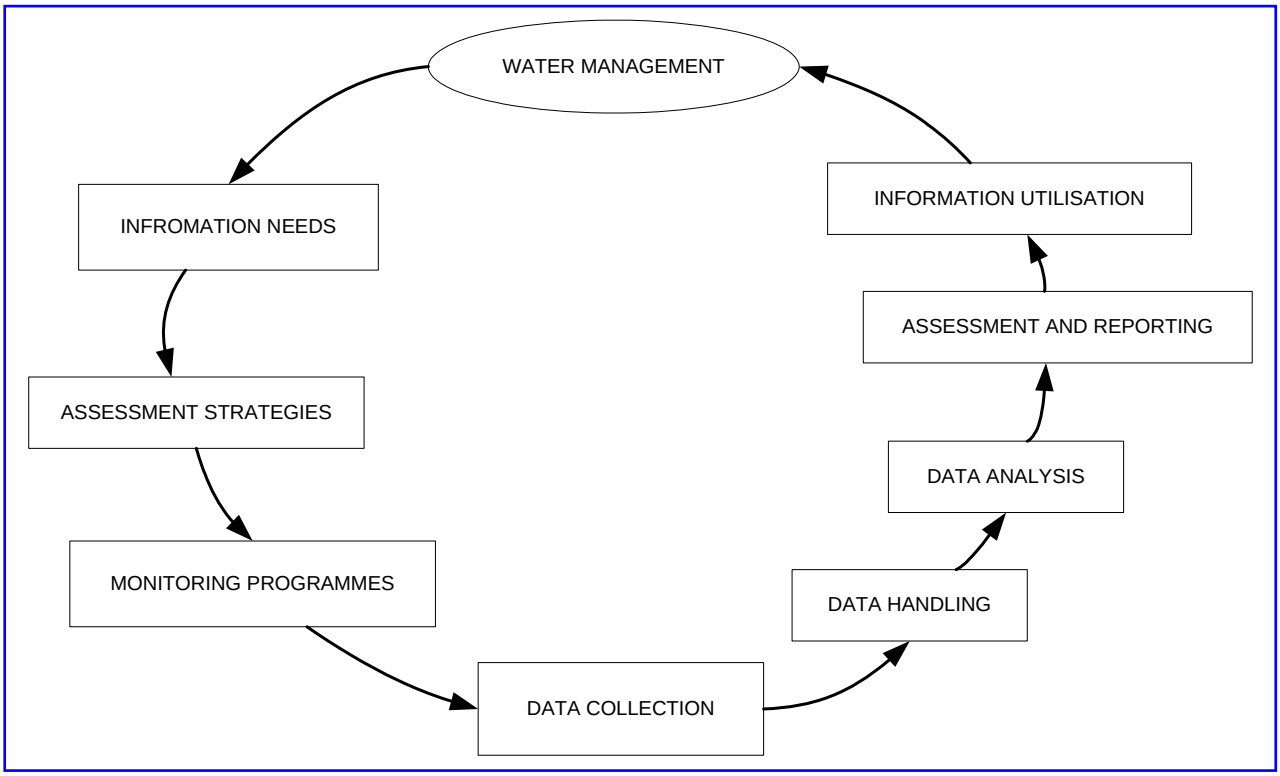
7. Compliance monitoring.

"*This is the monitoring used to determine whether specified water-quality criteria are being met. The criteria can be numerical or descriptive. Usually the regulations associated with individual criterion specify the location, frequency, and method of measurement*."

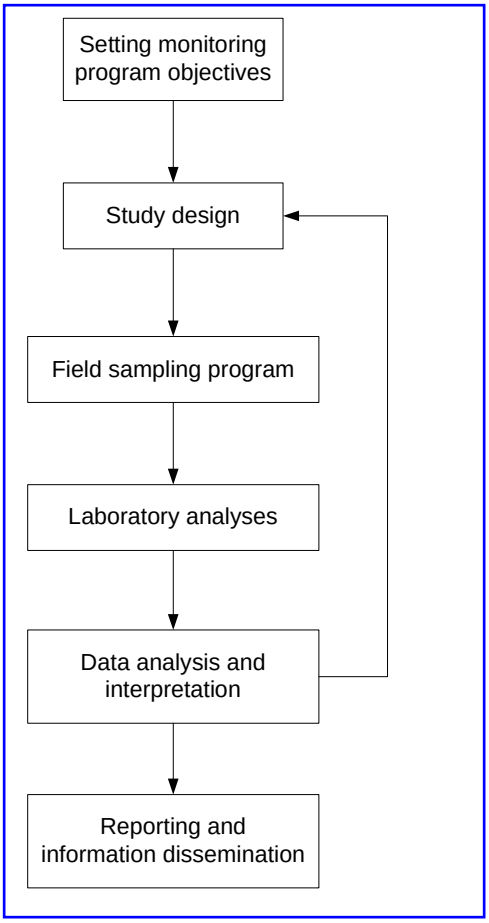
APPENDIX ii



National Water Quality Monitoring Council (2003).



UN/ECE Task Force on Monitoring & Assessment (2000).



The Australian and New Zealand Environment and Conservation Council and the Agriculture and Resource Management Council of Australia and New Zealand (2000).

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CHAPTER 1

SELECTION OF THE STATION SETTINGS

1.1 INTRODUCTION

This chapter is intended to provide a general overview of the monitoring site selection process, focusing mainly on the site-specific characteristics. It is beyond the scope of this chapter to evaluate all components of the site selection process. Detailed information on this topic can be found in the reference section.

In a water quality monitoring project, the decision of where to locate the monitoring stations is a critical success factor. Given that it is not possible to sample the whole target area or watershed, it is essential that the stations be placed where representative samples can be obtained, and where the data measured represents accurately and precisely the water body. After defining the study objectives, monitoring site selection is one of the most critical design factors in a monitoring program.

The site selection starts by viewing the big picture to ensure achieving the monitoring objectives, and then, translating those objectives into a detailed plan to assure quality data. This process is not a simple task. Primarily because in most water quality monitoring projects a monitoring network must be defined (utilization of several monitoring stations in the water body to monitor current, short and long-term water quality conditions) and secondly, due to the fact that not only scientific considerations must be understood and addressed, but also other factors must be considered and evaluated. Among these factors; natural, temporal and spatial variability, hydrological water body characteristics (*e.g.* cross section variability, stratification), climate influence (*e.g.* icing), biological factors (*e.g.* diel patterns of biological activity such as primary productivity, animals), and human induced variability (*e.g.* sediment inputs due to farming activity, communities development) need to be considered. Thus, during the planning process certain environmental, logistic and management factors, which are site-specific and can influence the site selection decision, must be addressed.

To ensure a successful site selection process, it is recommended to apply the Shewhart or Deming's PDCA cycle (Plan-Do-Check-Act) during the selection process. This is a highly effective technique to ensure the monitoring objectives and data quality requirements are considered during the different stages of the selection process.

The PDCA cycle is the basis for continual improvement. The cycle states that to continuously improve any process, system or product, four activities must be executed iteratively: PLAN, DO, CHECK and ACT. In its simple form, the cycle can be seen as a wheel with four mayor spokes: plan, do, check and act. Once an activity, or a process, is placed inside the wheel, it is very hard for it to get out. The only thing the activity or process can do is to move by the rim from one spoke to the next one: from planning to execution, from execution to verification, from verification to analysis, from analysis to planning again, and so on.

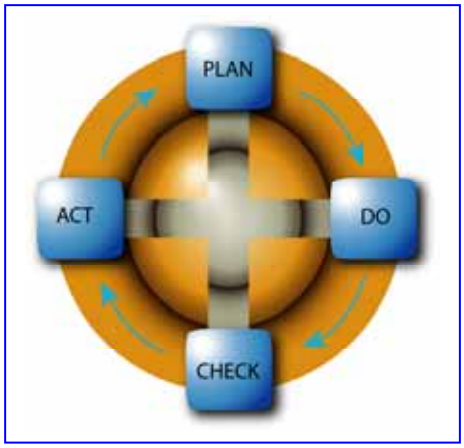


Figure 1.1 PDCA cycle

Thus, it becomes an on-going effort to improve the effectiveness, efficiency and quality of the core processes, systems, services or products. During the PLAN phase, the "what to be accomplished" is determined (*e.g*. undertake an action, solve a problem, improve a method) and all necessary planning activities are performed. After the activities of planning are completed, the execution or implementation of the plan takes place in the DO phase. Once the execution is finished, the outcomes are compared with the desired results in the CHECK phase. The final phase of the cycle is to ACT upon the results obtained during the CHECK phase (*e.g*. make changes and adjustments, run through the cycle again, implement and standardize). (Society of Manufacturing Engineers, 1993; Wealleans, 2001).

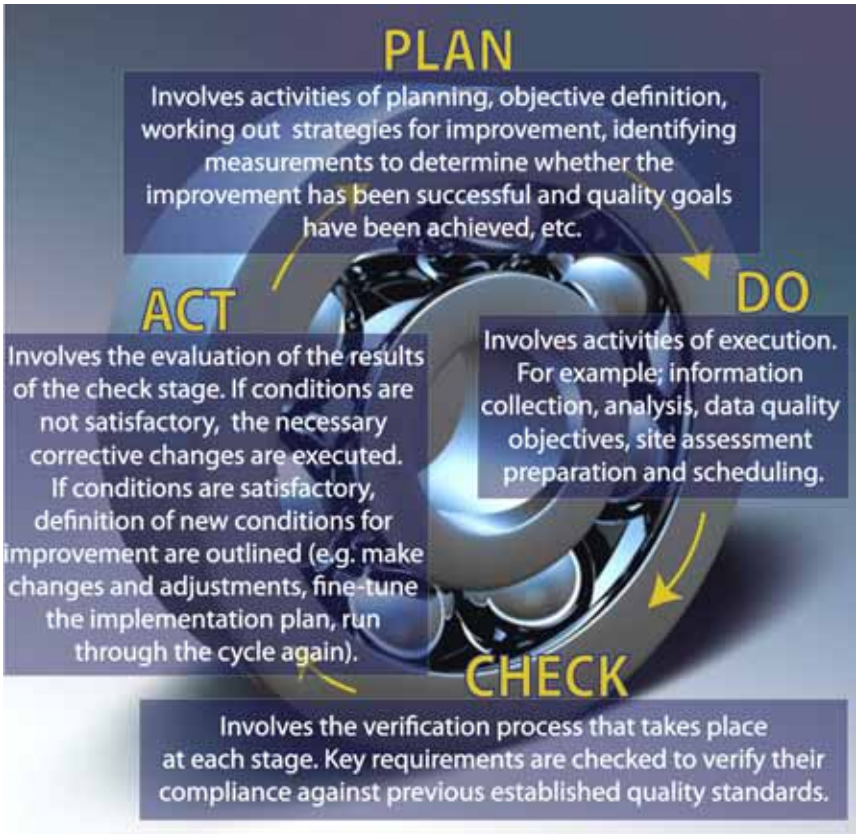


Figure 1.2 PDCA cycle activities

1.2 SITE SELECTION GUIDELINES

The degree of complexity of the site selection process is influenced by the extent of the geographic area to be monitored. The size of the monitoring area and the degree of complexity are directly related. To characterize a large geographic area, some kind of method must be employed to subdivide the area into smaller regions that maximize the representativeness between the sampling units and the target sample area. A common method that is utilized for this purpose is land classification systems. These systems can be subdivided into geographically dependent (*i.e*., Omernik 1987, Maxwell *et al*. 1995) or geographically independent (Anderson *et al*. 1976, Richards 1990, Poff and Ward 1990, Rosgen 1996, Detenbeck *et al*. 2000) as stated by the EPA (2002) and Olsen & Robertson (2003):

> *"Geographically dependent classification schemes have categories that describe specific places or regions. These classification frameworks are usually based on the premise that areas of similar climate, landform, and geology exhibit similar ecosystem potential and vulnerability to stressors. Geographically dependent frameworks tend to cover broad geographic regions at a pre-determined scale or nested scales, such as eco-regions".*

"*Geographically independent schemes have categories that describe similar features occurring at many locations, and are not limited to a specific scale, place or region. Geographically independent frameworks are usually determined by watershed attributes that can be defined independently of a geographic region, e.g., surface-water storage or runoff characteristics, or valley or stream-channel morphology*".

Olsen & Robertson (2003) emphasis the importance of basing the regionalization method on "*the distribution of the most strongly related environmental factors*", and the importance of knowing the degree of representativeness between the data collected in the different regions and the target population.

Once the regionalization is completed, two basic methods exist for site selection (USGS, 2004; USEPA, 2002; Olsen & Robertson, 2003):

- Professional judgment or deterministic method
- Statistical method or probability survey design

Site selection by professional judgment or deterministic method is based on expert knowledge, experience of experts, or best professional judgment. There are no specific guidelines for site selection using expert knowledge given the complexity of the different types of water bodies. Nevertheless, this approach may use a variety of criteria, for example: waterbody and land use characteristics; source of contaminants; influence of agriculture and urban development on a certain parameter; or known water quality problems.

Two points that must be taken into account when this method is employed are (USEPA, 2000):

a) Site selection is based on a nonrandomized method and the waterbody that represents a given station will depend on the particular waterbody.

b) No quantitative statements can be made about the level of confidence in the sampling results.

If statistical method or probability survey design are employed to select the monitoring sites, a variety of methods may be applied to randomly select them; for example, simple random sampling design, cluster or multistage sampling. The method to be employed will depend on the monitoring objectives, funding resources, type of waterbody, and the existing information of the target population. In general, these methods are used when rigorous analyses are required for environmental assessment with respect to mass-transport, remediation, and temporal or spatial variations. Even though the different design methods vary in complexity, and offer different advantages, there are certain common features among them (USEPA, 2002):

- "*Reduce bias in the sample results by ensuring that sample units represent the target population*.

- *Provide statistically unbiased estimates of the population mean, population proportions that pass or fail a standard, and other population characteristics.*

- *Allow documentation of the confidence and precision of the population estimates".*

For example, the Oregon Plan for Salmon and Watersheds (1999) considers three geographic scales in the site selection process: sample point, reach approach, and basin scale.

- Sample point is the most specific geographic scale where representative data is obtained from the specific location.
- Reach scale approach is used where multiple monitoring sites are selected; *i.e.* to reflect conditions and trends for a segment, *e.g.* stream.
- Basin scale is employed when landscape and stream patterns become the focus point.

Many of the different site selection methodologies employ a two-step procedure. The Australian and New Zealand Environmental and Conservation Council (2000) describes the two-step procedure as follows:

1. Select the location/locations within the watershed to satisfy the monitoring objectives (identification of the macro-location);

2. Identify the specific sample sites (micro-locations), which are independent of the monitoring objectives and are selected based on environmental conditions and representativeness of the sample.

Information on survey designs can be found in "Guidance for Choosing a Sampling Design for Environmental Data Collection USEPA QA/G-5S" and technical assistance on designing statistical water quality monitoring networks can be requested in http://www.epa.gov/wed/pages/EMAPDesign/index.htm.

Several references on how to address the monitoring network design and site selection criteria for individual monitoring station, and design by statistical and/or programming techniques can be found in Su-Young Park *et al.* (2006).

A good overview of network design procedures can be found in Harmanciogammalu *et. al.* (1999) "Water Quality Monitoring Network Design".

1.3 SITE-SPECIFIC CHARACTERISTICS (SSC)

The site-specific characteristics are all the environmental, logistic, and management factors that are particular to the monitoring site, that could influence the fulfillment of the monitoring or data quality objectives. For example, site selection can be affected by access (*i.e.* there is no access to the right sampling site), or certain laws and local regulations may control or prohibit the use of certain type of monitoring station platform.

Site selection can be seen as an interactive process between site-specific characteristics, and monitoring and data quality objectives. Site-specific characteristics can compromise the ideal scientific results if they are not properly addressed during the monitoring site selection process. To systematically address this problem, a project management support tool "the Site-Specific Characteristics Cycle (SSC cycle)" was developed (Figure 1.3) (Miles, 2008).

You can't control what you don't measure

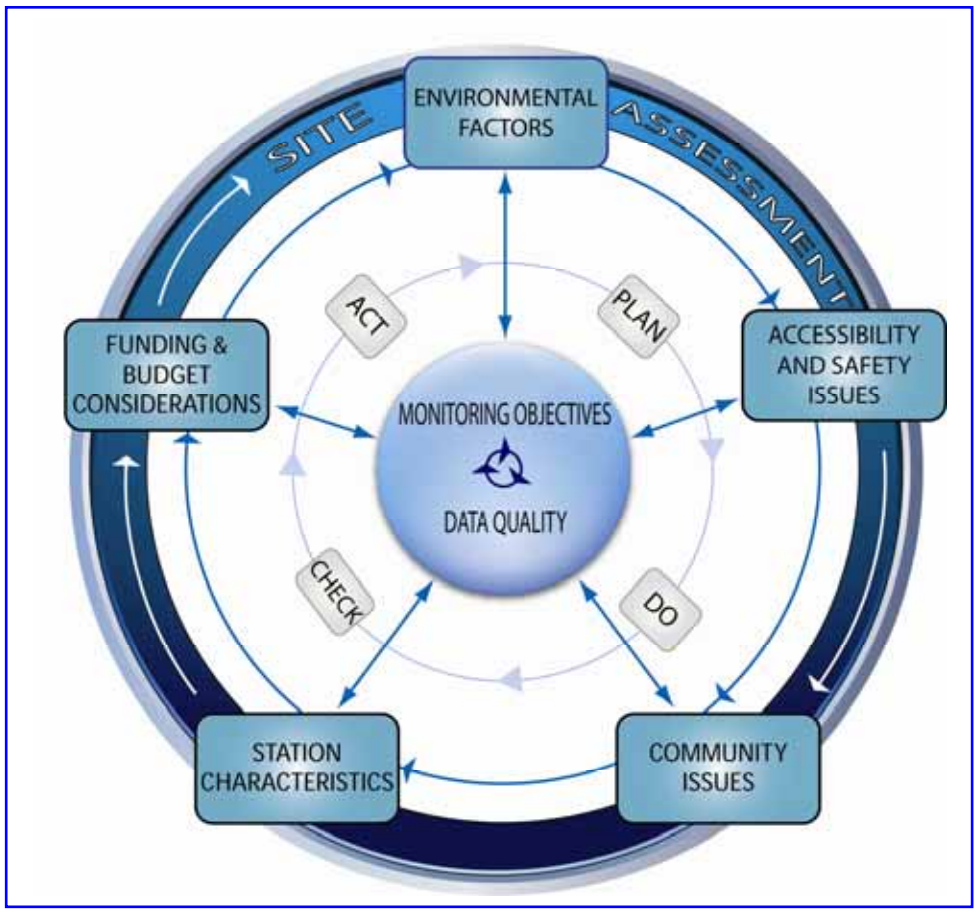


Figure 1.3 The SSC cycle

The SSC cycle is a management decision support tool designed to address the different site-specific characteristics that can influence water quality monitoring program objectives and data quality.

To assure the systematic and proper assessment of the site-specific characteristics, the cycle works under the continuous improvement philosophy. Continuous improvement can be defined as the "*recurring activity to increase the ability to fulfill requirements*" (American Society for Quality, 2000). It is the constant and never ending effort to improve the effectiveness, efficiency and quality of the core processes, systems, services or products. Thus, the activity or process enters a continuous feedback loop that ensures a methodical approach to its efficient implementation.

The site-specific characteristics are organized into five major subject areas: environmental factors, accessibility and safety, community issues, station characteristics, funding and budget considerations. All of these areas interact with each other and could trigger the inability to achieve ideal scientific results. By employing the SSC cycle, the site-specific characteristics are systematically and properly assessed to obtain the site locations that best address the monitoring objectives, and maximize data quality objectives.

Monitoring teams generally do not use a standard procedure that ensures a systematically and comprehensive evaluation of the site-specific characteristics (*i.e.* expert knowledge is one of the most commonly used approach that project managers employ). This accounts for the fact that site-specific characteristics are overlooked, misinterpreted, or even the best practice to address them are not known or even, not properly addressed, causing several problems in the capability to optimally fulfill the monitoring and data quality objectives.

It is a good practice to have a standard operation procedure (SOP) to evaluate the site-specific characteristics. A SOP will assure the quality and consistency of the site-specific characteristics assessment, and the implementation of good monitoring practices to address them. The SSC cycle was designed with this purpose in mind, to provide a management support methodology to systematically address the site-specific characteristics, and to minimize their negative impact on the monitoring and data quality objectives. In addition, in order to take into account the natural and anthropogenic environmental variability, a common concern over the life cycle of a water quality-monitoring project, the cycle works under a PDCA methodology. This approach helps to ensure that the negative impacts of the site-specific characteristics on the project objectives are permanently monitored, it enhanced the trouble-shooting capabilities, and assures the dynamicity of the cycle to achieve continuous improvement.

The goal of the SSC cycle is to create a user generated expert system based on rules, conventions, standards, subject-specific and expert knowledge, and information acquired through field experience, to support the decision making during the site selection phase of a continuous shallow water quality project.

An example of the cycle protocol follows:

1. The project manager and design team reviews the information of the SSC cycle and considers possible impacts of each site-specific characteristic on the monitoring objectives and data quality at each monitoring site (PLAN phase).

    - Site-specific characteristics are analyzed and matched with the monitoring and data quality objectives.
    - Pre-site selection is preformed.

A good question to have in mind when selecting the site is:

"What types of problems can arise when installing, operating and maintaining the station in this site?"

2. Relevant information is gathered under each subject area of the cycle (environmental, community, budget and funding, station characteristics, and accessibility and safety) to be used during the initial site assessment (PLAN phase).

3. The initial site assessment is performed. The planning decisions are evaluated against the real settings (DO phase).

    A site or field assessment is mandatory to identify the precise monitoring station site. Site assessment is an essential step in any monitoring project. Observation, expert knowledge, measurements and analysis will help to determine if the decisions made during the planning phase are viable, or if certain points must be modified due to unpredicted factors (CHECK and ACT phases).

    If possible, the initial site assessment must be conducted during the time period considered to have the greatest negative impacts on data quality. For example, if the site is in near proximity to a marina, the initial site assessment must be conducted during summer, where the greatest boating traffic is expected. However, not always this is possible. Therefore, during the initial site assessment, the assessment team must be alert to identify any variables of concern that could have a future effect on data quality.

4. The information gathered during the site assessment is used to evaluate the design specifications outlined during the planning phase (CHECK phase). This action triggers the necessary corrective changes, or delineates conditions and criteria for improvement (ACT phase).

5. Relevant information that surfaced during this process is added to the SSC cycle.

6. Site assessments are continuously performed as an audit and improvement tool to ensure that monitoring objectives and data quality are being met, and to provide steady information for the continuous improvement of the SSC cycle.

    Most commonly, site assessment is viewed as a one-time activity. This is not the case in the SSC cycle. Site assessment is an integral part of the SSC cycle, playing a major role in linking all the different site-specific characteristics. As part of the PDCA cycle, site assessment is seen as a continuous information collection process. Data is collected continuously during the project to fine-tune and improve the monitoring endeavor, to get a better understanding of the different site-specific characteristics that affect the project, and to enhance the information in the SSC cycle.

The SSC cycle provides a protocol or a management decision process to follow. How the information is organized and presented in the cycle will depend on user needs and preferences. It can be organized from general to specific; checklists with references can be used to perform a quick selection of the site-specific characteristics, and a manual, with detailed information, can be used to obtain the best practices on how to deal with the specific characteristics. It can be presented, as tables where all the information is included, or it can be written into a computer program as an expert system. It also can be personalized for the particular watershed having one cycle with specific information for lakes, another for rivers and another for estuaries. The PDCA methodology ensures the dynamicity and improvement of the cycle as new information is continuously added.

The quality of the information included in the SSC cycle will determine the quality of the guidelines that can be derived. The approach selected to display the information in the cycle will determine the effectiveness and efficiency to obtain the right guidelines. The quality of implementation of the cycle methodology will determine the level of assurance that the SSC were systematically and comprehensively evaluated.

To better understand the information to be included in the SSC cycle, examples of general guidelines, rules and standards for each of the five subject areas are provided in the following text.

1.3.1 Environmental Factors

Environmental factors are all the physical, biological, and chemical factors (characteristic of the intended site location) that could influence data quality.

The Australian and New Zealand Environment and Conservation Council (2000) stress the fact that:

> "*measurement parameters can vary from place to place within a site, randomly or in strata. When measurement parameters are being sampled in the water column, it is sometimes assumed that the water is well mixed and that a mid-water or mid-stream sample will be sufficiently representative. This may not be the case. Even if the monitoring goal is just to measure the average concentration of a chemical in the water at a site, the sampling process must be planned so that the within-site variation is included in the estimate*".

It may prove useful to create a log with the conditions of the study site over the entire year. This information is useful when siting, as well as, designing the monitoring station. For example, the information may reveal that the best place to set the station is in the middle of a channel or near the shoreline.

Environmental Factors: Physical	
Tides & water level	Annual tide data is needed for station siting purposes. The height of the station, placement of the sensor (low mean water) and other setting considerations are affected by tidal range. When sites are not influenced by tides, average maximum and minimum water levels must be obtained (*i.e.* influence of rain over water level and flow, stream and river banks conditions during periods of high water).
Waves	Waves can affect data quality in coastlines zones. The station design must take into account wave action. Also, the size of the waves may influence the maintenance activities of the monitoring stations.
Substrate conditions	Bottom substrate characteristic impacts the type of station configuration to be used. The degree of effort needed to set the station (*e.g.* hard clay, soft mud), or the strength needed to hold it in most weather conditions (*e.g.* anchoring a surface buoy), are affected by the bottom characteristic. The type of bottom can also influence data quality. For example, muddy bottom near the shore could create turbidity in the lower part of the water column. A sonde placed very close to a muddy bottom could suffer from sediment deposition and can foster biofouling, *e.g.* by chironomid worms.
Sediments	Some sections of a river, an estuary, or a lake have a higher propensity to have redistribution, accumulation, or resuspension of sediment particles (*e.g.* deposition zones, turbidity maximum zones). This phenomenon is produced by different factors such as bottom currents or runoff. This can result in a change of the floor topography. It is a good practice to place the station platform in a location where the accumulation or resuspension of sediments is minimum.
Erosion	High erosion areas can affect long term monitoring station. The station design must take this factor into account. Localized turbidity can be present in areas with high erosion; data quality may be affected.
Water physical properties	It is good practice to have an idea of the range of values of the water physical properties to understand under which conditions the sensors, and the monitoring stations, are going to operate (*e.g.* hypoxic or anoxic conditions).
Hazards	Even though it is hard to predict hazards from upstream activity, or channel units, such as debris torrents, extreme flow magnitude, bedload transport, failure of in-channel debris structures, streamside treethrow; some sites have a higher tendency to suffer from these hazards than other, or some sites are more protected than others in case debris flow in the water [4].
Extreme weather	Some geographical areas are more likely to suffer from extreme weather events than others. If extreme weather events are common in the sampling area, it is a good practice to have an idea of the type of events that can occur. This information is helpful in siting the monitoring location, or in defining certain configuration/design characteristics of the station.
Degree of ice formation	It is important to know the degree, or history, of ice formation at the monitoring site; or what areas near the monitoring site have a higher potential to freeze. This information is helpful for station design purposes, siting, and for planning the maintenance monitoring activities.

Table 1.1 Environmental Factors: Physical

Environmental Factors: Biological		
Vegetation	The surface and subsurface vegetation densities of the monitoring sites must be examined. It is possible that under certain conditions the local vegetation will influence the representativeness of the data. If the station is placed in the littoral zone, seasonal vegetation may cover the station in certain part of the year (*e.g. hydrilla verticillata*).	
Animals	Even though it is very difficult to account for possible animal influence, in some situations animals can have negative local effects. For example, crabs or fish, could cause turbidity effects, or damage the monitoring probes. Otters, beavers, turtles, or even large animals, such as alligators or seals, can influence readings, or destroy offshore monitoring stations. Birds can build nest on top of the monitoring stations, or use them as resting place to eat fish. Bird deterrent devices may be needed.	
Biofouling	Biofouling is one of the biggest factor affecting the operation, maintenance (the picture shows a datalogger left for one week in a highly fouling water) and data quality in water monitoring sensors. Most objects placed in the coastal zones waters, brackish waters or even in lakes (i.e. Lake Superior) will become covered with organisms after a period of time. Barnacles, sponges, algae, are a few of the many organisms that make up fouling communities. Stanczak (2004), gives a very concise description of how biofouling is generated. Biofouling is not a simple process, it is a complex process which often begins with the production of a biofilm. “The growth of a biofilm can progress to a point where it provides a foundation for the growth of seaweed, barnacles, and other organisms. In other words, microorganisms such as bacteria, diatoms, and algae form the primary slime film to which the macroorganisms such as mollusks, seasquirts, sponges, sea anemones, bryozoans, tube worms, polychaetes and barnacles attach”. For this biofilm to occur certain conditions must be favorable, including proper pH, temperature, humidity and nutrient availability. Biofouling can be subdivided into two categories. Calcareous fouling or hard fouling occurs when barnacles, encrusting bryozoans, mollusks, tube worms, and zebra mussels are the organisms that settle on the substrate. Non-calcareous or soft fouling is when organisms such as algae, slimes and hydroids settle on the biofilm (Stanczak 2004). Biofouling can be very specific of the geographical site and directly related to the bioproductivity and environmental conditions that affect the site. Therefore, no unique solution exists to control biofouling and the choice of the method will have to take into account, not only the site characteristics, but also, the general design of the monitoring station. There are different ways to prevent biofouling, such as, passive ways, choosing certain construction material, painting with antifouling coatings, or active ways such as using electric fields. One important issue to address during site selection is to understand the characteristics of the site in order to identify the type of biofouling and the site conditions that can foster it. For example, enclosed areas (such as marinas) are more likely to produce more biofouling than areas where flushing occurs, or warm waters will also foster biofouling. Alliance for Coastal Technologies (2003)	

Table 1.2 Environmental Factors: Biological

Environmental Factors: Anthropogenic	
Impacts of humans activities	Certain human activities can influence local water quality, thus having an effect on the representativeness of the data. It is a good practice to gather information of the different human activities near the monitoring location in order to understand possible effects and to better site the monitoring station.
Point sources	Companies can influence data quality if they discharge wastewaters directly into the water body. For example, the station can be place near a discharge pipe with very acidic conditions. It is important to survey the monitoring area to characterize wastewater discharges. Assess the degree to which these discharges impact the monitoring objectives; possible impacts on the monitoring station or sondes; and best monitoring locations to minimize, or maximize, their effect on the measurements.
Non-point sources	Some monitoring locations could be affected locally by run-off (*e.g.* close to a storm sewer carrying urban run-off). Although run-off is difficult to calculate, it is a good idea to inspect the area where the monitoring station will be located to assess if run-off can affect locally the data quality.

Table 1.3 Environmental Factors: Anthropogenic

Environmental Factors: Hydrodynamics	
1. Mixing Issues	
Water-quality monitoring site selection is determined by the data-quality objectives, and the best location for a site is often one that is best for measuring surface-water discharge. Although hydraulic factors in site location must be considered, it is more important to consider factors that affect the water-quality data (USGS, 2000).	
Edge vs. middle	Samples taken from the edge of a stream will be different from those taken near the middle. Water velocity and depth at the edges create different conditions for plant growth and animal life. Because conditions of the main stream may differ from those at the edge, sites should be located in the main current and away from the banks if possible, in areas of principal flow (Cassidy, 2003)
Upstream inputs	Check the entry points of drains. Water-quality measurements should be taken far enough downstream from drains or tributaries to allow for mixing of the waters, otherwise you will be taking a sample of the drain or tributary, not the stream. As a `rule of thumb' measure at least 100 meters downstream from any drain, pipe or tributary entering your stream (Cassidy 2003).
Lateral mixing	Lateral mixing in large rivers is not often completed for tens of miles downstream from a tributary or outfall. A location near the streambank may be more representative of local runoff, or affected by point-source discharges upstream, whereas a location in the center channel may be more representative of areas farther upstream in the drainage basin (USGS 2000)..
Lateral and vertical mixing	The lateral and vertical mixing of a wastewater effluent, or a tributary stream, can be rather slow with the main river, particularly if the flow in the river is laminar, and the waters are at different temperatures. Complete mixing of tributary and main stream waters may not take place for a considerable distance (sometimes many kilometers), downstream of the confluence (UNEP/WHO, 1996). The zone of complete mixing in streams and rivers may be estimated from the values in the following table (UNEP/WHO, 1996):

Average width (m)	Mean depth (m)	Estimated distance for complete mixing (km)	Average width (m)	Mean depth (m)	Estimated distance for complete mixing (km)
5	1 2 3	0.08-0.7 0.05-0.3 0.03-0.2	20	1 3 5 7	1.3-11.0 0.4-4.0 0.3-2.0 0.2-1.5
10	1 2 3 4 5	0.3-2.7 0.2-1.4 0.1-0.9 0.08-0.7 0.07-0.5	50	1 3 5 10 20	8.0-70.0 3.0-20.0 2.0-14.0 0.8-7.0 0.4-3.0

Table 1.4 Environmental Factors: Hydrodynamics – Mixing Issues

Environmental Factors: Hydrodynamics	
1. Mixing Issues	
Stream – Cross Sectional Variability	To minimize cross sectional variability on streams, the monitoring site must be located on a straight stretch of the stream. The require stretch, on either side of the station, will depend on the size of the stream, going from 10 m in small streams to 100 m in large streams. (BC Ministry of Environment, 2007).
Lakes and embayments	Where feeder streams or effluents enter lakes, or reservoirs, there may be local areas where the incoming water is concentrated, because it has not yet mixed with the main water body. Isolated bays and narrow inlets of lakes are frequently poorly mixed, and may contain water of a different quality from that of the rest of the lake. Wind action, and the shape of a lake, may lead to a lack of homogeneity; for example, wind can cause algae accumulation at one end of a narrow lake (UNEP/WHO, 1996).
Lakes horizontal mixing	If there is good horizontal mixing, a single station near the center or at the deepest part of the lake will normally be sufficient for the monitoring of long-term trends. However, if the lake is large, it has many narrow bays or contains several deep basins, more than one station will be needed. To allow for the size of a lake, it is suggested that the number of sampling stations should be the nearest whole number to the $\log_{10}$ of the area of the lake in km^2 (UNEP/WHO, 1996). Thus a lake of 10 km^2 requires one sampling station, 100 km^2 requires two stations, and so on. For lakes with irregular boundaries, it is advisable to conduct preliminary investigations to determine, whether and where, differences in water quality occur before deciding on the number of stations (UNEP/WHO, 1996).
Lakes-vertical stratification	The most important feature of water in lakes and reservoirs, especially in temperate zones, is vertical stratification, which results in differences in water quality at different depths. In stratified lakes, more than one sample point is necessary to describe water quality (UNEP/WHO, 1996).

Table 1.4 (Cont.) Environmental Factors: Hydrodynamics – Mixing Issues

2. Turbulence – Bubbles
Attempts should be made to locate the sensors, particularly optical turbidity sensors, away from sources of bubbles (e.g., rocks, boulders, riffles, abutments, piles, spillways, piers, or large woody debris) (White, 1999).
Turbulent streamflow may aid in mixing, but can create problems for some monitored parameters such as dissolved oxygen or turbidity. For a medium to small stream, with alternating pools and riffles, the best flow and mixing occur in the riffle portion of the stream; however, flooding may change the locations of shallows upstream from the monitoring site, and the measurement point may no longer represent the overall water-quality characteristics of the water body (USGS, 2000).
Areas protected from turbulent flows by bedrock outcroppings, or boulders, may protect equipment from bubbles. However, it must be assured that higher flows do not lead to water cascading onto the sensors (White, 1999).
In streams a good practice is to place the sonde in a pool of water removed from riffle areas. Pools are areas of fewer bubbles, have lower velocities and therefore are more secured areas for the sensors, and ensure the sensors will be underwater during low flow conditions (BC Ministry of Environment, 2007).

Table 1.5 Environmental Factors: Hydrodynamics – Turbulence - Bubbles

3. Variable Flow	
Water velocity	Excessive water velocity can introduce error. Attempts should be made to locate instruments in waters moving less than 1 m/s. (White, 1999).
Structures	Monitoring stations must be free from human regulation that cause large differences in water flow, such as release from dams upstream; variable flows caused by dams, weirs and similar structures (Cassidy, 2003).
Flow conditions	Low precipitations may cause very low water levels or even dry conditions.
Laminar flow	Although it is not always feasible, areas of laminar flow are preferred for more accurate instrument readings.

Table 1.6 Environmental Factors: Hydrodynamics – Variable Flow

1.3.2 Funding – Budget Considerations

Cost is a key factor in designing a water quality-monitoring program. As Cavanagh *et al.* (1998) emphasize,

> "*If the budget is insufficient to meet the program objective definitively (answer the required question with statistical confidence) then, either the objective has to be revised and simplified or the funds redirected to other programs. There is no point in conducting a program if it cannot provide valid information with the funds available. It is crucial that every effort is made to fit the objectives to the available budget. It is good practice to consult a statistician once the objective hypotheses have been formulated. This person will not only advise the program designers of the statistical tools and design necessary to answer the required question, but this input will clarify where monitoring effort should be better concentrated (hence defining the allocation of funds). This input will assist the program designer to determine if the budget will be sufficient to meet the minimum statistical requirements*"

Careful planning must be done during site selection in order to understand what are the ramifications that each sampling station has on the fulfillment of the project objectives. A very important point to keep in mind is that each sampling station is a cost and task driver.

Three major cost factors must be considered:

Set-up	The monitoring location will trigger the types of station configurations that are feasible, or best suited, to fulfill the monitoring objectives. For example, an offshore station will have a higher set-up cost than a station located at a pier.
Maintenance	The scheduled maintenance activities for the monitoring system will likely involve cleaning and calibration of the water quality monitoring sensors. Maintenance frequency is generally governed by: the fouling rate of the sensors and its rate varies by sensor type, hydrologic environment, season, type of energy used to power the sensors (*e.g.* battery or solar), and data storage capacity.
Access	The monitoring location will trigger an access cost that will include: type of vehicle needed to access the site (*e.g.* boat, truck, *etc.*), personnel needed (*e.g.* one, two or more depending on job and safety requirements), distance to site location, and other costs (*e.g.* lodging, meals, parking, *etc.*).

Table 1.7 Funding – Budget Considerations

1.3.3 Accessibility and Safety Issues

Accessibility and safety issues are two site-specific characteristics that play an important role in site selection. Monitoring stations should be accessible during the entire monitoring effort. Accessibility is influenced by laws, topography, landowner consent, among other things. Safety of the personnel and the equipment is a top priority; therefore, careful attention must be given to select monitoring sites that comply with the minimum safety requirements. It is possible that after reviewing the safety and accessibility information, several possible locations are selected, and the final location is chosen after the site assessment is performed.

Accessibility Issues	
Laws	Local, State or Federal regulations must be checked to see if any consideration must be taken when siting the stations.
Permission to access the site and authorization to sample	Check land ownership and determine if permission is needed to visit the site. Check if leases or agreements of water, or subaqueous bottom usage exist in the sampling area, which may require special permission to place a sampling station. White (1999) emphasis that "*a well thought out protocol for how to contact landowners, what information to provide them, and how to follow-up with landowners can significantly increase the likelihood of a landowner granting access*".
Topography-roads-navigable waters	The monitoring site must be accessible by boat, foot, truck or car.
Weather conditions (all year round)	The site must be accessible at all relevant times. Thus, it is important to know possible effects of the weather and flow conditions with respect to site accessibility. Special weather conditions must be considered, such as ice formation (for accessibility and safety issues). If winter conditions are very rough, it may require the removal of the equipment, or even the station platform.
Surveying	Sites must be accessible for surveying, if needed.
Data transfer	If data transfer is required, availability of cellular phone service, radio or landline (if possible connection) service must be checked. High-tension power lines, or radio towers, close to the site could interfere with data transfer.

Table 1.8 Accessibility Issues

Safety Issues	
Accessibility and maintenance	The site should be easily accessed and safe for the personnel conducting regular maintenance visits.
Equipment	The equipment can be damaged by natural, animal, or human activity. Natural: weather and flow conditions must be considered to determine if they can create a hazardous situation. Animals: proper precautions must be taken to minimize the risks of equipment damage by animals. Human: humans can damage the equipment either intentionally, or by accident. Intentional damage will include any act of vandalism or tamper. If possible the site must be selected where vandalism is kept at minimum. If this is not possible, the station must be designed to minimize potential vandalism. Accidental damage will include any damage cause without intention, *e.g.* with a boat. Therefore, the water site activities must be analyzed to understand what activities take place (*e.g.* crabbing, oystering, heavy boating traffic) in order to take proper precautions and minimize possible damage.

Table 1.9 Safety Issues

1.3.4 Community Issues

The role that the community plays, directly or indirectly, must be assessed when selecting a monitoring site. Many communities are very involved with the activities that take place in their localities. In these cases, it is essential to obtain community support in order to have a successful collaboration. It is important to understand what concerns the community has in the study area, and what activities take place in the monitoring locations (*i.e.* is the area used for swimming?). Possible impacts of the monitoring activities must be analyzed so they can be minimized, or discussed with the affected party. In general, it is easy to inform the community members adjacent to the monitoring site, but difficult to approach the whole community. Contact with local community leaders, local churches, community newsletter, town meetings, are possible channels to communicate the monitoring endeavor and obtain a successful collaboration. Points to consider:

Potential dangers from the stations	An area with heavy boating, swimming, or personal watercraft traffic could cause problems. Consequently, adequate assessment of these potential dangers, and how they can be eliminated, must be conducted (*i.e.* could they be eliminated by simple signaling, construction, *etc*?).
Community activities	An understanding of the activities that are performed in the area over the entire year must be acquired in order to assess possible data quality problems, or possible community complains.
Aesthetic	The installation of monitoring sites in front of private houses, or public areas, could create aesthetic problems.
Security	Community collaboration and involvement is a good approach to minimize station vandalism.

Table 1.10 Community Issues

1.3.5 Station Characteristics

Even though the station characteristics are not a site-specific characteristic, they are heavily influenced by them. For that reason, the station characteristics are an integral part of the SSC Cycle. The site and station characteristics must be analyzed to understand how they mutually influence each other. Given that there are many types of station configurations/designs, each one with its own strengths and weaknesses, it is important to consider the general characteristics of the station, and determine if it is the site that will define the type of station, or is the type of station that will define site location. For example, if the goal is to place the monitoring station on a fixed structure (*e.g*. bridge or pier) due to budget constraints; there must be a bridge or a pier near the intended site that complies with the representative data conditions. Each type of station triggers certain conditions that must be met in order to ensure safety, accessibility, and proper data gathering. For example, a permanent real-time reporting station will trigger different conditions in the station, and site selection, than a one-month continuous monitoring station. In addition, the evaluation of the other site-specific characteristics may trigger certain characteristics that the station must comply with (*e.g.* aesthetic).

1.4 INFORMATION SOURCES

Selecting the right monitoring site entails gathering a lot of information. There is a range of web information sources that can be easily accessed to assist in the siting process. In the following tables, some useful sources are provided.

MAPS	
NOAA	
NOS Data Explorer Data Explorer offers interactive mapping tools that allow users to locate NOS products in any area in the United States	http://oceanservice.noaa.gov/topics/welcome.html
USGS	
USGS Library	http://library.usgs.gov/
USGS water site maps	http://water.usgs.gov/maps.html
National Cooperative Geologic Mapping Program	http://ncgmp.usgs.gov/
Coastal and Marine Geology Program Internet Map Server and GIS Data	http://coastalmap.marine.usgs.gov/
Geography: Maps and Digital Data	http://geography.usgs.gov/products.html#maps
The National Map: The Nation's Topographic Map	http://nationalmap.gov/index.html
EPA	
Surf your Watershed	http://www.epa.gov/surf/
Other Sources	
National Atlas	http://www.nationalatlas.gov/
Geospatial data and information	http://www.geodata.gov/gos
Maps (Disaster or Emergencies) ReliefWeb	http://www.reliefweb.int/rw/dbc.nsf/doc100?OpenForm
Electronic Navigation Charts, NOAA	http://chartmaker.ncd.noaa.gov/MCD/enc/index.htm

Table 1.11 Information Sources: Maps

WEATHER DATA	
National Climate Data Center, NOAA	http://lwf.ncdc.noaa.gov/oa/ncdc.html
Weather Maps	http://www.hpc.ncep.noaa.gov/dailywxmap/index.html
NWISWeb Data for the Nation USGS	http://waterdata.usgs.gov/nwis/

Table 1.12 Information Sources: Weather Data

PHOTOS & Digital Satellite Data	
Terra Server USA from USGS (Excellent site to see aerial photos from any part of the US)	http://terraserver-usa.com/default.aspx
Digital Satellite Data USGS	http://www.usgs.gov/pubprod/satellitedata.html
Graphics, Photograph, and Video Collections (USGS)	http://www.usgs.gov/pubprod/multimedia.html
Visible Earth, NASA	http://visibleearth.nasa.gov/
Selected Satellite Products NOAA	http://www.osdpd.noaa.gov/OSDPD/OSDPD_high_prod.html
Links to Images and Data SEC – University of Wisconsin-Madison	http://www.ssec.wisc.edu/data/
Earth Observing System Data Service, NASA	http://eospso.gsfc.nasa.gov/eos_homepage/data_services.php
Google Earth	http://earth.google.com/

Table 1.13 Information Sources: Photos – Digital Satellite Data

TIDES & FLOW & BUOY	
Tide Tables NOAA	http://tidesonline.nos.noaa.gov/
Flow Data USGS	http://water.usgs.gov/waterwatch/
National Data Buoy Center, NOAA	http://www.ndbc.noaa.gov/dataindex.shtml
Tides from University of South Carolina	http://tbone.biol.sc.edu/tide/sitesel.html

Table 1.14 Information Sources: Tides – Flow – Buoy

MODELS	
USGS Hydrologic and Geochemical Models	http://water.usgs.gov/nrp/models.html
EPA Models	http://www.epa.gov/epahome/models.htm
The Princeton Ocean Model (POM) The model has been used for modeling of estuaries, coastal regions, basin and global oceans.	http://waterdata.usgs.gov/nwis/
Computer Library Models ODU	http://eng.odu.edu/cee/resources/model/

Table 1.15 Information Sources: Models

1.5 ANALYSIS OF PRELIMINARY INFORMATION

The data gathered during the pre-site selection must be organized to promote an accurate analysis, synthesis, understanding and communication. It is a good practice to have guidelines or standard operating procedures on how to organize the data for analysis. Employing a well-defined methodology allows the design team to systematically consider the different factors that affect the practical implementation of the project, and to evaluate the trade-offs that must be made in order to get, as close as possible, to the ideal scientific solution. Well-organized information can be managed and communicated more efficiently. In addition, organization allows for the identification of the need to collect further information or discard unnecessary data.

There are numerous ways to organize, summarize and arrange information in an orderly and comprehensive fashion. The best method to employ will depend upon the type of information being organized and the specific purpose for the information.

- Common formats employed in organizing data are: problem/solution, chronological, ranking, deductive or inductive order.

- Common graphical organizers are: mind mapping, network tree, interaction outline, series-of-events chain, among many others.

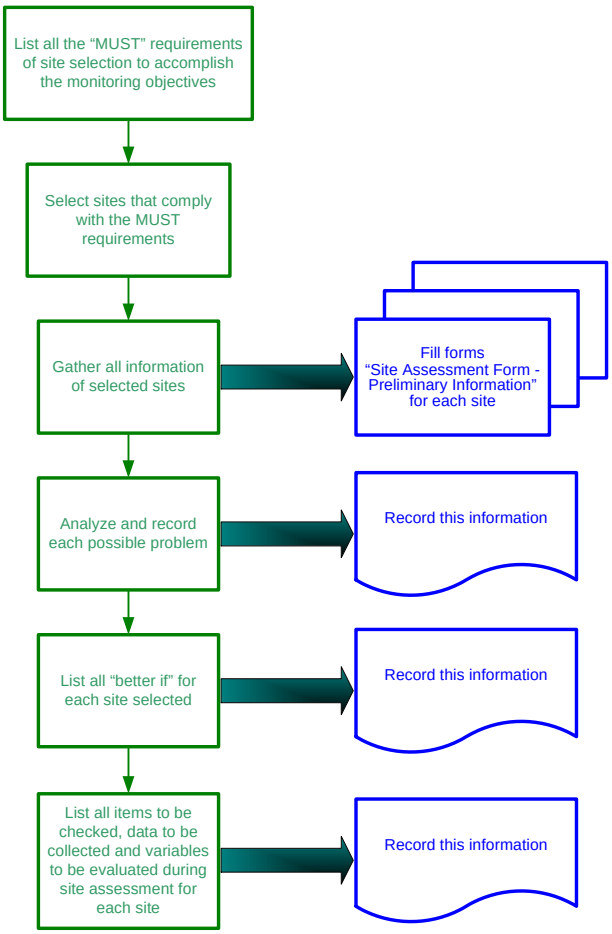
Given the reality that siting water quality monitoring stations is based mainly on experiential insights and subjective judgments, the monitoring team must employ these two steps:

1. Define a process to organize the data: the process must assure that all relevant data is collected; must facilitate orderly and efficient processing; and must provide the knowledge basis to enable professional judgment.

   A simple methodology to organize data is to create an outline of the relevant information that must be considered. The outline is a very simple method to arrange the information into a logical order, in a hierarchical and sequential manner. The data can be grouped by similar concepts, or content, by identifying the main topics, subtopics, and details under each subject. An example of an outline is presented in the Appendix section, Appendix 1 “Monitoring Site Location – Information Collection & Summary Instructive Form”.

2. Define a procedure to ensure that critical details are not overlooked in the selection process: when a lot of information must be managed; a lot of details must be remembered; in addition to the fact that trade-offs must be made; it is good practice to use a procedure that ensures that all critical factors are considered and not overlooked during the decision process.

   Information flow charts and checklists are simple tools employed to ensure that all relevant facts are not overlooked. As an example, an information flow chart is presented next.



1. The requirements that each monitoring site must fulfill are specified.

   The program objectives can trigger two different types of requirements in terms of site selection:

   The "**Musts**": Necessary and specific requirements; those key things that the site must have in order to accomplish the program objectives. Failure of any of these requirements is likely to cause problems meeting the program objectives.

   The "**Better if**": Second tier of requirements that are better if they are achieved, but if they are not met, the monitoring objectives are not affected. For example, given budget constraints, it will be better if the monitoring station is placed on a pier rather than constructing an off-shore station. This option eliminates the need of a monitoring vessel.

2. Each key requirement is analyzed in order to determine which monitoring location complies with these requirements; and those that do not comply, why they do not?

   Is possible to adapt or modify some features or attributes to change the nonconformity to conformity?

3. Select possible monitoring locations that comply with all the "MUST" requirements.

4. Analyze possible problems these locations have, or could have. List all potential problems.

5. List possible causes for each potential problem, and the risks associated with them.

   The risk reflects both the likelihood of an event and the severity of the impact if it did occur. For example, potential impacts (low, medium, high), and plausibility (low, medium, high).

6. List possible solutions. Develop preventive actions or contingency plans where possible or necessary. List pros and cons.

7. List all "better if" characteristics for each monitoring site.

8. List all information that must be checked, data to be collected, and variables to be evaluated during the site assessment.

The result of this planning phase is:

- To have the information organized for each potential monitoring site selected: location, map, pictures, relevant environmental data, permits if any to be obtained, *etc*.

- To have the necessary instructions and relevant information for the site assessment phase:

  - Information to be collected, checked, and analyzed
  - Problems to be aware of
  - Solutions or feasible alternatives

This information will be used during the site assessment planning meeting. Benefits that can be obtained from organizing the information are:

- Get the big picture and comprehend all possible factors of the monitoring sites that can affect the monitoring objectives.
- Define possible problems or concerns that can arise.
- Define preliminary preventive actions or contingency plans where necessary.
- Define monitoring sites to be evaluated during the site assessment phase.
- Define what items must be checked, data to be collected, and variables to be evaluated during the site assessment.

1.6 SITE ASSESSMENT

Site assessment is a crucial step in site selection. As Cavanagh *et al.* (1998) mention

> "*Once the objectives of the program are developed (including an evaluation of the budget constraints and statistical requirements) and related information is reviewed, it is wise to conduct a preliminary field inspection prior to further development of the program. The importance of actually "ground- truthing" an area at this stage of design cannot be over emphasized*".

Site assessment is an essential step in siting the monitoring stations. It is the first time in the monitoring project where planning decisions are evaluated against the real settings. As previously mentioned, observation, expert knowledge, measurements and analysis will help to determine if the decisions made during the planning phase are viable, or if certain points must be modified or changed given unpredicted factors.

Site assessment, as part of the SSC cycle, is not only a verification process, but also an information collection process. Information is collected to fine-tune the monitoring project, to get a better understanding of the watershed or waterbody, or even to change same variables to be monitored (*i.e.* during site assessment, it is observed that a new building project is been undertaken and this can have some future influence on some water quality variables). As integral part of the PDCA methodology, site assessment is an activity that will be performed continually during the whole monitoring project lifecycle. Information that can have a significant influence on data quality is continuously collected and properly recorded for future analysis.

The site assessment process starts with a meeting to go over the assessment plan. During this meeting, the project manager lays out the assessment plan, defines objectives, presents the key critical factors of the survey, reads over the general information (so each member has the whole picture), describes problems and possible solutions, defines the activities and measurements to be executed, and assigns responsibilities.

It is a good practice to have a critical mind during the survey, looking for possible problems not considered during planning

How to conduct, and what to expect, from a site assessment will depend greatly on the monitoring objectives. For example, an impact assessment project will trigger different requirements than a trend study. Nevertheless, common guidelines are given in three areas:

- → Human Activity
- → Mixing
- → Stratification

These three areas are part of the SSC Cycle and must be addressed during the cycle process. A few points are detailed in this section to emphasize their importance during the site assessment process.

1.6.1 Human Activity

It is very important to assess all possible human impacts during the site reconnaissance. Overlooked human activity can greatly impact directly and indirectly the success of the monitoring program (*i.e.* vandalism or point sources inputs to the water body). If possible, the initial survey must be conducted during the time period in which human activity is likely to have the greatest negative impact. For example,

- If boat traffic is seasonal in a narrow river, it is important to understand high peaks of traffic to assess possible impacts, *i.e.* where is the best place to set the station?
- What are the present uses of the water body within or in near proximity to the project site? *e.g.* bathing, washing, fishing, drinking water, recreation, commercial navigation, etc.

If human activities currently exist in near proximity of the monitoring site (*i.e.* marina, construction, farming, *etc.*), the survey should document the location and magnitude of these activities, and observe any possible linkages between these activities and water quality (at the moment of the survey or in the future).

1.6.2 Mixing

Mixing problems appear in rivers, streams and certain parts of lakes and estuaries. In order to adequately categorize a water body region with one monitoring site, it must be assured that the water in the selected site is sufficiently well mixed. Therefore, adequate cross-section measurements at different points across the width and depth near the prospective site must be taken to verify mixing conditions.

- <u>Results do not vary significantly</u>: the station can be established at any convenient point.

- <u>Results vary significantly</u>: consideration must be given to select another site, or use a <u>different</u> approach to meet the data quality objectives; for example, cross-section corrections.

In sites where poorly mixed conditions exist, USGS (2000) recommends a minimum of two cross-section measurements per year, to verify if significant changes in the distribution of the constituents of concern have occurred. Within the cross-section measurement sampling regime, vertical mixing measurement at a minimum of two depths is required.

In order to determine if seasonal changes affect significantly the distribution of constituent values in the cross section, USGS (2000) recommends that a minimum of six cross-section measurements, representing different flow conditions, be taken for longer term studies.

1.6.3 Stratification

Physical properties of water change due to seasonal temperature variations and mixing of water of different origins (*i.e.* freshwater entering a bay through runoff). The two factors that define stratification are: temperature and salinity. These factors are known as conservative properties, in contrast to other factors that change even though there is no stratification (*i.e.* oxygen, nutrients).

It is a good practice to investigate if different masses of water (in terms of salinity or temperature) exist in the water body to be monitored. If stratification occurs, measurements of water quality variables may be different depending on where they are taken in the water body.

There is no formal definition of a salinity gradient to define stratification. Most commonly, salinity increases with water depth, unless the water column is well mixed. Differences in salinity of 5 ppt or more can occur per meter in water with significant density gradient.

Given the variability of stratification scenarios (*i.e.* seasonal, regional, *etc.*), the best approach during site assessment is to get an idea of the probability of stratification occurrence. Quick measurements can be taken to categorize the site, but caution must prevail given the temporal variability of stratification.

Technically speaking, a thermocline is defined as a layer of water where the temperature decline exceeds one degree Celsius (1°C) per meter (Florida Lakewatch, 2004). Temperature stratification can be detected by taking a temperature profile of the water column. If there is a significant difference (for example, more than 3 °C) between the surface and the bottom readings, there is a “thermocline”.

1.6.4 Site Assessment Information Forms

Site assessment is not only a verification process, but also an information collection process. During site assessment, information is collected to fine-tune the monitoring project, to get a better understanding of the watershed, and/or to change some variables to be monitored.

It is a good practice to use forms during the site assessment to ensure the required activities are performed and the necessary information is collected and adequately recorded. At least two forms must be used:

- → A form that details all the activities or information necessary to carry out the site assessment.
- → A form to register the information collected during the site assessment.

An example of a site assessment form is presented in Appendix 1 (Appendix Section).

1.7 REFERENCE

Alliance for Coastal Technologies. 2003. **Biofouling Prevention Technologies for Coastal Sensors/Senor Platforms**. Workshop Proceedings. Solomons, Maryland. November 19-21. Indexing No. ACT-03-05.

American Society for Quality. 2000. **Quality management systems-Fundamentals and vocabulary**. ANSI/ISO/ASQ Q9000-2000.

Anderson, J.R., E.E. Hardy, J.T. Roach and R.E. Witmer. 1976. **A land use and land cover classification system for use with remote sensor data**. U.S. Geological Survey Prof. Paper 964, 28 pp. Reston, VA, USA

Australian and New Zealand Environment and Conservation Council (2000). **Australian Guidelines For Water Quality Monitoring And Reporting**. Australian Water Association.

BC Ministry of Environment. 2007. **Continuous Water-Quality Sampling Programs: Operating Procedures**. Watershed and Aquifer Science. Science and Information Branch.

California Department of Transportation. 2004. **Guidance Manual: Stormwater Monitoring Protocols**. Second Edition. CTSW-RT-00-005.

Cassidy Michael. 2003. **Waterwatch Tasmania Reference Manual: A guide for community water quality monitoring groups in Tasmania**. Waterwatch Australia.

Cavanagh, N., R.N. Nordin, L.W. Pommen and L.G. Swain. 1998. **Guidelines for Designing and Implementing a Water Quality Monitoring Program in British Columbia**. Ministry Of Environment, Lands And Parks. Province of British Columbia.

Detenbeck N.E., S.L. Batterman, V.J. Brady, J.C. Brazner, V.M. Snarski, D.L. Taylor and J.A. Thompson. 2000. **A test of watershed classification systems for ecological risk assessment**. Environmental Toxicology and Chemistry 19:1174-1181.

Harmanciogammalu Nilgun B., O. Fistikoglu, S.D. Ozkul, V.P. Singh, and M.N. Alpaslan. 1999. **Water Quality Monitoring Network Design**. Water Science and Technology Library. Springer.

Maxwell, J.R., C.J. Edwards, M.E. Jensen, S.J. Paustian, H. Parrott and D.M. Hill. 1995. **A hierarchical framework of aquatic ecological units in North America (neartic zone)**. NC-176:1-76. Technical Report. US Department of Agriculture, Forest Service, Washington, DC, USA.

Miles, Eduardo J. 2008. **The SSC cycle: a PDCA approach to address site-specific characteristics in a continuous shallow water quality monitoring project**. Journal of Environmental Monitoring:10, 604 – 611. DOI: 10.1039/b717406c.

Olsen, A.R. and Dale M. Robertson. 2003. **Monitoring Design**. Water Resources IMPACT. September. Volume 5, Number 5. National Water Quality Monitoring Council (NWQMC)American Water Resources Association. Virginia.

Omernik, J.M. 1987. **Ecoregions of the conterminous United States**. Annals of the Association of American Geographers 77 (1):118-125.

Oregon Plan for Salmon and Watersheds. 1999. **Water Quality Monitoring: technical guide book**. Version 2.0. Oregon Watershed Enhancement Board.

Poff, N.L. and J.V. Ward. 1990. **Physical habitat template of lotic systems: recovery in the context of historical pattern of spatiotemporal heterogeneity**. Environmental Management 14:629-645.

Richards, R.P. 1990. **Measures of flow variability and a new flow-based classification of Great Lakes tributaries**. Journal of Great Lakes Research 16:53-70.
Rosgen, D.L. 1996. **Applied River Morphology**. Wildland Hydrology, Pagosa Springs, CO, USA.

Simpson, J. H., and J. R. Hunter. 1974. **Fronts in the Irish Sea**. Nature, 250, 404–406.

Society of Manufacturing Engineers. 1993. **Tool and Manufacturing. Engineers Handbook. Volume 7. Continuous Improvement.** Ramon Bakerjian Editor. Fourth Edition. ISBN 0872634205.

Stanczak, Marianne. 2004. **Biofouling: It's Not Just Barnacles Anymore**. The Hot Topic Series. CSA Illumina. www.csa.com

Su-Young Park, Jung Hyun Choi, Sookyun Wang and Seok Soon Park. 2006. **Design of a water quality monitoring network in a large river system using the genetic algorithm**. Ecological Modeling. Volume 199, Issue 3, Pages 289-297.

UNEP and WHO. 1996. **Water Quality Monitoring - A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes**.

U.S. Environmental Protection Agency. 2003. **Delivering Timely Water Quality Information to Your Community**. The River Index Project: Lower Great Miami River Watershed. National Risk Management Research Laboratory. EPA625/R-03/002

U.S. Environmental Protection Agency. 2002a. **Development of Watershed Classification Systems for Diagnosis of Biological Impairment in Watersheds and Their Receiving Water Bodies**. National Center For Environmental Research. Grant Sorting Code 2003-STAR-A1. Summary Of Program Requirements.

U.S. Environmental Protection Agency. 2002b. **Delivering Timely Water Quality Information to you Community**. The Chesapeake Bay and National Aquarium in Baltimore EMPACT Projects. EPA/625/R-02/00X

U.S. Environmental Protection Agency. 2002c. **Consolidated Assessment and Listing Methodology Toward a Compendium of Best Practices**. First Edition. Office of Wetlands, Oceans, and Watersheds.

U.S. Environmental Protection Agency. 2000. **Guidance for Choosing a Sampling Design for Environmental Data Collection: for use in developing a quality assurance plan**. EPA QA/G-5S. Quality System Series.

U.S. Geological Survey. 2004. **National Field Manual for the Collection of Water-Quality Data. Techniques of Water-Resources Investigations**. Book 9. Handbooks for Water-Resources Investigations. Water Resources--Office of Water Quality. http://water.usgs.gov/owq/FieldManual/index.html

Wagner, Richard J., and Robert W. Boulger, Jr., Carolyn J. Oblinger, and Brett A. Smith. 2006. **Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and Data Reporting.** U.S. Geological Survey. Techniques and Methods 1–D3. http://pubs.usgs.gov/tm/2006/tm1D3/pdf/TM1D3.pdf

Wealleans. D. 2001. **The Organizational Measurement Manual**. Gower Publishing.

White Ted. 1999. **Automated Water Quality Monitoring: Field Manual. Prepared for: Ministry of Environment Lands, and Parks**. Water Management Branch for the Aquatic Inventory Task Force. Resources Inventory Committee. The Province of British Columbia.

CHAPTER 2

STATION PLATFORMS

2.1 INTRODUCTION

Deciding what type water quality monitoring station platform to employ is an iterative process. As part of the SSC Cycle, the selection process must assure that the data to be measured in the station platform will be of the required quality, and that the monitoring objectives will be met. There are many types of station configurations and designs, each one with its own strengths and weaknesses; so it is very helpful to have a general idea of the characteristics of different shallow water quality monitoring station platforms in order to select the best alternative that fulfills the monitoring objectives.

An outline of continuous shallow water quality monitoring station platforms is presented in this chapter. A more detail description of these configurations is provided in the following chapters:

- Chapter 4 describes the buoyant monitoring station platforms. Basic information on the buoyant systems for shallow waters is provided.
- Chapter 5 describes the fixed structure monitoring stations. The chapter contains construction standard operating procedures for three types of station platforms used at CBNERRVA.

2.2 TYPE OF PLATFORMS

Most continuous shallow water quality monitoring stations can be subdivided into two main categories: buoyant and fixed depth structured monitoring stations (Figure 2.1).

BUOYANT CONFIGURATIONS

Monitoring stations in which the monitoring sensors have certain degree of spatial mobility:

- vertically, for example by tides (*e.g.* surface buoy)
- horizontally, for example by currents (*e.g.* subsurface structure)

Many different buoyant monitoring stations exist for a wide range of near-shore, coastal and offshore applications.

FIXED STRUCTURE CONFIGURATIONS

Monitoring stations in which the monitoring sensors are located at a fixed position from the bottom substrate.

These stations can be classified into three categories:

DESIGNED PLATFORM	Monitoring stations that are specially designed by the user to fulfill the monitoring needs. These structures are generally deployed offshore. The sonde in these structures is generally placed on a fixed vertical position.
EXISTING STRUCTURE	Structures that already exist in the monitoring sites and the user takes advantage of them to set the monitoring station. The sonde in these structures is generally placed on a fixed vertical position.
ON RIVER & STREAM BANK STRUCTURE	The monitoring platforms are located on or close to the river or stream bank. The sonde in these structures is generally placed on an angle to the river or stream bank. These type of platforms can be divided into two groups, with or without equipment shelter.

- WITHOUT EQUIPMENT SHELTER: these stations comprise of a pipe anchored to the river or stream bank on an angle via some kind of structure (e.g. posts, pipes).
- WITH EQUIPMENT SHELTER: these stations are generally adaptations of the two well-known USGS sheltered structures (flow-through and sensor in-situ monitoring systems).

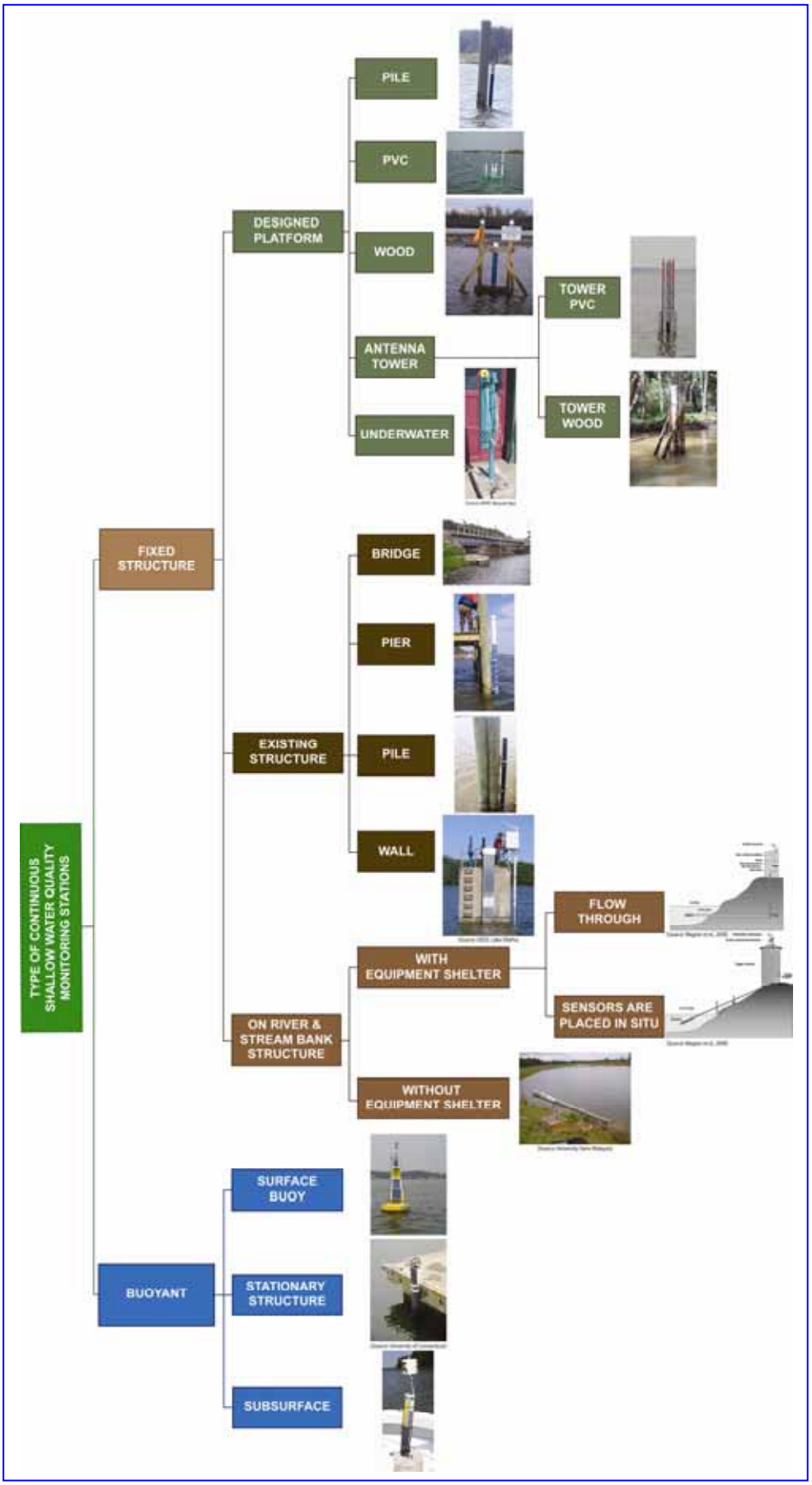


Figure 2.1 Types of continuous shallow water quality monitoring station platforms

2.3 DESIGN & SELECTION CONSIDERATIONS

The station configuration to be selected depends mainly on the settings of the monitoring location and the design requirements to comply with the monitoring objectives and data quality.

The station configuration selection process must address certain site-specific characteristics that provide the design framework for the station platform. These site-specific characteristics will trigger certain required design characteristics, or limit the utilization of specific types of station platforms. For example, if the monitoring site is located in deep water making hard to set a fixed station, a buoyant station platform maybe is the only viable option.

Due to the broad range of site-specific characteristics, most monitoring platforms would require custom modifications in order to obtain good quality measurements.

Some of the site-specific characteristics to address are:

Sampling depth	Permits
Water depth	Duration of monitoring project
Currents; Flow-Rate	Set-up Cost
Winds	Maintenance requirements and logistics
Wave action	Maintenance Cost
Tidal or water level range	Safety-Security for personnel and equipment
Yearly weather patterns	Water activity near the location (*i.e.* water sports)
Vegetation – Animal influence	Existing settings in the location
Bio-fouling potential	Community or interested parties concerns
Site accessibility	Data transfer possibilities

Sometimes, two or more stations are considered to best fit the design characteristics and it is difficult to reach a consensus of which station to select. In these cases multi-attribute criteria can be used to resolve the problem.

2.4 REFERENCE

Miles, Eduardo J. 2008. **The SSC cycle: a PDCA approach to address site-specific characteristics in a continuous shallow water quality monitoring project**. Journal of Environmental Monitoring:10, 604 – 611. DOI: 10.1039/b717406c.

2.4.1 Photo Reference

Flow Through and Sensors are Place in Situ Photos. Wagner, R.J., Mattraw, H.C., Ritz, G.F., and Smith, B.A., 2000. Guidelines and standard procedures for continuous water-quality monitors: site selection, field operation, calibration, record computation, and reporting. U.S. Geological Survey Water-Resources Investigations Report 00-4252, 53 p.

University Sains Malaysia Photo. Wetpond Station (Sonde 1) and Wetland Micro pool Station (Sonde 2). Water Quantity and Quality Monitoring Station. Application of Bio-Ecological Drainage System (BIOECODS) in Malaysia. River Engineering and Urban Drainage. Universiti Sains Malaysia. http://redac.eng.usm.my/html/projects/bioecods/

University of Connecticut Photo. 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

USGS Lake Olathe Photo. Water-Quality Study of the Lake Olathe Watershed, Northeast Kansas. http://ks.water.usgs.gov/studies/qw/olathe/

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CHAPTER 3

SELECTION & ASSEMBLY OF THE SENSORS PROTECTION DEVICE

3.1 INTRODUCTION

It is always a good practice to protect the monitoring sensors from local wildlife, debris and human tampering.

Four types of monitoring sensor protection devices are generally used:

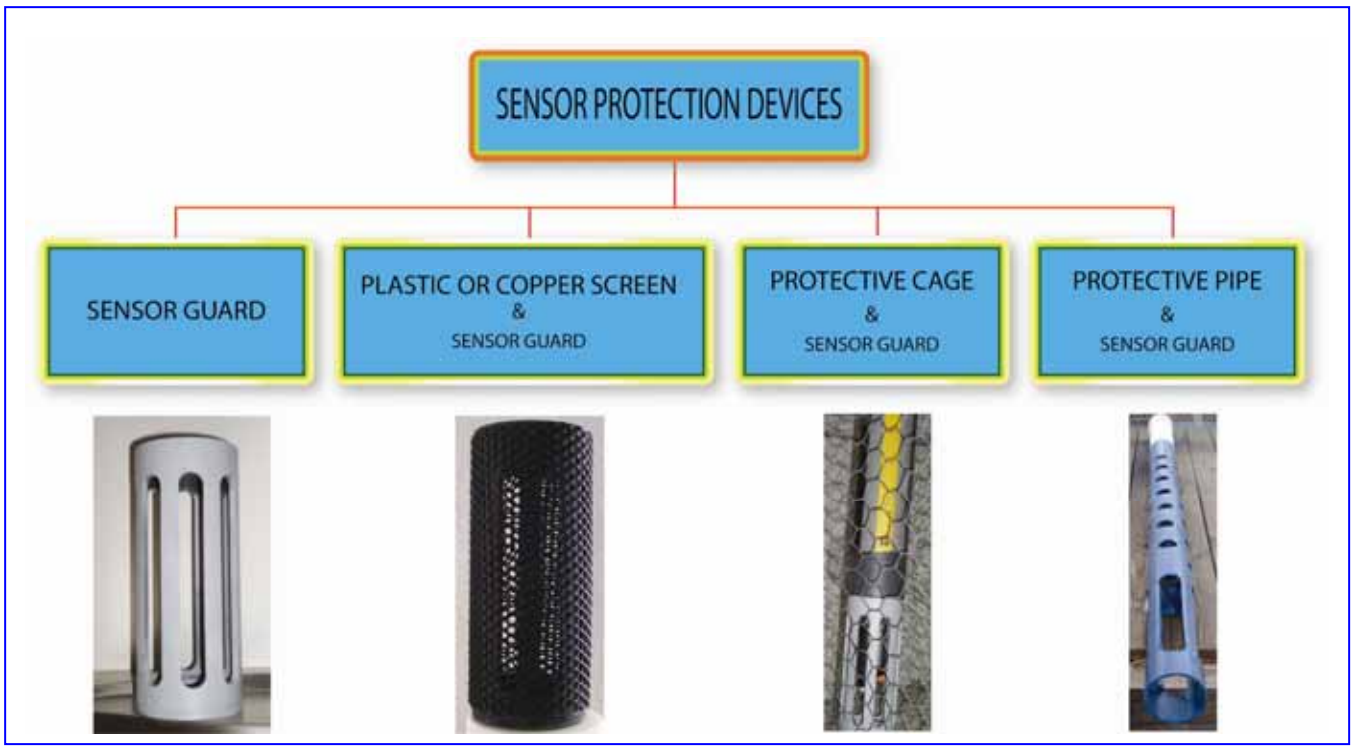


Figure 3.1 Sensor protection devices

1. Sensor or Probe guards are built in protective guards generally made of PVC or polyurethane and are recommended for use in environments with low degree of debris, wildlife or human activity. These devices come with the equipment.

2. Sensor guard wrapped with a plastic or copper screen are recommended for use in environments with large quantities of floating and/or submerged debris, particularly in rapidly moving rivers and streams. A good practice is to use a plastic (dark color, *e.g.* black) or copper screen with a mesh opening size ranging from 1/8 to 1/4 inch (3 to 6 mm). The screen is secured to the guard with rubber bands, cable ties or tape (duck or plastic electrical). The screen can be used with the protective cage or the protective pipe to provide additional shielding (CDMO, 2007). Precautions must be taken to avoid the appearance of different aquatic environmental conditions inside the screen than outside during sampling due to biofouling of the screen or physical fouling trapped on the mesh (Figure 3.2).

Figure 3.2 Fouled screens

(Source: Jacques Cousteau NERR; North Inlet-Winyah Bay NERR)

3. Protective cage has two basic designs:

- Available or modified cages (*e.g.*, crab pot, raccoon trapping cage, *etc.*)
- Special constructed cages

A protective cage can be used by itself, or can be employed with other sensor protection devices to provide additional safety. Cages can impede small animals (*e.g.* crabs) from settling into the built in protection guard and interfering with certain types of measurements. Protective cages have certain disadvantages, for example: maintenance issues due to fouling; animals can get trapped inside the cage; special water environment conditions can be created inside the cage due to fouling, trapping vegetation, or debris clogged mesh.

4. Protective Pipe

In this chapter, design guidelines to prepare a protective pipe are given. The work instructions prescribe a specific design method and it does not cover every conceivable approach.

- For further reference, the protective pipe is referred to as the "**guard-pipe**".
- The step-by-step instructions given in this chapter are limited to the activities necessary to construct the guard-pipe to be ready for field deployment.
- A **specific pipe diameter** is used due to the dimensions of the monitoring sensor employed at the Reserve; other diameters and materials may be used to meet each particular need.
- The final assembly of the guard-pipe in the monitoring station is addressed in Chapter 5 - Fixed Structure Monitoring Stations.

3.2 SENSOR PROTECTION DEVICE: GUARD-PIPE

The guidelines are written in a standard operating procedure style.

3.2.1 SUMMARY OF THE GUIDELINES

A 4 inch diameter Schedule 40 PVC pipe is utilized to protect the monitoring sensor. In order to ensure the same aquatic environmental conditions inside the pipe as outside, a set of 2 inch (5 cm) holes along the pipe, and four sets of windows (13 by 2 inches; 33 by 5 cm) at the bottom of the pipe are drilled to guarantee a good water flow. To ensure the monitoring sensor will be positioned at the windows depth when deployed, two small bolts are placed at the end of the pipe to act as stoppers. To minimize fouling, the pipe is painted with antifouling paint.

The monitoring sensor employed in this procedure is a multiparameter sonde that has a diameter of 8.9 cm (3.5 in) (type of the long term deployment sonde used at NERRS).

These design guidelines could be equally applied with any other type of pipe material or sensor diameter. It is a good practice to choose a pipe with a diameter of 1 or 2 inches (2.5 to 5 cm) larger than the diameter of the sonde, and with a length that exceeds the sonde's length by several inches (CDMO, 2007).

In this particular guard-pipe design, the pipe can be set in the monitoring station at a specific height above the substrate for fixed stations, or beneath the water level for buoyant stations.

3.2.2 QUALIFICATIONS & RESPONSIBILITIES

All users of these guidelines must be familiar with it before implementation and, if necessary, trained by personnel with previous experience in guard-pipe construction.

3.2.3 HEALTH AND SAFETY WARNINGS

The construction of the guard-pipe requires precaution in the use and handling of the tools and materials to assure safety.

- General safety precautions for working with electric and power tools must be taken.
- When using power tools safety glasses must be used.
- When drilling holes in a PVC pipe, safety precautions must be taken given that the drill bit can slip out of the hole and cause injuries.
- When painting with antifouling coating, protective gloves, glasses and clothing, and an air-purifying respirator must be used.
- Personnel engaged in the painting operations should review the paint Material Safety Data Sheets in order to acquaint themselves with the properties and hazards of the paint.

3.2.4 EQUIPMENT AND SUPPLIES

The following tables list the equipment and supplies needed to construct the guard-pipe.

EQUIPMENT		
Drill	2 in Drill Bit	Drill bits
Jig saw	Round File	Square
Measuring Tape	Straight File or Sand Paper	

Table 3.1

SAFETY EQUIPMENT	
Safety glasses	Dust mask
Vinyl gloves	Air-Purifying Respirator
Lab coat, apron or other suitable outfit to protect your clothes	

Table 3.2

SUPPLIES						
#	Supply	Description				
1	PVC Pipe	Schedule	Diameter	Length	Quantity	
		40	4 inch	16 ft	1	
2	Galvanized or stainless steel bolt (Hex Head) (recommended 316 SS)	Length	Diameter	Quantity		
		1 inch	5/16	2		
		8 inch	9/16	1		
3	Galvanized or stainless steel nuts		5/16	4		
4	4 in × 4 in PVC coupling					
5	PVC cleaner, prime and cement					
6	Padlock (*e.g.* #3 from Master Lock)					
7	Duck or Masking Tape	Small amount. To be used during the painting process.				
8	Permanent Marker	To be used to mark the PVC pipe				
9	String, a piece of soft cardboard or paper	For a 4 in pipe (15 in/ 37cm); for a 6 in pipe (22in/54cm) at least long.				
	OR					
	A piece of paper and a string	The string must be at least 16 ft long				
10	Ruler or straight stick	Preferable one meter long or longer. It will be used to mark straight lines in the PVC pipe				
11	Two pieces of 1-1½ inch PVC pipe.	Two or three ft long. Used as a helping device in the drilling process				
12	**Painting Supplies**					

There is a variety of ways to paint the inside - outside of the guard-pipe; using paint brushes and rollers, paint sprayers, paint sprayers guns, or special design paint tools. In this manual, three painting methods are briefly described:

a. Using paint brushes to paint the outside and inside

b. Using paint brushes to paint the outside and a pole with a sponge attached at one end to paint the inside

c. Using a special designed paint tub.

Table 3.3

SUPPLIES	
Antifouling coating	Micron Extra with Biolux (5696 Dark Blue) from Interlux, International Paint Inc or other similar. Choose the paint that works best under the environmental conditions the station will operate (*i.e.* fresh or salt water). Black paint is another recommended color. If black paint is selected, care must be taken if the painted pipe will stay out of the water during hot weather conditions; the black paint can cause an increase of the temperature inside the pipe. White or similar paints can not be used – they will cause reflection problems with the optical sensors.
Degreaser	PVC pipes are generally oily; it is a good practice to clean the inside and outer surfaces of the pipe with a degreaser (*e.g.* Simple Green) before painting. The cleaning improves the bonding between the coating and the PVC.

a.	Using paint brushes to paint the outside and inside
Paint Brushes	Any kind. Cheap are best to paint the outside of the pipe.
	1.5 inch wide to paint through the holes the inside of the pipe.

b.	Using paint brushes to paint the outside and a pole with a sponge attached at one end to paint the inside	
Paint brushes	Any kind. Cheap are best to paint the outside of the pipe	
Clean up sponge	Cheap is best to be used as the painting device.	
PVC or stick at least 8 ft long.	The sponge will be attached at one end (*i.e.* a ¾ in PVC pipe).	

c.	Using a special designed paint tub so the pipe can be submerged in the paint				
PVC pipe	Schedule	Diameter	Length	Quantity	
	40	6 in	8 ft	1	
PVC cap		6 in		1	
Wood	The type and quantity will depend on the type of holding structure to be designed.				

Cont. Table 3.3

3.2.5 CONSTRUCTION STEPS

One attribute that must be assured, in any type of protective pipe design, is that the aquatic environmental conditions inside the pipe are the same as the outside during sampling. In order to ensure this in the guard-pipe, four sets of 2 inch (5 cm) holes (ventilation holes) along the pipe, and four sets of windows (13 by 2 inches; 33 by 5 cm) at the bottom of the pipe are drilled to guarantee a good water flow.

The construction of the guard-pipe is divided into three main activities:

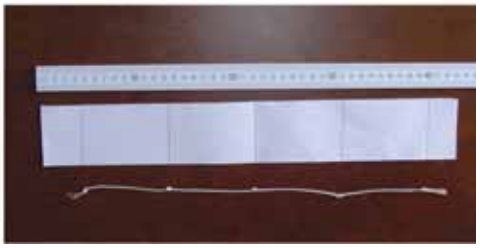
- Drilling the ventilation holes and windows.
- Painting the guard-pipe with antifouling paint.
- Preparing the safety lock system.

1 **Subdivide the PVC pipe into 4 equal sections**

There are a variety of ways to subdivide a PVC pipe into 4 equal sections, two methods are shown here.

Using a string or a piece of paper

1 **Divide the string or paper into 4 equal sections**



→ The length of each section is shown in Table 3.4.

PVC Pipe	O. D.	Outside Perimeter	Length of each of the 4 sections
4 in (10.16 cm)	4.5 in	14.1 in	3.53 in
	11.43 cm	35.9 cm	8.98 cm

Table 3.4 Length of sections

2 **Draw a 70 inch guide-line on the PVC pipe**

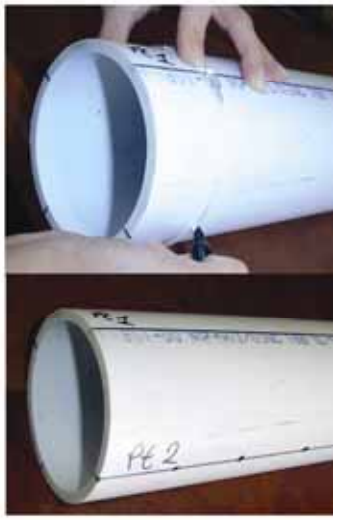
→ PVC pipes come with a specification line written across the pipe. Use this line as a guide.

→ Place a ruler aligned with the specifications and draw a line from one end of the PVC pipe to a 70 inch mark.

This line is labeled "Pt 1"

If the pipe does not come with a specification line, a guide line can be drawn with a T ruler; mark a perpendicular line at one end of the pipe.

3 **Divide the PVC pipe into 4 equal sections**



→ Place the first mark of the string or paper matching Pt 1, and wrap the string or paper around the pipe

→ Using the other marks of the string or paper, draw 3 more points along the PVC circumference, Pt 2, Pt 3 and Pt 4.

→ Using the "Pt 1 line" as a guide, repeat this process three more times along the PVC pipe (to minimize drawing errors, it is convenient that the Pt 1 points are approximately 5 inches apart from each other).

→ Join the points with a ruler so three lines are created.

- → Line Pt 2 (Pt 2 - Pt 2′ -Pt 2″)
- → Line Pt 3 (Pt 3 - Pt 3′ -Pt 3″)
- → Line Pt 4 (Pt 4 - Pt 4′ -Pt 4″)

Mark additional sections along the pipe and continue to draw the three lines up to the 70 inch mark.

Using a square piece of paper

Cut a piece of paper into a square (Side = 3 1/8 in or 8 cm), and draw the two diagonals.

1 Mark four point on each end of the PVC pipe

→ Place a ruler aligned with the specifications of the pipe and draw a line from one end of the PVC pipe to a 70 inch mark.

This line is labeled "Pt 1"

→ Place the square of paper with one of the corners aligned with the Pt 1 line.

→ Mark the Pt 2, Pt 3 and Pt 4 points (meeting points PVC pipe and corners of the square of paper).

→ Repeat this process at the other end of the PVC pipe.

2 Draw four lines along the PVC pipe

→ Attach a string from Pt 2 to Pt 2′ (*e.g.* with duck tape)

→ Mark several points along the line (this will be the Pt 2 line).

→ Repeat this process with Pt 3 and Pt 4.

→ Using a ruler connect these points to create 3 lines.

If several guard pipes are going to be constructed at the same time; an option to ease the work is to use a plastic cup to mark the division points.

Once the four points are marked at one end of the PVC pipe; a plastic cup is introduced at that end and the points are marked on the cup (a guide line is marked on the cup to define the penetration depth of the cup into the pipe).

The cup is inserted in a new PVC pipe, aligning the specification line to one of the points of the plastic cup.

2 Mark the drilling-hole points

A set of points are marked on each line. These points identify where the ventilation holes are going to be located.

→ On each line mark the drilling-hole points as listed in Table 3.5.

Table 3.5: Drill Hole Points (Inches)				
# of Hole	Pts 1	Pts 2	Pts 3	Pts 4
1	4	4	4	4
2	15	15	15	15
3	18	21	18	21
4	24	27	24	27
5	30	33	30	33
6	36	39	36	39
7	42	45	42	45
8	48	51	48	51
9	54	57	54	57
10	60	63	60	63

3 Drill a 2 inch hole at each drilling-hole mark

Use a 2 inch drill bit and drill a hole in each drilling-hole point.

→ Precaution must be taken when drilling holes in a round and slippery surface such as a PVC pipe. The drill could slip out of the hole and cause injuries.

→ The drill bit can get stuck in the hole, causing the drill to rotate; wrist injuries can occur.

NOTE 1: A 1-1 1/2 inch PVC pipe, 2 to 3 foot long can be used to help the drilling process if a drill press is not being used.

4 Mark the monitoring sensor windows

- Draw two tangent lines to connect each of the 4 inch and 15 inch holes.
- Employing a jig saw or any other type of saw, cut the PVC pipe to connect the two holes.

→ Four windows will be created.

5 Smooth the hole edges

Sanding the Guard Pipe at Jordan Marina

- File and sand the holes to smooth the edges.

6 Place bolt-stoppers

To ensure the monitoring sonde will be positioned at the windows depth when deployed, two small bolts are placed at the end of the pipe to act as stoppers. The monitoring sonde will rest on these bolts when deployed.

- Drill a 5/16 inch hole at 5 cm from the bottom of the PVC pipe.

→ One hole between the Pt 1 and Pt 2 lines, and the other hole between the Pt 3 and Pt 4 lines.

→ 1 in - 5/16 galvanized or stainless steel bolts are placed inward. One or two nuts are used to tighten the bolts in place.

NOTE:

→ The pipes should have an open bottom so that if debris enters it can fall out.

→ It is a good practice to avoid using only a long bolt at the bottom of the pipe to hold the sonde in place. There are two drawbacks: first, a long stainless steel bolt may affect turbidity readings and second, a long bolt does not permit an adequate cleaning of the pipe.

7

Antifouling coating

Precautions with antifouling coating

Antifouling paint is generally toxic. Careful attention must be given to how the paint is handled and applied. Some precautions for handling and using the antifouling paint are:

Handling - Storage

READ AND FOLLOW THE MANUFACTURER'S INSTRUCTIONS AND SAFETY PRECAUTIONS.

The label displays a number of warning and safety issues which indicate those areas where particular care should be taken.

- Ensure a well ventilated working area.
- Avoid prolonged or repeated skin contact.
- Avoid contact with eyes.
- Avoid breathing in fumes vapors or over spray mist.
- Keep away from all sources of ignition.
- Do not store or use in close proximity to strong oxidizing agents (*i.e.* peroxides, hypochlorites).

Protective Clothing and Equipment

- Always wear the personal protective equipment specified on the label or in the MSDSs.
- Remove watch straps as these can trap paint particles next to the skin.
- Wear safety glasses, goggles or suitable face shield; protective gloves, suitable outfit to protect your clothes (e.g. lab coat, apron).
- Use proper respiratory protection (organic vapor respirator).
- Skin protectan cream can be helpful.

Cleaning

- Never use solvent or thinners to clean the skin.
- Remove immediately any paint that does get onto the skin by washing with warm water and soap or an approved skin cleanser.
- Wash hands after use and before eating, drinking or using the toilet.
- Wash contaminated clothing before re-use, and clean personal protective equipment before storing or re-using.
- After washing, apply a skin conditioner.

NOTE: If a power painter spray is going to be employed, it must be noted that spray painting creates additional health hazards. Spray mists should NOT be inhaled and special equipment is required. Use air-supplied respiratory protection that is NIOSH approved.

Setting up the painting area and tools

- Paint the guard pipes in open air; in a well-ventilated area.
- At the 70 inch (180 cm) tape the guard pipe with duck-tape or masking tape to mark the end of the painting section.
- Place the guard pipe in a convenient position.
- Place plastic, paper or other conventional cover on the floor to collect paint drips.

Paint the guard-pipe

Clean PVC pipe with a degreaser

Using brushes or rollers

- Paint the inside of the pipe using the long thin brush. Paint through the holes while rotating the pipe.
- Paint the outside of the pipe with a cheap brush or a roller.

Using brushes or rollers to paint the outside
Using pole and sponge to paint the inside

- Prepare the painting pole.
  - Cut a clean-up sponge to a convenient size.
  - Tape the sponge to one end of the pole with duck-tape.

- Paint the inside of the pipe with the painting pole.
- Paint the outside of the pipe with a cheap brush or a roller.

Submerging the pipe in the paint

A painting tub is built with a 6 inch PVC pipe.

This is a good method to use when painting several pipes at the same time.

- Using a jigsaw make a 6 feet long 5 inches wide opening in the 6 inch pipe.
- At the close end, glue the 6 inch cap.
- Make a support structure to place the 6 in pipe and screw the pipe to the structure.

Fill the pipe with antifouling paint. Place small pieces of board at the bottom of the structure legs to level it so the paint covers the area of the guard pipe to be painted but does not leak out by the open end.

Once the pipe is painted, lift it to a vertical position and let the excess paint drip off into the 6 inch painting pipe-tub.

Given the great amount of paint employed at one time, special care must be taken to minimize spills during the whole painting process.

Usually two coats are required. Given the over coating time ranges from 8 to 15 hours, it is recommended to paint the second coat on the next day.

Dispose of all paintbrushes, gloves, papers, rollers and any other painting tool or equipment properly.

8 Preparing the safety lock system

A variety of methods exist to secure the multiparameter sensor in the guard-pipe to prevent vandalism.

The method to select will depend on the site risk factors.

Two simple safety systems are shown in this section:

Bolt-Padlock system

Drill a 3/8 inch hole at the end of the 8 in - 9/16 hex bolt.

Drill two 3/4 inch opposite holes in the 4 inch coupling.

Check that everything fits together.
The coupling will be glued to the guard-pipe during station deployment.

Cap-Bolt-Padlock system

- Cut the chain to the appropriate length.
  - During station deployment, two 3/4 inch opposite holes will be drilled in the guard-pipe to place the 8 inch bolt. The chain will be secured to the bolt. Therefore, the chain length will determine where the holes will be drilled
- Using a galvanized carriage bolt, secure a chain to the cap as shown in the figure.
- Place at the end of the chain a split link if the width of the chain is not big enough to accommodate the 8 inch bolt.

- The multiparameter sonde can be hanged from the 8 inch bolt using a rope, stainless steel wire or chain.

- Another option to hold the multiparameter sonde is to use a PVC pipe. This is a good alternative when the sonde will be placed in areas where wave action can shake the sonde at low water. A small weight is attached to the PVC pipe to provide extra mass to hold the sonde in place.
  - Make sure the rope, wire, chain or PVC pipe is long enough for the sonde to rest on the bolts-stoppers

- Another alternative to secure the data sonde is to hang the it from to the cap.

  This is a good alternative if:
  - The bolt or flat bar (where the padlock is secured) goes through the cap
  - There are some safety concerns that the hanging rope can be dropped accidentally in the tube when the bolt is removed

Locking System - Nexsens Technology

One option to achieve this is to drill a hole at the top of the cap to place a 3-4 inch carriage bolt (*e.g.* 9/16 in diameter). A hole is drilled at the end of the bolt so a carabiner, quick link or a snap hook can be placed.

MWSS MFG, Inc.

- A flanged end-cap or a self-closing sewer cap can also be used. These type of caps have the advantage of having a good surface area around it or a handle that facilitates taking the caps off.

The National Park Service (2006) employs an eye bolt installed on the underside of the cap to hang the datasonde. The threads of the bolt are scuffed after the nut is placed as a security measure so the nut cannot be removed.

National Park Service - Southeast Regional Office

3.3 EXAMPLES OF OTHER PIPE-GUARDS

In the following, some examples of other guard-pipe designs are given for illustrative purpose only.

- → Figure 3.3 shows guard-pipes designed by AMJ Environmental, YSI Incorporated.
- → Figure 3.4 shows a guard-pipe designed by Nexsens Technology.
- → Figure 3.5 shows a guard-pipe used in the continuous water-quality sampling programs of the Province of British Columbia, Canada.
- → Figure 3.6 shows a guard-pipe used in high-flow environments.

Figure 3.3 Guard-pipe by AMJ Environmental, YSI

Figure 3.4 Guard-pipe by Nexsens Technology

Figure 3.5 Guard-pipe by The Province of British Columbia

Even though, all the designs have different layouts and styles of holes, each one maintains the critical design factor, an adequate opening system to allow a free flow of water through the pipe.

If the monitoring site is in a high-flow environment, it is recommended to add additional protection to the sensors (BC Ministry of Environment, 2007). This can be done by cutting only two or three windows at the bottom part of the guard-pipe to guarantee a good water flow and leaving a solid part that can be faced upstream to provide the additional protection from the fast moving debris (Figure 3.6).

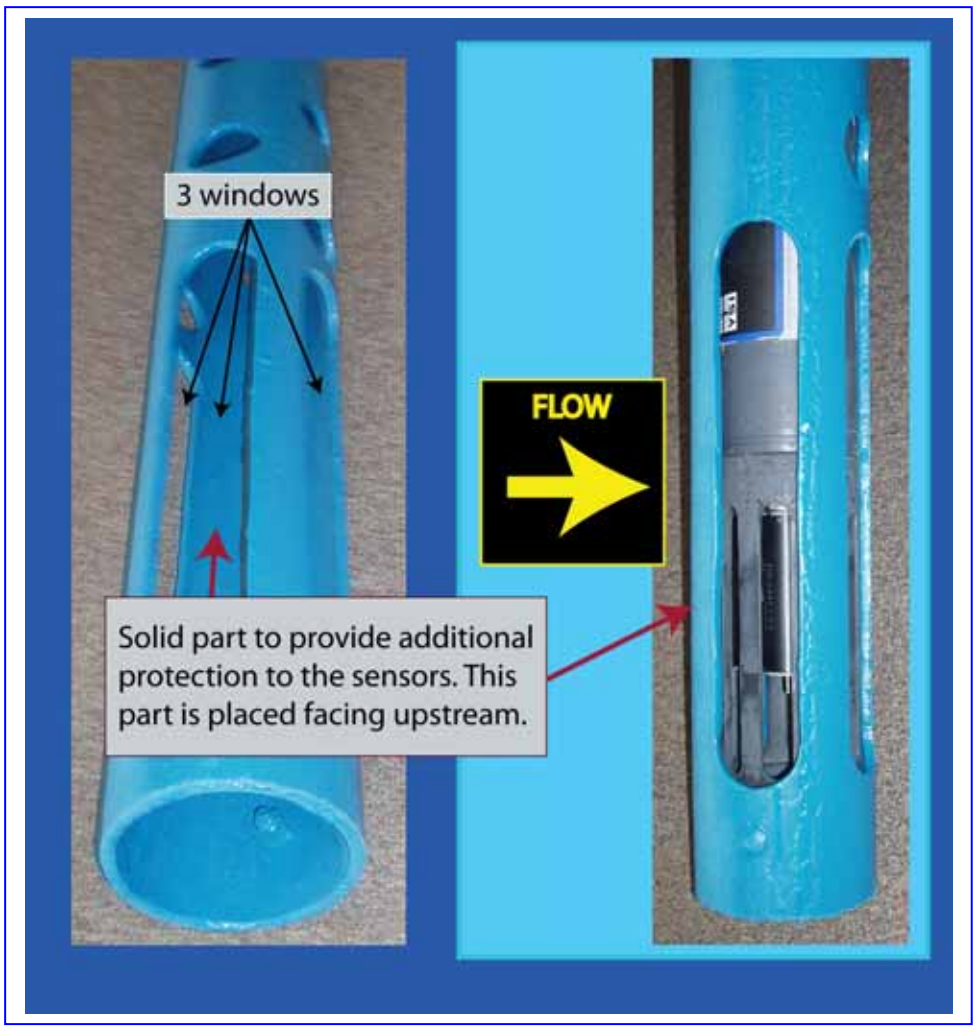


Figure 3.6 Guard-pipe for high-flow environments

3.4 PORTABLE PIPE-GUARD

Portable guard-pipes can be constructed to protect handheld multiparameter sondes (*e.g.* sondes to be used with the YSI MDS 650).

The same design principles must be applied to assure the same aquatic environmental conditions inside and outside the pipe.

For example, a portable guard-pipe for the YSI 600XL sonde is shown in Figure 3.7. This device is used to perform vertical profiling in high water flow environments.

Figure 3.7 Guard-pipe for YSI MDS 650

3.5 REFERENCE

Akzo Nobel. **Material Data Sheet**. Micron Extra Blue Antifouling.

BC Ministry of Environment. 2007. **Continuous Water-Quality Sampling Programs: Operating Procedures.** Watershed and Aquifer Science. Science and Information Branch. The Province of British Columbia.

CDMO. 2007. **YSI 6-Series Multi-Parameter Water Quality Monitoring Standard Operating Procedure. Version 4.1** National Estuarine Research Reserve System-Wide Monitoring Program (SWMP).

Hine Ken. **Paint Shop Health Concerns - What's In Today's Systems?** AutoInc. Magazine. Vol. XLV No. 2, February 1997.

Kopp Blaine S. and Hilary A. Neckles. 2004. **Monitoring Protocols for the National Park Service North Atlantic Coastal Parks: Ecosystem Indicators of Estuarine Eutrophication**. Version 1.0. USGS Patuxent Wildlife Research Center.

Miles, Eduardo J. 2008. **The SSC cycle: a PDCA approach to address site-specific characteristics in a continuous shallow water quality monitoring project**. Journal of Environmental Monitoring: 10, 604 – 611. DOI: 10.1039/b717406c.

Mining and Quarrying Occupational Health and Safety Committee. **Quarry Safe Hazardous Substances in Quarries**. 1996. Australia.

National Occupational Health and Safety Commission. **National Guidance Material for Spray Painting**. Commonwealth of Australia. June 1999.

National Park Service. 2006. **Core Parameter Fixed-Station Water Quality Monitoring**. Southeast Regional Office. Natural Resource Report . PS/SER/SECN/NRR—2007/xxx. http://science.nature.nps.gov/im/units/SECN/docs/3.1._Core_Parameter_Fixed_Station_WQ.pdf

3.5.1 Photo Reference

Photo Locking System – Nexsens Technology, Page XX. http://www.nexsens.com/

Photo MWSS MFG Inc. Page XX. Sewer Cap. http://www.mwssmfg.com/self-closing-sewer-caps.htm

Photo National Park Service. Page XX. National Park Service. 2006. **Core Parameter Fixed-Station Water Quality Monitoring**. Southeast Regional Office. Natural Resource Report . PS/SER/SECN/NRR—2007/xxx. http://science.nature.nps.gov/im/units/SECN/docs/3.1._Core_Parameter_Fixed_Station_WQ.pdf

Figure 3.3 - Guard-pipe by AMJ Environmental, YSI Incorporated.

Figure 3.4 - Deployment Pipe Assemblies. Nexsens Technology. http://www.nexsens.com/products/deployment_pipe_assemblies.htm

Figure 3.5 – Photo by Frank van der Have. An Example Of A Slotted Deployment Tube. BC Ministry of Environment. 2007. Continuous Water-Quality Sampling Programs: Operating Procedures. Watershed and Aquifer Science. Science and Information Branch. The Province of British Columbia. Resources Information Standard Committee. http://www.ilmb.gov.bc.ca/risc/pubs/aquatic/waterqual/assets/continuous_waterqual.pdf

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.

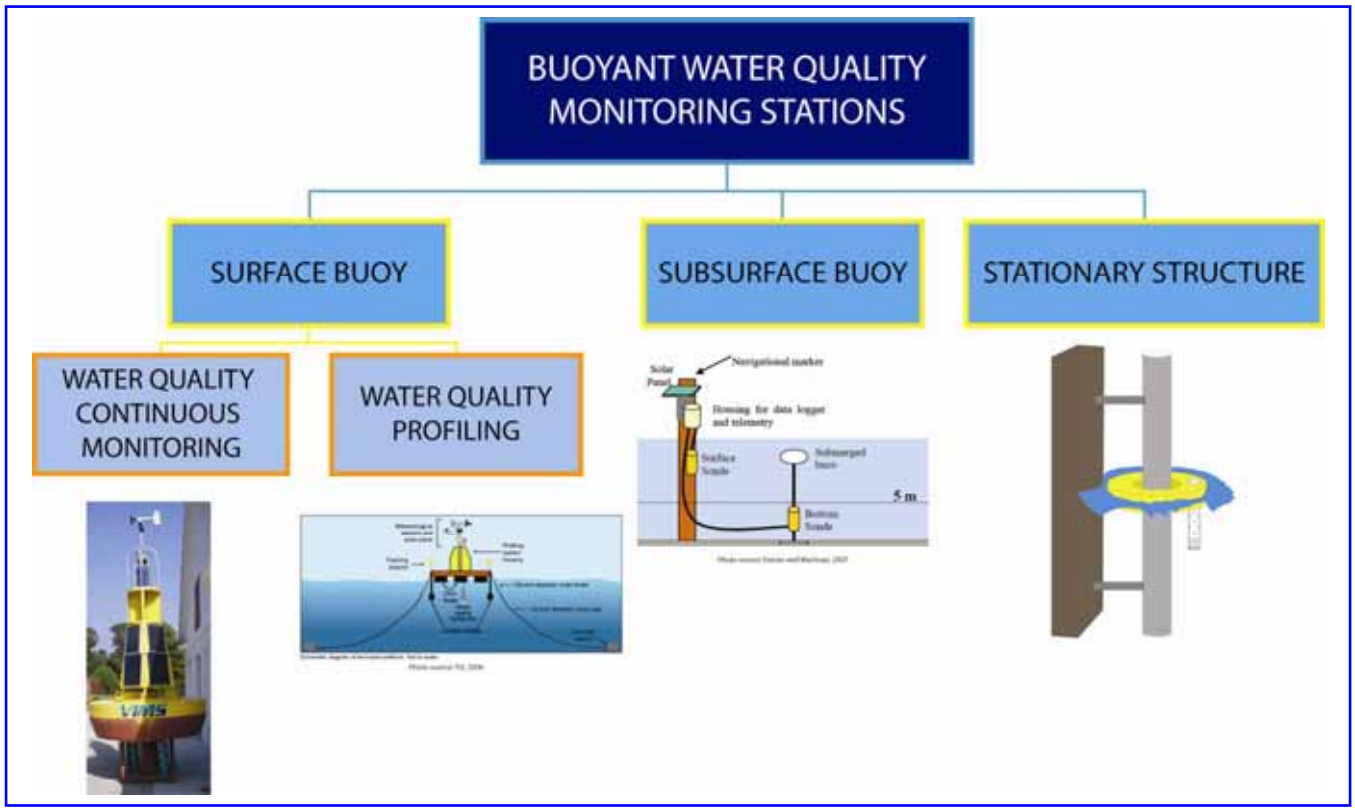


Figure 4.1 Types of near shore buoyant monitoring stations

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.

<u>Single point moored surface buoy systems</u>: 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.

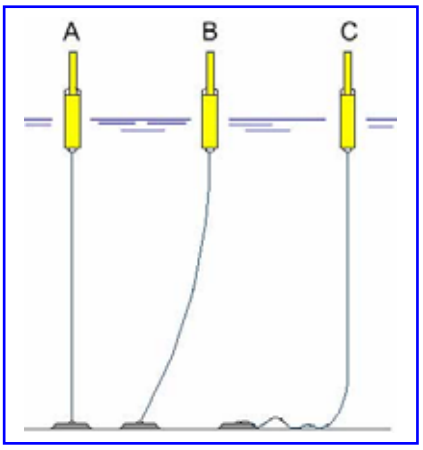


Figure 4.2 Mooring systems types (Soruce: CCG, 2001)

<u>Multileg surface buoy systems</u>: 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).

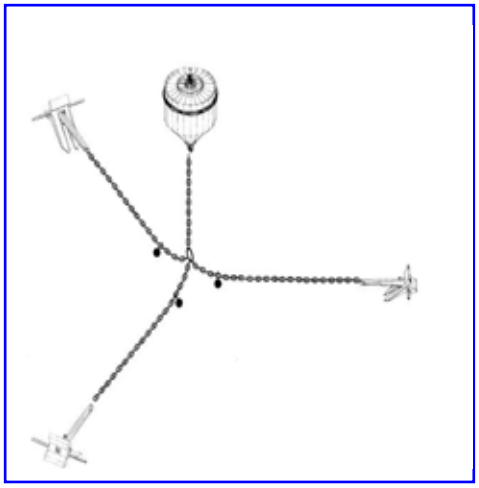


Figure 4.3 Single point mooring with drag anchors
(Sorce: U.S. Army Corps of Engineers *et. al.*,2005)

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).

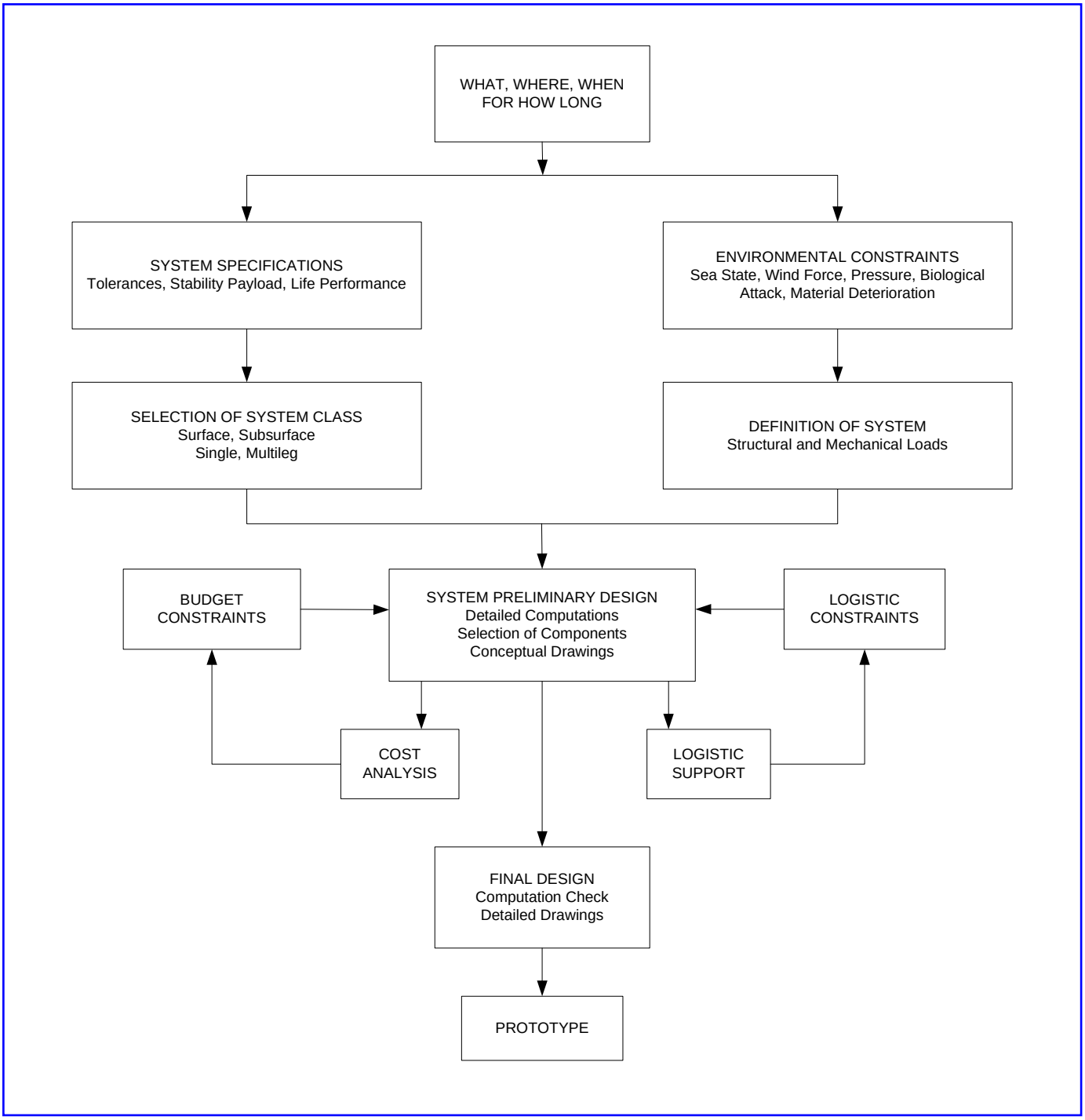


Figure 4.4 Buoy design flowchart (Soruce: Berteaux, 1976)

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.

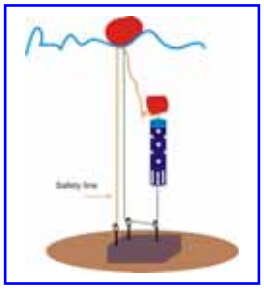


Figure 4.5 Sketch of a subsurface system

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.

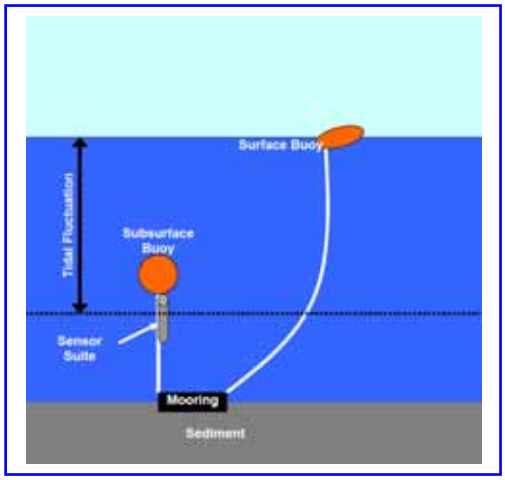


Figure 4.7 Application of subsurface buoy at New Bedford Harbor
(Soruce: Battelle, 2007)

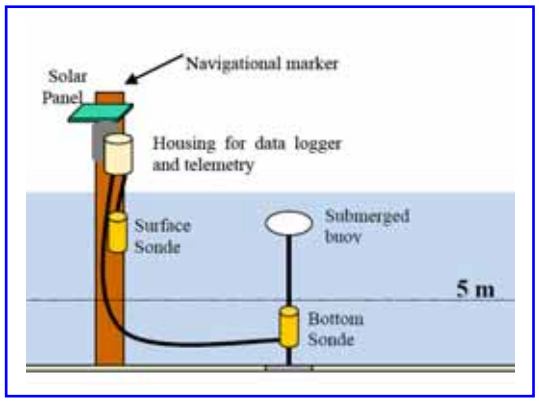


Figure 4.8 Application of subsurface buoy at Lakes King and Lake Victoria
(Source: Davies and Martinez, 2007)

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.

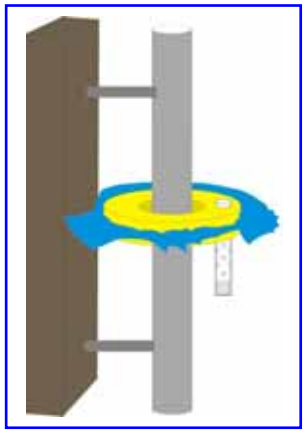


Figure 4.11 Sketch of a designed stationary structure buoyant system

4.5 REFERENCE

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.

Berteaux, H.O. 1976. **Buoy Engineering**. John Wiley & Sons. New York.

Bosart L.F. And William A. Sprigg. 1998. **The Meteorological Buoy and Coastal Marine Automated Network for the United States**. Board on Atmospheric Sciences and Climate. Commission on Geosciences, Environment, and Resources National Research Council. NATIONAL ACADEMY PRESS.

Canadian Coast Guard. 2001. **An Owner's Guide to Private Aids to Navigation**.

Cluney, T.J. and Christopher A. Kinner. 2000. **Equipment Design and Implementation For Continuous Monitoring in an Estuary**. NWQMC National Monitoring Conference. Conference Proceedings.

Cuetara Jay I., Jon R. Burau, and David H. Schoellhamer. 2001. **Hydrodynamic and Suspended-Solids Concentration Measurements in Suisun Bay, California, 1995 U.S.** GEOLOGICAL SURVEY. Water Resources Investigation Report 01-4086 Sacramento, California 2001.

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, SI 50 (Proceedings of the 9th International Coastal Symposium), 57 – 61. Gold Coast, Australia, ISSN 0749.0208.

Joosten H.P, Datawell B.V. and S. Hoekstra. 2004. **Elastic mooring of navigation buoys in shallow water**.

Miles, Eduardo J. 2008. **The SSC cycle: a PDCA approach to address site-specific characteristics in a continuous shallow water quality monitoring project**. Journal of Environmental Monitoring: 10, 604 – 611. DOI: 10.1039/b717406c.

Paul Walter, and Jim Irish, Jason Gobat and Mark Grosenbaugh. 1999. **Coastal Mooring Design: Taut Elastomeric and Chain Catenary Surface Buoy Moorings**. Proc. Oceans '99, 418-429.

Reynolds-Fleming Janelle V., Jason G. Fleming, and Richard A. Luettich, Jr. 2002. **Portable Autonomous Vertical Profiler for Estuarine Applications**. Estuaries: Vol. 25, No. 1, pp. 142–147.

Tupper George and Ian Waddington, Gabriele Ferrari. 2000. **Mooring Technology Proceedings** Inmartech 2000 Texel The Netherlands.

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.

YSI, 2006. **Monitoring and Protecting Water Quality in Lake Mead, Nevada**. Application Notes. 0506 A539.

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

Davies and Martinez Photo - 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 4.2 - 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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CHAPTER 5

FIXED STRUCTURE MONITORING STATIONS

5.1 INTRODUCTION

There are many types of fixed structures that can be used to place or fasten the monitoring sondes at a fixed position from the bottom substrate. In this section, three categories of fixed structures are described (Figure 5.1):

→ DESIGNED PLATFORM
→ EXISTING STRUCTURE
→ ON RIVER & STREAM BANK STRUCTURE

As explained in the Preface, research has shown that most of the project's life-cycle quality and cost are committed by the decisions taken by the end of the planning and design stages.

One of the best practices employed to improve quality, prevent errors, and minimize cost is by adapting or reviewing during the planning and design stages known techniques or processes that have shown through experience to achieve the desire result in a reliable, efficient, and effective way.

Design and construction guidelines are provided in this chapter to facilitate an understanding of the different station design requirements and to support and guide the monitoring team during the monitoring platform selection process.

The following guidelines are provided:

→ FOR DESIGNED PLATFORM:

- Detail guidelines: Antenna Tower-PVC; Antenna Tower-Wood; and Wood.
- General guidelines: PVC, pile and underwater structures.

→ FOR EXISTING STRUCTURE:

- General construction guidelines: pier and pile structures.

→ FOR ON RIVER & STREAM BANK STRUCTURE:

- General construction guidelines: on river & stream bank structures without equipment shelter.

Figure 5.1 Fixed shallow water continuous monitoring structures

5.2 DESIGNED PLATFORM: PILE

5.2.1 Introduction

A general overview of pile foundations is provided here as an introduction. A more detail description can be found in Collin 2002; Department of the Army, 1985; Gerwick, 2000; Tomlinson, 1994; and US Army Corps of Engineers, 1998, 2003.

The pile monitoring station is the most basic type of designed platform (Figure 5.2). A pile is a long column usually made of steel, reinforced concrete, pressure treated timber, or PVC that is driven into the ground to support the monitoring equipment. One possible classification of piles is: by the way in which they transmit their load to the ground; and by the way in which they are installed (The Hong Kong Polytechnic University; Abebe and Smith, 2005).

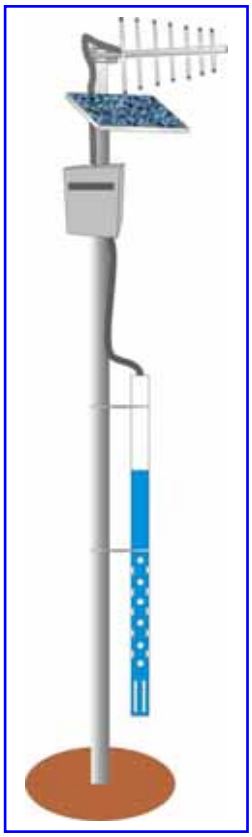


Figure 5.2 Sketch of a piling monitoring structure

- **Transmission of Load to the Ground**: Bearing or friction piles (Figure 5.3).

  Bearing Pile: A pile which rests its base on a relatively firm stratum of good bearing capacity such as rock, very dense sand or gravel. These piles transfer their load onto the firm stratum located at a considerable depth below the base of the structure.

  Friction Pile: A pile which rests on a stratum of limited bearing capacity[¶] and provides its support through friction resistance along the lateral surface of the pile. The pile transmits the load of the structure to the penetrable soil by means of skin friction or cohesion between the soil and the embedded surface of the pile.

- **Installation Method**: Displacement or replacement piles.

  Displacement Pile: The pile is driven or vibrated into the ground, and the soil is displaced downwards and sideways. To develop adequate frictional resistance, the pile is driven far enough into the lower substrate.

  Replacement Pile: The pile is placed or constructed in a previously drilled borehole.

Most commonly, displacement friction piles are employed for continuous shallow water quality monitoring projects. The main reason for using this type of pile is that bearing piles are more expensive to use. Usually the firm stratum is at a considerable depth; therefore, a longer pile and special installation equipment will be needed.

The bearing capacity of the pile is determined by the weight of the: pile, guard-pipe, and monitoring and telemetry equipment.

[¶] The bearing capacity of a pile is the load which can be sustained by a pile without producing excessive settlement or material movement (Shroff and Shah, 2003).

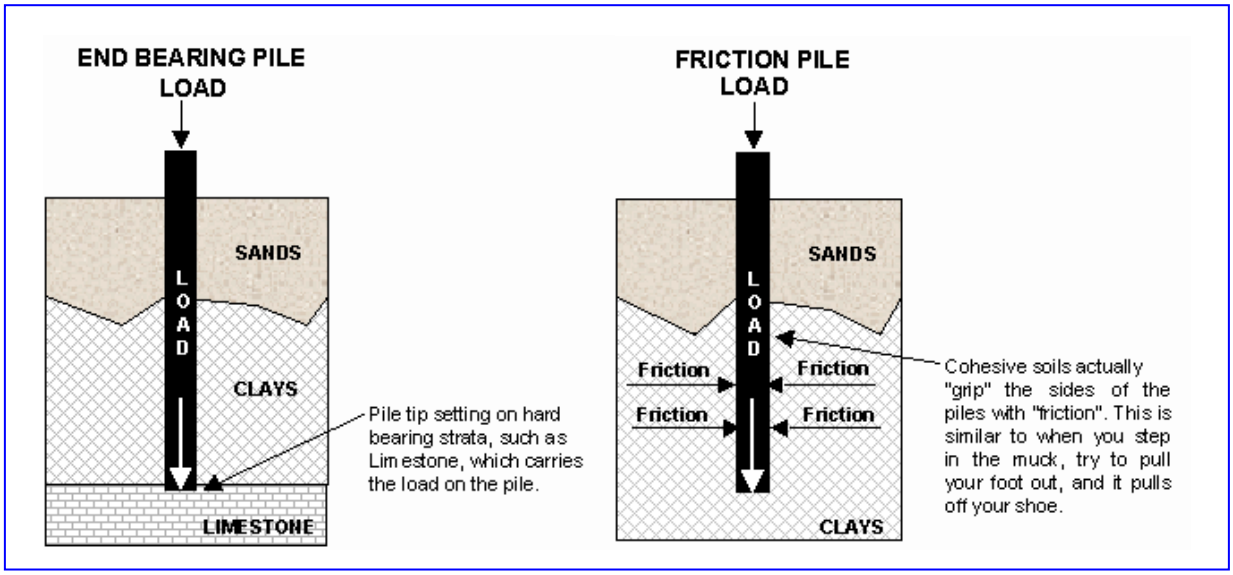


Figure 5.3 Sketch of bearing and friction piles (Source: FHWA, 2007)

5.2.2 Construction Guidelines

The site-specific and pile characteristics would determine if it is better to hire a professional marine piling driving company or perform the installation in-house.

An outline of design and construction considerations follows.

Site Characterization: the type of substrate at the monitoring site must be assessed. The type of soil will define the installation method and the minimum penetration depth to assure adequate lateral support.

Pile Material: generally, pile material consists of pressure treated timber, PVC, steel, or reinforced concrete. In terms of accessibility, cost, and ease of installation, pressure treated piles and PVC pipes are the materials of choice.

If a PVC pipe is employed, it is good practice to fill the pipe with concrete or sand and gravel to increase moment capacity.

For shallow water quality monitoring projects, the materials of choice are:

- **Pressure-treated wood**: Round timber piles (6 to 9 inch diameter – 14 to 20 feet long) or Posts (4"x6", 6"x6").
- **PVC**: Schedule 40; 6 to 10 inch pipe size diameter.

Note: During the pressure treatment process, preservative is added to the wood. The retention levels (expressed in terms of pounds of preservative per cubic foot of wood) refer to the amount of chemical preservative retained in the wood cell structure after the pressure process has been completed. The higher the retention level, the harsher the conditions that wood can be exposed to (Osmond *et al.*, 2003).

Application	Required Retention (pcf)
Fresh Water	0.80
Salt Water Immersion	2.50

Standards of the American Wood-Preservers' Association (www.awpa.com)

Installation Method: two basic installation methods exist for driving the pile into the soil; hammering or jetting (FHWA, 2007; Abebe and Smith, 2005).

- Hammer types include; drop, single acting air/steam, double acting air/steam, diesel or hydraulic or diesel with built-in energy measurement.
    - To drive timber piles use only gravity hammers.
    - Depending on the job, renting a small pile driving barge or portable marine pile driving equipment can be a good choice.

Figure 5.4 Drop hammer
(Source: Whatcom Waterfront Construction)

Figure 5.5 Small pile driving work barge
(Source: ASD Pty Ltd., Marine Pile Drivers)

- Jetting is the process of using water under pressure to erode the soil in order to aid the penetration of the pile. Jetting has very limited effect in firm to stiff clays or any soil containing much coarse gravel, cobbles, or boulders.

  For shallow waters a jetting system can easily be assembled; basically, it consists of the following equipment:

Water pump There are a variety of water pumps that would work well for jetting piles. A 2 inch 3 ½ to 5 ½ HP transfer pump with maximum flows from 145 to 200 gpm at maximum pressure of 40 to 50 psi works well in most shallow water environments.	
Couplings, pipe fittings, and valves to connect the jetting assembly to the water pump.	
Discharge and suction hoses (or PVC suction pipe).	
Jet pipes; Pipe and hose fittings	

NOTE

→ The installation method will be determined by the type of pile material, length of the pile, substrate characteristics, and the monitoring objectives (the station platform must comply with the monitoring objectives; thus, it is possible that the only way to ensure the monitoring objectives is to use a certain pile structure that requires a drop hammer to install).

→ Care must be taken if jetting will be used to install the pile in a sea grass bed. The high-pressure water disturbs the adjacent vegetation and sediments, and could cause irremediable damage to the sea grass adjacent to the construction area (Kelty and Bliven, 2003).

Deployment Tips

- **Pile Preparation**:
  - The pile must be inspected and cut (if needed) before installation.
  - It is a good practice for timber piles to cut or trim the bottom of the pile to a cone or inverted pyramid shape. This will ease the pile penetration. For hard substrates, a pile shoe may be used to protect the pile-tip from damage during driving.

Figure 5.6 View of pile bottom

  - It is a good practice, if the pile has different diameter size (top – end), to place the larger size as the end, and cut or trim this end. If the water freezes during winter, this may help to prevent the ice from lifting the pile out of the ground.
  - If hammering is used, it is a good practice to place steel bands or pipe clamp at the top to prevent splitting. If a sledge hammer is used for hammering, duck tape can be used to wrap the top part of the pile to increase its shock resistance.
  - If hammering is not used, and the pile will use an antenna tower to support the telemetry equipment; the antenna tower may be installed on land.

Figure 5.7 View of pile with the antenna tower mounted on land

- **Hammering**: Usually hammering will be needed to drive the wooden post or PVC pipe into the substrate. In most situations, a sledge hammer will be enough to do the job.
  - Hammer cushions must be used to protect the PVC pipe or wooden post.
    - Cushions must not be too hard because they may cause pile damage. Commonly cushion are made of hardwood, plywood, woven steel wire, laminated micarta and aluminum discs, and plastic laminated discs (US Army Corps of Engineers, 1998).
    - A piece of treated lumber (2" by 4" or 2" by 6") makes a good cushion.
- **Jetting**: Jetting may be used alone or may be needed to help the hammering process to aid the penetration of the pile into the bottom substrate.
  - It is good practice to make first a hole where the pile will be installed; this will ease the driving process, specially standing up the pile. It is important not to make the hole to big, to assure that sufficient resistance will be encountered by the pile as it is driven (adequate bearing power is develop).
  - During the jetting process, the best results are obtained when the water jet is close to the pile bottom and the jet is moved around the pile (to keep the pile in a straight position).
  - Moving the jet pipe up and down along the pile can help the driving process.

Figure 5.8 Jetting initial hole

Figure 5.9 Jetting process

  - Do not leave the jet pipe standing still while jetting, it can easily get stuck.
  - In hard substrates, turning the pile as it is being jetted may ease the pile driving process. Some kind of pipe clamp (L-clamp or a large C-clamp) can be used as a support to twist the pile.
  - It is a good practice to mark the pile and the jet pipe to ensure the pipe is hold at the same depth as the bottom of the pilling.
  - PVC pipes can be driven either open end or closed end. When driven open end, the soil will enter by the bottom of the pipe. If needed, to empty the pipe the water jet can be used.

- **Penetration Depth**

  - It is a good practice to mark the pile to ensure the desire penetration depth is reached.

    Even though the penetration depth depends on several factors, as a rule of thumb, the pile must be driven a minimum of one third of its height. The pile must be tight and secure before the installation process is stopped.

Figure 5.10 Pile station waiting for the guard-pipe to be placed.

- **Guard-Pipe Holding System**

  - Any type of pipe hanger device can be used to secure the guard-pipe to the pile. For example, clevis or conduit hangers are commonly employed (Figure 5.11).

    Some distance must be kept between the guard-pipe and the structure to minimize possible effects produced by the structure to the water quality data (*i.e.* seaweeds or any other type of biofouling growing on the structure).

Figure 5.11 Clevis and Conduit Hangers

Figure 5.12 View of different methods used to attach the guard-pipe to the pile.

Some advantages of the pile structure monitoring platform are: it is easy to construct, can be used in almost any type of shallow water monitoring environment, and it is a good platform alternative when the monitoring endeavor is for a very short period of time.

Some disadvantages of this type of structure are: 1) The station stability depends on two factors; the penetration depth and the pile material's strength; soft substrate environments may require large penetration depth, making it less cost-effective; 2) Special equipment may be needed to drive the piling into the ground to achieve the necessary penetration depth to ensure station stability; 3) Readily available PVC pipes in general come in 16 ft (4.9 m) length. To achieve adequate heights above the water level, pipes may be necessary to glue together, producing weak points in the structure.

Figure 5.13 View of different pile platforms
(Source: CBNERRVA, South Slough NERR, Rookery Bay)

5.3 DESIGNED PLATFORM: PVC STRUCTURES

PVC structures can be seen as Lego type structures given the great variety of existing PVC fittings, pipes, and accessories. In this section two basic PVC structures are given as guideline only; a two and a four leg structures.

5.3.1 Two Leg PVC Structure

The two-leg PVC monitoring station is constructed by driving two PVC pipes into the soil. These pipes are used as the platform frame. Two transverse PVC pipes are employed to fasten the two legs together and to hold the sensor guard in position (Figure 5.14).

Construction Material: schedule 40; 6 to 10 inch pipe size diameter.

The transverse PVC pipes can be coupled to the legs by: tee fittings; by drilling a hole in each leg and gluing the transverse PVC pipes to each leg; or by using some kind of pipe fastener device (Figure 5.15).

The guard-pipe can be fastened to the transverse PVC pipes by using double tees or some kind of pipe fastener device, such as a U bolt (Figure 5.16).

If double tees are employed to secure the guard-pipe to the transverse PVC pipes, a system of bolts and double-nuts can be used as shown in Figure 5.17 and 5.18.

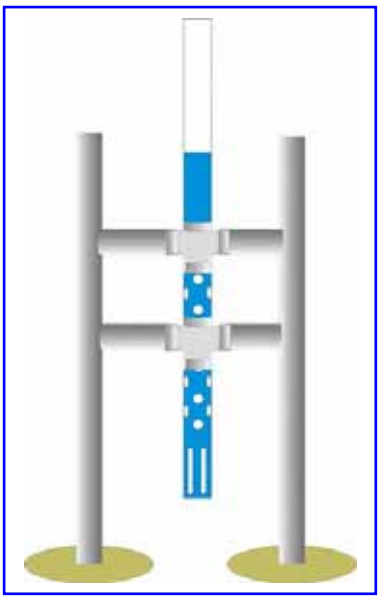


Figure 5.14 Sketch of a two-leg PVC structure

Figure 5.15 The Transverse PVC is fastened to the structure leg by a U-Bolt

Figure 5.16 The guard-pipe is fastened to the transverse PVC by a U-bolt

Figure 5.17 Sketch of a guard-pipe fastened to double tees using a bolt and double-nut holding system

Figure 5.18 Close-Up view of a bolt-double nut

5.3.2 Four Leg PVC Structure

The four leg PVC structure consists of a four-piling PVC arrangement in a square layout (Figure 5.20). The four PVC legs are coupled together using transverse PVC pipes. These pipes, as the guard-pipe, are hold in place by employing one of the fastening methods described in 5.3.1.

To increase structure stability, concrete or sand and gravel can be poured inside the legs.

Advantages of PVC Structures:

- Given the multiple PVC fittings and pipes in the market, a specific structure to fit most monitoring needs can be easily built.
- Simple construction
- Can be used in almost any environment

Disadvantages of PVC Structures:

- Care must be taken during construction so that each piece fits together
- Every glued joint is a weak point

Figure 5.19 Galvanized structure. USGS monitoring station.
(Source: Paul Perusse)

Using the same design principles, other types of material could be used (*e.g.* galvanized structures, Figure 5.19). Galvanized pipes are more expensive than PVC, but they have higher yield strength, and therefore can be more suitable for certain types of monitoring environments.

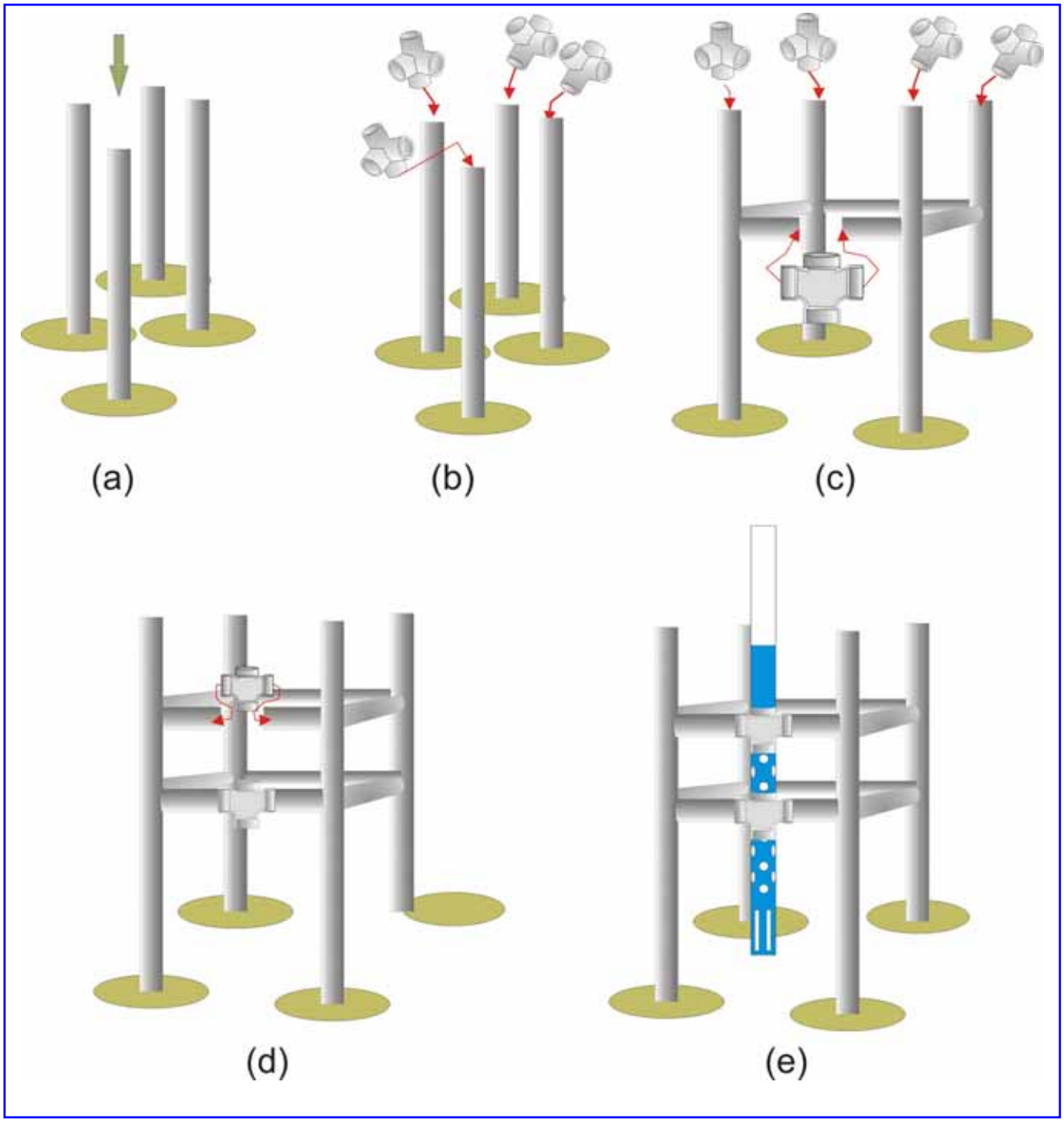


Figure 5.20 Sketch showing the construction steps of a four leg PVC structure

5.4 DESIGNED PLATFORM: UNDERWATER

Fixed underwater monitoring stations are commonly employed when:

→ Local regulations prohibit the installation of an offshore permanent monitoring station (*e.g.* piling, large buoy).

→ The risk of vandalism is high in the sampling area.

→ The monitoring objectives require sampling close to the bottoms sediments and:

- Minimal disturbance of the sampling area must be achieved; or
- The project has multiple temporary monitoring points, and/or given the duration of the project this type of platform is the most cost-effective option.

To deploy the guard-pipe or monitoring sonde at a fixed distance from the bottom sediments two methods are commonly employed:

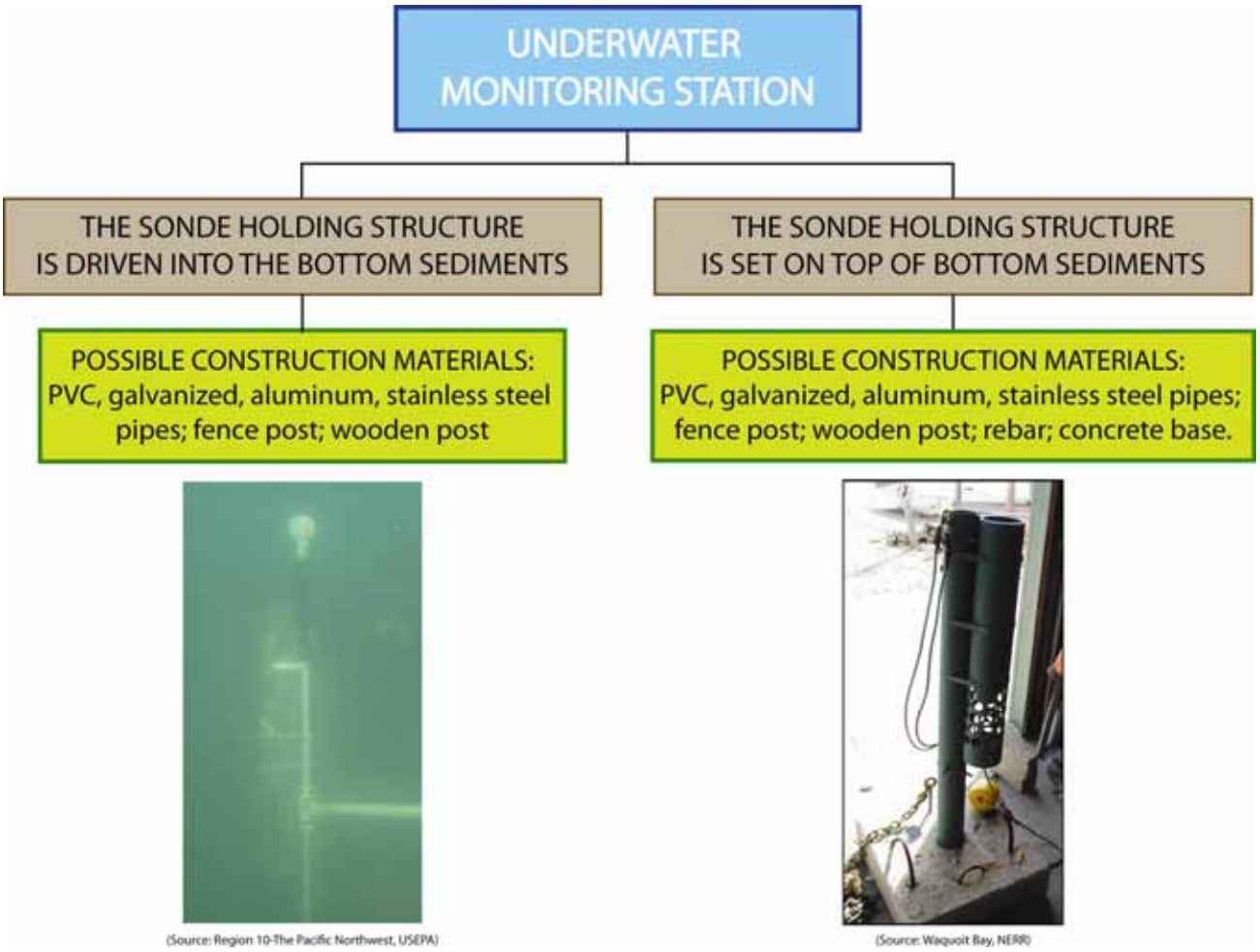


Figure 5.21 Underwater monitoring structures

In this section, construction guidelines are provided for an underwater monitoring structure designed at Waquoit Bay National Estuarine Research Reserve. These guidelines can be used as framework for designing other underwater structures.

1 Prepare the PVC pipe tower

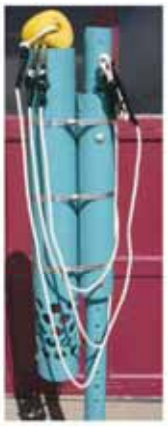
- Cut a 1.5 meter section of a 2 inch (schedule 40) PVC pipe.
- Drill 2 transverse holes at approximate 2 and 4 cm from the bottom of the pipe (hole diameter = diameter of the rebar). Two rebars will be inserted through these holes to secure the PVC tower in the concrete base.
- Drill 5/16 inch holes, every 5 cm holes, along the pipe. These holes will be use to set the sonde at the desired monitoring depth.

2 Prepare the concrete base

- Wood formwork: Cut out 4 pieces of approximate 0.5 meter long, 10 to 20 cm height of any type of lumber and nail the 4 pieces together.
- Cut the necessary rebars to make a good mesh.
- Place the PVC pipe tower in the middle of the formwork in a vertical position and pass 2 rebars through the designed holes.
- Place handles (can be rebars or rope) and an eye bolt to secure an extra anchor.
- Fill the formwork with cement mix.

3 Place the guard pipe

- Cut a 0.7 meter section of a 4 inch and a 0.4 meter section of a 2 1/2 (or 3) inch (schedule 40) PVC pipe.
- Drill the necessary holes and windows in the 4 inch pipe to allow the sensors direct exposure to the flow of ambient waters.
- Place the bolts at the bottom of the 4 inch pipe to hold the sonde in place.
- Drill 2 - 5/16 inch holes at the top and bottom of the 2 1/2 (or 3) inch pipe.
- Secure the two pipes together (*e.g* using hose clamps).
- Secure the pipes to the tower pipe using 5/16 bolts.



4 Set a small marker buoy for the PVC tower and ropes to secure and retrieve the sonde

Figure 5.22 View of the station maker buoy attached to a round cement weight

A station marker buoy may be used if needed (Figure 5.22).

To secure the marker buoy:

- Attach one end of a chain (at least 2 meter long) to the eye bolt at the base of the station and the other end to an extra anchor (*e.g.* concrete block).

- Attach the maker buoy to the extra anchor.

The anchor will be placed at some distance from the base of the station to prevent the marker buoy to get entangled with the sonde's marker buoy or the PVC tower.

At Waquoit Bay NERR, this underwater platform is used in low water environments (*e.g.* at low tide, the water surface is around 0.3 meter from the top of the station. Tides in Waquoit Bay are semidiurnal with an average range of about 0.4 m). An advantage of this particular platform design is that the monitoring depth can be adjusted by moving the guard-pipe up or down the PVC tower. For example, at Metoxit Point, the monitoring depth is set at 0.7 m and at Sage Lot at 0.5 m from the bottom, respectively. This ensures that at Metoxit Point the sensors are above the macro algal mats and at Sage Lot Pond (a salt pond) the sensor are sufficiently into the water column and above the eelgrass bed.

5.5 DESIGNED PLATFORM: ANTENNA TOWER

The antenna tower is an excellent construction material to build offshore monitoring platforms: it has high strength, it is versatile to use with other construction materials, and it provides a good supporting structure to fasten the guard-pipe and telemetry equipment.

In this section, detail guidelines are provided for two antenna tower monitoring platforms.

The guidelines are written in a standard operating procedure style.

5.5.1 SUMMARY OF THE GUIDELINES

Two platforms constructed using 10 foot galvanized tower sections are described in this section (Figure 5.23). The main difference between these configurations is the type of material employed to construct the structure frame:

- The antenna tower platform with wooden columns is constructed by driving two 16-foot (4 by 4 inches) pressure treated wooden posts into the ground for use as the platform columns. To further increase the station stability, 16-foot (2 by 6 inches) boards are employed as diagonal beams to support the structure columns. The antenna tower is secured to the two wooden columns using two-hole tubing straps.

- The antenna tower platform with PVC columns is constructed by driving three schedule 40, 4 inch diameter pipes into the ground for use as the platform columns. The antenna tower is secured to the three PVC columns using U-bolts.

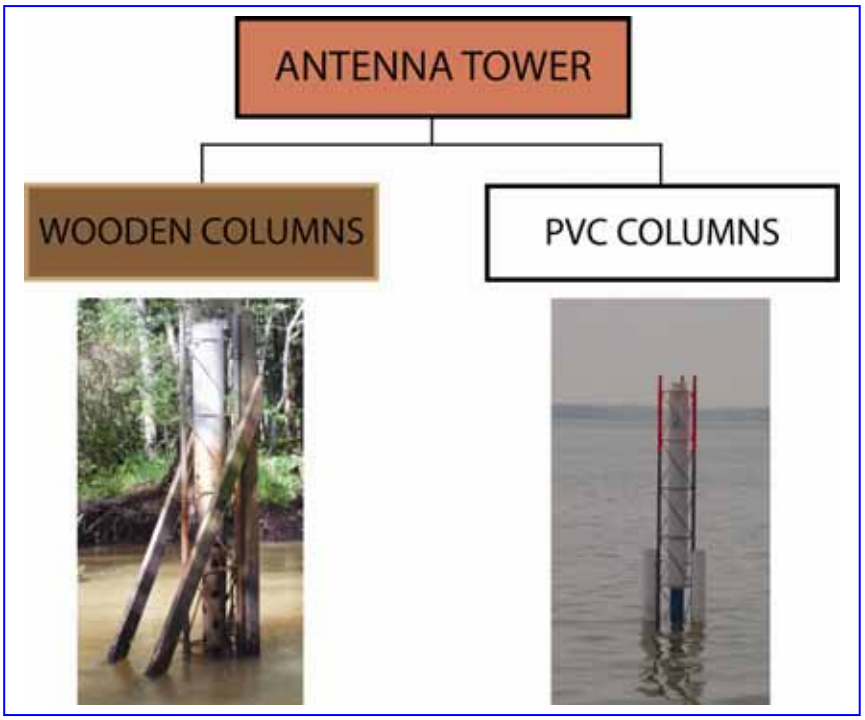


Figure 5.23 Antenna tower structures: wooden and PVC columns

The guard-pipe can be installed inside or outside the antenna tower:

→ **If installed inside**, the guard-pipe is secured to a 6 inch PVC pipe that is inserted into the antenna tower.

→ **If installed outside**, the guard-pipe is secured to the antenna tower by U-bolts.

These guidelines prescribe a specific design method to be followed. The requirements of these guidelines are subject to modification depending on the designer judgment.

5.5.2 QUALIFICATIONS & RESPONSIBILITIES

All users of these guidelines must be familiar with it before implementation and if necessary trained by personnel with previous experience in shallow water quality monitoring station construction.

5.5.3 HEALTH AND SAFETY WARNINGS

The construction of the monitoring structures requires precautions for safe handling and use of the tools and materials.

- General safety precautions for working with electric and power tools must be taken.
- When using power tools safety glasses must be used. When using circular saw earplugs must be used too.
- During field assembly, special care must be taken when using power tools, pumps, hammers, saws, or any other type of tools that can cause injuries. Adequate safety equipment must be used.
- Before field assembly, the construction team must go over the construction steps and safety requirements to assure each team member knows his/her responsibilities.

5.5.4 EQUIPMENT AND SUPPLIES

For assembly purposes, the antenna tower is divided into two parts: the tower system and the station frame (Figure 5.24).

The following equipment and supplies needed to:

- Prepare and assemble the tower system and station frame, and
- Deploy the monitoring platform

are listed in the following five sub-sections.

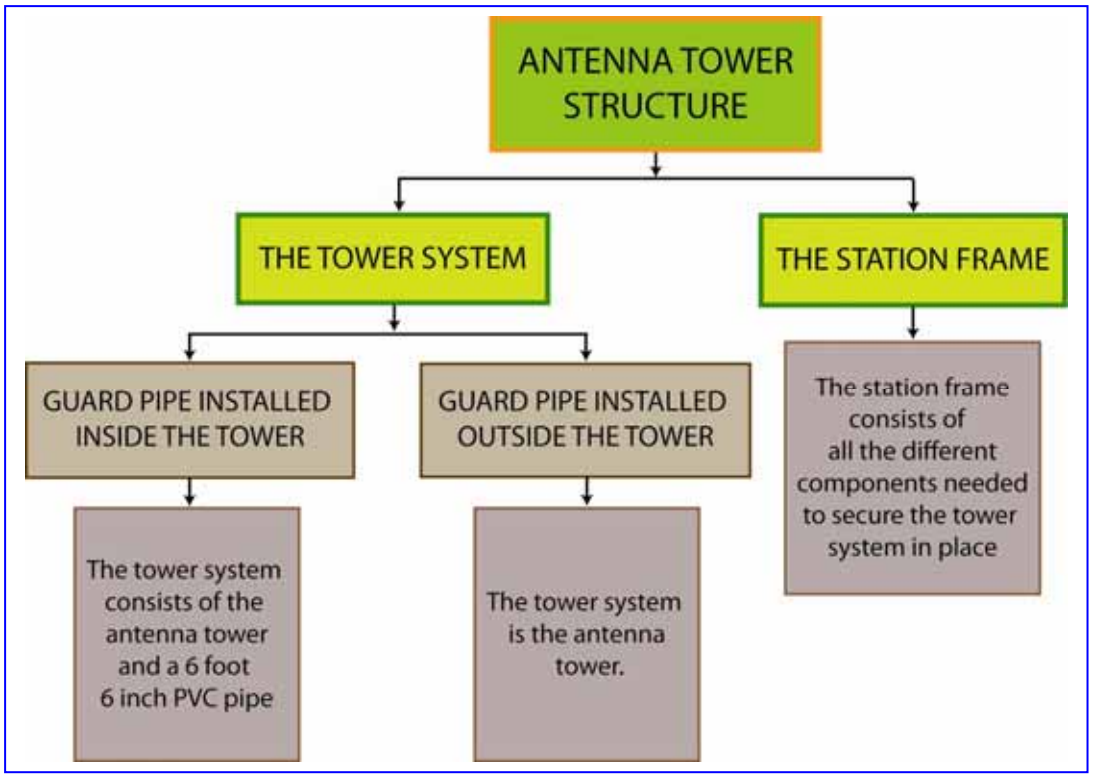


Figure 5.24 Antenna tower structure components

1. Wooden columns: equipment and supplies to construct the wooden columns on-land.

2. PVC columns: supplies needed for the PVC columns.

3. Tower System – Guard-Pipe Installed inside the Antenna Tower: equipment and supplies needed to construct and assemble the tower system on-land.

4. Deployment Antenna Tower with Wooden Columns: equipment and supplies needed to deploy the monitoring station at the site.

5. Deployment Antenna Tower with PVC Columns: equipment and supplies needed to deploy the monitoring station at the site.

Note: it is a good practice to take additional supplies, *e.g.* bolts, nuts, U-Bolts, *etc.*, in the event they are dropped in the water or break during the station deployment.

5.5.4.1 EQUIPMENT & SUPPLIES: ON-LAND CONSTRUCTION- Wooden Columns

EQUIPMENT	
#	Description
1	Hand Saw
2	Ruler or Tape Measure
3	Square
4	Circular Saw

Table 5.1 Construction Equipment
Antenna Tower with Wooden Columns

SAFETY EQUIPMENT	
#	Description
1	Safety glasses
2	Ear plugs
3	Dust mask

Table 5.2 Safety Equipment

SUPPLIES				
#	Description			
		Type	Length[1]	Quantity
1	Wood	4 by 4 treated	16 ft	2
		2 by 4 treated	16 ft	2 or 4[2]

Table 5.3 Construction Supplies for the Antenna Tower Platform with Wooden Columns

[1]The length of the 4 by 4 boards will depend on the mean tidal range at the monitoring site. Longer or shorter boards may be required. The 16 foot (4.9 m) long boards work well when the mean high water level is less than 2.5 meters (8.2 ft), with a penetration depth of 2 meters (6.6 ft) of less (there is a correspondence between the penetration depth and the mean high water level that the station can handle).

[2] Four pieces are used to make a more stable station (see step 6 of 5.5.5.2).

5.5.4.2 EQUIPMENT & SUPPLIES: ON-LAND CONSTRUCTION- PVC Columns

SUPPLIES				
#	Description			
		Type	Length[1]	Quantity
1	PVC pipe (schedule 40)	4 in	10 ft	3[2]

Table 5.4 Construction Supplies for the Antenna Tower Platform with PVC Columns

[1]The length of the PVC pipe will depend on the mean tidal range at the monitoring site. Longer or shorter pipes or additional pipes (if extensions are the option) may be required. The 10 foot

(3 m) PVC pipes work well when the penetration depth is around 4 to 5 foot (1.2 -1.5 m) and the mean low water less than 5 to 6 foot (1.5 – 1.8 m).

5.5.4.3 EQUIPMENT & SUPPLIES: ON-LAND CONSTRUCTION – Tower System: Guard-Pipe Installed Inside the Antenna Tower

EQUIPMENT	
#	Description
1	Hacksaw
2	Drill
3	Drill Bits
4	Square
5	Ruler/ tape measure
6	Screwdriver or screwdriver bit tips
7	Hammer / hand drilling hammer
8	Thread kit to make a 5/16 thread in PVC pipe

Table 5.5 Construction Equipment for Tower System: Guard-Pipe Installed Inside the Antenna Tower

SAFETY EQUIPMENT	
#	Description
1	Safety glasses

Table 5.6 Safety Equipment

SUPPLIES				
#	Description			
1	Tower	Type	Length	Quantity
		Galvanized	10 ft	1
	Ten foot galvanized tower section. The upright legs are 1 ¼ (32 mm) round galvanized tubes (outside diameter), while the crossbracing is solid round rod, with an inside equilateral triangle side of 9 5/16 to 10 in. There are several tower manufactures, *i.e.* Tessco Technologies.			
2	Sensor guard-pipe			
3	Reflectors (*i.e.*, red round bracketed nail-on Plexiglas reflectors)			Quantity
				3

Table 5.7 Construction Supplies: Tower System – Guard-Pipe Installed Inside the Antenna Tower

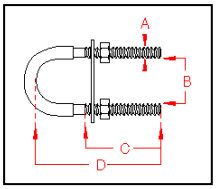
SUPPLIES				
Guard-Pipe Inside Tower				
1	6 inch PVC pipe; schedule 40	Length		Quantity
		6 ft		1
Two alternatives are presented here to hold the guard-pipe inside the 6” PVC pipe				
Using Hex Head Bolts		Using U Bolts		
#	Supplies for Hex Head Bolts			
1	Stainless steel or Galvanized Hex Head Bolts	Length	Diameter	Quantity
		1-1/2 in	5/16-18	6
2	Lock nut – stainless steel or galvanized	Type		Quantity
		5/16-18		12
#	Supplies for U Bolts			
1	Galvanized U bolts for 4 inch pipe with a minimum length of 8.75 inches.		A: 3/8 “ B: 4.5 “ C: > 1” D: > 8.75”	Quantity At least 3
2	Nut and washers			
NOTE: Bolts, nuts, washers must be of the same material to prevent corrosion.				

Table 5.7 Cont. Construction Supplies: Tower System – Guard-Pipe Installed Inside the Antenna Tower

5.5.4.4 EQUIPMENT & SUPPLIES: DEPLOYMENT - Antenna Tower with Wooden Columns

EQUIPMENT	
#	Tools
1	Hand Saw
2	Hacksaw
3	Sledge hammer
4	Hammer
5	Hand drilling hammer
6	Sockets
7	Combination Wrenches
8	Drill; Drill Bits (need one drill bit of 5.5 in long); screwdriver bit tips
9	Water pump with pipe 16 ft, minimum (if required)
10	Pipe wrenches (if there are multiple pipe extensions)
#	Miscellanies
1	Ruler
2	Square
3	Level
4	Tape Measure
5	Ladder

Table 5.8 Deployment Equipment: Antenna Tower with Wooden Columns

SAFETY EQUIPMENT	
#	Description
1	Safety glasses
2	Gloves

Table 5.9 Safety Equipment

SUPPLIES				
#	Description			
1	Wood	Type	Length	Quantity
		2 by 4 treated	4 ft	2
2	Galvanized carriage bolts	Length	Diameter	Quantity
		8 in	5/16-18	4
3	Two Hole Tubing Strap		1 ¼	At least 4
4	Lag bolts to set the straps on the 4 by 4			At least 8
5	Galvanized screws	2 – 2 ½		
	Miscellanies			
1	Reflectors (at least 4)			
2	Station Sign			
3	Marking Flag			
4	Duck tape			
5	Pencil/magic marker			
6	Pieces of wooden boards or other type of cushion to place on top of the 4 by 4 while pounding to prevent splitting			

Table 5.10 Deployment Supplies: Antenna Tower with Wooden Columns

5.5.4.5 EQUIPMENT & SUPPLIES: DEPLOYMENT - Antenna Tower with PVC Columns

EQUIPMENT	
#	Tools
1	Hand Saw
2	Hacksaw
3	Hammer
4	Sledge hammer
5	Hand drilling hammer
6	Sockets
7	Combination Wrenches
8	Drill; Drill Bits (need one drill bit of 5.5 in long); screwdriver bit tips
9	Water pump with pipe 16 ft, minimum (if required).
10	Pipe wrenches (if there are multiple pipe extensions)
PVC Pipe Filling Equipment	
#	Filling: Cement Mix
1	Round point shovel
2	Plastic or other type of container to mix the cement
3	Hoes or other tool to mix the cement
4	Buckets or Containers to carry fresh water
#	Filling: Sand & Gravel
1	Round point shovel

	Miscellanies
1	Ruler
2	Square
3	Level
4	Tape Measure
5	Ladder

Table 5.11 Deployment Equipment: Antenna Tower with PVC Columns

SAFETY EQUIPMENT	
#	Description
1	Safety glasses
2	Gloves

Table 5.12 Safety Equipment

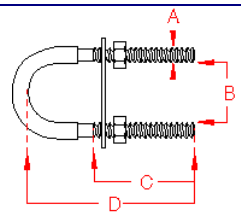
SUPPLIES					
#	Description				
1	Type of material to pour inside the PVC pipes		Quantity[1]		
		Fast setting concrete	8 - 60 lb bags		
		or			
		Sand and Gravel	Five 5 gal buckets (3.6 ft^3)		
2	Galvanized U bolts for 4inch pipe with a minimum length of 6.75 inches.		A	3/8 “	Quantity
			B	4.5 “	At least 6
			C	> 1”	
			D	> 6.75”	
3	PVC 4” to 4” couplings. The couplings will be needed if the 10 foot PVC pipes are driven more than 6 ft into the ground. See details in section 5.5.5.2. These couplings are not necessary if the PVC pipes are longer than 10 foot.				
	Guard-Pipe Outside Tower				
1	Galvanized U bolts for 4inch pipe with a minimum length of 6.75 inches.				Quantity
					2
	Miscellanies				
1	PVC glue				
2	Duck tape				
3	Marking Flag				
4	Station Sign				
5	Magic marker				
6	Pieces of wooden boards to be placed on top of the PVC pipes while pounding				

Table 5.13 Deployment Supplies: Antenna Tower with PVC Columns

[1] The quantity may vary depending on the length of the PVC pipe.

5.5.5 CONSTRUCTION & DEPLOYMENT STEPS

The sequential steps followed in the construction of an antenna tower monitoring station can be subdivided into two main activities: construction activities that take place on-land and construction activities that take place on-site (Figure 5.25).

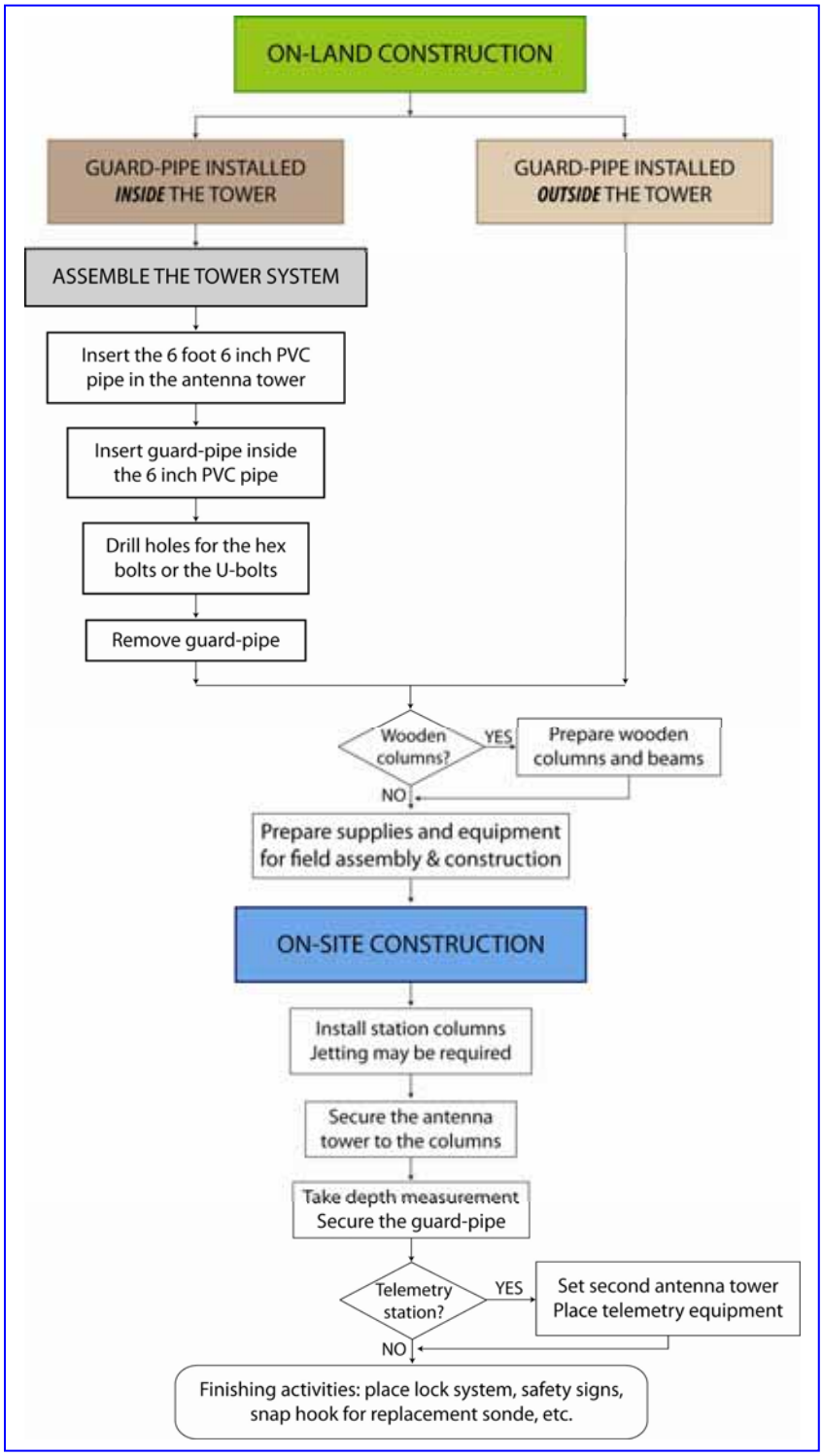


Figure 5.25 Sequential construction steps of an antenna tower station

5.5.5.1 ON-LAND CONSTRUCTION OF THE TOWER SYSTEM: Guard-Pipe Installed Inside the Antenna Tower

Two steps are needed to construct the tower system

1) Place a 6 foot, 6 inch PVC pipe inside the antenna tower

Place the 6 ft long 6 inch PVC pipe at the top-end of the antenna tower and tap it so it slides inside the tower.

This will produce a tight fit between the tower and the PVC pipe.

Figure 5.26 Inserting 6 foot long 6 in PVC pipe into the antenna tower.

2) Construct the holding system for the guard-pipe

Two alternatives are presented here.

Holding System: Using Hex Head Bolts

- Drill three holes, positioned in the pattern of an equilateral triangle, at 5 cm (2 inch) from the top of the PVC pipe using a 7/32 inch drill bit.
- Using a 5/16 inch thread, thread the three holes (Figure 5.27).
- Place a 5/16-18 x 1-1/2 bolt in each hole. Put one 5/16-18 lock nut in the outside and one in the inside of the pipe as shown in Figure 5.28.
- Place the guard-pipe inside the 6 inch PVC pipe until the 4 inch coupling hits the 3 bolts. Check that the guard-pipe is centered with respect to the 6 inch PVC pipe. If not, adjust the bolts so it is centered.
- Drill three holes at 2.5 cm (1 inch) from the bottom of the 6 inch PVC pipe.

  Be sure that the holes do not coincide with the guard-pipe holes. To ensure correct field assembly, draw a guideline once the guard-pipe is set in position; on the 6 inch PVC pipe and on the guard-pipe. This guideline will be used as an alignment reference during field assembly.

Figure 5.27 Threading top holes.

Figure 5.28 Hex head bolts with two lock nuts.

Thread the three holes (with a 5/16 inch thread). Place three 5/16-18 x 1-1/2 bolts in the holes. Set one 5/16-18 lock nut in the outside and one in the inside of each bolt (Figure 5.28)

Remove the guard-pipe.

Holding System: Using U-Bolts

Drill two holes at 5 cm (2 in) from the top of the 6 inch PVC pipe to set an U-bolt (Figure 5.29).

- The 4 inch coupling will rest on the U-bolt.
- To drill the holes, employ a long drill bit and use the U-bolt as a guide to ensure the U-bolt will fit into the holes during station assembly.

Drill two more sets of holes along the 6 inch PVC pipe. The holes must not be vertically aligned to permit a cross fitting (Figure 5.30).

Place the U-bolts and check that the guard-pipe is well secured.

Remove U-bolts and guard-pipe.

Figure 5.29 Drilling holes to place U-bolts.

Figure 5.30 View of two U-bolts in a cross position.

5.5.5.2 STATION DEPLOYMENT: ANTENNA TOWER WITH PVC COLUMNS

The deployment instructions are given as guidelines. The specific steps to follow must be evaluated based on each site's particular characteristics.

1 Assemble all the supplies and equipment. Go over the deployment steps.

- Before leaving for the site, check thoroughly the tools and supplies needed. A good practice is to go over the different deployment steps while checking that the required tools and supplies are on board.
- The station must be deployed at low tide. PVC pipes must be filled with concrete or sand and gravel. If the water level is above the PVC pipes at all times; extension pipes must be added to each PVC column.

2 Set the first 4 inch PVC pipe in place

- When hammering, it is a good practice to set a piece of wood on top of the PVC pipe for cushion purposes.
- Jetting may be needed to help the hammering process.
  - As the pipes are driven in, it is a good practice to level them as much as possible to ensure vertical penetration.
  - Extention PVC pipe may be required. This will depend on the water level and the penetration depth.

3 Place the antenna tower in position to mark where to set the other two PVC columns

- Once the locations of the two other PVC columns are marked, the antenna tower can be:
  - Removed: to provide a better pounding area.
  - Kept in place: to be used as a guide for driving in the other two PVC columns. This is generally the case when jetting is needed.

4 Place second and third PVC columns

- At least 1 - 2 foot of pipe must be kept above the water level.
- PVC pipe extensions may be required.

5 Flush the inside of the PVC columns

- The inside of the PVC pipes must be flushed to clean out the sand, mud or any other small debris.
- Set the water pump pressure at minimum. The purpose is to wash the fine particles up and out of the pipes, not to make a hole at the bottom. It is a good practice to insert the jet pipe up to half the length of the PVC during flushing.

6 Pour cement or sand and gravel into each PVC column

- The cement or sand and gravel will displace the water inside the PVC pipes.
- The cement must be mixed with **fresh** water.

7 Secure the antenna tower to the PVC columns

- Install at least 2 U-bolts per column.
- Another option to secure the antenna tower to the PVC columns is by using smaller U-bolts (*e.g.* 1.75 inch). Even though these type of U-bolts are available in most major home improvement stores, there are certain disadvantages of using them. See the Appendix Section, Appendix 5 for details.

8

Prepare the guard-pipe

- Check the distance that the guard-pipe must be set from the bottom (sampling height).
- Determine if the guard-pipe must be cut or an extension pipe must be added.
- Glue the 4 by 4 coupling on the top of the guard-pipe.

Guard-pipe installed inside the antenna tower

Holding System: U-Bolts

- Set the guard-pipe in position and place the top U-bolt. The 4 by 4 coupling will rest on this U-bolt.
- Place and fasten the other U-bolts.

Holding System: Hex Head Bolts

- Set the guard-pipe in position; align the guidelines (the guidelines were drawn during land assembly).
- The 4 by 4 coupling will rest on the top three hex bolts.
- Fasten the 5/16 - 18 x 1-1/2 bolts so the guard-pipe is centered. Two 1/2 inch combination wrenches can be used for this purpose. Set one wrench on the inside nut and one on the bolt. Tighten the bolts alternatively. Once the guard-pipe is centered, tight the inside and outside nuts on each bolt.
- Once the top hex bolts are secured; the bottom bolts can be fastened. This is a more difficult task given the bolts will be most probably under water.

Guard-pipe installed outside the antenna tower

- Set the guard-pipe in position and place the top U-bolt. The 4 by 4 coupling will rest on this U-bolt.
- Set at least one more U-bolt at a convenient distance from the top U-bolt to secure the guard-pipe to the antenna tower.

9 Telemetry Station

If data will be transmitted using telemetry equipment:

- In most situations a second antenna tower will be needed.
- Part of the telemetry equipment can be pre-installed on the second antenna tower or it can all be installed once the antenna tower is secured.
- Check that the solar panel is placed at the optimum:

  orientation and tilt angle

  for the particular location and season.

→ Refer to Chapter 6 for more information on how to install the telemetry equipment.

NOTE: Even though the telemetry equipment is mounted inside a weather resistant control box, it is important to ensure that the control box be above water at all times. Therefore, mean higher high water, wave action and storm surges must be taken into account when mounting the control box (EPA, 2002).

10 Station - Finishing touches

- Place safety signs, paint station, clean the station.

IS A SAFETY STRUCTURE NEEDED AROUND THE STATION ?

The need for a safety structure to protect the monitoring station depends on the following factors:

1. The monitoring site is located in an area where wave action and/or wind can be significant.
2. The maintenance of the station is performed by boat.
3. Maintenance of the sensors must follow a certain schedule independently of weather conditions. Thus, sometimes maintenance has to be performed in weather conditions that are very likely to generate collisions between the boat and station.

In these scenarios, it is a good practice to construct a safety structure where the boat can be moored and collision are prevented. Construction of a simple wooden safety structure is detailed next.

1 Set three 4 by 4 pressured treated posts around the station

- The posts are set in a triangle layout; each post located at one vertice of the triangle.
- The post are hammered or jetted to a convenient penetration depth.

2 Install 2 by 4 transverse boards to connect the 4 by 4 posts

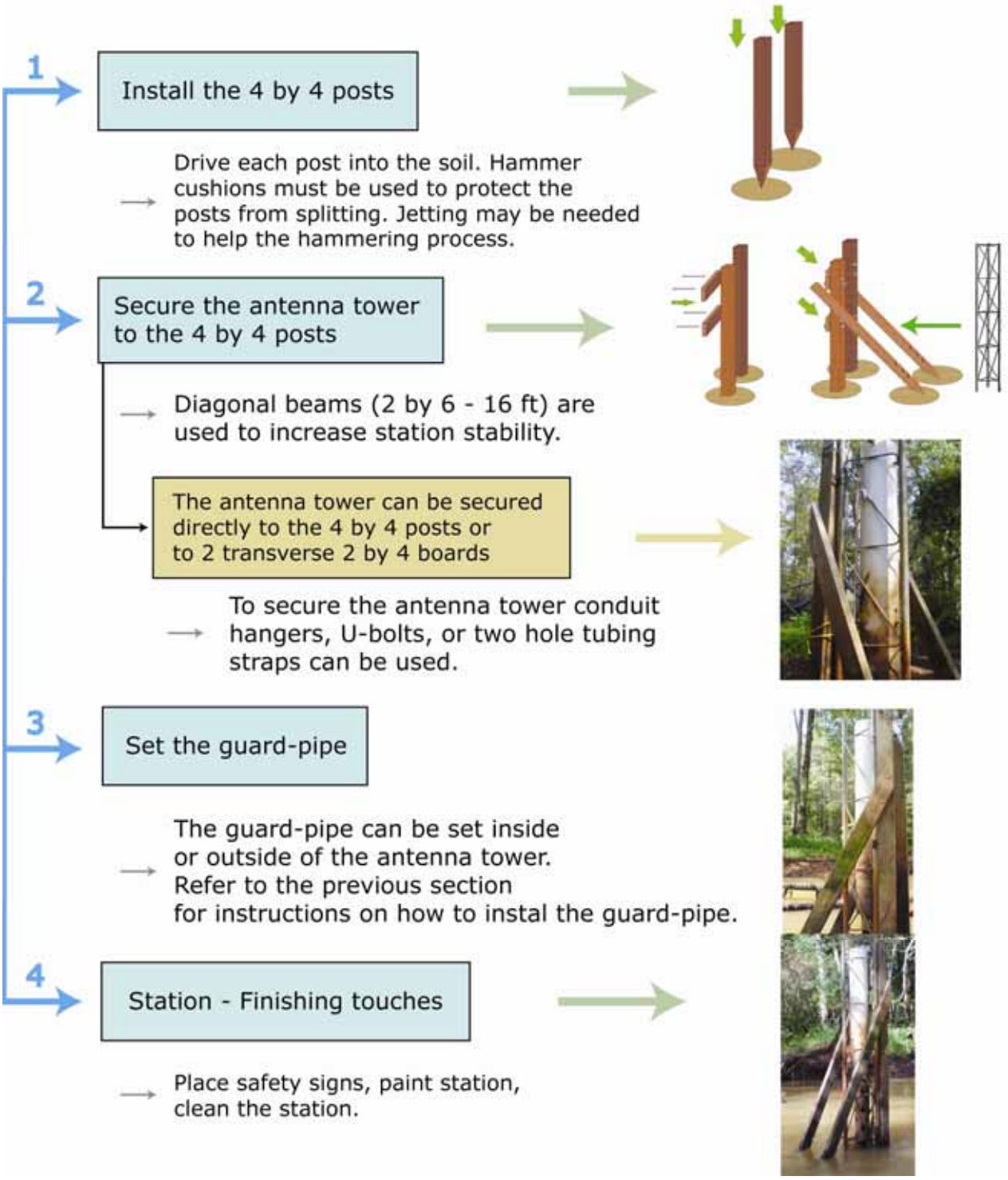
- At least 2 - 2 by 4 transverse boards are used to connect two 4 by 4 posts
- Is is good practice to use bolts to fasten the transverse board to the post. Drill 5/16 holes in each intersection and use 5/16-8 galvanized carriage bolts to secure the structure.

3 Finishing touches

- Saw the top parts of the 4 by 4 posts.
- If necessary, place safety signs.

5.5.5.3 STATION DEPLOYMENT: ANTENNA TOWER WITH WOODEN COLUMNS

Brief deployment instructions are given in this section. More detail instructions on how to prepare and install the 4 by 4 post can be found in section 5.6.5.



5.6 DESIGNED PLATFORM: WOODEN STRUCTURE

Wood is one of the most frequently construction materials used to built monitoring platforms given it is readily available, is cost effective, has a high strength to weight ratio, and it is very easy to use and work with common tools and fasteners. Therefore, there are many different type of designs of wooden structure platforms. In order to classify these structures, the number of columns was selected as the differentiation parameter (Figure 5.31).

In this section, construction guidelines are provided for a two-column structure used at CBNERRVA. Additional wooden platforms designs are presented at the end of this section for illustrative purpose only.

The guidelines are written in a standard operating procedure style.

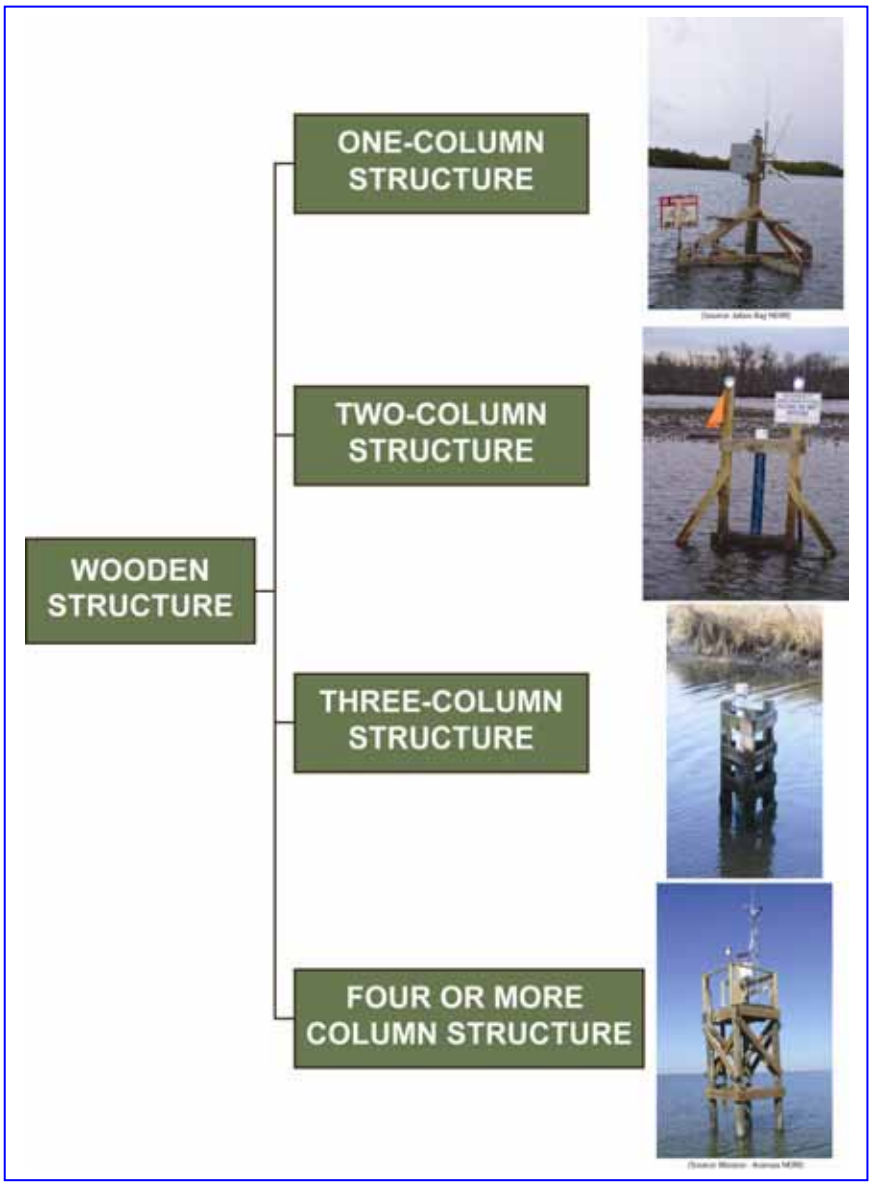


Figure 5.31 Designed platform: wooden structures

5.6.1 SUMMARY OF THE GUIDELINES

A monitoring platform constructed with pressure treated wood is described in this section. The structure is constructed by driving two 16-foot posts (4 by 4 inches thickness) into the ground for use as the platform columns. Transverse 2 by 6 inches boards are employed to secure the 4 by 4 posts and to hold the guard-pipe in place. To further increase the station stability, 16-foot (2 by 6 inches) boards are employed as diagonal beams to support the structure columns. Two basic methods are described to hold the guard-pipe at a fixed position from the bottom substrate.

These guidelines prescribe a specific design method to be followed. The requirements of these guidelines are subject to modification depending on the designer judgment.

5.6.2 QUALIFICATIONS & RESPONSIBILITIES

All users of these guidelines must be familiar with it before implementation and if necessary trained by personnel with previous experience in shallow water quality monitoring station construction.

5.6.3 HEALTH AND SAFETY WARNINGS

The construction of the monitoring structures requires precautions for safe handling and use of the tools and materials.

- General safety precautions for working with electric and power tools must be taken.
- When using power tools safety glasses must be used. When using circular saw earplugs must be used too.
- During field assembly, special care must be taken when using power tools, pumps, hammers, saws, or any other type of tools that can cause injuries. Adequate safety equipment must be used.
- Before field assembly, the construction team must go over the construction steps and safety requirements to assure each team member knows his/her responsibilities.

5.6.4 EQUIPMENT AND SUPPLIES

Two basic wooden platform designs are detailed in this section. The designs differ only on the type of system employed to hold the guard-pipe at a fixed position from the bottom substrate:

→ Using wooden boards.

→ Using some kind of fastening device (*i.e.* U-bolts, pipe hangers).

The following tables list the equipment and supplies needed to construct and deploy the wooden platforms.

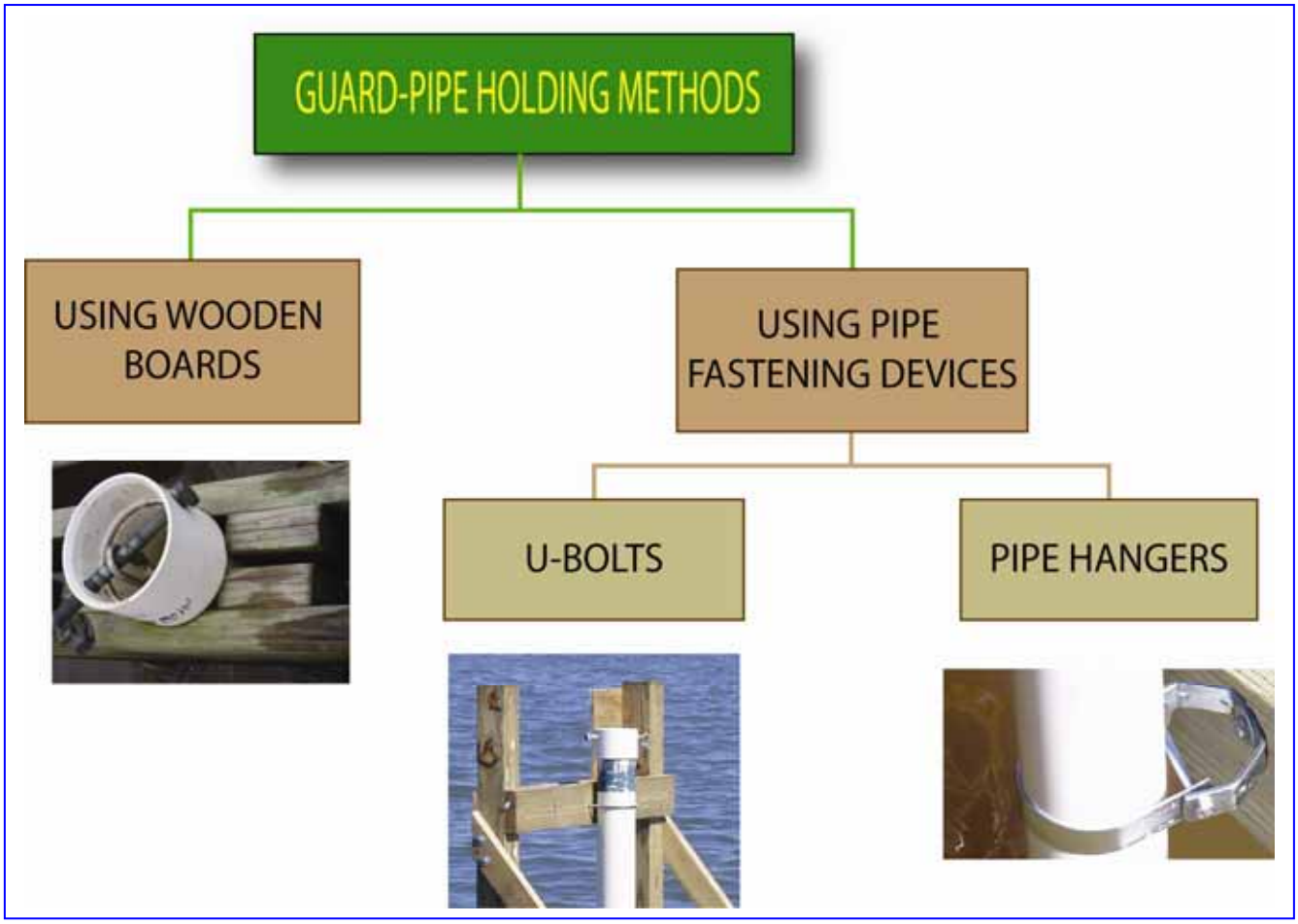


Figure 5.32 Types of guard-pipe holding methods in a wooden platform

5.6.4.1 EQUIPMENT & SUPPLIES: CONSTRUCTION

EQUIPMENT	
#	Description
1	Hand Saw
2	Circular Saw
3	Measuring Tape
4	Square
5	Drill
6	Drill Bits

Table 5.14 Construction Equipment

SAFETY EQUIPMENT	
#	Description
1	Safety glasses
2	Ear plugs
3	Dust mask

Table 5.15 Construction: Safety Equipment

SUPPLIES				
#	Description			
	Wood	Type	Length[1]	Quantity
1	For the station frame	4 by 4 treated	16 ft	2
		2 by 4 treated	16 ft	2 or 4[2]
	GUARD-PIPE HOLDING SYSTEM			
	Using wooden boards to hold the guard-pipe in place	2 by 6 treated	10 ft	2
	Using U-bolts or pipe hangers to hold the guard-pipe in place	2 by 6 treated	10 ft	1
If the guard-pipe holding system is wooden boards, then galvanized screws are needed.				
2	Galvanized screws		Length	Quantity
			2.5 in	At least 10

Table 5.16 – Construction: Supplies

[1]The length of the 4 by 4 boards will depend on the mean tidal range at the monitoring site. Longer or shorter boards may be required. The 16 foot (4.9 m) long boards work well when the mean high water level is less than 2.5 meters (8.2 ft) , with a penetration depth of 2 meters (6.6 ft) of less (there is a correspondence between the penetration depth and the mean high water level).

[2] Four pieces are used to make a more stable station (see step 6 of section 5.5.5.2).

5.6.4.2 EQUIPMENT & SUPPLIES: DEPLOYMENT

EQUIPMENT	
#	Tools
1	Hand Saw
2	Hacksaw
3	Sledge hammer
4	Hammer
5	Hand drilling hammer
6	Combination Wrenches
7	Drill; Drill Bits (6 and a 10 inch long). Screwdriver bit tips
8	Sockets
9	Water pump, pipe 16 ft if available (if required).
10	Pipe wrenches (if there are multiple pipe extensions)

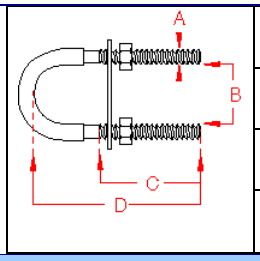
Table 5.17 Assembly & Deployment: Equipment - Tools

EQUIPMENT	
#	Miscellanies
1	Ruler
2	Tape Measure
3	Square
4	Level
5	Ladder

Cont. Table 5.17 Assembly & Deployment: Equipment - Tools

SAFETY EQUIPMENT	
#	Description
1	Safety glasses
2	Gloves

Table 5.18 Assembly & Deployment: Safety Equipment

SUPPLIES					
#	Description				
1	Wood to join and secure the diagonal beams	Type	Length	Quantity	
		2 by 4 treated	4 ft	2	
2	Guard-Pipe				
Holding System: Using wooden boards					
3	Galvanized carriage bolts	Length	Diameter	Quantity	
		8 in	5/16 in	4	
		10 or 12 in	½ in	8	
4	Galvanized screws	2 or 2.5 in			
5	Nuts and washers for the bolts				
Holding System: Using U Bolt or Pipe Hangers					
1	Galvanized carriage bolts	Length	Diameter	Quantity	
		8 in	5/16 in	12	
2	U-bolts or Conduit Hangers		Pipe ∅	Quantity	
			4 in	2	
	U-bolt specifications		A	3/8 “	
			B	4.5 “	
			C	> 1”	
			D	> 6.75”	
#	Miscellanies				
1	Duck tape				
2	Pencil/magic marker				
3	Marking Flag				

4	Station Sign
5	Reflectors (at least 4) (*i.e.*, red round bracketed nail-on Plexiglas reflectors
6	Two or three 2 ft, 2 by 4 pieces of wooden boards to be placed on top of the 4 by 4 while pounding in to prevent their splitting

Table 5.19 Assembly & Deployment: Supplies

5.6.5 CONSTRUCTION STEPS

The sequential steps followed in the construction of a wooden platform can be subdivided into two main activities: activities that take place on-land and activities that take place on-site.

- **On-Land activities**: Cut the 4 by 4 posts and 2 by 4 diagonal beams so they are ready for deployment; if wooden boards are going to be used to hold the guard-pipe in place, cut and prepare the holding boards.
- **On-Site activities**: all activities to deploy the station; driving the 4 by 4 posts, securing guard-pipe, driving the diagonal beams, *etc*.

5.6.5.1 PREPARATION OF THE 4 BY 4 POSTS AND DIAGONAL BEAMS

The construction steps are simple and straightforward. Basically the procedure consists of two steps:

1. Point one end of the 4 by 4 post
   - Draw a parallel line at 12 inches from one one end of the post.
   - Using a square, draw 12 inches parallel lines on each of the other three sides of the post.
   - Mark the middle points on each of the end edges of the post.
   - Draw a line joining the middle points with the corners of the 12 inches lines.
   - Using a circular saw or a hand saw, cut the four sections to a point.

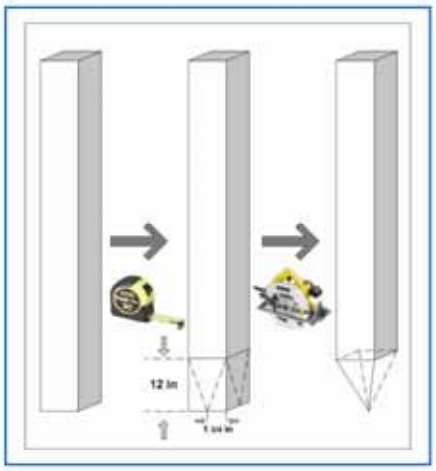


Figure 5.33 Cutting end points on the 4 by 4 posts.

2. Prepare the 2 by 4 diagonal beams
   - Cut end points on each of the 2 by 4 boards
   - Cut several teeth on each of the boards

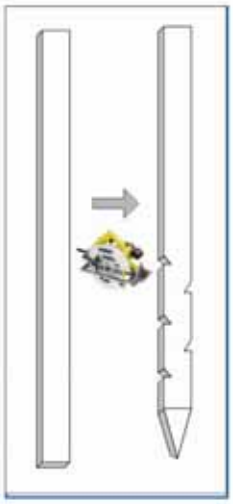


Figure 5.34 Cutting end points and teeth on the 2 by 4 boards.

5.6.5.2 PREPARATION OF THE GUARD-PIPE HOLDING SYSTEM MADE WOODEN BOARDS

The construction steps are simple and straightforward. Basically the procedure consists of three steps:

1. **Mark the 2 by 6s boards for cutting**
   - Cut 2 - 4 foot long - 2 by 6s.
   - Cut 2 - 5 foot long - 2 by 6s.
   - On each piece mark the following lines (as shown in Figure 5.35).
     - The middle line.
     - Two lines on each side of the middle line at a distance of 1 1/4 inches.
     - Two lines on each side of the middle line at a distance of 1 3/4 inches.
     - Two lines on each side of the middle line at a distance of 2 1/4 inches.

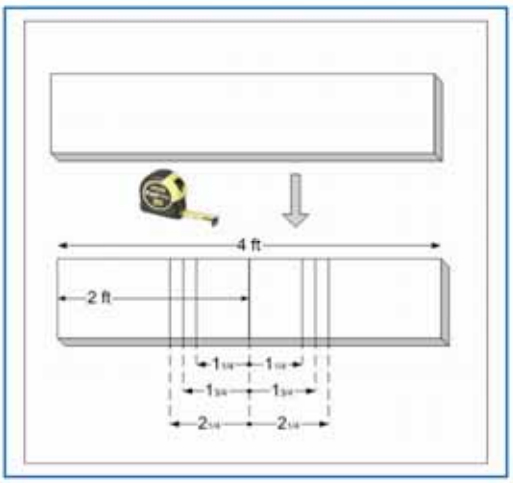


Figure 5.35 Marking the 4 foot long 2 by 6s board for cutting.

2. **Cut two openings in each 2 by 6s**
   - Using a circular saw make the following openings.
     - Between the 1 1/4 inch lines cut with a circular saw an opening of 1/2 inch deep.
     - Between the 1 1/4 inch line and the 1 3/4 inch line, make an opening of 1/4 inch deep.

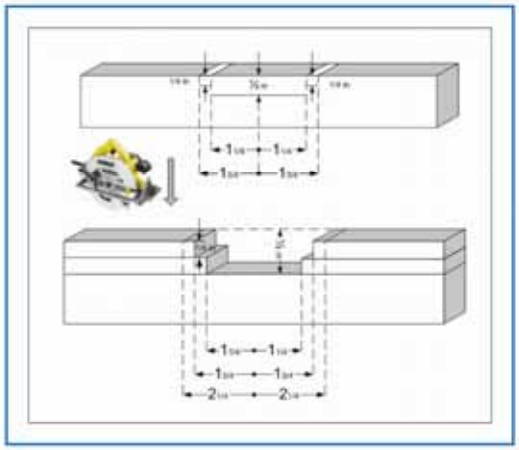


Figure 5.36 Cutting openings on each board.

3. **Screw 2 - 6 inch long - 2 by 6s on each board**
   - Cut 8 - 6 inch long - 2 by 6s.
   - Screw 2 pieces per board, one on each side of the 2 1/4 inch line.

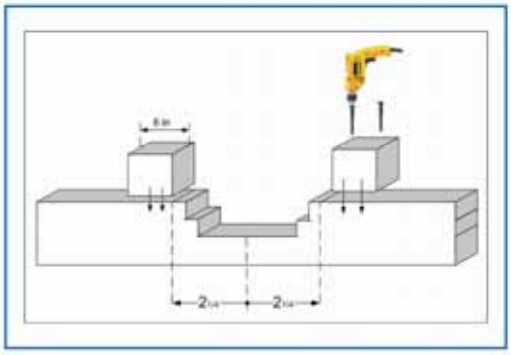


Figure 5.37 Screwing 6 in long - 2 by 6s

5.6.5.3 STATION DEPLOYMENT

The deployment of the wooden platforms is basically independent of the type of guard-pipe holding system. The sequential steps to deploy each type of platform design are briefly shown in Figures 5.38 and 5.39.

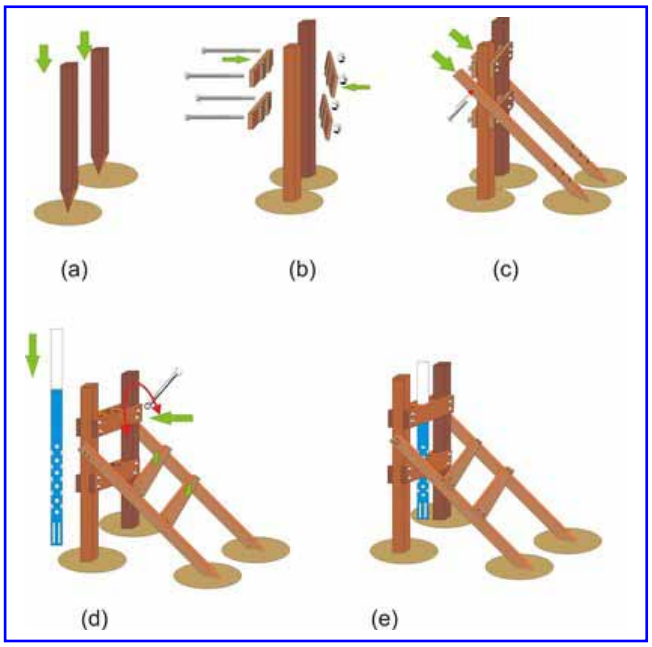


Figure 5.38 Sketch showing the deployment steps of a wooden platform that employs wooden boards to hold the guard-pipe in place.

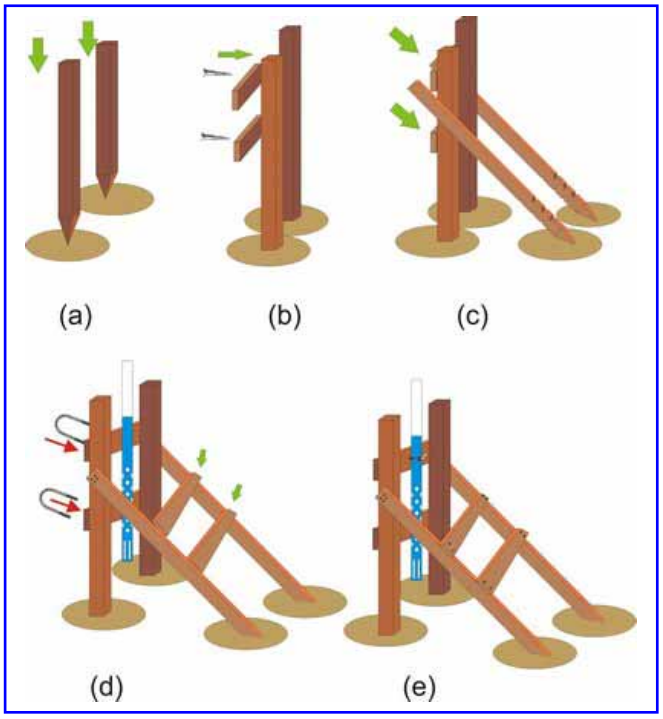


Figure 5.39 Sketch showing the deployment steps of a wooden platform using U-bolts to hold the guard-pipe in place.

The deployment instructions are given as guidelines only. The specific steps to follow must be evaluated based on each site's particular characteristics.

1 Assemble all the supplies and equipment. Go over the deployment steps.

- Before leaving for the site, check thoroughly the tools and supplies needed. A good practice is to go over the different deployment steps while checking that the required tools and supplies are on board.
- It is a good practice to deploy the station at low tide.

2 Set the 4 by 4 posts in place

- When hammering, it is a good practice to:
  - Tape the top of the 4 by 4 posts with duck tape to minimize wood splitting.
  - Set a piece of wood on top of the 4 by 4 posts for cushion purposes.
- Jetting may be needed to help the hammering process.
  - As the posts are driven in, it is a good practice to level them as much as possible to ensure vertical penetration.

3 Place the transverse boards

Guard-pipe holding system: wooden boards

- Screw the 4 - 2 by 6s to the 4 by 4 posts.
  - The 2 by 6s must be set in position and leveled.
  - The 5 foot long 2 by 6s are placed on the back side of the station. This will allow easy removal of the guard-pipe for station maintenance.

Guard-pipe holding system: pipe fastening devices

- Screw two - 2 by 6s to the 4 by 4 posts.
  - The 2 by 6s must be set in position and leveled. Place them on the back side of the station.

4 **Place the diagonal beams**

- It is a good practice to duck tape the top of the 2 by 4 to minimize wood splitting.
- Drill 2- 5/16 holes at each (diagonal beam) - (4 by 4) intersection.
- Using a hammer, drive a 5/16-8 galvanized carriage bolt into each hole; place washer and nut; tighten the nuts.
  - To increase the stability of the station, 4 diagonal beams may be used.

5 **Place the guard-pipe**

Guard-pipe holding system: wooden boards

- Drill 2- 1/2 holes at each (2 by 6) - (4 by 4) intersection.
- Using a hammer, drive a 1/2 - 10 or 12 galvanized carriage bolt into each hole; place washer and nut.
  - The bolts must be facing toward the back side of the station.
- Check the distance that the guard-pipe must be set from the bottom (sampling height).
- Determine if the guard-pipe has to be cut or an extension pipe must be added (the 4 by 4 coupling will rest on top of the 2 by 6s). Glue the 4 by 4 coupling to the guard-pipe.
- Set the guard-pipe inside the holding boards; tighten the nuts.

Guard-pipe holding system: using pipe fastening devices

- Check the distance that the guard-pipe must be set from the bottom (sampling height).
- Determine if the guard-pipe has to be cut or an extension pipe must be added. Glue the 4 by 4 coupling to the guard-pipe.
- Place one fastening device on each 2 by 6.
- Place the guard-pipe in position and tighten the U-bolt or pipe hanger.
- Place 2 - 2 by 6s on the front part of the station, parallel to the 2 by 6s that hold the guard-pipe. Screw them.
- Drill 2- 1/2 holes at each (2 by 6) - (4 by 4) intersection.
- Using a hammer, drive a 1/2- 10 or 12 inch galvanized carriage bolt into each hole; place washer and nut.
  - The bolts must be facing toward the back side of the station.

6

Station - Finishing touches

- Place safety signs, paint station, clean the station.

5.6.6 OTHER TYPES OF WOODEN PLATFORMS

The following illustrations are provided as examples of other types of wooden monitoring platforms.

Figure 5.40 One-column structure
(Source: Jobos Bay, NERR)

Figure 5.41 Three-column structure
(Source: Taskinas Creek, NERRVA)

Figure 5.42 Four-column structure
(Source: USGS South Florida Information Access)

Figure 5.43 Four-column structure
(Source: Mission-Aransas NERR)

5.7 EXISTING STRUCTURES

Existing structures are all the different types of structures that already exist at the monitoring sites and the user takes advantage of them to set the monitoring station.

The existing structures are subdivided into four main categories:

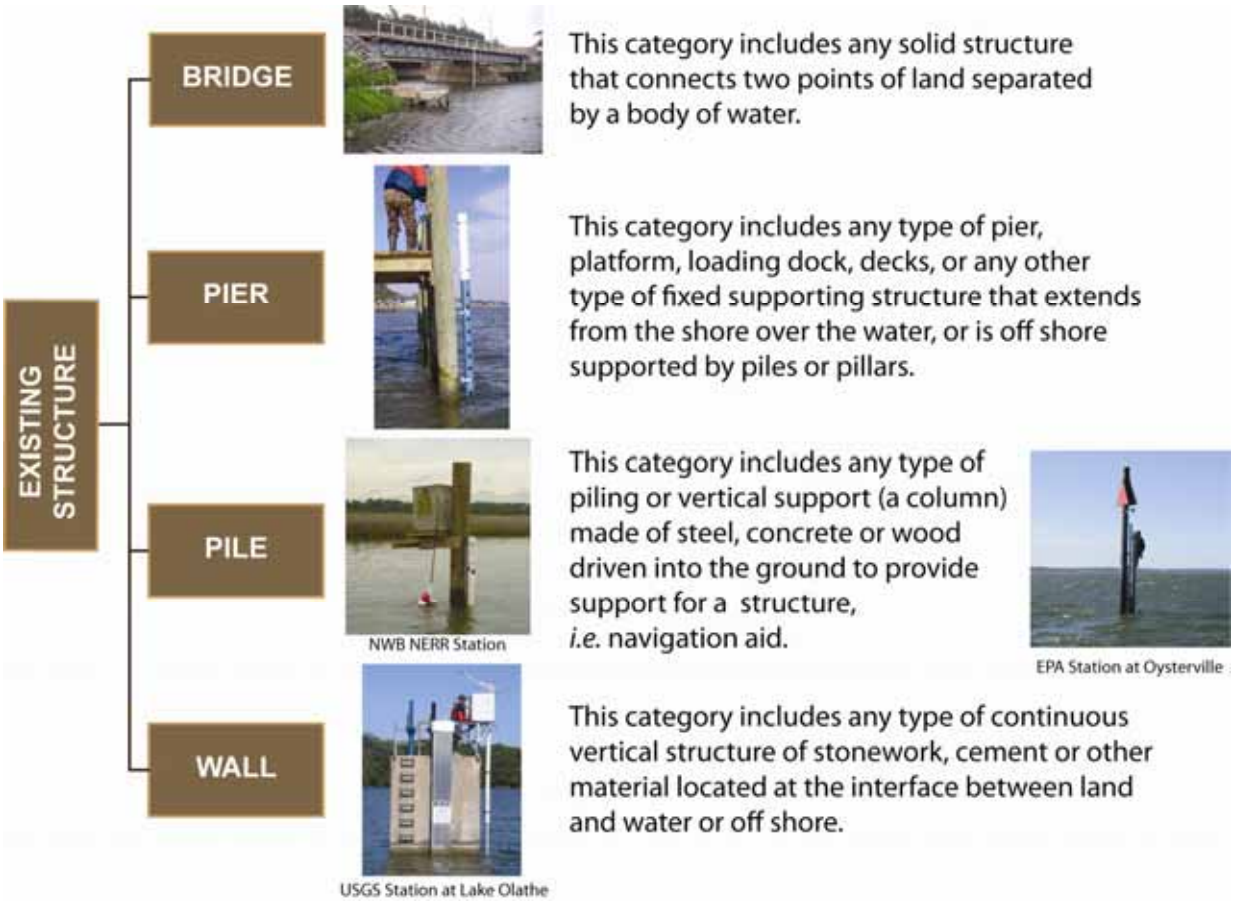


Figure 5.44 Existing Structures

Attaching the guard-pipe to an existing structure has its advantages and disadvantages. Advantages include ease of setting (cost/effort of installation is much less than an offshore-based station) and accessibility (the station can be accessed independent of weather conditions in most structures). The main disadvantage of this type of station is that the location of the existing structure cannot be changed. Once it is decided that an existing structure will be used (*i.e.* the station must be placed on a pier due to budget constraints); then an existing structure at the sampling site must be found where the monitoring objectives are fulfilled, and representative data can be collected.

The construction steps to secure the guard-pipe to an existing structure are simple and straightforward. Basically the procedure consists of three steps:

1 Select the location where to set the monitoring station.

- Once the existing structure is identified, possible effects of the structure on the water quality data must be addressed. For example, the fouling at the pile of a pier could reach the sensors and affect the representativeness of the water quality data.
- To minimize the existing structure effects on data quality the sensors must be set at a distance from the structure. The further away from the fixed structure the sensors are, the better.

2 Determine how the guard-pipe is going to be secured to the structure

- The fastening method to be employed will depend on the type of structure.
  - There are various types of devices that can be used to attach the guard-pipe to the existing structure. The most common type of devices is some kind of pipe hanger, *e.g.* U-bolts, marine hose clamp, pipe clamps, straps, or a particular fastening device specially designed for a particular structure.
  - The distance between the structure and the guard-pipe should be enough to allow cleaning of the structure and the outside of the guard-pipe.

3 Place the guard-pipe

- Check the distance that the guard-pipe must be set from the bottom (sampling height).
- Determine if the guard-pipe has to be cut or an extension pipe must be added. Glue the 4 by 4 coupling to the guard-pipe.
- If necessary, place a safety lock cap.

5.8 ON RIVER & STREAM BANK

5.8.1 ON RIVER & STREAM BANK: WITH EQUIPMENT SHELTER

On river and stream bank water quality monitoring stations with equipment shelter can be classified as flow-through and in-situ monitoring systems.

5.8.8.1 Flow-Through Monitoring System

In a flow-through system the surface water is pumped to a container mounted in a shelter where the multiparameter sonde is located. The water is then released by gravity back to the river or stream (Wagner *et al.*, 2006).

The flow-through configuration is commonly employed in sampling locations where the monitoring sensor can not be installed safely in the river or stream (BC Ministry of Environment, 2007). Environmental conditions that make propitious the application of a flow-through system are detailed in Table 5.20.

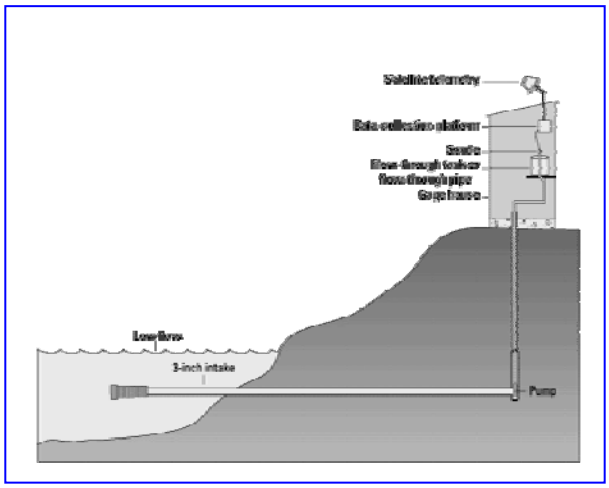


Figure 5.45 Flow-through monitoring system (Source: Wagner *et al.*, 2000)

Excessive turbulence and bubbles
Extreme danger of instrument damage from floating debris or bedload
Insufficient water depth to meet operational requirements
Unstable bank conditions or no structure available to anchor a deployment tube
Severe cold and ice during the winter

Table 5.20 Environmental conditions that make propitious the application of a flow-through system
(Source: BC Ministry of Environment, 2007)

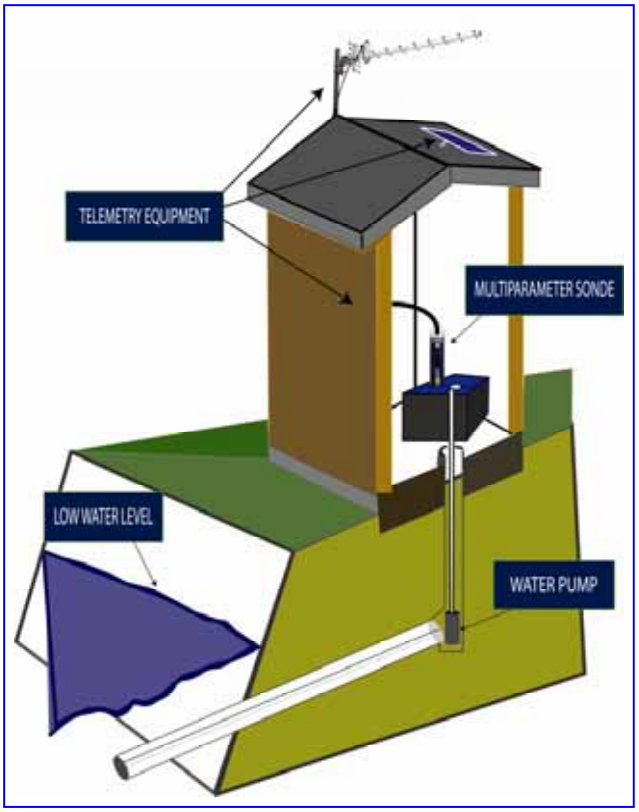


Figure 5.46 Sketch of flow-through monitoring system

5.8.8.2 In-Situ Monitoring System

In an in-situ monitoring system the sensors are placed at the measuring point in the river or stream cross section (Wagner *et al*., 2006).

General construction guidelines for the flow-through and in-situ monitoring systems can be found in Wagner *et al*., 2006 and in BC Ministry of Environment, 2007. Advantages and disadvantages of each type of structure are given in these publications. These guidelines will enable the monitoring team to construct or design shelter type monitoring structures. Guidelines on how to secure the guard-pipe to the bank are given in the next section.

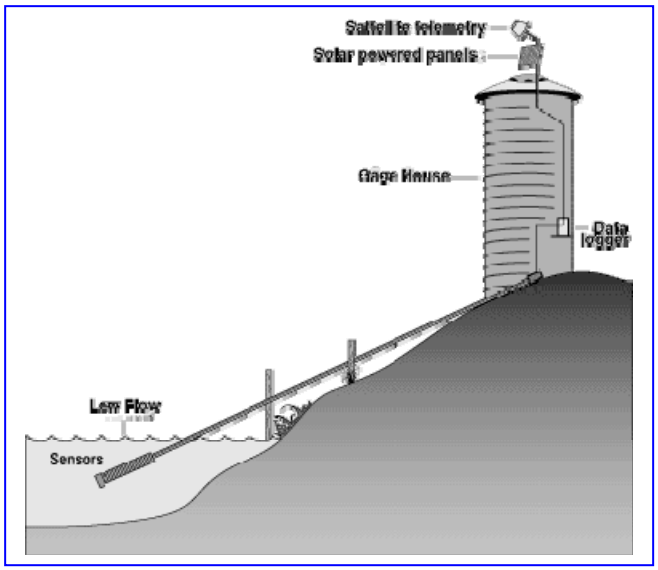


Figure 5.47 In-situ monitoring system with shelter
(Source: Wagner *et al*., 2000)

Figure 5.48 USGS monitoring station at Pete Mitchell Swamp, NC.
(Source: USGS North Carolina Water Science Center)

Figure 5.49 USGS monitoring station
at Spring Brook Creek, WA.
(Source: USGS Washington Water Science Center)

In-situ monitoring stations with shelter are a good option when monitoring equipment must be protected from the weather, and/or certain field tasks need protection from the weather for their execution. In addition, the shelter provides added protection from vandalism.

5.8.2 ON RIVER & STREAM BANK: WITHOUT EQUIPMENT SHELTER

On river and stream bank water quality monitoring stations without equipment shelter are basically composed of a guard-pipe secured to the bank on an angle (same layout as the in-situ monitoring system with shelter, in this case, without the shelter).

Different methods exist to secure the guard-pipe to the bank, going from special designed structures to using the trees at the site to anchor the guard-pipe. The following illustrations can be used as guidelines to select or design an on river & stream bank station.

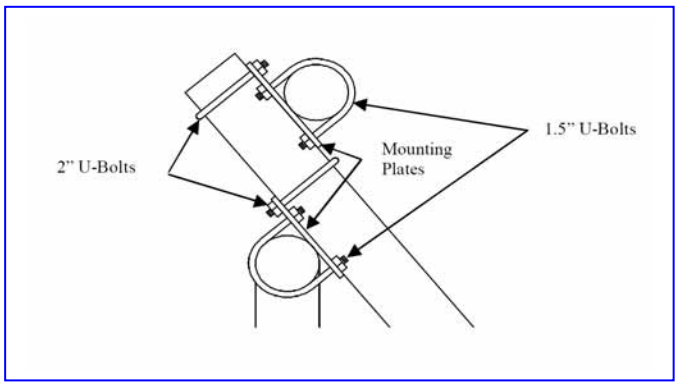


Figure 5.50 PVC pipe – U bolts mounting system
(Source: YSI Incorporated)

Figure 5.51 Lying on the bank
(Source: USGS, Tongue River, MT)

Figure 5.52 Cement foundation, pipe, pipe fasteners mounting system
(Source: Universiti Sains Malaysia)

Figure 5.53 Wood post & steel pipe structure
(Source: New South Wales Department of Natural Resources, Lower Richmond)

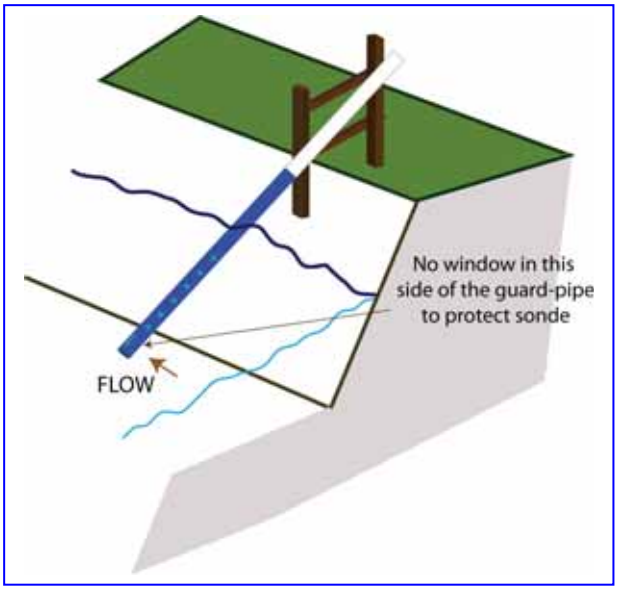


Figure 5.54 Wooden structure

5.9 REFERENCE

Ascalew Abebe and Ian GN Smith. 2005. **Pile Foundation Design: A Student Guide**. School of the Built Environment, Napier University, Edinburgh. http://www.sbe.napier.ac.uk/projects/piledesign/guide/index.htm

BC Ministry of Environment. 2007. **Continuous Water-Quality Sampling Programs: Operating Procedures.** Watershed and Aquifer Science. Science and Information Branch. The Province of British Columbia. Resources Information Standard Committee.

Collin James G. 2002. **Timber Pile Design and Construction Manual**. American Wood Preservers Institute (AWPI).

Department of the Army. 1985. **Pile Construction**. Field Manual No. 5-134.

Federal Highway Administration (FHWA). 2007. **Pile Driving Inspector's Tutorial**. United States Department of Transportation. Transportation Curriculum Coordination Council.

Gerwick Ben C. 2000. **Construction of Marine and Offshore Structures**. Second Edition. CRC Press.

Kelty, Ruth and Steve Bliven. 2003. **Environmental and Aesthetic Impacts of Small Docks and Piers: Workshop Report: Developing a Science-Based Decision Support Tool for Small Dock Management, Phase 1: Status of the Science**. NOAA Coastal Ocean Program, Decision Analysis Series Number 22. NOAA Coastal Ocean Program, 1305 East-West Highway, Silver Spring, MD, 20910.

Miles, Eduardo J. 2008. **The SSC cycle: a PDCA approach to address site-specific characteristics in a continuous shallow water quality monitoring project**. Journal of Environmental Monitoring:10, 604 – 611. DOI: 10.1039/b717406c.

Osmond Deanna L., Grace R. Lawrence, and Janet Young. 2003. **Dock and Pier Construction in Coastal Communities**. Environmental Stewardship for Homeowners #6 NORTH CAROLINA COOPERATIVE EXTENSION SERVICE. AG-565-01.

Shroff Arvind V. and Dhananjay L. Shah. 2003. **Soil Mechanics and Geotechnical Engineering**. Taylor & Francis.

The Hong Kong Polytechnic University. **Pile Foundations**. Department of Civil and Structural Engineering. http://www.cse.polyu.edu.hk/~ctpile/frame/frame.html

Tomlinson Michael J. 1994. **Pile Design and Construction Practice**. Taylor & Francis. London & New York.

US Army Corps of Engineers. 2003. **Wood Marine Piles**. UFGS-31 62 19.13

US Army Corps of Engineers. 1998. **Pile Driving Equipment**. Technical Instructions. TI 818-03.

U.S. Environmental Protection Agency. 2002. **Delivering Timely Water Quality Information to Your Community**. The Chesapeake Bay and National Aquarium in Baltimore EMPACT Projects. Office of Research and Development. National Risk Management Research Laboratory Cincinnati. EPA625/R-02/018

Wagner, Richard J., and Robert W. Boulger, Jr., Carolyn J. Oblinger, and Brett A. Smith. 2000. **Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and Data Reporting.** U.S. Geological Survey. Techniques and Methods 1–D3. http://pubs.usgs.gov/tm/2006/tm1D3/pdf/TM1D3.pdf

5.9.1 Photo Reference

Figure 5.3 - Federal Highway Administration (FHWA). 2007. Pile Driving Inspector's Tutorial. United States Department of Transportation. Transportation Curriculum Coordination Council.
http://www.fhwa.dot.gov/infrastructure/tccc/tutorial/piles/pile03d.htm

Figure 5.4 - Whatcom Waterfront Construction.
http://whatcomwaterfrontconstruction.com/

Figure 5.5 - ASD Commercial Diving and Marine Contractors
http://www.asddiving.com.au/
Marine Pile Drivers
http://www.marinepiledrivers.com/?gclid=CKeS9ob43ZoCFQQRswodUgojzQ

Figure 5.19 - Paul Perusse http://www.kayakvb.com/reports/

Figure 5.21 – T. Chris Mochon-Collura. Eelgrass Research, Hood Canal, WA. Region 10: The Pacific Northwest. U.S. Environmental Protection Agency.
http://yosemite.epa.gov/r10/OEA.NSF/Investigations/Dive+BOS

Figure 5.42 - Open-water ET site in ENR (2). Evapotranspiration Measurements and Modeling in the Everglades. US Geological Survey South Florida Information Access.
http://sofia.usgs.gov/projects/index.php?project_url=evapotrans

Figure 5.44 - Oysterville Station. Coastal Estuary Instrument Maintenance and Recovery, Willapa Bay, WA. Region 10: The Pacific Northwest. U.S. Environmental Protection Agency.
http://yosemite.epa.gov/r10/OEA.NSF/Investigations/Dive+BOS

Figure 5.45 - Wagner, Richard J., and Robert W. Boulger, Jr., Carolyn J. Oblinger, and Brett A. Smith. 2000. Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and Data Reporting. U.S. Geological Survey. Techniques and Methods 1–D3.

Figure 5.47 - Wagner, Richard J., and Robert W. Boulger, Jr., Carolyn J. Oblinger, and Brett A. Smith. 2006. Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and Data Reporting. U.S. Geological Survey. Techniques and Methods 1–D3.
http://pubs.usgs.gov/tm/2006/tm1D3/pdf/TM1D3.pdf

Figure 5.48 - Albemarle-Pamlico Study (ALBE), National Water-Quality Assessment (NAWQA). Station Photos 1991-2000. Pete Mitchell Swamp. Albemarle-Pamlico NAWQA. US Geological Survey North Carolina Water Science Center.
http://nc.water.usgs.gov/albe/index.html

Figure 5.49 - 12113346 Spring Brook Creek near Orillia Station. US Geological Survey Washington Water Science Center.
http://wa.water.usgs.gov/cgi/adr.cgi?12113346

Figure 5.50. - 5200 Continuous Monitor Operations Manual. YSI Incorporated.
https://www.ysi.com/DocumentServer/DocumentServer?docID=WQS_5200_MANUAL

Figure 5.51 Tongue River Surface-Water-Quality Monitoring Network**.** US Geological Survey Gaging Station at Tongue River at State Line.
http://mt.water.usgs.gov/projects/tongueriver/saranalyzer.htm

Figure 5.52 - Wetpond Station (Sonde 1) and Wetland Micro pool Station (Sonde 2). Water Quantity and Quality Monitoring Station. Application of Bio-Ecological Drainage System (BIOECODS) in Malaysia. River Engineering and Urban Drainage. Universiti Sains Malaysia. http://redac.eng.usm.my/html/projects/bioecods/

Figure 5.53 Water Quality Monitoring Station On Coastal Wetland Drain, Tuckean Swamp. Managing Connected Water Resources Project. New South Wales Department of Natural Resources. Australian Government.
http://www.connectedwater.gov.au/index.html

CHAPTER 6

TELEMETRY EQUIPMENT INSTALLATION

6.1 INTRODUCTION

Telemetry is defined as:

> *Highly automated communications process by which data are collected from instruments located at remote or inaccessible points and transmitted to receiving equipment for measurement, monitoring, display, and recording. (Encyclopedia Britannica)*
>
> *The science and technology of automatic measurement and transmission of data by wire, radio, or other means from remote sources, as from space vehicles, to receiving stations for recording and analysis (The American Heritage Dictionary)*

The recent progress in electronics and telecommunications has made remote telemetry systems very reliable and cost effective for use in water quality monitoring.

Telemetry can provide the following benefits in a water quality monitoring project:

→ Environmental data can be continuously monitored at near real-time.

→ More timely detection and prediction of environmental changes can be achieved.

→ Early detection and warning systems (*e.g.* alerts) can be developed of where and when a certain condition is favorable to occur (*e.g.* HAB event)).

→ A reduction of maintenance and project costs can be achieved.

- Reduction of travel and labor costs
  - Reduction of trips to the station to ensure the multiparameter sonde is working correctly. Telemetry allows the user to verify on-line if the multiparameter sonde is working properly.
  - It provides the ability to perform preventive and corrective maintenance, as it can be used to identify when a sensor failed, is close to fail, or requires maintenance.
  - Certain troubleshooting can be performed on-line without the need to send a person to the field.
- Allows to access remote data instantly; thus, eliminates manual data collection.

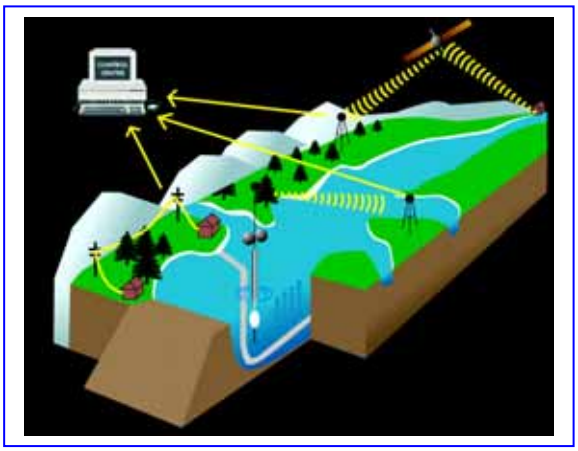


Figure 6.1 Cell phone, radio and satellite telemetry
(Source: Precision Measurement Engineering)

A brief description of the main components of a typical wireless telemetry system and basic guidelines to install the telemetry equipment at the monitoring station are provided in this chapter.

It is not the intention of this chapter to provide a detail description on how to design and implement a telemetry network. The chapter does not describe what requirements and constrains must be taken into account to determine the best wireless communication option capable of meeting the project's needs, neither describes the equipment, operational considerations and costs of the ground receiving station.

In addition, it is not the purpose of this chapter to provide a detail description on how to install a telemetry system (*i.e.* to connect and program the different telemetry equipment). The user must strictly follow the manufacturer's and the service providers' instructions and recommendations in this regard.

Mention of trade names or commercial products does not constitute endorsement or recommendation of their use.

Note: It is recommended to obtain expert help when designing an installing a wireless system.

6.2 TELEMETRY SYSTEM FOR A CONTINUOUS WATER QUALITY MONITORING PROJECT

The telemetry system is basically composed of three subsystems:

1. A data acquisition system: composed of the data collection platforms. A data collection platform (DCP) consists of all the equipment needed in each monitoring station to collect, store, encode and transmits the data: sensors, logger, power supply and the transmitter/antenna system. Each monitoring station with near real-time data transmission capabilities can be considered a data collection platform.

2. A signal transmission system: equipment needed to transmit the data from the DCP to the host or ground station (*e.g.* GOES satellite).

3. A data acquisition, analysis and dissemination system: the host or ground station that receives and manages the data.

Figure 6.2 Major components of NERR's telemetry system

This section provides a brief description of:

- The most common types of wireless communication options employed in continuous shallow water quality monitoring.

- The data collection platform equipment.

6.2.1 TYPES OF WIRELESS COMMUNICATION

The most common wireless communication options employed in continuous shallow water quality monitoring stations are (South, 2005; Blake, 2007):

VHF/UHF radio telemetry: In the VHF/UHF systems the airtime is free, and the systems are not to expensive to set up (if repeaters are not needed). Typically this type of wireless communication is good if the DCP and ground station are less than 30 miles apart (15 km). Some disadvantages of this type of telemetry are: the system is not easy to install; licensing costs must be incurred and line-of-sight is required.

Cellular telemetry: In areas with strong and reliable cell phone coverage, this can be a good option given the hardware is not too expensive and the system is easy to set up. Some disadvantages are: monthly service fees are required; data quality must be insured given that voice coverage is not the same as data coverage; and coverage can be dropped during peak system utilization.

Spread spectrum telemetry: Spread spectrum telemetry uses specific frequency bands (902 to 928 MHz) that are unlicensed and free. The equipment system is much easier to install than VHF/UHF, but it has a limited communication distance, averaging between 5 and 10 miles. In addition, given that are free bands it can suffer of band pollution.

Satellite telemetry: Satellite telemetry is the best option:

- For remote monitoring sites
- For locations where there is no cellular coverage.
- For locations that are too far distant for a line of sight radio connection.
- Other telemetry options are not economically feasible (the system cost to provide adequate communication is too high; *i.e.* need to place repeaters).

NOAA operates two Geostationary Operational Environmental Satellites (GOES West and East) that are used only by federal, state and local agencies and government sponsored environmental monitoring applications. Other users may apply for permission to use GOES but there is limited access.

Organizations that can not access GOES will use LEO satellites; for example ORBCOMM or Globalstar. These satellites service have a monthly service fee that would vary with the transmission frequency.

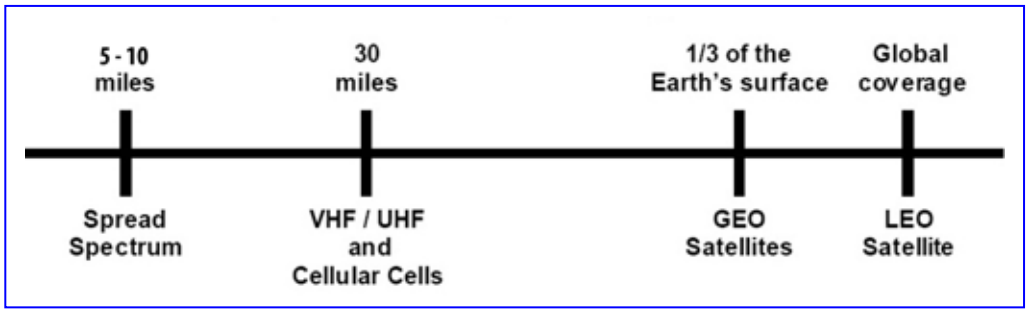
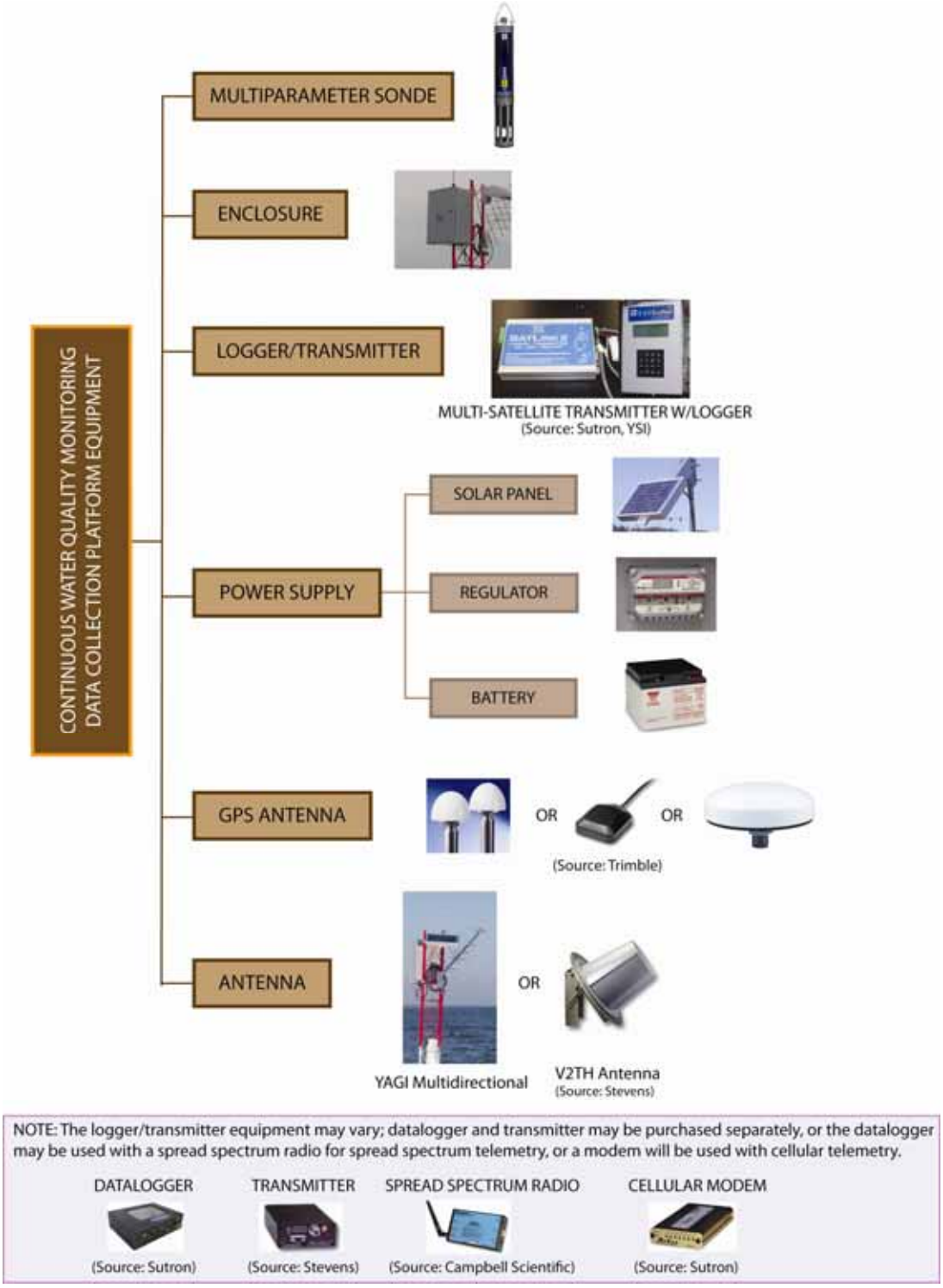


Figure 6.3 Typical maximum DCP-ground station communication ranges (South, 2005)

6.2.2 DATA COLLECTION PLATFORM EQUIPMENT

Telemetry systems are built from commercial off the shelf products. While the different telemetry systems have many common elements, they are each uniquely configured to meet specific application requirements; for example, stand alone data loggers or combined datalogger-transmitter (L-3 Communications).

Following, the basic satellite telemetry equipment is displayed.



6.3 FACTORS FOR CONSIDERATION WHEN DESIGNING A TELEMETRY NETWORK

When planning and designing a telemetry network, certain factors must be taken into account to assure the system will comply with the transmission, cost and operational requirements.

Some factors that must be addressed are:

- Architecture of the system.
- Implementation horizon.
- System requirements in terms of: the location and the number of DCPs, and transmission frequency (short and long-term scenarios).
- System integration and customization requirements.
- System installation requirements.
- Redundant transmission of data (if necessary).
- Cost of network installation, support and maintenance.
- Cost of transmission service.
- Data management requirements (data collection, quality control & quality assurance analysis, data processing, system management, user interface, data dissemination).

  If the cost of the ground receiving station is the limiting factor of installing a telemetry network, a possible solution is to use a company that provides the service of collecting the DCP data and delivering it to your organization via the web.

6.4 INSTALLATION GUIDELINES

The material presented in this section is based on the document "**Telemetry Installation Notes**" written by **Jay Poucher**, CDMO Telemetry Coordinator.

Jay Poucher can be contacted at jpoucher@sc.edu.

The purpose of this section is to provide general guidelines for the installation of satellite telemetry equipment in a water quality monitoring platform.

→ The installation activities can be subdivided into two parts:

a) **Activities that take place before going to the field**: include all the activities of designing the telemetry station, selecting the equipment, discussing the project with the technical representative, designing the monitoring platform or reviewing existing one to determine if modifications are needed, *etc*.

b) **Activities that take place on-site**: include all the activities of installation and set-up of the equipment, inspection and verification.

→ The installation activities, and the equipment and field tools requirements will vary depending on:

- The type of telemetry system to be installed.
- The type of monitoring platform.
- The monitoring site location.

→ It is recommended to obtain expert help (*e.g.* from the telemetry equipment representative or from a known organization that has a similar telemetry network installed) for advice and/or to discuss installation requirements and possibly request his/her present during the first installation.

Note: If another type of wireless communication is employed, *e.g.* cellular, the same installation guidelines can be used. The basic equipment (enclosure, solar panel, and grounding system) will be the same, the only difference would be the type of transmitter and associated antennas (*e.g.* instead of using a YAGI, a high gain antenna-cellular frequency, will be used).

6.4.1 Pre-Installation Activities

Due to the wide range of telemetry equipment and monitoring site characteristics, most telemetry system would require custom designs and best engineering judgment in order to obtain the best system performance.

Even though the great variability in telemetry systems designs, some pre-installation activities are common to all systems. Among them, it is worth to mention:

- Power equipment and antenna considerations.
- Monitoring platforms requirements.
- Development of an installation plan.

6.4.1.1 Power Equipment Considerations

→ **Power Consumption of the System**

The power consumption of a telemetry system is the sum of the average current drains of all the different equipments (*e.g.* datalogger, multiparameter sonde and peripheral equipments).

To calculate the power consumption, the percentage of time the equipments spent in active state (performing measurements, processing/sotring data) versus the time they spent in a quiescent state must be determined (Campbell Scientific, Power Supplies).

→ **Battery Considerations**

The battery must have the capacity to power the different equipment during the whole deployment cycle. If the battery is charged with a solar panel, the battery is required to have a reserve source of energy sufficient to operate the particular installation, with the highest power consumption during the night and periods of low sun light.

The energy for insolation (incoming solar radiation or energy from the sun) varies with the latitude and the month (*e.g.* the isolation levels in kWh/m2/day for Boston during Dec&Jan&Feb is 1.83 and 5.32 for Jun&Jul&Aug; while Miami receives 3.93 and 6.21 respectively) (NASA).

The battery must have certain reserve time to accommodate periods of low levels of isolation. Recommended reserve times based on latitude are shown in Table 6.1

Latitude of monitoring site	Recommended reserve time
0° to 30° (N or S)	144 to 168 hr
30° to 50° (N or S)	288 to 336 hr
50° to 60° (N or S)	732 hr
Polar regions	8,760 hr

Table 6.1 Recommended reserve time based on latitude
(Source: Campbell Scientific, Power Supplies)

The energy stored in a battery is known as "battery capacity". The common measure of battery capacity is the number of amp-hours that can be removed from a battery at a specified discharge rate at the nominal voltage of the battery (Photovoltaic Education Network).

To calculate the system's required battery capacity, a simple equation can be used (Campbell Scientific, Power Supplies):

Required battery capacity = (system's current drain) x (reserve time)/0.8

- The 0.8 value is to assume worst case conditions (limit the battery depth of discharge to 80%).

For polar regions the equation would be:

Required battery capacity = 2 x (system's current drain) x (reserve time)

Note:

- It is recommended to use sealed lead batteries.
- For extremely cold temperatures, Campbell Scientific recommends using the Cyclon battery manufactured by Hawker Energy Products.
- Daily Amp-Hour Usage Calculator can be found at: http://www.bigfrogmountain.com/calculators/dailyamphourusage.htm

→ Solar Panel Considerations

Required Solar Panel Current

The solar panel converts sunlight into direct current. The current the solar panel must provide (in terms of battery capacity) can be determined using the following equations (Campbell Scientific, Power Supplies):

Solar panel current > ((system amp-hr/day) x 1.2) / (Hours of light)

- 1.2 accounts for solar panel system loss.
- Hours of light: the number of hours in the day the sky is clear enough for the solar panel to source current (use the worst case condition, *i.e.* winter).

For polar regions solar panel current > (system amp-hr/day) x 2)

Solar radiation data can be obtained from National Renewable Energy Lab (NERL).

- **Solar radiation for 239 sites in the US** with extensive weather records can be found in the publication "Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors" http://rredc.nrel.gov/solar/pubs/redbook/
- **U.S. Solar Radiation Resource Maps**: 30-year average for a particular month can be found at http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/atlas/Table.html
- **Solar maps** can be found at http://www.nrel.gov/gis/solar.html

- For parts of the world with little solar radiation data, NREL created a crude global data set using data inferred from satellites.
- In addition, world radiation data can be found in World Meteorological Organization at http://wrdc-mgo.nrel.gov/

Solar Panel Orientation

Solar panels can be mounted at a fixed azimuth and tilt angle or on frames that allow for orientation adjustment.

Solar panels should face true, due or geographic south in the Northern Hemisphere and true, due or geographic north in the Southern Hemisphere.

Note: Geographic south is defined as azimuth=0°. Angles to the east of due south are negative, with due east having azimuth=-90°. Angles to the west of due south are positive, with due west having an azimuth=90° (Solar Plots Info).

Fixed orientation: orient solar panel to the geographic south (not magnetic south) in the Northern Hemisphere. Suggested tilt angles (referenced to the horizontal plane) are shown in Table 6.2. These tilt angles maximize output for winter. Even though optimization summer angles are different, the extra isolation that occurs during summer makes up for the less than optimum angle (Stein, 2008).

Site Latitude (°)	Tilt Angle above horizontal
0 – 10	10 degrees
11 – 20	Latitude + 5 degrees
21 – 45	Latitude + 10 degrees
46 – 65	Latitude + 15 degrees
> 65	80 degrees

Table 6.2 Suggested tilt angles
(Source: Campbell Scientific, Power Supplies)

Adjustable orientation: orient solar panel to the geographic south (not magnetic south). Suggested tilt angles above horizontal are given by the following equations (Landau, 2008):

- Tilt angle (winter) = (Latitude x 0.9) + 29°
- Tilt angle (spring and autumn) = Latitude - 2.5°
- Tilt angle (summer) = (winter angle) - 52.5°

Note: Generally, it is not worthy the effort to shift the solar panel orientation more than twice a year: once in the spring and once in the fall (Stein, 2008).

Bird Spikes

In most coastal environments, and particularly at off-shore stations, birds can be a problem, especially bird droppings. If this is the case at a particular monitoring site, bird spikes must be employed.

6.4.1.2 Monitoring Platform

MONITORING PLATFORM

NEW MONITORING PLATFORM WILL BE INSTALLED

If a new monitoring platform will be installed it must be designed to adequately hold the telemetry equipment and to comply with all the different safety requirements, in particular:

- Specified by the different manufacturers.
- To address the different environmental factors (*e.g.* wave action, winds).
- To minimize vandalism.

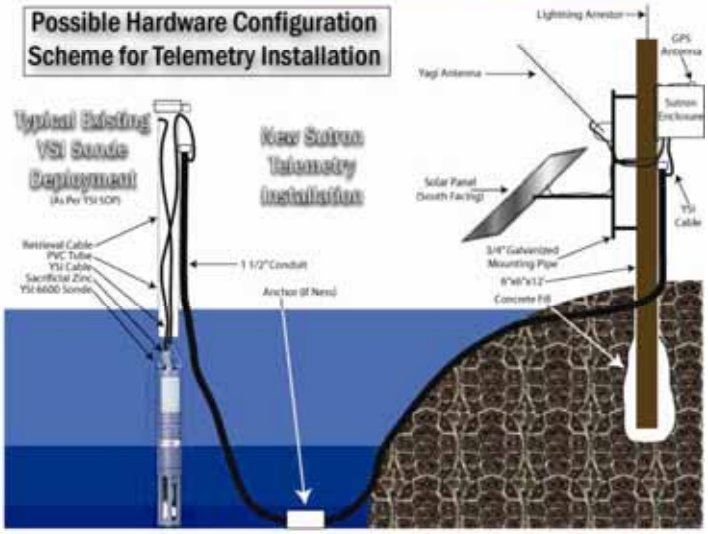
AN EXISTING MONITORING PLATFORM WILL BE USED

If an existing monitoring platform will be used to install the telemetry equipment, it must be determined if:

- The station can adequately hold the telemetry equipment and can comply with the safety requirements.
- The station must be overhauled or reconditioned.

If local regulations prohibit the installation of an offshore permanent monitoring station or it is not possible to modify the existing platform; the design team must consider if it is possible to set the telemeter station on-shore.

This option requires the utilization of a long field cable to connect the multiparameter sonde to the remote location.



(Source: Poucher, J.)

Note: Even though the telemetry equipment is mounted inside a weather resistant control box, it is important to ensure that the control box is above water at all times. Therefore, mean higher high water, wave action, wind footprint and storm surges must be taken into account when designing a new monitoring platform or when an existing platform is evaluated for installation (EPA, 2002).

6.4.1.3 Antenna Considerations

A satellite antenna must be pointed directly at the orbital location of the satellite in order to obtain the best signal. To correctly point the antenna the latitude and longitude of the monitoring site must be known to determine the required azimuth and elevation (azimuth is the direction to which the antenna must be rotated and the elevation is the angle the antenna must be raised with respect to the horizontal).

The azimuth and elevation can be obtained from the following web page:

http://www.dishpointer.com/

The web site employs a mashup of Google Maps to find the required information to correctly set the antenna. The monitoring site location can be easily be found by entering the zip code, latitude and longitude, county, or any other information permitted by Google Maps to pin-point a specific DCP location.

In addition to point the antenna to the correct orientation, the antenna must have a good line of sight to the satellite to provide the best signal. The optimum is to have a free visual path between the antenna and the satellite (free of obstacles, such as dense forest, buildings, hills, *etc*.). Even though, good signals can be obtained with some types of obstructions, for examples, trees (not heavy canopy).

6.4.1.4 Installation Plan

It is a good practice to develop an installation plan. The plan defines objectives, describes the correct installation procedures, details the key critical factors that must be considered during the installation, describes the tools and supplies needed, and defines other activities and measurements that need to be executed.

It is a good practice to have a meeting with the installation team to go over the different installation activities before going to the field.

INSTALLATION PLAN: Things to take into account

- Read all manufacturers' documents thoroughly.
  It is a good practice to write down, in a check list form:
  - The correct order for installing the components.
  - Verification and inspection steps.
- Make sure to have all necessary detail installation drawings.
- Be sure to have the necessary information to install the solar panel and the antenna.
- Make a list of tools and supplies needed. A good practice is to go over the different installation steps while checking that the required tools and supplies are on hand.
- Be sure to have the adequate software to run the transmitter and to program the multiparameter sonde, so it can interface adequately with the transmitter (*i.e.* in YSI 6600 the sample and hold function must be enabled after it is calibrated for deployment).

Basic tools and supplies that are commonly required during a telemetry system installation are detailed in Table 6.3.

Tools	Supplies
Sockets with ratchet (deep well)	WD-40 or similar
Straight-bit screwdrivers (small, medium, large)	Silicone dielectric grease
Phillips head screwdrivers (small, medium)	Electrical tape
Open ended wrenches	Rubberized tape
Hammer	Cable ties (blacks are preferably given the higher resistance to UV than other colors)
Pliers	
Level	
Inclinometer	Washers 3/8"
Wire strippers	25 feet 14 gauge interior 2 conductor Romex wire with ground
Volt/Ohm meter	
Magnetic compass	

Table 6.3 Basic tools and supplies for telemetry installation

6.4.2 Installation Activities

Two types of installation procedures are described in this section as guidelines only:

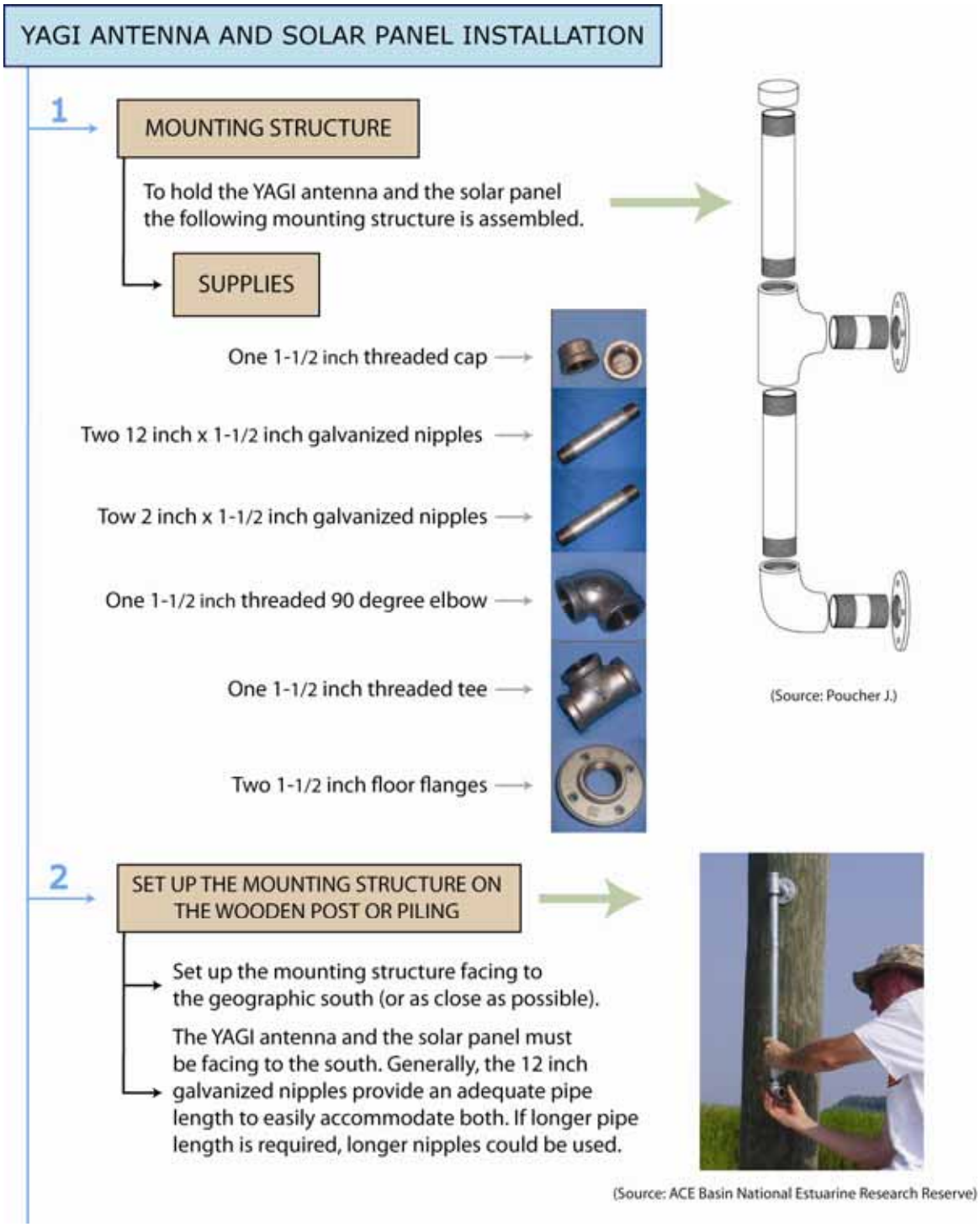
- Telemetry systems mounted on wooden pilings & posts (*e.g.* pile, piers, wooden structures).
- Telemetry systems mounted on platforms that use antenna tower as a construction material.

These guidelines provide basic information on how to install the telemetry equipment. They can be used to select a specific configuration or as the basis to define new design features to meet the particular needs.

Note: The specific installation steps to follow must be evaluated based on each system and site's particular characteristics.

6.4.2.1 Telemetry Equipment Mounted on Wooden Piling & Post

The following guidelines detail Delaware National Estuarine Research Reserve installation practices, designed by Mike Mensinger.



3 INSTALL THE YAGI ANTENNA

- Mount the antenna at the top nipple of the mounting structure.
  - The antenna connector should be facing down.
- Install the antenna and point it at the satellite.
  - Using a compass and inclinometer, adjust the antenna to match the required azimuth and elevation.
    - Remember
      - For elevation: horizon = 0˚ ; high noon = 90˚
      - To use the correct type of degree for the azimuth value (*i.e.* true or magnetic)
- During testing, slightly adjustments are made to obtain the best signal.

(Source: ACE Basin National Estuarine Research Reserve)

4 INSTALL THE SOLAR PANEL

- Mount the solar panel at the bottom nipple of the mounting structure.
- Orient the solar panel to the geographic south and tilt it to the required angle.

(Source: Delaware National Estuarine Research Reserve)

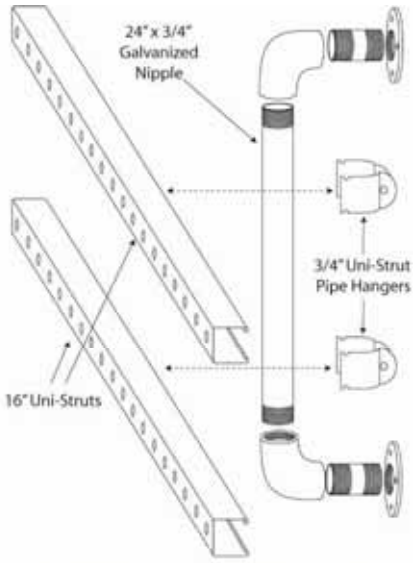
5 INSTALL LIGHTNING ROD

- Mount the lightning rod (refer to section 6.4.2.3).

ENCLOSURE INSTALLATION

1 MOUNTING STRUCTURE

To hold the enclosure the following mounting structure is assembled.



(Source: Poucher, J.)

SUPPLIES

One 24 inch x 1-1/2 inch galvanized nipple

Tow 2 inch x 1-1/2 inch galvanized nipples

Two 1-1/2 inch threaded 90 degree elbow

Two 1-1/2 inch floor flanges

Two 1-1/2 inch unistrut pipe hangers

Two unistrut
(length equal to the enclosure width)

2 SET UP THE MOUNTING STRUCTURE ON THE WOODEN POST & PILING

Try not to set up the mounting structure on the same side of the antenna and solar mounting structure.

3 INSTALL THE ENCLOSURE

Bolt the unisturts to the enclosure. Be careful not to damage the enclosure. Use washers as spacers to prevent the bolts to penetrate the interior of the enclosure (generally this step is done at the lab).

Secure the unistruts to the nipple using the unistrut pipe hangers.

(Source: AC Basin, Delaware and Weeks Bay NERR)

USING A MAST PIPE TO MOUNT THE SOLAR PANEL & ANTENNA

A mast pipe is a good alternative to use when:

- The existing platform has no room to adequately mount the solar panel and the antenna.
- The existing platform does not have the necessary height to adequately mount the solar panel and the antenna (*i.e.* there are some obstructions at the platform level, *e.g.* trees).
- The telemetry system would be installed on a pier, bridge , or shelter close to the monitoring station.

1 SET UP THE MAST PIPE

- It is a good practice to mark a line on the mast pipe to be used as the 0 degree mark (magnetic north).
- Mount the solar panel and the antenna on the mast pipe.

  Depending on the station, the solar panel and antenna could be mounted later, once the mast pipe is secured.

  - The 0 degree mark can be used to place the solar panel and antenna facing the correct orientation.
  - Using a compass and inclinometer, adjust the antenna to match the required azimuth and elevation (this step can be done later; it would depend on the height of the pipe).
  - Further adjustments would be needed once all the equipment is installed.
- The antenna can be secured to the mast pipe using a double crossarm stand.

  - Using nu-rails and/or U-bolts with a double pipe mounting brackets, a pipe of the desired length and diameter is fastened to the mast pipe. A second pipe is fastened vertically at the end of the first pipe in a cross stand arrangement to hold the antenna.
- Mount the lightning rod (refer to section 6.4.2.3).
- If the enclosure is mounted on the mast pipe, secure the unistruts to the mast pipe.
- Secure the mast pipe to the existing platform using any type of fastening device. Using the compass, the mast pipe is rotated so the mark is correctly positioned.

(Source: Rookery Bay NERR)

(Source: Campbell Scientific)

(Source: Rookery Bay NERR)

2 MOUNT THE REST OF THE TELEMETRY EQUIPMENT

- Mount the rest of the equipment as specified by the manufacturers.
- Set the antenna to the right elevation and azimuth, or make the necessary adjustments to the solar panel and the antenna so they are correctly positioned and oriented.

(Source: Chesapeake Maryland NERR)

Note: A procedure to easily access the equipment must be designed.
It is a good practice to designed this procedure at the begining of the installation plan given that it could trigger modifications in the planed configuration.

Further guidelines on how to set the lightning rod and grounding the enclosure; how to set the GPS antenna; and some considerations when connecting the equipment, are given in section 6.4.2.3

6.4.2.2 Telemetry Equipment Mounted on an Antenna Tower

The antenna tower is an excellent supporting structure to mount the telemetry equipment in almost any type of monitoring platform. Generally, one or two 10-foot galvanized tower sections are employed to build a telemetry monitoring station or to overhaul and existing one (antenna towers can be easily secured to piers, pilings, docks, or any other type of existing structure).

2 SET TOTAL TOWER LENGTH

The total tower length is determined to comply with the particular monitoring platform requirements:

- The tower must be cut.
- An additional 10 foot section must be added.

3 INSTALL THE SOLAR PANEL

If part of the equipment is installed on-board, it is a good practice to determine the orientation of the antenna tower at the monitoring station and mark the leg that is closely oriented to the 0 degree mark (magnetic north).

Then, mark one of the legs of the antenna tower (where the equipment will be mounted) to match the magnetic north leg.

Mount the solar panel and orient it to the geographic south and tilt it to the required angle.

4 INSTALL LIGHTNING ROD

Mount the lightning rod (refer to section 6.4.2.3).

5 SECURE ANTENNA TOWER

This step can be done later.

6 INSTALL THE YAGI ANTENNA

- The antenna connector should be facing down.

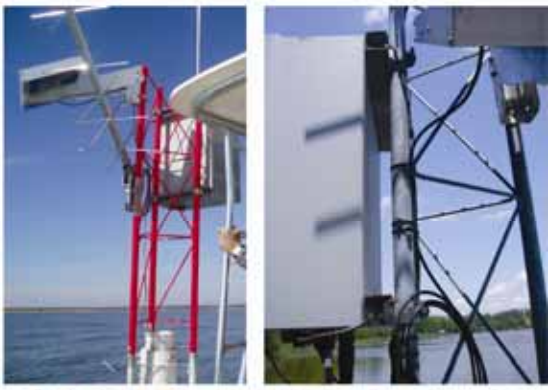
Install the antenna and point it at the satellite.

- Using a compass and inclinometer, adjust the antenna to match the required azimuth and elevation.
  - Remember
    - For elevation: horizon = 0° ; high noon = 90°
    - To use the correct type of degree for the azimuth value (*i.e.* true or magnetic)

During testing, slightly adjustments are made to obtain the best signal.

7 INSTALL THE ENCLOSURE

- Bolt the unisturts to the enclosure. Be careful not to damage the enclosure. Use washers as spacers to prevent the bolts to penetrate the interior of the enclosure (generally this step is done at the lab).
- Secure the unistruts to the nipple using the unistrut pipe hangers.



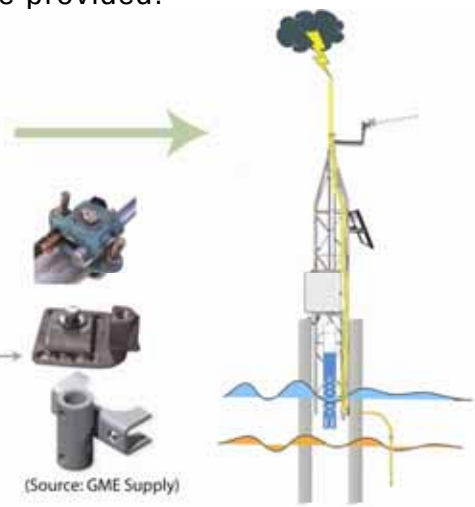
8 CONNECT EQUIPMENT

- Refer to section 6.4.2.3 for some connection points.

6.4.2.3 Additional Installation Considerations

Guidelines for installing the lightning rod and grounding the enclosure, and installing the GPS antenna are provided in this section. In addition, several points to take into account when connecting the telemetry equipment are provided.

LIGHTNING ROD INSTALLATION AND GROUNDING OF ENCLOSURE



(Source: GME Supply)

1 SUPPLIES

- Lightning rod.
- Ground rod (*e.g.* 6 foot copper rod).
- Mast clamp or mounting base (vertical or horizontal).
- Lightning conductor: aluminum or cooper wire.

2 MOUNT LIGHTING ROD

- Wooden Structure: the lighting rod can be mounted
  - On the post & piling: fasten the lighting rod on the top part of the post & piling using a vertical or horizontal mounting base. Position the mounting base approximately 2 inches (5 cm) from the top of the post & piling.
  - On the cap of the galvanized nipple: fasten the lighting rod onto the cap using a bolt.
- Antenna Tower or Mast Pipe:
  Fasten the lighting rod on the top part of the pipe or tower using a mast clamp. Position the mast clamp 2 inches (5 cm) from the top of the mast.
  - Insert the aluminum or cooper wire in the lighting rod mounting bracket, clamp or base and fasten the screws or bolts.
  - Make sure the lightning rod and conductor wire are tight.

(Source: ACE Basin and Jobos Bay NERR)

3 GROUND THE ENCLOSURE

- Connect a second wire to ground the enclosure and route it down to where the ground rod will be located.

4 DRIVE GROUND ROD INTO THE GROUND

- Cut ground wires to adequate length.
- Loosen the bolt from the clamp at the ground rod. Insert the conductor wire coming from the lightning rod and the conductor wire coming from the enclosure into the hole behind the screw. Tighten the screw so it holds the wires firmly .
  - Make sure the conductor wires do not have sharp bends.
- Drive the ground rod into the ground close to the monitoring station.

Note: It is a good practice to use a lightning arrestor in locations with heavy lightning exposure (Sutron).

GPS ANTENNA INSTALLATION

A GPS antenna is required in a satellite telemetry stations to synchronize the internal clock of the transmitter with the atomic time provided by the GPS satellites.

INSTALLATION CONSIDERATIONS

- Place the GPS antenna in the most open space possible.
- The antenna must have a clear view of the full sky so it can track the satellites.
  - → Obstructions would cause the GPS antenna to fail.

    For example, during winter ice and snow could cover the GPS antenna and degrade the signal to unacceptable levels.
- If a magnetic mount GPS antenna is used, it can be placed on top of the enclosure. For plastic enclosures an epoxy adhesive can be used.

(Source: Trimble)

- Mount the antenna so it is protected from strong winds or other weather events that may displace the antenna.
- In most cases, the magnetic GPS antenna comes with a small size coaxial cable. If the monitoring station is located in an area where rodents can damage the cable, it is a good practice to place the cable inside a conduit.

WHEN TO USE A GPS BULLET ANTENNA

(Source: Trimble)

The GPS bullet antenna must be used when (Sutron):

- When the cable length of the magnet mount antenna is not long enough.

  The new standard cable lengths for the GPS bullet antenna are 5 or 10 meters.
- In any location where the antenna must be mechanically mounted.

  Application examples include buoys, towers, ocean exposure, or anywhere with high winds or other problems that might move a magnetic antenna
- When an application requires a more robust cable..

  This antenna option provides a UV-rated cable approximately 0.3 inches in diameter.

Note: Typically, the system will take a on average from 5 to 15 minutes to acquire position fix information and to acquire time. If the system takes longer than this to acquire the time, you may need to reposition the GPS antenna (CDMO-NERR).

CONNECTION CONSIDERATIONS

- The manufacturer's installation instructions must be read thoroughly before beginning connecting the different equipment.
- It is a good practice to get professional help (*e.g.* technical representative) to assist you during the first telemetry installation.

MULTIPARAMETER SONDE

- The multiparameter sonde must be configured to enable the transmission of data (*e.g.* in a YSI multiparameter sonde the "sample and hold" feature must be active).
- Commonly the way the multiparameter reports the data needs to be adjusted depending on the types of probes that are connected. If the report menu is not set correctly, the wrong data will be transmitted.

TRANSMITTER

- The RF connector must be connected to the antenna before it is powered on. Damage can result to the transmitter if powered on without a load.
- Be sure to load the right program; if not, the transmitter might transmit at the wrong time and channel.

POWER SYSTEM

- The last two things to connect are the battery and the solar panel. Connect the battery first and then apply the solar power connection to the regulator.

COAXIAL CABLE & INSTALLATION

- Coaxial cables are not meant to be kinked.
- Even though, coaxial cable are flexible, they should never have a sharp bend or kink.
  - A kink anywhere in the cable causes a mini reflection to occur, creating a second signal and reducing the effectiveness of transmission.
- A kinked or twisted cable can not be corrected. It is recommended to replace the cable.
- To prevent a kink or a twist from occurring, unroll the wire as if it were coming off a spool. Once laid out straight, without any twist, route the cable to the destination like a snake.
  - Pre-plan the cable path prior to making the installation to prevent any hard turns.
- Excess coaxial cable can be carefully coiled in a series of loops and tied to the back of the enclosure and/or tower with a piece of #14 solid wire. Try not to make the loop too small.
- Cable ties are generally used to secure the cables to the station. The disadvantage of using cable ties is that in the long run the sun will make them brittle and they may break. An alternative method is to use # 14 gauge solid wire. If cable ties is the option, use BLACK cable ties.

FIRST TRANSMISSION

- It is a good practice to contact the technical representative before applying power. They can walk you through all the steps to test the equipment and connections before the first transmission.
- Be sure the battery is fully charged. The battery voltage needs to be above certain level for the transmitter to operate.

  For example, if the installation was completed in the late afternoon, the first transmission may not come until the next day after a morning recharge period.
- Antenna adjustments are commonly made to improve transmission. For example, adjusting the antenna may increase power level of 44 db to 47 db, which is a great improvement. The higher the score, the more robust transmissions will be during inclement weather.
- It is a good practice to have someone at the host site to check the incoming data during the first transmission. If needed, host site personnel can communicate to field personnel to make the necessary corrective actions.

Notes:

- It is a good practice to take several pictures of the station, in particular one of the connections. A laminated copy can be stored in the enclosure.
- Place one or two desiccant packs inside the enclosure.

6.5 REFERENCE

Allen Gale. **An Introduction to Telemetry**. Communication Notes. Department of Electrical and Computer Engineering & Technology at Minnesota State University, Mankato.

Barrett Eric C. and Leonard Frank C.. 1999. **Introduction to Environmental Remote Sensing**. Published by Routledge

Blake, Henke. 2007. **A Final Report Submitted to The NOAA/UNH Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET)**. North Star Science and Technology, LLC.
http://ciceet.unh.edu/news/releases/springReports07/pdf/henke.pdf

Campbell Scientific. **Power Supplies**. Application Notes Code 5-F. Revision 9.
http://www.campbellsci.com/documents/technical-papers/pow-sup.pdf

Campbel Scientific. **UT 10 Weather Station Installation Manual**. Revision 4/98
http://www.campbellsci.com/documents/manuals/ut10.pdf

Carden Frank, Russell P. Jedlicka, Robert Henry. 2002. **Telemetry Systems Engineering**. Published by Artech House.

Energistics .**217-AZIMUTH-CORRECTION**. Geoshare Data Model, Version 13.0
http://w3.posc.org/GeoshareSIG/technical/GDM/v13.0/217-AZIMUTH-CORRECTION.php

L-3 Communications. 2008. **Telemetry Tutorial**. ML1800 Rev. A

Landau, Charles R. 2008. **Optimum Orientation of Solar Panels**. MACS Lab.
http://www.macslab.com/optsolar.html

NASA. **Isolation at Specified Location**. http://aom.giss.nasa.gov/srlocat.html

Photovoltaic Education Network. **Photovoltaics.**
http://pvcdrom.pveducation.org/index.html

Poucher, Jay. 2006. **Sutron Telemetry Installation Notes**. Centralized Data Management Office. NERR. Internal Document. http://cdmo.baruch.sc.edu. To contact Jay Poucher jpoucher@sc.edu

Poucher, Jay. 2006. **Campbell Telemetry Installation Notes**. Centralized Data Management Office. NERR. Internal Document. http://cdmo.baruch.sc.edu. To contact Jay Poucher jpoucher@sc.edu

Precision Measurement Engineering. **Data Transmission**. **http://www.pme.com/**

The Gulf of Mexico Program, U.S. Coastal GOOS and NAML. 2000. **Harmful Algal Blooms Observing System (HABSOS).** Design and Implementation Plan for a Pilot Project for the Coastal Component of the U.S. Integrated Ocean Observing System: Detection and Prediction of Harmful Algal Events in the Northern Gulf of Mexico. Workshop Report. 27 November - 1 December, 2000 Pensacola Beach, Florida http://hpl.umces.edu/projects/HABSOS.pdf

Solar Plots Info. **Definitions**. http://www.solarplots.info/pages/definitions.aspx

Solinst. **STS Telemetry Systems**. Model 9100 Data Sheet.

Solinist. **Telemetry Systems**. **http://www.solinst.com/**

South, Scott. 2005. **Environmental Monitoring: Guide to Selecting Wireless Communication Solutions.** WaterWorld. Pg. 48.

Stein, Matthew. 2008. **When Technology Fails: A Manual for Self-Reliance, Sustainability, and Surviving the Long Emergency**. Chelsea Green Publishing.

U.S. Environmental Protection Agency. 2002. **Delivering Timely Water Quality Information to Your Community**. The Chesapeake Bay and National Aquarium in Baltimore EMPACT Projects. Office of Research and Development. National Risk Management Research Laboratory Cincinnati. EPA625/R-02/018

6.5.1 Photo Reference

Figure 6.2 - National Oceanic and Atmospheric Administration (NOAA) Photo Library Image. Image ID: spac0256, NOAA In Space Collection.

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CHAPTER 7

MAINTENANCE CONSIDERATIONS TO ENSURE DATA QUALITY

7.1 INTRODUCTION

To ensure good quality data during a water quality monitoring project a maintenance program must be in place for the monitoring sondes, platforms and equipment employed. There are three basic types of maintenance procedures (U.S. Department of Energy):

- **Reactive or corrective maintenance** is an unscheduled action performed on a system, equipment or one of its components in the attempt to restore it to a specified performance condition. Basically, the system or product is fixed once it brakes down or fails to perform as desired.
- **Preventive maintenance** is a scheduled action performed on a system, equipment or one of its components to detect or mitigate performance problems, degradations, functional or potential failures, *etc*. with the goal of maintaining the systems' or product's performance and it's level of reliability.
- **Predictive maintenance** is the action performed on a system, equipment or one of its components to determine their performance and act in accordance of the results. For example, instead of changing the oil in the car every X miles (preventive), the oil is analyzed to determine its performance and depending on the results, the oil will be kept or changed. Thus the oil can be changed before the X miles or kept for extra miles. The need for maintenance is determined by the condition of the system, equipment or component analyzed.

Even though, it is most probable that in a water quality monitoring endeavor all three of these types of maintenance procedures are going to be applied, the maintenance program must be focused on preventive and predictive maintenance.

To implement a successful maintenance program, the following three areas must be covered:

a) Training: the personnel that perform maintenance activities (*e.g*. calibration and post calibration of monitoring sensors, equipment and station inspections, cleaning and replacement of instruments or parts) must have the adequate training to ensure that they possess the necessary competence to do an effective and efficient job.

b) Procedures and record management: procedures and record management must be in place to ensure that (among other things):

→ The maintenance activities are well documented.
→ All instruments calibrated will conform to required specifications.
→ The operation and control of the processes are effective.
→ Methodologies to assess the root cause of problem are known.
→ Maintenance schedules are established.
→ Maintenance records are well kept and easily accessed and traceable.
→ Evidence of conformity of calibration is provided.

c) **Procurement and spare parts management**: to ensure the reliability of the monitoring endeavor, each monitoring equipment or system must have an adequate spare parts procedure to guarantee the availability of resources.

There are three main hardware systems that need to be addressed in a water quality monitoring maintenance program:

→ Monitoring sondes
→ Monitoring stations
→ Verification equipment

When addressing the maintenance program of these systems, it is important to consider that:

→ Not all equipment or components have equal importance and equal impact on data quality.

→ The probability of failure or mal-function is different between equipment, parts, and structures.

→ Service or maintenance cycles differ between equipment.

→ There is limited financial and personnel resources.

NOTE: To assure data quality, a quality assurance/control & maintenance program for the monitoring data must be in place. To obtain guidelines on how to approach this issue, the reader should consult EPA QA/G-5, EPA QA/G-8 and Helsel and Hirsch (2002).

7.2 SONDE MAINTENANCE

Data quality is directly related to the monitoring sonde performance. Therefore, it is crucial to have a sonde maintenance program.

In general, the maintenance program would be based on "maintenance cycles" correlated to the time frame the sondes can stay deployed without affecting data quality. The cycle will depend on the probes' characteristics, environmental conditions (*i.e.* high fouling environments), battery life, and any other factors that affect the sonde's performance. In most monitoring situations the maintenance cycles follow a seasonal pattern. For example, in high fouling environments, the length of time the sonde can remain deployed will decrease as water temperature increases; monitoring sondes that can be deployed for three weeks to one month in winter may need to be changed on a weekly basis in summer.

The sonde maintenance program must address at least the following procedures:

- ➔ Prepare the sonde for deployment
- ➔ Calibration for deployment
- ➔ Post-deployment performance verification

7.2.1 PREPARE THE SONDE FOR DEPLOYMENT

The sonde must be adequately prepared to handle the environmental factors that could influence data quality. These physical, biological, and chemical factors are characteristic of the monitoring site location. Therefore, no unique solution exists to address these factors and the best approach to control them will have to take into account, not only the site characteristics, but also, the deployment cycle and the design of the monitoring station.

Among the environmental factors, special attention must be given to biofouling given that is one of the main factors affecting the operation, maintenance and data quality of the sondes (some examples of common and extreme biofouling are displayed in Figure 7.1). Among the many methods employed to reduce or prevent biofouling, the most common ones are:

- Painting the housing of the sensors with anti-fouling coatings.
- Covering the housing of the sensors with anti-fouling copper tape.
- Using the adequate anti-fouling probes' wiper/wipers.
- Painting the entire wiper body, including the undersides with anti-fouling paint.
- Using sensors with copper alloy housings.
- Using copper-alloy sonde guard or painting the sensor guard with anti-fouling coatings (do not paint the threads).

Figure 7.1 Copper tape on guard and probes

NOTE:

→ Black anti-fouling paint is strongly recommended. The black color will eliminate any chance of stray reflection from the infrared light source when the probe is making measurements (YSI, 2009).

→ Painting the body of the instrument is not recommended. Instead of using paint, the body can be wrapped with plastic wrap and secure with duck tape or with plastic electrical tape.

→ In addition to the use of anti-fouling paint or copper product, during long-term deployments in extreme fouling environments, the deployment cycle must be adjusted to the appropriate length to ensure data integrity.

Figure 7.2 Biofouling examples (Source: CBNERRVA, NIW - NERR, CICORE)

7.2.2 CALIBRATION FOR DEPLOYMENT

It is crucial that all sensors are calibrated following strictly the manufacturer's calibration procedures. Therefore, management must assure that:

- Laboratory personnel have the necessary competence for the effective and efficient application of the calibration procedures.
- Systems are in place to assure sensor's performance verification.
- Records are kept to provide evidence that the requirements have being met.

  Two examples of calibration logs are presented in Figure 7.3 and 7.4.
- Critical parts, components and chemicals are in stock to ensure proper maintenance activities.

NOTE:

→ Many multiparameter sondes are equipped with depth sensors that measure water depth using a differential strain gauge transducer with one side of the transducer exposed to water and the other to a vacuum. The transducer measures the pressure of the water column plus the atmospheric pressure (YSI, 2008). During calibration, the depth is calibrated in air and a depth offset must be used if the pressure is different than 760 mm Hg.

To determine the correct depth offset, record the barometric pressure at the time of calibration from a meteorological station at the calibration site or a reliable local station. Tables 7.1 to 7.3 show offset correction as a function of atmospheric pressure. These tables can be use to determine the offset to use during calibration (CDMO, 2207).

→ When using a plastic or copper screen (or copper tape) at the bottom of the sensor guard there is a possibility that interference with turbidity readings could result from the screen. To cancel any affects it might have, it is necessary to calibrate the turbidity probe (1 point) in the zero standard with the deployment sensor guard installed.

(Source: NIW Bay NERR)

The amount of offset is generally determined by the reflectivity of the guard and screen. In case of using plastic screens, it is a good practice to use black screens or paint the screen with black antifouling paint. For copper screens, once the copper has taken on the patina color the amount of offset decreases. Another option would be to soak the parts in salt water to patina them before your calibration

If copper tape is used and replaced every deployment, then new offset must be determined every time the guard is re-taped.

Pressure mm Hg	Offset meter	Pressure mm Hg	Offset meter	Pressure mm Hg	Offset meter
680	-1.088	730	-0.408	780	0.272
681	-1.074	731	-0.394	781	0.285
682	-1.060	732	-0.381	782	0.299
683	-1.047	733	-0.367	783	0.313
684	-1.033	734	-0.353	784	0.326
685	-1.020	735	-0.340	785	0.340
686	-1.006	736	-0.326	786	0.353
687	-0.992	737	-0.313	787	0.367
688	-0.979	738	-0.299	788	0.381
689	-0.965	739	-0.285	789	0.394
690	-0.952	740	-0.272	790	0.408
691	-0.938	741	-0.258	791	0.421
692	-0.924	742	-0.245	792	0.435
693	-0.911	743	-0.231	793	0.449
694	-0.897	744	-0.218	794	0.462
695	-0.884	745	-0.204	795	0.476
696	-0.870	746	-0.190	796	0.489
697	-0.856	747	-0.177	797	0.503
698	-0.843	748	-0.163	798	0.517
699	-0.829	749	-0.150	799	0.530
700	-0.816	750	-0.136	800	0.544
701	-0.802	751	-0.122	801	0.557
702	-0.789	752	-0.109	802	0.571
703	-0.775	753	-0.095	803	0.585
704	-0.761	754	-0.082	804	0.598
705	-0.748	755	-0.068	805	0.612
706	-0.734	756	-0.054	806	0.625
707	-0.721	757	-0.041	807	0.639
708	-0.707	758	-0.027	808	0.653
709	-0.693	759	-0.014	809	0.666
710	-0.680	760	0.000	810	0.680
711	-0.666	761	0.014	811	0.693
712	-0.653	762	0.027	812	0.707
713	-0.639	763	0.041	813	0.721
714	-0.625	764	0.054	814	0.734
715	-0.612	765	0.068	815	0.748
716	-0.598	766	0.082	816	0.761
717	-0.585	767	0.095	817	0.775
718	-0.571	768	0.109	818	0.789
719	-0.557	769	0.122	819	0.802
720	-0.544	770	0.136	820	0.816
721	-0.530	771	0.150	821	0.829
722	-0.517	772	0.163	822	0.843
723	-0.503	773	0.177	823	0.856
724	-0.489	774	0.190	824	0.870
725	-0.476	775	0.204	825	0.884
726	-0.462	776	0.218	826	0.897
727	-0.449	777	0.231	827	0.911
728	-0.435	778	0.245	828	0.924
729	-0.421	779	0.258	829	0.938

Table 7.1 Depth Offset (mm Hg) (Source: CDMO, 2207)

Pressure mb	Offset meter	Pressure mb	Offset meter	Pressure mb	Offset meter
930	-0.849	980	-0.340	1030	0.170
931	-0.839	981	-0.329	1031	0.180
932	-0.829	982	-0.319	1032	0.191
933	-0.819	983	-0.309	1033	0.201
934	-0.809	984	-0.299	1034	0.211
935	-0.798	985	-0.289	1035	0.221
936	-0.788	986	-0.278	1036	0.231
937	-0.778	987	-0.268	1037	0.242
938	-0.768	988	-0.258	1038	0.252
939	-0.758	989	-0.248	1039	0.262
940	-0.747	990	-0.238	1040	0.272
941	-0.737	991	-0.227	1041	0.282
942	-0.727	992	-0.217	1042	0.293
943	-0.717	993	-0.207	1043	0.303
944	-0.707	994	-0.197	1044	0.313
945	-0.696	995	-0.187	1045	0.323
946	-0.686	996	-0.176	1046	0.333
947	-0.676	997	-0.166	1047	0.344
948	-0.666	998	-0.156	1048	0.354
949	-0.656	999	-0.146	1049	0.364
950	-0.645	1000	-0.136	1050	0.374
951	-0.635	1001	-0.125	1051	0.384
952	-0.625	1002	-0.115	1052	0.395
953	-0.615	1003	-0.105	1053	0.405
954	-0.605	1004	-0.095	1054	0.415
955	-0.594	1005	-0.085	1055	0.425
956	-0.584	1006	-0.074	1056	0.435
957	-0.574	1007	-0.064	1057	0.446
958	-0.564	1008	-0.054	1058	0.456
959	-0.554	1009	-0.044	1059	0.466
960	-0.544	1010	-0.034	1060	0.476
961	-0.533	1011	-0.023	1061	0.486
962	-0.523	1012	-0.013	1062	0.497
963	-0.513	1013	-0.003	1063	0.507
964	-0.503	1014	0.007	1064	0.517
965	-0.493	1015	0.017	1065	0.527
966	-0.482	1016	0.028	1066	0.537
967	-0.472	1017	0.038	1067	0.548
968	-0.462	1018	0.048	1068	0.558
969	-0.452	1019	0.058	1069	0.568
970	-0.442	1020	0.068	1070	0.578
971	-0.431	1021	0.079	1071	0.588
972	-0.421	1022	0.089	1072	0.599
973	-0.411	1023	0.099	1073	0.609
974	-0.401	1024	0.109	1074	0.619
975	-0.391	1025	0.119	1075	0.629
976	-0.380	1026	0.130	1076	0.639
977	-0.370	1027	0.140	1077	0.650
978	-0.360	1028	0.150	1078	0.660
979	-0.350	1029	0.160	1079	0.670

Table 7.2 Depth Offset (mb) (Source: CDMO, 2207)

Pressure in Hg	Offset meter	Pressure in Hg	Offset meter	Pressure in Hg	Offset meter
27.40	-0.870	28.90	-0.352	30.40	0.166
27.43	-0.860	28.93	-0.342	30.43	0.176
27.46	-0.849	28.96	-0.332	30.46	0.186
27.49	-0.839	28.99	-0.321	30.49	0.197
27.52	-0.829	29.02	-0.311	30.52	0.207
27.55	-0.818	29.05	-0.300	30.55	0.218
27.58	-0.808	29.08	-0.290	30.58	0.228
27.61	-0.798	29.11	-0.280	30.61	0.238
27.64	-0.787	29.14	-0.269	30.64	0.249
27.67	-0.777	29.17	-0.259	30.67	0.259
27.70	-0.767	29.20	-0.249	30.70	0.269
27.73	-0.756	29.23	-0.238	30.73	0.280
27.76	-0.746	29.26	-0.228	30.76	0.290
27.79	-0.736	29.29	-0.218	30.79	0.300
27.82	-0.725	29.32	-0.207	30.82	0.311
27.85	-0.715	29.35	-0.197	30.85	0.321
27.88	-0.704	29.38	-0.186	30.88	0.332
27.91	-0.694	29.41	-0.176	30.91	0.342
27.94	-0.684	29.44	-0.166	30.94	0.352
27.97	-0.673	29.47	-0.155	30.97	0.363
28.00	-0.663	29.50	-0.145	31.00	0.373
28.03	-0.653	29.53	-0.135	31.03	0.383
28.06	-0.642	29.56	-0.124	31.06	0.394
28.09	-0.632	29.59	-0.114	31.09	0.404
28.12	-0.622	29.62	-0.104	31.12	0.414
28.15	-0.611	29.65	-0.093	31.15	0.425
28.18	-0.601	29.68	-0.083	31.18	0.435
28.21	-0.591	29.71	-0.073	31.21	0.445
28.24	-0.580	29.74	-0.062	31.24	0.456
28.27	-0.570	29.77	-0.052	31.27	0.466
28.30	-0.559	29.80	-0.041	31.30	0.477
28.33	-0.549	29.83	-0.031	31.33	0.487
28.36	-0.539	29.86	-0.021	31.36	0.497
28.39	-0.528	29.89	-0.010	31.39	0.508
28.42	-0.518	29.92	0.000	31.42	0.518
28.45	-0.508	29.95	0.010	31.45	0.528
28.48	-0.497	29.98	0.021	31.48	0.539
28.51	-0.487	30.01	0.031	31.51	0.549
28.54	-0.477	30.04	0.041	31.54	0.559
28.57	-0.466	30.07	0.052	31.57	0.570
28.60	-0.456	30.10	0.062	31.60	0.580
28.63	-0.445	30.13	0.073	31.63	0.591
28.66	-0.435	30.16	0.083	31.66	0.601
28.69	-0.425	30.19	0.093	31.69	0.611
28.72	-0.414	30.22	0.104	31.72	0.622
28.75	-0.404	30.25	0.114	31.75	0.632
28.78	-0.394	30.28	0.124	31.78	0.642
28.81	-0.383	30.31	0.135	31.81	0.653
28.84	-0.373	30.34	0.145	31.84	0.663
28.87	-0.363	30.37	0.155	31.87	0.673

Table 7.3 Depth Offset (in Hg) (Source: CDMO, 2207)

NATIONAL ESTUARINE RESEARCH RESERVE SYSTEM

NERRS SWMP Water Quality Calibration Log

Reserve: _____ **Site Name:** _____ **File Name:** _____

Datasonde Maintenance

Date of Calibration: _____ mm/dd/yyyy **Technician(s):** _____

	TURB	ODO		TURB	ODO
Wipers replaced			Wipers park 180° from optics		
Batteries replaced			DO membrane replaced		
Format flash disk			Membrane integrity test		

Datasonde and Probe Identification Numbers

Datasonde		DO/ODO	
pH		Conductivity	
Turbidity			

Comments _____

Pre/Post Deployment Calibration: (turn on pH mV and DO Chrg in Report menu)

Pre-Deployment					Post-Deployment		Sensor Diagnostics	
Standards		**Before Cal**	**Calibrated**	**Error**			**Pre-Deployment**	
%DO @ 100% sat		%	%		%	%	RP DO chrg (range 25-75)	
BP @ cal (Rapid Pulse)		mm Hg			mm Hg		RP DO gain (0.8-1.7)	
Optical %DO @ 100% sat		%	%			%	Optical DO gain	
BP @ cal (Optical)		mm Hg			mm Hg		DO warm up test (hi/lo)	
Baro. Pres. (Depth Calib)	760.0	mm Hg	(760.0 for vented sonde)		760.0 mm Hg	(760.0 for vented)	Cell const (4.6-5.45)	
Depth	offset	m	m		m	offset	pH 7 (0 +/- 50 mV)	
							pH 10 (-180 +/- 50 mV)	
SpCond	mS/cm	mS/cm	mS/cm		mS/cm		pH 4 (+180 +/- 50 mV)	
							Calculated pH slope	
pH 7								
pH 10							**Post-Deployment**	
pH 4							DO chrg (range 25-75)	
							DO warm up test (hi/lo)	
Turb	NTU	NTU	NTU		NTU		pH 7 (0 +/- 50 mV)	
Turb	NTU	NTU	NTU		NTU		pH 10 (-180 +/- 50 mV)	
							pH 4 (+180 +/- 50 mV)	
Battery voltage		V (remove ext. power -650, 6038)			V (remove ext. power)		Calculated pH slope	

Programming

Interval	min	Start date	mm/dd/yyyy	Start time (std.time)	hh:mm:ss
Duration	days	Data file name		Battery life	days
Free memory	days	Set clock (status)	Y or N	Free bytes (status)	K

Parameters recorded: Date, Time, Temp°C, SpCon, Sal, DO%, DO mg/L, Depth, pH, Turb, Batt

Comments - Pre: _____

Comments - Post: _____

Figure 7.3 NERRS 6-series calibration log

HYDROLAB MULTIPROBE CALIBRATION/MAINTENANCE LOG

Calibration ____ Post Calibration ____ Initials:

Date: Time: Instrument: Battery Voltage:

If this is a post calibration, give date of original calibration _____

Function	Temp. of Standard	Value of Standard	Initial Reading	Calibrated to	Comments
Specific conductance					
pH calibrated (~7)					
pH slope (~ 4/10)					
Dissolved oxygen					

DATA NEEDED FOR DISSOLVED OXYGEN CALIBRATION

Altitude (A)=_____feet above msl	Barometric pressure _____ inches
Barometric Pressure (BP) Options	**Barometric Pressure Formulas**
Barometer	Barometric pressure (inches) _____ x 25.4 = BP _____mm
From local source after correction (CBP)	BP _____ mm = CBP _____mm - 2.5 (altitude ____/100)
Estimated from altitude only	BP _____ mm= 760 mm - 2.5 (altitude _____/100)

For older Hydrolabs: Table DO value_____ x ALTCORR_____ x BAROCORR _____= DO standard _____

Calibration ____ Post Calibration ____ Initials:

Date: Time: Instrument: Battery Voltage:

If this is a post calibration, give date of original calibration _____

Function	Temp. of Standard	Value of Standard	Initial Reading	Calibrated to	Comments
Specific conductance					
pH calibrated (~7)					
pH slope (~ 4/10)					
Dissolved oxygen					

DATA NEEDED FOR DISSOLVED OXYGEN POST CALIBRATION

Barometric Pressure (BP) Options	**Barometric Pressure Formulas**
Barometer	Barometric pressure (inches) _____ x 25.4 = BP _____mm
From local source after correction (CBP)	BP _____ mm = CBP _____mm - 2.5 (altitude ____/100)
Estimated from altitude only	BP _____ mm= 760 mm - 2.5 (altitude _____/100)

For older Hydrolabs: Table DO value_____ x ALTCORR_____ x BAROCORR _____= DO standard _____

Check previous maintenance and use; do the following before calibration:

Polish conductivity electrodes. Must be polished within the last two months or once every 15 field trips	Date:	Name/comments:
Change pH reference probe solution. Must be renewed within last two months or once every 15 field trips.	Date:	Name/comments:
Inspect DO membrane for nicks or bubbles. Must be changed within last six months or once every 15 field trips.	Date:	Name/comments:
Change battery in 400 series sonde. Change once a year. Change internal batteries for newer generation products according to guidelines in product manual.	Date:	Name/comments:

Figure 7.4 Multiprobe calibration log (Source: Texas Commission on Environmental Quality, 2003)

7.2.3 POST-DEPLOYMENT PERFORMANCE VERIFICATION

Sonde post-deployment performance verification should include: post-calibration or field performance assessment and field verification activities.

Post-calibration: activity done in a controlled laboratory environment after retrieval of the monitoring sensor. The sensor readings are compared to standard solutions to determine its performance. On-site post-calibration can be performed following the same procedures as laboratory calibrations.

Field performance assessment: activity conducted in the field. As soon as the sensor is retrieved it is placed in a standard solution and readings are recorded.

Field verification: indirect measurements of sonde performance. Using field-measuring equipment, water quality measurements are taken and compared to sonde readings.

Probe performance records are used for continual improvement, data analysis and nonconformity management. As an example, a post-calibration log is presented in Figure 7.5.

DEPLOYMENT INFORMATION

	DATE	TIME	WEATHER	TIDE	WIND SPEED	HUMIDITY
DEPLOYMENT:						
RETRIEVAL:						

VERIFICATION INFORMATION

	DO mg/l	Water Temp	Air Temp	Secchi Depth	Salinity	pH
DEPLOYMENT:						
RETRIEVAL:						

POST DEPLOYMENT DATA RETRIEVAL

DATE OF DOWNLOAD: _____ NAME OF *.dat FILE: _____

TIME YSI STOP LOGGING: _____ NAME OF *.txt FILE: _____

POST DEPLOYMENT CALIBRATION

DATE OF POST CALIBRATION: _____

Battery Volts: _____

Time Corrected: Y N

Faster Slower Difference in seconds: _____

Notes pH:

Spcond			
pH 7		pH mV:	mV range (-50 <-> 50) Optimum 0
pH 10		pH mV:	mV range (-230 <-> -140) Optimum -180
pH 4		pH mV:	mV range (130 <-> 230) Optimum 180

TURBIDITY 0 _____ 123 _____

CHLOROPHYLL 0 _____ Rd WT _____

FLUORESCENCE 0 _____

Temp C sonde is reading in Rd WT: _____ Corrected reading from Rd WT Table: _____

Notes :

DEPTH

Barometric Pressure: _____ mm Hg _____ millibars

Depth Offset at date's pressure: _____

Notes :

Depth Reading: _____

% DO

Theoretical %DO based on date's pressure: _____ DO % Reading: _____ DO Membrane Puncture: Y N

Notes :

CALIBRATION CONSTANTS Conductivity: _____ (Range: 4.6 to 5.45) DO Gain: _____ (Range: 0.8 to 1.7) DO Charge: _____ (Range: 25 to 75)

FOULING CONDITIONS

Possible Fouling Description: Slime, Mud/Sediment (slimy, sticky, rusty, thick), Worm tubes, Seaweed, Grasses, Algae, Amphipods, amphipod tubes, Barnicles, Mussels, Branching Bryozoan, Encrusting Bryozoan, Coral Lattice, Tunicates, etc.

		TURBIDITY	CHLOROPHYLL	ODO
Wipers Condition:	Parked	Y N	Y N	Y N
	Fouled	Y N	Y N	Y N

Animals of Physical Fouling Found in Guard: _____

SONDE BODY:

THERMISTOR:

OPTICAL PROBE FACES:

CONDUCTIVITY CHAMBERS:

pH BULB:

DEPTH CHANNEL:

Figure 7.5 YSI 6-series post-calibration log

During field verification, it is a good practice to take an independent measurement for each sensor parameter. Generally, field verification is performed during the monitoring sonde exchange phase. A possible sonde switch-out process could be:

1 Set the replacement sonde in the water to allow the probes to equilibrate to ambient conditions.

- The replacement sonde is deployed in a temporary position at the same depth as the deployed sonde to:
  - Allow the sonde a few minutes to equilibrate to the water temperature before taking the readings.
  - Obtain simultaneous readings with the deployed sonde.
- It is good practice to place a snap hook in the station to hang the replacement sonde. The rope to hang the replacement sonde will have the necessary length to ensure the sonde is placed at the monitoring depth.

2 Perform the field verification activities

- Field verification activities are performed following established measuring procedures.
- A field verification log must be filled. (*e.g.* Figure 7.6)

3 The monitoring sondes are exchanged

- It is good practice to obtain at least two simultaneous readings between the deployed sonde and the replacement sonde before the switch-out.
  - This ensures that there will be two common water quality measurements that can be used for data quality control and assurance purposes.
- Perform a visual inspection of the retrieved sonde and record anything that it is considered important for post-calibration or data quality purposes (*e.g.* fouling conditions, animals in the sonde guard, broken probes, physical fouling).
  - In highly fouling conditions or broken probes, it is good practice to take pictures of the deployed sonde for future addition to the MetaData or assist the scientist in understanding the data.

For on stream & river bank platforms, a different method to obtain simultaneous readings between the replacement sonde and deployed sonde must be used if the station has only one guard-pipe. Possible reasons for using only one guard-pipe are:

- → The guard-pipe is placed where there is a small pooling of water or the sampling area is not big enough to accommodate two sondes.
- → Due to high flow conditions, cost or maintenance issues it was decided to put only one guard-pipe.

If only one guard-pipe is used, a possible switch-out process could be:

1. Set the replacement sonde in the water to allow the probes to equilibrate to ambient conditions.

   - Allow the sonde a few minutes to equilibrate to the water temperature.

2. Obtain at two simultaneous readings between the deployed sonde and the replacement sonde

   - Collect stream or river water in a bucket or cooler.
   - Place the bucket in a secure area and place the replacement sonde inside the bucket.
   - Carefully remove the deployed sonde from the guard-pipe and place it inside the bucket.
     - Perform a visual inspection of the retrieved sonde and record anything that it is considered important for post-calibration or data quality purposes (*e.g.* fouling conditions, animals in the sonde guard, broken probes, physical fouling) in case the fouling is detached or changed while the sonde is in the bucket.
   - Let the sondes stand in the bucket until two simultaneous readings are obtained.
     - Even though certain water parameters (*e.g.* temperature) will change inside the bucket while waiting for the readings; the goal here is that the two sondes have two common water quality measurements that can be used for data quality control and assurance purposes.

For monitoring stations with telemetry capabilities, the following procedure is recommended to interchange the field cable connector between the deployed and the replacement sonde.

1. Remove the deployed sonde from the guard-pipe and put it in a horizontal position close to the replacement sonde

2. Clean and dry the field cable connector of the deployed sonde
   - If necessary, use a was bottle to rinse the dirt from the field cable connector and sonde connector.
   - Dry the field cable connector and the sonde connector with a towel, paper towel or kimwipe.

3. Remove the field cable connector from the deployed sonde and clean the inside of the connector
   - Use the cotton tipped sticks or kimwipes to clean and dry the inside of the field cable connector and the outside of the sonde connector.
   - Check that the pins, either in the field cable connector or in the sonde connector, are dry. If not, use the compress gas duster to dry them.

4. Connect the field cable to the replacement sonde
   - Remove the waterproof cap from the replacement sonde and connect the field cable connector.
     - A built-in key will ensure proper pin alignment. Rotate the cable gently until the key engages and then tighten the connector together by rotating clockwise.
   - Attach the strain relief connector to the sonde bail.
   - Put the waterproof cap to the sonde that is going to be serviced.

	WATER QUALITY MONITORING DEPLOYMENT AND RETRIEVAL LOG			
	Identification Number	Revision	Effective Date	Pages
				Page 1 of 1

Field Location		Crew	

DATALOGGER INFORMATION		
	YSI ID Number	Time (EST)
Deployment (in)		
Retrieval (out)		

WEATHER INFORMATION						
Weather Conditions measured with Kestrel		**Wind Speed**			**Cloud Cover**	
Current Wind Speed (m/s)		0	0-1 (knots)	0-1 (m/s)	0	Clear (0-10%)
		1	>1 - 10	1-5	1	Scatter/partly Cloudy (10-50%)
Air Temp (C)		2	>10 - 20	5-10	2	Partly to Broken (50-90%)
		3	>20 - 30	10-15	3	Overcast (>90%)
Relative Humidity (%)		4	>30 - 40	15-21	4	Foggy
		5	> 40	21-26	5	Hazy
					6	Cloud (no percentages)

Precipitation Type		**Wind Direction**			
10	None	E	fr East (90 deg)	S	fr South (180 deg)
11	Drizzle	ENE	fr East NE (67.5 deg)	SE	fr SE (135 deg)
12	Light Rain	ESE	fr East SE (112.5 deg)	SSE	fr South SE (157.5 deg)
13	Heavy Rain	N	fr North (0 deg)	SSW	fr South SW (202.5 deg)
14	Squally	NE	fr NE (45 deg)	SW	fr SW (225 deg)
15	Frozen Precipitation	NNE	fr North NE (22.5 deg)	W	fr West (270 deg)
16	Mixed Rain&Snow	NNW	fr North NW (337.5 deg)	WNW	fr West NW (292.5 deg)
		NW	fr NW (315 deg)	WSW	fr West SW (247.5 deg)

WATER INFORMATION						
Water and Secchi Depths		**Wave Heights**		**Tidal Stage**		**VERIFICATION SAMPLES**
Water Depth (m)		0	0 <0.1m	E	Ebb Tide	Chla Filter Volume
		1	0.1 <0.3m	F	Flood Tide	
Secchi Depth (m)		2	0.3 <0.6m	H	High Tide	
		3	0.6 <1.0m	L	Low Tide	
If Secchi can be seen at the bottom	SD > WD	4	1.0 <1.3m			
		5	>1.3m			

WATER COLUMN DEPTH PROFILE						
Depth m	Temperature	SpCond	Salinity	DO(%Sat)	DO(mg/l)	pH
0.10						
0.25						
0.50						
0.75						
1.00						
1.25						
1.50						
1.75						
2.00						
2.25						
2.50						

Comments:

Figure 7.6 Field verification log

Note:

Two conditions that must be met when transporting multiparameter sondes to and from the monitoring sites are:

- The sondes must be transported in a saturated environment.
- The sondes must be transported in a container that minimizes shocks and vibrations.

Two commonly employed methods are:

→ The sonde is transported wrapped up within a wet towel (CDMO, 2007).

- Soak a towel (large enough to wrap around the entire sonde) in tap water and wring out most of the water (check that it is wet; humid, not damp).
- Wrap the sonde in the towel, leaving some excess towel at the bottom of the sensor guard so it can be folded to ensure the guard is completely covered.
- Place the towel-wrapped sonde in a bucket, a cooler or other container for transportation to the monitoring site.
- It is good practice to transport the sondes in a container of sufficient size to allow the sondes to lie horizontally across the bottom.

→ The sonde is transported in a 5-gallon bucket filled with tap water.

- Drill one or two holes on the lid about 3½ - 4 inches in diameter.
- Place some type of cushion on the bottom of the bucket to minimize shocks and vibrations.
- If necessary, place some kind of weight on the bottom to prevent the bucket to tip over during transit due to the sonde's weight.
- Fill the bucket with tap water so that the probes stay submerged.
- Some kind of structure can be built to accommodate several buckets in a stable position during transit (in this case there is no need to place a weight inside the bucket).

7.3 STATION MAINTENANCE

The following activities must be included in the station maintenance program:

- Verification of station conditions during deployment-retrieval of monitoring sensors.
- Schedule on-site verification and cleaning of guard-pipes.
- Schedule retrieval of guard-pipes for cleaning and painting (once a year minimum).
- Schedule cleaning and rebuilding of monitoring platforms.
- Maintenance procedures and spare parts management.

IT IS A GOOD PRACTICE TO CLEAN THE INSIDE AND OUTSIDE OF THE GUARD-PIPE AFTER THE DEPLOYED SONDE IS RETRIEVED AND BEFORE THE NEWLY CALIBRATED SONDE IS DEPLOYED.

Figure 7.7 Cleaning inside the guard-pipe

The guard pipe must be cleaned on a frequent basis to minimize the influence of biological fouling and to eliminate any physical fouling that could be interfering with the measurements.

The best way to clean the inside of the guard-pipe is by using some kind of brush or mop. The brush can be purchased in any retail store or easily assembled. For example, a cleaning brush can be constructed using a 16 foot extension pole (Figure 7.7 and 7.8). To add extra cleaning power two scrub brushes can be bolted to the extension pole. Care must be taken when brushing the guard-pipe to minimize brushing off the anti-fouling paint. If cleaning is performed on a regular basis, minimum fouling will occur on the guard-pipe, therefore, a medium-soft brush will be enough to maintain the guard-pipe in good condition.

Figure 7.8 Guard-pipe cleaning brushes

To clean the outside of the guard-pipe, also a particular brush can be purchased in any retail store or easily assembled. For example, Figure 7.8 displays a brush to clean the outside of the guard-pipe constructed by bolting two scrub brushes to a 8 inch long – half 6 inch PVC pipe.

In some situation a chimney sweep brush is a good option. Even though the brush is tough on the anti-fouling paint, many pipes stay in year after year and in these cases the anti-fouling paint is not an issue and a chimney brush works well to clear the pipe of hard and soft biological fouling.

In certain types of guard-pipe installations (*e.g.* on river or stream bank) it is a good practice after brushing the pipe to rinse it by pouring a bucket of surface water down the pipe.

NOTE: Any evidence of physical and biological fouling that could have affected the monitoring data must be recorded for further analysis.

7.4 TELEMETRY EQUIPMENT MAINTENANCE

Proper maintenance of the Telemetry equipment is essential to obtain accurate data. Equipment must be in good operating conditions, routine and schedule maintenance and inspection must be peformed..

must include at least the following activities

to ensure that your telemetry equipment is mounted far enough above sea level to be clear of wave action and storm surges due to hurricanes. Take out equipment
(EPA 2002)

Battery: Campbell Scientific

Cyclic service life of rechargeable batteries

The industry definition of the “cyclic service life” of a battery is the period until it dorps to 60% of its rated capacity. For a 7 Ahr battery, this is when after repeated recharging, the battery can only deliver 4.2 Ahrs. When choosing a battery, you should also consider the number of recharge cycles you can expect from the battery until it reaches the end of tis cyclic life.

Several factors affect the cyclic service life, including ambient temp during charging and storage, number of discharge cycles, depth of discharge cycles and charging voltage. Clearly these are complex relationships.

The following may help you assess your batteries’ service life:

1) temperature: warmer temperatures decrease life because heat hastens chemicals reaction that cause corrosion of the internal electroedes. The temperature effects are graphed and described on the following page.

Depth of discharge

Determine minimum and maximum battery voltages in your daily data. Analyze the data using tool to count the number of times the voltage dropped below certain values.

Check for more info http://www.mpoweruk.com/life.htm

7.5 MEASURE THE DISTANCE FROM THE SONDE's HOLDING BOLTS TO THE BOTTOM SEDIMENTS

Water depth is one of the parameters measured by a monitoring sonde. A differential strain gauge transducer is generally employed to measure the pressure of the water column plus the atmospheric pressure above the water. To have an accurate water depth measurement, a program must be utilized to eliminate the errors produced by atmospheric pressure variations.

Water depth is the distance from the water surface to bottom sediments. The sonde measures water depth as the distance from the transducer to water surface; therefore to have an accurate water depth, the distance from the transducer to the bottom sediments must be added.

In a fixed structure monitoring platforms, the distance from the transducer to bottom sediments can be divided into two segments: the distance between the transducer and the bolts (where the monitoring sonde sits inside the guard-pipe) and the distance between the bolts and the bottoms sediments. The distance from the transducer to the bolts is fixed and known. The distance between the bolts and the bottom may vary; given the bottom can change over time.

In addition, verification measurements must be taken around the guard-pipe to check if physical fouling or different bottoms movements occurred under the guard-pipe that would cause an inaccurate water depth measurement.

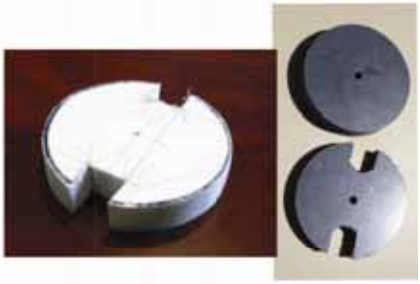
There are some environments that are more conducive to have bottom movements (*i.e.* deposition of sediments) than others; therefore the distance between the transducer to the bottom must be measured frequently.

To determine the distance between the bolts and the bottom, a special tool is utilized (made with an aluminum telescoping extension pole and a disk with two opposite openings). Three measurements are taken, one inside the pipe and two outside the pipe. These three measurements are utilized to calculate the distance between the bolts and the bottom.

The procedure to determine the distance between the bolts and the bottom is shown in the following page.

1 Build the measuring pole

- Cut a 3-3/4 inch diameter disk.
  - Materials: fiber glass, plastic, wood or any other convenient material.
  - The circular piece is made for a 4 inch PVC pipe; adjust diameter for other types of pipes.



- Cut two openings at opposite sides of the disk.
  - Make the openings big enough so the disk goes through the bolts easily.
- Secure the disk to a telescopic pole.
  - The disk can be attached to the telescopic pole permanently or by a coupling so it can be easily removed.
  - Telescopic poles come in a variety of length, with 24 ft the longest length that can be easily purchased in any home improvement retailer. If longer poles are needed, a good option is to create your own extension to be attached at the end of the pole.

2 Measure distance "bolts-bottom" inside the guard-pipe

- Lower the pole inside the guard-pipe until the disk hits the bolts.
- Set a ruler on top of the guard-pipe and mark the point where the ruler touches the pole with a rubber band.
  - This point is called **TOP-BOLTS distance (TB)**
- Rotate the pole so the openings match the bolts and the disk goes through the bolts.
- Lower the pole until the round piece hits the bottom.
- Mark this point with a second rubber band.
  - This point is called **TOP-BOTTOM INSIDE distance (TB Inside)**
- Remove the pole from the guard-pipe.

3 Measure distance "top-bottom" around the guard-pipe

- Cut two small pieces of duck tape and draw a line on them with a permanent marker. Mark one of these lines as "1" and the other as "2".
- Set the ruler on top of the guard-pipe to be used as a reference mark.

Select one random point at a distance of approx. 20 cm from the guard-pipe and lower the pole until the disk hits the bottom.

Move the pole around that point to verify that the depth remains constant and the pole is not sitting on top of a physical object (*e.g.* stone). If this is the case, choose another random point.

If the depth is different than the top-bottom inside distance, mark this point with the duck tape "1".

This point is called
TOP-BOTTOM OUTSIDE 1 distance (TB Outside 1)

Repeat this process - select a second point.

If the depth is different than the top-bottom inside distance, or TB Outside-1; mark this point with the duck tape "2".

This point is called
TOP-BOTTOM OUTSIDE 2 distance (TB Outside 2)

4 Calculate Bolts-Bottom Distance

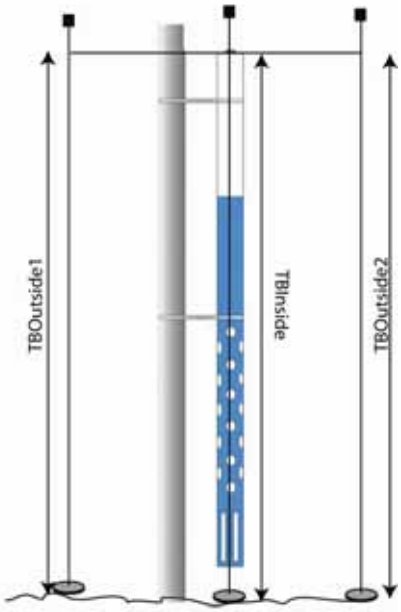
Two things that must be taken into account :

- Changes of the bottom topography under the guard pipe due to currents.
- Physical fouling under the guard-pipe.

Following, four different scenarios are presented.

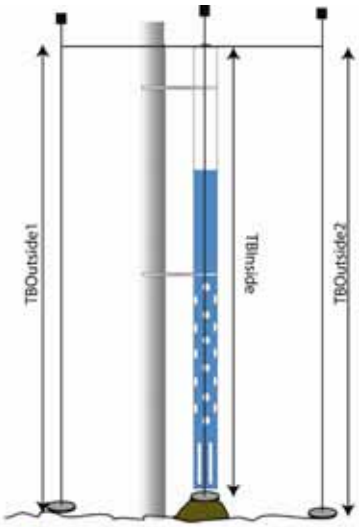
The three distances are similar
TB Inside ≅ TB Outside 1 ≅ TB Outside 2

The bottom under and around the guard-pipe is uniformly distributed in a horizontal plane. There are no physical objects below the guard pipe.



Bolts-Bottom Distance = 1/3 ([TB Inside + TB Outside 1 + TB Outside 2] - 3 TB)

TB Inside < TB Outside 1 or 2



The distance TB Inside is much smaller than the two TB Outside distances.

Possible physical fouling or sediment build up occurred under the guard-pipe.

→ Try to remove the physical fouling or built up sediment

- Removal is successful

  Bolts-Bottom Distance =

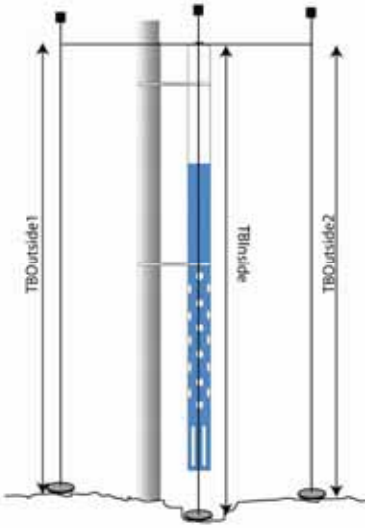
  1/3 ([TB Inside + TB Outside 1 + TB Outside 2] - 3 TB)

- Removal is not successful

  Bolts-Bottom Distance =

  1/2 ([TB Outside 1 + TB Outside 2] - 2 TB)

TB Inside > TB Outside 1 or 2

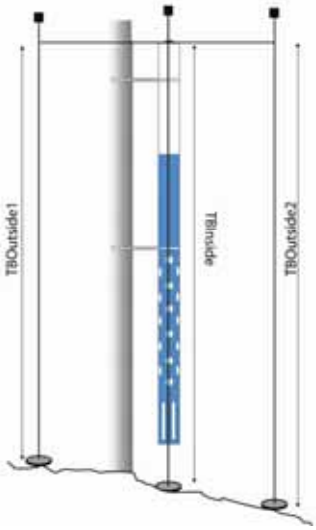


The distance TB Inside is much bigger than the two TB Outside distances.

There is a hole under the guard-pipe; possibly due to the interaction of nearstation current circulation with the monitoring platform.

Bolts-Bottom Distance = 1/2 ([TB Outside 1 + TB Outside 2] - 2 TS)

TB Outside 1 > TB Inside > TB Outside 2



The three distances exhibit a significant difference; showing a decline or an incremental pattern.

The bottom surface shows a slope around the monitoring station .

Bolts-Bottom Distance = TB Inside - TS

7.6 CORRECTION FACTOR FOR WATER LEVEL/DEPTH DATA REPORTING

Austin *et al.* (2004) state that multiparameter sondes equipped with non-vented pressure sensors are most commonly used for continuous water quality monitoring. Standard calibration protocols for the non-vented sensor use ambient atmospheric pressure at the time of calibration. Changes in atmospheric pressure between calibrations appear as changes in water depth. A 1.0 millibar change in atmosphere pressure corresponds to an approximate 1.0 centimeter change in water depth. Therefore, use of a non-vented pressure sensor can result in significant water depth errors for large-scale weather and storm events. This error is eliminated for level sensors because they are vented to the atmosphere throughout the data sonde deployment time interval. If proper atmospheric pressure data is available, non-vented sensor depth measurements can be post-corrected for deployments between calibrations. This correction combined with a common reference point from a survey station, results in more accurate water depth data.

Austin *et. al.* demonstrate the relative ease of adjusting non-vented depth sensor data for atmospheric pressure changes to reflect more accurate measurements.

Ambient laboratory atmospheric pressure was measured using a Varila pressure sensor with data being stored at 15 minute intervals on a Campbell 10X datalogger. Following retrieval of the instrument from the field, data can be downloaded and saved as an Excel file. Atmospheric pressure data collected at the appropriate time interval and the atmospheric pressure at the time of calibration can be added to the Excel file.

The raw depth data is adjusted by the following simplistic equation:

$$Depth_{adjusted} = Depth_{YSIraw} + \frac{\left(atm.\ pressure_{calibration} - atm.\ pressure_{ambient}\right)}{100}$$

In many cases, adjustment of the raw data can correct depth levels to positive values, which can result in more accurate and less confusing information (Figure 7.8, Table 7.4).

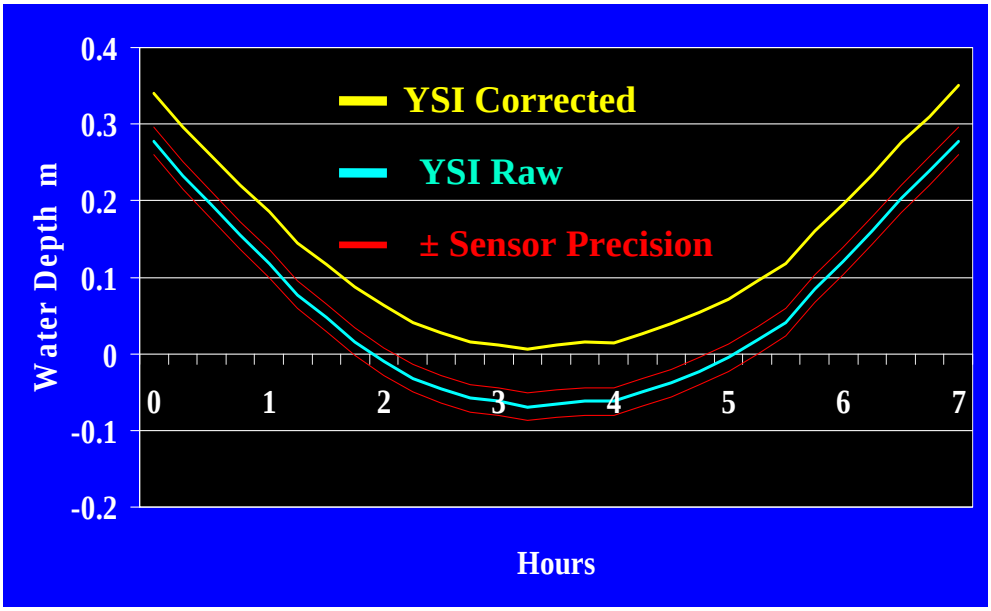


Figure 7.9 Raw vs. corrected YSI depth data from the York River over time (accuracy +/- 0.018 m)

Time	Raw Depth	Adjusted Depth	Ambient Pressure	Calibration Pressure
05:00	1.66	1.72	1014.8	1020.30
05:15	1.64	1.69	1014.8	1020.30
05:30	1.62	1.68	1014.9	1020.30
05:45	1.61	1.67	1014.4	1020.30
06:00	1.61	1.67	1013.9	1020.30
06:15	1.59	1.66	1014.0	1020.30
06:30	1.59	1.66	1013.4	1020.30
006:45	1.60	1.67	1013.1	1020.30
07:00	1.60	1.68	1013.0	1020.30

Table 7.4 Example of raw depth data using atmospheric pressure at time of calibration vs. adjusted data using ambient atmospheric pressure from weather station.

Additionally, extreme storm events, such as hurricanes, are marked by large depression in atmospheric pressure during the storm's passage. For example, in the case of Hurricane Isabel, a 30 millibar drop was observed resulting in a 0.30 m error in water depth level.

Given atmospheric pressure data at the time of instrument calibration and during instrument deployment, water depths are easily corrected (Figure 7.9).

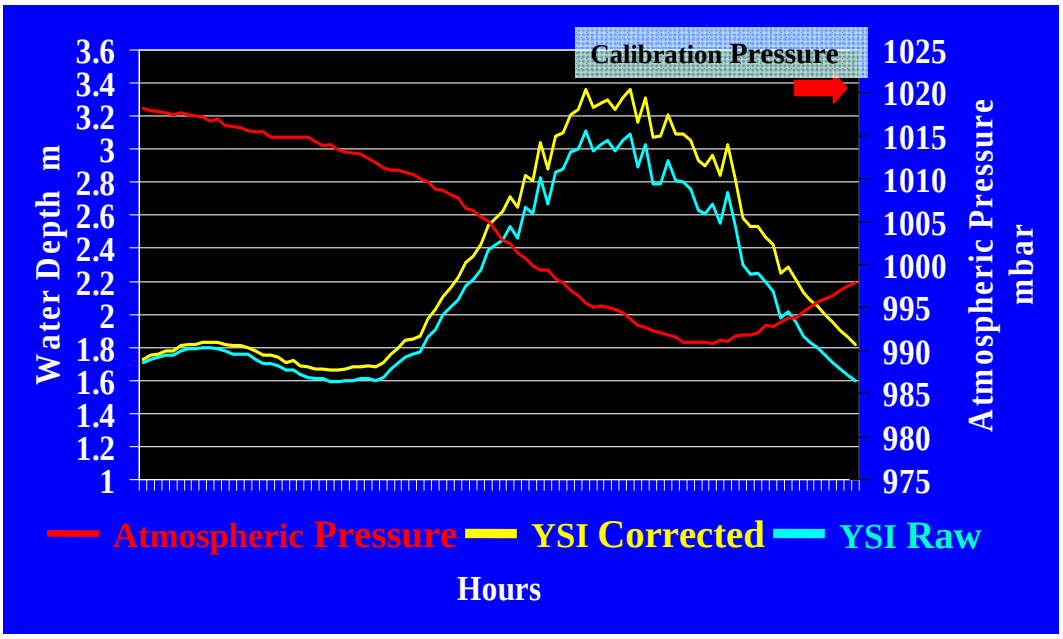


Figure 7.10 Raw vs. corrected YSI depth data using atmospheric pressure at time of Hurricane Isabel.

To further enhance the value of water level data, traditional optic or advanced GPS surveying systems can be used to reference water quality monitoring platforms in instruments to a standard vertical datum. Common local datums include mean sea level (MSL), mean lower low water (MLLW), and mean higher high water (MMHW).

Increase accuracy and value of water depth data can be realized by correcting for atmospheric pressure changes during the deployment period and reporting the data to a common vertical reference datum. Benefits of more accurate and vertically referenced water level data can facilitate AQ/QC efforts by removing erroneous negative values while providing water level information in a more user acceptable format, thereby increasing the use of water level data by a broader audience.

7.7 EQUIPMENT MAINTENANCE

As stated in ISO 9001:2600

> *The organization shall determine the monitoring and measurement to be undertaken and the monitoring and measuring devices needed to provide evidence of conformity of product to determined requirements.*
>
> *The organization shall establish processes to ensure that monitoring and measurement can be carried out and are carried out in a manner that is consistent with the monitoring and measurement requirements.*
>
> *Where necessary to ensure valid results, measuring equipment shall:*
>
> *a. be calibrated or verified at specified intervals or prior to use, against measurement standards traceable to international or national measurement standards; where no such standards exist, the basis used for calibration or verification shall be recorded;*
> *b. be adjusted or re-adjusted as necessary;*
> *c. be identified to enable calibration status to be determined;*
> *d. be safeguarded from adjustments that would invalidate the measurement result;*
> *e. be protected from damage and deterioration during handling, maintenance and storage.*

All the equipment used to calibrate and post-calibrate the sensors and field verifications must be maintained, calibrated or pass some quality assurance check to ensure their accuracy and that they perform to accepted standards.

Equipment histories, records and logs must be maintained.

7.8 REFERENCE

ANSI/ISO/ASQ Q9001-2000. **Quality management systems - Requirements**. American Society for Quality

Austin Joy, Terri Keffert, Jim Goings and William Reay. 2004. **Enhancing the Value of SWMP Depth Data**. Poster presented at the inauguration of the Catlett-Burress Research and Education Teaching Lab.

CDMO. 2007. **YSI 6-Series Multi-Parameter Water Quality Monitoring Standard Operating Procedure. Version 4.1** National Estuarine Research Reserve System-Wide Monitoring Program (SWMP).

Helsel D.R. and R.M. Hirsch. 2002. **Statistical Methods in Water Resources**. U.S. GEOLOGICAL SURVEY

Resources Inventory Committee. 1999. **Automated water quality monitoring: Field manual**. Ministry of environmental lands and parks. The Pro. of British Columbia.

Sullivan, G.P., R. Pugh, A.P. Melendez and W.D. Hunt. 2004. **Operations & Maintenance Best Practices: A Guide to Achieving Operation Efficiency**. US Department of Energy.

Texas Commission on Environmental Quality. 2003. **Surface Water Quality Monitoring Procedures, Volume 1: Physical and Chemical Monitoring Methods for Water, Sediment and Tissue**. Monitoring Operations Division.

U.S. Department of Energy. **Operations and Maintenance**. Energy Efficiency and Renewable Energy. Federal Energy Management Program. http://www1.eere.energy.gov/femp/operations_maintenance/om_strategies.html

U.S. Environmental Protection Agency.2002. **Guidance on Environmental Data Verification and Data Validation**. EPA QA/G-8.

U.S. Environmental Protection Agency.2002. **Guidance for Quality Assurance Project Plans**. EPA QA/G-5

YSI Incorporated. 2008. **6-Series - Multiparameter - Water Quality Sondes - User Manual**.

YSI Incorporated. 2009. **Calibration Tips for YSI 6-Series Sondes & Sensors**.

APPENDIX SECTION

APPENDIX 1

The following example forms are provided in this appendix:

1. **MONITORING SITE LOCATION - INFORMATION COLLECTION & SUMMARY INSTRUCTIVE**: This instructive provides guidelines of relevant information that must be collected from each site-location. The instructive can be used to organize the information to ease subsequent analysis.

2. **SITE ASSESSMENT FORM**: This form details all information to be collected during site assessment to be used in site selection process and/or data quality clarification.

3. **SITE INFORMATION FORM**: This form details all information to be collected relevant to the site in terms of location, direction, safety, contacts, etc.

4. **STATION INFORMATION FORM**: This form details the information relevant of the station. The information can be used to reconstruct the station in case something happens (*i.e.* hurricane) or to provide a brief description of the station, *i.e.* in the Reserve web page.

	MONITORING SITE LOCATION - INFORMATION COLLECTION & SUMMARY INSTRUCTIVE			
	Identification Number	Revision	Effective Date	Pages
				Page 1 of

The purpose of this instructive is to provide a guideline of relevant information that must be collected from each site location. The instructive can be used to organize the information to ease subsequent analysis.

1. Project Name.
2. Detail the monitoring objectives.
3. Detail key data quality requirements.
4. Translation of objectives and requirements into field characteristics.
5. Attach maps used to mark preliminary site locations.
6. Specify preliminary site locations. Names or labels to be used.
7. List descriptive and relevant information of each site:

7.1 Environmental Factors

7.1.1 Mixing conditions. List Rivers, streams, and other sources that can affect mixing. Distance from the site location and other relevant information.
7.1.2 Possible turbulence problems.
7.1.3 Structures or other sources that can cause variable flow conditions.
7.1.4 Tidal range or maximum and minimum water levels and flows.
7.1.5 Wave action information.
7.1.6 Sediment type.
7.1.7 Relevant water physical properties.
7.1.8 Type of relevant vegetation that can affect monitoring quality data.
7.1.9 Type of relevant animals that can affect monitoring quality data.
7.1.10 Possible areas that can cause run-off problems.
7.1.11 Any relevant information about biofouling.
7.1.12 Human activities or impacts that could affect monitoring quality data.
7.1.13 Upstream activities or potential debris sources that could produce hazards to monitoring sites.

7.2 Accessibility and Safety Issues

7.2.1 State if there are any relevant laws that could affect site location.
7.2.2 State if there are any potential problems to access these sites year round: weather factors, need of special access authorization, permits, other.
7.2.3 Describe preliminary access data. How these sites will be accessed? (car, boat, directions, distance, *etc*.).
7.2.4 List any necessary contact information.
7.2.5 List any special requirements that must be met to access any particular site.
7.2.6 State any relevant survey information.
7.2.7 State any relevant data transfer information (*e.g.* potential problems).
7.2.8 List obvious safety issues to be considered.

7.3 Community Issues

7.3.1 Describe community activities that could impact monitoring.
7.3.2 State if community acceptance of site location/monitoring activities must be obtained.

8. Describe possible problems or concerns that can appear.
9. Specify major funding and budget considerations.

	SITE ASSESSMENT FORM			
	Identification Number	Revision	Effective Date	Pages
				Page 1 of 2

Project Name	

1. LOCATION-DIRECTIONS-ACCESS

Site name		Station ID	
Site different from site specified in MONITORING SITE LOCATION		NO	YES
If **YES** describe New Information			

2. SITE DESCRIPTION

ENVIRONMENTAL FACTORS	
Mixing Issues. Any streams or rivers close to site. Distance to site.	
Turbulence/Bubbles	
Structures that can cause variable flow	
Water velocity or flow conditions	
Water depth	
Approximate width	
Tidal or water level issues	
Wave action	
Type of soil	
Description of floor surface (*i.e*. slope)	
Sediment accumulation?	
Run-off influence?	
Description of vegetation	
Human Impacts (Description of human activities in the sampling area)	
Possible environmental Hazards	
Other	
ACCESSIBILITY	
Survey	
Data Transfer	
SAFETY	
Any safety issue to consider	
COMMUNITY	
Community issues to consider	
STATION CHARACTERISTICS	
Any considerations for station structure and maintenance	
Any other relevant information	

3. ASSESSMENT ACTIVITIES

3.1 ACTIVITIES AND MEASUREMENTS

Activity/Measurement	Result or reference where to find the results	Responsible

3.2 PROBLEMS AND SOLUTIONS

Potential Problem	Solution Characteristics or Ideas

SITE ASSESSMENT FORM

Purpose: The purpose of this form is to record all relevant information during the site assessment.

Form structure and fine-tuning: Even though the form has a certain structure, the assessment team can add or delete sections to personalize the form to their needs and make it user friendly. For example, if several sites are in the same river, there is no need to fill one form for each site. The additional information can be added under each section as required. If a section is deleted, the title must be kept and a note of N/A (not applicable) must be added in order to assure the information was considered.

1. LOCATION-DIRECTION-ACCESS

The information in this section is intended to add any useful new information found during the assessment and/or in case a new site must be selected.

- Site name & Station ID: Station name and ID used for identification.
- New Information: All new information to located and access the new site must be detailed.

  For example, to access the site it was found that a new gate must be open; or landmarks are added to complement the driving direction in the water, other factor may influence the access in the future, *e.g.* vegetation, ice formation.

2. SITE DESCRIPTION

2.1 ENVIRONMENTAL FACTORS

- Factor & Description: Each relevant factor must be assessed and significant information recorded. It must be stated if future assessments are needed for any particular factor. For example, the site assessment is performed during a dry season, and high impact run-off areas are detected; therefore, possible assessment during raining period may be needed.

All possible impacts (*i.e.* human activities) identified during planning or through the assessment must be evaluated; documenting location, description, magnitude and possible risk or links associated between the activity and water quality.

2.2 ACCESSIBILITY

- Detail if the station can be surveyed and if it is possible to transfer data, *i.e.* via telemetry.

2.3 SAFETY

- Safety issues previously addressed are no longer an issue, and/or new safety issues must be taken into consideration.

2.4 COMMUNITY

- It is possible that some community issues previously addressed are not so and must be recorded, and/or new issues must be taken into consideration.

2.5 STATION CHARACTERISTICS

- What station would work must be recorded. For example, during planning it was decided to construct the station using a fixed structure. During site assessment, it is evaluated that the fixed station will not work given community issues and the best station will be a buoyant one.

2.6 ANY OTHER RELEVANT INFORMATION

- During site assessment the planning decisions are evaluated against the real settings; therefore, new relevant information may appear.

3. ASSESSMENT ACTIVITIES

3.1 NECESSARY ACTIVITIES AND MEASUREMENTS

- Activity/Measurement: Describe the activity or measurement to be performed.
- Result or reference where to find the results: Record the result of the activity/measurement or identify where the results are stored. The information must be recorded in such a way that the tracking of this information is easily accessed.
- Responsible: Name of the person responsible for the activity

3.2 PROBLEMS AND SOLUTIONS

- Potential Problem: Record the problem, new or old.
- Solution Characteristics or Ideas: Describe the solution or ideas to solve the problems

	SITE INFORMATION FORM			
	Identification Number	Revision	Effective Date	Pages
				Page 1 of 2

Project Name	

1. LOCATION

1.1 Site name				1.2 Station ID	
1.3 Site is marked in map	YES	NO	1.4 Map name or title		
1.5 Name of the waterbody or watershed					
1.6 Latitude			1.7 Longitude		
1.8 Describe where the site is located (water, pier, marina, etc.)					

2. DIRECTIONS & ACCESS

2.1 ROAD DIRECTIONS

2.1.1 Address		2.1.3 County	
2.1.2 State		2.1.4 Zip Code	
2.1.5 Description of how to reach the location (if needed attach photocopy of road map)			
2.1.6 Specify if there is any important landmarks or information that will help find or get to the site.			

2.2 WATER DIRECTIONS

2.2.1 Need to use boat ramp	YES	NO	2.2.2 Boat ramp proprietor	Public access	Private	
2.2.3 Hours of operation		2.2.4 Fee		2.2.5 Ramp type	Concrete	Dirt
2.2.6 Contact		2.2.7 Telephone				
2.2.8 Directions from boat ramp to site						
2.2.9 Need navigation map	YES	NO				
2.2.10 Need to cross any bridge that needs to be open	YES	NO				
2.2.11 Need to contact in advance to open bridge	YES	NO				
2.2.12 Contact		2.2.13 Telephone				
2.2.14 Tides or other precautions to consider						

2.3 IMPORTANT ACCESS INFORMATION				
2.3.1 Need special permit to access station	YES	NO		
2.3.2 Contact Name			email	
			email	
2.3.3 Telephone			2.3.4 Fax	
2.3.5 Need to do or get anything to access site (keys, call, etc.)				
2.3.6 Hours or schedule when site is accessible				
2.3.7 Any comments how to access the station				
2.3.8 Parking				
2.3.9 Toll		2.3.10 Traffic & Access concerns		
2.3.11 Restrooms				

3. EQUIPMENT

3.1 VEHICLES			
3.1.1 Need truck 4 by 4	YES	NO	
3.1.2 What type of vessel/s are needed			
3.2 WORKING GEAR			
3.2.1 Detail the working gear needed			

4. COMMUNICATION AND SAFETY

4.1 Cellular phone service					
4.2 Hospital		4.3 Address		4.4 Telephone	
4.5 Fire/Rescue phone		4.6 Address			
4.7 Safety considerations					

SITE INFORMATION FORM

Purpose: The purpose of this form is to provide all relevant information of the monitoring site.

Form structure and fine-tuning: Even though the form has a certain structure, sections of this form can be added or delete to personalize it. For example, if several sites are in the same river, there is no need to fill one form for each site. The additional information can be added under each section as required. If a section is deleted, the title must be kept and a note of N/A (not applicable) must be added in order to assure the information was considered.

1. LOCATION

The information in this section is intended to locate the site as clearly as possible.

1.1 Site name Station name
1.2 Station ID: ID used for identification
1.3 Site is marked in map: A map is very helpful in locating sites.
1.4 Map name or title: Provide the name/s of the maps used.
1.5 Name of the waterbody or watershed: For example, Poropotank River in the York River watershed.
1.6 Latitude: provide the latitude in decimal degrees (as often found as an option on GPS) and in degrees, minutes, and seconds (for printed maps), or degrees and decimal minutes.
1.7 Longitude: provide the longitude in decimal degrees (as often found as an option on GPS) and in degrees, minutes, and seconds (for printed maps), or degrees and decimal minutes.
1.8 Describe where the site is located: a brief description where the site is located.

2. DIRECTIONS & ACCESS

The information in this section is intended to give precise directions of how to get to the site and what accessibility considerations must be taken.

2.1 ROAD DIRECTIONS

Address: Street address (if there is one).
State: Name of the State where the site is located
County: Name of the County where the site is located.
Zip Code: Zip code (if there is one)
Description of how to reach location: Provide as much information as possible of how to reach the site by car. If location is not familiar, include distance form highways, roads, detail street names, etc. It will be helpful to attach a map showing major streets, roads. If no map is available, a hand draw map will do it.
Specify if there is any important landmarks or information that will help find or get to the site: In some places it will be helpful to specify landmarks to give orientations (*e.g.* church, gas station, etc.) or any other information (*e.g.* stop in Grammy Store and ask for directions).

2.2 WATER DIRECTIONS

- Boat ramp proprietor (need to use boat ramp): If a boat ramp is needed, it is important to know if it is privately own or for public access.
- Contact & Telephone: Name of the persons and telephones if needed to access the ramp.
- Directions from boat ramp to site: Describe directions of how to get to the site from the boat ramp. A navigation map may be useful to locate the site. All navigation relevant information must be included; for example, if the station is located in a river that has many low water areas, these must be marked to alert the field crew.
- Contact & Telephone (need to contact in advance to open bridge): Name and telephones of person responsible of bridge operation.
- Tides or other precaution to consider: It is a good practice to get information of the ramp accessibility, what is the maximum depth at average low waters? (to have an idea of the type of boat that can be launched), parking availability, etc.

2.3 IMPORTANT ACCESS INFORMATION

- Contact & Telephone: Name and telephone of the person/s in charge of giving access to the site.
- Need to do or get anything to access site: Describe what actions must be taken to access the site. For example, get a key form a special place, open gates, call someone to open a gate, etc.
- Hours or schedule when site is accessible: State if there is a special time frame when the site is accessible (*i.e.* the park close at 16:00).

- Parking & Toll: Describe if there are any parking issues (*i.e.* the boat ramp in summer can be full. Parking alternative). If there are tolls, state each fee.
- Traffic or Access Concerns: State if there are any traffic concerns. For example, rush hours tips; if there are dirt roads that after rain are hard to travel hauling a boat; construction; possible closure given hunting; animal migration, etc.

3. EQUIPMENT

3.1 VEHICLES

- Need truck 4 by 4: Describe if a special truck is needed, for example, a truck 4 by 4 with a closed trunk to take gear.
- What type of vessel/s are needed: Describe type of vessels needed.

3.2 WORKING GEAR

- Detail the working gear needed: List all the necessary gear needed. Basic gear can be described as a general group (*i.e.* weather gear), however, specific gear, as sampling equipment, must be described in detail.

4. COMMUNICATION AND SAFETY

This section describes which cellular accessibility and emergency information.

- Cellular phone service: It is important to know what companies cover (if any) the site area in order to know what type of communication device to carry.
- Hospital Information & Fire Rescue Information: Information of emergency facilities near the site.
- Safety considerations: Describe if there is any contaminant (*i.e.* animal waste, sewage discharge), poisonous plants, or other safety considerations to be aware off.

	STATION INFORMATION			
	Identification Number	Revision	Effective Date	Pages
				Page 1 of 1

Project Name	

1. STATION INFORMATION

1.1 Site name						
1.2 Type of water body						
1.3 Date installed			1.4 Time installed			
1.5 Latitude			1.6 Longitude			
1.7 Type of Configuration						
BUOYANT	FIXED STRUCTURE					
Surface Buoy Stationary Structure Subsurface	Existing Structure	Pier	Bridge	Piling	Wall	Other:
	Designed Structure	Pile	PVC	Wood	Tower	Other:
	On river & stream bank					
1.8 Information of the Guard-Pipe						
1.8.1 Guard-Pipe length			1.8.2 Distance from bolts to bottom			
1.8.3 Length of the rope use to hang the sensor inside the guard pipe (including couplings or knots)			1.8.4 Length of the rope use to hang the replacement sensor outside the guard pipe (including couplings or knots)			
1.8.5 Description of the Locking Safety System						
1.9 Configuration Information						
1.9.1 Basic description of the structure						
1.9.2 Survey data						
1.9.3 Other relevant information						

2. FIGURES OF SITE/STATION

STATION INFORMATION FORM

Purpose: The purpose of this form is to provide relevant information of the station.

Form structure and fine-tuning: Even though the form has a certain structure, sections of this form can be added or delete to personalize it.

1. STATION INFORMATION

1.1 Site name: Station or site name
1.2 Type of water body: provide the name of the water body where the station is located, *e.g.* James River Oligohaline.
1.3 Date: provide the date the station was installed.
1.4 Time installed: provide the time the station was installed.
1.5 Latitude: provide the latitude in decimal degrees (as often found as an option on GPS) and in degrees, minutes, and seconds (for printed maps), or degrees and decimal minutes.
1.6 Longitude: provide the longitude in decimal degrees (as often found as an option on GPS) and in degrees, minutes, and seconds (for printed maps), or degrees and decimal minutes.
1.7 Type of configuration: a briefly description of the type of station. For example, existing structure – pier.
1.8 Information of the guard-pipe: the idea of this section is to include all relevant information of the guard-pipe in case it needs to be rebuilt.
1.9 Configuration Information: provide information of the station configuration.

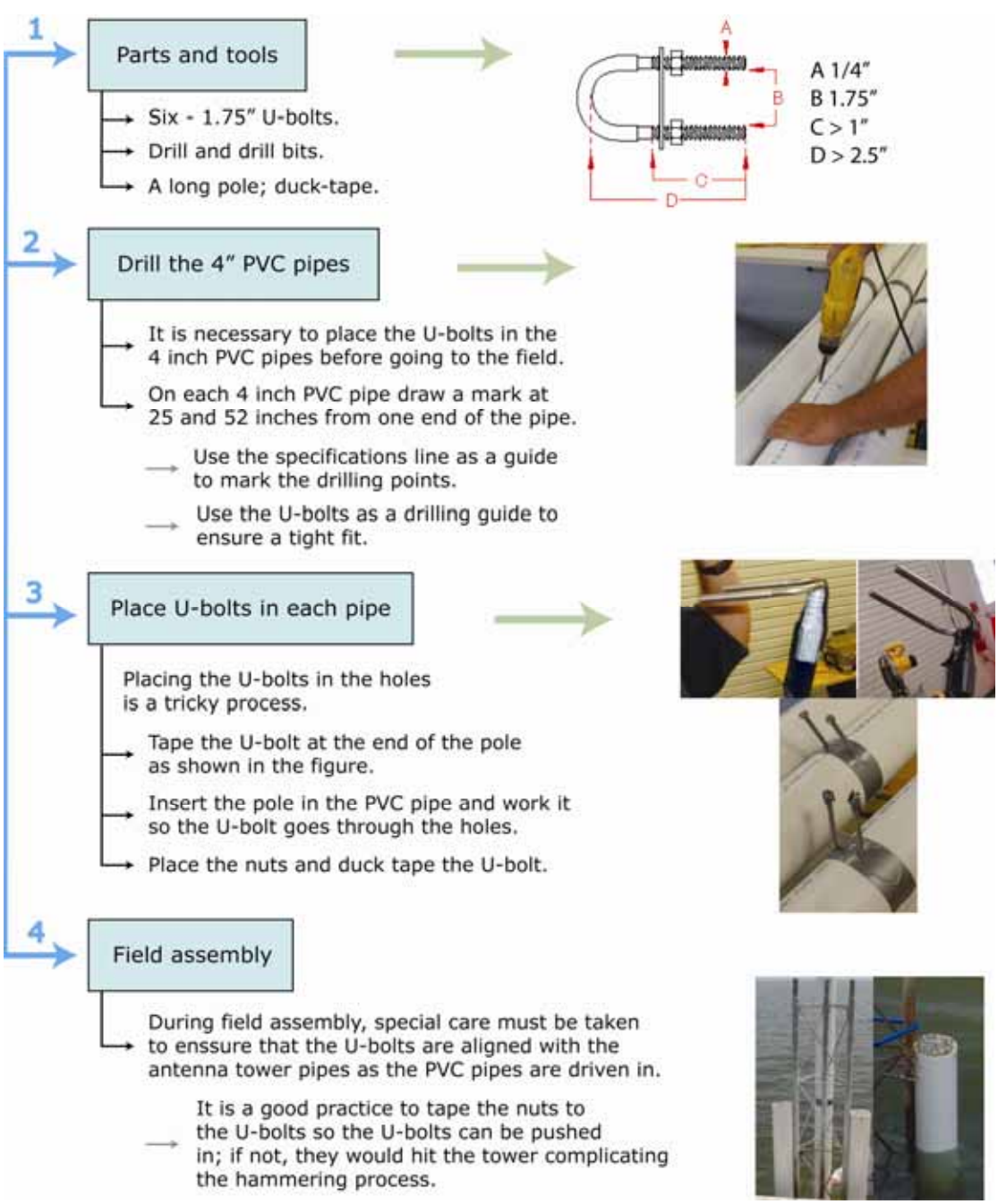
1.9.1 Basic description of the structure: provide a brief description of the station configuration. For example, if the station is located on a pier, description of the pier, dimension, relative location of the station on the pier, etc. are detailed.
1.9.2 Survey data: provide detail information of the survey data.

The information included in 1.7 and 1.8 will vary depending on the type of station. A rule of thumb is to include all the information that will be needed to reconstruct the station to achieve same monitoring depth.

2. FIGURES OF SITE/STATION

APPENDIX 5

Even though the 1.75" U-bolts are less expensive than the 8.75" U-bolts; there are some disadvantages in using them:

- It requires an on-land construction step.
- The station deployment process is more cumbersome.
- One pipe per column can only be used; no extension pipes can be employed if a higher penetration depth is required.

An example of securing the tower system to the PVC pipes using 1.75" U-bolts follows: