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Standard Guide for Monitoring Aqueous Nutrients in Watersheds[1]

This standard is issued under the fixed designation D 6146; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

Various forms of nitrogen and phosphorus are plant nutrients, both naturally occurring and manmade, that can threaten water resources. Nutrients that run off or infiltrate through the soil profile can result in unfishable and unswimmable streams, lakes, and estuaries, and unsafe surface and ground water used for drinking. High concentrations of nitrate in drinking water are a threat to young infants, and surface waters can suffer from algal blooms, fish kills, and unpalatable and unsafe water for swimming and drinking. Nutrients are also added to watersheds via chemigation.

This guide recommends a process for developing and implementing monitoring projects for nutrients in a watershed. It follows Guide D 5851 with more specifics applicable to watersheds and nutrients. These guidelines are presented for use in the nationwide strategy for monitoring developed by the Intergovernmental Task Force on Monitoring (ITFM). The nationwide monitoring strategy is an effort to improve the technical aspects of water monitoring to support sound water quality decision-making. It is needed to integrate monitoring activities more effectively and economically to achieve a better return of investments in monitoring projects (**1**).[2]

Guide D 6145 is offered as a guide for monitoring actual and potential nonpoint and point source pollution within a watershed. The guide is applicable to surface water and ground water resources, recognizing the need for a comprehensive understanding of naturally occurring and manmade impacts to the entire watershed hydrologic system.

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1. Scope

1.1 *Purpose*—This guide is intended to provide general guidance on a watershed monitoring program directed toward the plant nutrients nitrogen and phosphorus. The guide offers a series of general steps without setting forth a specific course of action. It gives assistance for developing a monitoring program but not a program for implementing measures to improve water quality.

1.2 This guide applies to waters found in streams and rivers; lakes, ponds, and reservoirs; estuaries; wetlands; the atmosphere; and the vadose and subsurface saturated zones (including aquifers). This guide does not apply to nutrients found in soils, plants, or animals.

1.3 Nutrients as used in this guide are intended to include nitrogen and phosphorus in dissolved, gaseous, and particulate forms. Specific species of nitrogen include: nitrate, nitrite, ammonia, organic, total Kjeldahl, and nitrous oxide. The

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[1] This guide is under the jurisdiction of ASTM Committee D19 on Water and is the direct responsibility of Subcommittee D19.02 on General Specifications, Technical Resources, and Statistical Methods.

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[2] The boldface numbers given in parentheses refer to a list of references at the end of this standard.

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species of phosphorus include total, total dissolved, organic, acid-hydrolyzable, and reactive phosphorus as described in (**2**)

1.4 *Safety*—Health and safety practices developed for a project may need to consider the following:

1.4.1 During the construction of sampling stations:

1.4.1.1 Drilling practices during monitoring well installations,

1.4.1.2 Overhead and underground utilities during monitoring well drilling,

1.4.1.3 Traffic patterns/concerns during sampling station installation,

1.4.1.4 Traffic patterns/concerns during surveying sampling station locations and elevations,

1.4.1.5 Drilling through materials highly contaminated with fertilizers, and

1.4.1.6 Installing monitoring equipment below the soil surface.

1.4.2 During the collection of water samples:

1.4.2.1 Using acids for sample preservation,

1.4.2.2 Sampling during flooding events and ice conditions,

1.4.2.3 Traffic on bridges,

1.4.2.4 Condition of sampling stations following flood events,

1.4.2.5 Sampling of water or soils, or both, highly contaminated with fertilizers,

1.4.2.6 Conditions of sampling stations resulting from vandalism,

1.4.2.7 Adverse weather conditions, and

1.4.2.8 Transporting liquid samples.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

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2. Referenced Documents

2.1 *ASTM Standards:* [3]

D 515 Test Methods for Phosphorus in Water
D 653 Terminology Relating to Soil, Rock, and Contained Fluids
D 1129 Terminology Relating to Water
D 1357 Practice for Planning the Sampling of the Ambient Atmosphere
D 1426 Test Methods for Ammonia Nitrogen in Water
D 1739 Test Method for Collection and Analysis of Dustfall (Settleable Particulate Matter)
D 3370 Practices for Sampling Water from Closed Conduits
D 3590 Test Methods for Total Kjeldahl Nitrogen in Water
D 3856 Guide for Good Laboratory Practices in Laboratories Engaged in Sampling and Analysis of Water
D 3858 Test Method for Open-Channel Flow Measurement of Water by Velocity-Area Method
D 3867 Test Methods for Nitrite-Nitrate in Water
D 4410 Terminology for Fluvial Sediment
D 4448 Guide for Sampling Ground Water Monitoring Wells
D 4696 Guide for Pore-Liquid Sampling from the Vadose Zone
D 4700 Guide for Soil Sampling from the Vadose Zone
D 5092 Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers
D 6145 Guide for Monitoring Sediment in Watersheds
D 5851 Guide for Planning and Implementing a Water Monitoring Program

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this guide, refer to Terminology D 1129 and Guide D 5851.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *aquifer*—a geologic formation containing water, usually able to yield appreciable water.

3.2.2 *ground water*—that part of the subsurface water that is the saturated zone. **(D 653, D18)**

3.2.3 *nonpoint pollution*—a condition of water within a water body caused by the presence of undesirable materials from diffuse locations with no particular point of origin.

3.2.4 *vandose zone*—the zone of soil located between the surface and the water table that is not saturated.

3.2.5 *watershed*—all lands enclosed by a continuous hydrologic surface drainage divide and lying upslope from a specified point on a stream. **(D 4410, D19)**

4. Significance and Use

4.1 The user of this guide is not assumed to be a trained technical practitioner in the water quality field. The guide is an assembly of the components common to all aspect of watershed nutrient monitoring and fulfills a need in the development of a common framework for a better coordinated and a more unified approach to nutrient monitoring in watersheds.

4.2 *Limitations*—This guide does not establish a standard procedure to follow in all situations and it does not cover the detail necessary to meet all of the needs of a particular monitoring objective. Other standards and guides included in the references describe the detail of the procedures.

5. Monitoring Components

5.1 A watershed monitoring program of nutrients is comprised of a series of steps designed to collect nutrient data to achieve a stated objective. The purposes of monitoring may be several and include: analyzing trends, studying the fate and transport of nutrients, defining critical areas, assessing compliance, measuring the effectiveness of management practices, testing for sufficient levels, making wasteload allocations, testing models, defining a water quality problem, and conducting research (**3**).

5.1.1 Monitoring to analyze trends is used to determine how water quality is changing over time. In some cases baseline monitoring is included as the early stage of trend monitoring.

5.1.2 Fate and transport monitoring is conducted to determine whether pollutants move and where they may go.

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[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

5.1.3 Water quality monitoring can be used to locate critical areas within watersheds exhibiting greater pollution loading than other areas.

5.1.4 Nutrient monitoring may also be used to assess compliance with water quality plans or standards.

5.1.5 Nutrient monitoring may assess the effectiveness of individual management practices in improving water quality or, in some cases, may be used to evaluate the effect of an entire nutrient management program in a watershed.

5.1.6 The testing of nutrient levels in water bodies may be used to see if sufficient amounts are present to support certain aquatic organisms.

5.1.7 Monitoring of receiving water bodies may be used to determine wasteload allocations between point and nonpoint sources. Such allocations require a thorough knowledge of the individual contributions from each source.

5.1.8 Nutrient monitoring may be used to fit, calibrate, or test a model for local conditions.

5.1.9 Nutrient monitoring may be used for research questions such as the accuracy of different types of samplers in collecting a representative sample.

5.1.10 Finally, nutrient monitoring may be used to give adequate definition to a water quality problem or determine whether a problem exists. Guide for Planning D 5851 provides overall guidance on water monitoring.

5.1.11 This guide suggests and discusses the following steps in designing a watershed monitoring program for nutrients. More detail on each step may be found in (**3**).

5.2 *Step 1: Water Quality Need*—The first step is to define the need for nutrient monitoring. The need statement should include several components: the potential or real water quality issue requiring attention (for example, eutrophication), the potential water resource use impairment (for example, recreation), the name of the actual water resource (for example, Long Lake), the potential threats or causes (for example, phosphorus), and the potential sources that may cause a problem (for example, agriculture) (**3**). Very often the need is to identify a water quality problem, but in some cases, the need may be to assess the existing water quality whether a problem exists or not. An example of a need statement might be: "The lack of recreation in Long Lake is due to excessive eutrophication caused by excessive phosphorus loading possibly from agricultural sources."

5.3 *Step 2: Objectives*—The second step in developing a nutrient monitoring program is to define the monitoring objectives. The objectives of the monitoring study should address the water quality need or problem. An objective statement should include an infinitive verb, an object word or phrase, and some limits on the objective such as the surface or ground water resource or watershed boundaries and variables to monitor. An example of a monitoring objective might be: "To determine the effect of implementing agricultural management practices on phosphorus concentrations in Long Lake." When several objectives are used, a hierarchial approach may be used to determine higher priority objectives. An objective tree can be used to distinguish among several objectives. To determine how several objectives can be linked, the following question can be asked: "Does the achievement of objective A contribute directly to the achievement of objective B?" If it does then objective A feeds into objective B and a diagram can be built showing all possible objectives and their linkages.

5.3.1 To assess whether objectives are being achieved, objective attributes could be determined. Attributes define the level of achievement for each objective. They answer the question of how close are we to achieving our goals? For example, are we 50 % of the way to achievement? These attributes for nutrient monitoring objectives are often binary; that is, either the objective is accomplished or not.

5.4 *Step 3: Statistical Design*—A statistical experimental design should be stated that is consistent with the objectives of the monitoring program. Appropriate experimental designs could include: reconnaissance, plot, single watershed, above-and-below, two watersheds, paired watershed, multiple watersheds, and trend stations (**3**). The design selected will dictate most other aspects of the monitoring project including the study scale, the number of sampling locations, the sampling frequency, and the station type.

5.4.1 Reconnaissance or synoptic designs may be used as a preliminary survey where no data exist or to assess the magnitude and extent of a problem. This type of sampling could be used to identify critical areas as well. A critical area is one that is contributing a significant amount of nutrients to the water body of interest. Randomization in sampling locations may be important for reconnaissance monitoring. Reconnaissance monitoring could be used in a "whole aquifer" study with well placement located randomly or on a grid basis.

5.4.2 Plot designs have been commonly used in agricultural experiments for 100 years (**4**). Plots are generally small areas that can be replicated on the land or waterscape. Plots allow replication and control of certain variables, such as soil type. Plot designs are analyzed using Analysis of Variance (**3**).

5.4.3 The single watershed before-and-after approach has been sometimes used to compare water quality conditions before a watershed treatment to after. Generally, this technique is not recommended, since the results are confounded with time and climate variables, and should be avoided. For example, the water quality differences from year-to-year may be caused by climate differences not the watershed activity.

5.4.4 The above-and-below design is used after a watershed practice is in place. Sampling is conducted both upstream and downstream, or in the case of ground water monitoring, up-gradient and down-gradient from the activity of interest. Although this design is not as susceptible to the effect of climate as the single watershed design, the differences in water quality between the two stations may be partly due to inherent watershed differences such as soils or geology. If monitoring is conducted before and after the practice in installed, the design would follow the paired watershed approach described below.

5.4.5 Ground water monitoring using this approach is referred to as up-gradient versus down-gradient monitoring. This is probably the most commonly used strategy in ground water studies and is appropriate for most designs. Placement of the wells is important because ground water sites are three dimensional. Gradients may occur in both vertical as well as horizontal directions. Also due to heterogeneity at some sites, gradient directions may change over time.

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