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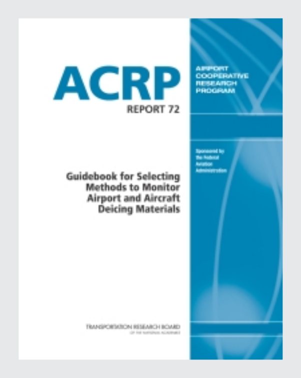

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AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP REPORT 72

Guidebook for Selecting Methods to Monitor Airport and Aircraft Deicing Materials

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AIRPORT COOPERATIVE RESEARCH PROGRAM

Airports are vital national resources. They serve a key role in transportation of people and goods and in regional, national, and international commerce. They are where the nation's aviation system connects with other modes of transportation and where federal responsibility for managing and regulating air traffic operations intersects with the role of state and local governments that own and operate most airports. Research is necessary to solve common operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the airport industry. The Airport Cooperative Research Program (ACRP) serves as one of the principal means by which the airport industry can develop innovative near-term solutions to meet demands placed on it.

The need for ACRP was identified in *TRB Special Report 272: Airport Research Needs: Cooperative Solutions* in 2003, based on a study sponsored by the Federal Aviation Administration (FAA). The ACRP carries out applied research on problems that are shared by airport operating agencies and are not being adequately addressed by existing federal research programs. It is modeled after the successful National Cooperative Highway Research Program and Transit Cooperative Research Program. The ACRP undertakes research and other technical activities in a variety of airport subject areas, including design, construction, maintenance, operations, safety, security, policy, planning, human resources, and administration. The ACRP provides a forum where airport operators can cooperatively address common operational problems.

The ACRP was authorized in December 2003 as part of the Vision 100-Century of Aviation Reauthorization Act. The primary participants in the ACRP are (1) an independent governing board, the ACRP Oversight Committee (AOC), appointed by the Secretary of the U.S. Department of Transportation with representation from airport operating agencies, other stakeholders, and relevant industry organizations such as the Airports Council International-North America (ACI-NA), the American Association of Airport Executives (AAAE), the National Association of State Aviation Officials (NASAO), Airlines for America (A4A), and the Airport Consultants Council (ACC) as vital links to the airport community; (2) the TRB as program manager and secretariat for the governing board; and (3) the FAA as program sponsor. In October 2005, the FAA executed a contract with the National Academies formally initiating the program.

The ACRP benefits from the cooperation and participation of airport professionals, air carriers, shippers, state and local government officials, equipment and service suppliers, other airport users, and research organizations. Each of these participants has different interests and responsibilities, and each is an integral part of this cooperative research effort.

Research problem statements for the ACRP are solicited periodically but may be submitted to the TRB by anyone at any time. It is the responsibility of the AOC to formulate the research program by identifying the highest priority projects and defining funding levels and expected products.

Once selected, each ACRP project is assigned to an expert panel, appointed by the TRB. Panels include experienced practitioners and research specialists; heavy emphasis is placed on including airport professionals, the intended users of the research products. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, ACRP project panels serve voluntarily without compensation.

Primary emphasis is placed on disseminating ACRP results to the intended end-users of the research: airport operating agencies, service providers, and suppliers. The ACRP produces a series of research reports for use by airport operators, local agencies, the FAA, and other interested parties, and industry associations may arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by airport-industry practitioners.

ACRP REPORT 72

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- Denver International Airport
- Detroit Metropolitan Wayne Co. Airport
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- Anheuser-Busch Brewery
- Pfizer

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FOREWORD

By Joseph Navarrete
Staff Officer
Transportation Research Board

ACRP Report 72: Guidebook for Selecting Methods to Monitor Airport and Aircraft Deicing Materials provides a step-by-step process for identifying, evaluating, and selecting methods to monitor storm water that is subject to runoff containing deicing materials. The guidance addresses identifying the parameters to be monitored and discusses the appropriateness of various monitoring methods and instrument types to meet an airport's specific needs. The guidebook also provides recommendations for setup, operation, and maintenance of each monitoring method.

Many airports have storm water management systems that require regular monitoring for deicing materials to comply with environmental permits or to support their storm water management needs. Yet airport personnel may not have the expertise to select the most appropriate monitoring methods to meet their unique situation. Moreover, there has been considerable industry uncertainty about the performance, reliability, and appropriateness of various methods for specific monitoring situations.

The research, led by Gresham, Smith and Partners, began with an assessment of current practice relative to on-site airport monitoring systems. Next, the research team reached out to non-airport contacts, including municipal water treatment facilities and those in the food and beverage, personal care products, brewery, and pharmaceutical industries, to see if any of their monitoring methods could be appropriately used in an airport setting. The research team also investigated emerging on-site monitoring methods. Based upon this research, the team developed the guidebook.

The guidebook is organized into six chapters, with the first chapter providing an introduction and overview. Chapter 2 gives guidance for determining the applicable monitoring parameters, which is the first step to selecting the appropriate monitoring method. The second step, described in Chapter 3, helps the reader in determining whether on-site or off-site methods should be used. Once the monitor type required for each parameter has been determined, the next step is selecting the monitoring method; to assist in this effort, Chapter 4 is supplemented with criteria tables. Chapter 5 provides guidance in selecting specific equipment types. Finally, recommendations for implementing the monitoring system are provided in Chapter 6.

The guidebook also includes helpful appendices that define relevant technical terms and provide sample outreach materials to help communicate the selection process to nontechnical stakeholders.

Technical information on various on-site monitoring methods is provided in a series of fact sheets. These fact sheets, which are organized by the parameter being monitored, describe key factors such as how the method works, its current level of adoption within the industry, implementation considerations, cost, and advantages/disadvantages.

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CHAPTER 1

Introduction

1.1 Applicability

Airports have complex storm water management systems because of their extensive areas of open space, variety of operations, history of expansion projects, and mix of extended paved areas and grass surfaces. Airport operators and tenants can apply a variety of deicing and anti-icing chemicals (collectively *deicers*) to clear ice and snow from aircraft and/or pavement depending on a variety of weather and operational factors. These deicers are mixed with storm water runoff and collected by the airport's storm water drainage system. Deicer-affected storm water runoff can be discharged to surface waters, municipal storm sewers, and publicly owned treatment works (POTWs) via a sanitary sewer system, as well as hauled off-site for processing or treated on-site. Some form of storm water monitoring is generally required to facilitate characterization and control the deicing discharges to one or all of these discharge or disposal locations.

Storm water monitoring is the act of obtaining a quantitative measurement of storm water characteristics. A monitoring *parameter* represents a particular type of storm water characteristic, which may be chemical (e.g., ammonia) or physical (e.g., temperature). Individual airport operators are often required by environmental permits to monitor their storm water for a variety of parameters at multiple locations and frequencies. Monitoring requirements may be imposed by environmental permits such as storm water discharge permits and permits to discharge to sanitary sewers. Airport operators may also choose to perform additional monitoring to support their storm water management needs.

To gather the needed parameter data, airport personnel must select appropriate monitoring methods. Airport personnel tasked with selection of storm water monitoring methods may not be familiar with the types of monitors available, ancillary infrastructure requirements, regulatory approvals, operation and maintenance requirements, or capital and operating costs. This *Guidebook for Selecting Methods to Monitor Airport and Aircraft Deicing Materials* (referred to hereafter as the *guidebook*) has been developed to provide airport personnel background information on the potential drivers for monitoring, monitoring parameters, types of monitors available, details on individual monitoring methods applicable and potentially applicable to airport applications, and information on the design and implementation of storm water monitoring systems.

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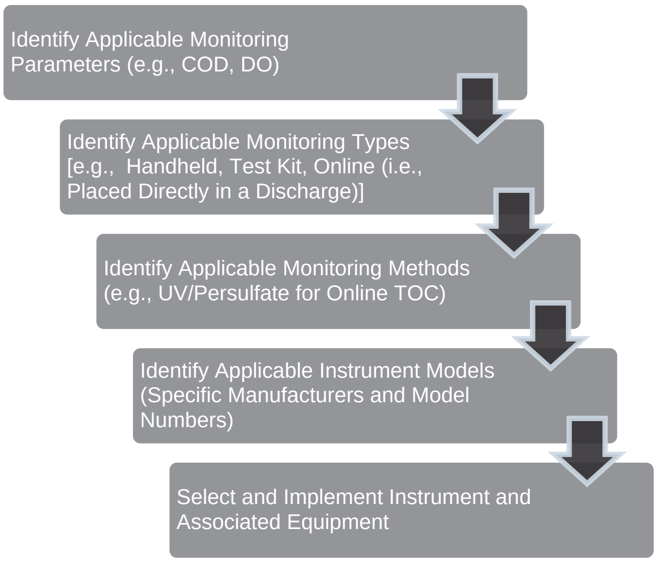
1.2 Process for Selecting a Monitoring Method



This guidebook provides a step-wise process for selection of applicable monitoring methods. The guidebook chapters contain descriptions of the individual selection process steps listed in the following bullets and provide critical background information on the particular topic area.

- Identify applicable monitoring parameters.
- Identify applicable monitoring types.
- Identify applicable monitoring methods.
- Identify applicable instrument models.
- Select and implement monitoring method.

The contents of the chapters are summarized in the following.

Chapter 2: Identify Applicable Monitoring Parameters presents information on the types of parameters that are commonly monitored in airport storm water. Background information is presented on reasons that storm water monitoring is typically required, including specific data needs. Parameters considered for this guidebook are defined, and the methods approved by the U.S. Environmental Protection Agency (EPA) and commonly used by analytical laboratories are listed. A parameter screening worksheet is included at the end of the chapter to aid in the parameter screening process.

Chapter 3: Identify Applicable Monitoring Types defines broad monitoring method types. The monitoring methods with common features are categorized into four monitoring types: test kits, handheld monitors, online monitors, and off-site methods. Monitoring method types tend to have common features, which allows for a screening process to occur at the monitoring type level.

Chapter 4: Identify Applicable Monitoring Methods provides the parameter-specific monitoring methods. Summary information for the methods is organized into criteria tables for comparison of methods by parameter so that the user can begin screening methods. Detailed information for each method is listed in fact sheets containing requirements and limitations of the methods.

Chapter 5: Identify Applicable Instrument Models offers advice on the selection of individual instrument models. Selection is an airport-specific procedure, and airport personnel will need to use their site-specific criteria for individual instrument selection.

Chapter 6: Implementation of Monitoring Systems presents information on the design and operational requirements associated with the monitoring methods. This information focuses on the ancillary infrastructure required to support methods as well as proper operation and maintenance procedures to facilitate the collection of accurate and reliable data for the airport.

1.3 Guidebook Scope and Use

This guidebook is organized to support informed selection of storm water monitoring methods for performing analysis of a parameter. An informed selection of monitoring methods requires both general information and site-specific knowledge. General information is the type of information that is applicable to most airports, such as maintenance requirements and

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method interferences. Site-specific information includes parameters that change from airport to airport, such as storm water characteristics and data requirements.

This guidebook assumes little advance knowledge on the part of the user regarding the monitoring methods or the data requirements. Airport personnel that are already familiar with portions of the selection process, such as the regulatory requirements or parameter definitions, may skip those sections and advance to the selection of monitoring types and monitoring methods.

In preparing this guidebook, the research team prepared a survey to determine the current state of storm water monitoring by airports. The survey was sent to a cross-section of airports in the United States and Canada. Several European airports were also sent the survey. The survey asked airport personnel responsible for storm water monitoring what storm water parameters were monitored, what monitoring methods were used, and the satisfaction with the monitoring methods at their airports. The results of the survey were used to determine the focus of the information presented in the guidebook. The survey results confirmed that the most complex monitoring methods had the most issues. Because of the issues with complex monitoring methods, they tended to receive lower satisfaction ratings. Primary issues experienced by airports tended to be associated with sampling and maintenance for online monitors. Although these monitors can provide accurate and frequent data, if the sampling and maintenance requirements are not understood, or their importance is ignored, the data obtained can be misleading or incorrect. Therefore, this guidebook considers the entire process of sampling and analysis and provides guidance on the issues that airports may experience because of their common storm water characteristics.

Airport operators who responded to the survey by indicating that they were currently using one or more monitoring methods were subsequently interviewed to determine satisfaction with the methods. Results of the surveys and interviews indicate that several airport operators have made improvements or adjustments to monitoring methods. Descriptions of the improvements and adjustments are included to assist other airport operators that may encounter similar issues.

Information in this guidebook was also gathered from manufacturers' literature regarding monitoring method capability and limitations. Manufacturers' literature was further categorized for easy comparison.

Other industries that perform storm water or wastewater monitoring were interviewed regarding the potential applicability of their methods to monitoring and analysis in the aviation industry. Manufacturers were interviewed and research publications were reviewed to determine if any method enhancements or new methods would be available in the near future.

1.4 Summary of Tips for Selection, Implementation, and Operation of On-Site Monitors

Tips for the selection, implementation, and operation of on-site monitors are as follows:

1. Selection of appropriate monitoring systems should take into consideration:
    - Parameters to monitor.
    - Monitoring types.
    - Monitoring methods.
    - Manufacturer.
    - Model.
2. The capital cost analysis should consider costs for:
    - Instrument.
    - Sample collection system.
    - Pretreatment and support systems.

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3. The annual cost analysis should consider costs for:
   - Utilities (chemicals, power, water).
   - Consumables.
   - Operation labor.
   - Maintenance labor.
   - Laboratory analytical work for calibration and correlation.
   - Parts replacement and repair.
4. Obtaining accurate readings for on-site monitors may require:
   - Understanding that many on-site monitors are not plug-and-play items. Airport operators must adapt the setup, operation, and maintenance of the units to the environment in which they are used.
   - Understanding of the range of instrument measurement capabilities.
   - Calibration of instrument to a standard single-constituent solution with a concentration determined at an analytical laboratory.
   - Automatic and periodic manual calibration checks.
   - Correlation factors derived from site-specific testing.
   - Appropriate scaling of instrument output.
   - Understanding of the effects of interfering constituents and conditions.
   - Regular maintenance.

If monitoring methods that have been successfully used in non-storm-water applications are considered, they need a critical assessment of their performance in a storm water and deicing environment. Extensive testing under actual monitoring conditions is recommended to understand potential operational issues.

A relatively small number of on-site monitoring methods have regulatory approval. A number of airports have successfully obtained regulatory approval for use of specific on-site monitoring methods for demonstration of compliance.

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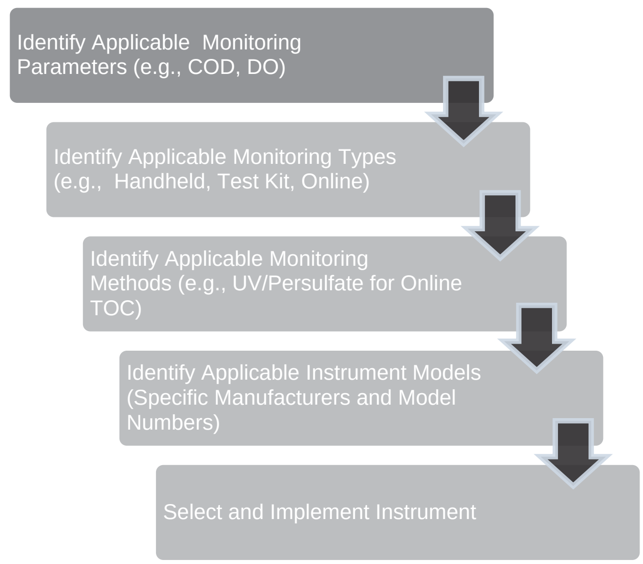
CHAPTER 2

Identify Applicable Monitoring Parameters

2.1 Parameter Screening



Storm water parameters may be monitored using traditional off-site methods where samples are collected at sample locations by automatic or manual means and sent to an off-site laboratory for analytical testing. Most often the laboratory analyses use methods that have been specifically approved by regulatory agencies such as the EPA. Off-site monitoring data are characterized by fewer samples of higher quality data but have potential for long delays between sampling and acquisition of analytical results.

Storm water parameters can also be monitored using on-site monitoring methods. On-site monitoring methods involve various combinations of sampling and analysis that all occur on the airport site. Some on-site monitoring methods are approved by regulatory agencies for use in compliance reporting, but many are not. On-site monitoring of data is characterized by the ability to collect a greater number of samples with a shorter delay between sampling and acquisition of analytical results.

This chapter describes a parameter screening process to guide users through the selection of parameters that will be monitored at their airport. Once parameters have been identified, airport personnel can use the parameter list to facilitate the identification of applicable monitoring types. The parameter screening process considers the potential sample requirements that exist at the airport for each parameter. A parameter screening form to aid in the selection process is included at the end of this chapter.

The screening for parameters to be monitored is performed by considering each reason that monitoring may be required (i.e., the drivers for monitoring). Each monitoring driver may result in a list of multiple parameters at multiple sampling locations. For example, an airport's National Pollutant Discharge Elimination System (NPDES) permit may list several outfalls, each with different monitoring parameters. In addition, there may be deicer management system processes that utilize monitoring to facilitate actions such as storm water diversion.

At each location, the critical function of each parameter should be considered to determine which monitoring method is appropriate for that parameter. The primary criteria for considering appropriate monitoring methods are the monitoring driver and the action that will be performed as a result of the measurement. Monitoring drivers with actions that will be performed immediately (i.e., storm water diversion) will require immediate monitoring results. Monitoring drivers with actions that can be delayed (i.e., percent deicer capture estimates) can be performed

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with delayed monitoring results. If a monitoring method for one parameter is to be performed on-site, it may be convenient for airport personnel to perform the analyses for the parameter from other sampling locations on-site as well.

2.2 Drivers for Monitoring

The need to monitor the characteristics of storm water discharges affected by airport and aircraft deicing materials is frequently driven by one of the following factors:

- Regulatory drivers based on compliance requirements in permits authorizing discharge of storm water.
- Process control drivers based on the need to direct and convey storm water to specific areas in a deicer management system.
- Tracking and accounting drivers based on the desire to quantify the constituents and characteristics of storm water.

Those drivers provide the information necessary to determine the parameters to be monitored, sampling types, analyses to be conducted, monitoring locations, and frequency of monitoring.

2.2.1 Regulatory Drivers

The Federal Water Pollution Control Act (FWPCA) of 1972, commonly known as the Clean Water Act (CWA), established the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters. Through Section 402 of the CWA, NPDES was created as a system for permitting point source discharges to the waters of the United States. The NPDES permit program generally requires that point source dischargers of pollutants to waters of the United States (i.e., direct dischargers) obtain an NPDES permit or their state equivalent.

The NPDES program addresses municipal sources from POTWs and nonmunicipal sources. Airports are generally regulated as nonmunicipal sources under the Industrial Storm Water Program element of NPDES, although regulation through other aspects of the program is possible, especially if the airport is regulated as a municipal entity or if an airport discharges into a municipal storm sewer system. In most cases, airports receive one of two types of NPDES permits for storm water direct discharges into surface waters associated with deicing: coverage under general NPDES permits or individual NPDES permits. General NPDES permits cover many facilities that have similar operations or similar types of discharges, whereas individual NPDES permits are issued based on site-specific activities or discharges. The NPDES permits contain five basic sections: a cover page, effluent limits, monitoring and reporting requirements, special conditions, and standard conditions. The information contained in a NPDES permit provides basic information on the pollutants to be monitored, the monitoring location, the sample type, and the monitoring frequency.

The CWA provides two levels of control for point source direct discharges to surface waters: technology-based limits (based on the ability of dischargers in the same industrial category to treat discharges) and water-quality-based limits (based on the water quality criteria and conditions of water bodies receiving the discharges). One or both of those means of permitting discharges may affect the specific numeric effluent limits contained in a NPDES permit. If both technology-based limits and water-quality-based limits are applicable for a given parameter, the most restrictive of the limits is incorporated into the permit. To this point, effluent limits in NPDES permits have been either water-quality-based or technology-based as derived from the best professional judgment of permit writers. Water-quality-based effluent limits and corresponding monitoring

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requirements can be derived from a variety of sources, including water quality criteria for specific sections of individual surface waters and total maximum daily load (TMDL) assessments, which allocate specific pollutant loads to particular discharges.

As of the date of this guidebook, the EPA was in the process of determining what, if any, national technology-based standards or requirements may be applicable to deicing activities at airports. Nationally applicable technology-based limits or requirements for deicing activities could be incorporated into NPDES permits by the state, tribal, or federal regulatory authority.

Some airports, or portions of airports, may be regulated as municipal separate storm sewers (MS4s). An MS4 is a conveyance or system of conveyances (including roads, catch basins, curbs, gutters, ditches, manmade channels, and storm drains) that is owned or operated by a public body, designed and used for collecting storm water, is not a combined sewer, and is not part of a POTW. An entity that is an MS4 requires an individual permit and programs that may include monitoring and control of pollutants within its drainage area. Some airports may also discharge into MS4s maintained by other entities such as municipalities. Those airports may have requirements for monitoring, practices, or controls for their discharges into the MS4.

The CWA also established a regulatory program to address indirect discharges from industries, including airports, to POTWs through the National Pretreatment Program, a component of the NPDES Permit Program. The National Pretreatment Program requires industrial and commercial dischargers, called industrial users (IUs), to obtain permits or other control mechanisms to discharge to the POTW. Such a permit may specify the effluent quality that necessitates that an IU pretreat or otherwise control pollutants before discharging to a POTW.

The conditions in the IU permits are necessary to allow POTWs to meet their own NPDES permit conditions. Since most municipalities issue local ordinances that identify the requirements for obtaining a user permit and authorize pretreatment permits, discharge parameters and conditions will vary. POTWs may also charge fees to permittees to offset the cost of treatment based on the pollutant concentration, pollutant mass loading, and/or volume of discharged storm water.

Both NPDES permits and IU permits from POTWs may incorporate effluent limitations and require periodic monitoring of discharges. The permits may also specify the acceptable laboratory analysis methods and provide requirements for monitoring type, monitoring frequency, and reporting. The conditions in NPDES, IU, and other permits typically provide airport operators with their initial drivers to consider for the need for and benefits of on-site monitoring of deicer-affected storm water.

Reasons On-Site Monitoring May Be Used for Permit Compliance

- The frequency of monitoring is high (e.g., more than once per day).
- The monitored location is remote and/or difficult to get to.
- Compliance points also serve as storm water diversion points.
- Compliance parameters are in terms of mass loadings, where frequent measurements of flow and concentration are used to calculate load.
- There is significant variation in concentrations that must be understood for compliance purposes.
- Fast response time to track changes in discharge characteristics is required or desired.
- If the permits require the airport to determine and report the percent of applied deicer that is collected.

In many cases, use of conventional off-site monitoring methods (grab or automatic sample collection plus laboratory analysis) will be sufficient to meet the parameter and sampling frequency requirements in NPDES and IU permits. Potential circumstances where use of on-site monitoring methods for regulatory compliance purposes may be beneficial are listed in the “Reasons On-Site Monitoring May Be Used for Permit Compliance” sidebar. Whatever the reason for using on-site monitoring for compliance purposes, it is critical to determine if use of the on-site method needs to be approved by the applicable regulatory agencies.

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2.2.2 Storm Water or Deicer Management System Process Control Drivers

Airports may find that it is beneficial or cost effective to use on-site monitoring as part of control systems for storm water or deicer management, even if that on-site monitoring is not used for compliance purposes. Potential uses for on-site monitors in storm water and deicer management systems include:

- Segregating or diverting storm water based on pollutant concentration (e.g., concentrations higher than a permit effluent limitation or concentrations that are internal control set points for further processing),
- Blending storm water streams of different concentrations together to facilitate more efficient treatment and reduction of peak concentrations in discharges, and
- Controlling flow or mass loadings into treatment systems or to POTWs.

Online monitors can be used as part of an automatic diversion or control system for storm water and deicer management. With an automatically controlled diversion system, measurements of particular storm water parameters made by the online monitor are sent to a control panel/computer that subsequently triggers a change to system equipment position or rates (e.g., gate, valve, or pump) that affects the storm water flow. This results in the ability to create separate streams of storm water runoff that can be managed according to their characteristics. Use of an automatically controlled diversion system frequently results in the need to convey, treat, and discharge smaller volumes of water than would be required if all storm water during the deicing season was collected and/or processed. The installation of an online monitor often allows for a reduction in storage capacity, pump capacity, pipe sizes, and treatment capacity, resulting in overall reductions in both capital and operating costs.

2.2.3 Tracking and Accounting Deicer

In some cases, airport operators may find that they are required to track and account for the quantity of deicer-related parameters in storm water. Typically tracked values may be flow rates, pollutant concentrations, and/or mass loadings for various parameters.

A need to track discharge quantities could be driven by:

- Tracking loads to POTW,
- Tracking loads or flows to surface waters,
- Tracking loads or flows in and out of on-site deicer treatment facilities,
- Calculating percent capture of applied deicer, or
- Calculating fees for flows or loads to surface waters or POTW.

An airport operator may need to track mass loads of pollutants to a POTW or surface waters to comply with discharge monitoring requirements. Similarly, an airport operator may need to track loads in the influent to an on-site treatment system or a POTW as a means of managing the flow rates. As flows and loads change in the storm water, the airport would have to measure both the flow and the concentrations to accurately determine the load rates, or may have to cease discharge if a maximum total has been reached. Since flow rate and concentration can change quickly, a large number of sample data points may be required to monitor the cumulative loading.

An airport may choose to determine the percent of applied deicer that is captured by a deicer management system. Total deicer applied could be determined from application records, with a factor applied for the percent of deicer available for capture, and then sampling results would be used to estimate the amount of deicer captured in the storm water collection system. Use of on-site

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Deicers in the Environment

The chemicals in deicers are regulated primarily because of their potential effects on aquatic life in receiving streams. These chemicals include the primary deicer constituent (typically propylene glycol) and the various additives. Potential negative effects on aquatic life can occur if the chemicals in deicers reach threshold concentrations and/or loadings under certain environmental conditions. The water quality standards can be based on potential toxic effects of individual constituents or on the cumulative effects of multiple constituents.

The most common effect of the primary deicer constituents in the environment and the most common reason for the regulation of deicer discharges are the effects that they have on the oxygen content in the receiving waters. When the primary deicer constituents are discharged, they can become a food source for bacteria in the environment. Bacteria also use oxygen when degrading primary deicer constituents. Primary deicer constituent concentrations can range into thousands of mg/L, leading to oxygen demands in a similar range. The saturation concentration of oxygen in surface water is between 6.6 mg/L (100°F) and 14 mg/L (32°F) (American Public Health Association et al., 2005, p. 4–139). As a result, far more oxygen can be consumed to degrade primary deicer constituents than is available in the water. When the temperatures and nutrients allow bacterial activity to occur in streams with deicer, oxygen concentrations can be depleted, negatively affecting aquatic life. Cold temperatures and nutrient limitation will limit the amount of bacterial growth, and reaeration of the stream will add in oxygen removed by the bacterial degradation of deicer.

monitoring (especially online) for deicer-related pollutants would be a good means of capturing the inherent variability in concentrations, thus providing a more accurate calculation of the deicer captured. In addition, if decisions based on the results require quick actions, such as storm water capture or adjustment to the sampling plan frequency or locations, then on-site methods may be performed to quickly determine the monitoring results.

Airports that discharge deicer to POTWs are billed for the load that they discharge. The loading is typically based on a unit price per pound of pollutant discharged. The amount is usually called a *surcharge* for wastewater concentrations that exceed the concentration typical of sanitary wastewater. The amount of deicer discharged to a POTW must be monitored for billing purposes. On-site or off-site monitoring may be performed to determine the storm water concentration for billing purposes.

2.3 Potential Monitoring Parameters

The potential monitoring parameters applicable to each airport are unique to the airport's permit conditions, deicer types, and deicer management requirements. The most common parameters are directly related to primary deicer constituents and include glycols, surrogates for primary deicer constituents, and ammonia. Commonly required monitoring parameters applicable to monitoring of general storm water quality include pH, dissolved oxygen, temperature, total suspended solids, and flow.

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Percentage of Surveyed Airports That Perform Monitoring for a Parameter

Glycols or surrogates (BOD, COD, or TOC)	67%
Ammonia	8%
pH	67%
DO	54%
Temperature	54%
TSS	4%
Flow	29%

A description of the most commonly encountered monitoring parameters is provided in the following sections.

2.3.1 Glycols

Glycols, especially propylene glycol and ethylene glycol (EG), are the primary deicer constituents serving as freezing point depressants in aircraft deicing fluids (ADFs) and aircraft anti-icing fluids (AAFs). Glycols are frequently included in airports' monitoring programs because of NPDES effluent limits or monitoring requirements. Glycols are also monitored at some airports with deicer treatment or recycling systems for the purpose of deicer management. Glycols are typically analyzed by collecting samples and shipping them to a laboratory. Because glycols are expensive to analyze at a laboratory and there is a significant delay for the results, the concentration of glycol in airport storm water is often determined by measuring concentrations of surrogate parameters and developing correlations to glycols, as discussed is Section 2.3.2 and 2.4.

2.3.2 Surrogates for Primary Deicer Constituents

The organic compounds typically used as the primary deicer constituents in ADFs and AAFs are propylene glycol, ethylene glycol, and (potentially) glycerin. The organic compounds serving as the primary deicer constituents in pavement deicers are formates, acetates, glycerin, and propylene glycol. Urea had historically been used as a pavement deicer and may still be used at some airports. Urea breaks down in storm water to ammonia and is discussed in Section 2.3.3. The term *deicer* as used in this guidebook will refer to either ADFs/AAFs or pavement deicers.

The primary deicer constituent concentrations in storm water are typically determined using a surrogate parameter. A surrogate parameter is a parameter that is measured instead of the desired parameter. The decision or need to use a surrogate parameter is often driven by the absence of direct means of measuring the parameter of interest or the ability to get better information when a surrogate is used. The specific surrogate parameter selected is typically chosen based on the data needs, ability to correlate results to deicer concentrations, frequency of data collection, time to complete the analysis, and cost. The most common surrogate parameters for the primary deicer constituents are listed in the following.

2.3.2.1 Biochemical Oxygen Demand

When biodegradable compounds degrade, dissolved oxygen in the water is consumed and there is a resulting oxygen demand. Biodegradable compounds in deicers include propylene glycol, ethylene glycol, glycerin, formates, and acetates.

Frequently, the oxygen demand is characterized by the parameter *biochemical oxygen demand* (BOD). The EPA-approved method for BOD used by certified analytical laboratories places a sample in a closed jar with bacteria and nutrients and measures the decrease in dissolved oxygen that occurs as the bacteria consume the pollutants. This biological degradation in the laboratory BOD test is similar to what can happen in the environment, and as a result BOD is often chosen by regulatory agencies as a monitoring and limited parameter in discharge permits. BOD limits and monitoring requirements are typically included in discharge permits when there is known potential for discharge of compounds that have a potential to decrease the dissolved oxygen concentration in the receiving waters. POTW permits for industrial users also often use BOD for monitoring and limits because those facilities have BOD limits in their own NPDES permits. The standard laboratory method for BOD is denoted as BOD_5, which indicates that the test is

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performed over a 5-day period. The BOD_5 analysis has several issues that may affect the ability to accurately measure the oxygen demand, including:

- The bacteria seed used may not be conditioned to the chemical(s) being tested,
- Toxicity in the sample may inhibit degradation and yield a false low result,
- There is often high variability in the sample results (Liptak 2003, p. 1226),
- Airport samples may contain samples with higher and more variable BOD concentrations than are typically seen from other industries, which requires sample dilution that introduces the possibility of error in the test results, and
- Five days are required to get a result.

The laboratory results for BOD_5 typically represent a conservatively higher oxygen demand than the oxygen demand in surface waters. The actual oxygen demand in surface waters will be limited because of in-stream conditions for nutrient availability, temperature, and bacteria availability. Low water temperatures typical of streams during deicing events typically inhibit biological activity and reduce the biological oxygen demand. However, some BOD analyses may result in low values if the laboratory uses a bacterial seed that is unconditioned to the deicer chemicals.

Carbonaceous BOD is a subset of the BOD analysis. Denoted as CBOD, it is the BOD caused only by the conversion of carbon to carbon dioxide. The CBOD therefore does not measure the oxygen demand from non-carbon sources such as ammonia. There are no on-site monitoring methods that measure only carbonaceous BOD. These analyses are typically performed in off-site laboratories.

2.3.2.2 Chemical Oxygen Demand

To avoid the issues with the BOD_5 method, the chemical oxygen demand (COD) parameter is sometimes used as a measure of oxygen demand. Rather than using bacteria, a COD test uses chemicals reacting with organic compounds to determine the oxygen demand. The chemicals oxidize the organic compounds. As a result, COD values are typically higher than actual in-stream oxygen demand from biodegradation because direct use of COD assumes that all of the chemically reactive compounds are biologically reactive. If both BOD_5 and COD are measured, the COD value should be larger than the BOD_5 value. This relationship can be used as a quick quality control check of the sample results.

In deicing monitoring, it is typically assumed that all of the COD contribution is attributed to deicers. However, there is generally a low, background contribution from other sources in storm water collection systems. The typical background concentration range can be determined by monitoring outside of the deicing season.

2.3.2.3 Total Organic Carbon

Another surrogate parameter to BOD_5 is total organic carbon (TOC). The TOC method converts all of the organic carbon in a sample to carbon dioxide and measures the amount of carbon dioxide produced. Because the conversion of organic compounds to carbon dioxide is essentially complete in a TOC analysis, TOC represents a more conservative representation of the potential oxygen demand. TOC correlates well with the concentration of organic compounds and to COD in water samples dominated by a single constituent (e.g., propylene glycol). In samples that contain a mixture of constituents, such as glycols, acetates, and formates, the correlations among TOC, COD, and BOD become less accurate.

2.3.3 Ammonia–Nitrogen

Ammonia–nitrogen is defined as the concentration of nitrogen contained in the compound ammonia in a water sample. Ammonia–nitrogen frequently appears in airport NPDES permits

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because most entities regulating water quality have numeric standards for the ammonia concentrations acceptable in surface waters. The standards exist because ammonia can be toxic to some kinds of aquatic life depending on temperature and pH (Levelton Consultants Limited, 2007, p. 40). Young life stages of some aquatic species are more susceptible to ammonia toxicity.

Historically, ammonia has been a significant consideration in airport NPDES permits stemming from the use of urea as a pavement deicer. Urea degrades in the environment into ammonia–nitrogen. With the conversion of much of the aviation industry to non-urea pavement deicers, the issues surrounding ammonia monitoring are less significant. However, ammonia–nitrogen can be present in current storm water discharges as a result of historical urea use. In addition, ammonia–nitrogen may be present in biological deicer treatment system discharges where nitrogen-based compounds are added as a nutrient from the biomass and in storm water runoff from areas where fertilizers have been used for landscaping or farms applications.

Whether an airport has an effluent limit for ammonia–nitrogen or simply monitoring requirements is dependent on a mathematical analysis of the reasonable potential that airport discharges will exceed the regulatory in-stream water quality criteria.

2.3.4 pH

The pH value is a measure of the acidity or alkalinity of a water sample. The pH scale uses values between 0 and 14, with values decreasing from 7 to 0 indicating strength of an acid and values increasing from 7 to 14 indicating strength of a base. Strictly speaking, pH is the measure of hydrogen ion concentration in water. Streams are typically near neutral, or have a pH of approximately 7. Surface water pH values further away from neutral will inhibit aquatic life. Water discharges with a pH value of less than 2 or greater than 12 are defined by the EPA as hazardous waste.

The pH values of storm water runoff can be affected by multiple conditions, including breakdown of primary deicer constituents on the airfield. Acidic conditions can occur when primary deicer constituents are exposed to warm temperatures, resulting in partial degradation of deicer by bacteria, which results in the byproduct formation of acids.

2.3.5 Dissolved Oxygen

Dissolved oxygen (DO) is a requirement for most aquatic life. Because of DO's importance to aquatic life, virtually all surface waters have DO numeric water quality standards for minimum in-stream concentrations. For some airports, outfall discharges are required to meet minimum DO concentrations.

The DO of a stream can be reduced as oxygen is used during biological breakdown of degradable chemicals. This is described in Section 2.3.2.1.

2.3.6 Water Temperature

Some surface waters have water quality standards for maximum temperature of discharges based on the type of aquatic life found in the area. If discharges have sufficient potential for high temperatures, NPDES permits may contain monitoring requirements and/or limits for maximum temperatures at various times of the year. The temperature of streams can also be important for airports because natural stream temperatures typically fluctuate with the seasons and reduce or accelerate the biological oxygen demands occurring in a stream.

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Discharges with temperatures above permitted levels can inhibit aquatic life. Temperature of storm water runoff from airports is typically not an issue; however, discharges from processes such as treatment or heating and cooling processes could be outside of the normal surface water ranges for a season. This may necessitate the need for monitoring and control of the temperature of the discharges.

2.3.7 Total Suspended Solids

Suspended solids in storm water runoff may pose threats to the environment because they can (1) cause sedimentation in a stream and harm benthic life, and (2) block light and inhibit aquatic life. Total suspended solids (TSS) are the class of solids that are associated with particulates from inorganic solids (e.g., silt, sand) or organic solids (e.g., biosolids or decaying vegetation).

Inorganic solids in discharges from airports may be the result of particulates from paved and unpaved surfaces as well as sand application to the ramp areas for traction. Although sand is not strictly defined as a deicer, it is applied at the same time as deicing chemicals. Organic solids may be present in airport discharges from deicer treatment systems or storm water storage systems as a result of the biological activities in those systems. Organic solids may also be present in storm water discharges from biological growths on airfield surfaces, soils, and infrastructure. When these growths occur in surface waters, they are often characterized as *nuisance growths.* Deposition of biological solids in a stream and their breakdown by bacteria can decrease the DO concentration as the bacteria in the stream degrade and consume oxygen in the water.

If the airport is required to determine if the solids in surface water samples are inorganic or organic suspended solids, a specialized solids analysis called *volatile suspended solids* will measure only the suspended solids associated with the organic solids. Instruments that measure solids in the field will only determine the TSS. The volatile fraction must be determined using off-site laboratory methods.

TSS limits and monitoring requirements in IU permits from POTWs are common. Many storm water NPDES permits contain monitoring requirements but not TSS limits. NPDES permits involving construction discharges or discharges from biological treatment systems are more likely to have TSS limits.

2.3.8 Flow

Monitoring or estimation of flow rates discharged from airport outfalls into surface waters is often required in discharge permits.

Monitored flow rates and volumes can be used in calculation of storm water discharge fees, for consideration of downstream erosion and flooding impacts, and in support of storm water runoff modeling.

Flow rates are also often used for calculation of mass loading rates (mass of pounds of the parameter in a time period). Calculated mass loads are generally required for deicer discharges to treatment systems or POTWs or for discharges to receiving waters with TMDLs. Loads in storm water can be compared to applied deicer usage records to determine the percentage of deicer collected.

Mass loading rates are calculated by multiplying the flow rate (volume per unit time) by the concentration of a given parameter (mass per unit volume). The loading is calculated by:

$$\text{Loading}(\text{lbs/day}) = \text{flow}(\text{gpm}) * \text{concentration}(\text{mg/L}) * 0.0120$$

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Or for metric units

$$\text{Loading}(\text{kg/day}) = \text{flow}(\text{m/day}) * \text{concentration}(\text{mg/L}) * 0.00100$$

Mass loads (mass of a parameter) are the loading rates multiplied by the time period of interest.

2.4 Correlation Between BOD/COD/TOC/Glycol

As discussed in Section 2.3.1, glycol analyses typically require off-site laboratory analyses and are expensive. Surrogate parameters that can be measured by on-site analyses are sometimes used to estimate the glycol or other primary deicer constituent concentrations in storm water based on correlations. Propylene glycol concentrations can be correlated to COD and TOC because of the oxidation reaction used in the monitoring methods. Correlation is defined as the mathematical relationship between the parameter values derived from different test methods.

The oxidation reaction of propylene glycol shown in the following equation is used as a basis for understanding the relationships of the parameters.

$$\underset{\text{MW 76.09 g/mol}}{\underset{\mathbf{C_3H_8O_2}}{\text{PROPYLENE GLYCOL}}} + \underset{\text{MW 32.00 g/mol}}{\underset{\mathbf{4\,O_2}}{\text{OXYGEN MOLECULE}}} \rightarrow \underset{\text{MW 44.01 g/mol, MW carbon 12.01 g/mol}}{\underset{\mathbf{3\,CO_2}}{\text{CARBON DIOXIDE}}} + \underset{\mathbf{4\,H_2O}}{\text{WATER}}$$

Where MW = molecular weight.

In the reaction, for every molecule of propylene glycol oxidized (chemically or biologically), four molecules of oxygen are consumed and three molecules of carbon dioxide are produced. The amount of oxygen required in a complete oxidation is known as the theoretical oxygen demand. Using the molecular weights, the following relationships can be found:

Propylene glycol concentration:	$1 * 76.09 = 76.09$ mg/L
Theoretical oxygen demand:	$4 * 32.00 = 128.00$ mg/L
Organic carbon (from carbon dioxide produced):	$3 * 12.01 = 36.03$ mg/L

For propylene glycol, the theoretical oxygen demand is essentially the same as the COD (Johnson, Varney, and Switzenbaum 2001, p. 17) because the COD test oxidizes virtually all of the propylene glycol in the sample.

Using the theoretical oxidation relationship, the correlations are:

$$\text{Propylene glycol concentration} * 128.00/76.09 = \text{COD concentration}$$

or

$$\text{Propylene glycol concentration} * 1.69 = \text{COD concentration}$$

and

$$\text{Propylene glycol concentration} * 36.03/76.09 = \text{TOC concentration}$$

or

$$\text{Propylene glycol concentration} * 0.474 = \text{TOC concentration}$$

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Correlations for other primary deicer constituents (i.e., ethylene glycol, glycerin, acetates, and formates) can be estimated using oxidation reactions in a similar manner. The relationships listed previously are for propylene glycol, and if other compounds are in the sample in significant concentrations, the correlation will change based on the oxidation reaction for the other compounds. Therefore, it is difficult to get good correlations to COD, BOD, or TOC for storm water samples if the primary deicing compound concentration is not significantly greater than concentrations of the other compounds in the sample.

The relationships listed previously are for propylene glycol as a pure compound. Correlation of a pure compound sample will result in a near-perfect linear relationship because only one compound is oxidizing and causing the oxygen demand and the carbon dioxide production. Correlation testing using a calibration solution will result in this type of relationship. The correlation to storm water samples will generally be good for high deicer concentrations but will become less accurate as the deicer concentration approaches the background concentration for COD or TOC.

A correlation for a calibration solution will give an incorrect assessment of the accuracy of the correlation for actual storm water samples—especially at low concentration. In storm water samples, other compounds may be present, including organics from deicer additives, contaminants, and breakdown products of the primary deicer constituents. These other organic compounds will have different correlations to the oxygen demand or the carbon dioxide production, causing deviations from the ideal, single-compound correlation.

Determining the correlation accuracy of deicer to COD or TOC at low concentration requires both the propylene glycol concentration and the COD or TOC concentration to determine the variability. Variability at low concentrations will be site-specific and will be caused by the individual sample stream water quality. Many measurements will be required to determine the variability. Measurements at higher deicer concentrations are not as critical because the oxygen demand (for COD) or carbon dioxide production (for TOC) will be almost completely from propylene glycol and therefore will approximate the ideal correlation. Measurements of both parameters (propylene glycol and either COD or TOC) for the correlation should be weighted to the lower concentrations to accurately determine the range where significant deviations from ideal correlation begin to occur. It is recommended that correlations below approximately 300 mg/L propylene glycol be checked for significant deviations.

Correlation of deicer to BOD_5 is performed by laboratory testing because there is no mathematical model to accurately estimate theoretical BOD_5. To develop the correlation to propylene glycol, for example, the ratio of BOD_5 to COD is determined through laboratory testing. The ratio is then inserted into the theoretical correlation between propylene glycol and COD. Literature values indicate that the ratio of BOD_5 to COD for a propylene glycol solution is approximately 0.55 (Johnson, Varney, and Switzenbaum 2001, p. 2). Using the relationship between BOD_5 and COD and the correlation between propylene glycol concentration and COD from before gives the correlation between propylene glycol and BOD_5 ($0.55 * 1.69 = 0.93$):

$$\text{Propylene glycol concentration} * 0.93 = \text{BOD}_5 \text{ concentration}$$

2.5 Using the Parameter Screening Worksheet

A parameter screening worksheet was developed for this guidebook to facilitate the screening of potential drivers for monitoring and to determine the parameters an airport needs to monitor. As each monitoring driver (i.e., NPDES permit discharge or storm water diversion)

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is reviewed for each required monitoring location, the worksheet can be used to document the findings for each required location. The monitoring drivers for each parameter can be indicated with check marks under the monitoring driver heading on the worksheet. The worksheet is used to organize the monitoring requirements for the airport. The data from the worksheet can be used as the baseline documentation for the remainder of the on-site monitoring screening process described in the next chapters.

Parameter Screening Worksheet

Airport: ______________________________

Sample Location: ______________________________

Analysis Performed by: ____________________ Date: ____________

Parameter	Monitoring Driver Required For:					Off-Site Method	On-Site Method			Method Number[1]
	NPDES Permit	Flow Diversion	Treatment Monitoring	San. Sewer Discharge	Other		Handheld	Test Kit	Online	
Glycol										
Biochemical oxygen demand (BOD)										
Chemical oxygen demand (COD)										
Total organic carbon (TOC)										
Ammonia										
pH										
Dissolved oxygen (DO)										
Water temperature										
Total suspended solids (TSS)										
Other 1:										
Other 2:										
Other 3:										
Other 4:										
Flow										

[1]See Table 4.7 for method numbers

Notes: ______________________________

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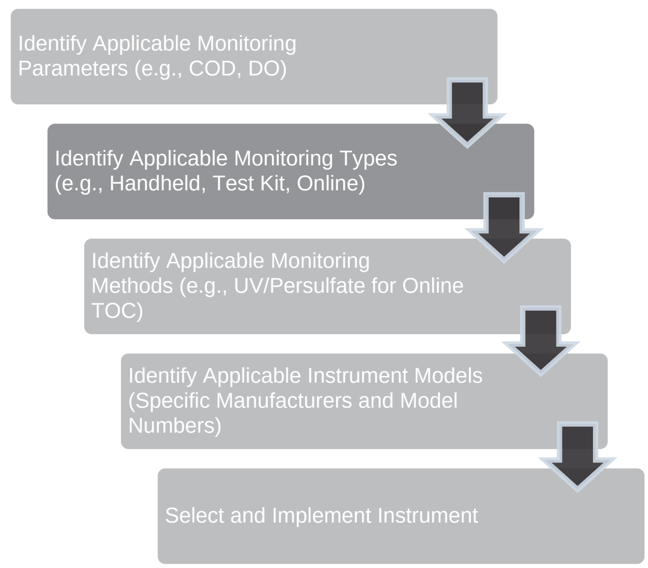
CHAPTER 3

Identify Applicable Monitoring Types

3.1 Screening of Monitoring Types

Monitoring type refers to the general means by which samples are collected and analyzed. For the purposes of this guidebook, *monitoring type* falls into two main categories:

- Off-site monitoring types, and
- On-site monitoring types.



Off-site monitoring refers to the most traditional type of monitoring—where the sample is collected on-site and is shipped off-site for laboratory analysis.

On-site monitoring refers to the type of monitoring where the sample is collected on-site and also analyzed on-site. In this guidebook, the on-site monitoring type is further divided into three subcategories: handheld, test kits, and online.

Monitoring type screening is performed to define which types of monitoring are appropriate for use at a particular airport. The airport operator can use the Parameter Screening Worksheet at the end of Chapter 2 as the starting point and select the monitoring types that are applicable for each parameter. Selection of monitoring types should take into consideration the data needs for each parameter at each monitoring location.

The first decision in the screening process is whether the samples should be analyzed off-site or on-site. The number of samples that must be collected to meet the data objectives, the timeframe when sample results must be known, the frequency at which data points are needed, and data quality requirements will be the determining factors as to whether an off-site monitoring type or on-site monitoring type is selected.

3.2 Off-Site Monitoring Types

The traditional means for collecting storm water monitoring data is by sample collection and off-site laboratory analysis of the samples. Samples are collected at the sites of interest, either manually or with auto-samplers, and sent off-site to an analytical laboratory. A wide variety of laboratory analytical methods are available. Although the laboratory monitoring methods associated with the off-site monitoring type can be more rigorous because of the quality control performed at laboratories and the fact that analyses are con-

Off-Site Monitoring Selected

√ Few samples required (i.e., daily).
√ Time delay for result is acceptable.
√ High data quality required.

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ducted in a controlled environment, the off-site monitoring type as a whole has several potential disadvantages, the severity of which is site-specific:

- Sampling, particularly if performed manually, can be expensive because of labor costs.
- The logistics and timing of dispatching sampling staff can be a challenge, especially if sampling sites are difficult to access or adverse weather presents a safety hazard.
- There are typically regulatory requirements for sample handling, transportation, and storage.
- Only the storm water characteristics at the time of sample collection are measured.
- It can be difficult to capture the variability of storm water characteristics or catch particular conditions, such as peak deicer discharge periods.
- Hold-over times for analytical samples can provide constraints in developing the desired sampling program.
- Typically there is a delay before results are available from the laboratory, ranging from 1 to 3 weeks.
- Real-time decisions cannot be made based on sample results.

Some parameters (e.g., temperature and flow) cannot be measured by off-site methods. Other parameters (e.g., pH, DO) have very short hold times, which typically precludes analyses by off-site methods for these parameters. The other parameters have on-site or off-site methods that may be applicable for monitoring airport storm water discharges.

3.2.1 Laboratory Methods Associated with Off-Site Monitoring

Table 3.1 lists the EPA-approved methods for storm water monitoring parameters typically applicable to airports. The methods listed in Table 3.1 are approved by the EPA for compliance with NPDES discharge permits.

Table 3.1. EPA-approved methods for the water quality parameters typical for storm water and deicer monitoring.

Parameter	EPA Method	Listed Detection Limit (mg/L)	Sample Handling Notes
Glycol	No specific EPA-defined method, typically modified EPA method 8015 is used, should be specified in permit	–	–
BOD	405.1	2	Hold time 48 hrs
COD	410.1 COD by titration – mid level	5	Hold time 28 days
	410.2 COD by titration – low level	5	Hold time 28 days
	410.4 COD by semi-automated colorimetry	3	Hold time 28 days
TOC	415.1 Combustion or oxidation	1	Hold time 28 days
	415.3 By UV absorbance (UVA) (drinking water method)	Approx. 0.1	Hold times 28 days (DOC)/48 hrs (UVA)
Ammonia	350.1 Ammonia by automated colorimetry	0.01	Hold time 28 days
	350.2 Ammonia by colorimetry	0.05	Hold time 28 days
	350.3 Ammonia by electrochemical	0.03	Hold time 28 days
pH	150.1 Electrochemical method	0.1[1]	15 min
	150.2 Electrochemical	0.1[1]	15 min
DO	360.2 Winkler method	Not available	8 hrs
	360.1 Electrochemical	Not available	15 min
Temperature	170.1 Temperature by thermometer	Not available	Must be performed in the field
TSS	160.2	4	7 days
Flow	Not available	Not available	Field

[1]Value is measurement precision.
Source: Methods for the Chemical Analysis of Water and Wastes (EPA 1983)

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3.3 On-Site Monitoring Types

On-site monitoring types involve on-site collection of samples and on-site analysis of the samples. The analyses associated with this monitoring type may be conducted right at the sampling location or somewhere else at the airport site. The analytical results from on-site monitoring are generally available much more quickly than the results associated with off-site monitoring, leading to better ability to make real-time decisions. The analytical methods associated with on-site monitoring are typically limited to those that can either be performed automatically or with a few simple steps.

On-Site Monitoring Selected

√ Many or continuous samples required.
√ Results used for real-time decisions.
√ Lower data quality is acceptable.

Less rigorous quality control is generally performed for the analytical methods associated with on-site monitoring as compared to the laboratory methods associated with off-site monitoring. For instance, laboratories typically will analyze samples spiked with compounds of interest to check for interferences and perform calibrations checks. These types of quality control sample checks are not typically performed with methods used in on-site monitoring. According to the manufacturers' information collected as part of this project, the accuracy of analytical methods associated with on-site monitoring is consistent with similar laboratory methods. Therefore, if the appropriate calibrations and maintenance are performed, and the user is knowledgeable in the use of the method, on-site monitoring can provide results that are as accurate as off-site laboratory methods.

3.3.1 Types of On-Site Monitors

Once the parameters that require on-site monitoring are identified, the next step in the process of implementing the monitoring system is selecting the monitoring types. The monitoring types, for purposes of this guidebook, are handheld, test kit, and online monitors. The monitoring types are defined in the following sections.

Selection of the proper monitoring type will allow for the desired monitoring approach to meet the data requirements while minimizing the maintenance needs of the system. For some parameters, some of the monitoring types are not available.

3.3.1.1 Handheld

As defined in this report, the term *handheld monitor* refers to any type of on-site monitor that is typically carried out to the sample site to perform the measurement (see Figure 3.1). Both the sampling of the water stream and the analytical function are accomplished by the portable monitor. Handheld monitors typically have an electrode that is inserted into the stream to be sampled. The most common of this monitoring type is the pH meter.

Figure 3.1. Example of a handheld monitor: a pH meter.

Handheld monitors are typically less expensive to purchase and require less capital for maintenance. Handheld monitors typically have low operation and maintenance (O&M) costs. The primary maintenance function typically required is calibration. Handheld monitors are generally easy to operate accurately with proper study and understanding of the instruction manual. Handheld monitors are portable and can be used for monitoring multiple locations; however, the units may have shorter service lives than the other types of monitors because they are subjected to field conditions. Monitoring only occurs when personnel are present to perform the monitoring.

Handheld monitors typically require periodic calibration, ranging from every few hours for pH meters to approximately annually (or longer) for temperature meters. Handheld monitors also typically require some maintenance, such as replacement of batteries, replacement of probes

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or probe membranes, and replacement of solutions. The maintenance is generally easier than the maintenance required for the equivalent laboratory equipment.

Handheld units are the most common type of monitoring for measuring pH, DO, and temperature.

3.3.1.2 Test Kits

Figure 3.2. Example of a test kit: a COD digester.

As defined in this report, the term *test kit* refers to any type of monitor system for which a sample is collected and analyses are performed by airport personnel on the airport site but away from the sample location—typically in an on-site laboratory area (see Figure 3.2). Test kit systems typically require reagents and require several steps for analysis. The most commonly used test kit system at airports consists of chemical test vials and a spectrophotometer.

Test kits are typically slightly more expensive than handheld monitors to purchase. Test kits typically have longer service lives than handheld monitors if they are maintained properly, but may require more capital expense for consumable parts than handheld units. The test kit methods range from easy to moderately difficult to use, depending on the procedures required for the parameter. Some test kits are portable and can be taken into the field, but typically analyses are performed in an on-site area set up as a laboratory.

The analytical instruments of test kits typically require periodic maintenance and calibration. Similar to handheld monitors, the maintenance is generally easier than the maintenance required for the equivalent laboratory equipment. The test kit methods for some parameters differ from the methods used at an off-site laboratory. Comparison of test kit results to off-site laboratory-based results is recommended to verify that results are sufficiently similar, especially at the extremes of the applicable concentration ranges.

Historically, test kit monitors were considered an easier-to-use, less sophisticated means of performing analytical testing at the sampling site. One of their primary advantages is faster turnaround time for analytical results. Test kit analyses could be performed very near to the sampling site—for example, in a vehicle at the sample collection site—which reduces sample holding time and reduces delay in getting analytical results. As technology has progressed, the boundary between test kits and some analytical methods performed by certified laboratories has blurred. An example of this is the COD analyses commonly performed on-site at airports, which are based on the laboratory method for COD analyses. There are now a wide variety of parameters that can be analyzed using test kits, although the number of parameters with available test kits is not as extensive as the number of parameters that can be analyzed with off-site analyses.

Some test kit methods have been approved for compliance purposes.

3.3.1.3 Online

Figure 3.3. Example of an online monitor: a TOC monitor.

Online monitors are permanently mounted devices designed to both sample flow streams and analyze the samples on a regular basis without direct involvement of facility staff (see Figure 3.3). The online monitors are the only type where the sample is analyzed directly without the sample-to-sample intervention of airport personnel. Automatic collection of data allows substantial quantities of data to be collected under a wide variety of conditions, eliminating the need to mobilize staff for limited sampling events. Online monitors also greatly increase the chances of characterizing unpredictable swings in storm water characteristics that are a common occurrence with deicer discharges.

Online monitors store the analytical data and most can transmit the data over computer or phone lines. Because online monitors collect and analyze samples automatically, data from online monitors can be used to make real-time decisions such as storm water flow diversion.

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While online monitors collect and analyze samples without facility staff present, staff involvement is necessary to facilitate calibration, verify results, troubleshoot, perform preventative maintenance, and achieve proper operation of the instruments. Without proper care and periodic personnel visits, data from online monitors could provide incorrect information, which may affect storm water and deicer management system control decisions. While the staff is needed for maintenance, the labor hours required per sample analyzed are typically far less than is required for monitoring types that require sampling by staff.

Online monitors take measurements one of two ways:

- A sensor is installed in the sample stream, or
- A sample is automatically collected and then analyzed within the unit.

For monitor types where the sensing unit is placed directly in the sample stream, periodic observation and maintenance of the sensors are required to verify that the sensor is submersed and clean. In storm water containing deicer, the sample streams can have significant biogrowth, and the electrode can become covered with the biogrowth. Electrodes should be cleaned periodically to prevent the build-up of biogrowth. Some of these submersible units have automatic cleaning functions that can reduce the need for manual cleaning.

For monitors that collect and analyze samples within a unit that is not directly submersed in the sample stream, a sample collection system is typically required to convey the sample to the monitor. The sample collection system includes pumps to continuously transfer samples of the stream to the unit, filters or other sample-conditioning equipment, and piping to deliver the sample to the monitor. Since the organic content is typically high, there can be biogrowth in sample systems such that they require cleaning. Inside the equipment, small-diameter tubing can also become clogged with biogrowth, requiring periodic maintenance of the unit.

Online monitors may not be truly continuous, depending on the method, because some units require discrete blocks of time to perform the individual analyses. Several minutes may be required for some methods.

Online monitors are generally more complex to operate and troubleshoot. Despite their sophistication and capabilities, online monitors are typically not plug-and-play. Airport operators seeking accurate and reliable results will need to understand that the units need to be set up, calibrated, and maintained in a way that takes into consideration the environment in which they are used, the characteristics of the samples they are measuring, and the data that are being sought. Online monitors require maintenance, periodic calibration, and checks by airport personnel. Several parameters require reagent tanks to be refilled periodically. Most units require temperature-controlled environments for electronic equipment and freeze protection of the sample or reagents.

Also, data may need to be downloaded in the field to maintain a historical record unless telemetry or a communication system is installed with the monitoring system.

Data Sondes

Data sondes are portable monitors that perform functions similar to a permanently mounted online monitor. Data sondes can be temporarily placed into a stream or storm water structure and left for an extended period of time to collect analytical data. The units can collect significant amounts of monitoring information at short measurement intervals using sensors installed in the instrument. The parameters measured are limited to those that can be analyzed using electrodes (i.e., ammonia–nitrogen, pH, DO, temperature, and TSS). Data sondes store the data internally in the data sonde hardware until the data are retrieved using a portable computer. Data sondes are most typically used for collecting data during studies such as water quality assessments. The battery life of a data sonde is approximately 30 days, and the memory capacity is approximately 190 days for multi-parameter-monitoring data sondes.

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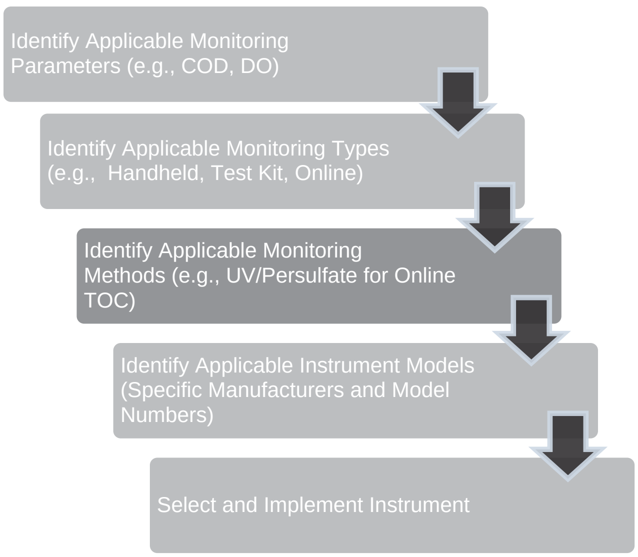
CHAPTER 4

Identify Applicable Monitoring Methods

4.1 Screening of Monitoring Methods



Once the monitor type required for each parameter has been determined, the next step in the instrument selection process is selecting the monitoring methods. The monitoring method is the specific process by which the parameter is analyzed. Each parameter may have several methods by which it can be analyzed. For example, temperature can be analyzed by infrared, thermocouple, glass-bulb, or other handheld methods.

Selection of the proper monitoring method will allow for the desired monitoring approach while minimizing the maintenance needs of the system. For each parameter, general background information and common monitoring method issues are presented in the following section.

4.2 Use of the Criteria Tables and Fact Sheets

Criteria tables and fact sheets were developed for this guidebook to organize the monitoring method selection process. Criteria tables are provided in Appendix A as a tool for comparing monitoring methods for each parameter. The fact sheets included with this report offer detailed information on each of the monitoring methods.

4.2.1 How to Use the Criteria Tables

The criteria tables are designed as a screening tool to narrow down the potential monitoring methods applicable for a particular parameter and sampling location. Handheld and test kit method criteria tables are separate from online methods. Critical features of the monitoring methods are compared head-to-head so that features important for the airport's specific needs can be weighted for the selection process. The site-specific requirements can then be weighted by airport personnel to aid in determining the best monitoring methods for the situation.

The criteria tables are divided into three parts: (1) method and use status, (2) implementation considerations, and (3) typical costs. Tables 4.1 through 4.3 provide the definitions and further information regarding the criteria used. The first section of each criteria table describes methods and typical uses (see Table 4.1). The second section of each criteria table presents implementation considerations (see Table 4.2). Finally, the third section of each criteria table discusses typical costs, including capital and operating cost ranges (see Table 4.3).

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Table 4.1. Criteria tables' method and use criteria.

Criterion	Description	Reason It Is Important
Method	Short description of the analytical method used to make the measurement	Some manufacturers' literature is ambiguous as to which method is used. Confirm with manufacturer when selecting equipment that the selected method is used.
Type (handheld and test kit only)	Method type	Differentiates between the two types of methods (handheld or test kit).
Demonstrated technology for airport storm water?	Defined as successful implementation at one airport for one entire season	Demonstration provides reason to believe the method can work at other airports, but is not a guarantee.
General availability of technology	Provides information on number of manufacturers supplying equipment using this method	Limited number of vendors may indicate that spare parts are difficult to get or method is not well used.

Table 4.2. Criteria tables' implementation consideration criteria.

Criterion	Description	Reason It Is Important
Regulatory-approved method	Does the method have a federal or local regulatory approval?	Significant consideration for NPDES discharge or compliance monitoring. Not important for internal monitoring.
Measurement range	Range in which method can accurately measure	Compare to the expected storm water range.
Accuracy	Measurement accuracy as a percentage of measurement	Provided by manufacturers. Other factors may influence the actual accuracy.
Siting constraints/needs (online only)	Utility or other needs for implementation	Getting utilities to the sampling point may be a significant cost.
Flow and stream constraints	Requirements for the sample collection	Sample stream may need continuous water supply or filtering may be required.
Interferences	Parameters that can cause a measurement malfunction	Determine if these are present in the storm water at critical concentrations.
Staff time requirements	Provides information on expected labor needs	Significant consideration for airports with limited environmental staff of for installations in remote locations.
Level of staff knowledge	Provides information on complexity of method	Consideration for potential staff training requirement.
O&M issues	Provides information on expected operation (including calibration) and maintenance labor needs	Significant consideration for airports with limited maintenance staff.

Table 4.3. Criteria tables' typical costs criteria.

Criterion	Description	Notes
Capital costs	Estimated range for cost of the equipment and installation for online equipment	Costs are in ranges so that qualitative comparisons can be made. Costs should be confirmed with suppliers during detailed comparisons.
Typical additional capital costs (online only)	Estimated range for capital cost for other recommended system equipment	Cost for utility connection and small shelter are not included.
Annual operation and maintenance costs	Estimated range for annual operating and maintenance costs	Contract maintenance costs typical for airports are included, but O&M labor by airport personnel is not included. The typical range listed under "Staff Time Requirements" should be used with the airport's labor rate to estimate the airport's labor cost.

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4.2.2 How to Use the Fact Sheets

The fact sheets in this guidebook are information sheets that summarize the technical capabilities and applicability for each monitoring method. The information in the fact sheets was derived from manufacturers' information and field operating experience gained from airports. The objective of the fact sheets is to present data on a monitoring method in sufficient detail to support final selection of a method. The fact sheets also provide information addressing implementation considerations.

The first section of each fact sheet summarizes the method and typical uses (see Table 4.4). The second section of each fact sheet describes implementation considerations (see Table 4.5). Finally, the third section of each fact sheet presents typical costs, including capital and operating cost ranges (see Table 4.6).

4.2.3 Typical Installation Location Criteria for Online Monitors

Online monitors are typically installed to measure the parameter of concern in one sample stream. The online monitor should be selected and optimized to work within the expected characteristics of the sample stream. Characteristics of sample streams associated with typical storm water drivers (see Section 2.2) can be used as criteria for locating online monitors. The criteria are also summarized in the on-site monitor fact sheets under "Typical Installation Locations."

4.2.3.1 Outfall Monitoring

Outfall monitoring is generally end-of-pipe monitoring or in-ditch monitoring where storm water is determined to be discharging into waters of the state (i.e., a receiving stream) or discharging from a process (i.e., treatment).

Since outfall monitoring tends to be for discharges to a receiving stream, the regulated levels of allowable deicer concentration (i.e., effluent limits) tend to be in the lower range, and the monitoring method requires high accuracy. Also, the primary deicer constituents generally are not significantly degraded, and correlation between surrogate parameters and deicer concentrations is generally accurate.

Table 4.4. Fact sheets' method and use criteria.

Criterion	Description	Reason It Is Important
Parameter	Parameter applicable to method	Note that the reported value may be correlated to the parameter rather than being a direct measurement of the parameter. See Chapter 5 for discussion.
Type	Method type	Differentiates between the three types of methods.
Method description	Short description of the analytical method used to make the measurement	Some manufacturers' literature is ambiguous as to which method is used. Confirm with manufacturer when selecting equipment that the selected method is used.
Level of technology development	Defines the range of years the technology has been in general use	Methods that are emergent (i.e., 1 to 5 years of general use) are more likely to have unknown issues than well-established methods.
Demonstrated technology for airport storm water?	Defined as successful implementation at one airport for one entire season	Demonstration provides reason to believe the method can work at other airports, but is not a guarantee.
General availability of technology	Provides information on number of manufacturers supplying equipment using this method	Limited number of vendors may indicate that spare parts are difficult to get or method is not widely used/researched.

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Table 4.5. Fact sheets' implementation consideration criteria.

Criterion	Description	Reason It Is Important
Typical installation locations	Examples of airport processes for which method is applicable	See following text for discussion of the airport processes.
Regulatory-approved method	Does the method have a federal or local regulatory approval?	Significant consideration for NPDES discharge or compliance monitoring. Not important for internal monitoring.
Measurement range	Range in which method can accurately measure	Compare to the expected range.
Accuracy	Measurement accuracy as a percentage of measurement	Provided by manufacturers. Other factors may influence the actual accuracy.
Response time	Typical time from sample collection to result	Consideration for systems that use results for diversion.
Siting constraints/needs (Online only)	Utility or other needs for implementation	Getting utilities to the sampling point may be a significant cost.
Flow and stream constraints	Requirements for the sample collection	Sample stream may need continuous water supply or filtering may be required.
Interferences	Parameters that can cause a measurement malfunction	Determine if these are present in the storm water at critical concentration.
Staff time requirements	Provides information on expected labor needs	Significant consideration for airports with limited environmental staff or for installations in remote locations.
Level of staff knowledge	Provides information on complexity of method	Consideration for potential staff training requirements.
O&M issues	Provides information on expected maintenance labor needs	Significant consideration for airports with limited maintenance staff.
Data retrieval	Typical communication connection supplied by manufacturers	Consideration for remote systems or automatic control of systems.
Recommended features	Recommended additional equipment of successful operation	Considerations for all airport installations.
Optional features	Additional equipment that may be required for successful operation	Considerations for special cases.

4.2.3.2 Flow Diversion Within a Storm Water Drainage System

Flow diversion is defined as a deicer management method where storm water drainage from a single stream is routed to multiple locations on the basis of the storm water characteristics. The most typical means for segregating portions of the drainage is on the basis of primary deicer constituent concentration.

The most effective means of flow segregation and diversion uses online monitoring systems to measure concentrations on a near-continuous basis, with the monitoring data transmitted to control systems that execute the mechanical diversion process. This is usually performed by online or frequent monitoring that triggers an action to divert storm water using equipment

Table 4.6. Fact sheet typical costs criteria.

Criterion	Description	Notes
Capital costs	Estimated range for cost of the equipment and installation for online equipment	Costs are in ranges so that qualitative comparisons can be made. Costs should be confirmed with suppliers during detailed comparisons.
Typical additional capital costs (online only)	Estimated range for capital cost for other recommended system equipment	Costs for utility connection and small shelter are not included.
Annual operation and maintenance costs	Estimated range for annual operating and maintenance costs	Contract maintenance costs typical for airports are included, but O&M labor by airport personnel is not included. The typical range listed under "Staff Time Requirements" should be used with the airport's labor rate to estimate the airport's labor cost.

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such as a valve closing or a pump activating. Online monitoring for the purpose of flow diversion typically requires monitoring accuracy in the middle range of deicer concentrations. In many cases, the online monitoring instrument and data transmittal settings are tuned to improve the accuracy at deicer concentrations near the diversion concentration. The accuracy of the monitors may decrease as the deicer concentrations move away from the diversion concentration.

4.2.3.3 Load Accounting Within a Deicer Management System

Load accounting is defined as a process by which the mass load of deicer is calculated based on flow rate and concentration data. Typically, accurate accounting for load requires online flow monitors and online concentration monitors. The online monitors must be capable of accurate measurements over a wide range of concentrations and flows. Some methods have wide ranges of accuracy but only at the lower or higher deicer concentrations. Load accounting may be performed for determining the percentage of deicer capture or for billing for deicer discharge to a POTW.

4.2.3.4 Treatment System Effluent Monitoring

Treatment system effluent is defined as a discharge that has undergone the treatment process. The treated effluent flow stream is assumed to be discharged to surface waters or a POTW. Since the deicer has been treated, the primary deicer constituents may not be present, but degradation compound may be present. Online monitors are used at some airports to measure concentrations of parameters such as BOD, COD, or TOC that are typically used to determine the treatment efficiency. The monitoring results could also be used for compliance purposes. The monitored effluent concentrations are typically in the lower range of measurable concentrations.

4.3 Descriptions of Monitoring Methods

The monitoring methods most typically applicable to deicer-affected storm water at airports are listed in Table 4.7 and are described in the following sections. The criteria tables for comparing

Table 4.7. Analytical methods by parameter and type of monitoring.

<table>
<tr><th rowspan="2">Monitor Type</th><th colspan="4">Parameter</th></tr>
<tr><th>BOD</th><th>COD</th><th>TOC</th><th>BOD/COD/TOC by correlation</th></tr>
<tr><td rowspan="3">**Online**</td><td rowspan="3">Biological oxidation (58)</td><td>Photochemical oxidation (59)</td><td>Thermal catalytic combustion (63)</td><td>Refractometry (66)</td></tr>
<tr><td rowspan="2">Electrochemical oxidation (60)</td><td>UV/persulfate oxidation (64)</td><td>Optical/absorbance (67)</td></tr>
<tr><td>UV/ozone oxidation (65)</td><td>Optical/absorbance, reflectance, and fluorescence (68)</td></tr>
<tr><td>**Handheld**</td><td>N/A</td><td>N/A</td><td>N/A</td><td>Refractometry (69)</td></tr>
<tr><td rowspan="2">**Test kits**</td><td rowspan="2">N/A</td><td>Photochemical oxidation (61)</td><td rowspan="2">N/A</td><td rowspan="2">Colorimetric (EG in water) (70)</td></tr>
<tr><td>Colorimetric (dichromate) (62)</td></tr>
</table>

Note: The fact sheet number is listed in parentheses under the analytical method.

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Table 4.7. (Continued).

<table>
<tr><th rowspan="2">Monitor Type</th><th colspan="5">Parameter</th></tr>
<tr><th>NH_3-N</th><th>pH</th><th>DO</th><th>Temp</th><th>TSS</th></tr>
<tr><td rowspan="3">Online</td><td>Colorimetric (71)</td><td>Glass electrode (76)</td><td>Amperometric/ polarographic sensor (82)</td><td>Thermocouple (88)</td><td>Scattered light detection (95)</td></tr>
<tr><td>Ultraviolet/ absorbance (72)</td><td rowspan="2">Glass free (77)</td><td rowspan="2">Optical/ fluorescence sensor (83)</td><td rowspan="2">Resistance-temperature detectors (RTDs)/ thermistors (89)</td><td>Optical/absorbance (96)</td></tr>
<tr><td>Ammonia selective electrode (73)</td><td>Laser diffraction (97)</td></tr>
<tr><td rowspan="5">Handheld</td><td rowspan="5">Ammonia selective electrode (74)</td><td>Glass electrode (78)</td><td>Amperometric/ polarographic sensor (84)</td><td>Infrared detector (90)</td><td rowspan="5">Optical/ absorbance (98)</td></tr>
<tr><td rowspan="4">Glass free (79)</td><td rowspan="4">Optical/ fluorescence sensor (85)</td><td>Bimetal (91)</td></tr>
<tr><td>Glass liquid thermometer (92)</td></tr>
<tr><td>Thermocouple (93)</td></tr>
<tr><td>Resistance-Temperature Detectors (RTDs)/ thermistors (94)</td></tr>
<tr><td rowspan="2">Test kits</td><td rowspan="2">Colorimetric (75)</td><td>Test strips (80)</td><td>Winkler titration (86)</td><td rowspan="2">N/A</td><td>Optical/ absorbance (99)</td></tr>
<tr><td>Colorimetric (81)</td><td>Colorimetric (87)</td><td>Laser diffraction (100)</td></tr>
</table>

Note: The fact sheet number is listed in parentheses under the analytical method.

handheld and test kit methods are presented in Appendix A. The criteria tables for comparing online methods are presented in Appendix A.

4.3.1 Deicer Parameters

Measurement of the concentration of the primary deicer constituents is required for most deicer management systems. When considering the methods for monitoring these deicer constituents, it is critical to understand that *there is no on-site monitoring method that directly measures the primary deicer constituents (glycol, formate, or acetate) in storm water*. Every on-site method used to measure concentrations of these constituents acts as a surrogate measurement by reacting a chemical with the deicer constituent and/or measures a physical response of the deicer constituent. The presence of multiple organic constituents (e.g., glycols plus acetates and formates from pavement deicers) may affect the accuracy of the on-site monitor output, especially if the instrument was not calibrated to multiple compounds or if the correlations for BOD, COD, TOC, and deicer constituents were not derived based on the presence of multiple deicer

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organic compounds. Therefore, care must be taken in interpreting the results from instruments used to measure these parameters.

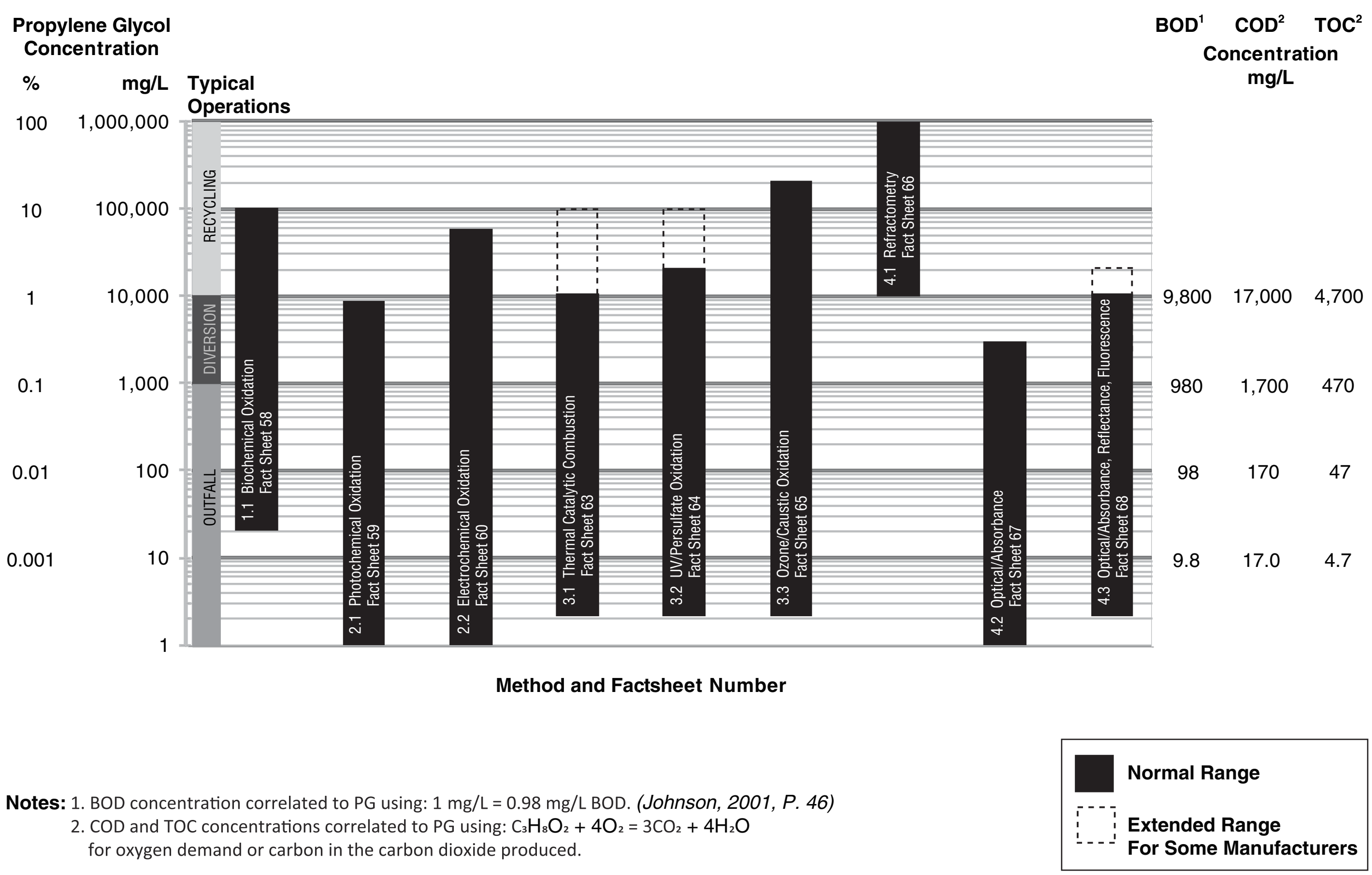
If the storm water is dominated by a single constituent (e.g., propylene glycol), with only minor contributions from other organics, then good correlations can be established between the measurements of surrogate parameters (COD, BOD, TOC) and the individual constituent [propylene glycol (PG) in this case]. The higher the concentration of the primary deicer constituent relative to concentrations of other organic compounds, the better the correlation.

When the deicer concentration is low, effects from other parameters in the storm water can be a significant part of the measured value of surrogate parameters. Although a monitor may be able to achieve accurate measurements at low concentrations when only deicer is monitored, the presence of other compounds in the storm water may determine the lower range at which the instrument accurately measures deicer concentrations. It is important, therefore, to determine if other compounds that could interfere with the measurement are present in the storm water in significant concentrations.

On-site monitoring methods for commonly identified parameters are discussed in the following sections. The typical measurement ranges of online deicer monitoring are compared in Figure 4.1.

4.3.1.1 Glycols

There are no on-site monitoring methods that measure glycols directly. Refractometers have acquired the reputation of measuring glycol because they most typically have been applied in



Notes: 1. BOD concentration correlated to PG using: 1 mg/L = 0.98 mg/L BOD. *(Johnson, 2001, P. 46)*
2. COD and TOC concentrations correlated to PG using: $C_3H_8O_2 + 4O_2 = 3CO_2 + 4H_2O$ for oxygen demand or carbon in the carbon dioxide produced.

Figure 4.1. Typical ranges for online deicer monitoring methods.

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deicer management systems to measure samples from areas of highly concentrated ADF application such as deicing pads. Refractometers, in fact, do not measure glycol directly. Refractometers measure the density of a sample by measuring the light-bending property (refractance). If multiple constituents with varying densities are in the sample, the ability of a refractometer to accurately measure glycol may be compromised. Only laboratory methods, such as the gas chromatograph/mass spectrometry method (GCMS), will accurately identify compounds as glycols and isolate the glycol fraction from other organics in the sample.

Refractometers have the capability of achieving good correlations with glycol concentrations. The correlation is generally good because refractometers are used at high glycol concentrations (>1% or 10,000 mg/L), where the effects of other constituents are small. In cases where glycol concentrations lower than 1% are to be measured, or where the storm water contains a variety of compounds in significant proportions, refractometers are not appropriate, and indirect analyses such as BOD, COD, TOC, or other surrogates to deicer are used to estimate the deicer concentration in storm water.

Refractometers are discussed in more detail in Section 4.3.1.5.1, Online BOD/COD/TOC by Correlation with Other Measurements.

4.3.1.2 Biochemical Oxygen Demand

For purposes of this report, all BOD monitoring methods, whether on-site or off-site, measure oxygen used in the degradation of biodegradable constituents by living bacteria housed in the monitoring device. The amount of oxygen consumed by bacteria to degrade the compounds is used to calculate oxygen demand expressed as BOD. Some methods or monitors can be set up to correlate their output to BOD—and may even have "BOD" or a similar biological reference in their name—but unless the method or monitor uses living bacteria, it is classified as a different monitoring method.

Because the online BOD monitor uses bacteria in the analysis of a sample, it is the closest online measurement to a BOD_5 analysis. In this regard it could more accurately estimate the oxygen demand in the receiving stream than COD or TOC.

One major difference between the laboratory BOD_5 methods and the online BOD monitor is the time that the compounds are exposed to the bacteria. For a standard BOD_5 laboratory test, the chemicals are exposed to the bacteria for 5 days. The oxygen used by bacteria in that 5-day period is measured and used to calculate the BOD_5. In a typical online BOD monitor, the contact time for the flow-through cell is approximately 4 min. The fact that glycols degrade quickly facilitates the likelihood of a correlation between online BOD, BOD_5, and glycol concentration with a short contact time. However, compounds that are more difficult to degrade may not be degraded significantly by the online BOD monitors because of the short detention time. Therefore the correlation to laboratory measurements (BOD_5) will be more difficult if there are difficult-to-degrade compounds. The presence of multiple biodegradable compounds in the storm water with different degradation rates also reduces the ability to achieve a satisfactory correlation with BOD_5.

Another difference between the laboratory methods and the online monitors for BOD is that the laboratory method for BOD_5 is performed at 68°F (20°C) (American Public Health Association et al. 2005, p. 5-5) and the online BOD monitor operates at 86°F (30°C). The differences in contact time and temperature may lead to different biological conditions and measurement responses. Therefore, online BOD should be considered a correlation to laboratory BOD_5 concentrations in a similar way to COD or TOC. As a result of the differences in test conditions, when using the online BOD instruments, it is important to field test the instrument output in response to samples with various combinations of expected constituents at known concentrations and compare the results to laboratory BOD_5 test results.

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There is a substantial start-up period for an online BOD monitor. The lengthy start-up period is required to develop a stable bacteria culture in the monitor. Several airports with BOD monitors will freeze the bacteria culture for storage over the summer and then thaw the frozen seed to start the culture the next season. This technique can shorten the startup period from 14 days to between 2 and 5 days. If a frozen seed culture is not available, splitting a culture from an operating BOD monitor will also reduce the start-up time. Otherwise, the bacteria culture must be grown using the bacteria in the storm water and a whole milk mixture recommended by the manufacturer.

During operation, if there is a sudden change in concentration, up to 45 min may be required for the online BOD monitor to stabilize on the concentration value. There is a delay in the result because the monitor increases or decreases the feed rate of the sample to the unit to achieve a constant DO decrease across the reaction chamber. The larger the concentration change, the longer the duration for the mechanical and biological system to stabilize on the new reading.

The online BOD monitor performs several functions to keep the bacterial culture alive. The monitor adds DO and nutrients to the water and heats the water to approximately 86°F. If a very high concentration spike or toxic material is fed to the monitor, the bacteria population will die and the bacteria in the monitor will have to be re-established.

Since the online BOD monitors use DO probes in the measurement, the items discussed in Section 4.3.4.1, Online DO, are also applicable.

Laboratory-grade equipment to perform BOD measurements on-site according to the EPA-approved method can be purchased. Analyses of samples on site using standard laboratory methods, other than the simplified methods mentioned in this guidebook, are considered the same as off-site laboratory analyses.

Other features of the online BOD monitors can be found on Fact Sheet 58.

4.3.1.3 Chemical Oxygen Demand

All COD monitoring methods use a chemical and/or an energy source (i.e., light or electricity) to degrade the deicers and other degradable compounds to carbon dioxide (CO_2) and water. The methods then measure the amount of oxygen used in the oxidation process to determine the primary deicer constituents and other degradable organic compound concentrations.

4.3.1.3.1 Online COD. Online methods for COD measurement include the photochemical oxidation method and the electrochemical oxidation method.

The photochemical oxidation method is a relatively new method that has no known applications at airports. The photochemical oxidation method requires filtration of the sample because solids can block the small-diameter tubing used in the monitor. The method does not generate hazardous waste like the EPA-approved method for COD because the photochemical oxidation method uses titanium dioxide and UV light rather than chromium and mercury. Other features of the COD photochemical oxidation method can be found on Fact Sheet 59.

The electrochemical oxidation method was used for several years at the Wilmington Air Park for monitoring the treatment system performance. The electrochemical oxidation method correlated well to laboratory COD analyses for short time periods; however, the calibration would fail at various times. It is suspected that pavement deicers were changing the conductance of the storm water and interfering with the instrument. The electrochemical method may be appropriate for monitoring conditions when only ADFs are present but should be avoided when there is potential for pavement deicers to be present. Other features of the COD electrochemical oxidation method can be found on Fact Sheet 60.

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4.3.1.3.2 Test Kits for COD. Test kit methods include the photochemical oxidation method and the dichromate method.

The test kit photochemical oxidation method is essentially the same process as the online method but performed manually on individual samples. The photochemical oxidation method is inexpensive to operate per sample, and results are available in a few minutes. The method generally correlates well with the EPA-approved method for COD. Other features of the COD photochemical oxidation method can be found on Fact Sheet 61.

The dichromate method is the EPA-approved method for COD analyses, is widely used, and is a very simple procedure. The dichromate method requires a 2-hour digestion period to chemically oxidize the organics, followed by a cooling period for the samples. The COD in the sample test tube is measured by colorimetric means in a spectrophotometer. This method also generates a hazardous waste because mercury and chromium are used in the reagents. The spent reagents must be disposed of as hazardous waste, and this increases the costs and labor required for performing the analyses. An alternate method that is not approved by the EPA does not include the hazardous metals as reagents. The acids in the non-approved method are not as strong; however, glycol is readily degradable and the test results should not be significantly different from the EPA-approved method. Airport personnel may wish to request that the alternate method be used for monitoring if COD parameters are not required for compliance monitoring. Other features of the COD dichromate method can be found on Fact Sheet 62.

4.3.1.4 Total Organic Carbon

On-site TOC monitoring methods are generally installed as online methods. TOC analysis performed by airport personnel according to the EPA-approved method is considered an off-site method for purposes of this guidebook.

All TOC monitor methods convert the organic portion of primary deicer constituents (glycols, acetates, formates) and other organic chemicals containing carbon to carbon dioxide. The TOC methods then measure the amount of carbon dioxide produced to determine the total concentration of carbon compounds (including those from deicers and other constituents). The methods use one of three oxidation methods to convert the organic chemicals to carbon dioxide: thermal (heat), UV/persulfate, or UV/ozone.

If the inorganic carbon content in the sample stream is high, measurement of low TOC values may not be accurate. One issue common to TOC measurements is that most monitors measure total carbon (TC) and total inorganic carbon (TIC) and then subtract the two values to get the organic portion or TOC. When two measurements that are nearly the same value are subtracted, the result has a high degree of uncertainty. A graphical illustration of using TIC and TC to determine the TOC is shown in Figure 4.2. TIC is mainly from carbonates, so in areas where groundwater has been in contact with limestone bedrock, the accuracy for low TOC concentrations may be an issue.

There are several methods available for measuring TOC. Each TOC method requires sample filtering because the monitors will not handle solids.

One method of oxidizing carbon for TOC is by using a furnace (thermal oxidation). The thermal oxidation method has a slight delay in start-up while the furnace comes up to temperature (a few hours). Manufacturers warn that high concentrations of dissolved solids (salts) can cause deposits in the furnace requiring early replacement of the furnaces. The thermal oxidation method also has a slightly higher utility demand than the UV/persulfate method. Other features of the TOC thermal oxidation method can be found on Fact Sheet 63.

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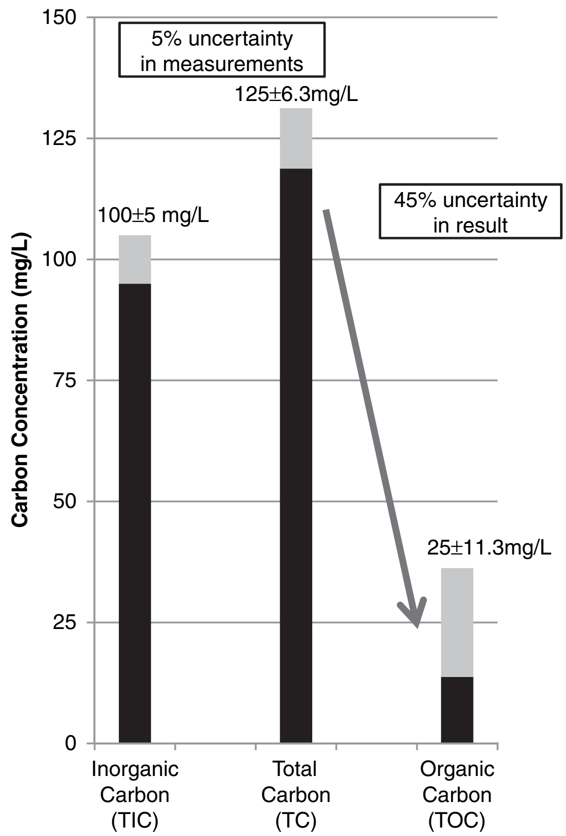

Figure 4.2. Example of organic carbon measurements and uncertainty.

TOC monitor usage tip:

High concentrations of inorganic carbon may affect low TOC concentration accuracy.

A second method of oxidizing carbon is by using ultraviolet light (UV) and persulfate to oxidize the organic compounds (UV/persulfate oxidation). The UV/persulfate method requires use of the chemical reagents sodium persulfate and phosphoric acid. Phosphoric acid is a strong acid and should be handled with care. Other features of the TOC UV/persulfate oxidation method can be found on Fact Sheet 64.

A third method of oxidizing organic compounds is by using UV, ozone, and a caustic (UV/ozone oxidation). The UV/ozone oxidation method requires the chemical reagent caustic soda, also known as sodium hydroxide. Caustic soda is a strong base and should be handled with care. Other features of the TOC ozone/caustic soda oxidation method can be found on Fact Sheet 65.

4.3.1.5 BOD/COD/TOC by Correlation

Monitors that measure BOD, COD, and TOC directly can be purchased. It is also possible to indirectly obtain BOD, COD, TOC, and PG output from virtually any on-site monitor measuring organic compounds through means of correlation. In the correlation method, monitor measurements can be converted to output in terms of BOD, COD, TOC, or PG through the use of mathematical relationships between the measured parameter and the desired output parameter. The correlated methods measure some feature of the chemicals in the sample and then correlate the measurement to a known standard.

It is important to note when setting up an instrument that correlation is not the same as calibration. Calibration is tuning the instrument output to a known standard for the instrument's

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inherent measurement parameter. Correlation is converting the instrument output from the instrument's inherent measurement parameter to another parameter through mathematical relationships developed offline. For some applications, only the calibration step is needed. In other applications, both the calibration and correlation step are required. To determine the calibration and correlation needs, it is critical to understand the instrument's inherent measurement parameter and the desired output parameter.

4.3.1.5.1 Online BOD/COD/TOC by Correlation with Other Measurements. BOD, COD, and TOC values can be obtained by correlation with refractometry measurements under certain conditions. Refractometry is a relatively quick and easy method used as a means of determining glycol concentrations greater than 1% when glycol is the primary constituent in the sample. At concentrations below 1%, refractometry often loses accuracy due to other compounds in the sample influencing the measurement.

Refractometry measures the light-bending property of a sample related to the sample density. At high concentrations, the density will be significantly related to the concentrated compound. At low concentrations, other parameters in the water will also have a significant effect on the density. Therefore, the correlation between refractometer measurement (density) and primary deicer constituent concentration will fail when other chemicals also have an effect. Because the concentration of other chemicals in the water is dependent on the site-specific conditions, the concentration at which the correlation between refractometer measurement and primary deicer constituent concentration ceases to be accurate is also site-specific. Example correlations of actual glycol concentrations to refractometer-measured glycol concentrations are presented in Figures 4.3 and 4.4. Other features of the refractometer method can be found on Fact Sheet 66.

Other online methods for getting output in terms of BOD/COD/TOC/PG through correlations generally use some kind of optical method. Optical methods include absorbance, reflectance, and fluorescence. Most chemicals will absorb light at several specific wavelengths. Chemicals may also reflect light at other wavelengths or fluoresce (give off light) under certain conditions. Optical monitors use absorbance at one or multiple wavelengths to determine the primary deicer constituent concentration. Glycols have poor absorbance response, so some manufacturers correlate to other constituents in the deicer. If the other constituents in the storm water change, for example by switching deicer manufacturers, the correlation would no longer be valid.

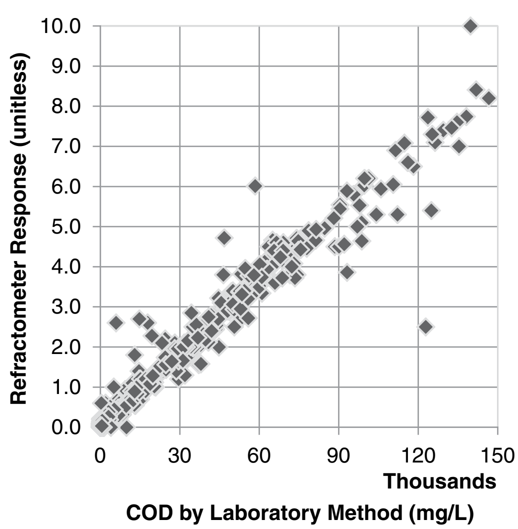

Figure 4.3. Online refractometer high-concentration correlation.

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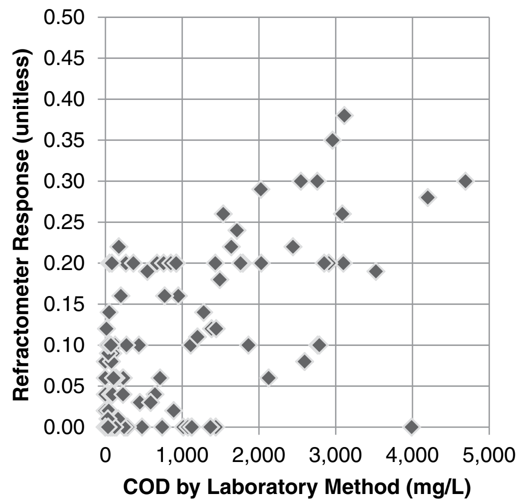

Figure 4.4. Online refractometer low-concentration correlation.

Solids in the water may interfere with the measurements. Also, bacterial growth may block the light used for measurement and cause maintenance issues. Other features of the optical methods can be found on Fact Sheets 67 and 68.

4.3.1.5.2 Handheld BOD/COD/TOC by Correlation. Correlations of BOD, COD, and TOC can also potentially be obtained using correlations to handheld refractometers. The handheld refractometer method has the same limitation as the online method regarding low concentration accuracy. Handheld units are generally not as accurate as online refractometer units because they are more influenced by field conditions. Laboratory refractometers tend to be the most accurate because of the clean environment; however, the limitation regarding other chemicals in the sample affecting the density measurement will lead to inaccurate correlations at low concentrations. Other features of the refractometer method can be found on Fact Sheet 69.

4.3.1.5.3 Test Kits for BOD/COD/TOC by Correlation. Test kits for EG in water were developed for use in boiler feed applications. These test kits measure PG in addition to EG. Since EG test kits were developed for specific concentration ranges and water that have few other interferences, the accuracy of this method for general storm water analysis is unknown. Test kits that measure glycols may be useful as presence/absence indication in the field. Other features of the test for EG in water can be found on Fact Sheet 70.

4.3.2 Ammonia–Nitrogen

Ammonia–nitrogen monitor methods use one of three ways to determine the concentration of ammonia: (1) the colorimetric method, (2) the optical method, and (3) the ion-selective electrode (ISE) method.

4.3.2.1 Online Ammonia–Nitrogen

Online monitors for ammonia–nitrogen also use the methods mentioned previously: colorimetric, optical, or ISE.

The colorimetric method collects a sample, reacts the sample with an indicator chemical, and measures the color response. Colorimetric method monitors require filtering of the samples

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because they do not tolerate solids. The monitors may also experience bacteria growth and plugging of the internal tubing. Other features of the colorimetric test method can be found on Fact Sheet 71.

Optical methods for ammonia–nitrogen are similar to the optical methods used in the BOD/COD/TOC by correlation method. The amount of ammonia–nitrogen in the sample is estimated by the absorbance of light at a specific wave length. Unlike glycol, ammonia–nitrogen has a strong absorbance. Similar to the other optical methods, solids in the water may interfere with the measurements, and bacterial growth in the monitors may block the light used for measurement. Filtering of the sample and regular cleaning of the optics is required for accurate measurements. Other features of the absorbance method can be found on Fact Sheet 72.

ISE methods use an electrode similar to a pH electrode. The electrode is inserted into the flow stream and connected to the monitor unit. If deicers are also present to provide a food source, bacteria may grow and cover the electrode in slime. The slime will degrade the primary deicer compounds to form acids, which will cause the electrode to measure a pH that is more acidic than the stream concentration. Automatic cleaning systems are recommended to extend the duration between manual cleanings. Other features of the ISE method can be found on Fact Sheet 73.

4.3.2.2 Handheld Ammonia–Nitrogen

Handheld ammonia–nitrogen meters use the ISE method. The electrodes, like the online versions, are similar to pH electrodes. Electrodes must be stored in damp conditions and calibrated prior to measurement. Calibration of an ISE probe is similar to calibration of a pH probe using two buffer solutions. Other features of the ISE method can be found on Fact Sheet 74.

4.3.2.3 Test Kits for Ammonia–Nitrogen

Test kits for measuring ammonia–nitrogen use the colorimetric method. The colorimetric method may require some simple laboratory preparation of the samples. Samples may have to be filtered if the solids concentration is high. See Chapter 5 for a discussion of laboratory accessories that improve the efficiency of sample analyses.

Other features of the colorimetric method can be found on Fact Sheet 75.

4.3.3 pH

Monitoring methods for pH use either the ISE method or colorimetric method to determine the pH concentration.

4.3.3.1 Online pH

Online monitors use ISE methods to determine the pH. The pH electrodes come in two different forms: glass and non-glass electrodes.

Glass electrodes are the most common type of pH electrode. The electrode is inserted into the flow stream and connected to the monitor unit. Because the tip of the electrode has a glass bulb, it must be protected from damage from solids in the stream or contact with the walls.

If deicers are also present in the stream to provide a food source, bacteria may grow and cover the electrode in slime. Slimes may produce acidic products and will cause the electrode to read more acidic. The actual pH value of the stream may not be significantly affected by the slime, and measurement of the electrode will be inaccurate for the stream. Automatic cleaning systems are recommended to extend the duration between manual cleanings, but automatic cleaning

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will not completely replace manual cleaning. Periodic calibration and electrode cleaning are the two most important elements of successful pH monitoring. Other features of the glass electrode method can be found on Fact Sheet 76.

The non-glass electrodes are less susceptible to damage and hold a calibration slightly longer. Non-glass electrodes were developed for the food industry. These electrodes are more expensive than similar glass electrodes and may not be suitable for long-term deployment in a storm water stream (Schaepman 2005). Other features of the non-glass electrode method can be found on Fact Sheet 77.

4.3.3.2 Handheld pH

Methods for handheld monitors use glass or non-glass electrodes similar to the online methods. Care and maintenance are similar for the two types of electrodes. The non-glass electrodes are slightly less susceptible to damage and are slightly more expensive. Other features of the glass electrode method can be found on Fact Sheet 78. Other features of the non-glass electrode method can be found on Fact Sheet 79.

4.3.3.3 Test Kits for pH

Test kit methods for pH use either test trips or a colorimetric method.

Test strips are easy-to-use, disposable paper strips. They are generally made for a specific pH range. The test strips are inserted into the sample and then compared to a color chart. If the test strips get wet prior to use, they should not be used for measurement. Test strips give qualitative results (i.e., test strips give a range of concentration that the pH is within and not a specific value). Because test strips are qualitative, they may not be accepted by regulatory agencies for discharge monitoring. Other features of the test strip method can be found on Fact Sheet 80.

Colorimetric methods use an indicator chemical that changes color depending on the pH concentration. The indicator is accurate only within a range of pH values, and a sample with high turbidity or existing color may make reading of the color difficult. To obtain a pH value, the sample color is compared to a color chart, or a colorimeter or spectrophotometer can be used to read the intensity of the color to obtain a precise pH value. Other features of the colorimetric method can be found on Fact Sheet 81.

4.3.4 Dissolved Oxygen

4.3.4.1 Online DO

Online DO monitors use one of two types of DO method: the amperometric method or the optical method.

The amperometric method has been the industry-standard method for measuring DO for many years. Obtaining accurate and consistent results using this method requires periodic membrane replacement of the electrode. The installation of the membrane is not a simple procedure. During use, the membrane can foul or tear, leading to inaccurate measurements. The electrode tip near the membrane needs to be kept clean because bacterial growth near the tip will consume DO local to the electrode and will cause a lower DO measurement than what is in the sample stream. The frequency of cleaning can be high in streams containing deicer. Other features of the amperometric method can be found on Fact Sheet 82.

The optical method uses light to detect the DO of the sample stream. The optical method consumes DO near the electrode, so if the stream is stagnant and the DO is low, the electrode will consume all of the DO local to the electrode and read a concentration lower than the actual DO of the sample stream. Consumption of DO by the electrode is not an issue when the stream is moving.

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Optical electrodes generally hold their calibrations longer than amperometric electrodes because they are less influenced by biofouling. The electrode for the optical method requires much less maintenance, but still requires cleaning to prevent bacterial growth on the electrode. Other features of the optical method can be found on Fact Sheet 83.

4.3.4.2 Handheld DO

As with online units, handheld DO monitors use amperometric or optical electrodes. The issues with the electrodes are similar to the online methods. Care and maintenance of the electrodes during storage are critical to long-term, accurate measurements. Handheld DO monitoring may be subject to inconsistency because of variation in the sample point from one monitoring event to the next. Other features of the amperometric method can be found on Fact Sheet 84. Other features of the optical method can be found on Fact Sheet 85.

4.3.4.3 Test Kits for DO

Test kits use either the Winkler method or the colorimetric method.

The Winkler method was the initial laboratory method to determine DO concentration. The method is complex, labor intensive, and requires multiple titration steps. The method has been extensively tested in a wide variety of water samples because it was the primary method for determining DO for over 100 years (American Public Health Association et al. 2005, p. 4–136). Other features of the Winkler method can be found on Fact Sheet 86.

The colorimetric method uses an indicator chemical to determine the DO concentration. The indicator compound reacts with DO in the sample and changes color, similar to a pH indicator. A sample with high turbidity or existing color may make reading of the color difficult. To obtain a DO concentration, the sample color is compared to a color chart, or a colorimeter or spectrophotometer can be used to read the intensity of the color to obtain a precise DO concentration. Other features of the colorimetric method can be found on Fact Sheet 87.

4.3.5 Water Temperature

4.3.5.1 Online Temperature

Online water temperature monitors use either the thermocouple method or resistance-temperature detector (RTD) electrode method. In practical use, the thermocouple and RTD methods are similar. The electrode is placed in the sample stream and connected to the monitor.

Some other monitor units for other parameters may also measure the water temperature internal to the units. However, if the monitor is one that requires a sampling system, the sample passing through a pump and into a heated shelter may be several degrees warmer than the ambient water temperature, so temperatures measured by online monitors may not be appropriate for airport storm water monitoring. Other features of the thermocouple method can be found on Fact Sheet 88. Other features of the RTD method can be found on Fact Sheet 89.

4.3.5.2 Handheld Temperature

Handheld monitors use several different methods to measure water temperature. The methods include the infrared method, bimetal thermometer method, glass thermometer method, thermocouple method, and RTD method.

Infrared monitors measure the infrared radiation from an object. Infrared monitors only measure the surface temperature, so if there are solids or ice on the surface, the infrared monitor will not measure the true water temperature. The infrared method may be applicable where access to the water stream is limited. Other features of the infrared method can be found on Fact Sheet 90.

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Bimetal thermometers have a dial readout and are the type used as oven or grill thermometers. Bimetal thermometers are sturdy for field use but slower to react to temperature changes. Accuracy of the reading is dependent on the scale of the dial used. Other features of the bimetal thermometer method can be found on Fact Sheet 91.

Glass thermometers are the typical fluid-filled, glass-tube thermometers that are familiar to most people. Thermometers were historically typically filled with mercury, but other fluids are now more common because of the toxicity of mercury. Because glass thermometers are fragile, they are not recommended for field use, and mercury-containing thermometers should never be used in the field. Other features of the glass thermometer method can be found on Fact Sheet 92.

Thermocouple and RTD monitors are similar to the online monitors. Other features of the thermocouple method can be found on Fact Sheet 93. Other features of the RTD method can be found on Fact Sheet 94.

4.3.6 Total Suspended Solids

4.3.6.1 Online TSS

Online monitors for TSS use one of three methods: (1) the scatter method, (2) the optical method, and (3) the laser method. The TSS methods are actually turbidity measurements that are correlated to TSS concentration. Turbidity is the cloudiness in water caused by suspended particles.

All of the methods for TSS require maintenance to keep the monitors clean. Sample streams that contain deicers tend to have bacterial growth that will need to be cleaned from the measurement section of the sensors.

The scatter method is the standard turbidity measurement that measures the amount of light that is scattered at an angle from a beam of light. The standard turbidity measurement using the scatter method is referred to as nephelometric turbidity (measured in nephelometric turbidity units, or NTUs) and measures the light intensity at a 90-degree angle from the light beam. Other features of the scatter method can be found on Fact Sheet 95.

The optical methods use absorbance of light beams by the sample to correlate to the TSS concentration.

Other features of the optical method can be found on Fact Sheet 96.

The laser method is similar to the scatter method except that a laser is used to provide the light source. Other features of the laser method can be found on Fact Sheet 97.

4.3.6.2 Handheld TSS

Handheld monitors use an optical method similar to the online monitor. Other features of the optical method can be found on Fact Sheet 98.

4.3.6.3 Test Kits for TSS

Test kits use optical methods or laser methods similar to the online monitors. Other features of the optical method can be found on Fact Sheet 99. Other features of the laser method can be found on Fact Sheet 100.

4.3.7 Flow

Flow is generally defined as a unit of volume passing a point over a period of time. Typical reporting units for storm water flow include cubic feet per second (cfs), million gallons per day (mgd), or gallons per minute (gpm). Measurement of flow is typically required by discharge

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monitoring permits and sewer discharge permits. Monitoring methods are generally divided by two field conditions: full flow in pipes and partial pipe flow or open channel flow.

4.3.7.1 Monitoring in Pipes Flowing Full

Determining the flow rate of a pipe that is flowing full requires only measurement of the velocity and knowledge of the cross-sectional area based on pipe size [flow (Q) equals velocity (V) times cross-sectional area (A)]. Several types of meters are available for full-pipe flow applications. Only flow meters that are intended for use with flow that has solids should be used for storm water applications. Magnetic flow meters (magmeters—see Figure 4.5) are the most common flow meters for full-pipe flow applications for storm water applications. Magmeters are installed directly in a pipe to measure velocity and calculate flow based on the known cross-sectional area. Their readings are highly accurate when a pipe is under full flow conditions, and as such they are most frequently used in force mains under pressure. Use of magmeters in gravity piping presents risks since often the gravity storm drain pipes are not flowing full. If a pipe is not flowing full, the velocity readings from the magmeter and the calculated flow rate (which assumes full diameter of the pipe being used) will be in error.

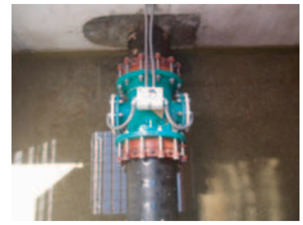

Figure 4.5. Example of a magmeter.

4.3.7.2 Monitoring in Pipes Not Flowing Full or in Open Channels

Determining the flow rate of a pipe that is not flowing full or in an open channel is more difficult than for pipes flowing full. The accuracy of results from non-full pipes or open channels is typically less than for full pipes. As a result, care must be taken when comparing flow rates based on different measurement methods. Flow monitoring methods in non-full pipes and open channels include flumes, weirs, and area-velocity meters.

4.3.7.2.1 Flumes. The most accurate method of flow measurement for open channel flow over a wide range of flow rates is a flume (Grant 1995, p. 60). A flume is a designed flow constriction in which the flow rate is related to the water level in the flume. An automatic and/or manual level-sensing instrument is part of the flume device. The accuracy of the flow measurement is related to the device used to make the level measurement and is within approximately 2% for most applications. Several types of flumes have been developed, but the most common is the Parshall flume (see Figure 4.6).

Figure 4.6. Example of a Parshall flume.

There are three critical considerations associated with use of flumes for monitoring storm water flow:

1. Capital expense for installation,
2. Size needed to capture the defined flow range, and
3. Handling and management of solids.

In a new storm water system being designed with flow monitoring needs, flumes should be considered in the design first. Retrofitting existing storm water systems to incorporate flumes can be costly. Flumes can be placed in large manholes or at the discharge end of the system. Placement of a flume requires consideration of the downstream hydraulics. A Parshall flume can tolerate slight submergence of the discharge end, but the discharge flow must generally be free-flowing or unobstructed. Obstruction of downstream flow will interfere with the flow measurement. If flow is obstructed (i.e., there is a downstream constriction that causes water to back up) and the obstruction cannot be removed, then a flume cannot be used.

Flumes are sized for the expected flow range. Therefore, the hydraulics of the upstream system must be known to determine the flume size. The maximum flows and associated pipe diameters at a typical slope (1%) for Parshall flumes are listed in Table 4.8.

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Table 4.8. The maximum flows for Parshall flumes and example storm sewer system sizes.

Flume Size (ft)	Maximum Flow (gpm)	Size of Concrete Pipe Flowing Full (in.)
0.75	3,980	15
1	7,240	18
2	14,900	24
3	22,600	30
4	30,500	30
5	38,400	36
6	46,400	42

Notes: (1) Flume size for Parshall flumes is the width of the throat.
(2) Maximum flow is for 2 ft of head for a 0.75-ft flume and 2.5 ft of head for larger flumes.
(3) Concrete pipe is for a 1% slope with a Manning friction factor of 0.013.
Source: Grant 1995, p.74.

Care must be taken in using flumes to measure the full range of flows in storm water drainage structures. Peak flows can often exceed the capacity of the flume, and flow measurements will give inaccurate results if the water levels exceed the flume height.

Smaller Parshall flumes may trap solid objects because of the narrowing of the flow in the throat. Tree branches or ice have been known to get caught in flumes and disrupt the flow measurement. Access to the flume should be included for cleaning of the flume as well as level instrument maintenance (See Chapter 5).

Figure 4.7. Example of a weir.

4.3.7.2.2 Weirs. A weir is a raised obstruction in the flow—generally a metal plate or flat concrete surface—that causes water to flow over it (see Figure 4.7). The water level upstream of the weir is related to the flow rate. An automatic and/or manual measuring device is part of the weir device. Two common types of weirs are the v-notch weir and the rectangular weir. A v-notch weir is a plate with a "v" shape cut into it with a defined angle. A rectangular weir is a horizontal plate. For storm water systems, v-notch weirs are typically used for low flow measurements, and rectangular weirs are used for high flow measurements. The accuracy of the flow measurement is related to the device used to make the level measurement and is within approximately 2% to 5% for most applications.

Water must freely discharge over the weir. Obstruction of downstream flow will interfere with the flow measurement. If flow is obstructed (i.e., there is a downstream constriction that causes water to back up) and the obstruction cannot be removed, then a weir cannot be used.

Because water must flow over a weir freely, floating solids that tend to get caught on the weir disrupt the flow measurement. Also, because water ponds upstream of a weir, solids will settle behind the weir. Frequent removal of the floating solids and periodic removal of the settled solids at the weir are required to maintain accurate flow measurement.

Weirs placed in the flow path of a pipe, culvert, or open channel may also reduce the peak flow capacity of the conveyance structures when the structures are flowing full. The loss of flow capacity can be calculated with basic hydraulic calculations and should be checked before a weir is installed.

4.3.7.2.3 Area-Velocity Meters. Area-velocity meters measure both the depth of flow and the velocity to determine the flow rate. Area-velocity meters do not require a flow-altering device such as a weir or flume. Instead they rely on velocity measurement, flow depth

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Table 4.9. Estimated minimum measurable flow rates for area-velocity meters in various sized pipes.

Pipe Diameter (in.)	Minimum Detected Flow (gpm)
12	25
18	32
24	38
36	45
48	52

measurements, and a calculation of flow rate based on the shape and size of the conveyance structure.

Area-velocity flow meters have technology-based limits on capabilities at the lower end of both depth and velocity measurements. Most units place a sensor in the bottom of the pipe that measures the flow velocity rate using ultrasonic or Doppler methods. The flow depth must be a minimum of approximately 1.5 in. above the sensor for the sensor to measure the velocity. The meter can typically measure to a minimum velocity of approximately 1 ft/s. The accuracy of the flow measurement is within approximately 5% for most applications. The minimum measurable flow rates by an area-velocity meter for various pipe sizes are listed in Table 4.9.

Area-velocity meters cannot be used in corrugated pipes because of the turbulence caused by the corrugations. A smooth insert can be placed in the lower half of the pipe section to eliminate the turbulence. The area-velocity sensors also tend to be susceptible to siltation and damage from debris in storm water pipes. If the sensor and electric/communication cords are not properly secured, they may dislodge due to the force of the water at higher flow rates. Accumulation of solids over the sensor will obstruct the ability of the sensor to make accurate flow measurements.

4.3.7.2.4 Selection of a Flow Meter. The type of flow meter selected should be based on the need for and desired use of the data and the environment in which the flow monitoring will occur. Several factors should be considered in the selection:

- How accurate does the data need to be?
- What are the ranges of flow that need to be measured?
- Is flow information critical in real time?
- What is the infrastructure in which the flow monitoring equipment will be mounted?
- What are the potential power sources for the flow monitoring equipment?

Accuracy is an important consideration in the selection of a flow monitor. Do the flow values need to be accurate or are qualitative trends in the flow important? Also, is accuracy critical over the entire flow range or are there times when accuracy is more critical, such as peak-flow or low-flow periods?

In cases where accurate low-flow measurements and measurement of a wide range of flow rates are required, compound flow measurement may be used. An example of a compound flow measurement device is a v-notch weir cut into a rectangular weir. When the flow rate exceeds the v-notch weir, the flow rate is calculated by the combination of the v-notch weir and the rectangular weir. Another example is a v-notch weir that is upstream of an area-velocity meter. Flow measurements are made at both devices, but the reading for the v-notch is used at low flows and the reading from the area-velocity meter is used at higher flows.

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If the flow data are not critical for real-time decisions, a monitor with local data storage can be used and the data downloaded as needed. If the data are critical for real-time decisions, a flow meter must be able to communicate with the other equipment. The flow meter must also have a high degree of reliability because when the device is not functioning, the ability to make real-time decisions is lost.

All automatic flow monitoring devices require electrical power to operate. If electrical power is not already available, it will need to be supplied to the monitoring site. Some flow meters have an option for solar-power-compatible collectors to supply power.

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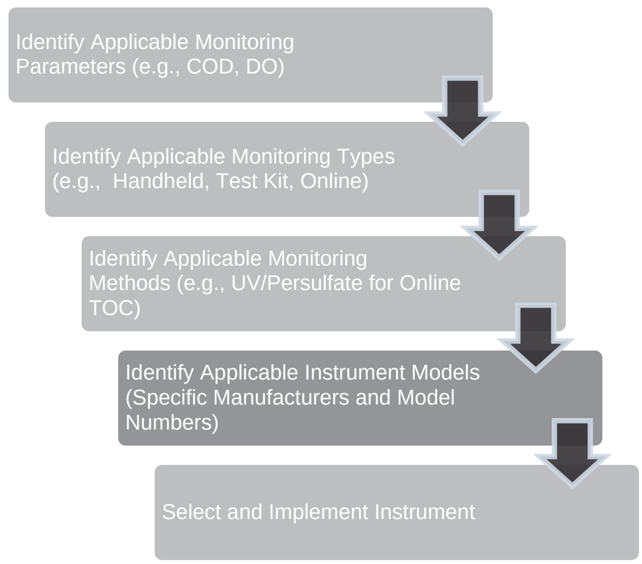
CHAPTER 5

Identify Applicable Instrument Models

5.1 Selecting the Manufacturer and Model



The final step in selecting an instrument for on-site monitoring is determining a manufacturer and model. Providing recommendations of manufacturers and models is not within the scope of this guidebook. As a result, selection of a manufacturer and model is up to the discretion of the individual airport operator.

The information obtained through the monitoring instrument selection process, including screening of monitoring parameters, determination of on-site monitoring needs, determination of applicable monitoring types, and determination of appropriate monitoring methods for each parameter, will provide a short list of potential instruments for each application. Airport personnel can use a variety of readily available information sources to determine potential manufacturers and models for their needs. Potential information sources are:

- Manufacturer and manufacturer's representative listings, often provided by instrument type in catalogues, magazines, or websites;
- Manufacturer and manufacturer's representative websites;
- Trade shows;
- Recommendations from other airports; and
- Internet searches.

Airport operators should approach the selection of the instrument with caution because the manufacturer's name for an instrument doesn't always accurately represent the monitoring method used. As an example, just because a monitor has TOC in the name does not guarantee that the monitor uses a TOC method. Also, some monitors use a method that is similar to but not exactly the same as an EPA-approved method. Therefore, when selecting a manufacturer and model, it is important to understand what method the instrument uses.

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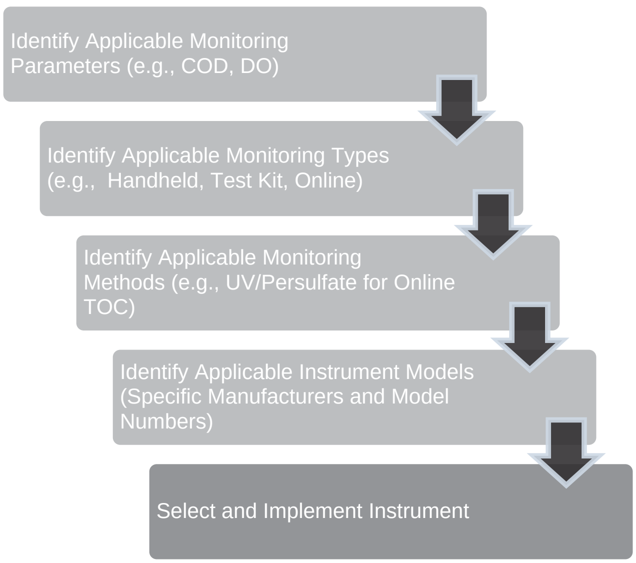
CHAPTER 6

Implementation of Monitoring Systems



Once the monitoring method, manufacturer, and instrument model have been selected, the monitoring system must be implemented. The monitoring system includes the monitoring instrument plus the equipment and protocols needed to support its function. Typical aspects of the implementation phase as related to the type of monitoring methods are represented in Table 6.1.

In many ways, the implementation phase for on-site monitoring systems is as important as the monitor selection when it comes to obtaining accurate and reliable monitoring data. The criticality of the monitoring system implementation phase is related to effects of the environment in which the monitors are used and to the means by which many on-site instruments produce output.

On-site monitoring methods for water-based systems typically work by measuring a response to a water characteristic in a particular sample and correlating the response to a standard. If the monitor is not exposed to a representative sample, if the sample is not properly pretreated, if the instrument is not set up to properly relate the actual measured characteristic to desired output parameters, or if the instrument is not functioning properly because of maintenance issues, inaccurate results can be obtained.

The sections that follow provide guidance on the aspects of implementation.

Table 6.1. Implementation activities by monitoring type.

Implementation Phase	Activity	Monitoring Type		
		Handheld	Test Kits	Online
Design and installation	Sampling location	X	X	X
	Site preparation	(1)	(1)	X
	Sample preparation	X	X	X
	Utility supply			X
	Communication and control			X
	Shelters			X
Setup, operation, and maintenance	Calibration	X	X	X
	Correlation	X	X	X
	Maintenance			X

(1) Some site preparation may be required for personnel access to sample stream.

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6.1 Guidance on Design and Installation

Following selection of the specific instrument, design and installation of the monitoring system is the next critical step for obtaining accurate and representative data. It is not uncommon for perfectly suitable monitoring methods and instruments to produce unreliable data because the design and installation of the systems associated with the instrument are insufficient. Because the installation is integral to the proper functioning of the monitor system, the following section is included to aid in the successful application of the monitoring method.

6.1.1 Sampling Location

Determining locations for sampling for handheld monitors or collection of storm water samples for test kits requires consideration of access, safety, and sample representation.

6.1.1.1 Obtaining Representative Samples

Representative sample measurement is achieved by designing a sampling system and sampling protocols with verifiable results as well as implementing a representative maintenance program to ensure that the sampling collection system is operating properly.

Sample collection is most representative where the sample stream is well mixed. A well-mixed stream will avoid stratification and preferential sampling that may concentrate or limit the constituents in the collected sample. A well-mixed sample occurs when the sample stream is turbulent or flow is concentrated into a small area. Examples of where turbulent and concentrated flows occur are a flume or rapids, following a bend in the flow, or downstream of a weir.

Online instruments that monitor water-soluble parameters (deicer and ammonia) have filters or other solid-rejecting features. Solids in the sample stream sent to these monitors will increase the amount of maintenance required for operation. It is recommended that the samples be collected from the upper portion of a flow stream to avoid collection of solids. Water-soluble parameters mix quickly in water streams and will not stratify like solids; therefore, sample results will be accurate with reduced maintenance of the monitor.

TSS Sample Collection

A sample collected from the bottom of a slow moving stream will tend to have a higher TSS concentration because the solids will concentrate at the stream bottom.

Locations where backflow can occur should be avoided for sampling, especially for online monitors since there may be no way to determine that a backflow condition occurred when samples are collected automatically. Backflow can occur near outfalls where the surface waters are susceptible to flooding, where high flows in a branch cause temporary backflow into the sampled stream, or at discharges with tidal influence. Under backflow conditions, water other than the intended sample stream is being sampled, and the results of the monitoring will be invalid or not representative of the discharge. Backflow can also give inaccurate flow measurements for weirs and flumes since these devices assume a forward flow.

Care should also be taken not to collect a sample at the location where two flows join. Sample eddies may cause a condition where the flows do not mix well and the sample is collected preferentially from only one of the streams rather than both. Samples should be collected downstream of the junction of two flows, after the flows have had a chance to mix.

Sample collection for online monitors requires special consideration. Many online monitors require use of a *sample loop*. The sample loop is the system that collects the sample from the storm water stream and delivers it to an online monitor. If the discharge from the monitor is returned just downstream of the sample location, downstream storm water handling is simplified—particularly if the monitoring is part of a diversion system. In this way, sample loop water can

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be diverted with the rest of the storm water instead of a separate system being implemented for the sample loop flow.

The sample loop usually includes a pump station structure (manhole) where pumps are located to lift the sample stream from a storm sewer to the online monitor. Flow rates for monitors that require filtering are typically in the 10 gpm to 20 gpm range. Flow rates for monitors that do not require filtering are lower. Piping of the loop should be as short as possible to reduce the time delay between sample collection and sample analysis. The piping should be sized for high velocities so that biofouling does not occur within the piping. One airport surveyed installed sample pumps that can reverse direction and eliminated check valves so that the sample lines can be back-flushed if they plug. Allowing the sample line to back-flush each time the pump stops has reduced the maintenance and failure of the sample loop systems.

Some TOC monitors use a compressed air blast to clean the filters in the sampling loop. One airport surveyed was experiencing corrosion issues in the sample shelters in which TOC monitors were installed. The airport theorized that the compressed air blast was stripping chemicals (including sulfides) from the sample water and the air was escaping into the TOC monitor cabinet, causing the corrosion. Airport personnel installed air-release valves on the sample loop and discharged the air to the outside of the sampling shelter. Corrosion in the sample shelter appears to have decreased since the change was made.

Handheld meter accuracy is most reliable if the probe can be fully submerged directly in the flowing stream.

6.1.1.2 Access to Sample Locations

Sampling of deicer-affected storm water will typically occur during winter, and snow or ice may make access difficult. An appropriate health and safety plan describing appropriate apparatus and conditions should be provided for any sampling staff. Typical probe cables are 4 to 6 ft in length, and this length should be considered in selecting the sampling location. Grab samples may be collected and probes inserted into the sample if close proximity to the water surface is not possible, such as from a deep storm sewer.

Grab samples for test kit methods are easier to collect from above a sample stream than from a horizontal position. A bailer is typically used to collect a sample and transfer it to sample bottles. Bridges or sewer pipe discharges readily provide access above the flow stream. Safety regulations may require that railing be installed at locations where an elevation drop of more than 4 ft exists. Safety experts should be consulted for specific location requirements.

For locations where online monitor probes are installed, access similar to that needed for handheld monitors should be included. The online monitor probes require periodic cleaning and calibration, and personnel will need access to perform these functions. Cable lengths for online monitors can be specified longer than the 4 ft to 6 ft typical of handheld meters so the platform elevation relative to the water level is not as restrictive as for a handheld meter.

Online monitors should be visited daily, so easy access to the sampling location by airport personnel, particularly in winter weather conditions, is a must. The sampling locations may be inside or outside of the security fence and remote from other airport access. Therefore, considerations for routes to be traveled, gate access, and plowing of roads should be addressed for each sampling location.

6.1.2 Sample Preparation

Samples measured using on-site devices may need proper preparation or conditioning to increase the reliability of the measurement and protect the instrument. Guidelines for sample

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holding times for test kit analyses should be followed. If guidelines do not exist, holding times for similar standard methods should be adopted.

Samples entering online meters can create conditions that affect the instrument and hence the accuracy of the instrument measurement. Deicer compounds provide a food source for nuisance bacteria in storm water streams. Biogrowth in the sampling system is a particular problem for online monitors. The biogrowth occurs on the pipes and tubing walls and plugs the small-diameter sample tubing inside the monitors. Ongoing maintenance of the instrument to prevent biogrowth can be time-consuming and expensive.

An innovative approach to preventing biogrowth in online monitors has been developed by a surveyed airport for their two TOC monitors used in the deicer management system. A dilute chlorine solution is continuously injected into the sample stream to the online monitor. The chlorine solution (fed as a 0.8% bleach solution) is sufficient to prevent biological buildup on the online monitor filter and limit biogrowth in the tubing of the monitor. Split-sample testing results indicate that the TOC monitor measurements are not affected by the low chlorine dosage. The sample loop flow rate is much smaller than the average storm water flow, and the chlorine is diluted below active level in the storm water discharge.

Chlorination of the sample system cannot be used for BOD monitors because the chlorine will harm the bacteria used for the measurement. If chlorination of the sample system is used for preventing biogrowth in ammonia monitors, split samples should be collected to verify that the chlorine is not oxidizing the ammonia and affecting the results.

Automatic cleaning systems can be installed in monitoring systems that analyze samples internally or on probe systems. Probe systems such as pH or temperature can be equipped with water-jet systems that remove biogrowth from the probe face. Potable water must be available at the sampling site for jet cleaning systems. DO probes are equipped with wiper systems; however, in conditions with biogrowth issues such as deicer storm water streams, wiper systems are not as effective because the biogrowth will coat the wiper. DO monitor systems with the optical/fluorescence probes may be equipped with water-jet cleaning by some manufacturers.

If potable water is not available at the sampling site, compressed air may be substituted for the water jet.

6.1.3 Utility Supply

All of the online monitors require electricity, and many require a water connection. Providing utilities to the sampling site may be as costly and complex as the installation of the monitoring instruments.

Locations where online monitoring occurs, near storm water manholes or discharges, may not have existing electric utilities nearby. Although many of the online instruments only require 120-volt power, ancillary equipment such as sample pumps and shelter heaters may require 240-volt or greater power. Because of the power requirements for the ancillary systems and because of the long distances the power may be fed, it is recommended that the power be supplied at a higher voltage (480 volts or 240 volts) and transformed at the sample location.

Some jurisdictions require electronic equipment to be UL listed prior to installation. Some monitoring units may not have UL listings, especially those manufactured in Europe. It is recommended that electrical code requirements be confirmed and the applicable certification be verified with the manufacturer.

Potable water supply is required for some online monitors and is required for most automatic cleaning systems. Some monitors do not require a continuous supply of potable water, and the

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water requirement may be supplied by a local tank that is refilled by airport personnel as needed. If the sampling location is remote from the terminal or other airport buildings, getting potable water to the sampling site may be challenging. If water cannot be supplied to the sample site, choices of monitoring instruments that require water supply would be eliminated. Ancillary cleaning units that use water may also have options that use compressed air. For the systems that use compressed air for cleaning, an air compressor and additional electrical power replace the water connection.

6.1.4 Communications and Controls

The ability of online monitors to provide significant amounts of real-time data is a key to their usefulness in storm water and deicer management. Full utilization of the real-time data capabilities may require development of systems and protocols for communicating the data to airport staff as well as storm water and deicer management control systems.

Real-time communication of the results can be required for:

- Control of equipment that performs storm water diversion,
- Remote observation by personnel to track data and diagnose issues, and
- Control of loading of the stream flow.

6.1.4.1 Communication Method Considerations

To take advantage of the data provided by online monitors, the monitor will need to communicate with a local airport communication network. The most common method to transfer information from a monitor to a control system is via 4-mA (milliamp) to 20-mA control wire, referred to as analog communication. Analog communication is limited in the resolution of the data it can transmit. The resolution for most communication systems is approximately 4,000 units. So for a monitor that has a 0 mg/L to 20,000 mg/L range, the control system will only have a resolution of approximately 5 mg/L (20,000 divided by 4,000). Electrical noise in the system will decrease the resolution even further. If the control system has to record the instrument reading with more precision, more expensive digital communication must be used.

Other than data results, online monitors can communicate alarms or other events through various types of communication protocols. The protocols for this kind of communication should be considered based on the complexity and needs of the control system. Monitoring and recording of events such as loss of sample, calibration error, or other events will alert airport personnel to perform maintenance and diagnose potential issues with sample results.

Some airports have issues with lightning inducing high voltages in copper wires buried near the ground surface and destroying communication equipment. Fiber optic communication wires are recommended for locations that have potential for lightning strikes.

6.1.4.2 Control Method Considerations

If the monitoring data are used for control of storm water or deicer management system equipment, the following considerations should be assessed.

6.1.4.2.1 Diversion Considerations. Systems that divert storm water rely on real-time data to make control decisions. There may be an inherent assumption that the sample results are continuous and that diversion can be made very quickly. Some online monitors have an adjustable parameter that allows the time between sample collections to be selected by the operator. Most online monitors do not provide instantaneous readings but rather require some time for the analysis to occur. The analysis period can range from a few seconds to as much as 20 min. The analysis period may be a defined interval or a variable period necessary to reach a stable

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measurement. With some instruments, the output of the monitor may appear to be continuous, but users are cautioned to understand the analysis interval since this may affect interpretation of results. Both sample collection times and sample analysis times will delay storm water concentration information from being used to make a diversion control decision. Increasing the sampling frequency may increase the reagent usage or power usage from that quoted by manufacturers.

6.1.4.2.2 Considerations for Treatment Influent or Effluent Monitoring. When considering the method for monitoring treatment system influent and effluent flows for BOD, COD, or TOC, the effects of the treatment process on storm water should be considered. The treatment process may affect both calibration and correlation factors, including the relationships among PG, BOD, COD, and TOC. Therefore, instruments on untreated streams need to be set up differently from instruments on treated streams. The specific settings are determined on a site-specific basis.

In cases where the stream characteristics do not affect the calibration and correlation setup for an instrument, a single online instrument could be used to analyze samples from multiple locations. Collection of multiple samples is accomplished by manifolding the instrument intake to alternate between treatment system influent and effluent samples. One unit may not be appropriate for BOD monitors. Alternating between influent and effluent samples may not yield accurate results for BOD monitors and biological treatment systems because different compounds are present in the influent and effluent samples. The effluent sample will contain compounds that are resistive to biological degradation. The short contact time of the BOD monitors may not allow sufficient time for the bacteria in the instrument to acclimate and degrade the effluent compounds. When alternated with easily degraded influent samples containing deicer, the bacteria may not adjust to less easily degraded compounds in the effluent. No airports are known to have tested alternating influent and effluent samples using a BOD monitor.

6.1.5 Combining Sampling with Flow Rates for Accurate Loads

Load is determined by multiplying the parameter concentration by the flow rate and a conversion factor. If load information is required, both accurate flow and concentration data are required. Ideally flow and concentration data are multiplied together in short time steps to accurately track the load. Data from most types of flow monitors are available nearly continuously, so the short time duration is not an issue for flow data. Because sample collection and analysis times vary significantly for online monitors, the frequency of the concentration data is usually the limiting factor. The flow data should be averaged over the same frequency as the interval between concentration results to achieve the best accuracy.

It is generally more accurate to monitor loadings of storm water downstream of a storage tank or basin. The concentrations will not vary as greatly as upstream of the storage. The concentration will not change as significantly during the sampling interval, and therefore the loading estimate will be more accurate. Sample intervals may also be extended for large storage basins with permanent storage because the basins will provide continuous equalization.

6.1.6 Recommendations for Equipment Shelters

Equipment shelters are recommended for online monitors that will not be installed inside existing buildings. Preconstructed shelters can be purchased with integrated lighting, ventilation, and power. Venting of the storm water lines should be directed outside the shelter to avoid potential corrosion and issues with health and safety. Potable water, if available, should be provided to aid in equipment cleaning or preparation of solutions at the site. Heating should

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be provided to provide freeze protection since some solutions may have minimum recommend storage temperatures. In warm climates, air-conditioning or temperature-controlled ventilation may be necessary in the summer to prevent damage to electronic equipment. Local occupancy regulations should be consulted to determine additional applicable requirements.

It is recommended that the shelter be sized slightly larger than what may seem necessary in order to account for needs such as reagent storage or possible additional equipment such as automated samplers.

6.2 Guidance on Setup, Operation, and Maintenance

Proper selection of the monitoring method in addition to proper design and installation of the instrument and support systems will greatly increase the chances of accurate and reliable measurements. These steps alone are not sufficient, however. It is critical that the on-site monitors be properly set up, operated, and maintained.

Proper setup, operation, and maintenance of handheld and test kit monitors can typically be accomplished by following the guidance in the instrument manuals and consulting with the instrument manufacturer. Setup, operation, and maintenance of online instruments, however, often requires going beyond the guidance given by manufacturers and making adaptations to procedures that are specific to the individual airport's storm water and deicing environments.

6.2.1 Calibration

Calibration is defined as the process by which the monitoring method is adjusted to achieve accurate measurements of the parameter within the expected range.

It is important to remember that the response the method uses to determine concentration is only indirectly related to the concentration of the parameter(s) of interest. Since the actual chemical is not positively identified and concentration is not directly measured, as they are in analytical laboratory measurements, it is important to minimize issues that may interfere with the monitoring process.

During operation, calibration and calibration checks will determine if the monitoring method will accurately measure the parameter concentrations. Operators should not take for granted that calibration solutions are correct or that automatic calibrations are being performed properly. The steps to be considered for proper calibration of online monitors are listed in the following.

Steps for Proper Calibration of Online Monitors

1. Select calibration compound based on method and parameter of interest.
2. Select the calibration solution concentration based on the instrument range.
3. Analyze the calibration solution periodically by a laboratory.
4. Review the automatic calibration data to determine if the unit is drifting.
5. Periodically analyze calibration check samples.

6.2.1.1 Selection of Calibration Compound

The selection of the calibration compound is very important to the calibration process. The calibration compound does not necessarily need to be the chemical of interest, but the calibration compound should give a response similar to the chemical of interest. Manufacturers will recommend compounds based on response and stability. For example, TOC monitor manufacturers typically recommend potassium hydrogen phthalate (KHP) because this compound is not biodegradable and therefore the solutions have good long-term stability. KHP will not work for calibrating BOD monitors because the compound is not biodegradable.

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Selection of the calibration concentration should be made based on the expected range of measurements. Laboratory instruments will use the calibration result and a blank (or automatic zero point) to determine a correlation line. If the calibration concentration is higher than the typical sample concentrations (i.e., a pure propylene glycol solution), the instrument response may not be the same as in the concentration range where samples are typically measured. The same is true if the calibration concentration is lower than the typical sample concentrations. If a calibration compound other than one of the primary deicer compounds (e.g., propylene glycol) is used, the concentration of the calibration compound in solution should be determined so that the resulting parameter concentration (COD or TOC) is within the range of expected measurements.

Diluted deicer and propylene glycol solutions may biodegrade if stored in open containers at room temperature. If deicer or propylene glycol is used as the calibration solution, the calibration solution should be tested in an analytical lab periodically to confirm the concentration. Solutions that have degraded should be replaced. Even if a different calibration compound is used, it is good practice to periodically have a laboratory analyze calibration solutions to confirm the concentration. The frequency of calibration solution analyses can be decreased for compounds that have demonstrated long-term stability.

If the monitor performs automatic calibrations, the raw calibration data should be reviewed to determine the accurate functioning of the instrument. Most monitoring instruments will provide a response value, which is the unadjusted measurement made by the instrument. If the response value is typically within a narrow range, the instrument is consistently measuring the calibration solution in the same way. If the response value changes, the instrument is drifting and the instrument response is inconsistent with the correlated measurement. A drifting response value is usually an early indication of instrument failure, and maintenance procedures should be performed to determine the cause of the drift.

The operators should also periodically perform a manual calibration check on an independent sample to verify that the instrument is measuring accurately. The calibration check is performed on a sample with a known concentration, created separately from the calibration solution. The calibration check sample may be a single compound in laboratory-grade water, but it is recommended that the sample be created by spiking deicer (or pure propylene glycol) into a storm water sample that is known to not contain deicer.

6.2.2 Maintenance

Maintenance of online monitors and their support systems in a deicing environment is critical to successful operation and requires a commitment of time and knowledgeable personnel. Preventative maintenance should be performed in the non-deicing season to ensure proper operation during the deicing season. Preventative maintenance should include examination for worn parts and replacement of parts that are near the end of their useful lives.

Typical maintenance activities include:

- Checking for functioning of equipment (pumps, valves),
- Replacing worn or broken tubing,
- Cleaning of biofouling,
- Checking and replacing calibration standard fluids,
- Performing off-season preventative maintenance,
- Replacing of malfunctioning probes, and
- Preventative maintenance for extended non-deicing season shutdown.

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6.2.3 Monitor Site Visits

Online monitors should be visited once per day to verify proper operation. Since monitors will be visited frequently during the deicing season, easy access should be provided. During a site visit, the following items should be checked:

- The monitor has power and the system is functioning.
- The previous daily sample results agree with expectations (deicing events have higher concentrations).
- Automatic calibrations have occurred and the response value is typical.
- Auxiliary systems are functioning.
- Sample loop flows are within an acceptable range.
- Reagent or solution levels are okay for the next operating period.

In addition, calibration checks should be periodically performed.

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Definitions

5-day biochemical oxygen demand (BOD_5)—The oxygen required for the biological degradation of organic compounds in a sample by bacteria and nutrients after 5 days.

Aircraft deicing fluids—Deicers and anti-icers applied to aircraft; typically the primary deicer constituent is propylene glycol in the United States and ethylene glycol in Canada. Glycerin is the primary deicer constituent in a few products.

Ammonia–nitrogen—The concentration of nitrogen contained in the compound ammonia in a water sample.

Automatic diversion system—Storm water diversion system where a monitor is used to detect pollutant concentration, and an electronic system is used to control the diversion of storm water based on the levels of pollutant detected by the monitor.

Biochemical oxygen demand (BOD)—The oxygen required for the biological degradation of a pollutant sample by bacteria and nutrients.

Chemical oxygen demand (COD)—The oxygen required for the chemical reaction with organic compounds in a sample.

Composite sample—A sample made up of samples collected over a period of time. Samples may be time weighted (collected at set intervals) or flow weighted (collected when a volume of water passes the sample location).

Data sonde—A monitor that is temporarily placed into a stream or storm water structure and left for an extended period of time to collect analytical data.

Deicer—Either liquid or dry chemical applied to melt ice or prevent ice from forming on a surface. In this guidebook it can refer to either aircraft or pavement deicers or anti-icers.

Dissolved oxygen (DO)—Oxygen that is dissolved in a water sample.

Effluent limitation—Any restriction on quantities, discharge rates, and concentrations of pollutants discharged from point sources into waters of the United States.

Grab sample—Single sample that is collected at one point in time.

Handheld monitor—Any type of monitor that is typically carried out to the sample site to perform the measurement.

Load accounting—Measurement and tracking of a parameter mass load (typically pounds in the United States) over time.

Manual diversion system—Storm water diversion system where valves in the storm water system are manually opened or closed to divert storm water.

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Monitoring driver—Reason that monitoring may be performed.

Monitoring type—Handheld, test kit, or continuous monitor.

National Pollutant Discharge Elimination System (NPDES)—U.S. EPA's program for permitting point source discharges to waters of the United States.

National Pretreatment Program—A component of the NPDES program that requires industrial and commercial dischargers, called industrial users, to obtain permits or other control mechanisms to discharge to the POTW.

Online monitor—Permanently mounted devices designed to sample flow streams and analyze the samples on a regular basis without direct involvement of facility staff.

Off-site monitoring—Collecting samples and sending them to an analytical laboratory for analysis.

On-site monitoring—Collecting samples and analyzing them at the airport.

Parameter—A parameter may be a chemical (e.g., ammonia), a physical characteristic (e.g., temperature or flow), or the result of analytical testing (e.g., biochemical oxygen demand).

Pavement deicer—Deicers applied to aircraft operations areas. The compounds are typically applied undiluted. The primary deicer constituents are sodium formate, sodium acetate, and potassium acetate.

pH—A measure of the acidity or alkalinity of a sample.

Total organic carbon (TOC)—The measurement of carbon dioxide produced during the conversion of all organic carbon in a sample.

Refractometer—An instrument that uses a light beam to measure the refractance (light bending property) of water. Refractance is correlated directly to density and indirectly to chemical concentrations in a water sample.

Storm water—Precipitation runoff, including rain and snowmelt.

Storm water monitoring—The act of obtaining a quantitative measurement of storm water characteristics.

Surcharge fee—Fee charged by a municipal treatment plant for wastewater with pollutant concentrations that exceed the concentration of typical sanitary wastewater.

Surrogate—A parameter that is measured in place of another parameter. A mathematical relationship exists between the two parameters such that the surrogate parameter's concentration can be used to estimate the desired parameter concentration.

Technology-based effluent limit—Discharge limits established as part of the NPDES program based on the ability of dischargers in the same industrial category to treat discharges.

Test kit monitor—Any type of monitor system for which a sample is collected and analyses are performed by airport personnel away from the sample location—typically in an on-site laboratory area.

Total suspended solids—A class of solids associated with particulates (i.e., sand or silt) that can cause sedimentation in a stream or block light and that will inhibit aquatic life.

Water-quality-based limit—Discharge limits established as part of the NPDES program to protect the quality of the receiving water.

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Acronyms and Abbreviations

ADF	Aircraft deicing fluid
BOD	Biochemical oxygen demand
BOD_5	5-day biochemical oxygen demand
COD	Chemical oxygen demand
CWA	Clean Water Act
DO	Dissolved oxygen
EPA	Environmental Protection Agency
FWPCA	Federal Water Pollution Control Act
ISE	Ion-selective electrode
IU	Industrial user
KHP	Potassium hydrogen phthalate
mA	Milliamp
NPDES	National Pollutant Discharge Elimination System
NTU	Nephelometric turbidity unit
POTW	Publicly owned treatment works
RTD	Resistance-temperature detector
TC	Total carbon
TIC	Total inorganic carbon
TOC	Total organic carbon
TSS	Total suspended solids
UV	Ultraviolet

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APPENDIX A

On-Site Monitoring Method Criteria Tables

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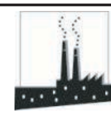
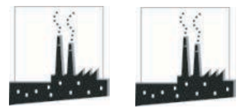
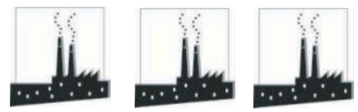
LEGEND FOR CRITERIA TABLES

Method and Use Status		Icon	Notes
Method Description		N/A	Method name and general description of method or equipment.
Demonstrated Technology for Airport Stormwater?	Yes		Typical installation or is a demonstrated airport technology
	No	∅	Atypical installation and no known usage at airports
General Availability of Technology	Single Manufacturer		1 manufacturer
	Few Manufacturers		2-4 manufacturers
	Many Manufacturers		5+ manufacturers
Implementation Considerations			
Regulatory-Approved Method	Federal Approval (Method name/number)	**FEDERAL** (EPA Method ###.#)	US EPA or Standard Method approved
	State or Local Approval	**STATE**	Approved by specific state or local authorities
	None Reported	∅	No known approvals for method, based on results of airport survey and information from manufacturers.
Measurement Range		N/A	Parameter concentration range the method or equipment is able to detect.
Accuracy		N/A	Accuracy as a percent of the measured value (or full range value if noted).
Siting Constraints / Needs	For online monitors only.		
	Requires Potable Water Supply		Potable water needed for sample dilution or automatic cleaning. Water tap for operator convenience is not included.
	Requires Temperature-Controlled Environment		Equipment may require freeze-protection for sample withdrawal. Electronic equipment typically has venting for moderate temperature. Cooling for environments with high temperatures was not considered.
	Requires Other Infrastructure		Other infrastructure includes compressed air system for cleaning or other infrastructure.
	None Significant	∅	

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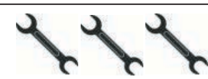
LEGEND FOR CRITERIA TABLES

Method and Use Status		Icon	Notes
Flow and Stream Constraints	Sample Requires Filtration		Equipment may require filtration of sample stream to prevent plugging of small diameter tubing by solids or to prevent solids from interfering with measurement.
	Requires or Optimized for Constant Flow		Equipment may alarm or give incorrect reading if constant sample is not supplied.
	Special Requirement		Refer to Factsheet for special requirement.
	None Significant		
Interferences		N/A	List of chemical or physical interferences and concentrations (where available) for the method.
Staff Time Requirements	Low		Less than 1 hour/week to perform test and for typical maintenance/operations
	Moderate		Between 1 and 4 hours/week to perform test and for typical maintenance/operations
	High		More than 4 hours/week to perform test and for typical maintenance/operations
Level of Staff Knowledge	Low		Only general understanding of equipment and use is necessary for successful operation
	Moderate		Moderate level of understanding including equipment operation, maintenance, and calibration. Training may be necessary for successful operation.
	High		High level of understanding including operation, maintenance, calibration, ability to troubleshoot. Training is required for successful operation.
O&M Issues	Low		Ratings based on comparison against other monitors of same parameter and type. Refer to Fact Sheets for detailed information.
	Moderate		
	High		

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LEGEND FOR CRITERIA TABLES

Method and Use Status		Icon	Notes
Typical Costs			
Capital Cost	For the purchase of the equipment. Equipment listed under Optional System components in "Notes" section of Fact Sheets are not included.		
	Very Low	$	Less than $2,000
	Low	$$	$2,000-10,000
	Medium	$$$	$10,000-25,000
	High	$$$$	$25,000-50,000
	Very High	$$$$$	$50,000+
Typical Additional Capital Cost	For online monitors only. Includes required equipment or infrastructure not included in the capital cost category.		
	Low	$	Less than $2,000
	Medium	$$	$2,000-10,000
	High	$$$	$10,000+
Annual Operations and Maintenance Cost	Includes consumables, parts and regular maintenance contracts. Staff labor is accounted for in "Staff Time Requirements" above.		
	Low	$	Hand Held and Test Kits: Less than $500; On-line Monitors: Less than $2,000
	Medium	$$	Hand Held and Test Kits: $500-2,000; On-line Monitors: $2,000-8,000
	High	$$$	Hand Held and Test Kits: $2,000+; On-line Monitors: $8,000+

BOD/COD/TOC and Correlation Methods Online Monitors	Parameter			
Characteristics	BOD	COD		TOC
Method	Biochemical Oxidation	Photochemical Oxidation	Electrochemical Oxidation	Thermal Catalytic Combustion
Demonstrated Technology for Airport Storm Water?	✓	Ø	Ø	✓
General Availability of Technology	🏭	🏭	🏭	🏭🏭🏭
Implementation Considerations				
Regulatory-Approved Method?	STATE	Ø	Ø	FEDERAL (EPA Method 415.1)
Measurement Range	20 to 100,000 mg/L BOD	0.2 to 15,000 mg/L COD	1 to 100,000 mg/L COD	0 to 5,000 mg/L TOC (Up to 50,000 mg/L TOC depending on manufacturer and model)
Accuracy	±3%	±5%	±5%	±2%
Siting Constraints/Needs	🚰🏠	🚰🏠➕	🚰🏠➕	🚰🏠
Flow and Stream Constraints	🧪	🧪	Ø	🧪
Interferences	- Pollutants which can kill or inhibit bacteria	- Chlorides (>2,000 mg/L)	- High salt concentrations	Ø
Staff Time Requirements	🕒🕒🕒	🕒🕒	🕒	🕒
Level of Staff Knowledge	🎓🎓🎓	🎓🎓	🎓🎓	🎓🎓
O&M Issues	🔧🔧🔧	🔧🔧	🔧	🔧
Typical Costs				
Capital Cost	$$$$$	$$$$	$$$$	$$$$
Typical Additional Capital Cost	$	$	$	$
Annual Operations and Maintenance Cost	$$	$$$	$	$$
Fact Sheet Number	58	59	60	63

continued next page

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BOD/COD/TOC and Correlation Methods (continued) Online Monitors					
	Parameter				
	TOC		BOD/COD/TOC by Correlation		
Method	UV/Persulfate Oxidation	UV/Ozone Oxidation	Refractometry	Optical/Absorbance	Optical / Absorbance, Reflectance, and Fluorescence
Demonstrated Technology for Airport Storm Water?	✓	✓	✓	∅	∅
General Availability of Technology	🏭🏭🏭	🏭	🏭🏭🏭	🏭🏭🏭	🏭
Implementation Considerations					
Regulatory-Approved Method?	**FEDERAL** (EPA Method 415.1)	∅	∅	∅	∅
Measurement Range	0 to 10,000 mg/L TOC (Up to 50,000 mg/L TOC depending on manufacturer and model)	0 to 100,000 mg/L TOC	>1% glycol (approximately 10,000 mg/L BOD)	0 to 5,000 mg/L COD (Up to 45,000 mg/L COD with proper configuration)	0 to 5,000 mg/L TOC (Up to 10,000 mg/L TOC with proper configuration)
Accuracy	±4% (or as low as ±2% depending on manufacturer and model)	±3%	±1%	±2%	±3%
Siting Constraints/Needs	🚰🏠✚	🚰🏠	🏠	🏠✚	🚰
Flow and Stream Constraints	∅	∅	filter 🔄	filter 🔄	filter 🔄
Interferences	- Salt (>0.5%)	- Chloride (>30%) - Calcium (>12%)	- Suspended solids - High salt concentrations	- Application specific, depends on sample chemical composition	- Application specific, depends on sample chemical composition
Staff Time Requirements	🕐	🕐	🕐	🕐	🕐
Level of Staff Knowledge	🎓🎓	🎓🎓	🎓	🎓	🎓
O&M Issues	🔧🔧	🔧	🔧🔧	🔧🔧	🔧🔧
Typical Costs					
Capital Cost	$$$$	$$$$$	$$	$$$	$$$$$
Typical Additional Capital Cost	$$	$	$	$	$
Annual Operations and Maintenance Cost	$$$	$$	$	$	$$
Fact Sheet Number	64	65	66	67	68

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BOD/COD/TOC and Correlation Methods Handheld Monitors and Test Kits				
	Parameter			
Characteristics	**COD**		**BOD/COD/TOC by Correlation**	
Method	Photochemical Oxidation	Colorimetric	Refractometry	Colorimetric
Type	Test Kit	Test Kit	Handheld	Test Kit
Demonstrated Technology for Airport Storm Water?	Ø	✓	✓	✓
General Availability of Technology	🏭	🏭🏭🏭	🏭🏭🏭	🏭
Implementation Considerations				
Regulatory-Approved Method?	Ø	FEDERAL (EPA Method 410.4)	Ø	Ø
Measurement Range	0.2 to 15,000 mg/L COD	0 to 15,000 mg/L COD	>1% glycol (approximately 10,000 mg/L BOD)	1 to 15,000 mg/L glycol
Accuracy	±5%	±5 mg/L	±1%	1/2 to 1 color standard increment (concentration is read as a range)
Flow and Stream Constraints	Ø	Ø	Ø	Ø
Interferences	- Chlorides (>2,000 mg/L)	- Chorine (>1,000 mg/L) - Ammonia (>50 mg/L)	- Suspended solids - High salt concentrations	- Test does not differentiate between PG or EG - High dissolved solids (>700 mg/L)
Staff Time Requirements	🕒🕒	🕒	🕒	🕒
Level of Staff Knowledge	🎓🎓	🎓	🎓	🎓
O&M Issues	🔧🔧	🔧	🔧	🔧
Typical Costs				
Capital Cost	$$$	$$	$	$
Annual Operations and Maintenance Cost	$$$	$	$	$
Fact Sheet Number	**61**	**62**	**69**	**70**

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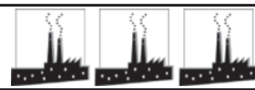
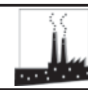
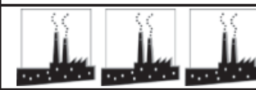
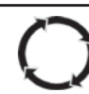
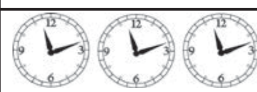
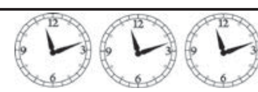
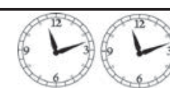
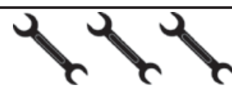
	Ammonia (NH3-N) Online Monitors		
Characteristics			
Method	Colorimetric	Ultraviolet Absorbance	Ammonia Selective Electrode
Demonstrated Technology for Airport Storm Water?	✓	∅	✓
General Availability of Technology			
Implementation Considerations			
Regulatory-Approved Method?	FEDERAL (EPA Method 350.1)	∅	FEDERAL (EPA Method 350.3)
Measurement Range	1 µg/L to 400 mg/L	0.02 to 5 mg/L	0.1 to 1,000 mg/L
Accuracy	±2% of full range value	±2-5% of full range value	±2% of full range value
Siting Constraints/Needs			
Flow and Stream Constraints	∅	∅	
Interferences	- Chloride - Calcium and magnesium (1,500-2,500 mg/L) - Nitrate/nitrite (30-250 mg/L) - Turbid or strongly acidic/alkaline samples (pH<3 or >12) - Sulfides (300 mg/L) - Grease/oils	- Solids/turbid samples (max. 150 mg/L or 60 NTU) - Organic matter - Grease/oils	- Amines - Mercury - Silver - Potassium - Grease/oil - Large changes in ionic strength
Staff Time Requirements			
Level of Staff Knowledge			
O&M Issues			
Typical Costs			
Capital Cost	$$$	$$$	$$
Typical Additional Capital Cost	$$	$$	$$
Annual Operations and Maintenance Cost	$	$	$
Fact Sheet Number	**71**	**72**	**73**

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Ammonia (NH3-N) Handheld Monitors and Test Kits		
Characteristics		
Type	Handheld	Test Kit
Method	Ammonia Selective Electrode	Colorimetric
Demonstrated Technology for Airport Storm Water?	✓	✓
General Availability of Technology	🏭🏭🏭	🏭🏭🏭
Implementation Considerations		
Regulatory-Approved Method?	**FEDERAL** (EPA Method 350.3)	∅
Measurement Range	2 to 200 mg/L	0.01 to 50 mg/L
Accuracy	±10% of measured value	±4% of full range
Flow and Stream Constraints	∅	∅
Interferences	- Amines - Mercury - Silver - Potassium - Grease/oil - Large changes in ionic strength	- Chloride - Calcium (>50,000 mg/L) and magnesium (>300,000 mg/L) - Nitrate/nitrite (600-5,000 mg/L) - Turbid or strongly acidic/alkaline samples - Sulfides (>6,000 mg/L) - Orthophosphate (>5,000 mg/L)
Staff Time Requirements	🕒	🕒
Level of Staff Knowledge	🎓	🎓
O&M Issues	🔧🔧	🔧
Typical Costs		
Capital Cost	$	$
Annual Operations and Maintenance Cost	$	$
Fact Sheet Number	**74**	**75**

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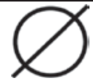
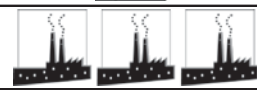
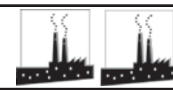
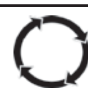
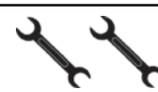
	pH Online Monitors	
Characteristics		
Method	Glass Electrode	Glass Free
Demonstrated Technology for Airport Storm Water?		
General Availability of Technology		
Implementation Considerations		
Regulatory-Approved Method?	FEDERAL (EPA Method 150.2)	
Measurement Range	0 to 14	0 to 14
Accuracy	±0.2 Standard Units	±0.2%
Siting Constraints/Needs		
Flow and Stream Constraints		
Interferences	- Minor interferences from lithium, sodium and potassium - Highly acidic solutions can affect probe (pH<1)	-Minor interferences from highly acidic or basic solutions
Staff Time Requirements		
Level of Staff Knowledge		
O&M Issues		
Typical Costs		
Capital Cost	$	$
Typical Additional Capital Cost	$	$
Annual Operations and Maintenance Cost	$	$
Fact Sheet Number	**76**	**77**

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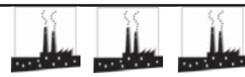
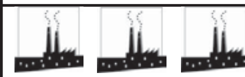
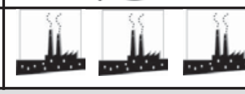
pH Handheld Monitors and Test Kits				
Characteristics				
Method	Glass Electrode	Glass Free	Test Strips	Colorimetric
Type	Handheld	Handheld	Test Kit	Test Kit
Demonstrated Technology for Airport Storm Water?	✓	∅	∅	∅
General Availability of Technology				
Implementation Considerations				
Regulatory-Approved Method?	**FEDERAL** (EPA Method 150.1)	∅	∅	∅
Measurement Range	0-14	0-14	4-10 (typical)	5.9-8.5
Accuracy	±0.02 Standard Units (typical)	±0.01 Standard Units (typical)	±0.2-1.0 Standard Units	±0.1 Standard Units
Flow and Stream Constraints	∅	∅	∅	∅
Interferences	- Minor interferences from lithium, sodium and potassium - Highly acidic solutions can affect probe (pH<1)	- Minor interferences from highly acidic or basic solutions	- High concentrations of chlorine or bromine	- Chlorine (>6 mg/L)
Staff Time Requirements				
Level of Staff Knowledge				
O&M Issues				
Typical Costs				
Capital Cost	$	$	$	$
Annual Operations and Maintenance Cost	$	$	$	$
Fact Sheet Number	**78**	**79**	**80**	**81**

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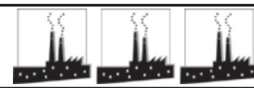
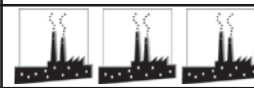
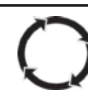
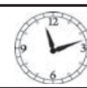
Characteristics	Dissolved Oxygen (DO) Online Monitors	
Method	Amperometric/ Polarographic Sensor	Optical/Fluorescence Sensor
Demonstrated Technology for Airport Storm Water?	✓	∅
General Availability of Technology		
Implementation Considerations		
Regulatory-Approved Method?	**FEDERAL** (EPA Method 360.1)	**FEDERAL** (EPA Approved; Method # Not Available)
Measurement Range	0.01-80 mg/L	2 µg/L to 20 mg/L
Accuracy	±1%	±1 to 15%
Siting Constraints/Needs		
Flow and Stream Constraints		
Interferences	- Dissolved Inorganic Salts - Reactive Compounds/Gases (e.g., CL_2, H_2S) - Temperature sensitive	- Air bubbles
Staff Time Requirements		
Level of Staff Knowledge		
O&M Issues		
Typical Costs		
Capital Cost	$$	$$
Typical Additional Capital Cost	$	$
Annual Operations and Maintenance Cost	$	$
Fact Sheet Number	**82**	**83**

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Characteristics	Dissolved Oxygen (DO) Handheld Monitors and Test Kits			
Method	Amperometric/ Polarographic Sensor	Optical/Fluorescence Sensor	Winkler Titration	Colorimetric
Type	Hand Held	Hand Held	Test Kit	Test Kit
Demonstrated Technology for Airport Storm Water?	✓	∅	✓	✓
General Availability of Technology	🏭🏭🏭	🏭🏭🏭	🏭🏭🏭	🏭🏭🏭
Implementation Considerations				
Regulatory-Approved Method?	**FEDERAL** (EPA Method 360.1)	**FEDERAL** (EPA Approved; Method # Not Available)	**FEDERAL** (EPA Method 360.2)	∅
Measurement Range	0 to 50 mg/L	0 to 50 mg/L	0.2 to 20 mg/L	0 to 15 mg/L
Accuracy	±2 to 6%	±1 to 15%	±0.1%	Color comparator only identifies range in DO concentration ±0.01 mg/L
Flow and Stream Constraints	∅	∅	∅	∅
Interferences	- Dissolved Inorganic Salts - Reactive Compounds/Gases (e.g., CL_2, H_2S) - Temperature sensitive	- Air bubbles	- Nitrate. Can be eliminated by using azide-containing reagents - Reducing or oxidizing substances (e.g., organic matter) - Sulfides	- Nitrate. Can be eliminated by using azide-containing reagents - Reducing or oxidizing substances (e.g., organic matter) - Sulfides - Copper, Iron, Chromium, Manganese, and Nickel (10 mg/L for high concentration DO samples)
Staff Time Requirements	🕒	🕒	🕒	🕒
Level of Staff Knowledge	🎓	🎓	🎓🎓	🎓
O&M Issues	🔧🔧	🔧🔧	🔧	🔧
Typical Costs				
Capital Cost	$	$	$	$
Annual Operations and Maintenance Cost	$	$	$	$
Fact Sheet Number	**84**	**85**	**86**	**87**

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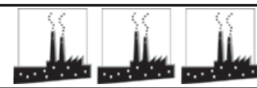
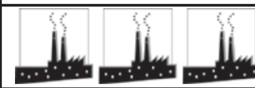
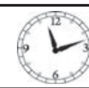
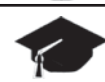
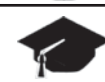
A-14 Guidebook for Selecting Methods to Monitor Airport and Aircraft Deicing Materials

Characteristics	Temperature Online Monitors	
Method	Thermocouple	Resistance-Temperature Detectors (RTD)/ Thermistors
Demonstrated Technology for Airport Storm Water?		
General Availability of Technology		
Implementation Considerations		
Regulatory-Approved Method?	**FEDERAL** (EPA Approved; Method # Not Available)	**FEDERAL** (EPA Method 170.1)
Measurement Range	-418 to 2282°F (-250 to 1250°C)	32 to 212°F (0 to 100°C)
Accuracy	±1.9 to 4.0°F (±1.0 to 2.2°C)	±0.2 to 0.4°F (±0.1 to 0.2°C)
Siting Constraints/Needs		
Flow and Stream Constraints		
Interferences	- Electromagnetic (i.e., high-voltage wires, magnetic flow meters)	- Electromagnetic (i.e., high-voltage wires, magnetic flow meters)
Staff Time Requirements		
Level of Staff Knowledge		
O&M Issues		
Typical Costs		
Capital Cost	$	$
Typical Additional Capital Cost	$	$
Annual Operations and Maintenance Cost	$	$
Fact Sheet Number	**88**	**89**

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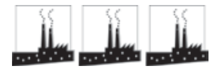
Characteristics	Temperature Handheld Monitors				
Method	Infrared Detectors	Bimetal	Glass Liquid Thermometer	Thermocouple	Resistance-Temperature Detectors (RTD)/ Thermistors
Demonstrated Technology for Airport Storm Water?	∅	∅	✓	✓	✓
General Availability of Technology					
Implementation Considerations					
Regulatory-Approved Method?	∅	∅	FEDERAL (EPA Method 170.1)	FEDERAL (EPA Approved; Method # Not Available)	FEDERAL (EPA Method 170.1)
Measurement Range	-76 to 3632°F (-60 to 2000°C)	-94 to 1004°F (-70 to 540°C)	-328 to 1112°F (-200 to 600°C)	-418 to 2282°F (-250 to 1250°C)	-328 to 752°F (-200 to 400°C)
Accuracy	±3.6°F (±2°C)	±1.8°F (±1°C)	±0.05 to 0.9°F (±0.03 to 0.5°C)	±1.8 to 4.0°F (±1.0 to 2.2°C)	±0.2 to 0.4°F (±0.1 to 0.2°C)
Flow and Stream Constraints	✚	∅	✚	✚	✚
Interferences	- Electromagnetic (i.e., high-voltage wires, magnetic flow meters) - Surface reflectivity	∅	∅	- Electromagnetic (i.e., high-voltage wires, magnetic flow meters)	- Electromagnetic (i.e., high-voltage wires, magnetic flow meters)
Staff Time Requirements					
Level of Staff Knowledge					
O&M Issues					
Typical Costs					
Capital Cost	$	$	$	$	$
Annual Operations and Maintenance Cost	$	$	$	$	$
Fact Sheet Number	**90**	**91**	**92**	**93**	**94**

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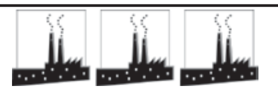
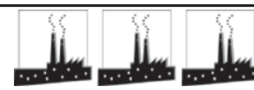
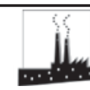
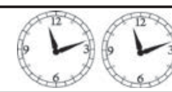
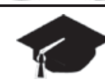
Characteristics	Total Suspended Solids (TSS) Online Monitors		
Method	Scattered Light Detection	Optical/Absorbance	Laser Diffraction
Demonstrated Technology for Airport Storm Water?	∅	∅	∅
General Availability of Technology			
Implementation Considerations			
Regulatory-Approved Method?	∅	∅	∅
Measurement Range	0 to 1,000 mg/L (up to 4,000 mg/L depending on manufacturer and model)	10 to 10,000 mg/L	10 to 3,000 mg/L
Accuracy	±5% (down to ±1% depending on manufacturer and model)	±5%	Not Available
Siting Constraints/Needs	∅		
Flow and Stream Constraints	+	∅	+
Interferences	- Air bubbles - Dyes or coloring	- Air bubbles - Dyes or coloring	None known
Staff Time Requirements			
Level of Staff Knowledge			
O&M Issues			
Typical Costs			
Capital Cost	$$	$$	$$$
Typical Additional Capital Cost	$	$	$
Annual Operations and Maintenance Cost	$	$	$
Fact Sheet Number	**95**	**96**	**97**

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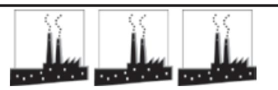
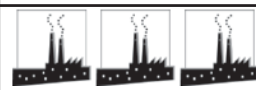
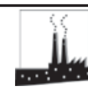
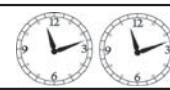
Total Suspended Solids (TSS)
Handheld Monitors and Test Kits

Characteristics			
Method	Optical/Absorbance	Optical/Absorbance	Laser Diffraction
Type	Handheld	Test Kit	Test Kit
Demonstrated Technology for Airport Storm Water?	∅	∅	∅
General Availability of Technology			
Implementation Considerations			
Regulatory-Approved Method?	∅	∅	∅
Measurement Range	1 to 400,000 mg/L	0 to 750 mg/L	10 to 3,000 mg/L
Accuracy	±4% or 1 mg/L, whichever is greater	Not available	Not available
Flow and Stream Constraints	∅	+	∅
Interferences	- Air bubbles - Dyes or coloring	- Air bubbles - Dyes or coloring	None known
Staff Time Requirements			
Level of Staff Knowledge			
O&M Issues			
Typical Costs			
Capital Cost	\$\$	\$	\$\$\$
Annual Operations and Maintenance Cost	\$	\$	\$
Fact Sheet Number	**98**	**99**	**100**

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APPENDIX B

Outreach Materials

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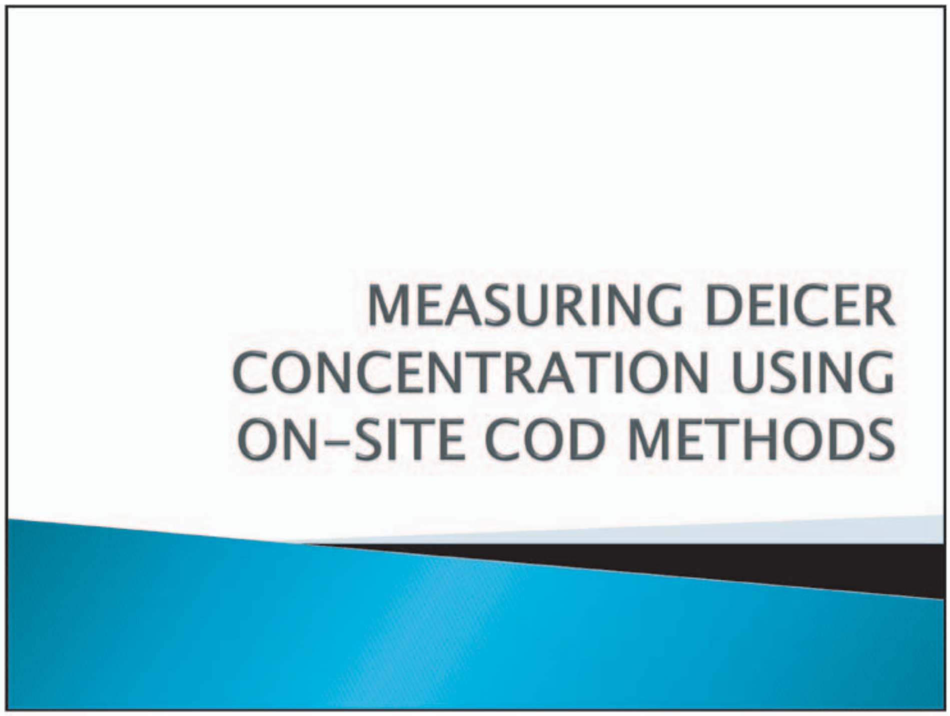

This presentation is intended to provided baseline information on means by which on-site COD monitoring can be used to measure deicer concentrations in storm water. This presentation was created as a template from which airport-specific information on on-site monitoring can be communicated to airport management, regulators, or other interested stakeholders. Note that not all slides or information is appropriate for all three audiences. Airport-specific information will need to be added to this presentation.

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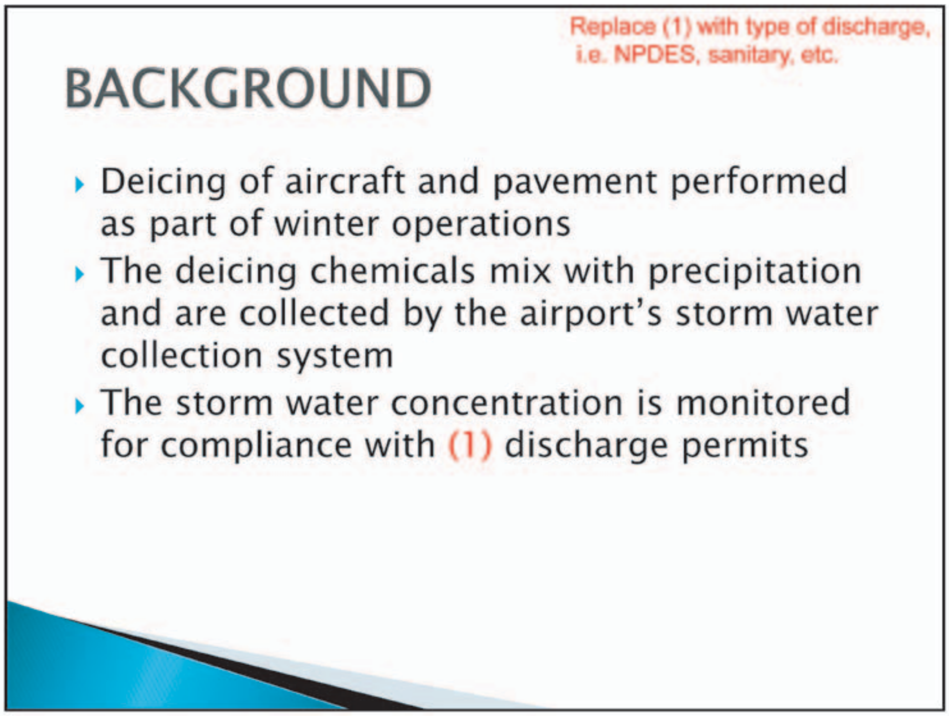

Talking Points: (1) Deicing is a necessary part of airport operations – it cannot be eliminated.

(2) Applied deicing chemicals are collected prior to discharge to the environment – mention airport-specific collection methods such as pads, segregated collection, or GRVs if used by the airport.

(3) Describe the discharge of the storm water and the permit monitoring required for compliance with the applicable permit conditions.

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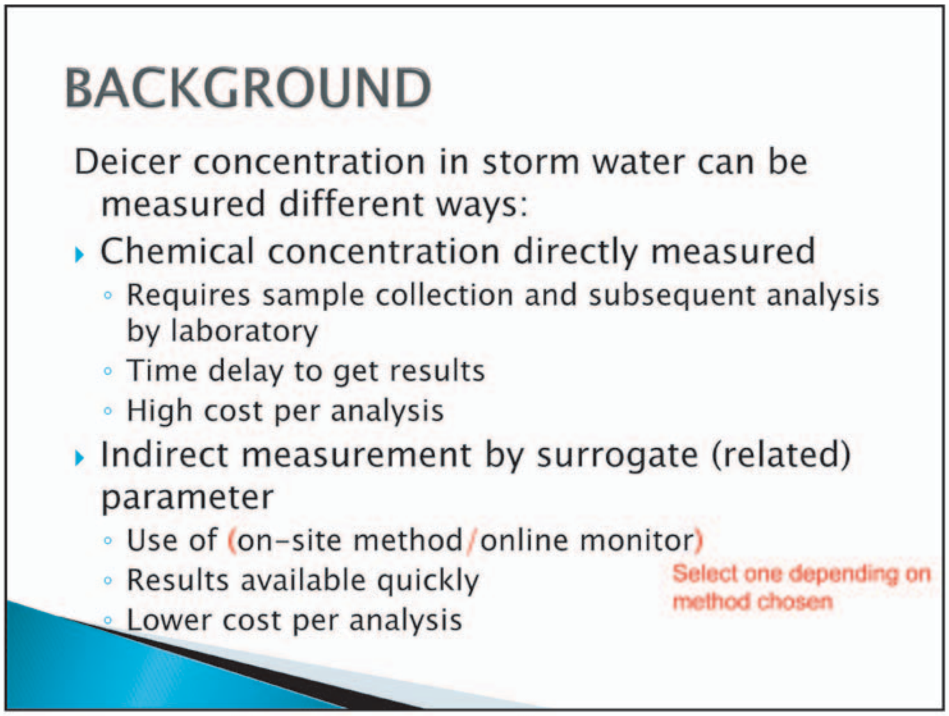

Talking Points: (1) The main point is that there are various ways to measure deicer concentration.

(2) Discuss the typical method of deicer compliance monitoring: shipping samples to a laboratory and the disadvantages.

(3) Discuss the on-site monitoring and the advantages to airport operations. Focus should be on on-site test-kit monitoring or online monitoring depending on the proposed monitoring method.

(4) The airport is attempting to balance cost, data accuracy, and reliability to achieve the monitoring goal.

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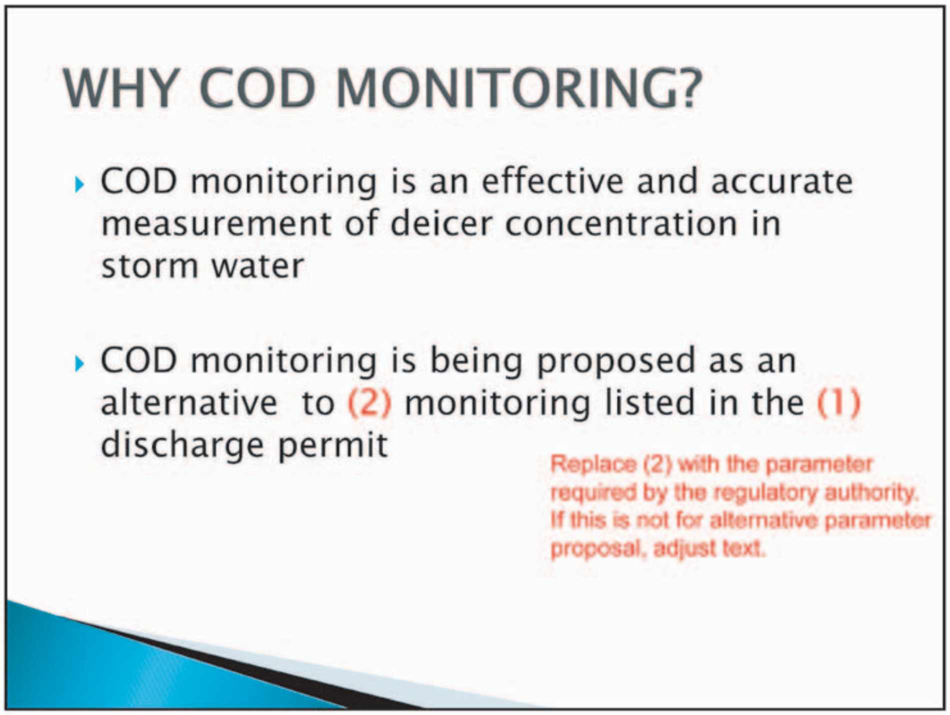

Talking Points: (1) Describe that COD monitoring is an alternative for deicer monitoring because it measures a property of the deicer chemicals.
(2) The airport has a requirement for discharge monitoring for a deicer parameter and the airport believes that monitoring for COD would be a better option.

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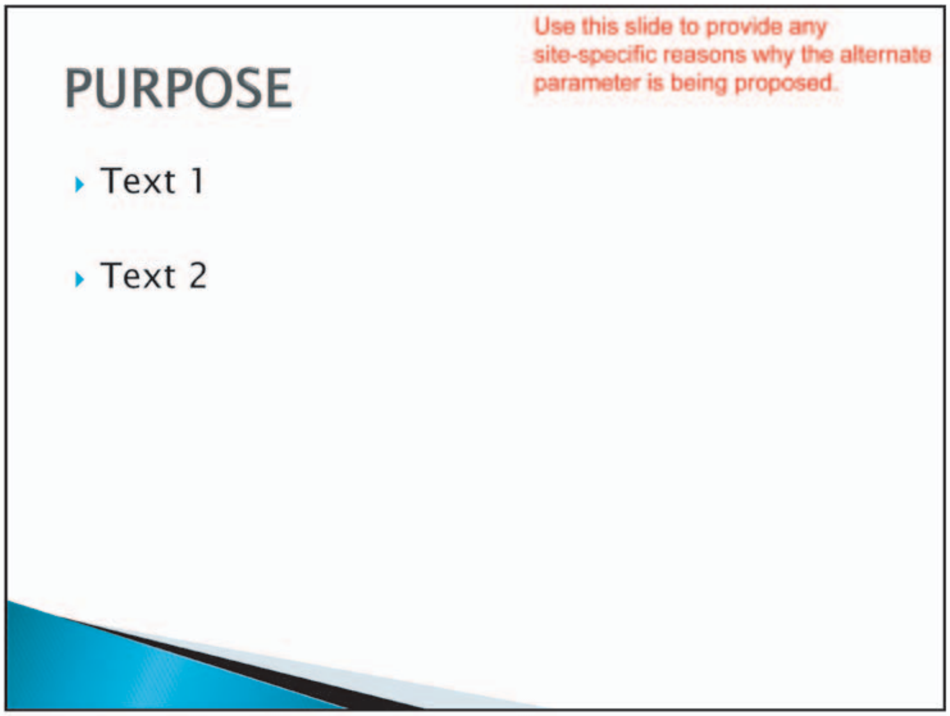

Talking Points: Discuss the specific reasons that COD is being proposed. These can range from logistics for sampling, real-time storm water diversion, or adjustment of flow rates for load control. Typically the primary reason for on-site monitoring is that the airport can respond and be proactive regarding the storm water quality, rather than become aware of storm water quality issues at a later date.

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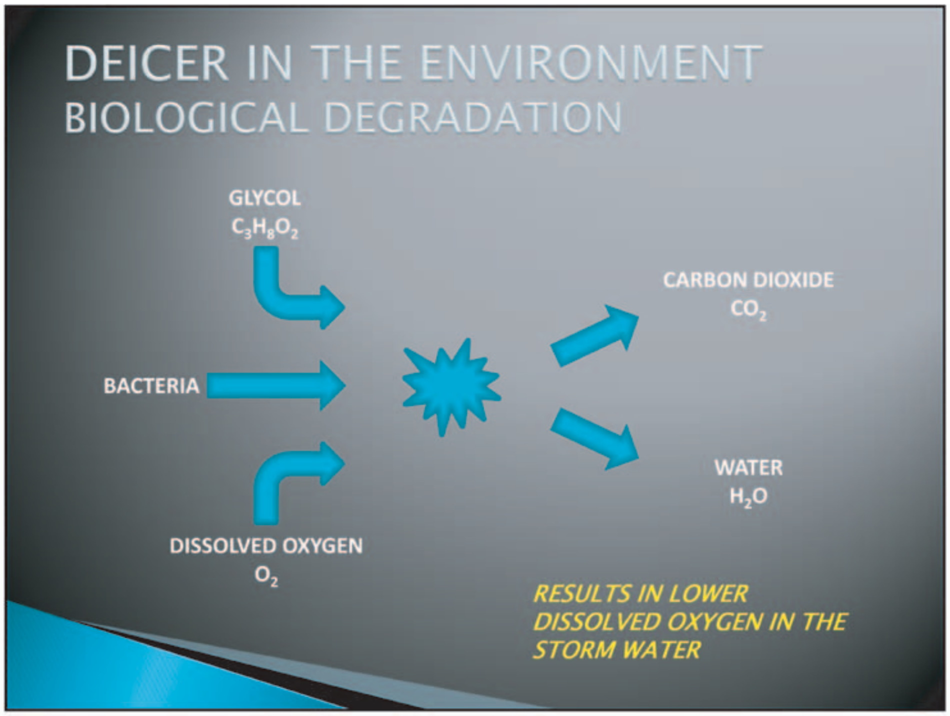

Talking Points: (1) Discuss the background for environmental reason why deicers are regulated including: decrease of dissolved oxygen in surface water because of bacterial breakdown.

(2) Presenter may also want to discuss that biological breakdown can be slowed down by temperature typical of deicer discharges and lack of nutrients for biological growth.

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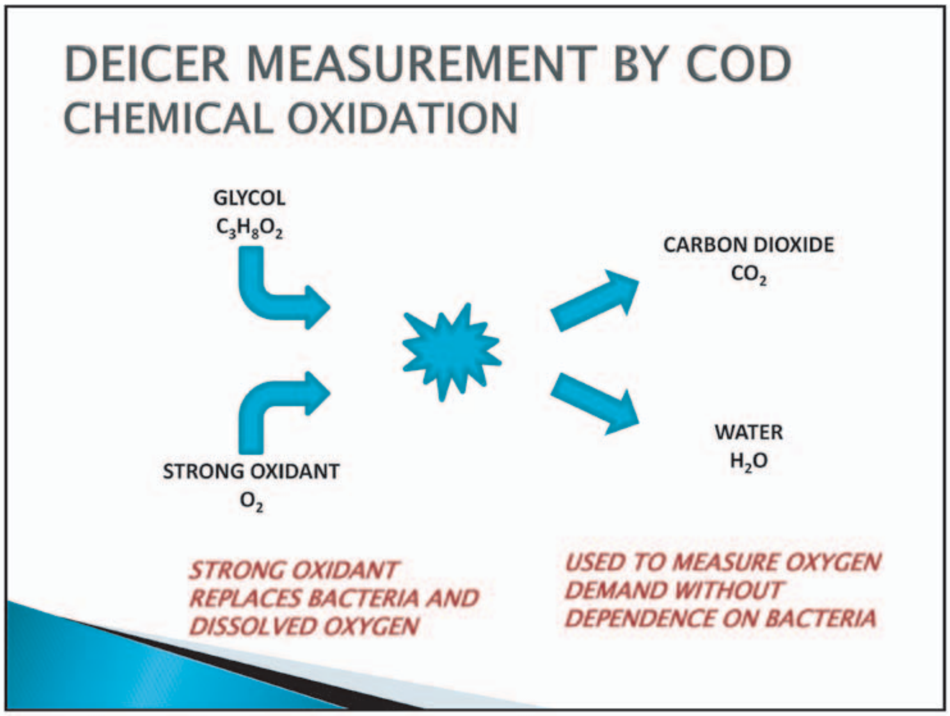

Talking Points: (1) Discuss how the COD measurement is similar to the biology-based environmental breakdown process of organics.

(2) Oxidation using the COD test method is slightly more conservative for oxygen demand because it does not depend on bacteria for breakdown. Bacteria could be inhibited by toxicity or being "unconditioned" to the chemical in the sample.

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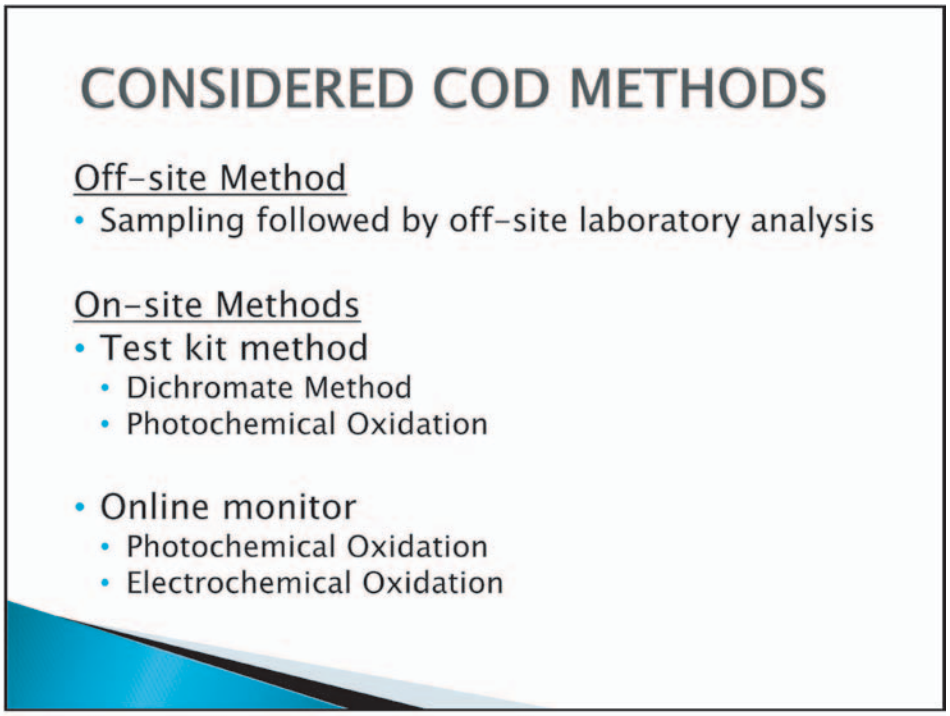

Note: There are multiple types and methods for COD analyses.
Talking Points: (1) Analysis can be performed by off-site laboratory.
(2) Online methods can be incorporated into diversion.
(3) Test kits can be used at multiple locations.

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Use this slide for Dichromate method

ON–SITE COD METHOD SUMMARY

Dichromate Method

- Potassium Dichromate is the strong oxidant
- US EPA approved method (EPA 410.4)
- Results in hours vs. 5 days for BOD_5 analysis
- Method can be performed on–site

Note: There are three methods for COD analyses; choose the slides based on the method chosen.

Talking Points: (1) Dichromate method is the most common COD method; regulators should be familiar with this method.

(2) This method is well tested, is US EPA approved, and has wide application in storm water analyses.

(3) Faster results will allow for real-time decisions regarding storm water discharges.

(4) Analyses performed on-site will allow for additional sampling, if desired, without additional logistics.

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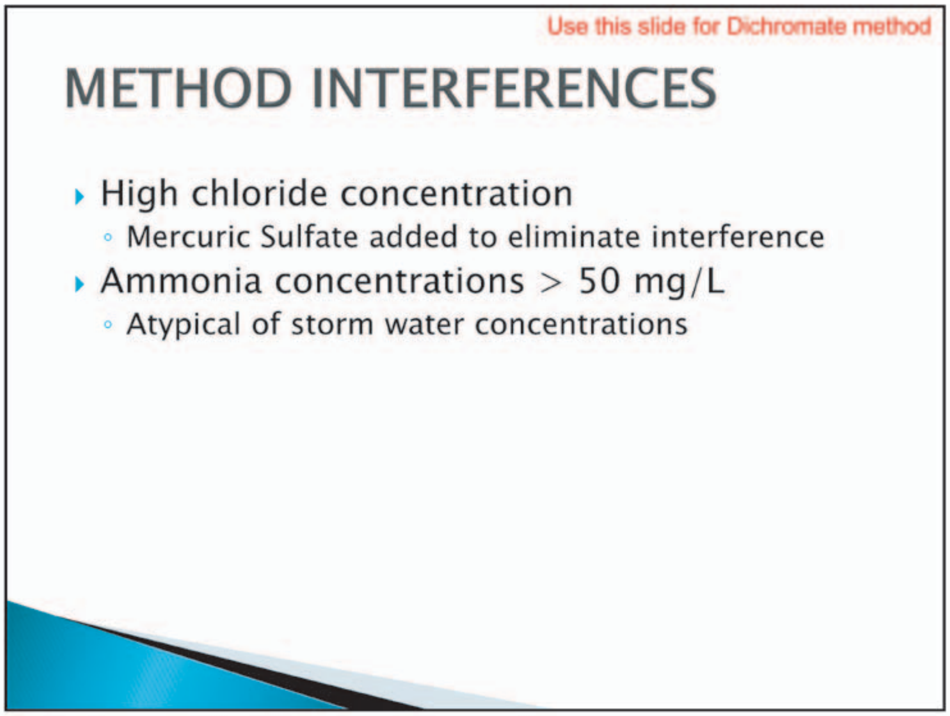

Talking Points: (1) Interferences for this method are well established.
(2) Mercury compound added to eliminate chloride interference.
(3) Ammonia interference not expected in storm water unless urea is used for pavement deicing.

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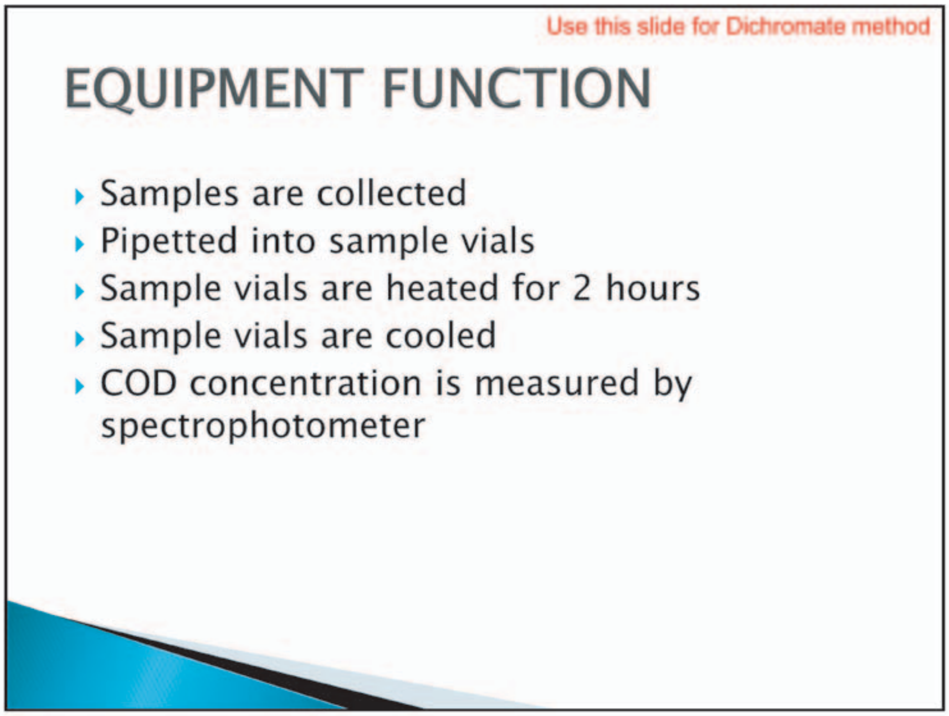

Talking Points: (1) Procedure is simple and can be performed without extensive training. (2) The results are read from the spectrophotometer so no interpretation or data calculations are required.

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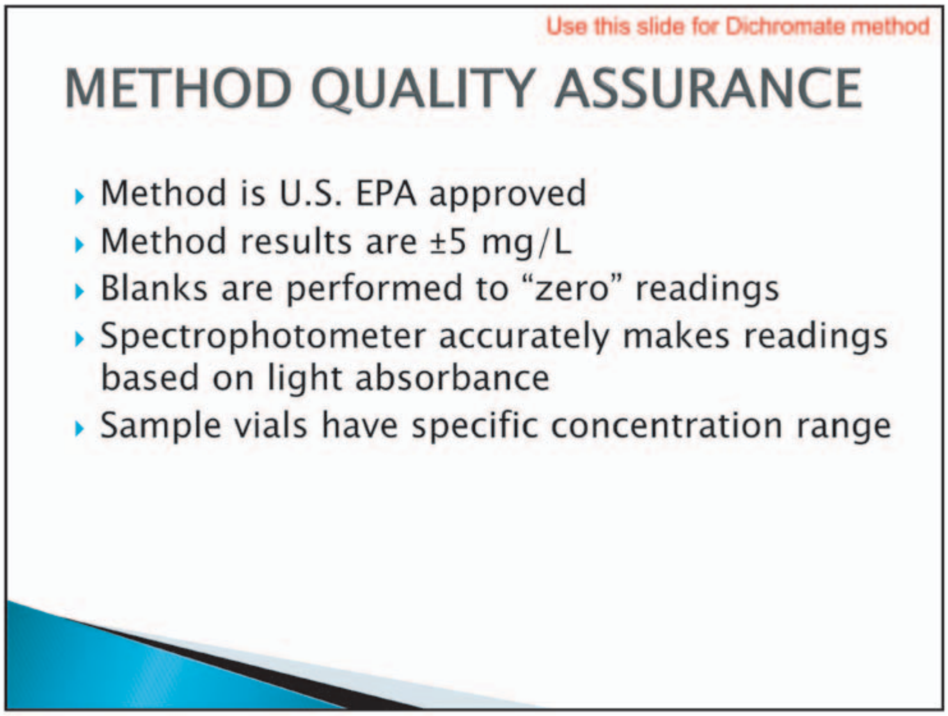

Talking Points: (1) Method is well tested and approved by U.S. EPA for discharge monitoring reporting.
(2) Results are typically repeatable and accurate.
(3) The only calibration of the unit is running a blank – a sample of distilled water.
(4) Measurement is based on light absorbance: a simple, reliable measurement.
(5) Sample vials have a specific concentration range to maintain accuracy.

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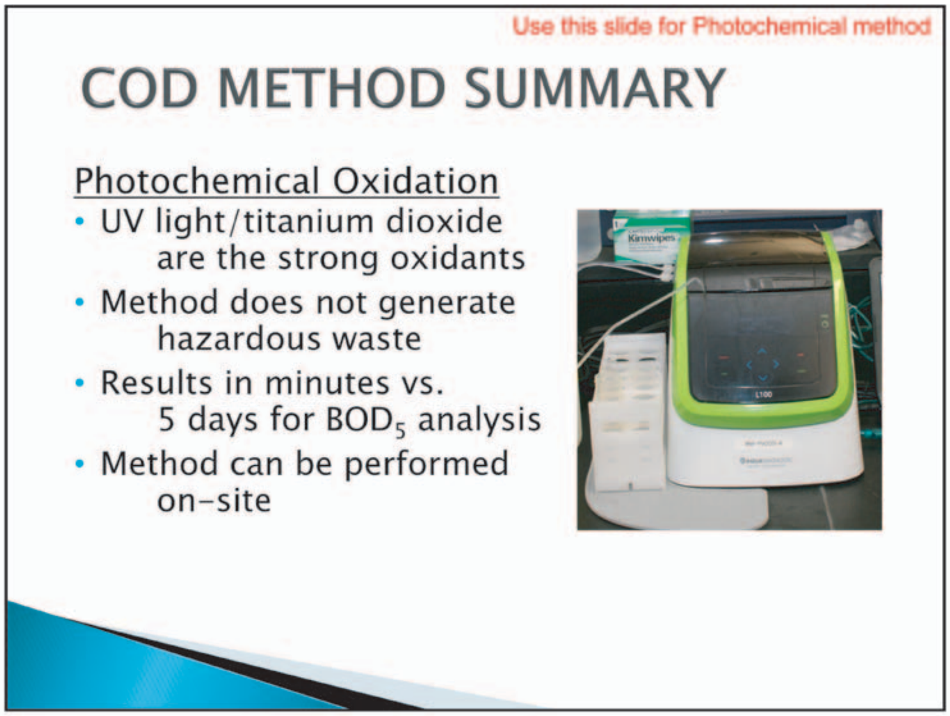

Note: There are three methods for COD analyses; choose the slides based on the method chosen.
Talking Points: (1) This method is similar to the more common dichromate method.
(2) This method does not generate hazardous waste like the more common COD analysis.
(3) Faster results will allow for real-time decisions regarding storm water discharges.
(4) Analyses performed on-site will allow for additional sampling, if desired, without additional logistics.

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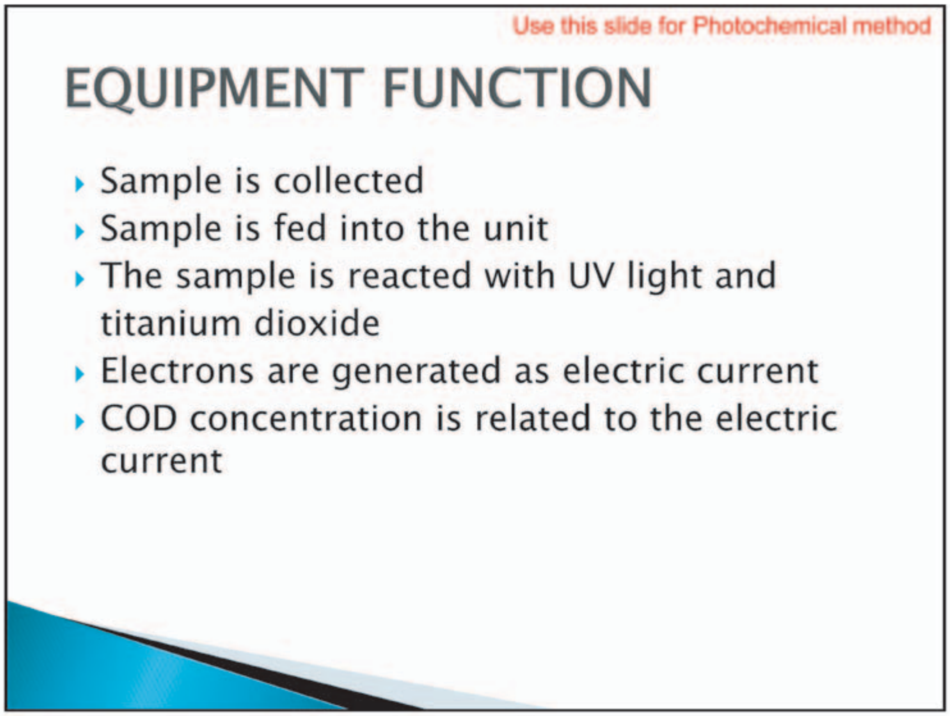

Talking Points: (1) Procedure is simple and can be performed without extensive training. (2) The results are read from the spectrophotometer (or online monitor) so no interpretation or data calculations are required.

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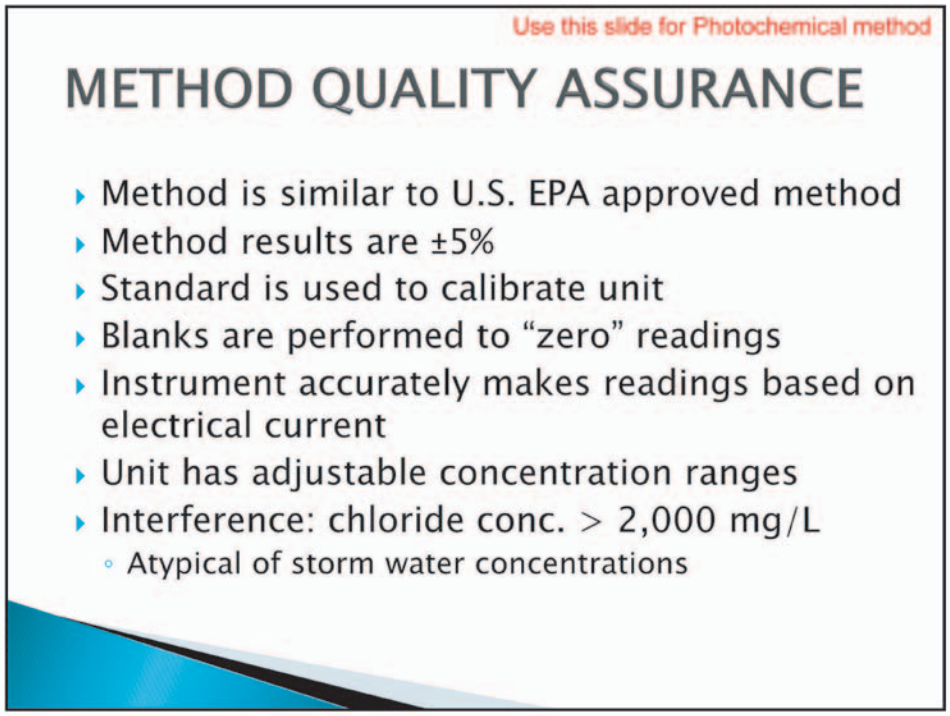

Talking Points: (1) Method is similar to U.S. EPA approved method.
(2) Method accuracy is similar to other analytical methods.
(3) The monitor is calibrated by running blanks and standards.
(4) Measurement is based on a produced electrical current: an accurate measurement for electronic equipment.
(5) Monitor has three adjustable concentration ranges to maintain accuracy.
(6) Interference by chloride is not typically in concentration range of storm water unless chloride concentrations exceed approximately 2,000 mg/L. If mineral salts are used for landside pavement deicing and the discharge is combined with air-side discharges, the airport should verify that the chloride concentrations do not approach this concentration.

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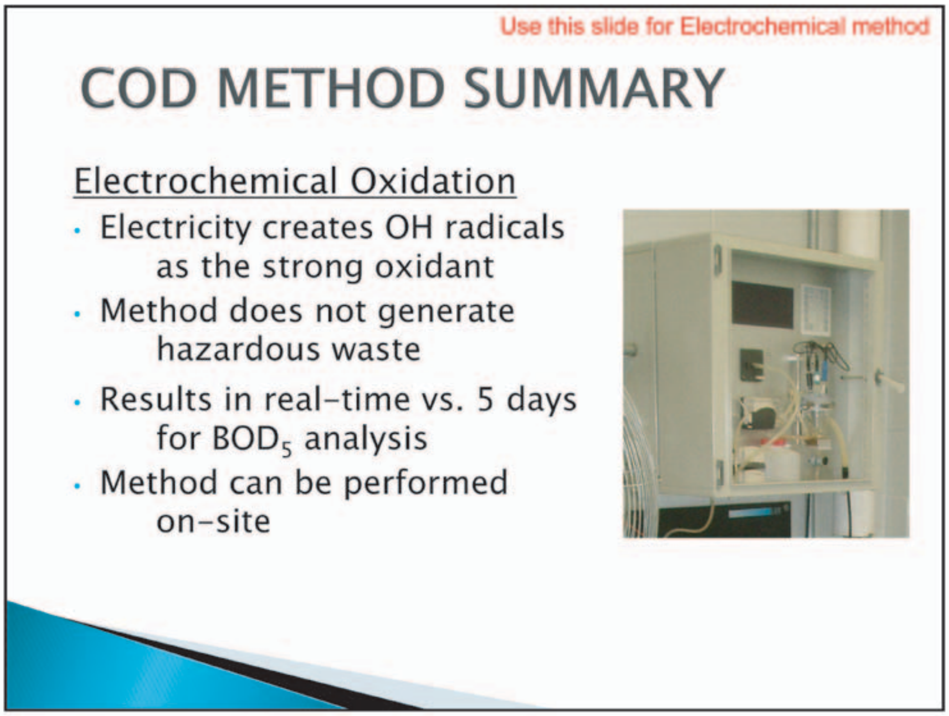

Note: There are three methods for COD analyses; choose the slides based on the method chosen.

Talking Points: (1) This method is similar to the more common dichromate method.
(2) This method does not generate hazardous waste like the more common COD analysis.
(3) Faster results will allow for real-time decisions regarding storm water discharges.
(4) Analyses performed on-site will allow for additional sampling, if desired, without additional logistics.

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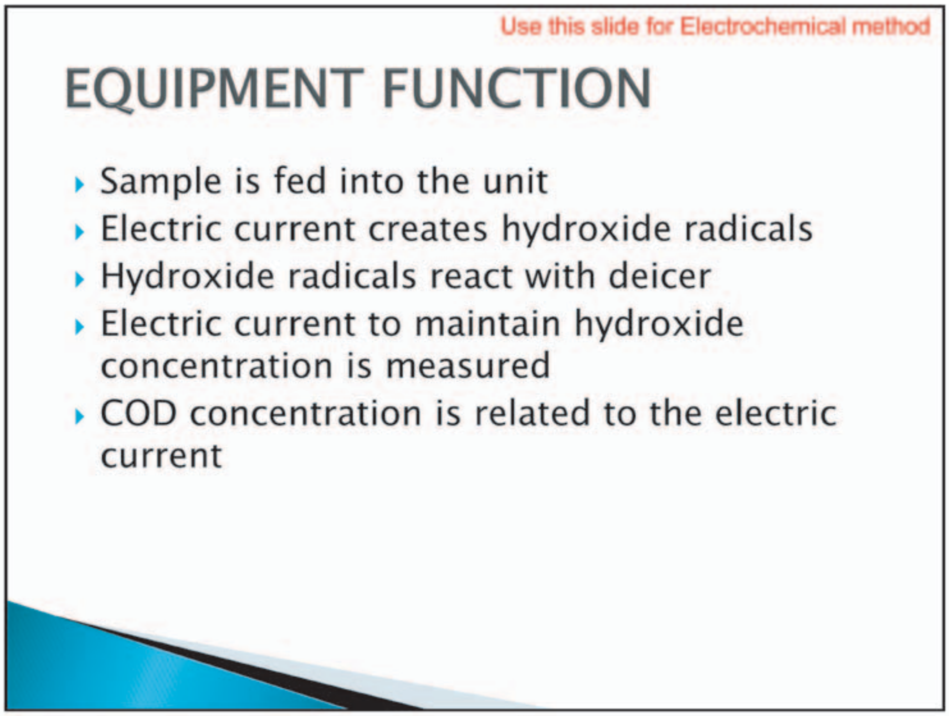

Talking Points: (1) Procedure is simple and the on-line monitor can be maintained with some training.
(2) The results are read from the online monitor so no interpretation or data calculations are required.

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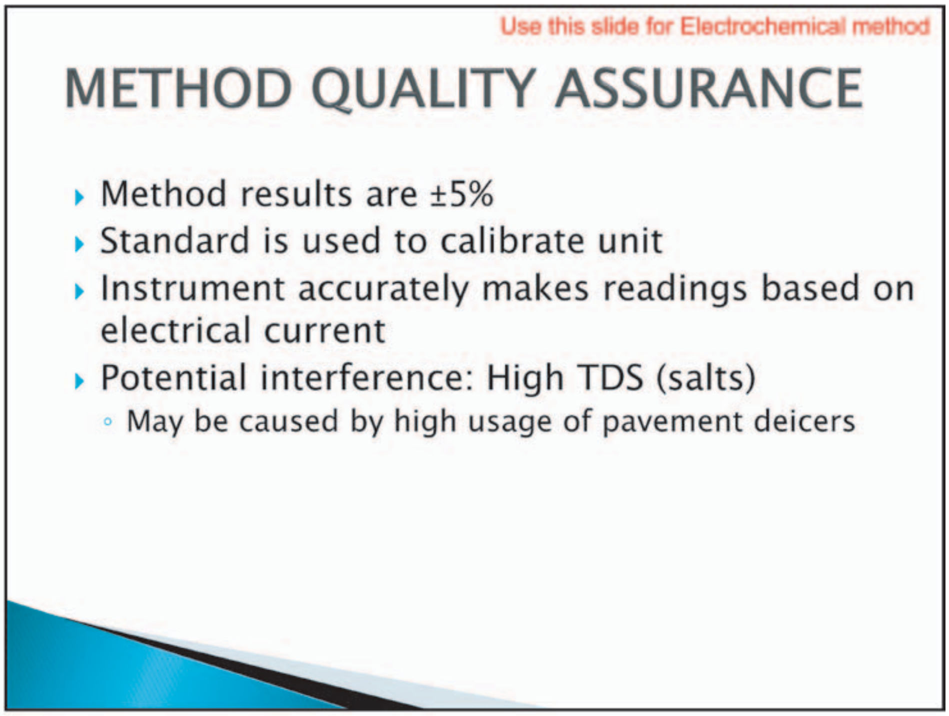

Talking Points: (1) Method accuracy is similar to other analytical methods.
(2) The unit is calibrated by running a standard.
(3) Measurement is based on electrical current through the solution: an accurate measurement for electronic equipment.
(4) Interference by salts causes changes in the electrical current through sample, and pavement deicers in high concentration may interfere with measurement.

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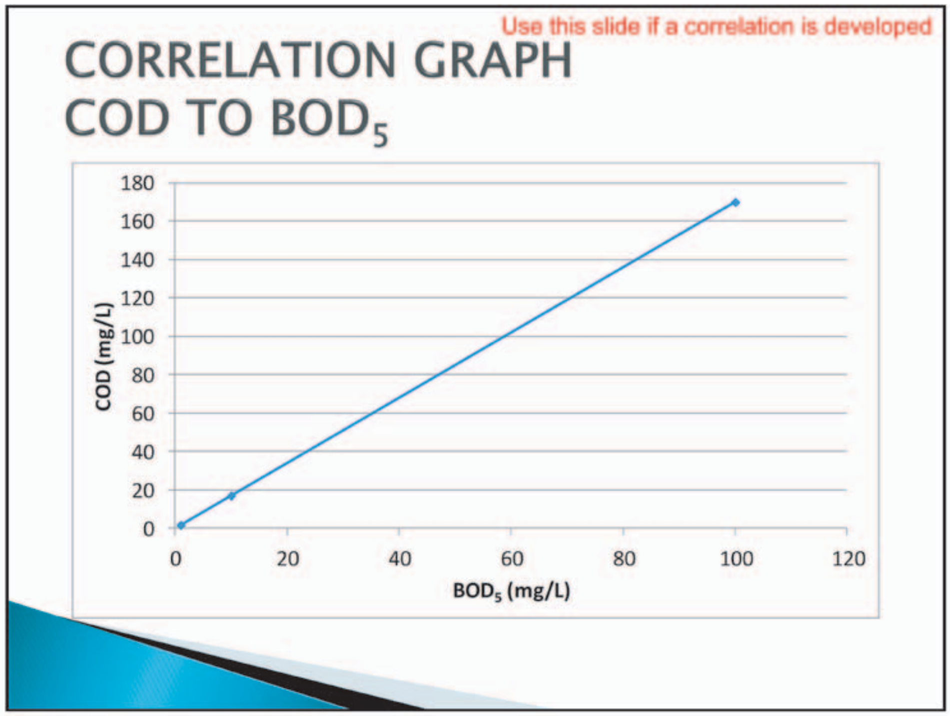

Note: Airport should analyze samples (between 10 and 50 samples recommended) over the concentration range expected to develop a correlation.

Talking Points: (1) Discuss accuracy over the range.

(2) Discuss accuracy at any critical points, such as diversion concentration.

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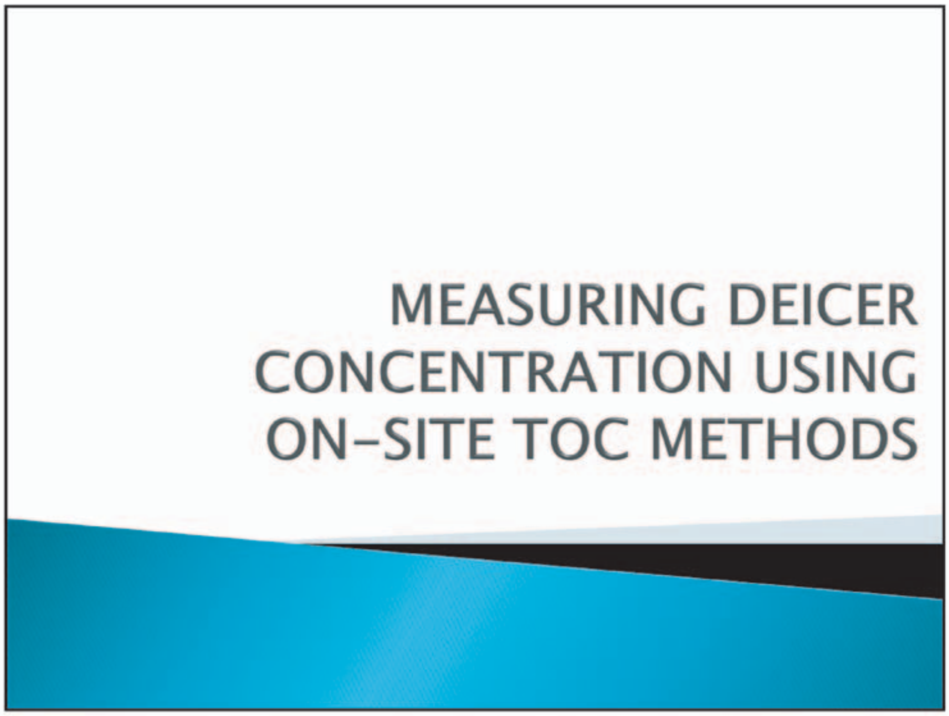

This presentation is intended to be used as baseline information on means by which on-site TOC monitoring can be used to measure deicer concentrations in storm water. This presentation was created as a template from which airport-specific information on on-site TOC monitoring can be communicated to airport management, regulators, or other interested stakeholders. Note that not all slides or information is appropriate for all three audiences. Airport-specific information will need to be added to this presentation.

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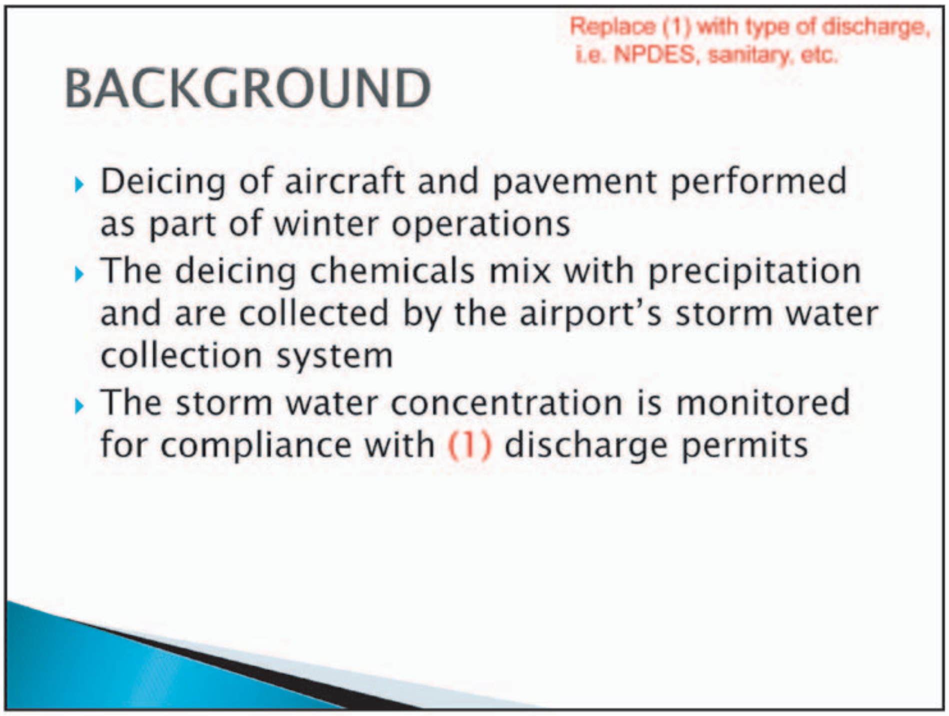

Talking Points: (1) Deicing is a necessary part of airport operations – it cannot be eliminated.
(2) Applied deicing chemicals are collected prior to discharge to the environment – mention airport-specific collection methods such as pads, segregated collection, or GRVs.
(3) Describe the discharge of the storm water and the permit monitoring required for compliance with the applicable permit conditions.

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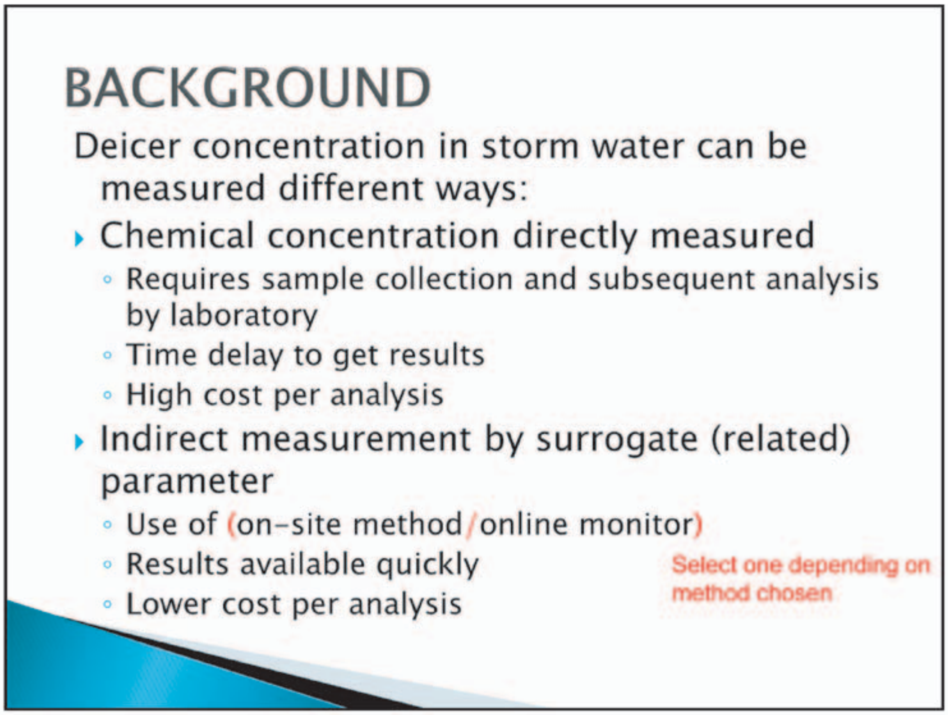

Talking Points: (1) The main point is that there are various ways to measure deicer concentration.
(2) Discuss the typical method of deicer compliance monitoring: shipping samples to a laboratory and the disadvantages.
(3) Discuss the on-site monitoring and the advantages to airport operations. Focus should be on on-site test-kit monitoring or online monitoring depending on the proposed monitoring method.
(4) The airport is attempting to balance cost, data accuracy, and reliability to achieve the monitoring goal.

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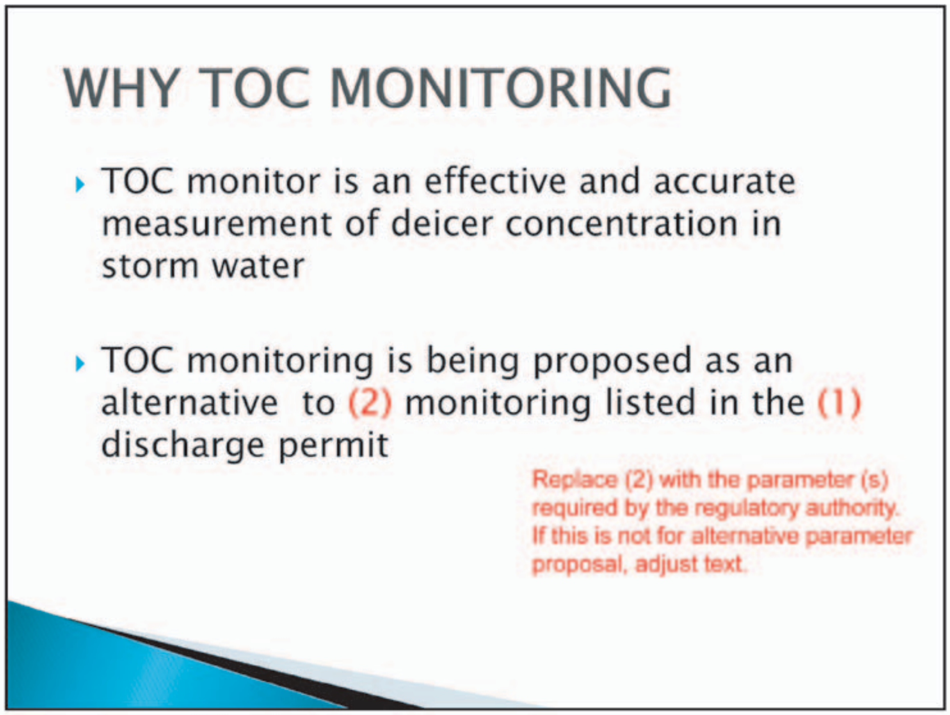

Talking Points: (1) Describe that TOC monitoring is an alternative for deicer monitoring and it measures the same property a different way.
(2) The airport has a requirement for discharge monitoring for a deicer parameter and the airport believes that monitoring for TOC would be a better option.

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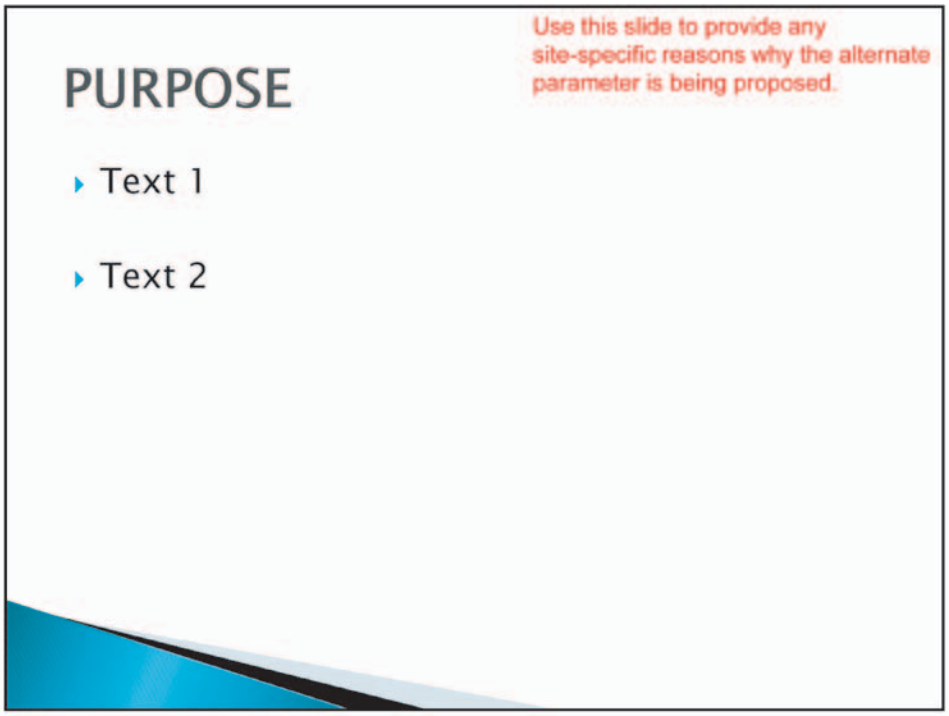

Talking Points: 1) Discuss the specific reasons that TOC is being proposed. These can range from logistics for sampling, real-time storm water diversion, or adjustment of flow rates for load control.

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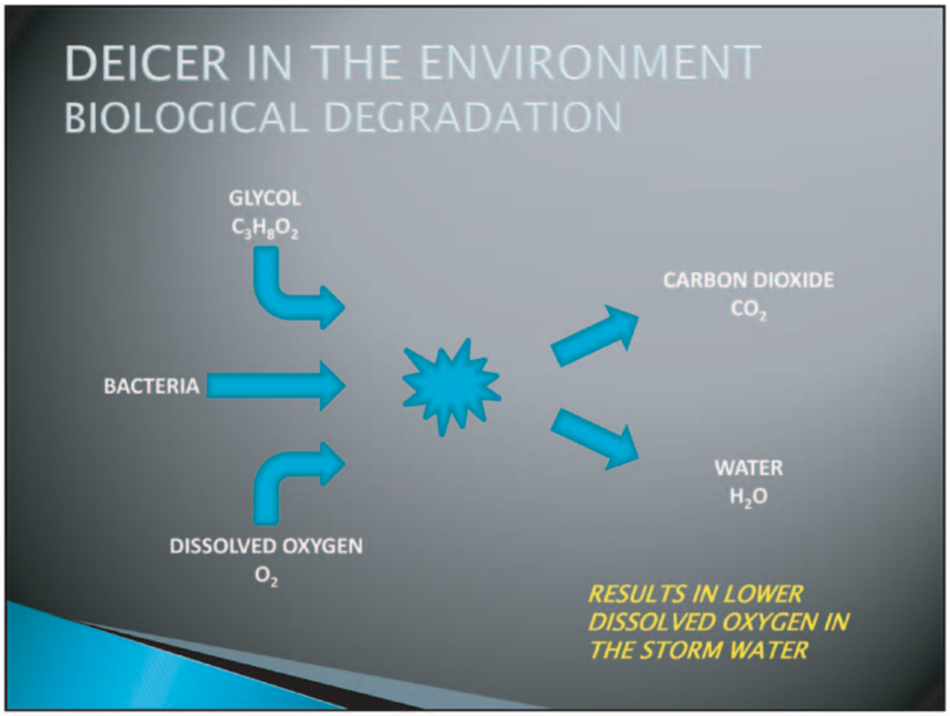

Talking Points: 1) Discuss the background for environmental reason why deicers are regulated: decrease of dissolved oxygen in surface water because of bacterial breakdown. 2) Presenter may also want to discuss that biological breakdown can be slowed down by temperature typical of deicer discharges and lack of nutrients for biological growth.

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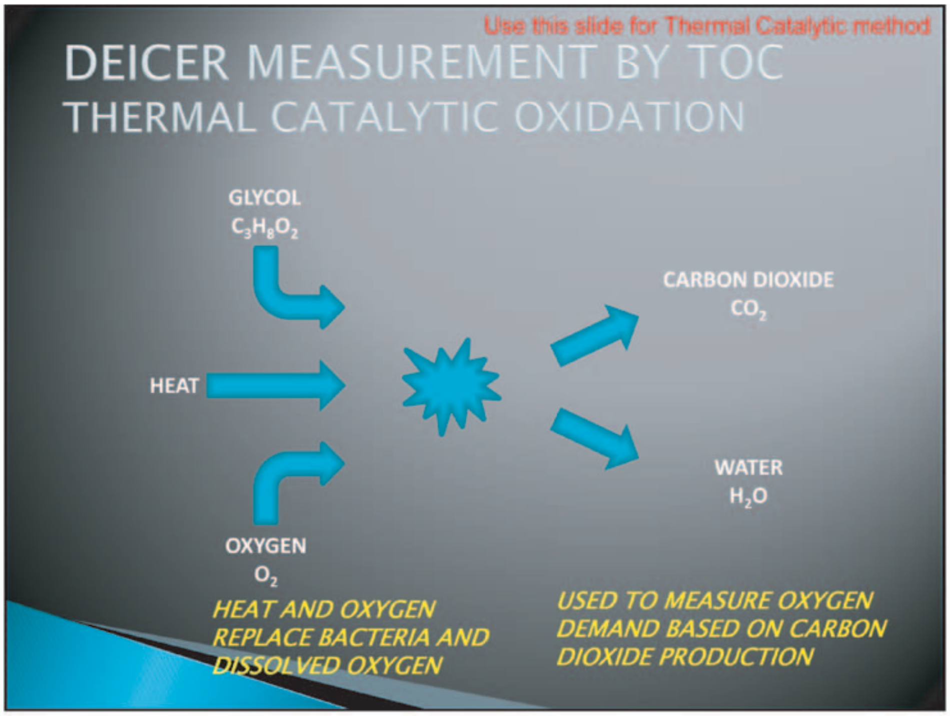

NOTE: there are three methods for TOC analyses, choose the slides based on the method chosen.

Talking Points: 1) Discuss how the TOC measurement is similar to the environmental breakdown.

2) TOC is slightly more conservative because it does not depend on bacteria for breakdown.

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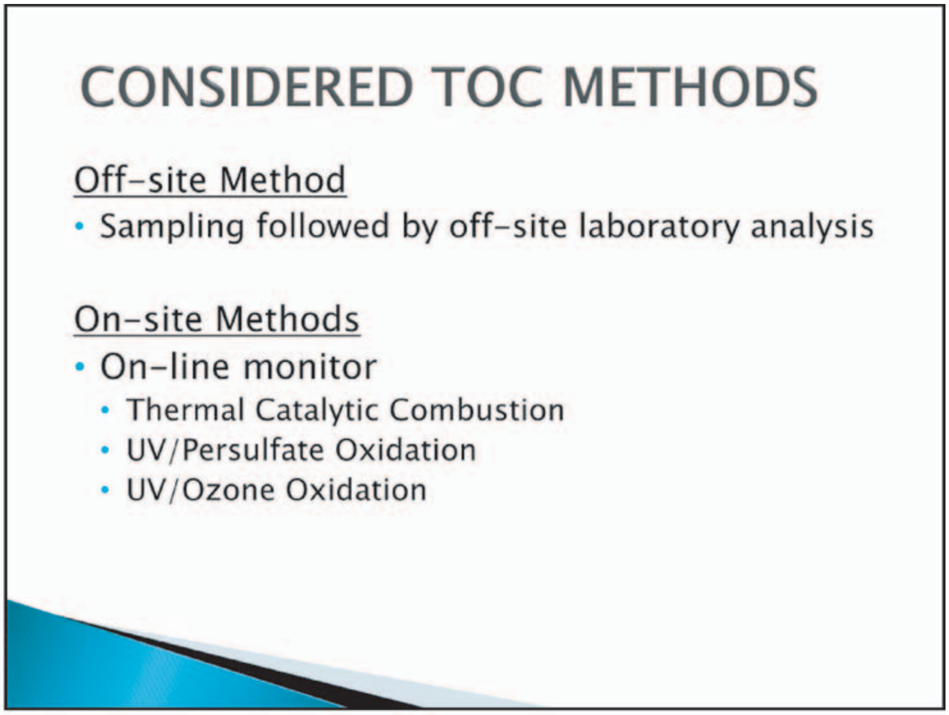

NOTE: there are multiple types and methods for COD analyses.
Talking Points: 1) Analysis can be performed by off-site laboratory
2) Online methods can be incorporated into diversion.

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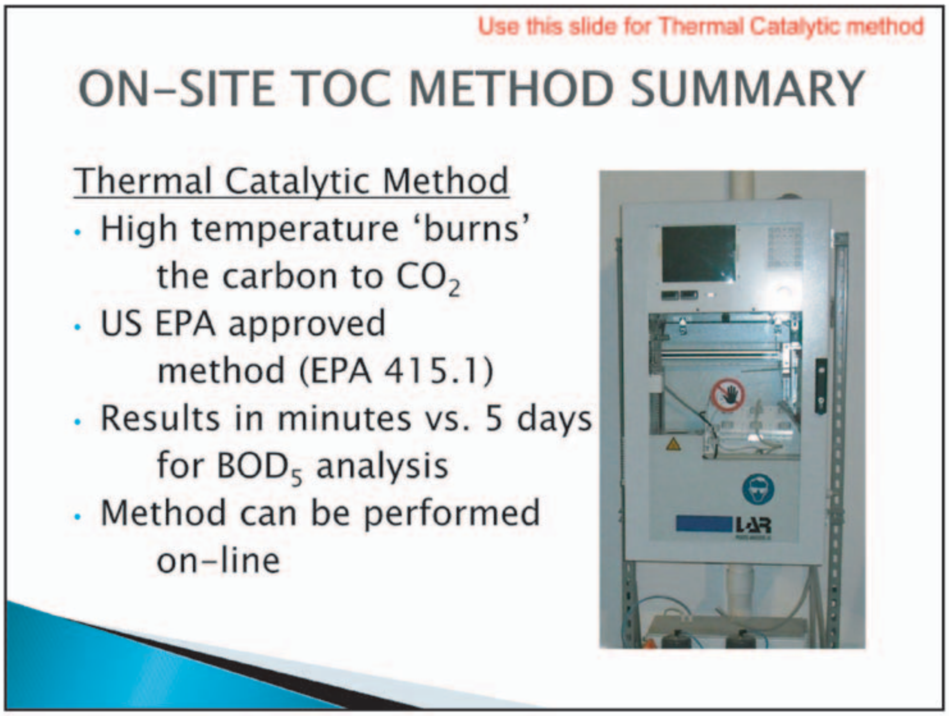

Talking Points: 1) Thermal catalytic method is the most common TOC method and is the method commonly used by laboratories for TOC analyses.
2) This method is well tested, is US EPA approved, and has wide application in storm water analyses.
3) Faster results will allow for real-time decisions regarding storm water discharges.
4) Analyses performed on-site will allow for additional sampling, if desired, without additional logistics.

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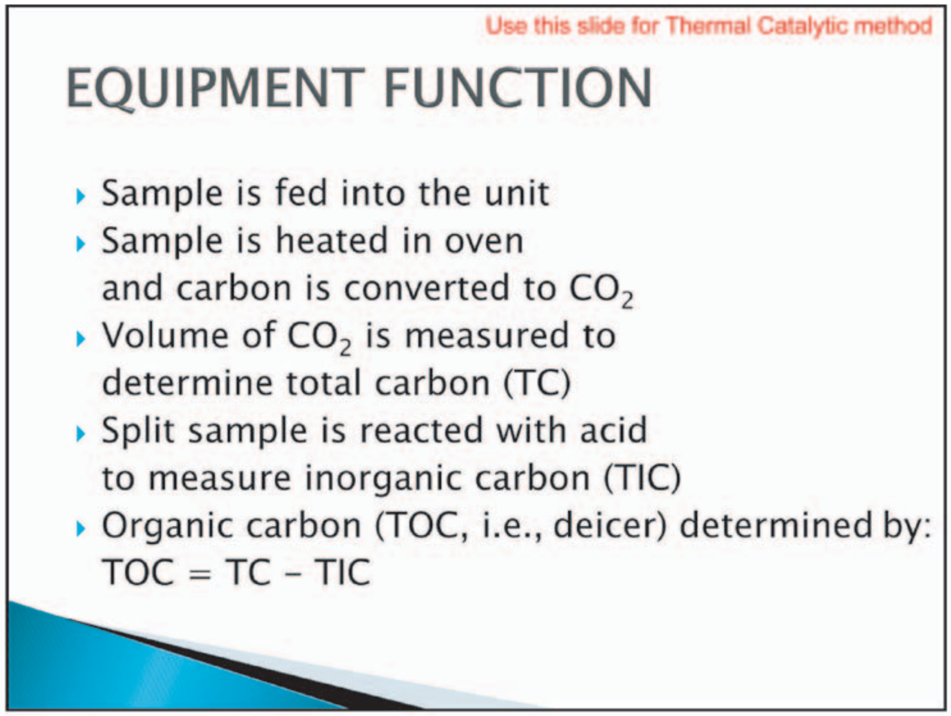

Talking Points: 1) Procedure is simple and the on-line monitor can be maintained with some training.
2) The results are read from the on-line monitor so no interpretation or data calculations are required.
3) Monitors typically make a separate measurement for inorganic carbon and subtract result to get Total Organic Carbon (TOC) – delete this bullet if monitor is set up to measure total carbon.

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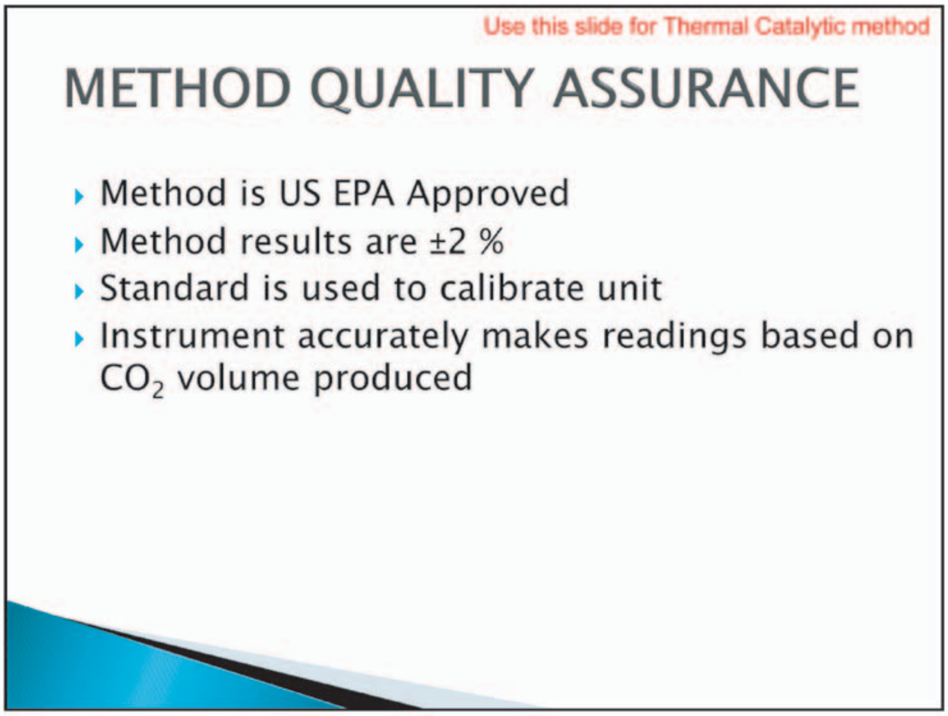

Talking Points: 1) Method is well tested and approved by US EPA for discharge monitoring reporting.
2) Results are typically repeatable and very accurate.
3) The unit is calibrated by running a standard.
4) Measurement is based on measurement of carbon dioxide produced.

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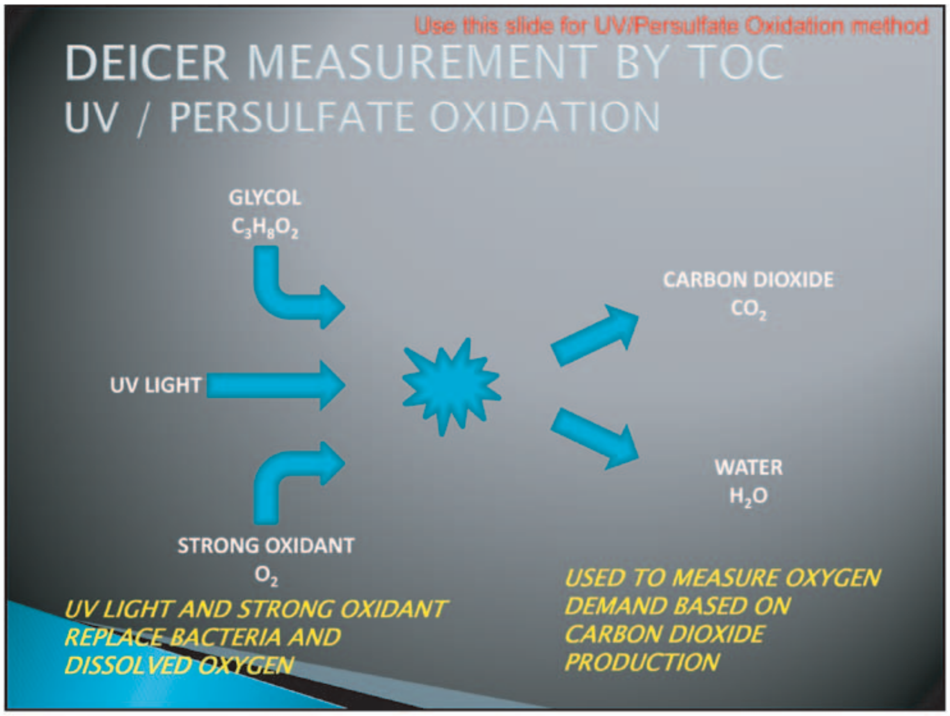
Guidebook for Selecting Methods to Monitor Airport and Aircraft Deicing Materials



NOTE: there are three methods for TOC analyses, choose the slides based on the method chosen.

Talking Points: 1) Discuss how the TOC measurement is similar to the environmental breakdown.

2) TOC is slightly more conservative because it does not depend on bacteria for breakdown.

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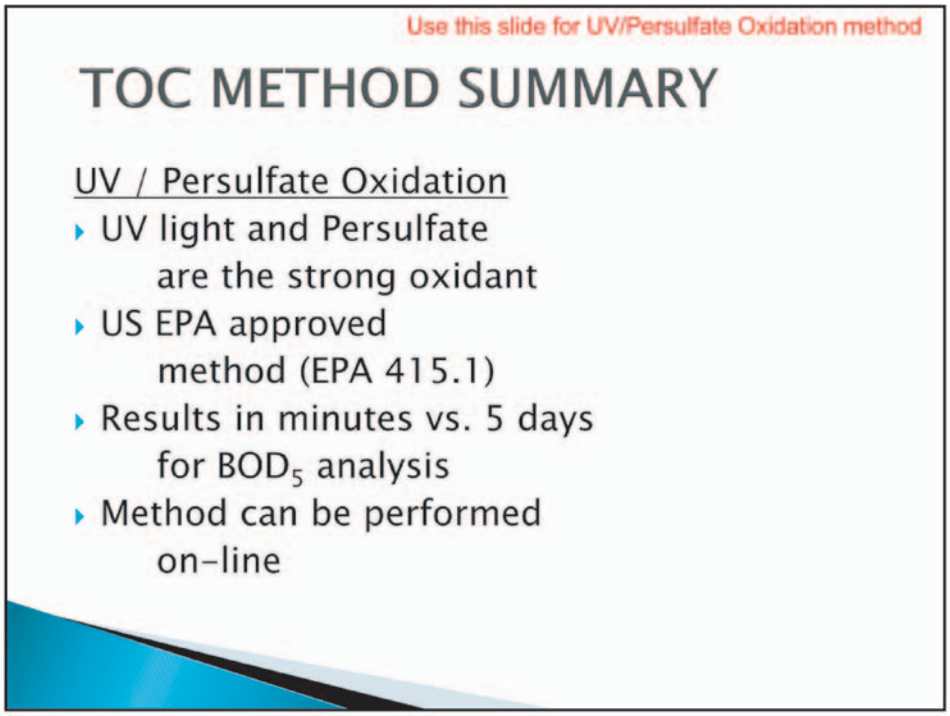

Talking Points: 1) UV/Persulfate method is well tested, is US EPA approved, and has wide application in storm water analyses.
2) Faster results will allow for real-time decisions regarding storm water discharges.
3) Analyses performed on-site will allow for additional sampling, if desired, without additional logistics.

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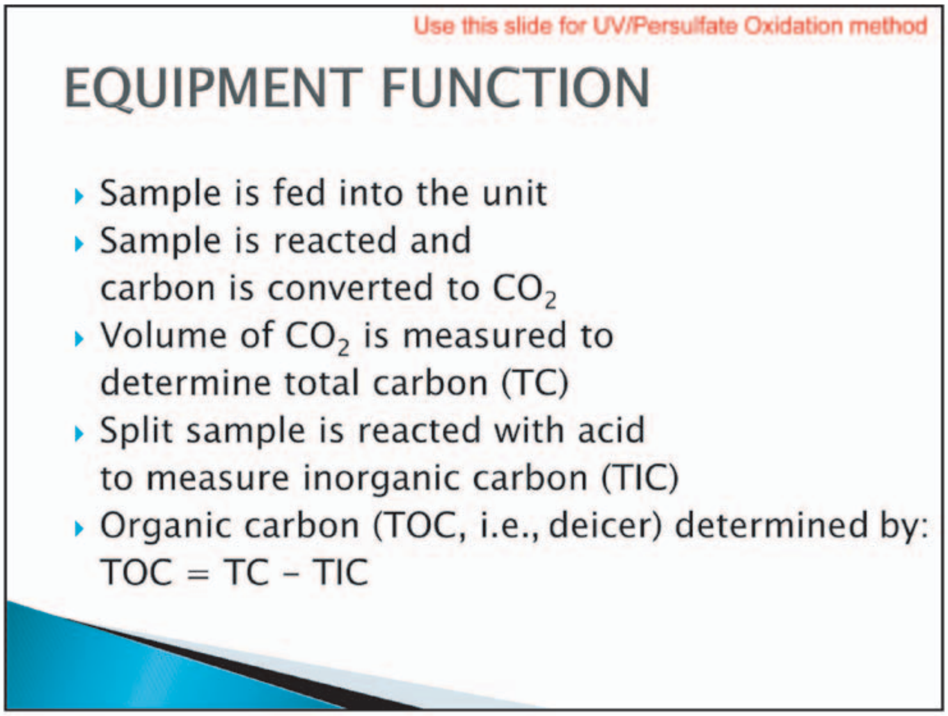

Talking Points: 1) Procedure is simple and the on-line monitor can be maintained with some training.
2) The results are read from the on-line monitor so no interpretation or data calculations are required.
3) Monitors typically make a separate measurement for inorganic carbon and subtract result to get Total Organic Carbon (TOC) – delete this bullet if monitor is set up to measure total carbon.

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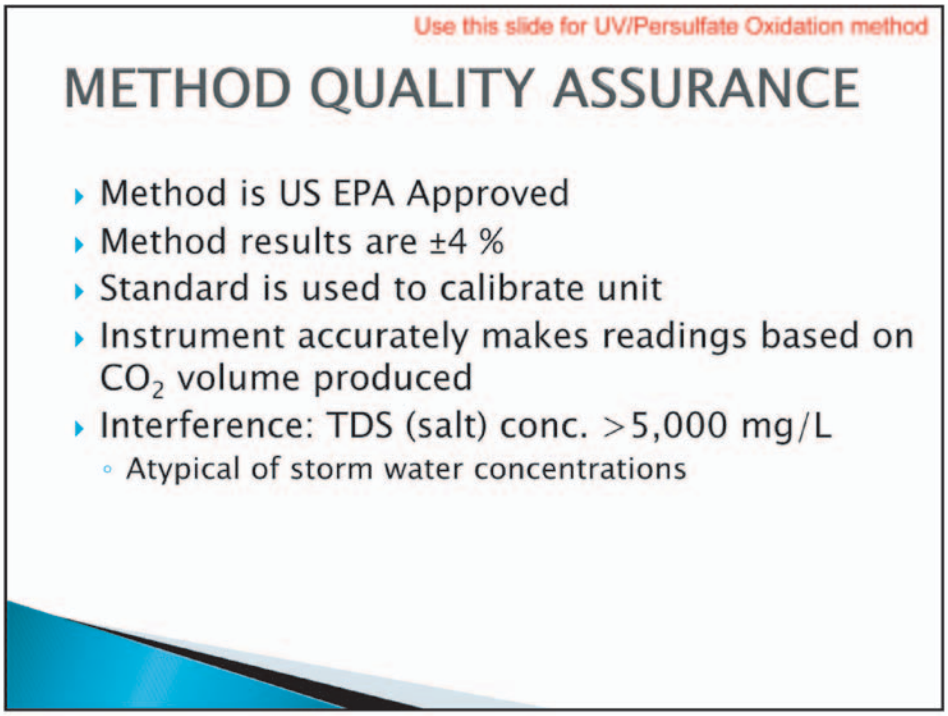

Talking Points: 1) Method is well tested and approved by US EPA for discharge monitoring reporting.
2) Results are typically repeatable and very accurate.
3) The unit is calibrated by running a standard.
4) Measurement is based on measurement of carbon dioxide produced.
5) Range where TDS interference occurs is greater than typical storm water TDS.

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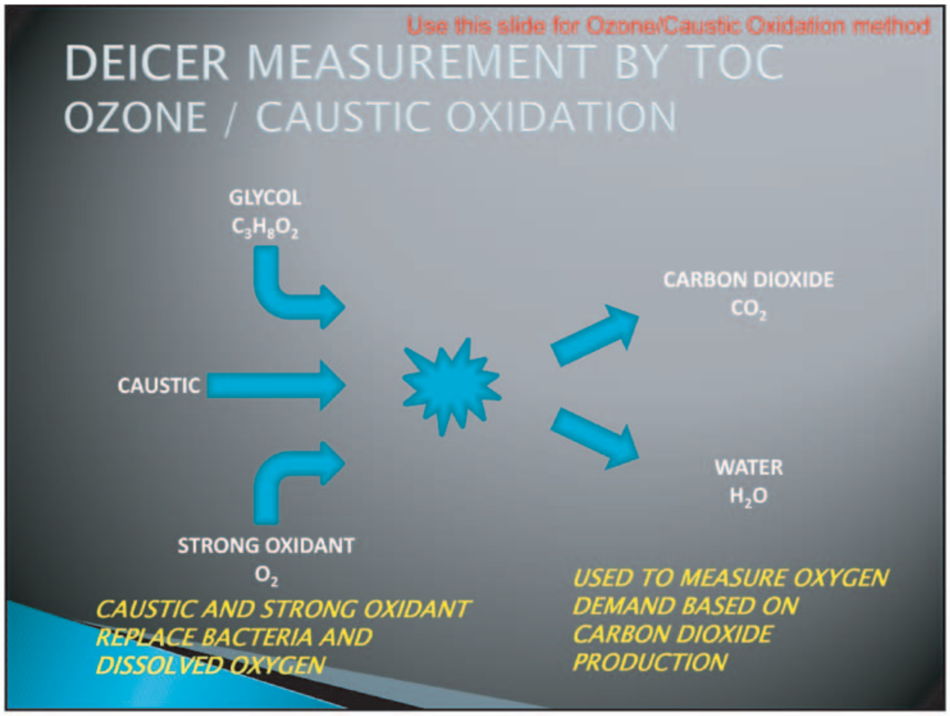

NOTE: there are three methods for TOC analyses, choose the slides based on the method chosen.

Talking Points: 1) Discuss how the TOC measurement is similar to the environmental breakdown.

2) TOC is slightly more conservative because it does not depend on bacteria for breakdown.

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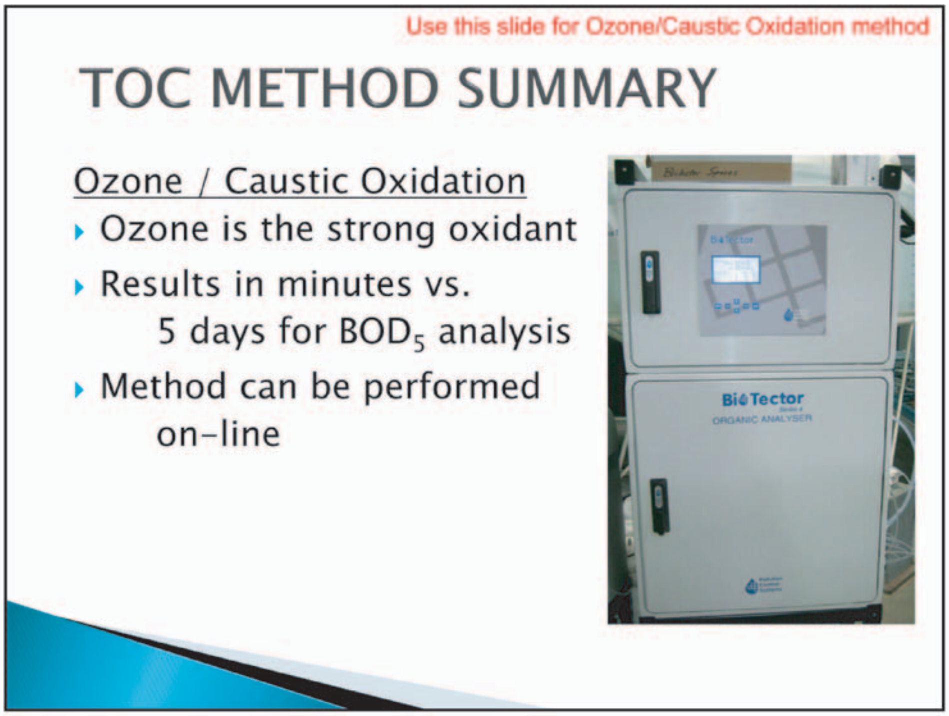

Talking Points: 1) Ozone/caustic method is similar to the US EPA approved methods but use a different oxidant.
2) Faster results will allow for real-time decisions regarding storm water discharges.
3) Analyses performed on-site will allow for additional sampling, if desired, without additional logistics.

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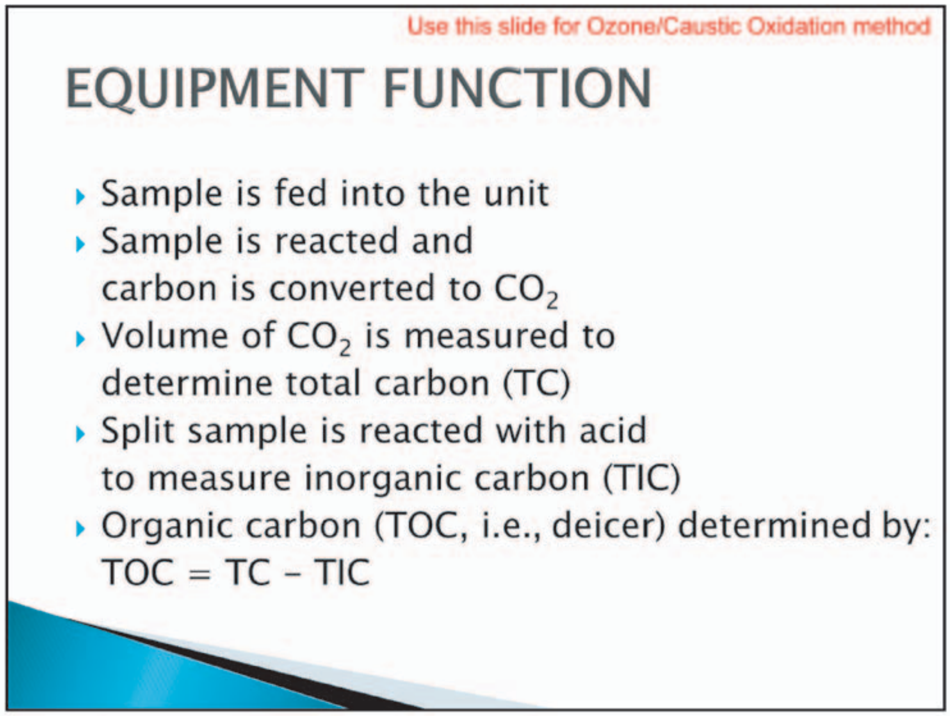

Talking Points: 1) Procedure is simple and the on-line monitor can be maintained with some training.
2) The results are read from the on-line monitor so no interpretation or data calculations are required.
3) Monitors typically make a separate measurement for inorganic carbon and subtract result to get Total Organic Carbon (TOC) – delete this bullet if monitor is set up to measure total carbon.

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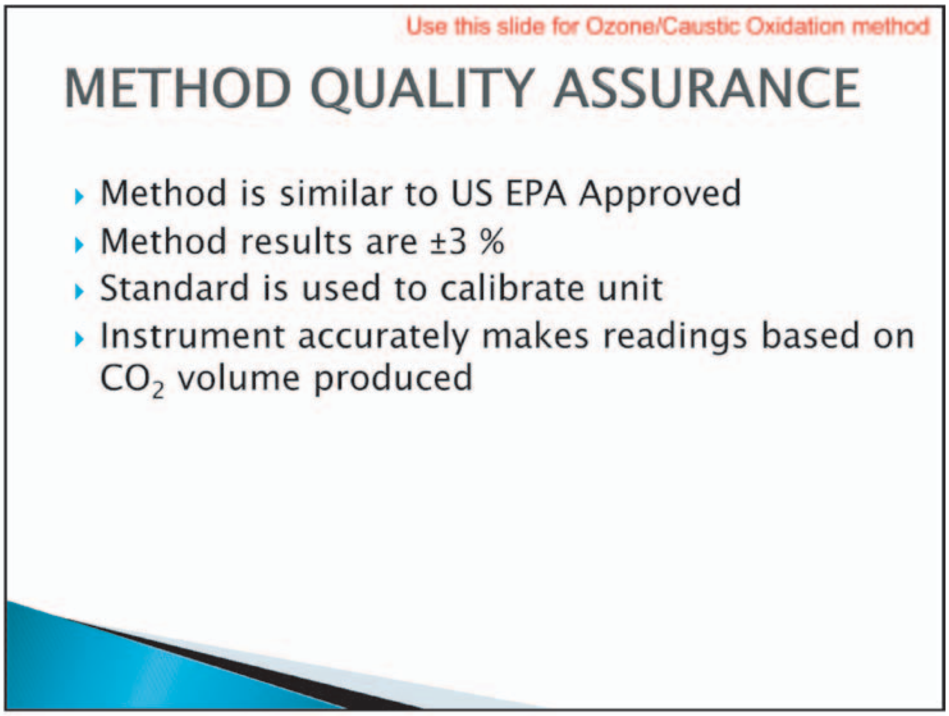

Talking Points: 1) Method is similar to US EPA approved method.
2) Method accuracy is similar to other TOC analytical methods.
3) The unit is calibrated by running a standard.
4) Measurement is based on measurement of carbon dioxide produced.

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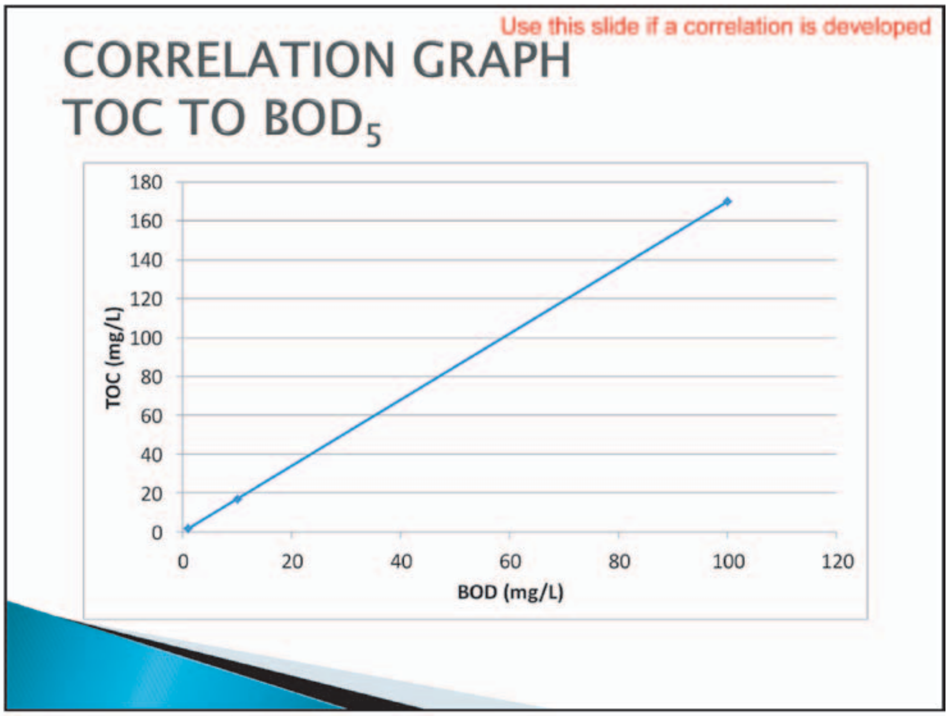

NOTE: Analyze samples (between 10 and 50 samples recommended) over the concentration range expected to develop a correlation.
Talking Points: 1) Discuss accuracy over the range.
2) Discuss accuracy at any critical points, such as diversion concentration.

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Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation

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ACRP
FACT SHEETS

AIRPORT COOPERATIVE RESEARCH PROGRAM

Sponsored by the Federal Aviation Administration

On-Site Monitoring Methods

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

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FACT SHEETS

On-Site Monitoring Methods #58–100

ACRP Report 72

Guidebook for Selecting Methods to Monitor Airport and Aircraft Deicing Materials

AIRPORT COOPERATIVE RESEARCH PROGRAM 2012

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LEGEND FOR FACT SHEETS

Method and Use Status		Notes
Parameter		Identifies parameter being considered.
Type	Online Monitor, Handheld Monitor or Test Kit	Identifies equipment type being considered.
Method Description		Method name and general description of method or equipment.
Level of Technology Development	Emergent	1-5 years
	Evolving	5-15 years
	Well Established	15+ years
Demonstrated Technology for Airport Stormwater?	Yes	Typical installation or is a demonstrated airport technology.
	No	Atypical installation and no known usage at airports.
General Availability of Technology	Single Manufacturer	1 manufacturer
	Few Manufacturers	2-5 manufacturers
	Many Manufacturers	5+ manufacturers
Implementation Considerations		
Typical Installation Locations		- Outfall discharge (typically low concentration) - Diversion/treatment influent (typically high concentration) - Collection system monitoring (wide range of concentrations) - Treatment effluent (typically low concentration not glycols). Applicable to online monitors only.
Regulatory-Approved Method	Federal Approval (Method Name/Number)	U.S. EPA or Standard Method approved.
	State or Local Approval	Approved by specific state or local authorities
	None Reported	No known approvals for method, based on results of airport survey and information from manufacturers.
Measurement Range		Parameter concentration range the method or equipment is able to detect.
Accuracy		Accuracy as a percent of the measured value (or full range value if noted).
Response Time		Typical timeframe necessary to obtain parameter concentration from method.
Siting Constraints/Needs		Description for online monitors only to identify special site conditions or infrastructure needed for equipment to operate (i.e., utilities).
Flow and Stream Constraints		Description of flow or stream constraints needed for equipment to operate properly.
Interferences		List of chemical or physical interferences and concentrations (where available) for the method.
Staff Time Requirements	Low	Less than 1 hour/week to perform test and for typical maintenance/operations.
	Moderate	Between 1 and 4 hours/week to perform test and for typical maintenance/operations.
	High	More than 4 hours/week to perform test and for typical maintenance/operations
Level of Staff Knowledge	Low	Only general understanding of equipment and use is necessary for successful operation.
	Moderate	Moderate level of understanding including equipment operation, maintenance, and calibration. Training may be necessary for successful operation.
	High	High level of understanding including operation, maintenance, calibration, ability to troubleshoot. Training is required for successful operation.

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LEGEND FOR FACT SHEETS

Method and Use Status		Notes
O&M Issues		List of known operational and maintenance issues such as calibration, cleaning, replacement of parts or equipment, etc.
Data Retrieval		Visual; Local Readout; Ethernet; Analog Connection; Serial Port Connection; USB Connection; Wireless Communication; Datalogger; Web Interface.
Recommended Features		Identifies equipment features that are recommended if the method or equipment is to be implemented at airport.
Optional Features		List of optional features for equipment provided by at least one manufacturer. Recommended optional system components are listed in the notes section.
Typical Costs		
Capital Cost	Very Low	For the purchase of the equipment. Equipment listed as optional system components in notes section is not included. Less than $2,000
	Low	$2,000-10,000
	Medium	$10,000-25,000
	High	$25,000-50,000
	Very High	$50,000+
Typical Additional Capital Cost	Low	For online monitors only Less than $2,000
	Medium	$2,000-10,000
	High	$10,000+
Annual Operations and Maintenance Cost	Low	Typical costs of a service contract. Staff labor is accounted for in “Staff Time Requirements.” Handheld and Test Kits: Less than $500 Online Monitors: Less than $2,000
	Medium	Handheld and Test Kits: $500-2,000 Online Monitors: $2,000-8,000
	High	Handheld and Test Kits: $2,000+ Online Monitors: $8,000+

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FACT SHEET 58

Biochemical Oxidation

1. Description

Analytical Process

This unit continuously collects a sample from the storm water sample loop. The solids are reduced by the configuration of the intake port located in the sample loop. The sample is conditioned by increasing the temperature to approximately 86° Fahrenheit and adding nutrients and oxygen. The instrument measures the influent DO and then feeds the sample into a vessel containing bacteria. The bacteria degrade the deicer and consume DO in the process. The instrument then measures the DO of the effluent from the unit. The monitor controls the flow rate of the sample stream to maintain a constant DO drop. BOD concentration is correlated to the flow rate of sample required to maintain the DO drop. See Chapter 5 of the guidebook for discussion of correlation to other parameters.

If there is insufficient BOD to maintain the bacteria, the monitor will periodically feed a substrate food source into the bacteria to maintain the population.

Advantages

Most closely approximates the U.S. EPA-approved 5-Day BOD method.

A study has been conducted indicating good correlations with lab BOD data (Portland International).

Some airport operators have gained local or state regulator approval for compliance monitoring purposes.

Disadvantages

Requires maintenance of living bacteria to make a measurement.

High sample flow rate required for sample intake (see notes).

Internal tubing has the potential to clog due to biological growth.

Some airports have found it difficult to maintain and keep calibrated.

Notes

Most significant reason for use: compliance with low-concentration BOD limits required (between 15 and 100 mg/L).

Most significant reason to avoid: high amount of maintenance required.

Typical equipment includes monitor unit and sample loop piping.

Recommended system components include sample shelter.

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Typical replacement items include internal pumps and DO probes.

Consumables include nutrient solutions, glycol solutions, calibration standards, and tubing.

Significant changes in concentrations may require up to 45 min. for reading to stabilize.

Instrument requires a sample intake of between 5 and 35 gpm. This can be independent of the stream flow rate since sample can be a loop flow from a sump. The instrument uses the sample loop velocity and sample intake configuration to avoid filtering the sample. The discharge from the sample loop will have the same concentration as the influent so it is recommended that this be returned upstream of sample diversion location. The monitor also alarms if sample loop runs dry, so recommendation is to withdraw and return sample loop to same location. The monitor can also use a significant amount of water (several thousand gallons of water per month) for sample dilution, so a continuous water supply is recommended.

Airport users reported that a time-intensive operations and maintenance program is needed to achieve good results. The instrument has an auto-calibration feature, and the recommended frequency is daily using glycol solutions. The calibration solutions tend to degrade over time, especially if not kept chilled, so replacement may be required every 4 to 6 weeks to prevent mis-calibration. Calibration checks are recommended monthly, at a minimum, by feeding a glycol calibration standard into the manual sample port. Maintenance or replacement is required annually on the internal pumps and DO probes. Airports have reported delays in getting replacement parts from the manufacturer. The instrument uses 1970s era DOS-based software, which has limited communication functionality; communication with the instrument can only be performed with a modem and analogue-based phone, both of which are obsolete.

Additional Notes for Startup

Startup requires a minimum of 2 days (up to 2 weeks) to develop the living bacteria culture. Some users suggest chilled storage of the bacteria at the end of the deicing season to aid in the next season startup. The DO probes also require storage in water when not in use.

2. Selection Criteria

Method and Use Status

Parameter	Biochemical oxygen demand (BOD).
Type	Online monitor.
Method of Description	Biochemical oxidation. Bacteria degrade organic chemicals in the water sample with the resulting dissolved oxygen change measured.
Level of Technology Development	Well established.

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Demonstrated Technology for Airport Storm Water?	Yes.
General Availability of Technology	Single manufacturer.

Implementation Considerations

Typical Installation Locations	Diversion, collection system monitoring, outfall discharge, treatment influent.
Regulatory-Approved Method	Approved by specific state or local authorities.
Measurement Range	20 to 100,000 mg/L BOD (by manufacturer—airport testing indicated accurate as low as 5 mg/L).
Accuracy	±3%.
Response Time	Programmable, 3 min. minimum (see notes).
Siting Constraints/Needs	- Potable water, filtered. - Electricity. - Temperature-controlled environment.
Flow and Stream Constraints	- For gravity storm sewers, a sample pump/sample loop is typically required. - Sample pump flow rate is recommended to be between 5 to 35 gpm (15 gpm typical). - Chlorine and sediment filters required for potable water line. - Water softener may be necessary for potable water if hardness is greater than 100 mg/L.
Interferences	Pollutants that can kill or inhibit bacteria (i.e., fuel, AFFF, and potentially high concentrations of pavement deicer).
Staff Time Requirements	High.
Level of Staff Knowledge	High.
O&M Issues	- Bacteria are sensitive to environmental conditions, and successful operation is dependent on maintaining steady population of bacteria. - If bacteria are inhibited, instrument can provide inaccurate readings or go offline. - High maintenance is required to prevent small-diameter tubing from clogging. - DO probe maintenance is essential for accurate measurements. - Recommend PG to maintain bacteria when sample BOD is low—not ADF because additives can inhibit bacteria.
Data Retrieval	Local readout, analog connection.
Recommended Features	Offline manual sample operation (included in standard units).
Optional Features	None.

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Typical Costs

Capital Cost	Very high.
Typical Additional Capital Cost	Low.
Annual Operations and Maintenance Cost	Medium.

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COD
Online Monitor

FACT SHEET 59

Photochemical Oxidation

1. Description

Analytical Process

The instrument collects a sample from a continuous sample loop at a programmable time interval (up to 4 per hour). The sample is withdrawn from the sample loop through a filter. The sample is fed into a reaction chamber containing a titanium dioxide sensor. The titanium dioxide sensor is exposed to UV light, and an electrical potential is applied. The UV light and the titanium dioxide oxidize the deicer, and the analyzer measures the electrons that are given off. The resulting current caused by the electron is correlated to COD. See Chapter 5 for discussion of correlation to other parameters.

Note: Prior to sampling, the range of COD concentration must be selected and the instrument calibrated to that range.

Advantages

No handling or disposal of hazardous reagents is required.

Very small sample volumes required.

Results in mg/L COD have potential to correspond to the units of many permits.

Less expensive per sample to operate than COD test kit.

Disadvantages

Recalibration is required for each of the four ranges of concentrations.

Recalibration is required as frequently as every 25 samples tested.

Consumables (electrolyte reagents, titanium dioxide sensors, sample filters) must be replenished as frequently as every 5 days, depending on operational conditions.

Notes

Most significant reason for use: method similar to COD method used for compliance.

Most significant reason to avoid: untested for airport storm water use.

Typical equipment includes monitor unit and sample loop piping.

Recommended system components include sample shelter.

Typical replacement items include internal pump motor, solenoid valve, and reference electrode.

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Consumables include electrolyte reagents, titanium dioxide sensors, sample filters, calibration standards, and tubing.

The unit can switch between the following ranges (in mg/L COD): 0–25; 0–150; 0–1,500; 0–15,000. The unit will signal an alarm if a sample concentration is over the range.

The unit should be recalibrated approximately every 25 samples or when the range is changed by feeding a sorbitol solution into the manual sample port. Keep the calibration solutions chilled when not in use or replace every 4 to 6 weeks because the calibration solution tends to degrade over time.

The typical lifetime of the reference electrode is 12 to 20 months.

Since this unit has not been installed at an airport, the potential for biofouling of sample tubing is unknown, but expected, because of the biofouling experience by other monitors. A chlorination system is recommended to be tested if biofouling does occur (see Fact Sheet 65). The unit has been used successfully in the wastewater industry.

Bench top and portable models are similar and have the same accuracy. Bench top and portable model information is on Fact Sheet 61.

2. Selection Criteria

Method and Use Status

Parameter	Biochemical oxygen demand (BOD).
Type	Online monitor.
Method of Description	Photochemical oxidation. Titanium dioxide with a UV light catalyst degrades the chemicals in the water sample, and the electrochemical potential change is measured. The electrochemical potential change is correlated to COD.
Level of Technology Development	Emergent.
Demonstrated Technology for Airport Storm Water?	No.
General Availability of Technology	Single manufacturer.

Implementation Considerations

Typical Installation Locations	Diversion, collection system monitoring, outfall discharge, treatment influent, treatment effluent.
Regulatory-Approved Method	None reported.
Measurement Range	0.2 to 15,000 mg/L COD (see notes).
Accuracy	±5%.

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Response Time	Programmable, 15 min. minimum.
Siting Constraints/Needs	- Potable water, filtered. - Electricity. - Compressed air. - Temperature-controlled environment.
Flow and Stream Constraints	- For gravity storm sewers, a sample pump/ sample loop is typically required. - Sample pump flow 10 gpm (minimum). - 25 to 50 μm filter is recommended.
Interferences	Chlorides (>2,000 mg/L).
Staff Time Requirements	Medium.
Level of Staff Knowledge	Moderate.
O&M Issues	Must be calibrated if switching between concentration ranges (see notes).
Data Retrieval	Local readout, analog connection, USB connection.
Recommended Features	Offline manual sample operation (included in standard units).
Optional Features	Dual stream sampling.

Typical Costs

Capital Cost	High
Typical Additional Capital Cost	Low
Annual Operations and Maintenance Cost	High

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FACT SHEET 60

Electrochemical Oxidation

1. Description

Analytical Process

The instrument collects a sample from a continuous sample loop at a programmable time interval (up to 15 per hour). The sample is fed into a reaction chamber where an electrode creates hydroxyl radicals that oxidize the deicer in the sample. The instrument measures the change in electrical potential created and reports the results as COD. See Chapter 5 of the guidebook for discussion of correlation to other parameters.

Advantages

No handling or disposal of hazardous reagents is required.

Disadvantages

Pavement deicers cause interference with readings because of the change in storm water conductivity.

Internal tubing has the potential to clog due to biological growth.

Notes

Most significant reason to avoid: issues with potential pavement deicer.

Typical equipment includes monitor unit and sample loop piping.

Recommended system components include sample shelter.

Typical replacement items include electrodes and internal pumps.

Consumables include reagents, calibration standards, and tubing.

Airport users reported pavement deicing materials can cause significant inaccuracy in readings.

The instrument has an auto-calibration and the recommended frequency is daily. Recommended calibration solution is potassium hydrogen phthalate (KHP). Calibration checks are recommended monthly by feeding a KHP calibration standard (for full range) followed by deionized water (for zero) into the manual sample port.

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2. Selection Criteria

Method and Use Status

Parameter	Chemical oxygen demand (COD).
Type	Online monitor.
Method of Description	Electrochemical oxidation. Electrical current degrades the chemicals in the water sample and the electrochemical potential change is measured. The electrochemical potential change is correlated to COD.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	No. [Note: Tested and discontinued at Wilmington, Ohio (ILN)].
General Availability of Technology	Single manufacturer.

Implementation Considerations

Typical Installation Locations	Diversion, collection system monitoring, outfall discharge, treatment influent, treatment effluent.
Regulatory-Approved Method	None reported.
Measurement Range	1 to 100,000 mg/L COD.
Accuracy	±5%.
Response Time	30 sec.
Siting Constraints/Needs	- Potable water. - Electricity. - Compressed air. - Temperature-controlled environment.
Flow and Stream Constraints	- For gravity storm sewers, a sample pump/sample loop is typically required. - Sample pump flow rate up to 3 gpm.
Interferences	High salt concentrations (can be from pavement deicers).
Staff Time Requirements	Low.
Level of Staff Knowledge	Moderate.
O&M Issues	Tubing can get clogged with biological growth.
Data Retrieval	Local readout, analog connection, serial port connection.
Recommended Features	Offline manual sample operation (included in standard units).
Optional Features	Dual stream sampling.

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Typical Costs

Capital Cost	High.
Typical Additional Capital Cost	Low.
Annual Operations and Maintenance Cost	Low.

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FACT SHEET 61

Photochemical Oxidation

1. Description

Analytical Process

A sample is collected, filtered, and placed in a small beaker. The intake tubing of the unit is placed into the sample, and it is fed into a reaction chamber containing a titanium dioxide sensor. The titanium dioxide sensor is exposed to UV light, and an electrical potential is applied. The UV light and the titanium dioxide oxidize the deicer, and the analyzer measures the electrons that are given off. The measurement is reported as COD. See Chapter 5 for discussion of correlation to other parameters.

Note: Prior to sampling, the range of COD concentration must be selected and the instrument calibrated to that range. The range is typically selected based on previous results or compliance/diversion concentration.

Advantages

No handling or disposal of hazardous reagents (i.e., chromium or mercury) is required.

Less expensive operation per sample than COD test kit (dichromate method).

Disadvantages

Must be recalibrated for each of the four ranges of concentrations.

Must be recalibrated as frequently as every 25 samples tested.

Consumables must be replenished as frequently as every 5 days, depending on operational conditions.

Notes

Most significant reason for use: faster result than U.S. EPA-approved COD method.

Most significant reason to avoid: not a U.S. EPA-approved method.

Typical equipment includes monitor unit and filtration unit.

Recommended system components: none.

Typical replacement items: none.

Consumables include electrolyte reagents, titanium dioxide sensors, sample filters, and calibration standards.

Available as either a handheld (portable) unit or benchtop unit. The unit can switch between the following ranges (in mg/L COD): 0–25; 0–150; 0–1,500; 0–15,000.

Online models are similar and have the same accuracy. Online model information is contained in Fact Sheet 59.

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2. Selection Criteria

Method and Use Status

Parameter	Chemical oxygen demand (COD).
Type	Test kit.
Method of Description	Photochemical oxidation. Titanium dioxide with a UV light catalyst degrades the chemicals in the water sample, and the electrochemical potential change is measured. The electrochemical potential change correlated to COD.
Level of Technology Development	Emergent.
Demonstrated Technology for Airport Storm Water?	No.
General Availability of Technology	Single manufacturer.

Implementation Considerations

Typical Installation Locations	N/A.
Regulatory-Approved Method	None reported.
Measurement Range	0.2–15,000 mg/L COD (see notes).
Accuracy	±5%.
Response Time	6 min.
Siting Constraints/Needs	N/A.
Flow and Stream Constraints	None known.
Interferences	Chlorides in concentration above 2,000 mg/L.
Staff Time Requirements	Medium.
Level of Staff Knowledge	Moderate.
O&M Issues	- Replace consumables. - Must be calibrated for specific concentration ranges (see notes).
Data Retrieval	Local readout, USB connection.
Recommended Features	None known.
Optional Features	None known.

Typical Costs

Capital Cost	Medium.
Typical Additional Capital Cost	N/A.
Annual Operations and Maintenance Cost	High.

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FACT SHEET 62

Colorimetric (Dichromate)

1. Description

Analytical Process

A sample is collected and pipetted into a reaction vial containing an oxidant (sulfuric acid) and an indicator compound (dichromate). The sample is then digested for two hours at 150°C. The oxidant converts the deicer and in the process the dichromate is reduced to chromic ions, which are green. The color of the sample is then measured using a photometer or spectrophotometer and reported as mg/L COD. See Chapter 5 for discussion of correlation to other parameters.

Advantages

Simple procedure.

U.S. EPA approved method and familiar method to most regulators.

Can test multiple samples as a batch.

Low maintenance.

Disadvantages

Extended time until result—typical time to perform analysis is 2.5 to 3 hours.

Standard method results in chromium and mercury waste.

Data from a color wheel is qualitative (i.e., reported as a range rather than a specific value).

Notes

Most significant reason for use: U.S. EPA-approved method.

Most significant reason to avoid: time delay to sample result and not online.

Typical equipment includes sample tubes, sample digester, and photometer/spectrophotometer.

Recommended system components: none.

Typical replacement items include photometer/spectrophotometer light source.

Chlorine removal methods are available for this method if sample has high chlorine content.

Consumables include reagents for test and have a shelf life of 5 months.

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Dichromate method (with and without mercury) includes U.S. EPA-approved analysis concentration ranges: 3–150 mg/L and 20–1,500 mg/L. The 0.7–40 mg/L range and 200–15,000 mg/L range are not U.S. EPA-approved methods. A non-U.S.-EPA-approved method that uses manganese instead of mercury and chromium is available for the range of 20–1,000 mg/L COD—this method does not generate a hazardous waste.

A blank solution is used to zero the photometer or spectrophotometer during each test. A photometer has internal calibration software that can be updated by downloading the program from the manufacturer's website. Recommend checking for calibration updates every 6 months or annually.

Accuracy of method may be confirmed by creating a standard curve of samples with known COD concentrations.

2. Selection Criteria

Method and Use Status

Parameter	Chemical oxygen demand (COD).
Type	Test kit.
Method of Description	Colorimetric (dichromate). Organic chemicals are broken down in an acid–dichromate solution to form a pink-colored chromium complex. The COD concentration is determined by comparison of the sample to a color chart or measuring the light intensity using a photometer or spectrophotometer.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	Yes.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	N/A.
Regulatory-Approved Method	Federal approval (EPA Method 410.4).
Measurement Range	0 to 15,000 mg/L COD.
Accuracy	±5 mg/L.
Response Time	1 to 2 hours.
Siting Constraints/Needs	N/A.
Flow and Stream Constraints	None known.
Interferences	- Chlorine (>1,000 mg/L). - Ammonia (>50 mg/L).
Staff Time Requirements	Low.

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Level of Staff Knowledge	Low.
O&M Issues	None known.
Data Retrieval	Visual, local readout.
Recommended Features	None known.
Optional Features	Mercury and chromium-free reagents available (non-U.S.-EPA-approved method).

Typical Costs

Capital Cost	Low.
Typical Additional Capital Cost	N/A.
Annual Operations and Maintenance Cost	Low.

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FACT SHEET 63

Thermal Catalytic Combustion

1. Description

Analytical Process

TOC monitors generally make two measurements: inorganic carbon (mineral or generally carbonate compounds) and total carbon. The TOC is determined by subtracting the inorganic carbon from the total carbon.

This unit collects a sample from the sample loop at a programmable time interval (up to 20 per hour). Most instruments filter the sample. The sample is then split into two parts. One sample is mixed with acid, which converts the inorganic carbon to carbon dioxide. The volume of carbon dioxide from inorganic carbon is measured. The second sample is then fed into a high-temperature furnace that converts all of the carbon into carbon dioxide. The volume of carbon dioxide from all carbon is measured. The inorganic carbon is subtracted from the total carbon to determine the TOC. Note: The concentration of inorganic carbon in airport storm water is typically expected to be negligible compared to the total carbon, so some manufacturers configure the instrument to measure only total carbon. See Chapter 5 for discussion of correlation to other parameters.

Advantages

No handling or disposal of hazardous reagents is required.

Measures the full range of potential deicer concentrations in airport storm water.

Uses an approved U.S. EPA method.

Disadvantages

Filtration system maintenance is required.

Internal tubing has the potential to clog due to biological growth.

Some costly parts require periodic replacement.

Delayed start-up while furnace achieves temperature.

Potential for pavement deicer high concentrations to increase maintenance required.

Notes

Most significant reason for use: fast result.

Most significant reason to avoid: time delay for unit to start (furnace temperature).

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Typical equipment includes monitor unit and sample loop piping.

Recommended system components include sample shelter and bleach solution feed.

Typical replacement items include internal pumps, furnace lining (1 year), and furnace unit (3 years).

Consumables include air filter, carbon dioxide filter, sample filters, reagents, calibration solutions, and tubing.

Range of instrument must be selected at time of purchase—examples are (in mg/L TOC): <200; <4,000; <50,000.

Airport users reported good results with proper operations and maintenance program. Biogrowth may be controlled by injecting low-concentration bleach solution into sample line.

The instrument has an auto-calibration feature, and the recommended frequency is daily. Recommended calibration solution is potassium hydrogen phthalate (KHP). Calibration checks are recommended monthly by feeding a KHP calibration standard (for full range) followed by deionized water (for zero) into the manual sample port.

2. Selection Criteria

Method and Use Status

Parameter	Total organic carbon (TOC).
Type	Online monitor.
Method of Description	Thermal catalytic combustion. High temperatures burn the carbon in the water sample, and the release of carbon dioxide is measured.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	Yes.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	Diversion, collection system monitoring, outfall discharge, treatment influent, treatment effluent.
Regulatory-Approved Method	Federal approval (EPA Method 415.1).
Measurement Range	0 to 5,000 mg/L TOC (see notes). (Up to 50,000 mg/L TOC depending on manufacturer and model)
Accuracy	±2%.

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Response Time	Programmable, 3 min. minimum.
Siting Constraints/Needs	- Potable water (depending on manufacturer and model). - Electricity. - Temperature-controlled environment.
Flow and Stream Constraints	- For gravity storm sewers, a sample pump/sample loop is typically required. - Pre-filters required (depending on manufacturer and model). - Sample pump flow rate is recommended to be between 3 to 30 gpm (15 gpm, typical).
Interferences	None known.
Staff Time Requirements	Low.
Level of Staff Knowledge	Moderate.
O&M Issues	High concentrations of suspended solids or salts can cause increased maintenance.
Data Retrieval	Local readout, analog connection.
Recommended Features	- Offline manual sample operation (included in standard units). - Potable water available for ease of maintenance (required for operation of some units).
Optional Features	- Dual stream sampling. - Additional parameter measured (total nitrogen). - Serial port connection.

Typical Costs

Capital Cost	High.
Typical Additional Capital Cost	Low.
Annual Operations and Maintenance Cost	Medium.

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TOC
Online Monitor

FACT SHEET 64

UV/Persulfate Oxidation

1. Description

Analytical Process

TOC monitors generally make two measurements: inorganic carbon (mineral, or generally carbonate compounds) and total carbon. The TOC is determined by subtracting the inorganic carbon from the total carbon.

This unit collects a sample from the sample loop at a programmable time interval (up to 8 per hour). Most instruments filter the sample. The sample is then split into two parts. One sample is mixed with acid, which converts the inorganic carbon to carbon dioxide. The volume of carbon dioxide from inorganic carbon is measured. The second sample is then fed into a chamber with persulfate and exposed to ultraviolet light, which converts all of the carbon into carbon dioxide. The volume of carbon dioxide from all carbon is measured. The total carbon is subtracted from the inorganic carbon to determine the TOC. See Chapter 5 for discussion of correlation to other parameters.

Advantages

Uses an approved U.S. EPA method.

Disadvantages

May not measure the full range of potential deicer concentrations in airport storm water.

Filtration system maintenance is required.

Internal tubing has the potential to clog due to biological growth.

Potential for pavement deicer interferences at high concentrations.

Notes

Most significant reason for use: fast result.

Most significant reason to avoid: chemical required for operation.

Typical equipment includes monitor unit, sample loop piping, and air compressor.

Recommended system components include sample shelter and bleach solution feed.

Typical replacement items include internal pumps and UV lamp (2 years).

Consumables include carbon dioxide filter, sample filters, reagents, calibration solutions, and tubing.

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Range of instrument must be selected at time of purchase. Examples are (in mg/L TOC): <10; <100; <500; <1,000; <5,000; <10,000; <50,000.

One airport user reported adding a bleach solution feed to prevent biological growth in tubing.

The instrument has an auto-calibration feature; the recommended frequency is daily. Recommended calibration solution is potassium hydrogen phthalate (KHP). Calibration checks are recommended monthly by feeding a KHP calibration standard (for full range) followed by deionized water (for zero) into the manual sample port.

2. Selection Criteria

Method and Use Status

Parameter	Total organic carbon (TOC).
Type	Online monitor.
Method of Description	UV/Persulfate oxidation. Sodium persulfate with UV light degrade the carbon in the water sample and the release of carbon dioxide is measured.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	Yes.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	Diversion, collection system monitoring, outfall discharge, treatment influent, treatment effluent.
Regulatory-Approved Method	Federal approval (EPA Method 415.1).
Measurement Range	0 to 10,000 mg/L TOC (see notes). (Up to 50,000 mg/L TOC depending on manufacturer and model.)
Accuracy	±4% (or as low as ±2% depending on manufacturer and model).
Response Time	Programmable, 8 min. minimum.
Siting Constraints/Needs	- Potable water. - Electricity. - Compressed air. - CO_2 scrubber. - Venting for reaction gases. - Temperature-controlled environment.
Flow and Stream Constraints	- For gravity storm sewers, a sample pump/sample loop is typically required.

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	- Sample intake and discharge up to 15 gpm (on some models).
Interferences	Salt (>0.5%).
Staff Time Requirements	Low.
Level of Staff Knowledge	Moderate.
O&M Issues	- Tubing can get clogged with biological growth. - High salts and hardness can cause increased maintenance.
Data Retrieval	Local readout, analog connection.
Recommended Features	Offline manual sample operation (included in standard units).
Optional Features	- Serial port connection and datalogger. - Dual stream sampling.

Typical Costs

Capital Cost	High.
Typical Additional Capital Cost	Medium.
Annual Operations and Maintenance Cost	High.

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FACT SHEET 65

UV/Ozone Oxidation

1. Description

Analytical Process

TOC monitors generally make two measurements: inorganic carbon (mineral, or generally carbonate compounds) and total carbon. The TOC is determined by subtracting the inorganic carbon from the total carbon.

This unit collects a sample from the sample loop at a programmable time interval (up to 8 per hour). The sample is then split into two parts. One sample is mixed with acid, which converts the inorganic carbon to carbon dioxide. The volume of carbon dioxide from inorganic carbon is measured. The second sample is then fed into a chamber with ozone and sodium hydroxide (caustic soda) and exposed to ultraviolet light, which converts all of the carbon into carbon dioxide. The volume of carbon dioxide from all carbon is measured. The total carbon is subtracted from the inorganic carbon to determine the TOC. See Chapter 5 for discussion of correlation to other parameters.

Advantages

Back flushing feature helps prevent clogging.

Larger diameter tubing helps prevent clogging.

Measures the full range of potential deicer concentrations in airport storm water.

Disadvantages

Ozone generator required.

Use of caustic requires handling safety precautions.

Notes

Most significant reason for use: fast result.

Most significant reason to avoid: ozone and caustic required for operation.

Typical equipment includes monitor unit, sample loop piping, and ozone generator.

Recommended system components include sample shelter.

Typical replacement items include internal pumps and electronic relays.

Consumables include air filter, sample filter, reagents, calibration solutions, and tubing.

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Range of instrument can be selected automatically or manually during operation; examples include (in mg/L TOC): <1,250; <10,000; <15,000; <100,000.

The instrument has an automatic calibration check feature with a programmable frequency (daily is typical) using a calibration solution. Operation experience is with glycol calibration solution. Note that glycol calibration solutions tend to degrade over time so replacement every 4 to 6 weeks will help prevent mis-calibration. KHP, which degrades more slowly, may be used, but is not known to have been tested. Manual calibration checks are recommended monthly, at a minimum, by feeding a glycol calibration standard into the manual sample port. Maintenance or replacement is required annually on the internal pumps.

2. Selection Criteria

Method and Use Status

Parameter	Total organic carbon (TOC).
Type	Online monitor.
Method of Description	UV/ozone oxidation. Ozone with UV light degrade the carbon in the water sample, and the release of carbon dioxide is measured.
Level of Technology Development	Emergent.
Demonstrated Technology for Airport Storm Water?	Yes.
General Availability of Technology	Single manufacturer.

Implementation Considerations

Typical Installation Locations	Diversion, collection system monitoring, outfall discharge, treatment influent, treatment effluent.
Regulatory-Approved Method	None reported.
Measurement Range	0 to 100,000 mg/L TOC (see notes).
Accuracy	±3%.
Response Time	Programmable, 7 min. minimum.
Siting Constraints/Needs	- Potable water. - Electricity. - Temperature-controlled environment.
Flow and Stream Constraints	- For gravity storm sewers, a sample pump/ sample loop is typically required.
Interferences	- Chloride (>30%). - Calcium (>12%).
Staff Time Requirements	Low.
Level of Staff Knowledge	Moderate.

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O&M Issues	Replace consumables.
Data Retrieval	Local readout, analog connection, serial port connection.
Recommended Features	Offline manual sample operation (included in standard unit).
Optional Features	- Additional parameters measured (total nitrogen, total phosphorus). - Multi-stream sampling (up to 6 streams). - Digital outputs/contacts.

Typical Costs

Capital Cost	Very high.
Typical Additional Capital Cost	Low.
Annual Operations and Maintenance Cost	Medium.

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BOD/COD/TOC by Correlation

Online Monitor

FACT SHEET 66

Refractometry

1. Description

Analytical Process

This method uses the fact that the speed of light decreases when it passes through denser fluids. This is the reason that objects sticking out of water appear to bend when viewed at an angle.

This unit is installed inline with the sample stream or in an offline sample loop or flow cell. The sample is fed continuously into a cell, and a beam of light is projected through the sample at an angle. Photodetectors are used to measure the angle that the light bends as it passes through the sample. The more dense the solution, the more the light will bend. The result is temperature corrected, and the density of the sample is reported. An additional step can be included in which a correlation is made between densities and concentrations for a reference compound. The reading can then be converted from density to concentration of the compound (i.e., deicer or COD). See Chapter 5 for discussion of correlation to other parameters.

Advantages

Easy to operate.

No reagents are required.

Disadvantages

Poor accuracy for sample streams with low concentrations (<10,000 mg/L BOD).

Frequent cleaning of lens is typical to maintain accuracy.

Filtration maintenance is typical to maintain accuracy.

Notes

Most significant reason for use: fast result and low maintenance.

Most significant reason to avoid: inaccurate at moderate to low concentrations.

Typical equipment includes monitor unit, local controller, and sample loop piping.

Recommended system components include sample shelter.

Typical replacement items: none.

Consumables: none.

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Airport users reported this to be an effective, low-maintenance solution for high concentration sample streams (>1% glycol), especially at deicer pad collection or glycol recycling operations.

Commonly used at airports in the preparation and mixing of aircraft deicers.

Manual calibration checks recommended weekly and manual calibrations recommended monthly. Calibration checks can be performed using a handheld refractometer. Annual factory recalibration by the manufacturer is also recommended. Regular maintenance is required for manual cleaning of the optics. Biogrowth may be controlled by injecting low-concentration bleach solution into sample line.

2. Selection Criteria

Method and Use Status

Parameter	BOD/COD/TOC by correlation.
Type	Online monitor.
Method of Description	Refractometry. The refractive index, or light bending property, of the water sample is measured and correlated to a concentration of deicer.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	Yes.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	Diversion, treatment influent.
Regulatory-Approved Method	None reported.
Measurement Range	>1% glycol (approximately 10,000 mg/L BOD).
Accuracy	±1%.
Response Time	Immediate.
Siting Constraints/Needs	- Electricity. - Temperature-controlled environment. - Install perpendicular to a horizontal pipe to keep instrument flooded.
Flow and Stream Constraints	- For gravity storm sewers, a sample pump/ sample loop is typically required. - Continuous flow through instrument recommended. - Inline filter to reduce total suspended solids.
Interferences	- Suspended solids. - Chemicals which cause changes in sample density (e.g., salts).

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Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	- Calibrate frequently to minimize drift. - Clean frequently to remove build up of films and dirt on lens.
Data Retrieval	Local readout, analog connection.
Recommended Features	None known.
Optional Features	None known.

Typical Costs

Capital Cost	Low.
Typical Additional Capital Cost	Low.
Annual Operations and Maintenance Cost	Low.

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BOD/COD/TOC
by Correlation

Online Monitor

FACT SHEET 67

Optical/Absorbance

1. Description

Analytical Process

The method is based on the principle that the absorbance of light at a particular wavelength is proportional to the concentration of the compound that is absorbing the light.

This unit is installed inline with the sample stream or in an offline sample loop or flow cell. The sample flows continuously into a cell where a beam of UV and visible light is projected through the sample and a photometer measures the absorbance spectrum. The concentration of deicer is reported based on internal calculations as BOD, COD, or TOC. See Chapter 5 for discussion of correlation to other parameters.

Advantages

No temperature-controlled shelter is required—a canopy is recommended by manufacturer.

No reagents are required.

Automatic cleaning of lens reduces maintenance.

Disadvantages

Local calibration is dependent on constituents and concentrations, which tend to be variable.

Technology should be tested on airport storm water.

Inaccurate at low concentrations because of interference by other chemicals or solids in sample.

Notes

Most significant reason for use: fast result.

Most significant reason to avoid: maintenance issues.

Typical equipment includes monitor unit, controller, mounting equipment, and flow cell.

Recommended system components include canopy.

Typical replacement items: none.

Consumables: none.

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Glycol has low absorbance properties, so some manufacturers develop a correlation based on other constituents in the deicer.

Regular maintenance is performed to check the automatic cleaning mechanism and to manually clean the optics. Manual calibration checks are recommended monthly, at a minimum. Annual factory recalibration by the manufacturer is also recommended.

Other parameters may be analyzed with the monitor, such as total suspended solids, nitrates, and temperature.

2. Selection Criteria

Method and Use Status

Parameter	BOD/COD/TOC by correlation.
Type	Online monitor.
Method of Description	Optical/absorbance. The absorbance of UV-visible light through the water sample is measured and correlated to a concentration of deicer.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	No.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	Diversion, collection system monitoring, outfall discharge, treatment influent, treatment effluent.
Regulatory-Approved Method	None reported.
Measurement Range	0 to 5,000 mg/L COD. (Up to 45,000 mg/L COD with proper configuration.)
Accuracy	±2%.
Response Time	Programmable, 1 min. minimum.
Siting Constraints/Needs	- Electricity. - Compressed air. - Canopy for weather protection.
Flow and Stream Constraints	- Installed submerged in sample stream or in a flow cell. - For gravity storm sewers, a sample pump/sample loop is typically required with flow cell.

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Interferences	Application specific, depending on sample stream chemical composition.
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	- Clean frequently to remove buildup of films and dirt on lens. - Check automatic cleaning equipment to maintain accuracy. - Calibration is dependent on concentrations and constituents in sample.
Data Retrieval	Local readout, analog connection.
Recommended Features	Automatic cleaning with compressed air.
Optional Features	- Flow cell. - Additional parameters measured (total suspended solids, temperature). - Serial port connection, digital outputs/ contacts. - USB connection, Ethernet, or cellular communication.

Typical Costs

Capital Cost	Medium.
Typical Additional Capital Cost	Low.
Annual Operations and Maintenance Cost	Low.

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BOD/COD/TOC
by Correlation
Online Monitor

FACT SHEET 68

Optical/Absorbance, Reflectance, and Fluorescence

1. Description

Analytical Process

The method is based on the principle that the absorbance, reflectance, and fluorescence of light at a particular wavelength are proportional to the concentration of the compound that is absorbing the light. The unit uses calculation algorithms along with an internal library of reference spectra to calculate the concentration of deicer.

This unit collects a sample from the sample stream continuously and records measurements at a programmable time interval (up to 60 per hour). The sample flows continuously into a cell where a beam of UV and visible light is projected through the sample, and a photometer measures the absorbance, reflectance, and fluorescence. The concentration of deicer is reported based on internal calculations as BOD, COD, or TOC. See Chapter 5 of the guidebook for discussion of correlation to other parameters.

Advantages

No temperature-controlled shelter is required.

No reagents are required.

Real-time and historical data available through web-based user interface.

Automatic cleaning of lens reduces maintenance.

Disadvantages

Local calibration is dependent on constituents and concentrations, which tend to be variable.

Inaccurate at low concentrations because of interference by other chemicals or solids in sample.

Notes

Most significant reason for use: fast result.

Most significant reason to avoid: new technology under testing.

Typical equipment includes monitor unit and sample loop piping.

Recommended system components include canopy.

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Typical replacement items: none.

Consumables: none.

Technology is currently under testing on airport storm water.

The instrument has an auto-calibration feature, and the recommended frequency is daily. Regular maintenance is performed to check the automatic cleaning mechanism and to manually clean the optics. Manual calibration checks are recommended monthly, at a minimum. Annual factory recalibration by the manufacturer is also recommended.

Other parameters may be analyzed with the monitor, such as total suspended solids, nitrates, temperature, and flow rate.

2. Selection Criteria

Method and Use Status

Parameter	BOD/COD/TOC by correlation.
Type	Online monitor.
Method of Description	Optical/absorbance, reflectance, and fluorescence. The absorbance, reflectance, and fluorescence of UV-visible infrared light through the water sample is measured and correlated to a concentration of deicer.
Level of Technology Development	Emergent.
Demonstrated Technology for Airport Storm Water?	No.
General Availability of Technology	Single manufacturer.

Implementation Considerations

Typical Installation Locations	Diversion, collection system monitoring, outfall discharge, treatment influent, treatment effluent. Diversion and collection system monitoring may be limited by the upper range of instrument.
Regulatory-Approved Method	None reported.
Measurement Range	0 to 5,000 mg/L TOC. (Up to 10,000 mg/L TOC with proper configuration.)
Accuracy	±3%.
Response Time	Programmable, 2 min. minimum.
Siting Constraints/Needs	- Potable water. - Electricity.

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Flow and Stream Constraints	- For gravity storm sewers, a sample pump/sample loop is typically required. - Continuous flow through instrument recommended. - Inline filter (if sand and grit are present).
Interferences	Application specific, depending on sample stream chemical composition.
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	- Clean frequently to remove buildup of films and dirt on lens. - Check automatic cleaning equipment to maintain accuracy. - Calibration is dependent on concentrations and constituents in sample.
Data Retrieval	Local readout, analog connection, web interface, USB connection, Ethernet connection, cellular communications.
Recommended Features	None.
Optional Features	- Additional parameters measured (TSS, temperature, nitrate). - Dual stream sampling.

Typical Costs

Capital Cost	Very high.
Typical Additional Capital Cost	Low.
Annual Operations and Maintenance Cost	Medium.

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FACT SHEET 69

Refractometry

1. Description

Analytical Process

This method uses the fact that the speed of light decreases when it passes through denser fluids. This is the reason that objects sticking out of water appear to bend when viewed at an angle.

A drop of sample is placed on the instrument sample platform. A beam of light is projected through the sample at an angle. Photodetectors are used to measure the angle that the light bends as it passes through the sample. The more dense the solution, the more the light will bend. The result is temperature corrected, and the density of the sample is reported. An additional step can be included in which a correlation is made between densities and concentrations for a reference compound. The reading can then be converted from density to concentration of the compound (i.e., deicer or COD). See Chapter 5 for discussion of correlation to other parameters.

Advantages

Easy to operate.

No reagents are required.

Disadvantages

Poor accuracy for sample streams with low concentrations (<10,000 mg/L BOD).

Lens must be frequently cleaned to maintain accuracy.

Filtration maintenance is typical to maintain accuracy.

Notes

Most significant reason for use: fast result.

Most significant reason to avoid: inaccurate at moderate to low concentrations.

Typical equipment includes: monitor unit.

Recommended system components: none.

Typical replacement items: none.

Consumables: none.

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Airport users reported this to be an effective, low-maintenance solution for high-concentration sample streams (>1% glycol), especially at deicer pad collection or glycol recycling operations.

Commonly used at airports in the preparation and mixing of aircraft deicers.

Manual calibration checks are recommended weekly and manual calibrations are recommended monthly. Handheld unit can be used to check calibration of an online refractometer.

2. Selection Criteria

Method and Use Status

Parameter	BOD/COD/TOC by correlation.
Type	Handheld monitor.
Method of Description	Refractometry The refractive index, or light bending property, of a water sample is measured and correlated to a concentration of deicer.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	Yes.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	N/A.
Regulatory-Approved Method	None reported.
Measurement Range	>1% glycol (approximately 10,000 mg/L BOD).
Accuracy	±1%.
Response Time	Immediate.
Siting Constraints/Needs	N/A.
Flow and Stream Constraints	None known.
Interferences	- Suspended solids. - Chemicals that cause changes in sample density (e.g., salts).
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	Calibrate frequently to minimize drift.
Data Retrieval	Local readout.
Recommended Features	None known.
Optional Features	None known.

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Typical Costs

Capital Cost	Very low.
Typical Additional Capital Cost	N/A.
Annual Operations and Maintenance Cost	Low.

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FACT SHEET 70

Colorimetric (EG in Water)

1. Description

Analytical Process

A sample is collected and placed in a reaction vial. An oxidant (periodic acid) and an indicator compound (purpald) are added. The oxidant converts the ethylene glycol and/or propylene glycol to formaldehyde, which reacts with indicator compound. The color of the sample is then compared to a color chart or measured using a photometer.

Advantages

Correction factors are defined to convert test results when measuring propylene glycol.

Good for screening water quality.

Disadvantages

Data is qualitative (i.e., reported as a range rather than a specific value).

Notes

Most significant reason for use: indicator for presence/absence of ADF.

Most significant reason to avoid: not a qualitative method (does not give a concentration).

Typical equipment includes reaction vials and color comparator or photometer.

Recommended system components: none.

Typical replacement items include photometer light source.

Consumables include reagents.

This test was developed for testing boiler water, and interferences from storm water may not be completely known. Ranges for the color comparison test kits are 1–15 mg/L ethylene glycol or 1,000–15,000 mg/L. Ranges when using the photometer are 0.6–10 mg/L ethylene glycol or 5–65 mg/L propylene glycol.

Consumables include reagents for test and have a shelf life of 5 months.

Visual comparisons do not have a calibration step. When a photometer is used for the measurement, a blank solution is used to zero photometer during each visual test. The photometer has internal calibration software that can be updated by downloading the program from the manufacturer's website. It is recommended that personnel check for calibration updates approximately every 6 months.

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2. Selection Criteria

Method and Use Status

Parameter	BOD/COD/TOC by correlation.
Type	Test kit.
Method of Description	Colorimetric (EG in water). Periodic acid [iodic(VII) acid] oxidizes glycol to formaldehyde, which then reacts with chemical (purpald) in a basic solution (high pH) to form a purple-colored complex. The glycol concentration is determined by comparison of the sample to a color chart.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	Yes.
General Availability of Technology	Single manufacturer.

Implementation Considerations

Typical Installation Locations	N/A.
Regulatory-Approved Method	None reported.
Measurement Range	1 to 15,000 mg/L glycol.
Accuracy	½ to 1 color standard increment. (Concentration is read as a range.)
Response Time	Immediate to 2 min.
Siting Constraints/Needs	N/A.
Flow and Stream Constraints	None known.
Interferences	- Test does not differentiate between propylene glycol or ethylene glycol. - Extreme high or low temperatures. - Strong oxidizers or aldehydes. - Low pH samples (pH < 4). - High dissolved solids (>700 mg/L).
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	- 5 month chemical shelf life. - Kits should be stored in the dark. - Not applicable for sea water samples.
Data Retrieval	Visual; serial port connection.
Recommended Features	None known.
Optional Features	None known.

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Typical Costs

Capital Cost	Very low.
Typical Additional Capital Cost	N/A.
Annual Operations and Maintenance Cost	Low.

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Ammonia
Online Monitor

FACT SHEET 71

Colorimetric

1. Description

Analytical Process

The instrument collects a sample from a continuous sample loop at a programmable time interval (up to 6 per hour). The sample loop contains a filter for the sample. The sample is fed into a reaction chamber and combined with hypochlorite and phenol catalyzed by (typically) manganese. The reaction produces a compound with a bright blue color (indophenols) with a maximum light absorbance at a wavelength of 630 nm. The measurement is reported as ammonia–nitrogen.

Advantages

Low detection limit.

Automatic cleaning and calibration.

Disadvantages

Long calibration and cleaning times, up to 45 min.

Several potential types of interferences.

Notes

Most significant reason for use: diversion of storm water for ammonia.

Most significant reason to avoid: maintenance on online monitor.

Typical equipment includes sample collector, filtration components, and monitor unit.

Recommended system components include cleaning system and sample shelter.

Typical replacement items include internal pumps.

Consumables include sample and internal tubing, filtration membrane, and reagents

Colorimetric methods include phenate and salicylate methods that form colored complexes.

Samples with high alkalinity and hardness can be treated with citrate to prevent clouding of solution. If sulfide interferences occur, they can be removed by reducing pH. Turbidity interferences can be removed by filtering samples

Mercuric chloride, which has been used for sample preservation, should be avoided because of chloride interference and mercury disposal issues.

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Start-up requires installation of sample and reagent tubing and filling reagent vessels. Instruments have an auto-calibration feature, and the recommended frequency is daily. Calibration checks are recommended weekly, at a minimum. Reagents should be replaced monthly. Tubing should be checked weekly, and typically tubing is replaced approximately every 6 months.

2. Selection Criteria

Method and Use Status

Parameter	Ammonia (NH_3-N).
Type	Online monitor.
Method of Description	Colorimetric. Ammonia reacts with hypochlorite and other reagents to produce an intense blue complex (phenate method) or green complex (salicylate method). The ammonia concentration is determined by measuring the light intensity of the sample using a colorimeter, photometer, or spectrophotometer.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	Yes.
General Availability of Technology	Many manufacturers

Implementation Considerations

Typical Installation Locations	Diversion, collection system monitoring, outfall discharge, treatment influent, treatment effluent.
Regulatory-Approved Method	Federal approval (EPA Method 350.1).
Measurement Range	1 μg/L to 400 mg/L.
Accuracy	±2% of full range value.
Response Time	15 min.
Siting Constraints/Needs	- Electricity. - Temperature-controlled environment. - Water connection or air compressor for cleaning.
Flow and Stream Constraints	- For gravity storm sewers, a sample pump/sample loop is typically required. - Minimal sample/stream flow is necessary for equipment to operate. - Standby feature.
Interferences	- Chloride. - Calcium and magnesium (1,500–2,500 mg/L).

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	- Nitrate/nitrite (30–250 mg/L). - Turbid or strongly acidic/alkaline samples (pH < 3 or > 12). - Sulfides (300 mg/L). - Grease/oils.
Staff Time Requirements	High.
Level of Staff Knowledge	High.
O&M Issues	- Weekly maintenance/calibration. - Biannual maintenance. - Potential tubing clogging. - Replace tubing annually.
Data Retrieval	Local readout, analog connection, Ethernet.
Recommended Features	- Pre-filtration of samples. - Cleaning system.
Optional Features	- Pre-filtration of samples. - Cleaning system. - Monitor unit can typically monitor for additional parameters (e.g., temperature, nitrate, pH). - System alarms.

Typical Costs

Capital Cost	Medium.
Typical Additional Capital Cost	Medium.
Annual Operations and Maintenance Cost	Low.

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Ammonia
Online Monitor

FACT SHEET 72

Ultraviolet Absorbance

1. Description

Analytical Process

The method is based on the principle that the absorbance of light at a particular wavelength is proportional to the concentration of the compound that is absorbing the light.

This unit is installed inline with the sample stream or in an offline sample loop or flow cell. The sample flows continuously into a cell where a beam of UV light is projected through the sample and a photometer measures the absorbance spectrum. The concentration is reported as ammonia–nitrogen.

Advantages

Automatic cleaning and calibration.

Inexpensive reagents needed for system.

Disadvantages

Biofouling of flow cell may affect reading.

Notes

Most significant reason for use: diversion of storm water for ammonia.

Most significant reason to avoid: maintenance on online monitor.

Typical equipment includes sample collector, filtration components, and monitor unit.

Recommended system components include cleaning system and sample shelter.

Typical replacement items include battery and lamp.

Consumables include filtration membrane and reagents.

Startup requires installation of sample and reagent tubing and filling reagent vessels. Instruments have an auto-calibration feature, and the recommended frequency is daily. Calibration checks are recommended weekly, at a minimum. Tubing is recommended to be checked weekly. Cleaning and zeroing solutions should be replenished weekly. Reagent chemicals should be replaced monthly. Battery and lamp may need replacement every 2 years.

Shutdown is recommended if analyzer is not in use for 2 to 3 days. Reagents should be removed and covered, and the system should be flushed.

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2. Selection Criteria

Method and Use Status

Parameter	Ammonia (NH_3-N).
Type	Online monitor.
Method of Description	Optical/absorbance. Ammonia reacts with hypochlorite and other reagents to produce an intense blue complex (phenate method) or green complex (salicylate method). The ammonia concentration is determined by measuring the ultraviolet light intensity of the sample using a colorimeter, photometer, or spectrophotometer.
Level of Technology Development	Evolving.
Demonstrated Technology for Airport Storm Water?	No.
General Availability of Technology	Single manufacturer.

Implementation Considerations

Typical Installation Locations	Diversion, collection system monitoring, outfall discharge, treatment influent, treatment effluent.
Regulatory-Approved Method	None reported.
Measurement Range	0.02 to 5 mg/L.
Accuracy	2–5% of full range value.
Response Time	10 min.
Siting Constraints/Needs	- Electricity. - Temperature-controlled environment. - Sample collection line to analyzer. - Sample waste discharge.
Flow and Stream Constraints	- For gravity storm sewers, a sample pump/sample loop is typically required. - Two sample connections. - Higher flows needed for equipment to operate compared to colorimetric analyzers (0.5–5 l/min). - Standby feature.
Interferences	- Solids/turbid samples (max. 150 mg/L or 60 NTU). - Organic matter. - Grease/oils.
Staff Time Requirements	High.
Level of Staff Knowledge	High.

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O&M Issues	- Potential clogging of tubing if solids criteria are exceeded. - Weekly reagent refill.
Data Retrieval	Local readout, serial port connection.
Recommended Features	Two forms of ammonia can be monitored (e.g., total ammonia and free ammonia).
Optional Features	- Service/maintenance alarms. - Pre-filtration of samples.

Typical Costs

Capital Cost	Medium.
Typical Additional Capital Cost	Medium.
Annual Operations and Maintenance Cost	Low.

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FACT SHEET 73

Ammonia Selective Electrode

1. Description

Analytical Process

The ion selective probe is placed in the sample stream. Ammonia passes through the gas-permeable membrane proportional to the concentration. In the thin film between the membrane and a pH glass electrode, the ammonia causes a pH change. The change in pH is reported as ammonia–nitrogen.

Advantages

Quick response time.

In-stream measurement.

Disadvantages

Biofouling of membrane may affect reading.

Rupture of membrane will give inaccurate readings.

Notes

Most significant reason for use: diversion of storm water and less maintenance that other online monitors.

Most significant reason to avoid: maintenance of in-stream probe.

Typical equipment includes electrode and monitor unit.

Recommended system components include cleaning system.

Typical replacement items: none.

Consumables include electrode membrane, reagents (for “known addition” method) or filling solution, and tubing.

Startup requires installing electrode membrane, filling electrode with filling solution, and connecting to analyzer module. Installation of sample and reagent tubing is necessary for “known addition” method. Instruments have auto-calibration feature with a typical frequency of several hours. Calibration checks are recommended daily, at a minimum. Checks of tubing and replenishing reagent solutions for “known addition” method are recommended weekly. Electrode membranes are typically replaced every 6 months to annually.

When a probe is temporarily not in use (i.e., out of service less than 1 week) it should be rinsed and stored in a standard solution. If probe is not in use for more than 1 week, the membrane should be removed, and it should be disassembled and stored for future use.

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2. Selection Criteria

Method and Use Status

Parameter	Ammonia (NH_3-N).
Type	Online monitor.
Method of Description	Ammonia selective electrode. Ammonia measurement is made using an ion-selective, gas permeable membrane. Ammonia diffuses through the membrane and alters the ability of an internal electrode solution to conduct electricity. The change in conductance is proportional to the ammonia concentration in solution.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	Yes.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	Diversion, collection system monitoring, outfall discharge, treatment influent, treatment effluent.
Regulatory-Approved Method	Federal approval (EPA Method 350.3).
Measurement Range	0.1 to 1,000 mg/L.
Accuracy	±2% of full range value.
Response Time	Immediate to 2 min.
Siting Constraints/Needs	- Structure needed to mount probe (e.g., culvert, storm sewer). - Electricity. - Temperature-controlled environment. - Connection to air compressor for cleaning.
Flow and Stream Constraints	- Installed submerged in sample stream. - Flow is necessary for equipment to operate.
Interferences	- Amines. - Mercury. - Silver. - Potassium. - Grease/oil. - Large changes in ionic strength.
Staff Time Requirements	Medium.
Level of Staff Knowledge	Moderate.
O&M Issues	- 6-month membrane life. - Periodically refill electrode.

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	- Store electrode in ammonia storage solution when not in use. - Potential clogging of tubing.
Data Retrieval	Local readout, USB connection, Ethernet, serial port connection.
Recommended Features	Cleaning system.
Optional Features	- Probes that compensate for potassium interference. - SCADA system integration. - Alarms. - Cleaning system. - Monitor unit can typically connect to other probes to monitor additional parameters (e.g., temperature, nitrate, pH). - Use “known addition” instruments to measure low concentrations of ammonia.

Typical Costs

Capital Cost	Medium.
Typical Additional Capital Cost	Medium.
Annual Operations and Maintenance Cost	Low.

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FACT SHEET 74

Ammonia Selective Electrode

1. Description

Analytical Process

The ion selective probe is placed in the sample stream. Ammonia passes through the gas-permeable membrane proportional to the concentration. In the thin film between the membrane and a pH glass electrode, the ammonia causes a pH change. The change in pH is reported as ammonia–nitrogen.

Advantages

Quick response time.

Disadvantages

Rupture of membrane will give inaccurate readings.

Notes

Most significant reason for use: easy to operate.

Most significant reason to avoid: maintenance of handheld probe.

Typical equipment includes electrode and monitor unit.

Recommended system components: none.

Typical replacement items: none.

Consumables include electrode membrane and filling solution.

Startup requires installing electrode membrane, filling electrode with filling solution, and connecting to analyzer module. Calibration checks are recommended daily, at a minimum. Replenishing internal filling solution is recommended, when the probe won't calibrate. Electrode membranes are typically replaced every 6 months to annually, depending on use.

When probe is temporarily not in use (i.e., out of service less than 1 week) it should be rinsed and stored in a standard solution. If probe is not in use for more than 1 week, the membrane should be removed, and it should be disassembled and stored for future use.

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2. Selection Criteria

Method and Use Status

Parameter	Ammonia (NH_3-N).
Type	Handheld monitor.
Method of Description	Ammonia selective electrode. Ammonia measurement is made using an ion-selective, gas permeable membrane. Ammonia diffuses through the membrane and alters the ability of an internal electrode solution to conduct electricity. The change in conductance is proportional to the ammonia concentration in solution.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	Yes.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	N/A.
Regulatory-Approved Method	Federal approval (EPA Method 350.3).
Measurement Range	2 to 200 mg/L.
Accuracy	±10% of measured value.
Response Time	Immediate to 2 min.
Siting Constraints/Needs	N/A.
Flow and Stream Constraints	- Sufficient depth for probe immersion.
Interferences	- Amines. - Mercury. - Silver. - Potassium. - Grease/oil. - Large changes in ionic strength.
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	- 6-month membrane life. - Calibrate using known ammonia concentration solutions. - Periodically refill electrode. - Electrode must be rinsed before measuring ammonia. - Store electrode in ammonia storage solution when not in use.
Data Retrieval	Local readout.

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Recommended Features	- Storage solution for probe. - Replaceable probe.
Optional Features	Monitor unit can typically connect to other probes to monitor additional parameters (e.g., temperature, nitrate, pH).

Typical Costs

Capital Cost	Very low.
Typical Additional Capital Cost	N/A.
Annual Operations and Maintenance Cost	Low.

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Ammonia
Test Kit

FACT SHEET 75

Colorimetric

1. Description

Analytical Process

A sample is collected and pipetted into a reaction vial containing hypochlorite and phenol catalyzed by (typically) manganese. The reaction produces a compound with a bright blue color (indophenols) with a maximum light absorbance at a wavelength of 630 nm. The color intensity is measured using a photometer, colorimeter, or spectrophotometer. The measurement is reported as ammonia–nitrogen.

Advantages

Little sample is needed to perform test.

Disadvantages

Several potential types of interferences.

Notes

Most significant reason for use: relatively easy to perform in on-site lab.

Most significant reason to avoid: uses chemical reagents.

Typical equipment includes reaction vials, pipettes, and a spectrophotometer/colorimeter/photometer.

Recommended system components: none.

Typical replacement items include lamp for spectrophotometer/colorimeter/photometer.

Consumables include reagents.

Colorimetric methods include phenate and salicylate methods to form colored complexes.

Samples with high alkalinity and hardness can be treated with citrate to prevent clouding of solution.

If sulfide interferences occur, they can be removed by reducing pH. Turbidity interferences can be removed by filtering samples.

Mercuric chloride, which has been used for sample preservation, should be avoided because of chloride interference and mercury disposal issues.

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Check accuracy of method by creating a standard curve of known glycol concentrations. Use blank solutions to zero equipment during each test. Recommend performing standard curve checks weekly or monthly.

Replace standard solutions every 90 days to 6 months.

2. Selection Criteria

Method and Use Status

Parameter	Ammonia (NH_3-N).
Type	Test kit.
Method of Description	Colorimetric. Ammonia reacts with hypochlorite and other reagents to produce an intense blue complex (phenate method) or green complex (salicylate method). The ammonia concentration is determined by measuring the light intensity of the sample using a colorimeter, photometer, or spectrophotometer.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	Yes.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	N/A.
Regulatory-Approved Method	None reported.
Measurement Range	0.01 to 50 mg/L.
Accuracy	±4% of full range.
Response Time	15 min.
Siting Constraints/Needs	None known.
Flow and Stream Constraints	N/A.
Interferences	- Chloride. - Calcium (>50,000 mg/L) and magnesium (>300,000 mg/L). - Nitrate/nitrite (600–5,000 mg/L). - Turbid or strongly acidic/alkaline samples. - Sulfides (>6,000 mg/L). - Orthophosphate (>5,000 mg/L).
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.

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O&M Issues	None known.
Data Retrieval	Visual; local readout.
Recommended Features	N/A.
Optional Features	N/A.

Typical Costs

Capital Cost	Very low.
Typical Additional Capital Cost	N/A.
Annual Operations and Maintenance Cost	Low.

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pH
Online Monitor

FACT SHEET 76

Glass Electrode

1. Description

Analytical Process

The probe is immersed in the flow stream. The probe compares the hydrogen ion concentration of the sample to a reference solution inside the probe. Between the sample and the reference solution is a glass layer sandwiched between hydrated gel layers. When there is a difference in the hydrogen ion concentration, an electrical potential is created. The resulting voltage is measured, corrected for temperature, and read as the pH value.

Advantages

Simple operation.

Disadvantages

Increased calibration is typically needed for low pH streams/samples.

Biofouling on probe may affect reading.

Probe may not calibrate or will give erratic readings if it dries out.

Notes

Most significant reason for use: diversion of storm water for pH.

Most significant reason to avoid: maintenance of in-stream probe.

Typical equipment includes pH electrode (probe) and monitor unit.

Recommended system components include cleaning system.

Typical replacement items include probe.

Consumables include reference solution and calibration buffers.

Probe must be kept submerged in solution to avoid drying out.

Probes are typically calibrated daily using two or three buffers with known pH (values of 3, 7, and 10).

Replace junctions (i.e., salt bridge) for combination electrodes every few months to increase equipment life. Reference electrodes are filled with gel or liquid reference solution. Probes may need to be replaced every 6 months to annually. Probe cannot be mounted horizontally. A sodium error that occurs at pH values greater than 10 can be reduced or eliminated by using a low-sodium-error electrode.

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2. Selection Criteria

Method and Use Status

Parameter	pH.
Type	Online monitor.
Method of Description	Glass electrode. Measurement of the hydrogen ion concentration in a sample using the electrical potential difference between a hydrogen ion-sensitive electrode and reference electrode.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	Yes.
General Availability of Technology	Many manufacturers

Implementation Considerations

Typical Installation Locations	Diversion, collection system monitoring, outfall discharge, treatment influent, treatment effluent.
Regulatory-Approved Method	Federal approval (EPA Method 150.2).
Measurement Range	0 to 14.
Accuracy	±0.2 standard units.
Response Time	Several seconds to 1 min.
Siting Constraints/Needs	- Structure needed to mount probe (e.g., culvert, storm sewer). - Electricity. - Water connection or air compressor for cleaning.
Flow and Stream Constraints	Installed submerged in sample stream. Must remain submerged at all times.
Interferences	- Minor interferences from lithium, sodium and potassium. - Highly acidic solutions can affect probe due to acid stripping (pH < 1).
Staff Time Requirements	Low.
Level of Staff Knowledge	Moderate.
O&M Issues	- Care must be taken when using glass electrodes to prevent breakage. - Frequent calibration using known buffer solutions. - Electrode must be kept submerged when not in use to prevent dehydration.
Data Retrieval	Analog connection, USB connection, telephone connection, wireless connection, cellular communication.

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Recommended Features	- Analyzer with internal adjustment for temperature. - Cleaning system if sample stream is slow moving.
Optional Features	- Automatic cleaning and calibration. - Monitor unit can typically connect to other probes to monitor additional parameters (e.g., temperature, conductivity, DO).

Typical Costs

Capital Cost	Very low.
Typical Additional Capital Cost	Low.
Annual Operations and Maintenance Cost	Low.

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pH
Online Monitor

FACT SHEET 77

Glass Free

1. Description

Analytical Process

The probe is immersed in the flow stream. The probe, referred to as an ion-selective field affect transistor (ISFET), is made up of two semiconductors with a gate between them. The gate is sensitive to pH. The flow of electrical current between the semiconductors through the gate is related to the sample pH. When the probe is immersed in a sample, the resulting current between the semiconductors is measured, corrected for temperature, and read as the pH value.

Advantages

Less likely to break compared to glass electrodes.

Additional mounting and placement options available for probe.

Long shelf life and calibration intervals.

Can be stored dry, but not for excessive amounts of time.

Disadvantages

May be too specialized for airport needs.

Typically needs manufacturer-specific analyzer and probe.

Semiconductor is sensitive to light.

Biofouling on probe may affect reading.

Notes

Most significant reason for use: diversion of storm water for pH.

Most significant reason to avoid: maintenance of in-stream probe and expensive probe.

Typical equipment includes pH electrode (probe) and monitor unit.

Recommended system components include cleaning system.

Typical replacement items include probe.

Consumables include calibration buffers.

Non-glass probes are typically used in the food processing industry.

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Probes are typically calibrated daily using two or three buffers with known pH (values of 3, 7, and 10).

Probes typically have longer life compared to glass electrodes due to breakage. Probes may need replacement after 18 months.

2. Selection Criteria

Method and Use Status

Parameter	pH.
Type	Online monitor.
Method of Description	Glass free. Measurement of the hydrogen ion concentration in a sample using the electrical potential between two semiconductors (source and drain electrodes) on either side of an ion-sensitive electrode (gate electrode). Also known as ISFET technology.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	No.
General Availability of Technology	Few manufacturers.

Implementation Considerations

Typical Installation Locations	Diversion, collection system monitoring, outfall discharge, treatment influent, treatment effluent.
Regulatory-Approved Method	None reported.
Measurement Range	0–14.
Accuracy	±0.2%.
Response Time	Several seconds to 1 min.
Siting Constraints/Needs	- Structure needed to mount probe (e.g., culvert, storm sewer). - Electricity. - Water connection or air compressor for cleaning.
Flow and Stream Constraints	Typically not intended for continuous online use.
Interferences	Minor interferences from highly acidic or basic solutions.
Staff Time Requirements	Low.
Level of Staff Knowledge	Moderate.

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O&M Issues	- Reference electrode is sealed and cannot be refilled, which results in probe replacement when calibration cannot be maintained. - Periodic calibration using known buffer solutions. - Clean electrode periodically using soap/ detergent.
Data Retrieval	Analog connection.
Recommended Features	Cleaning system if sample stream is slow moving.
Optional Features	- Automatic cleaning and calibration. - Monitor unit can typically connect to other probes to monitor additional parameters (e.g., temperature, conductivity, DO).

Typical Costs

Capital Cost	Very low.
Typical Additional Capital Cost	Low.
Annual Operations and Maintenance Cost	Low.

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FACT SHEET 78

Glass Electrode

1. Description

Analytical Process

The probe is immersed in the flow stream. The probe compares the hydrogen ion concentration of the sample to a reference solution inside the probe. Between the sample and the reference solution is a glass layer sandwiched between hydrated gel layers. When there is a difference in the hydrogen ion concentration, an electrical potential is created. The resulting voltage is measured, corrected for temperature, and read as the pH value.

Advantages

Simple operation.

Familiar to most individuals.

Disadvantages

Biofouling on probe may affect reading.

Probe may not calibrate or will give erratic readings if it dries out.

Notes

Most significant reason for use: most standard method for pH measurement.

Most significant reason to avoid: maintenance of handheld probe.

Typical equipment includes pH electrode (probe) and monitor unit.

Recommended system components: none.

Typical replacement items include probe.

Consumables include reference solution and calibration buffers.

Probes are typically calibrated daily using two or three buffers with known pH (values of 3, 7, and 10). If probe cannot be calibrated, it is typically replaced. Normal replacement is every 6 months to annually.

Reference electrode may be filled with gel or liquid reference solution.

Some manufacturers report that they have probes that do not require being submerged in solution, but it is recommended that probes remain submerged to extend life and avoid drying out.

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2. Selection Criteria

Method and Use Status

Parameter	pH.
Type	Handheld monitor.
Method of Description	Glass electrode. Measurement of the hydrogen ion concentration in a sample using the electrical potential difference between a hydrogen ion-sensitive electrode and reference electrode.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	Yes.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	N/A.
Regulatory-Approved Method	Federal approval (EPA Method 150.1).
Measurement Range	0 to 14.
Accuracy	±0.02 standard units (typical).
Response Time	Several seconds to 1 min.
Siting Constraints/Needs	N/A.
Flow and Stream Constraints	Sufficient depth for probe immersion.
Interferences	- Minor interferences from lithium, sodium, and potassium. - Highly acidic solutions can affect probe due to acid stripping (pH < 1).
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	Electrode must be rinsed before measuring pH.
Data Retrieval	Local readout.
Recommended Features	Internal adjustment for temperature.
Optional Features	Monitor unit can typically connect to other probes to monitor additional parameters (e.g., temperature, conductivity, DO).

Typical Costs

Capital Cost	Very low.
Typical Additional Capital Cost	N/A.
Annual Operations and Maintenance Cost	Low.

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pH
Handheld Monitor

FACT SHEET 79

Glass Free

1. Description

Analytical Process

The probe is immersed in the flow stream. The probe, referred to as an ion-selective field affect transistor (ISFET), is made up of two semiconductors with a gate between them. The gate is sensitive to pH. The flow of electrical current between the semiconductors through the gate is related to the sample pH. When the probe is immersed in a sample, the resulting current between the semiconductors is measured, corrected for temperature, and read as the pH value.

Advantages

Less likely to break compared to glass electrodes.

Long shelf life and calibration intervals.

Can be stored dry, but not for excessive amounts of time.

Disadvantages

May be too specialized for airport needs.

Typically needs manufacturer-specific analyzer and probe.

Semiconductor is sensitive to light.

Biofouling on probe may affect reading.

Notes

Most significant reason for use: need for a more robust probe than typical

Most significant reason to avoid: expense of probe.

Typical equipment includes pH electrode (probe) and monitor unit.

Recommended system components: none.

Typical replacement items: none.

Consumables include calibration buffers.

Non-glass probes are typically used in the food processing industry.

Probes are typically calibrated daily using two or three buffers with known pH (values of 3, 7, and 10). If probe cannot be calibrated, it is typically replaced. Normal replacement is every 6 months to annually.

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2. Selection Criteria

Method and Use Status

Parameter	pH.
Type	Handheld monitor.
Method of Description	Glass free. Measurement of the hydrogen ion concentration in a sample using the electrical potential between two semiconductors (source and drain electrodes) on either side of an ion-sensitive electrode (gate electrode). Also known as ISFET technology.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	No.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	N/A.
Regulatory-Approved Method	None reported.
Measurement Range	0 to 14.
Accuracy	±0.01 standard units (typical).
Response Time	Several seconds to 1 min.
Siting Constraints/Needs	N/A.
Flow and Stream Constraints	Sufficient depth for probe immersion.
Interferences	Minor interferences from highly acidic or basic solutions.
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	- Reference electrode is sealed and cannot be refilled, which results in probe replacement when calibration cannot be maintained. - Periodic calibration using known buffer solutions. - Clean electrode periodically using soap/detergent.
Data Retrieval	Local readout.
Recommended Features	None known.
Optional Features	Monitor unit can typically connect to other probes to monitor additional parameters (e.g., temperature, conductivity).

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Typical Costs

Capital Cost	Very low.
Typical Additional Capital Cost	N/A.
Annual Operations and Maintenance Cost	Low.

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FACT SHEET 80

Test Strips

1. Description

Analytical Process

The test strip is immersed in the sample for several seconds. An indicator compound in the pad at the end of the test strip reacts with the hydrogen ions in the sample and changes color. The color of the test strip is then compared to a color chart to determine the range of the pH value.

Advantages

Good for water quality screening.

Very easy to use.

Disadvantages

Data is qualitative (i.e., reported as a range rather than a specific value).

Test strips typically have a shelf life up to 5 years.

Notes

Most significant reason for use: quick check for internal use.

Most significant reason to avoid: not acceptable for compliance.

Typical equipment includes test strips.

Recommended system components: none.

Typical replacement items: none.

Consumables include test strips.

This method consists of determining pH using disposable test strips.

Test strips do not require calibration.

Test strips should be disposed of if compromised (i.e., exposed to water or past expiration date).

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2. Selection Criteria

Method and Use Status

Parameter	pH.
Type	Test kit.
Method of Description	Test strips. Test strips contain an indicator that changes color when immersed in a sample. The pH value is determined by comparing the color of the test strip to a color chart.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	No.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	N/A.
Regulatory-Approved Method	None reported.
Measurement Range	4–10 (typical).
Accuracy	±0.2–1.0 standard units.
Response Time	Immediate.
Siting Constraints/Needs	N/A.
Flow and Stream Constraints	High concentrations of chlorine or bromine.
Interferences	High concentrations of chlorine or bromine.
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	None known.
Data Retrieval	Visual.
Recommended Features	N/A.
Optional Features	N/A.

Typical Costs

Capital Cost	Very low.
Typical Additional Capital Cost	N/A.
Annual Operations and Maintenance Cost	Low.

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pH
Test Kit

FACT SHEET 81

Colorimetric

1. Description

Analytical Process

A sample is collected into a sample vial and a few drops of an indicator compound are added. The sample is mixed, and the indicator compound reacts, creating a color change. The color of the sample is then compared to a standard color chart or measured using a colorimeter to determine the pH value.

Advantages

Easy to use.

Disadvantages

Data range is limited, but typically within airport storm water concentrations.

Notes

Most significant reason for use: quick check for internal use.

Most significant reason to avoid: uses chemical reagents.

Typical equipment includes sample tube and color comparator or colorimeter.

Recommended system components: none.

Typical replacement items include bulb for colorimeter.

Consumables include reagents and pH standards.

Visual tests are not calibrated. Use blank solutions to zero colorimeter or during each visual test. Check accuracy of method by performing test with solutions of known pH. Recommend checking accuracy weekly or monthly.

Replace standard solutions every 90 days to 6 months.

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2. Selection Criteria

Method and Use Status

Parameter	pH.
Type	Test kit.
Method of Description	Colorimetric. Absorbance of a sample is measured after adding a known amount of phenol red indicator. The measured absorbance corresponds to the pH value.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	No.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	N/A.
Regulatory-Approved Method	None reported.
Measurement Range	5.9–8.5.
Accuracy	±0.1 standard units.
Response Time	Immediate.
Siting Constraints/Needs	N/A.
Flow and Stream Constraints	N/A.
Interferences	Chlorine (>6 mg/L).
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	- Periodic battery and light source replacement. - Periodic calibration.
Data Retrieval	Local readout.
Recommended Features	N/A.
Optional Features	Colorimeter can typically test for additional parameters (e.g., ammonia, COD).

Typical Costs

Capital Cost	Very low.
Typical Additional Capital Cost	N/A.
Annual Operations and Maintenance Cost	Low.

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FACT SHEET 82

Amperometric/Polarographic Sensor

1. Description

Analytical Process

The probe is placed in the sample stream. Dissolved oxygen (DO) passes through a membrane (typically Teflon) and into a fluid adjacent to a pair of electrodes. A potential difference is created between the electrodes, and the dissolved oxygen is reduced at the working electrode. The limiting current is proportional to the concentration of DO.

Advantages

Good for severe fouling environments.

Automatic cleaning and calibration.

Disadvantages

Membrane replacement can be difficult.

Biofouling of probe can affect reading.

Notes

Most significant reason for use: diversion of storm water for DO or requirement for continuous measurement.

Most significant reason to avoid: maintenance of in-stream probe.

Typical equipment includes DO probe and monitor unit.

Recommended system components: none.

Typical replacement items include DO probe.

Consumables include DO probe membrane and electrolyte solution.

Probes analyze for low-, medium-, and high-range DO.

Probes should be installed in sample stream for several hours prior to calibration to reach equilibrium. Instruments have an auto-calibration feature, and the recommended frequency is daily. Probes can also be calibrated in DO-saturated solution or air. Weekly calibration checks are recommended, at a minimum. Probes can be zeroed using nitrogen gas or sodium sulfate solution.

Probe membrane should be cleaned weekly. When probe is not in use, it should be rinsed and stored in water to prevent drying out. Replace membrane and electrolyte every month to annually, depending on use. The average life of a probe is several years.

Monitors can also be configured as submerged data sondes.

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2. Selection Criteria

Method and Use Status

Parameter	Dissolved oxygen (DO).
Type	Online monitor.
Method of Description	Amperometric/polarographic sensor. The dissolved oxygen of a sample is measured using a gas-permeable, membrane-covered electrode with an amperometric/polarographic sensor.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	Yes.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	Diversion, collection system monitoring, outfall discharge, treatment influent, treatment effluent.
Regulatory-Approved Method	Federal approval (EPA Method 360.1).
Measurement Range	0.01–80 mg/L (typical maximum necessary for water is 15–20 mg/L).
Accuracy	±1%.
Response Time	Several seconds.
Siting Constraints/Needs	- Structure needed to mount probe; probe must be mounted upright. - Electricity. - Shelter for weather protection of analyzer. - Connection to water or air compressor for cleaning.
Flow and Stream Constraints	- Installed submerged in sample stream. Must remain submerged at all times. - Flow is necessary for accurate reading.
Interferences	- Dissolved inorganic salts. - Reactive compounds/gases (e.g., Cl_2, H_2S). - Temperature sensitive.
Staff Time Requirements	Low.
Level of Staff Knowledge	Moderate.
O&M Issues	- Periodic membrane replacement. - Susceptible to biofouling. - Refilling of electrode solution is necessary.
Data Retrieval	Analog connection, USB connection, datalogger.
Recommended Features	Cleaning system.

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Optional Features	- Automatic cleaning and calibration. - Monitor unit can typically connect to other probes to monitor additional parameters (e.g., temperature, conductivity, pH, TSS). - Service/maintenance alarms. - Ball/float mounting systems available.

Typical Costs

Capital Cost	Low.
Typical Additional Capital Cost	Low.
Annual Operations and Maintenance Cost	Low.

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FACT SHEET 83

Optical/Fluorescence Sensor

1. Description

Analytical Process

The probe is placed in the sample stream. A fluorescent film on the surface of the probe is exposed to light. The fluorescent compound shines following removal of the light; however, dissolved oxygen in the water colliding with the film shortens the duration of the fluorescence. The length of time that the fluorescence is shortened is proportional to the concentration of DO.

Advantages

Chemicals and membranes are not necessary.

Less frequent calibration and sensor replacement than amperometric/polarographic method.

Disadvantages

Biofouling can affect reading.

Notes

Most significant reasons for use: diversion of storm water for DO or requirement for continuous measurement.

Most significant reason to avoid: maintenance of in-stream probe, but less maintenance than amperometric/polarographic sensor.

Typical equipment includes DO probe and monitor unit.

Recommended system components include cleaning system.

Typical replacement items include DO probe.

Consumables include sensor cap (some models).

Probes are calibrated in saturated solution or air. Calibration checks are recommended weekly, at a minimum. Probes can be zeroed using nitrogen gas or sodium sulfate solution. Probes must be submerged in solution.

Probe sensor should be manually cleaned weekly, and frequently by an automatic wiper system. When probe is not in use, it should be rinsed and stored in water to avoid drying out. The average life of a probe is several years. For the models that have sensor caps, they are typically replaced every 30 to 90 days.

Monitors can also be configured as submerged data sondes.

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2. Selection Criteria

Method and Use Status

Parameter	Dissolved oxygen (DO).
Type	Online monitor.
Method of Description	Optical/fluorescence sensor. A light source excites an oxygen-permeable, luminescent/fluorescent material in contact with the sample. The light source is turned off and the material fluoresces (gives off light). Dissolved oxygen in the sample changes the amount of light given off, and the difference is read by a light sensor.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	No.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	Diversion, collection system monitoring, outfall discharge, treatment influent, treatment effluent.
Regulatory-Approved Method	(EPA has approved use, but method number is not available. It is likely the method will be 360.3).
Measurement Range	2 μg/L to 20 mg/L.
Accuracy	±1 to 15%.
Response Time	Several seconds.
Siting Constraints/Needs	- Structure needed to mount probe, probe must be mounted upright. - Electricity. - Shelter for weather protection of analyzer. - Connection to water or air compressor for cleaning.
Flow and Stream Constraints	- Installed submerged in sample stream. - Flow is necessary for equipment to operate.
Interferences	Air bubbles.
Staff Time Requirements	Low.
Level of Staff Knowledge	Moderate.
O&M Issues	- Calibration. - Membrane replacement. - Susceptible to biofouling.
Data Retrieval	Analog connection, USB connection, Ethernet, wireless communication.

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Recommended Features	- Automatic calibration. - Service/maintenance alarms. - Cleaning system.
Optional Features	- Cleaning system. - Automatic calibration. - Service/maintenance alarms. - Monitor unit can typically connect to other probes to monitor additional parameters (e.g., temperature, conductivity, pH).

Typical Costs

Capital Cost	Low.
Typical Additional Capital Cost	Low.
Annual Operations and Maintenance Cost	Low.

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FACT SHEET 84

Amperometric/Polarographic Sensor

1. Description

Analytical Process

The probe is placed in the sample stream. DO passes through a membrane (typically Teflon) and into a fluid adjacent to a pair of electrodes. A potential difference is created between the electrodes, and the dissolved oxygen is reduced at the working electrode. The limiting current is proportional to the concentration of DO.

Advantages

Fewer potential interferences than the alternative method (Winkler titration method).

Disadvantages

Membrane replacement can be difficult.

Notes

Most significant reason for use: typical method for DO measurement.

Most significant reason to avoid: maintenance of handheld probe.

Typical equipment includes DO probe and monitor unit.

Recommended system components: none.

Typical replacement items include DO probe.

Consumables include DO probe membrane and electrolyte solution.

Probes are typically calibrated daily. Probes are calibrated in saturated DO solution or air. If probe cannot be calibrated, it is typically replaced. Normal replacement is every 6 months to annually. Probes can be zeroed using nitrogen gas or sodium sulfate solution.

Probe membrane should be cleaned weekly. When probe is not in use, it should be rinsed and stored in water solution to avoid drying out. Replace membrane and electrolyte every month to annually, depending on use. The average life of a probe is several years.

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2. Selection Criteria

Method and Use Status

Parameter	Dissolved oxygen (DO).
Type	Handheld monitor.
Method of Description	Amperometric/polarographic sensor. The dissolved oxygen of a sample is measured using a gas-permeable, membrane-covered electrode with an amperometric/polarographic sensor.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	Yes.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	N/A.
Regulatory-Approved Method	Federal approval (EPA Method 360.1).
Measurement Range	0 to 50 mg/L (typical maximum necessary for water is 15–20 mg/L).
Accuracy	±1.5 to 15%.
Response Time	Several seconds.
Siting Constraints/Needs	N/A.
Flow and Stream Constraints	Sufficient depth for installation of a probe.
Interferences	- Dissolved inorganic salts. - Reactive Compounds/Gases (e.g., Cl_2, H_2S). - Temperature sensitive.
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	- Periodic membrane replacement. - Refilling of electrode solution is necessary.
Data Retrieval	Local readout.
Recommended Features	- Installed submerged in sample stream. - Flow is necessary for equipment to operate.
Optional Features	Monitor unit can typically connect to other probes to monitor additional parameters (e.g., temperature, conductivity, pH).

Typical Costs

Capital Cost	Very low.
Typical Additional Capital Cost	N/A.
Annual Operations and Maintenance Cost	Low.

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Dissolved Oxygen
Handheld Monitor

FACT SHEET 85

Optical/Fluorescence Sensor

1. Description

Analytical Process

The probe is placed in the sample stream. A fluorescent film on the surface of the probe is exposed to light. The fluorescent compound shines following removal of the light; however, dissolved oxygen in the water colliding with the film shortens the duration of the fluorescence. The length of time that the fluorescence is shortened is proportional to the concentration of DO.

Advantages

Chemical and membranes are not necessary.

Less frequent calibration and sensor replacement than amperometric/polarographic method.

Monitor unit can monitor additional parameters (e.g., temperature).

Disadvantages

Bright sunlight may affect reading.

Notes

Most significant reason for use: ease of use.

Most significant reason to avoid: maintenance of handheld probe, but less maintenance than amperometric/polarographic sensor.

Typical equipment includes DO probe and monitor unit.

Recommended system components: none.

Typical replacement items include sensor cap.

Consumables: none.

Probes are calibrated in saturated DO solution or air. Calibration checks are recommended monthly, but may be able to be completed every several months. Probes can be zeroed using nitrogen gas or sodium sulfate solution.

Probe sensor should be cleaned weekly. Sensor cap needs to be replaced annually. When probe is not in use, it should be rinsed and stored in water to avoid drying out. The average life of a probe is several years.

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2. Selection Criteria

Method and Use Status

Parameter	Dissolved oxygen (DO).
Type	Handheld monitor.
Method of Description	Optical/fluorescence sensor. A light source excites an oxygen-permeable, luminescent/fluorescent material in contact with the sample. The light source is turned off and the material fluoresces (gives off light). Dissolved oxygen in the sample changes the amount of light given off, and the difference is read by a light sensor.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	No.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	N/A.
Regulatory-Approved Method	(EPA has approved use, but method number is not available. It is likely the method will be 360.3.)
Measurement Range	0 to 50 mg/L (typical maximum necessary for water is 15–20 mg/L).
Accuracy	±1 to 15%.
Response Time	Several seconds.
Siting Constraints/Needs	N/A.
Flow and Stream Constraints	Sufficient depth for installation of a probe.
Interferences	Air bubbles.
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	- Calibration. - Membrane replacement.
Data Retrieval	Local readout.
Recommended Features	N/A.
Optional Features	None known.

Typical Costs

Capital Cost	Very low.
Typical Additional Capital Cost	N/A.
Annual Operations and Maintenance Cost	Low.

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Dissolved Oxygen
Test Kit

FACT SHEET 86

Winkler Titration

1. Description

Analytical Process

A sample bottle is filled completely with water so that no air bubbles are included. Manganese sulfate, alkali-iodide-azide reagent, and sulfuric acid are added to the sample and mixed. The sample is then titrated to two different end points with sodium thiosulfate. The amount of sodium thiosulfate required to reach the titration endpoint is proportional to the DO concentration.

Advantages

Very accurate in the absence of interferences.

Disadvantages

Limited range in DO measurement.

Requires reagents and titration typically.

Titrating past end point can produce erroneous results.

Notes

Most significant reason for use: none.

Most significant reason to avoid: complexity of method.

Typical equipment includes: titration apparatus.

Recommended system components: none.

Typical replacement items: none.

Consumables include reagents.

Analysis must be performed immediately upon sample collection or within 45 min. Do not allow the sample to become agitated.

This method does not require calibration.

Shelf life of reagents is approximately 1 to 2 years.

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2. Selection Criteria

Method and Use Status

Parameter	Dissolved oxygen (DO).
Type	Test kit.
Method of Description	Winkler titration. Manganese is added to an alkaline sample (high pH) solution containing iodide to form a solid. The solution is acidified, resulting in a colored solution containing iodide molecules (I2). The solution is then titrated with thiosulfate. The volume of thiosulfate needed to reach the endpoint is used to determine the amount of dissolved oxygen in the sample.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	Yes.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	N/A.
Regulatory-Approved Method	Federal approval (EPA Method 360.2).
Measurement Range	0.2 to 20 mg/L.
Accuracy	±0.1%.
Response Time	30 min. (time to perform analysis).
Siting Constraints/Needs	N/A.
Flow and Stream Constraints	None known.
Interferences	- Nitrate. Can be eliminated by using azide-containing reagents. - Reducing or oxidizing substances (e.g., organic matter). - Sulfides.
Staff Time Requirements	Low.
Level of Staff Knowledge	Moderate.
O&M Issues	None known.
Data Retrieval	- Visual identification of titration end point. - Calculation for DO using volume of titrant used.
Recommended Features	N/A.
Optional Features	N/A.

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Typical Costs

Capital Cost	Very low.
Typical Additional Capital Cost	N/A.
Annual Operations and Maintenance Cost	Low.

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Dissolved Oxygen Test Kit

FACT SHEET 87

Colorimetric

1. Description

Analytical Process

A sample bottle is filled completely with water so that no air bubbles are included. A reagent is added to the sample and mixed, resulting in a color change. The color is then compared to a color chart or measured using a photometer or spectrophotometer to determine the DO concentration.

Advantages

More accurate than Winkler titration method.

Can be performed in an onsite lab.

Disadvantages

Limited range of DO measurement.

Notes

Most significant reason for use: does not require maintenance of probe.

Most significant reason to avoid: requires chemical reagents and onsite lab.

Typical equipment includes reaction vials and a color chart/photometer/spectrophotometer.

Recommended system components: none.

Typical replacement items include lamp for photometer/spectrophotometer.

Consumables include reagents.

Analysis must be performed immediately upon sample collection or within 45 min. Do not allow the sample to become agitated.

This method does not require calibration.

Replace spectrophotometer or photometer bulb or light source as necessary.

Shelf life of reagents is approximately 1 to 2 years.

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2. Selection Criteria

Method and Use Status

Parameter	Dissolved oxygen (DO).
Type	Test kit.
Method of Description	Colorimetric. Manganese is added to an alkaline sample solution (high pH) containing iodide to form a solid. The solution is acidified, resulting in a colored solution containing iodide molecules (I2). Intensity of color is compared to a color chart, or the wavelength is measured by a spectrophotometer.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	Yes.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	N/A.
Regulatory-Approved Method	None reported.
Measurement Range	0 to 15 mg/L.
Accuracy	- Color comparator only identifies range in DO concentration ±0.01 mg/L.
Response Time	Immediate.
Siting Constraints/Needs	N/A.
Flow and Stream Constraints	None known.
Interferences	- Nitrate. Can be eliminated by using azide-containing reagents. - Reducing or oxidizing substances (e.g., organic matter). - Sulfides. - Copper, iron, chromium, manganese, and nickel (10 mg/L for high-concentration DO samples).
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	None known.
Data Retrieval	Visual; local readout.
Recommended Features	N/A.
Optional Features	N/A.

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Typical Costs

Capital Cost	Very low.
Typical Additional Capital Cost	N/A.
Annual Operations and Maintenance Cost	Low.

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Temperature
Online Monitor

FACT SHEET 88

Thermocouple

1. Description

Analytical Process

The temperature probe is immersed in the sample stream. The probe contains two different metal strips joined at one end. The voltage produced between the two metal strips is proportional to the temperature.

Advantages

Quick response.

Disadvantages

Poor to fair long-term stability (duration the unit will stay calibrated).

Fair accuracy.

Sensor must be immersed to obtain temperature. Some probes identify the immersion level for accurate temperature reading.

Notes

Most significant reason for use: requirement for continuous temperature measurement.

Most significant reason to avoid: maintenance of in-stream sensor.

Typical equipment includes temperature sensor and monitor unit.

Recommended system components: none.

Typical replacement items: none.

Consumables: none.

Accuracy of sensor can be checked using a hot water or ice bath. When temperature readings are erratic or not accurate, the sensor is replaced.

Service life of a thermocouple sensor varies depending on exposure elements, but they typically have a long service life (i.e., over 10 years).

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2. Selection Criteria

Method and Use Status

Parameter	Temperature.
Type	Online monitor.
Method of Description	Thermocouple. The sensor is composed of two different metal strips joined at one end. When temperature changes, a voltage is produced between the two metals. The voltage is correlated to the temperature.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	Yes.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	Diversion, collection system monitoring, outfall discharge, treatment influent, treatment effluent.
Regulatory-Approved Method	Thermocouples are not included under the EPA method for temperature, but are approved for use in other environmental methods.
Measurement Range	–418°F to 2282°F (–250°C to 1250°C).
Accuracy	±1.9°F to 4.0°F (±1.0°C to 2.2°C).
Response Time	Several seconds.
Siting Constraints/Needs	- Structure needed to mount sensor. - Electricity.
Flow and Stream Constraints	- Sensor must be submerged in sample stream. - Internal sensor and wiring can become damaged if protective sheath is not intact and components come in contact with water.
Interferences	Electromagnetic (i.e., high-voltage wires, magnetic flow meters).
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	- Periodic sensor and battery replacement. - Periodic calibration.
Data Retrieval	Local readout.
Recommended Features	- Shielded sensors to reduce electromagnetic interference. - Waterproof enclosure.

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Optional Features	- Monitor unit can typically connect to other probes to monitor additional parameters (e.g., DO, conductivity, pH). - Highly sensitive temperature sensors are available.

Typical Costs

Capital Cost	Very low.
Typical Additional Capital Cost	Low.
Annual Operations and Maintenance Cost	Low.

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FACT SHEET 89

Resistance-Temperature Detectors (RTD)/Thermistors

1. Description

Analytical Process

The temperature probe is immersed in the sample stream. Thermistors are composed of a sensor containing semiconductors connected to a monitoring unit. RTD thermometers are composed of a metal sensor that is typically wire-wound, coiled, or thin-film platinum connected to a monitoring unit. A current is passed through the probe, and the electrical resistance is proportional to the temperature.

Advantages

Quick response.

Accurate readings.

Disadvantages

Fragile sensor.

Thermistors have poor long-term stability (duration the unit will stay calibrated).

Sensor must be immersed to obtain temperature.

Notes

Most significant reason for use: requirement for continuous temperature measurement.

Most significant reason to avoid: maintenance of in-stream sensor.

Typical equipment includes temperature sensor and monitor unit.

Recommended system components: none.

Typical replacement items: none.

Consumables: none.

Typically, when temperature readings are not accurate, the sensor is replaced. Accuracy of sensor can be checked using a hot water or ice bath.

Factors such as excessive exposure to vibration or heat typically cause sensors to fail. Sensor probes or connection wires may need to be replaced approximately every couple of years, depending on use of equipment.

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2. Selection Criteria

Method and Use Status

Parameter	Temperature.
Type	Online monitor.
Method of Description	Resistance-temperature detectors (RTD)/thermistors The temperature sensor is made of a material for which electrical resistance changes when temperature changes. Thermistors are typically composed of ceramic or polymer, while RTDs are typically composed of pure metal. The resistance is correlated to the temperature.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	Yes.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	Diversion, collection system monitoring, outfall discharge, treatment influent, treatment effluent.
Regulatory-Approved Method	Federal approval (EPA Method 170.1).
Measurement Range	32°F to 212°F (0°C to 100°C).
Accuracy	±0.2°F to 0.4°F (±0.1°C to 0.2°C).
Response Time	Several seconds.
Siting Constraints/Needs	- Needs to be mounted carefully to avoid damaging the sensor. - Structure needed to mount sensor. - Electricity.
Flow and Stream Constraints	- Sensor must be submerged in sample stream. - Internal wiring can become damaged if protective sheath is not intact and components come in contact with water.
Interferences	Electromagnetic (i.e., high-voltage wires, magnetic flow meters).
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	- Periodic sensor and battery replacement. - Periodic calibration.
Data Retrieval	Local readout, USB connection, analog connection.

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Recommended Features	- Shielded sensors to reduce electromagnetic interference. - Waterproof enclosure.
Optional Features	Monitor unit can typically connect to other probes to monitor additional parameters (e.g., DO, conductivity, pH).

Typical Costs

Capital Cost	Very low.
Typical Additional Capital Cost	Low.
Annual Operations and Maintenance Cost	Low

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FACT SHEET 90

Infrared Detector

1. Description

Analytical Process

The monitor unit detects infrared energy given off by an object. The peak of the infrared energy is related to the temperature of the object.

Advantages

Easy to use.

Disadvantages

Technology is not typical for storm water installations.

Fair accuracy.

Sensors are sensitive and must be protected from dirt, dust, flames, and so forth.

Notes

Most significant reason for use: inaccessible sample location.

Most significant reason to avoid: potential interferences and inaccuracy of surface reading.

Typical equipment includes monitor unit.

Recommended system components: none.

Typical replacement items: none.

Consumables: none.

Temperature sensors are typically purchased based on expected temperature range.

Detectors are calibrated based on measurement of targets with known temperature. Emissivity of the target must be also known. To calibrate for emissivity effects, a blackbody calibration instrument is required. It is recommended that infrared detectors be calibrated annually. Most manufacturers calibrate infrared monitors for a yearly fee.

Service life of an infrared sensor varies depending on use, but they typically have a service life exceeding 10 years. If a component fails, typically the entire unit is replaced.

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2. Selection Criteria

Method and Use Status

Parameter	Temperature.
Type	Handheld monitor.
Method of Description	Infrared detectors. A noncontact temperature sensor that measures infrared energy emitted by a material. The energy detected is converted to an electrical signal that is displayed as temperature.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	No.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	N/A.
Regulatory-Approved Method	None reported.
Measurement Range	–76°F to 3632°F (–60°C to 2000°C).
Accuracy	±3.6°F (±2°C).
Response Time	Immediate.
Siting Constraints/Needs	N/A.
Flow and Stream Constraints	Only surface temperature is monitored.
Interferences	- Electromagnetic (i.e., high-voltage wires, magnetic flow meters). - Surface reflectivity.
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	- Periodic sensor and battery replacement. - Periodic calibration. - Sensor cleaning.
Data Retrieval	Local readout, analog connection.
Recommended Features	None known.
Optional Features	Audible and visible alarms.

Typical Costs

Capital Cost	Very low.
Typical Additional Capital Cost	N/A.
Annual Operations and Maintenance Cost	Low.

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FACT SHEET 91

Bimetal

1. Description

Analytical Process

The temperature probe is immersed in the sample stream. The probe is composed of two different metals joined at one end that expand/contract at different rates depending on temperature. Temperature corresponds to the mechanical displacement (i.e., thermal expansion) between the two metals. The readout is typically a dial.

Advantages

Familiar to most individuals.

Disadvantages

Slow response time.

Limited length of immersion probe.

Notes

Most significant reason for use: ease of use.

Most significant reason to avoid: close contact with sample (i.e., sensor and dial are attached—no wire in between).

Typical equipment includes monitor unit.

Recommended system components: none.

Typical replacement items: none.

Consumables: none.

Typically used in the laboratory (i.e., not in the field).

Bimetal thermometers consist of a metal stem, coil of two different metals, and a temperature indicator (as one unit).

Accuracy of thermometer can also be checked using a hot water or ice bath.

Bimetal thermometers are replaced as an entire system.

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2. Selection Criteria

Method and Use Status

Parameter	Temperature.
Type	Handheld monitor.
Method of Description	Bimetal. A sensor composed of strips of two different metals joined at one end that expand/contract at different rates depending on temperature. The mechanical displacement (i.e., thermal expansion) between the two metals is correlated to the temperature.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	No.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	N/A.
Regulatory-Approved Method	None reported.
Measurement Range	–94°F to 1004°F (–70°C to 540°C).
Accuracy	±1.8°F (±1°C).
Response Time	Up to 5 min.
Siting Constraints/Needs	N/A.
Flow and Stream Constraints	Sufficient depth for sensor immersion.
Interferences	None known.
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	Periodically calibrate.
Data Retrieval	Visual.
Recommended Features	Displays temperature within a specified range. Need to know temperature range of flow/stream.
Optional Features	None known.

Typical Costs

Capital Cost	Very low.
Typical Additional Capital Cost	N/A.
Annual Operations and Maintenance Cost	Low.

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Temperature
Handheld Monitor

FACT SHEET 92

Glass Liquid Thermometer

1. Description

Analytical Process

The glass tube filled with mercury or other liquid is inserted into a sample or sample stream. The level of the liquid corresponds to temperature, which is read on an etched scale on the glass tube.

Advantages

Familiar to most individuals.

Disadvantages

Fragile and typically contains mercury, which requires special handling and disposal if thermometer is broken.

May be difficult to read.

Notes

Most significant reason for use: ease of use.

Most significant reason to avoid: high potential for breaking.

Typical equipment includes monitor unit.

Recommended system components: none.

Typical replacement items: none.

Consumables: none.

Glass liquid thermometers consist of an etched glass cylinder containing either mercury or alcohol.

Glass liquid thermometers are usually calibrated using calibration baths. Accuracy of thermometer may be checked using a hot water or ice bath. Typically, when temperature readings are not accurate, the thermometer is replaced, or a correction factor is used when measuring temperature.

Glass liquid thermometers are replaced as an entire system.

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2. Selection Criteria

Method and Use Status

Parameter	Temperature.
Type	Handheld monitor.
Method of Description	Glass liquid thermometer. A glass tube filled with mercury or other liquid that increases/decreases level when immersed in a sample. The level of the liquid corresponds to temperature, which is read on an etched scale on the glass tube.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	Yes.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	N/A.
Regulatory-Approved Method	Federal approval (EPA Method 170.1).
Measurement Range	–328°F to 1112°F (–200°C to 600°C).
Accuracy	±0.05°F to 0.9°F (±0.03°C to 0.5°C).
Response Time	Several seconds.
Siting Constraints/Needs	N/A.
Flow and Stream Constraints	Sufficient depth for sensor immersion.
Interferences	None.
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	- Breakage of glass tube. - Mercury disposal.
Data Retrieval	Visual.
Recommended Features	Purchase thermometers that do not contain mercury.
Optional Features	N/A.

Typical Costs

Capital Cost	Very low.
Typical Additional Capital Cost	N/A.
Annual Operations and Maintenance Cost	Low.

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Temperature
Handheld Monitor

FACT SHEET 93

Thermocouple

1. Description

Analytical Process

The temperature probe is immersed in the sample stream. The probe contains two different metal strips joined at one end. The voltage produced between the two metal strips is proportional to the temperature.

Advantages

Familiar to most individuals.

Disadvantages

Poor to fair long-term stability (duration the unit will stay calibrated).

Fair accuracy.

Notes

Most significant reason for use: ease of use.

Most significant reason to avoid: periodic recalibration required.

Typical equipment includes: monitor unit.

Recommended system components: none.

Typical replacement items: none.

Consumables: none.

Accuracy of sensor can also be checked using a hot water or ice bath. Typically, when temperature readings are not accurate, the sensor is replaced. Sensors can also be calibrated by the manufacturer or with a certified reference thermometer.

Service life of thermocouple sensor varies depending on exposure elements, but they typically have a long service life.

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2. Selection Criteria

Method and Use Status

Parameter	Temperature.
Type	Handheld monitor.
Method of Description	Thermocouple. The sensor is composed of two different metal strips joined at one end. When temperature changes, a voltage is produced between the two metals. The voltage is correlated to the temperature.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	Yes.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	N/A.
Regulatory-Approved Method	Thermocouples are not included under the EPA method for temperature, but are approved for use in other environmental methods.
Measurement Range	–418°F to 2282°F (–250°C to 1250°C).
Accuracy	±1.8°F to 4.0°F (±1.0°C to 2.2°C).
Response Time	Several seconds.
Siting Constraints/Needs	N/A.
Flow and Stream Constraints	- Sufficient depth for sensor immersion. - Internal sensor and wiring can become damaged if protective sheath is not intact and components come in contact with water.
Interferences	Electromagnetic (i.e., high-voltage wires, magnetic flow meters).
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	- Periodic sensor and battery replacement. - Periodic calibration.
Data Retrieval	Local readout.
Recommended Features	Shielded sensors to reduce electromagnetic interference.
Optional Features	Monitor unit can typically connect to other probes to monitor additional parameters (e.g., DO, conductivity, pH).

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Typical Costs

Capital Cost	Very low.
Typical Additional Capital Cost	N/A.
Annual Operations and Maintenance Cost	Low.

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Temperature
Handheld

FACT SHEET 94

Resistance-Temperature Detectors (RTD)/Thermistors

1. Description

Analytical Process

The temperature probe is immersed in the sample stream. Thermistors are composed of a sensor containing semiconductors connected to a monitoring unit. RTD thermometers are composed of a metal sensor that is typically wire-wound, coiled, or thin-film platinum connected to a monitoring unit. A current is passed through the probe, and the electrical resistance is proportional to the temperature.

Advantages

Familiar to most individuals.

Accurate readings.

Disadvantages

Fragile sensor.

Sensor must be immersed to obtain temperature.

Notes

Most significant reason for use: ease of use.

Most significant reason to avoid: none.

Typical equipment includes monitor unit.

Recommended system components: none.

Typical replacement items: none.

Consumables: none.

RTD thermometers are composed of a metal sensor that is typically wire-wound, coiled, or thin-film platinum connected to a monitoring unit. Thermistors are composed of a sensor containing semiconductors connected to a monitoring unit.

Accuracy of sensor can be checked using a hot water or ice bath. Typically, when temperature readings are not accurate, the sensor is replaced.

Factors such as excessive exposure to vibration or heat typically cause sensors to fail. Depending on use of equipment, sensor probes or connection wires may need to be replaced every couple of years.

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2. Selection Criteria

Method and Use Status

Parameter	Temperature.
Type	Handheld monitor.
Method of Description	Resistance-temperature detectors (RTD)/thermistors. The temperature sensor is made of a material for which electrical resistance changes when temperature changes. Thermistors are typically composed of ceramic or polymer, while RTDs are typically composed of pure metal. The resistance is correlated to the temperature.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	Yes.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	N/A.
Regulatory-Approved Method	Federal approval (EPA Method 170.1).
Measurement Range	–328°F to 752°F (–200°C to 400°C).
Accuracy	±0.2°F to 0.4°F (±0.1°C to 0.2°C).
Response Time	Several seconds.
Siting Constraints/Needs	N/A.
Flow and Stream Constraints	- Sufficient depth for sensor immersion. - Internal wiring can become damaged if protective sheath is not intact and components come in contact with water.
Interferences	Electromagnetic (i.e., high-voltage wires, magnetic flow meters).
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	- Periodic sensor and battery replacement. - Periodic calibration.
Data Retrieval	Local readout, USB connection, analog connection.
Recommended Features	Shielded sensors to reduce electromagnetic interference.
Optional Features	Monitor unit can typically connect to other probes to monitor additional parameters (e.g., DO, conductivity, pH).

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Typical Costs

Capital Cost	Very low.
Typical Additional Capital Cost	N/A.
Annual Operations and Maintenance Cost	Low.

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Total Suspended Solids
Online Monitor

FACT SHEET 95

Scattered Light Detection

1. Description

Analytical Process

This unit is installed inline with the sample stream or in an offline sample loop or flow cell. The sample flows continuously into a cell where a beam of infrared or visible light is projected through the sample. The amount of infrared or visible light that bounces off particles in the sample is measured by a photosensor adjacent to (for 180°) or perpendicular to (for 90°) the light emitter and correlated to a concentration of total suspended solids.

Advantages

Best for measuring lowest ranges (<10 mg/L TSS).

No consumables are required.

Automatic cleaning of lens reduces maintenance.

Disadvantages

Does not directly monitor solids concentration—is a correlation to turbidity.

Notes

Most significant reason for use: requirement for continuous TSS measurement.

Most significant reason to avoid: maintenance of online monitor and limited range.

Typical equipment includes monitor unit.

Recommended system components include cleaning system.

Typical replacement items: none.

Consumables: none.

Calibration curve needs to be developed at an independent lab using the gravimetric method.

Two styles available: immersion type (used in a tank or channel), and insertion type (used in a pipe).

Automatic cleaning systems using wipers tend to require more maintenance than those using air jets or water jets.

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2. Selection Criteria

Method and Use Status

Parameter	Total suspended solids (TSS).
Type	Online monitor.
Method of Description	Scattered light detection. The amount of infrared or visible light that bounces off the solids in the sample is measured by a photosensor adjacent to or perpendicular to the light emitter. The light measured is correlated to the total suspended solids concentration.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	No.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	Diversion, collection system monitoring, outfall discharge, treatment influent, treatment effluent.
Regulatory-Approved Method	None reported.
Measurement Range	0 to 1,000 mg/L (up to 4,000 mg/L depending on manufacturer and model).
Accuracy	±5% (down to ±1% depending on manufacturer and model).
Response Time	Immediate.
Siting Constraints/Needs	Electricity (some models are battery powered).
Flow and Stream Constraints	- For gravity storm sewers, a sample pump/ sample loop is typically required. - Flow velocity < 9.8 ft/s.
Interferences	- Air bubbles. - Dyes or coloring.
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	- Lens cleaning. - Calibration.
Data Retrieval	Local readout.
Recommended Features	- Automatic cleaning system (compressed air or water jet). - Air bubble compensation to reduce interference.
Optional Features	- Analog connection. - Ultrasonic cleaning.

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Typical Costs

Capital Cost	Low.
Typical Additional Capital Cost	Low.
Annual Operations and Maintenance Cost	Low.

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Total Suspended Solids
Online Monitor

FACT SHEET 96

Optical/Absorbance

1. Description

Analytical Process

This unit is installed inline with the sample stream or in an offline sample loop or flow cell. The sample flows continuously into a cell, where a beam of UV or visible light is projected through the sample. The absorbance of UV or visible light by solids in the sample is measured by a photosensor across from the light emitter and correlated to a concentration of total suspended solids.

Advantages

No consumables are required.

Automatic cleaning of lens reduces maintenance.

Disadvantages

Does not directly monitor solids concentration—is a correlation to turbidity.

Notes

Most significant reason for use: requirement for continuous TSS measurement.

Most significant reason to avoid: maintenance of in-stream sensor.

Typical equipment includes monitor unit.

Recommended system components: none.

Typical replacement items: none.

Consumables: none.

Available ranges of units (in mg/L TSS) include 10 to 2,000; 30 to 30,000; 100 to 10,000; 800 to 80,000

Two styles available: immersion type (used in a tank or channel) and insertion type (used in a pipe).

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2. Selection Criteria

Method and Use Status

Parameter	Total suspended solids (TSS).
Type	Online monitor.
Method of Description	Optical/absorbance. The absorbance of UV or visible light by solids in the sample is measured by a photosensor across from the light emitter. The absorbance is correlated to the total suspended solids concentration.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	No.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	Diversion, collection system monitoring, outfall discharge, treatment influent, treatment effluent.
Regulatory-Approved Method	None reported.
Measurement Range	10 to 10,000 mg/L (see notes).
Accuracy	±5%.
Response Time	Immediate.
Siting Constraints/Needs	- Electricity (some models are battery powered). - Compressed air or potable water (if needed for cleaning equipment).
Flow and Stream Constraints	For gravity storm sewers, a sample pump/ sample loop is typically required.
Interferences	- Air bubbles. - Dyes or coloring.
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	- Check auto-cleaning equipment. - Calibration checks as needed. - Annual recalibration.
Data Retrieval	Local readout; analog connection.
Recommended Features	- LED compensation to reduce drift. - Automatic cleaning system (compressed air or water jet).
Optional Features	Serial port connection.

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Typical Costs

Capital Cost	Low.
Typical Additional Capital Cost	Low.
Annual Operations and Maintenance Cost	Low.

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FACT SHEET 97

Laser Diffraction

1. Description

Analytical Process

This unit is installed inline with the sample stream or in an offline sample loop or flow cell. The sample flows continuously into a cell where a beam of laser light is projected through the sample. The amount and angle of laser light that bounces off solids in the sample are measured by a photosensor at a low angle across from the light emitter and correlated to a concentration of total suspended solids.

Advantages

Provides particle size analysis in addition to TSS.

No calibration is typically necessary.

No consumables are required.

Disadvantages

Biological growth that fouls the instrument lenses can be increased by the presence of deicer.

Does not directly monitor solids concentration—is a correlation to turbidity.

The lack of analog communication requires staff to visit instrument on-site to download data.

Notes

Most significant reason for use: requirement for continuous TSS measurement.

Most significant reason to avoid: maintenance of in-stream sensor.

Typical equipment includes monitor unit.

Recommended system components: none.

Typical replacement items: none.

Consumables: none.

Instrument reads a volumetric measurement of sediment in the sample. A conversion factor to mg/L TSS is required.

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2. Selection Criteria

Method and Use Status

Parameter	Total suspended solids (TSS).
Type	Online monitor.
Method of Description	Laser diffraction. The amount and angle of laser light that bounces off the solids in the sample are measured by a photosensor at a low angle across from the light emitter. The light detected and the angle are correlated to a total suspended solids concentration.
Level of Technology Development	Emergent.
Demonstrated Technology for Airport Storm Water?	No.
General Availability of Technology	Single manufacturer.

Implementation Considerations

Typical Installation Locations	Diversion, collection system monitoring, outfall discharge, treatment influent, treatment effluent.
Regulatory-Approved Method	None reported.
Measurement Range	10 to 3,000 mg/L.
Accuracy	Not available.
Response Time	5 min. minimum (programmable).
Siting Constraints/Needs	- Potable water. - Electricity. - Weatherproof shelter.
Flow and Stream Constraints	- For gravity storm sewers, a sample pump/sample loop is typically required. - Sample pump flow rate is typically <1 gpm.
Interferences	None known.
Staff Time Requirements	Medium.
Level of Staff Knowledge	Low.
O&M Issues	- Biological growth on lenses can cause drift. - Tubing can get clogged with biological growth.
Data Retrieval	Local readout, serial port communication.
Recommended Features	None known.
Optional Features	None known.

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Typical Costs

Capital Cost	Medium.
Typical Additional Capital Cost	Low.
Annual Operations and Maintenance Cost	Low.

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Total Suspended Solids
Handheld Monitor

FACT SHEET 98

Optical/Absorbance

1. Description

Analytical Process

A sample is collected and placed into a sample vial. The sample vial is placed into a photosensor. The absorbance of UV and/or visible light by solids in the sample is measured by a photosensor across from the light emitter and correlated to a concentration of total suspended solids.

Advantages

Easy to use.

Disadvantages

Some models have a short useful life (approximately 2 years).

Does not directly monitor solids concentration—is a correlation to turbidity.

Notes

Most significant reason for use: ease of use.

Most significant reason to avoid: maintenance of handheld probe.

Typical equipment includes monitor unit.

Recommended system components: none.

Typical replacement items: none.

Consumables: none.

This monitor is a portable version similar to the online instruments. The calibration curve needs to be developed at an independent lab using the gravimetric method.

Some models include air bubble compensation to reduce interferences.

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2. Selection Criteria

Method and Use Status

Parameter	Total suspended solids (TSS).
Type	Handheld monitor.
Method of Description	Optical/absorbance. The absorbance of UV and/or visible light by solids in the sample is measured by a photosensor across from the light emitter. The light absorbed is correlated to the total suspended solids concentration.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	No.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	N/A.
Regulatory-Approved Method	None reported.
Measurement Range	1 to 400,000 mg/L.
Accuracy	±4% or 1 mg/L, whichever is greater.
Response Time	Immediate.
Siting Constraints/Needs	N/A.
Flow and Stream Constraints	Sufficient depth for probe immersion.
Interferences	- Air bubbles. - Dyes or coloring.
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	- Lens cleaning. - Calibration.
Data Retrieval	Local readout.
Recommended Features	None known.
Optional Features	None known.

Typical Costs

Capital Cost	Low.
Typical Additional Capital Cost	N/A.
Annual Operations and Maintenance Cost	Low.

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Total Suspended Solids
Test Kit

FACT SHEET 99

Optical/Absorbance

1. Description

Analytical Process

A sample is collected and placed into a sample vial. The sample vial is placed into a photosensor. The absorbance of UV and/or visible light by solids in the sample is measured by a photosensor across from the light emitter and correlated to a concentration of total suspended solids.

Advantages

Benchtop photometer may be used for other analyses.

Disadvantages

Does not directly monitor solids concentration—is a correlation to turbidity.

Notes

Most significant reason for use: ease of use.

Most significant reason to avoid: maintenance of handheld probe.

Typical equipment includes monitor unit.

Recommended system components: none.

Typical replacement items: none.

Consumables: none.

This monitor is a benchtop version similar to the online instruments. The calibration curve needs to be developed at an independent lab using the gravimetric method.

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2. Selection Criteria

Method and Use Status

Parameter	Total suspended solids (TSS).
Type	Test kit.
Method of Description	Optical/absorbance. The absorbance of UV and/or visible light by solids in the sample is measured by a photosensor across from the light emitter. The light absorbed is correlated to the total suspended solids concentration.
Level of Technology Development	Well established.
Demonstrated Technology for Airport Storm Water?	No.
General Availability of Technology	Many manufacturers.

Implementation Considerations

Typical Installation Locations	N/A.
Regulatory-Approved Method	None reported.
Measurement Range	0 to 750 mg/L.
Accuracy	Not available.
Response Time	Immediate.
Siting Constraints/Needs	N/A.
Flow and Stream Constraints	None known.
Interferences	- Air bubbles. - Dyes or coloring.
Staff Time Requirements	Low.
Level of Staff Knowledge	Low.
O&M Issues	- Calibration. - Replace batteries.
Data Retrieval	Local readout.
Recommended Features	Carrying case.
Optional Features	Serial port connection.

Typical Costs

Capital Cost	Very low.
Typical Additional Capital Cost	N/A.
Annual Operations and Maintenance Cost	Low.

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Total Suspended Solids
Test Kit

FACT SHEET 100

Laser Diffraction

1. Description

Analytical Process

A sample is collected and placed into a sample vial. The sample vial is placed into a photosensor. The amount and angle of laser light that bounces off solids in the sample are measured by a photosensor at a low angle across from the light emitter and correlated to a concentration of total suspended solids.

Advantages

Provides particle size analysis in addition to TSS.

No calibration is typically necessary.

No consumables are required.

Portable design can be taken out for testing samples in the field.

Disadvantages

Biological growth that fouls the instrument lenses can be increased by the presence of deicer.

Does not directly monitor solids concentration—is a correlation to turbidity.

Notes

Most significant reason for use: no maintenance of handheld units.

Most significant reason to avoid: requires chemical reagents and on-site lab.

Typical equipment includes monitor unit.

Recommended system components: none.

Typical replacement items: none.

Consumables: none.

This monitor is a portable/benchtop version of the online instrument.

Instrument reads a volumetric measurement of sediment in the sample. A conversion factor to mg/L TSS is required.

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2. Selection Criteria

Method and Use Status

Parameter	Total suspended solids (TSS).
Type	Test kit.
Method of Description	Laser diffraction. The amount and angle of laser light that bounces off the solids in the sample is measured by a photosensor at a low angle across from the light emitter. The light detected and the angle are correlated to a total suspended solids concentration.
Level of Technology Development	Emergent.
Demonstrated Technology for Airport Storm Water?	No.
General Availability of Technology	Single manufacturer.

Implementation Considerations

Typical Installation Locations	N/A.
Regulatory-Approved Method	None reported.
Measurement Range	10 to 3,000 mg/L.
Accuracy	Not available.
Response Time	Immediate.
Siting Constraints/Needs	N/A.
Flow and Stream Constraints	None known.
Interferences	None known.
Staff Time Requirements	Medium.
Level of Staff Knowledge	Low.
O&M Issues	- Biological growth on lenses can cause drift. - Replace batteries.
Data Retrieval	Local readout, serial port communication.
Recommended Features	None known.
Optional Features	None known.

Typical Costs

Capital Cost	Medium.
Typical Additional Capital Cost	N/A.
Annual Operations and Maintenance Cost	Low.

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