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# Standard Guide for Maintenance and Rehabilitation of Ground-Water Monitoring Wells[1]

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ϵ[1] NOTE—Paragraph 1.5 was added editorially October 1998.

## INTRODUCTION

This guide for maintenance and rehabilitation promotes procedures appropriate to ground-water monitoring wells installed to evaluate the extent and nature of contamination, progress of remediation, and for long-term monitoring of either water quality or water level.

## 1. Scope

1.1 This guide covers an approach to selecting and implementing a well maintenance and rehabilitation program for ground-water monitoring wells. It provides information on symptoms of problems or deficiencies that indicate the need for maintenance and rehabilitation. It is limited to monitoring wells, that are designed and operated to provide access to, representative water samples from, and information about the hydraulic properties of the saturated subsurface while minimizing impact on the monitored zone. Some methods described herein may apply to other types of wells although the range of maintenance and rehabilitation treatment methods suitable for monitoring wells is more restricted than for other types of wells. Monitoring wells include their associated pumps and surface equipment.

1.2 This guide is affected by governmental regulations and by site specific geological, hydrogeological, geochemical, climatological, and biological conditions.

1.3 The values stated in SI units are to be regarded as the standard.

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

1.5 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

## 2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]
D 1889 Test Method for Turbidity of Water[3]
D 4044 Test Method for (Field Procedures) Determining Instantaneous Change in Head (Slug Tests) for Determining Hydraulic Properties of Aquifers[2]
D 4412 Test Methods for Sulfide Reducing Bacteria in Water and Water-Formed Deposits[4]
D 4448 Guide for Sampling Ground Water Monitoring Wells[5]
D 4750 Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)[2]
D 5088 Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites[6]
D 5092 Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers[6]
D 5254 Practice for the Minimum Set of Data Elements to Identify a Ground-Water Site[6]
D 5299 Guide for the Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities[6]
D 5408 Guide for the Set of Data Elements to Describe a

[1] This guide is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Ground Water and Vadose Zone Investigations.

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[2] *Annual Book of ASTM Standards*, Vol 04.08.
[3] *Annual Book of ASTM Standards*, Vol 11.01.
[4] *Annual Book of ASTM Standards*, Vol 11.02.
[5] *Annual Book of ASTM Standards*, Vol 11.04.
[6] *Annual Book of ASTM Standards*, Vol 04.09.

Ground-Water Site; Part 1—Additional Identification Descriptors[6]

D 5409 Guide for the Set of Data Elements to Describe a Ground-Water Site; Part 2—Physical Descriptors[6]

D 5410 Guide for the Set of Data Elements to Describe a Ground-Water Site; Part 3—Usage Descriptors[6]

D 5472 Test Method for Determining Specific Capacity and Estimating Transmissivity at the Control Well[6]

D 5474 Guide for Selection of Data Elements for Ground-Water Investigations[6]

D 5521 Guide for Development of Ground Water Monitoring Wells in Granular Aquifers[6]

2.1.1 In addition, ASTM Volume 11.01 on Water (I) and Volume 11.02 on Water (II) contain numerous test methods and standards that may be of value to the user of this guide.

## 3. Terminology

3.1 *Definitions*:

3.1.1 Except where noted, all terms and symbols in this guide are in accordance with the following publications in their order of consideration:

3.1.1.1 Terminology D 653,

3.1.1.2 Guide D 5521,

3.1.1.3 *Compilation of ASTM Standard Terminology*, 7th Edition, 1990, and

3.1.1.4 *Webster's Ninth New Collegiate Dictionary*, 1989.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *well development*—actions taken during the installation and start-up of a well for the purpose of mitigating or correcting damage done to the adjacent geologic formations and filter materials that might affect the well's ability to produce representative samples.

3.2.2 *well maintenance*—any action that is taken for the purpose of maintaining well performance (see Discussion) and extending the life of the well to provide samples that are representative of the ground water surrounding it. Maintenance includes both physical actions taken at the well and the documentation of those actions and all operating data in order to provide benchmarks for comparisons at later times.

3.2.2.1 *Discussion*—Desired level of well performance can vary depending on the design objectives.

3.2.3 *well preventive maintenance*—any well maintenance action that is initiated for the purpose of meeting some preestablished rule or schedule that applies while well performance is still within preestablished ranges.

3.2.4 *well reconstructive maintenance*—any preventive or rehabilitative well maintenance action involving the replacement of a major component (for example, pump, surface protection).

3.2.5 *well redevelopment*—any preventive or rehabilitative well maintenance action, taken after start-up, for the purpose of mitigating or correcting deterioration of the filter pack or adjacent geologic formations, or both, due to the well's presence and operation over time, usually involving physical development procedures, applied in reaction to deterioration.

3.2.6 *well rehabilitation*—for the purposes of this guide, synonymous with well rehabilitative or restorative maintenance.

3.2.7 *well rehabilitative or restorative maintenance*—any well maintenance action that is initiated for the purpose of correcting well performance that has moved outside of preestablished ranges.

## 4. Significance and Use

4.1 The process of operating any engineered system, such as monitoring wells, includes active maintenance to prevent, mitigate, or reverse deterioration. Lack of or improper maintenance can lead to well performance deficiencies (physical problems) or sample quality degradation (chemical problems). These problems are intrinsic to monitoring wells, which are often left idle for long periods of time (as long as a year), installed in non-aquifer materials, and installed to evaluate contamination that can cause locally anomalous hydrogeochemical conditions. The typical solutions for these physical and chemical problems that would be applied by owners and operators of water supply, dewatering, recharge, and other wells may not be appropriate for monitoring wells because of the need to minimize their impact on the conditions that monitoring wells were installed to evaluate.

4.2 This guide covers actions and procedures, but is not an encyclopedic guide to well maintenance. Well maintenance planning and execution is highly site and well specific.

4.3 The design of maintenance and rehabilitation programs and the identification of the need for rehabilitation should be based on objective observation and testing, and by individuals knowledgeable and experienced in well maintenance and rehabilitation. Users of this guide are encouraged to consult the references provided.

4.4 For additional information see Test Methods D 1889, D 4412, D 5472, and Guides D 4448, D 5409, D 5410 and D 5474.

## 5. Well Performance Deficiencies

5.1 Proper well design, installation, and development can minimize well performance deficiencies that result in the need for maintenance and rehabilitation. Practice D 5092 and Guide D 5521 should be consulted. Performance deficiencies include: sand, silt, and clay infiltration; low yield; slow responses to changes in ground-water elevations; and loss of production.

5.2 *Preventable Causes of Poor Well Performance*:

5.2.1 Inappropriate well location or screened interval. These may be unavoidable if a requirement for site characterization or monitoring exists,

5.2.2 Inappropriate drilling technique or methodology for materials screened,

5.2.3 Inadequate intake structure design (screen, filter material, and so forth),

5.2.4 Inappropriate well construction materials. This may lead to corrosion or collapse,

5.2.5 Improper construction, operation, or maintenance, or combination thereof, of borehole or well, wellhead protection, well cap, and locking device,

5.2.6 Ineffective development,

5.2.7 Inappropriate pump selection, and

5.2.8 Introduction of foreign substances.

5.3 *Physical Indicators of Well Performance Deficiencies Include*:

5.3.1 *Sand, Silt, and Clay Infiltration*—Causes include inappropriate and inadequate well drilling (for example, auger flight smearing), improper screen and filter pack, improper casing design or installation, incomplete development, screen corrosion, or collapse of filterpack. In rock wells, causes include the presence of fine material in fractures. The presence of sand, silt, or clay can result in pump and equipment wear and plugging, turbid samples, filterpack plugging, or combination thereof.

5.3.2 *Low Yield*—Causes include dewatering, collapse or consolidation of fracture or water-bearing zone, pump malfunction or plugging, screen encrustation or plugging, and pump tubing corrosion or perforation.

5.3.3 *Water Level Decline*—Causes include area or regional water level decline, well interference, and chemical or microbial plugging or encrustation of the borehole, screen, or filterpack.

5.3.4 *Loss of Production*—Usually caused by pump failure, but can also be caused by dewatering, plugging, or well collapse.

5.3.4.1 *Well Collapse*—Can be caused by tectonism, ground subsidence, failure of unsupported casing (that is, in caves or because of faulty grout), corrosion and subsequent failure of screen and casing, improper casing design, local site operations, freeze-thaw, or improper chemical or mechanical rehabilitation.

5.3.5 Observation of physical damage or other indicator.

## 6. Sample Quality Degradation

6.1 All of the preceding physical well performance deficiencies can result in sample quality degradation by dilution, cross-contamination, or entrainment of solid material in water samples. In addition, chemical and biological activity can both degrade well performance and sample quality. Any change in well or aquifer chemistry that results from the presence of the well can interfere with accurate characterization of a site.

6.2 *Physical Indicators*—Chemical and biological activity that can lead to sample quality degradation include:

6.2.1 *Chemical Encrustation*—Precipitation of calcium or magnesium carbonate or sulfate, iron, or sulfide compounds can reduce well yield and specific capacity.

6.2.2 *Biofouling (Biological Fouling)*—Microbial activity can result in slime production and the precipitation of iron, manganese, or sulfur compounds and occasionally other materials such as aluminum oxides. Biofouling may be accompanied by corrosion or encrustation, or both, and can result in reduced specific capacity and well yield. Biochemical deposits can interfere with sample quality by acting as chemical sieves.

6.2.3 *Corrosion*—Corrosion of metal well and pump components (that is, stainless steel, galvanized steel, carbon steel, and low carbon steel) can result from naturally aggressive waters (containing $H_2S$, NaCl) or electrolysis. The presence of contaminants contributes to corrosion through contributions to microbial corrosion processes and formation of redox gradients. Nonaqueous phase solvents may degrade PVC and other plastics. Other environmental conditions such as heat or radiation may contribute to material deterioration (such as enhanced embrittlement). Metals such as nickel or chromium may be leached from corroding metals. Degradation of plastic well components may result in a release of monomers (such as vinyl chloride) to the environment (see Note 1).

NOTE 1—Naturally aggressive (for metals) waters have been defined as low pH (<7.0), high DO (>2 mg/L), high $H_2S$ (>1 mg/L), high dissolved solids (>1000 mg/L), high $CO_2$(>50 mg/L), and high $Cl^-$ content (>500 mg/L). However, local conditions may result in corrosion at less extreme values. Expression of corrosion is also dependent on materials load.

6.2.4 *Change in Turbidity*—Causes include biofouling and intake structure, screen or filter pack clogging or collapse. Increase in turbidity may not always be the result of a problem with the well. Changes in the purging and sampling procedures and devices used can affect the turbidity of water from a monitoring well. For example, using a bailer where a pump was previously utilized, or pumping at a higher rate than previously used could increase turbidity; likewise, pumping a well that was previously bailed could increase turbidity.

6.2.5 *Change in Sand/Silt Content or Particle Counts*—Causes include biofouling (resulting in clogging or sloughing) and intake structure clogging or collapse. Increase in the sand/silt content may not always be the result of a problem with the well. Changes in the purging and sampling procedures and devices used can affect the sand/silt content of water from a monitoring well. For example, using a bailer where a pump was previously utilized, or pumping at a higher rate than previously used could increase the sand/silt content; likewise, pumping a well that was previously bailed could increase the sand/silt content.

6.3 *Chemical Indicators (Observed in Ground Water Samples)*—Chemical and biological activity that can lead to sample quality degradation include (see Note 2):

NOTE 2—Changes in chemical indicators can also be a result of site-wide changes in hydro-geochemistry.

6.3.1 *Iron (Changes in Total Fe, $Fe^{2+}/Fe^{3+}$, Iron Minerals and Complexes)*—Causes include corrosion, changes in redox potential, and biofouling.

6.3.2 *Manganese (Changes in Total Mn, $Mn^{2+}/Mn^{4+}$, Manganese Minerals and Complexes)*—Causes include changes in redox potential and biofouling.

6.3.3 *Sulfur (Changes in Total $S^{2-}/S^0/SO_4{}^{2-}$, Sulfur Minerals and Complexes)*—Causes include changes in redox potential and biofouling.

6.3.4 *Changes in Redox Potential (Eh)*—Causes include microbial activity and changes in $O_2$, $CH_4$, $CO_2$, N, S, Fe, and Mn species present in the system.

6.3.5 *Changes in pH*—Causes include corrosion; microbial activity; dissolved gases such as oxygen, carbon dioxide, and hydrogen sulfide; and encrustation.

6.3.6 *Changes in Conductivity*—Causes include changes in total solids content, microbial activity, and corrosion.

6.3.7 *Changes in the Type and Concentration of Gases*—Dissolved oxygen, carbon dioxide, nitrogen, hydrogen sulfide, and methane are indicators of redox status and microbial activity.

## 7. Maintenance Planning, Monitoring, and Treatment

7.1 The purpose of maintenance is to detect and control deterioration in well performance. Maintenance should be based on objective observation and testing of the well and aquifer to determine the factors that can cause clogging, turbidity, and corrosion. Monitoring well maintenance must not alter the chemistry of the ground water being monitored. Maintenance is best implemented routinely, from installation through the life of the well, but can be implemented after deteriorated wells have been rehabilitated.

7.2 *Goals for Maintenance*:

7.2.1 Maintenance is intended, to the degree possible, to prevent or slow deterioration of the well system's structure, prevent contamination of ground water, or to ensure hydraulic performance. To address these goals, a maintenance plan should be developed and followed with adjustments to meet changing conditions.

7.2.2 A maintenance plan includes those practices, including preventive design and construction practices (see 5.1), an assessment of identified and potential problems (see 5.2, 6.1, 6.2), procedures for how these potential problems will be monitored and evaluated (see Sections 6 and 7), and a decision-making process on how to proceed to address problems as they occur. The decision-making process should include, as a minimum, who will make the decisions based on what criteria, a set of alternatives such as establishing a program of preventive treatment, replacing components on an as-needed basis, and how to proceed if more intrusive rehabilitation or decommissioning is needed. This decision-making process should be triggered if there are changes in condition or performance detected in routine monitoring that show deterioration or the potential to affect the well's ability to provide acceptable information. The decision-maker must decide what the standards are and the importance of detected changes. It is understood that there is no single level of performance or maintenance standards that exists or is possible due to the individual character of wells and site conditions.

7.2.3 In setting the goal(s) for an acceptable level of performance, the users of this guide should keep in mind what is possible in a given situation and evaluate whether desired standards can be met. The decision process should include personnel with special knowledge or skill in well maintenance and rehabilitation, especially field or contractor personnel with direct experience in these activities.

7.3 *Maintenance Program Design*—The design of a maintenance program should incorporate all available information about site-specific factors that could cause sand, silt, or clay infiltration, sample turbidity or alteration, corrosion, or clogging. Such information can include biological activity, redox potential, pH, conductivity, alkalinity, and major ions present in the ground water. Hydraulic performance and water chemistry should be benchmarked at installation and periodically during operations so that changes in performance can be detected. The frequency of maintenance is typically site specific and may be dependent on the proposed sampling schedule. Quantities of sediment in samples should be recorded and compared through the life of the well.

7.4 *Maintenance Monitoring*—Monitoring well maintenance includes routine physical inspection and analyses of hydraulic performance and sample quality. Personnel should first review records for as-built and previous conditions and compare the current conditions and measurements to those recorded previously. Any deviation, for example in total depth, should trigger a repair or rehabilitation decision.

7.4.1 *Methods of Physical Inspection Include*:

7.4.1.1 Surface facility inspection, including check of location, coordinates, elevation, and unique well identification,

7.4.1.2 Borehole mirror survey (above the water surface), camera, or televiewer,

7.4.1.3 Geophysical logs as appropriate to evaluate well construction,

7.4.1.4 Measurement of total depth, and

7.4.1.5 Inspection of pulled components.

7.4.2 *Methods of Analysis of Hydraulic Performance Include*:

7.4.2.1 Geophysical logs as appropriate to evaluate geology/hydrologic conditions, and

7.4.2.2 Drawdown/recovery measurements (in response to pumping).

7.4.2.3 *Flow Measurements*—Both temporary and permanent methods are used. Temporary methods such as bucket or weir are used to test new pumps or retest existing pumps. Permanent wellhead methods such as turbine or Doppler flow meters are more appropriate for extraction well arrays, but may be used for monitoring wells in some circumstances.

7.4.2.4 *Slug Testing*—If slug test data is available from an earlier test, the change in hydraulic performance can be inferred by performing another slug test. Slug tests are especially useful with low flow conditions or in contaminated settings. The reader should refer to Test Method D 4044.

7.4.3 *Methods of Analysis of Sample Quality Include*:

7.4.3.1 Time-series monitoring of site-specific chemical parameters of maintenance concern.

7.4.3.2 Pumped grab samples or biofilm collection for biofouling indicators such as Biological Activity Reaction Test (BART) analysis, heterotrophic iron and sulfur bacteria, sulfate reducing bacteria (SRB), microscopy, and biofilm mineralogical and elemental analyses (see Note 3).

NOTE 3—Biofilm indicator methods can only be considered qualitative at the present time.

7.5 *Rehabilitative Maintenance*:

7.5.1 Rehabilitation for removal of entrapped pollutants should be the last phase in the life cycle of a working well. If rehabilitation is unsuccessful, decommissioning may be required. Rehabilitation of a viable well is not a permanent solution for performance problems and should be followed by maintenance. Methods of rehabilitation must not, more than transiently, change the chemistry of the ground water being monitored. Methods are also limited by the typically small size and relative fragility of monitoring wells.

7.5.2 When determining whether rehabilitation or decommissioning is appropriate, decision criteria should include: planned life length of well, cost, and effectiveness of rehabilitation. In the event that well replacement is chosen, Guide D 5299 should also be consulted.

7.5.3 The appendix contains a list of references for detailed information on maintenance and rehabilitation.

## 8. Equipment and Materials

8.1 Selection of equipment and materials for maintenance and rehabilitation depends on well construction and site-specific geological, hydrogeological, geochemical, climatological, and biological conditions. Practice D 5088 should be consulted.

8.2 *Equipment for Physical and Chemical Measurements*:

8.2.1 Drawdown (water depth) equipment includes measuring (tape) devices, airline, electric or acoustic sounder, and recording transducer. See Test Method D 4750.

8.2.2 Flow meters include calibrated bucket (<10 gpm or 0.6 L/s), and orifice weir (>10 gpm) or any other appropriate, accurate device.

8.2.3 Other instruments, such as electronic colorimetric instruments, spectrophotometers, electronic pH and mV meters, turbidometers, particle counters, multi-probes, flow-through cells, multiparameter meters and other types of probes (dissolved oxygen, temperature, TDS, specific and ion electrodes, and so forth), and geophysical logging tools (see Note 4).

NOTE 4—Calibrated portable instruments may be used for maintenance monitoring to encourage frequent monitoring without significant loss of accuracy. Some redox-sensitive parameters are preferably analyzed at the well head using flow-through cells.

8.3 Equipment for analysis of microbial components includes light microscope and biofilm sample collection apparatus.

8.4 Equipment for redevelopment and rehabilitative maintenance of wells will depend on the action needed. Routine hand tools would be needed for a variety of purposes, and special tools may be required for pump service. Spare parts and major components for pumps used should be readily available to maintenance personnel. Devices used for well redevelopment are identical to those used in development, and described in Guide D 5521 and references. If chemicals, flushing, or specialized procedures such as cryogenic $CO_2$ treatments are employed, the necessary mixing and pumping equipment should be onsite in working order.

## 9. Maintenance

9.1 Selection of procedures for both maintenance and rehabilitation is limited by the need (and often regulatory requirements) to minimize their impact on the conditions that monitoring wells were installed to evaluate. Usually only physical, not chemical, methods are acceptable. If chemicals are used, chemical purity, alteration of existing conditions, and regulations must be considered. Maintenance includes routine preventive practices to avoid damage to the physical structure and access to the well, including nonchemical weed removal (to avoid concrete splitting) or changing or protecting locks (if they are subject to corrosion or freezing).

9.2 *Maintenance Evaluation*—Methods by which the need for maintenance is identified include collection and analysis of physical and chemical data on a routine basis. Some methods include:

9.2.1 Visual inspection of surface facility, borehole, and pulled components. Concrete pads should be inspected for cracks, separation from well, and heaving. Surface casing should be inspected for cracks or damage. Traffic cover (for flush-mounted wells) should be inspected for fit, cracks, and leaks. Locks should be serviceable and prevent unauthorized entry into the well. (See Practice D 5092.)

9.2.2 Borehole geophysical logging using televisions, flowmeters, and calipers can be useful to identify water movement, casing breaks and damage, clogging, and biofouling.

9.2.3 *Water Level and Well Depth Measurement*. Well depth measurement may indicate that materials may be filling up the well or that other obstructions may be present. A weighted measuring tape is typically used for bottom depth measurements. (See Test Method D 4750.) Bottom sounding in wells with dedicated pumping systems may be difficult or impossible without removing the system. Dedicated bottom sounders, consisting of a dedicated weight and cable that extends from the well bottom to the well cap have been used to eliminate this concern.

9.2.4 *Pump Performance*—Manufacturer's specifications for maintenance should be met, and there should be a visual inspection for clogging. While visual inspection of a pump or associated hardware could reveal the cause of diminished pump performance, removal and reinstallation of the equipment may introduce contaminants to the well or sampling system. Some manufacturers publish performance testing and trouble-shooting procedures to assess pump performance without pump removal. Also, some manufacturers do not require or recommend routine maintenance for their sampling pumps, only repairs when needed, using performance testing instead of routine maintenance.

9.2.5 *Drawdown Measurement*—See Practice D 5092.

9.2.6 *Flow Measurement*—Obvious increases or decreases in flow capacity may indicate the need for rehabilitation. The pump flow output should be checked against nominal performance to evaluate pump performance.

9.2.7 *Evaluation of Chemical Data Trends*—Obvious deviations from established trends not attributable to other causes may indicate the need for rehabilitation.

## 10. Rehabilitation

10.1 Rehabilitation is the repair and replacement of surface and downhole components of the well found to be deficient by visual inspection.

10.1.1 The goals for rehabilitation are by nature site-specific. What is possible in a given formation, or with feasible means are dependent on site-specific factors.

10.1.2 Standards for rehabilitate should be flexible. There are limits to effectively rehabilitate monitoring wells. Some wells cannot be rehabilitated to set standards due to conditions external to the well or due to well deficiencies.

10.2 *Rehabilitation Procedures*:

10.2.1 Methods include redevelopment to remove fine-grained materials from the well and to remove materials clogging the well screen. An economic evaluation comparing well replacement cost with the cost of the time and materials for rehabilitation should be performed. Monitoring wells are usually replaced rather than rehabilitated if redevelopment is not effective.

10.2.2 Rehabilitation should continue by the means selected until an irreducible minimum in the condition is reached. At that point, a decision must be made to employ another method, accept the condition, reevaluate and make repairs indicated, or decommission the well. If a more effective method of rehabilitation is employed, the process should be repeated until another irreducible minimum is reached, then evaluated again. If a condition is uncovered that cannot be rehabilitated, then decommissioning and new construction are indicated.

10.3 *Redevelopment*—Redevelopment can be accomplished using pumps, surge blocks, compressed air (for example, air lift method), or water jetting, or combination thereof. In certain conditions, chemicals and steam may be used for redevelopment for bacterial problems. The reader should consult Guide D 5521 for appropriate methods. It is noted that the goals for redevelopment are the same as the goals identified in Guide D 5521.

## 11. Reporting and Record Keeping

11.1 Reporting and record keeping are important components of both maintenance and rehabilitation.

11.2 *Maintenance*—Because monitoring well maintenance includes routine physical inspection and analysis of hydraulic performance and sample quality in order to detect and control deterioration in well performance, data must be compared for each well through time. An organized record-keeping system that permits data storage and retrieval is necessary to document and analyze changes through time. Such systems include paper files and computer databases.

11.3 *Rehabilitation*—Records of test method's results and observations that led to the decision for rehabilitation should be kept. Records of the rehabilitation and subsequent test methods and results should also be retained.

11.4 *General Information That Should Be Recorded*:

11.4.1 Location of well,

11.4.2 Well name/number,

11.4.3 Method/materials/date of construction,

11.4.4 As-built diagram,

11.4.5 Drill log,

11.4.6 Purpose of well,

11.4.7 Historical trends,

11.4.8 Water quality data,

11.4.9 Observations leading to maintenance or rehabilitation,

11.4.10 Test methods and results prior to maintenance or rehabilitation,

11.4.11 Dates of observation/testing/maintenance/rehabilitation,

11.4.12 Work performed, and

11.4.13 Post-maintenance or rehabilitation test methods and results.

11.5 Additional information related to the other data needs can be found in Practice D 5254. If additional information is needed, the users of this guide are referred to Guide D 5408.

## 12. Keywords

12.1 biofouling; development; encrustation; ground water; maintenance; monitoring well; rehabilitation

# APPENDIX

**(Nonmandatory Information)**

## X1. ADDITIONAL REFERENCES

NOTE X1.1—Not all methods referenced for rehabilitation of water wells are directly appropriate for monitoring wells, but may be adapted for some purposes.

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