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Ground Water Forum Issue Paper

Best Practices for Environmental Site Management: Recommended Contents of a Groundwater Monitoring Report

Index

AUDIENCE

This issue paper is intended for use by federal, state, tribal and stakeholder project managers developing groundwater monitoring reports under various regulatory programs. EPA recommends that project managers work with their project hydrogeologist to scope the content of a groundwater monitoring report and tailor the report content to meet their site-specific needs.

PURPOSE AND SCOPE

The purpose of this issue paper is to recommend information to include in groundwater monitoring reports that will lead to improved report consistency and a useful, readable format. Incorporation of the recommended information will standardize groundwater monitoring report deliverables, which may in turn inform site characterization strategies, analysis of remedial alternatives, monitoring network optimization, remedy performance evaluation, continual refinement of the conceptual site model (CSM), and technical evaluation of groundwater data in five-year reviews.

The recommended format ensures that groundwater monitoring reports present data in a form that advances knowledge of site conditions. The format also ensures that monitoring reports evaluate and consider newly collected data in the context of the site conditions and operations. This issue paper is intended to be used in conjunction with the *Guidance for Monitoring at Hazardous Waste Sites: Framework for Monitoring Plan Development and Implementation (EPA, 2004a) and Performance Monitoring of MNA Remedies for VOCs in Ground Water* (EPA, 2004b).

Sampling frequency and required decisions will dictate the level of detail needed in a groundwater monitoring report. In general, groundwater sites require reports prepared at different frequencies and that vary in scope and content. For example, a report prepared for a quarterly sampling event likely will be more abbreviated than an annual report, which will be more comprehensive and contain most, if not all, of the recommended contents.

The guidelines are not intended to be used verbatim or as boiler plate. Rather, groundwater monitoring reports are tailored to reflect each site's unique characteristics.

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INTRODUCTION

Groundwater monitoring is an integral component of site characterization, risk management, and remediation, and provides critical information for developing and maintaining a site-specific CSM (EPA, 2011a). Under CERCLA, groundwater monitoring reports are typically introduced during the remedial investigation and feasibility study (RI/FS) stage prior to remedy selection and are generated following the Record of Decision (ROD) for sites that include a groundwater component as part of the selected remedy. Similar reports are required during corresponding stages of the RCRA corrective action process.

Groundwater monitoring reports serve five basic functions:

- Present new data generated from the groundwater monitoring program, as described in the groundwater monitoring plan, in an easy-to-comprehend manner.
- Evaluate new data in the context of earlier data, the remedial action or corrective action objectives (RAOs or CAOs), remediation timeframes, and the site-specific CSM.
- Document maintenance to the groundwater monitoring network, deviations from approved methods, and other unexpected conditions.
- Ensure that sampling methods and quality control measures are appropriate.
- Draw conclusions and make recommendations, as appropriate.

Groundwater monitoring programs rely on detailed groundwater monitoring plans that describe the collection of data required to inform site cleanup decisions. These plans generally include:

- A monitoring network that is sufficient to provide robust site characterization data and also to provide ongoing evaluation of progress toward and attainment of RAOs. Typically, this involves a network that characterizes and tracks plumes in three dimensions over time (EPA, 1992; EPA, 1994).
- Sample collection methods that reliably produce data that reflect conditions in the aquifer surrounding the wells (EPA, 1992).
- Adequate quality assurance and quality control (QA/QC) to be able to quantify field and analytical uncertainty in the data (EPA Order CIO 2105.0).

Groundwater monitoring plans require periodic updates to ensure that they reflect current data quality objectives (DQOs) for the site. DQOs often change over the life cycle of a project. Monitoring well networks are initially established to determine the nature and extent of groundwater contamination for the RI, including establishing background groundwater quality. During the FS, new wells are often installed to evaluate various remedies or to implement a pilot or treatability study. As the site transitions to remediation, the monitoring program will focus on performance objectives. Wells that were installed for characterization may not provide data relevant for long-term performance monitoring. It is important to review the purpose of each well and examine the data periodically to evaluate its continued value in the monitoring program. However, at any stage of monitoring, it is likely that the largest (and most difficult to quantify) source of uncertainty will be spatial definition of the plume(s). Plume extent and stability must be demonstrated throughout the process to support human health and ecological risk management.

RECOMMENDED[1] GROUNDWATER MONITORING REPORT OUTLINE

The results of each groundwater sampling event may be compiled in separate groundwater monitoring reports, but typically, the results of all sampling events within a given year are summarized and interpreted in an annual report. The annual report evaluates the historical and current year groundwater data to provide an updated understanding of the plume(s). Interpretation of the data, conclusions, and in some cases recommendations are integral components of groundwater monitoring reports. It is recommended that an annual groundwater monitoring report also evaluate the current groundwater monitoring plan (i.e., monitoring network, sampling methodologies, and frequency) and if necessary, recommend opportunities for monitoring optimization. Annual reports may also address remedy performance.

1 DISCLAIMER: This outline is recommended and not prescribed. Stakeholders should modify it to meet their site-specific needs and the different types of monitoring reports required.

Exhibit 1 shows a recommended outline of a groundwater monitoring report. The sections that follow summarize the content recommended for each section in the outline.

Exhibit 1: Recommended Outline

1. Executive Summary
2. Site Background and Current Conceptual Site Model
3. Monitoring Network and Schedule
4. Data Presentation
5. Evaluation of New Data
6. Conceptual Site Model Evaluation
7. Conclusions
8. Recommendations
9. References
10. Appendices

1. EXECUTIVE SUMMARY

The Executive Summary generally provides a synopsis of the sample collection and data analysis activities that occurred during the reporting period.

It is recommended that the executive summary include:

- Brief description: Describe the groundwater contamination problem at the site in sufficient detail that the reader may understand why groundwater monitoring is required.
- Selected remedy: If in the remedial implementation phase, present the RAOs, contaminants of concern, and selected remedy from the site decision documents.
- Purpose and goals of monitoring: State the purpose of monitoring, such as investigation-phase, remedial implementation, or long-term performance monitoring. The goals of the monitoring may be, for example, to bound the plume(s) in three dimensions or evaluate progress toward restoration RAOs.
- Narrative summary of new data: Describe the new data and compare to the CSM. State whether the data met expectations regarding quality, contaminant distribution, extent and magnitude of contamination as well as progress toward remedial goals.
- Actions taken on previous recommendations: Summarize actions taken during the reporting period in response to previous recommendations, or explain why the actions were not taken. Such actions might include increasing monitoring frequency based on changes in concentrations, properly abandoning wells no longer needed, installing new wells, testing for additional contaminants of concern, etc.
- Summary of conclusions. These might include:
  - Monitoring well network remains adequate or, if inadequate, why alteration is needed.
  - Data are valid and representative of aquifer conditions.
  - Progress toward remedial goals.
  - Implications of unexpected results or events.
  - Groundwater migration under control.
- Summary of recommendations. These might include:
  - Changes to future monitoring plans and opportunities for monitoring optimization.
  - Changes to monitoring well network; either addition or deletion of wells.
  - Present opportunities for remedial action optimization.
  - Carry forward previous recommendations not acted upon, and present those newly identified.

2. SITE BACKGROUND AND CURRENT CONCEPTUAL SITE MODEL (CSM)

The CSM serves as the framework for integrating long-term or performance monitoring data into existing data sets and placing current data into context. Iterative evolution of the CSM during the performance monitoring phase can support remedy implementation and optimization efforts, identify potential challenges as remedy implementation progresses, and assist in assessment of performance metrics to help ensure that remedies are functioning as intended.

Inclusion of the following elements of the background and CSM in this section is recommended:

- Remedial goals (RAOs/CAOs), points of compliance, and exit strategy: Describe the site-specific RAOs, referencing the relevant decision document(s). List the groundwater cleanup levels and include the point of compliance (where the facility will demonstrate it has achieved cleanup levels).
- Site history, regulatory history, current regulatory framework (permitting, corrective action, or enforcement authority): Provide a brief overview of the facility history, ownership, operations, wastes handled and known releases. Include regional location, pertinent boundary features, and general physiography. Discuss regulatory history, including past enforcement actions and current enforcement mechanism (e.g., order, permit, federal facilities agreement, etc.).
- Potential receptors, land use: Discuss current and historical property use, describing potential receptors (current and future). Include human populations and environmental systems that are currently or potentially at risk of contaminant exposure. Describe human use of or access to the site and adjacent lands. Include current and possible future uses of groundwater or surface water.
- Geologic/hydrologic setting: Describe the regional and site-specific geologic and hydrogeologic characteristics and heterogeneities affecting groundwater flow. Include regional/local stratigraphy (including relevant geologic setting and history of aquifer deposition or formation), facies model, structural geology, groundwater flow patterns, and seasonal variations in the groundwater flow regime. Note the vertical gradients along with anthropogenic influences that may affect the hydrogeology of the site (i.e., water supply and/or production wells, surface changes that alter recharge). Describe seasonal and permanent surface water bodies and any interaction with groundwater.
- Maps and cross-sections: Include maps and cross-sectional views illustrating the geologic and hydrogeologic setting of the site. Provide water level contour and/or potentiometric surface maps for each hydrogeologic unit.
- Contaminants of concern (COCs), contaminant sources, and nature and extent of contamination: Briefly discuss contaminant source areas, including their location, design features (if any), history of release(s), waste characteristics, hazardous classification, quantity of chemicals released (if known), chemical composition (including breakdown products), remedial actions to remove or treat sources, and whether active sources still remain. Describe the three-dimensional extent of non-aqueous phase liquid and the dissolved plume(s) of contamination, the horizontal and vertical direction of contaminant movement, and an evaluation of factors such as heterogeneities that might influence plume movement, including adequacy of any important aquitards. Document the potential for matrix diffusion as a secondary source.
- Groundwater investigation and remediation: Briefly document the chronological history of groundwater investigation and remedial activities, including interim measures. Describe remediation efforts and methodology.
- Tables: Include a table of historical analytical results for each COC in an appendix. Also include a table of the evolution of the monitoring network, sampling methods, and analytical methods.
- Figures: Provide a map and cross-sectional views of contaminant plumes for each COC above the action level. In an appendix include chart(s) of contaminant concentration over time for each COC that has a cleanup goal. (These charts should be linear unless contaminant ranges exceed 2 orders of magnitude, in which case they may best be presented on a logarithmic scale.) Post any changes that might have impacted results, such as sampling or analytical methodology or sampling teams.

Information on CSMs from EPA resources can be found in Figure 4 of *Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration* (EPA, 1993) and *Performance Monitoring of MNA for VOCs in Groundwater* (EPA, 2004).

3. MONITORING NETWORK AND SCHEDULE

The Monitoring Network and Schedule section explains the current monitoring plan. Specifically, it discusses how each sampling location supports the purpose of the groundwater monitoring system(s) (e.g., characterization, detection monitoring, extent monitoring, performance monitoring, point of compliance monitoring, groundwater quality trends, flow patterns, contaminant mobility, etc.), as well as how the particular sampling event fits into the overall monitoring schedule.

It is recommended that this section:

- Provide location and construction details for current monitoring wells in a table, including horizontal and vertical survey information, and construction details (well depth, well diameter, depth and elevation of screen intervals), and assigned aquifer units. Survey datum information can be included in a footnote. [A similar table identifying all (current and past) monitoring wells can be included in an appendix.] Well logs for any new wells that were installed during the reporting period can be included in an appendix.
- Present map(s) depicting monitoring (sampling and water level measurement) locations for each sampled medium and each major hydrogeologic unit. Maps generally include a date, report name, and a citation for the source document from which it was copied or adapted.
- Present the monitoring schedule in a stand-alone table or in bullet format. Specify monitoring parameters, analytes, and sampling frequency for each monitoring location. Footnotes can be used, where appropriate, to add detail (e.g., analytical methods) or to note changes in the monitoring schedule from previously submitted reports. Cite the applicable monitoring plan, and note and explain any deviations.
- Include an operation and maintenance (O&M) plan summary for the remedial system and monitoring wells. Include scheduled maintenance and monitoring, referring to sections of corresponding work plans. Describe any deviations from the O&M plan as well as observations and actions taken. Include system components and wells that needed replacement, repairs, work over, plugging and abandonment, or redevelopment. The information could be included in a table, in narrative form, or both.
- Describe sampling methodologies and provide a review of the methods.

4. DATA PRESENTATION

The Data Presentation section documents all data collected in the field (water levels and water quality field parameters) and the analytical results from groundwater samples collected during the period covered by the report.

It is recommended that data presented in figures be a readable font size and that all historical data (hydrologic and analytical) be appended and available in a manipulable electronic format for data evaluation and analysis.

Consider including the following types of data in this section:

- Water level measurements: Present water level measurements in a table. The data should be posted and contoured on potentiometric surface maps for each hydrostratigraphic unit and for each measurement event. For sites with active groundwater extraction systems, a map excluding water levels from pumping and infiltration wells should be included; the effect of such wells on the potentiometric surface is inevitably exaggerated due to well inefficiencies. The measurement date(s) should be included in the legend; implications of data not collected contemporaneously should be discussed in the text.
- Field measurements of water quality: Summarize water quality data collected in the field, including field parameters recorded during well purging, in a table. Scanned copies of field notes, including well purging details for pumped wells, should be included in an appendix.
- Analytical contaminant data: Present concentration data (including data qualifiers) for important COCs on a table. Non-detect results should be presented as less than the method reporting limit or practical quantitation limit (<MRL or <PQL) and not abbreviated as "ND." Present contaminant concentration maps for each contaminant in each hydrostratigraphic unit. Exceedances of standards, performance monitoring changes, and other notable details (for example, the first appearance of NAPL in a well) should be depicted using a color scheme or other technique that highlights the information visually and described in a legend. Maps should include a title block with date and version number. For an updated version of a base map, include the appropriate citation for the source document from which it was copied or adapted. Be sure to post concentration data at each sampling location and contour the data. It may be possible to present multiple contaminants on the same map using different color schemes described in a legend. If there are multiple sampling rounds during the reporting period, the map presentation may include the data from the most comprehensive sampling event, or if all wells are sampled during each event, a map for each event may be produced. Alternatively, a single map presenting the average or maximum detection for each

well during the reporting period may be produced. For large or complex sites, include insets to enlarge areas of dense data or else use a larger map or a series of maps.

- Quality assurance and quality control: Summarize the QA/QC protocols established for the site. Discuss field and laboratory QA/QC methods, including field blanks and performance samples, if appropriate. Summarize the data validation reports and discuss any issues affecting data quality, including whether samples were representative and whether analytical results are reliable. This may include deviations from the SAP methodologies for sampling, sample handling, and sample analysis. Include data validation reports in an appendix.

5. EVALUATION OF DATA

The Evaluation of Data section discusses the results and updated evaluations, including statistical or other analyses. The focus is on identifying how the data fit with the current CSM and whether the selected remedy is meeting RAOs progressing toward attainment. If the new data differ from expectations under the current CSM or indicate potential impacts to continued achievement of or progress toward RAOs, the issues are generally identified in this section.

It is recommended that this section:

- Discuss any natural or anthropogenic events or factors that occurred during the reporting period and may affect the data set. Such events may explain changes in potentiometric surface maps, contaminant concentration contours, contaminant transport and/or plume extent. For instance, flooding change the hydrology, and well inundation may cause sample bias.
- Discuss any anomalous features on potentiometric surface maps for each hydrostratigraphic unit. Anomalous mounds or sinks that appear in potentiometric surface maps can represent new additions or discharges of water to the monitored aquifer or mistakes in data transcription or interpretation. In general, a potentiometric surface should be a smooth surface. Abrupt changes in surface might indicate geologic features that act as boundaries. If new wells have been installed and the resulting map has anomalous different contours, there may be errors in mapping and survey data; for example, the new wells may simply not have been surveyed to the same datum as the older wells. Anomalous mounds may also be the result of contouring intervals selected and contouring algorithms used for plotting. Any computer-generated potentiometric surface maps should be double checked manually.
- Present hydrographs of groundwater elevations for key wells in each hydrostratigraphic unit and in surface water monitoring points. Hydrographs can assist in determining the degree of surface water influence or aquifer-wide changes over time. They can also help identify and quantify the differences between different hydrostratigraphic units.
- Discuss any anomalies or unexpected changes on contaminant plume maps. Similar to potentiometric surfaces, contaminant contours should generally be smooth surfaces. For example, hot spots that appear in data sets can imply a new release or transport of a previously unidentified release to that location, or contaminant sinks can indicate biotic and/or abiotic destruction of contaminants.
- For sites with complex hydrogeology, consider presenting cross-sections along and perpendicular to groundwater flow directions depicting hydrogeology, monitoring points, updated contaminant levels, and capture zones (if applicable). Cross sections or other three-dimensional presentations (e.g., block diagrams) can help with visualization of transport processes and interaction with geologic media and should reflect geologic and hydrogeologic interpretation.
- Compare new data with previous data and any established performance criteria to establish evidence of remedial progress. For sites with sufficient data, this comparison may also be supported by statistical or other numeric analyses.
- Discuss and provide the rationale for the statistical analysis approach and associated data requirements. For many statistical methods, an evaluation of the data distribution is necessary to determine if the method assumptions have been met for the statistical methods used.
- Discuss the results of any statistical comparisons, including well-by-well trend analyses or statistical evaluations of plume changes over time. For sites with a long history, it is recommended that trend analyses include only recent data (e.g., the past 8 to 10 years) to support evaluation of remedy progress. Data may be

tabulated, and trends may be presented and evaluated from time-series graphs. Graphs and any supporting analyses may be presented in an appendix. For example, if linear regression analyses are presented, include the histogram. If trends are variable across a plume, a plume map showing the current trend at each well can be useful. These tools are typically used to support conclusions regarding remedy progress, evidence of a new release (in detection monitoring), and remedy completion.

- Discuss trends in the context of achieving RAOs and the applicable remedy completion strategy.
- Assess measurement variability from analysis of QA/QC data. Data must be validated to support any conclusions drawn in the report.
- Describe observed changes in land use and hydrologic conditions, particularly changes that can affect infiltration, evapotranspiration, etc. Note that even tree removal can have a surprisingly significant effect on hydrologic conditions through decreased evapotranspiration.

6. CONCEPTUAL SITE MODEL EVALUATION

A thorough evaluation of the CSM, incorporating all new data and information, is a key component of the groundwater monitoring report. All aspects of the CSM are reviewed and revised where necessary in light of the new monitoring data. A narrative description of how the new data compare to historical data sets, including a discussion of how the new data support or challenge the previous CSM, is recommended. Describe all modifications to the CSM. This description includes updates to all the two- and three-dimensional graphic components of the CSM (e.g., cross sections, groundwater flow maps, contaminant trend plots, etc.) if they are impacted by the new data set.

The CSM evaluation addresses the following questions:

- Are the new data consistent with the established CSM? Do the new data support or alter the CSM? Include supporting discussion and cite figures and/or plots to substantiate revisions to the CSM.
- Do the new data have implications for the current remedial approach and the effectiveness of the remedy?
- Do the new data sets offer additional information on the suspected source(s) of groundwater contamination? Are previous assumptions about the location, dimensions, chemical characteristics, and magnitude of the source(s) supported by the data? Have the current suspected sources been adequately characterized? Are there newly identified sources?
- Are the analytical results consistent with the historical contaminant and geochemical trends? Do the data trends continue to support the CSM and the remedial approach selected? If data trends do not support the previous CSM, what do the new trends suggest?
- Are there any observed changes in site hydrology/hydrogeology (e.g., water elevations, groundwater velocities)? Are groundwater elevations, flow directions, velocities, etc. within historical ranges and consistent with the established CSM?
- Are there any changes in land use? If so, do these changes affect the final remedy?
- Are the current data consistent with previous projected cleanup timeframes?
- Have any new areas of uncertainty been identified with the new data set? All areas of suspected uncertainty should be discussed.

A detailed discussion on updating the CSM may be found in the fact sheet *Environmental Cleanup Best Management Practices: Effective Use of the Project Life Cycle Conceptual Site Model* (EPA, 2011).

7. CONCLUSIONS

Describe in this section the significance of the monitoring data and any conclusions generated from the evaluation of the data. Include a discussion of whether or not the monitoring well network is sufficient to meet the stated monitoring objectives as well as any issues identified with monitoring locations or frequency, analytes and/or sampling methods. Discuss conclusions related to specific wells, such as attainment, construction issues, performance monitoring, if applicable, etc. Also discuss plume migration, whether site remediation is meeting objectives, and progress toward meeting RAOs.

8. RECOMMENDATIONS

In this section, recommend any changes needed to the groundwater monitoring plan. Present the rationales for

these changes and support them with relevant data. For example, changes might be needed to:

- Future monitoring locations or depths. Describe specific changes to locations of monitoring wells. This can include locations where monitoring is no longer required based on shrinking volume of contamination and locations where new wells are required, such as for monitoring performance when conditions change.
- Monitoring frequency. Historical data sets might indicate that the current monitoring frequency may be changed to reflect expectations along established trends, e.g., stable plumes may be monitored with less frequency. A change to more frequent sampling might be caused by unexpected contaminant increases or to monitor the performance of a pilot study or remedy change.
- Sampling methods. For example, changing from a low-flow to a passive sampling method.
- Chemical analyses. Emerging compounds or new information on site chemical use might warrant additions to the list of contaminants of concern, which in turn may require a change in analyses. For sites with cleanup goals based on practical quantitation limits available at the time the remedy was selected, improved analytical capabilities may result in lower detection limits and lower cleanup goals. Periodic analyses of the Appendix IX list of analytes may reveal additional contaminants at RCRA sites.

Also in the Recommendations section, discuss the following topics, as applicable to the site:

- Whether the evaluation of new data recommends remedy/monitoring optimization. In addition, if the data show additional/new sources, the report may recommend further characterization of these areas.
- Whether changes in land use may have potential effects on the CSM. These changes may indicate the need for additional well installation or data collection.
- Monitoring well upgrades, redevelopment, replacement of damaged or degraded wells, or abandonment of wells either damaged or no longer needed for groundwater chemistry data. Before decommissioning wells determined unnecessary or unsuitable for groundwater chemistry data, consider if they may still be valuable for water level measurements. However, wells that provide a conduit for contaminant migration or are otherwise improperly constructed may need to be replaced.

9. REFERENCES

The References section of a groundwater monitoring report should list all the references consulted in preparing the report. Be sure to use a consistent format for citations in the text as well as for the listed references. Include document numbers, authors, dates, and any information that can help readers identify the document.

10. APPENDICES

Much of the data, analyses, and background information mentioned in a groundwater monitoring report may be included as appendices, especially if presenting the information as tables or figures would make the body of the report very large. All the analytical results for the reporting period accompany the report. Historical sampling results and other types of data are often provided on a CD. Data submitted to EPA will comply with the Region's Electronic Data Deliverable (EDD) requirements (EPA, 2011b). If a Region does not have an EDD format, the EPA project manager will specify the electronic format for data submissions.

It is recommended that the following data be included in an appendix:

- Well construction data: Present the data in an appendix only if the site has a large number of wells; otherwise, present the data in a report table. List all the wells at the site, whether currently included in the sampling program or not. Data presented typically include: well ID; well status (whether actively in the monitoring program); well location survey information (with survey system information and datum information); well depth; well diameter; well material; depth to screen top; depth to screen bottom; and elevation information (including survey datum), such as ground elevation, measuring point elevation, screen top elevation, and screen bottom elevation. Additional information may include the date each well was drilled, the drilling company, the drilling method, and if wells are installed in more than one aquifer or water-bearing zone, the aquifer each well intercepts.

- Sampling rationale for each well included in the monitoring network: Present the rationale in an appendix only if the site has a large number of wells; otherwise, include it in a report table.
- Groundwater elevation records: Include a table with water levels measured during the reporting period, but present the full historical record in an appendix. Include the measuring point elevation, the depth-to-water measurements, and the water level elevations. If hydrographs are included, the charts may also be included in an appendix.
- Logs for wells and borings and as-built diagrams for wells: Assemble and provide this information for all wells drilled at the site. If such a collection is maintained and included in five-year review reports, this appendix may need to include only wells drilled since the last five year review, with the older logs included by reference. At a bare minimum, include logs for any borings installed during the reporting period.
- Current year analytical data: Include a table presenting data for all analytes, with the detection limit, regulatory goals, and footnotes explaining any missing data. A table containing current year data for contaminants of concern is included in the report tables, along with a table of any field parameter data collected.
- Historical analytical data: The table is typically updated annually and included as an appendix. It may include all analytes, which can become unmanageable if there is a long analyte list and a large number of wells; hence, the table may include only the contaminants of concern. At a minimum, the analytes used in any data analyses presented in the report are included on a CD in a manipulable electronic format (e.g., Excel files or another format consistent with the electronic data storage system for that Region).
- Laboratory data reports and accompanying data validation summaries: Laboratory analytical reports from the reporting period, accompanying laboratory data validation reports and data validation summaries conducted by the report authors should be included as an appendix. Laboratory analytical reports are often included on a CD in an electronic format.
- Field sampling notes: Include an appendix with chain-of-custody forms, field sampling data sheets, any monitoring deviation forms, and scanned pages from the field log book.
- Statistical trend analyses: This appendix might include several sub-appendices, such as charts of historical data for the primary contaminants of concern. These charts may be presented on either linear or log-linear graphs, as appropriate, for wells with sufficient detections to allow trend analysis. Another sub-appendix might include statistical trend analysis graphs for each well. If linear regression analysis has been done, this appendix includes any histograms associated with tests for normality.
- Operational records for operating treatment system(s): If not included in a separate referenced O&M report, discuss the treatment system operations. Discuss and include relevant information and operating data. Include a narrative description of any treatment system operation or changes in operation that had an apparent effect on water levels or contaminant trends.
- Operation and Maintenance of Monitoring Well Network: Monitoring wells degrade over time and become less reliable. An evaluation of the condition of wells in a monitoring network can be a component of routine monitoring. Often wells require redevelopment, removal of biofouling, or replacement of pumps. In time wells will become unusable and require abandonment and replacement. An integral component of routine monitoring is the O&M of the well network.

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For a detailed discussion of monitoring well network optimization visit the website for the Monitoring and Remediation Optimization System Decision Support Tool and Application http://www.gsi-net.com/en/software/free-software/maros-30.html (MAROS 3.0).