Planning Quality for Successful International Environmental Monitoring

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Abstract—*Federal, State, and municipal government entities are increasingly depending on geospatial data for a myriad of purposes. This trend is expected to continue. Information sharing and interoperability are in line with the Federal Executive Order 12906 (Clinton, 1994) which calls for the establishment of the National Spatial Data Infrastructure (NSDI). If other organizations voluntarily implement the U.S. Environmental Protection Agency's quality planning approach—or a similar approach that embraces the same critical quality elements—for projects that include geospatial data, then an increased level of confidence will be achieved for information that is shared between organizations and countries.*

Introduction

Within the Federal government, many agencies are developing, expanding and configuring their geospatial databases to facilitate data exchange and interoperability. These actions are in line with Federal Executive Order 12906 (Clinton, 1994. Amended by Bush, 2003) which calls for the establishment of the National Spatial Data Infrastructure (NSDI). The NSDI is defined as the technologies, policies, and people necessary to promote sharing of geospatial data throughout all levels of government, the private and nonprofit sectors, and the academic community.

When the applications of geospatial data and information have the same objectives, the NSDI appears to be a Amagic bullet;" however, some Federal agencies are apt to be involved in more litigation than others. This is especially true for regulatory agencies, such as the U.S. Environmental Protection Agency (EPA). EPAs mission is to protect human health and to safeguard the natural environment—air, water, and land—upon which life depends.

To accomplish its mission, EPA works to develop and enforce regulations that implement environmental laws enacted by Congress. EPA is responsible for researching and setting national standards for a variety of environmental programs, and, when appropriate, delegates to States and tribes the responsibility for issuing permits and for monitoring and enforcing compliance. Where National standards are not met, EPA can issue sanctions and take other steps to assist the States and tribes in reaching the desired levels of environmental quality.

Data, and the technology used to create them, are one of the primary drivers in the creation of space law and in many cases are the foundation upon which existing space law rests (Gabrynowicz, 1996). The technology involved in creating data may include, but not be limited to, one or more of the following:

- Remote sensing apparatus, such as satellites and aerial photographs, that are used to capture images
- Global positioning satellites, that are used to establish location
- Geographic information systems, a system of hardware, software, data, people, organizations, and institutional arrangements that are used to collect, store, analyze, and disseminate georeferenced information

Data may also originate from non-technological sources, such as:

- Mechanical or engineering drawings, used for many purposes such as depicting and envisioning structure
- Pre-existing (or archived) data, direct or transformed to be used as an integral part of the project at hand
- Text reports that may contain data such as chemical analyses

Because societies, technologies, cultures, and people are rapidly changing, definitions for key words and phrases used throughout this paper are addressed:

Technology is the combination of skills, knowledge materials, machines, and tools, that people use to convert, or change, raw materials into valuable goods or services—in the context of this paper, data are produced (De Sutter, J., 2003).

Information is the representation of data (or raw facts) to a receiver; it is the most important resource of a modern organization. Information is data in a usable form, processed in some way, it is data plus interpretation.

Data Package is the composite of the deliverable item(s) from producer to client. The data package may include, but not be limited to:

- Data
- Metadata (data about data)
- Information
- Conclusions

The process, progress, and closure of national and international space law cases that must consider geospatial data and concepts may become hindered by the lack of consistency in the formation and content of a data package (Lunetta and others 1991). At the time of this writing, geospatial data package content and structure are being submitted to clients in a manner that suits the creator (vendor) of the package, at times within consultation with the client. In other words, often there is no consistency in the way data packages are structured.

This inconsistency may require reviewers to take an inordinate amount of time searching the package to find case-relevant information, provided the information is available in the package. This problem is compounded when a reviewer must compare two packages, from two vendors (prosecution and defense) to determine consistency or points-of-departure. If the case-relevant information is contained in the packages, the reviewer may find it necessary to determine where this information is in the package, and how the vendors presented the information. In some situations, the reviewer may be required to normalize the data in each package in order to make a proper comparison (i.e., resolution).

The questions arise then: If parties are going to voluntarily create consistent data packages as deliverables, on what basis should the packages be structured? What element(s) crosses the real and imaginary borders of science and politics that would be palatable to all nations, data providers, clients, and stakeholders? The answer lies in the examination of processes common to companies throughout the world. Developed first as a means of efficiency, and to ensure continuity of production processes, Standard Operating Procedures (SOPs) have been written to ensure that if one employee departed, another could take his/her position and the production line would still operate relatively smoothly.

Another, primary, reason Standard Operating Procedures (SOPs) are written is to ensure that, within an organization, products have a consistent level of quality. Equally important, an organization must ensure that employees implement the SOPs; it is not enough to have them on the shelf. Over the centuries, companies have found, on an international level, that SOPs:

- Ensure smooth production
- Help to ensure consistent quality
- Demonstrate to clients that their concerns are addressed
- ....and more

"Error may be transferred from one data process step to the next unknown to the analysts until it manifests in the final product,..." (Lunetta, 1991). SOPs may facilitate tracking the source of errors and thereby reduce error propagation. The ability to reduce error propagation increases the overall quality of geospatial products. For more than a decade, the geospatial science community has been engaged in identifying potential sources of error, discussing the impact of the error and making recommendations to overcome error-related impediments. Vigilance is required because technology in general, and the tools used in geospatial analysis is always evolving. Therefore, SOPs need to be periodically reviewed and revised and appropriate in order to ensure the continual improvement of quality.

The link of SOPs to quality and the importance of following SOPs has been recognized and articulated by the scientific community. The impact of the "SOP to quality" link in the geospatial and space law arena is best exemplified by one case in which a private manufacturer of aeronautical products was not found liable for inaccurate data used in an aeronautical chart (*Brocklesby v. The United States and Jepperson & Co*). Jepperson had changed the chart format text to graphic form, and, the court said of Jepperson, "...in the process it had the ability and opportunity to detect the error." The court also held that the manufacturer had the right to seek indemnification against its co-defendant, the United States, who through the Federal Aviation Administration (FAA), supplied the information used on the chart. This decision resulted in passing a new law to provide indemnification by the United States in future cases (Gabrynowicz, 1996).

This particular case is important enough to be restated: Jepperson claimed they were not liable because the defective data came from the FAA. The court held that Jepperson could have verified the data by following the process in their own Standard Operating Procedures which required it to check the data to determine its validity and completeness.

The processes described in Jepperson's SOPs to check data validity and completeness are Quality Assurance (QA) and Quality Control (QC) procedures.

The NSDI and Global Spatial Data Infrastructure (GSDI) are conceptually sound and are making progress in their objectives; however, neither organization has fully addressed QA and QC procedures. Additionally, the Federal Geographic Data Committee (FGDC), though it factors QA and QC procedures into its products, has not separately and explicitly addressed QA and QC procedures – neither in its documentation nor its organizational structure.

Consistent means to share geographic data among all users could produce significant savings for data collection and use and could enhance decision making. Executive Order 12906 calls for the establishment of the National Spatial Data Infrastructure defined as the technologies, policies, and people necessary to promote sharing of geospatial data throughout all levels of government, the private and non-profit sectors, and the academic community. The goal of this Infrastructure is to reduce duplication of effort among agencies, improve quality, and reduce costs related to geographic information, to make geographic data more accessible to the public, to increase the benefits of using available data, and to establish key partnerships with States, counties, cities, tribal nations, academia and the private sector to increase data availability.

The NSDI has come to be seen as the technology, policies, criteria, standards, and people necessary to promote geospatial data sharing throughout all levels of government, the private and non-profit sectors, and academia (FGDC, 2004). NSDI provides a base or structure of practices and relationships among data producers and users that facilitates data sharing and use. NSDI is a set of actions and new ways of accessing, sharing, and using geographic data that enables far more comprehensive analysis of data to help decision-makers chose the best course(s) of action. Much has been accomplished in recent years to further the implementation of the NSDI, but there is still much to be done to achieve the vision: current and accurate geographic data that are readily available across the country (FGDC, USGS, 2004).

Cooperation and partnerships for spatial data activities among the Federal government, State and local governments, and the private sector will be essential for developing a robust infrastructure. The twenty-first century will see geographic information transported from remote nodes using computer networks to support decision making throughout the Nation. The National Information Infrastructure (NII) will provide the technology infrastructure to make this possible. The costs of creating and maintaining digital spatial data are high, so it is particularly important that spatial data collection not be duplicated, and that data be shared to fully realize its potential benefits. Largely for these reasons, the National Performance Review (prepared under the guidance of former Vice President Gore) urged the formation of spatial data partnerships between Federal agencies, State and local governments, and the private sector. After examining the pros and cons of several current spatial data programs that involve partnerships, the Mapping Science Committee (MSC) of the National Academies of Science (Mapping Science Committee, 1993) agreed that a partnership model, the subject of this report, is an excellent approach for enhancing the NSDI. The MSC serves as a focus for external advice to Federal agencies on scientific and technical matters related to spatial data handling and analysis. One of the Committee's roles is to provide advice on the development of the NSDI for making informed decisions at all levels of government and throughout society in general. Recently a number of State geographic information councils have been established to coordinate spatial data activities within the respective States. Such councils can also encourage partnerships between State and local government agencies, coordinate arrangements between State agencies and the private sector, and provide points of contact for partnerships with the Federal government organizations. The MSC agrees with the recommendation of the Federal Geographic Data Committee (FGDC) in its strategic plan to help form or strengthen these State geographic information councils (Mapping Science Committee, 1993).

The relationship of the FGDC and the NSDI is that the FGDC is responsible for steering the NSDI. A recent report form the US Government Accountability Office (GAO) clearly addresses the need for improvement in identifying and reducing duplicative investments (GAO, 2004a). In their report the GAO notes that the Federal Enterprise Architecture effort, and FGDC's reporting process - are insufficiently developed and have not produced consistent and complete information (GAO, 2004b). In addition to its other responsibilities, the Office of Management and Budget (OMB) Circular A-16 charges FGDC with leading the preparation of a strategic plan for the implementation of the NSDI. Such a plan could ensure coherence among the many geospatial coordination activities that are under way and provide ways to measure success in reducing redundancies. In 1994, FGDC issued a strategic plan that described actions Federal agencies and others could take to develop the NSDI, such as establishing data themes and standards, training programs, and partnerships to promote coordination and data sharing. In April 1997, FGDC published an updated planCwith input from many organizations and individuals having a stake in developing the NSDICthat defined strategic goals and objectives to support the vision of the NSDI as defined in the 1994 plan. Unfortunately, no further updates have been made (GAO, 2004c); the current work can be viewed at their website http://www.fgdc.gov/nsdi/nsdi.html. In addition, the current National Geospatial Strategy Document, FGDC's 1997 plan, is also out of date. (GAO, 2004d).

OMB Circular A-16 established the NSDI and the FGDC. OMB A-16 links the FGDC and NSDI to quality in the statement "A coordinated approach for developing spatial data standards that apply to collecting, maintaining, distributing, using, and preservation of data will improve the quality of spatial data and reduce the cost of derivative products created by federal and non-federal users" (OMB A-16, 2002a). Since the focus of the GAO report was on duplicative efforts, the GAO did not include a review of quality issues in their study of the FGDC and the NSDI geospatial information. A search of the GAO report for the word "quality," and phrase "information quality" confirms this suspicion because a word search of the study yielded nothing more than "quality of air...," "...water quality..," etc. Recognizing that the improvement of quality does not "just happen," OMB developed its own Information Quality Guidelines (IQGs), however OMB's IQGs have not "trickled-down" to the FGDC and NSDI. The authors anticipate that GAO may subsequently report on FGDC and NSDI quality issues, since the referenced GAO report does not include recommendations regarding the establishment and implementation of IQGs.

The authors of this paper believe that a consistent approach to quality planning, information technology, and information management, will provide the basis for solution of the issues identified by the US GAO, and more. In addition, it is critical that the information shared be of known quality. A baseline level of quality assurance, including adequate documentation, is required to ensure confident, interoperability of data.

Why is Planning for Geospatial Projects Important?

Planning is important in geospatial projects because it allows the project team to identify potential problems that may be encountered on a project and develop ways to work around or solve those problems before they become critical to timelines, budgets, or final product quality. Many examples exist of how a lack of planning impacts quality in geospatial projects. Lack of planning and detailed knowledge about data needs can cost a project a great deal of time and effort. Also the graded approach to developing QA Project Plans increases efficiency in that QA Project Plan elements are planned to be commensurate with the scope, magnitude, or importance of the project itself.

Developing and implementing a good QA Project Plan provides value to a geospatial project by:

- Guiding project personnel through the implementation process, helping ensure that choices are consistent with the established objectives and criteria for the project and providing material for the final report.
- Fostering project transparency, better communication among the project team members, and better results for the decision maker.
- Reducing the risk of schedule and budget overruns.
- Leading to a more defensible outcome than a project without proper planning documentation.
- Documenting the criteria and assumptions in one place for easy review and referral by anyone interested in the process.
- Providing consistency, making it easy for others to review the procedures and ensuring that individual steps are not overlooked in the planning phase.

In addition to these benefits, a project with a well-defined QA Project Plan often takes less time and effort to complete than a project without a planning document. Projects without planning documents are more likely to need additional money and time to correct or redo collection, analysis, or processing of data. The savings resulting from good planning typically outweighs the time and effort spent to develop the QA Project Plan. Poor quality planning often results in poor decisions. The costs of decision-making mistakes can be enormous and far outweigh the costs of proper planning for quality.

Quality Assurance Project Plan

The QAPP is a necessary and pivotal plan to guide and assure known quality in scientific and engineering projects. It is defined as a "document describing in comprehensive detail the necessary Quality Assurance (QA), Quality Control (QC), and other technical activities that must be implemented to ensure that the results of the work performed will satisfy the stated performance criteria" (EPA, 2001a), and it is composed of a number of elements.

What are the Characteristics of a Scientifically Sound Geospatial Data Project Plan?

A scientifically sound, quality-based geospatial QA Project Plan generally:

- Provides documentation of the outcome of the systematic planning process.
- Is developed using a process designed to minimize or control errors.
- Documents the standard operating procedures to be followed.
- Documents the data sources, format, and status of the existing (also called secondary or non-direct measurements) data to be used in the project [including topological status, accuracy, completeness, and other needed Federal Geographic Data Committee (FGDC) metadata].
- Is frequently updated as new information becomes available or as changes in methodology are requested.
- Provides for the documentation of any changes from the original plan.

Current Trends in Geospatial QA

Literature searches reveal that the geospatial science community continues to conduct research and promulgate guidance regarding spatial accuracy (Mower and Congalton 2000) (Lunetta and Lyon, 2004). However, spatial accuracy alone is not enough. Information Technology (IT) and Information Management (IM), provide the foundation of support for geospatial science. Ensuring that IT and IM are sound and minimize the chance of corrupting the data stored or passed through them is an essential step in handling any type of electronic data (Brilis, 2003a).

The U.S. Environmental Protection Agency has a Geospatial Quality Program (GQC) which guides the Geospatial Quality Council (GQC). Since its' formation in 1999, the GQC has developed numerous geospatial quality guidance documents and training courses to bridge the gap between the quality assurance community and the geospatial science community. The "Progress and Products" section of the GQC website contains downloadable QA guidance documents (Brilis 2003b).

In addition, the entire life cycle of geospatial information must be considered for a holistic approach to assuring quality. The life cycle consists of: Quality Planning; Data Acquisition; Data Input; Data Storage; Data Transformation; Data Output; and the often overlooked area of Data and Information Use and Misuse. This journal article focuses on the first step, Quality Planning.

Who Can Benefit from this Document?

Anyone developing geospatial projects or using geospatial data for EPA will benefit from this document. This document helps in the creation of a QA Project Plan that specifically addresses the issues and concerns related to the quality of geospatial data, processing, and analysis. This document also helps anyone who is:

- Creating geospatial data from maps, aerial photos, images, or other sources.
- Generating or acquiring the aerial photos or images.
- Using existing data sources in their geospatial projects.
- Generating new geospatial data from Global Positioning System (GPS) receiver data on horizontal and vertical positions.
- Developing complex analysis programs that manipulate geospatial data.
- Overseeing applications programming or software development projects—to understand how planning is related to developing software programs that use geospatial data.
- Reviewing QA Project Plans for geospatial data—to understand the steps and details behind the planning.
- Serving as a QA Officer for a group that creates or uses geospatial data.

The benefits of a QA Project Plan are to communicate, to all parties, the specifications for implementation of the project design and to ensure that the objectives are achieved for the project. It does not guarantee success every time, but the prospects are much higher with a QA Project Plan than without one (EPA, 2002a).

Graded Approach

Systematic planning for QA/QC is based on a common-sense, graded approach. The graded approach is the process of basing the level of application of managerial controls applied to an item or work according to the intended use of the results and the degree of confidence needed in the quality of the results. This means that the extent of systematic planning and the approach to be taken match the general importance of the project and the intended use of the data. For example, when geospatial data processing is used to help generate data either for decision making (i.e., hypothesis testing) or for determining compliance with a standard, EPA recommends that the systematic planning process take the form of the Data Quality Objectives (DQO) Process that is explained in detail within Guidance for the Data Quality Objectives Process (QA/G-4) (EPA, 2000a).

The Graded approach to QA Project Plans implies that, for projects of very limited scope, quality objectives, or size, a simple description of the use of weekly or monthly status e-mails may be appropriate. For more complex projects with many processing steps, data sources, and complex processing methods, more formal reports may be specified and documented.

Secondary Use of Data

Secondary use of data is the use of data collected for other purposes or from other sources, as distinct from the primary acquisition or purpose. Sources may include literature, industry surveys, compilations from computerized databases and information systems, and results from computerized or mathematical models of environmental processes and conditions.

Geospatial projects, almost always use existing data from a source external to the project. When designing a project and, in turn, developing a QA Project Plan, the question of which Geographic Information System (GIS) data sources to use is important.

Overview of the Components of a QA Project Plan

This section provides a list of the components of a QA Project Plan included in EPA Requirements for Quality Assurance Project Plans (QA/R-5) (EPA, 2001b). The components of a QA Project Plan are categorized into "groups" according to their function, and "elements" within each group that define particular components of each group and form the organizational structure of the QA Project Plan. QA groups are lettered and QA elements are numbered. The four groups are:

Group A—Project Management

The elements in this group address the basic area of project management, including the project history and objectives, roles and responsibilities of the participants, etc. These elements ensure that the project has a defined goal, that the participants understand the goal and the approach to be used, and that the planning outputs have been documented.

Group B—Data Generation and Acquisition

The elements in this group address all aspects of project design and implementation. Implementation of these elements ensure that appropriate methods for sampling, measurement and analysis, data collection or generation, data handling, and QC activities are employed and are properly documented.

Group C—Assessment and Oversight

The elements in this group address the activities for assessing the effectiveness of project implementation and associated QA and QC activities. The purpose of assessment is to ensure that the QA Project Plan is implemented as prescribed.

Group D—Data Validation and Usability

The elements in this group address the QA activities that occur after the data collection or generation phase of the project is completed. Implementation of these elements ensures that the data conform to the specified criteria, thus achieving the project objectives.

Table 1 shows a complete list of the QA Project Plan groups and elements. Subsequent sections of this paper provide more detail about the content of each section.

Suggested Content of QA Plan Elements

The QA Plan structure described in the groups above leaves the content of each section open to the discretion of the QA Plan author(s). There are a number of suggested contents for each of the groups. This content is "suggested" because each geospatial project is unique. The suggested content is not a "one-size-fits-all" scenario.

To exemplify the range of geospatial products, two types of projects are presented for illustrative purposes. Example 1: A hazardous waste site manager may need geospatial information to take an alleged violator to court Example 2: Geospatial projects - this may require near real-time satellite imagery. A researcher may be involved in evaluating the effect of city growth on the environment, therefore archived images of the site in addition to near real-time satellite images may be required to conduct this type of assessment.

Because of the wide-array of geospatial applications, the content for each QA Plan group is suggested. The QA

Table 1. Summary of QA Groups and Elements.

Group	Element	Title
A	1	Title and Approval Sheet
	2	Table of Contents
	3	Distribution List
	4	Project/Task Organization
	5	Problem Definition/Background
	6	Project/Task Description
	7	Quality Objectives and Criteria
	8	Special Training/Certification
	9	Documents and Records
B	1	Sampling Process Design
	2	Sampling and Image Acquisition Methods
	3	Sample Handling and Custody
	4	Analytical Methods
	5	Quality Control
	6	Instrument/Equipment Testing, Inspection, and Maintenance
	7	Instrument/Equipment Calibration and Frequency
	8	Inspection/Acceptance for Supplies and Consumables
	9	Data Acquisition (Nondirect Measurements)
	10	Data Management
C	1	Assessments and Response Actions
	2	Reports to Management
D	1	Data Review, Verification, and Validation
	2	Verification and Validation Methods
	3	Reconciliation with User Requirements

Plan author(s) should consider contacting the project manager, and/or the appropriate QA professional to ensure that critical quality items are addressed in the QA Plan.

The suggested content is presented in the next sections.

Group A—Positioning the Project in Earthly Perspective

Title and approval sheet

Suggested Content:

- Title of plan.
- Name of organization.
- Names, titles, and signatures of appropriate officials.
- Approval signature dates.

Table of contents

Suggested Content:

- Table of contents.
- List of tables, figures, references, and appendices.
- Document control format when specified by the Project Manager.

Distribution list

Suggested Content:

- Individuals and organizations who receive approved QA Project Plan.
- Individuals and organizations responsible for implementation.
- Individuals and organizations who receive updates.

Project/task organization

Suggested Content:

- Identified roles and responsibilities.
- Documentation of the QA Manager's independence of the unit generating the data.
- The individual responsible for maintaining the official QA Project Plan is identified.
- Organization chart showing lines of responsibility and communication.
- List of outside external organizations and subcontractors in the organization chart.

Problem definition/background

Suggested Content:

- The specific problem to be solved or decision to be made.
- Description of the project's purpose, goals, and objectives.
- Identification of programs this project supports.
- Description of the intended use of the data to be gathered or processed.

Project/task description

Suggested Content:

- Sufficient background for a historical and scientific perspective for project tasks.
- Schedule and cost.

Quality objectives and criteria

Suggested Content:

- The quality objectives for the project.
- The performance and acceptance criteria used to evaluate quality. (Use the systematic planning process to develop quality objectives and performance criteria [see EPA Quality Manual for Environmental Programs, Section 3.3.8.1 (EPA, 2000a), for more information]).

Special training/certification

Suggested Content:

- Any training or certification specifications for the project.
- Plans for meeting these specifications.

Documents and records

Suggested Content:

- Description of the mechanism for distributing the QA Project Plan to project staff.
- List of the information to be included with final products, including metadata records, calibration and test results (for GPS or remote sensing tasks), processing descriptions provided by data vendors (for example, address matching, success rate reports from address matching vendors).
- List of any other documents applicable to the project, such as hard-copy map source material, metadata provided with data from secondary data sources, interim reports, and final reports.
- All applicable specifications for the final disposition of records and documents, including location and length of retention period.

Group B—Data Generation and Acquisition

Sampling process design

Suggested Content:

- Description of the data or image acquisition design.
- For geospatial data to be collected, the design for acquisition (for example, how and where locational data will be acquired).

Sampling and image acquisition methods

Suggested Content:

- Description of data, photography, or imagery collection procedures.
- Methods and equipment to be used.
- Description of GPS equipment preparation.
- Description of performance criteria.
- Description of corrective actions to be taken if problems arise.

Sample handling and custody

Suggested Content:

- Description of needs for handling and transfer of hard-copy imagery or other hard-copy data inputs.

Analytical methods

Suggested Content:

- Image processing and/or photo-analysis methods to be used.
- List of method performance criteria, if applicable.
- QC activities needed for GPS measurements, field observations, map digitization, image acquisition, image processing, or image analysis.
- The frequency of each check and corrective action needed when limits are exceeded.

Quality control

Suggested Content:

- Develop QC checklist for each step of data collection, checking and assessing the quality of map digitizing or satellite ground-truthing results.
- Ensuring that the requested special bands have been delivered.
- Checking against independent data sets such as other images or vector products.
- Examining the cloud coverage of images to ensure that cloud coverage extent does not impede use of the data.
- Ensuring that the view angle of imagery is as specified.

Instrument/equipment testing, inspection, and maintenance

Suggested Content:

- Description of how inspections and acceptance testing of instruments, equipment, and their components affecting quality will be performed and documented.
- Description of how deficiencies will be resolved.

- Description of (or reference to) periodic preventive and corrective maintenance of measurement or test equipment.

Instrument/equipment calibration and frequency

Suggested Content:

- Instruments used for data collection whose accuracy and operation need to be maintained within specified limits.
- Description of (or reference to) how calibration will be conducted.
- How calibration records will be maintained and traced to the instrument.

Inspection/acceptance for supplies and consumables

Suggested Content:

- Description of how and by whom supplies and consumables will be inspected and accepted.

Data acquisition (nondirect measurements)

Suggested Content:

- Description of secondary data used.
- Description of the intended use of the data.
- Acceptance criteria for using the data in the project and any limitations on that use.
- Information Technology issues.
- Logistical consistency.

Data management

Suggested Content:

- Description of the project management or activities.
- Flow charts of data usage and processing.
- Description of how data will be managed to reduce processing errors.
- Description of the mechanism for detecting and correcting errors in data processing.
- Examples of checklists or forms to be used.
- Description of the hardware/software configuration to be used on the project.
- Description of the procedures that will be followed to demonstrate acceptability of the process.
- Description of the data analysis or statistical techniques to be used.
- Information Technology issues:
    - Security.
    - Electronic Exchange Formats.
    - Hardware/Software Configuration.

Group C—Assessment/Oversight

Assessments and response actions

Suggested Content:

- Description of each assessment.
- Information expected and success criteria.
- Assessments to be done within the project team and which are done outside the project team.
- The scope of authority of assessors.
- Discussion of how response actions to assessment findings are to be addressed.
- Description of how corrective actions will be carried out.

Reports to management

Suggested Content:

- Frequency and distribution of reports issued to management that document assessments, problems, and progress.
- Individuals or organizations responsible for preparing the reports and actions recipients would take upon receipt of the reports.

Group D—Data Validation and Usability

Data review, verification, and validation

Suggested Content:

- The criteria to be used to validate and verify the final product.

Verification and validation methods

Suggested Content:

- Description of validation and verification processes for the final products.
- Discussion of issues related to resolving problems detected and identification of individuals or authorities who determine corrective actions.
- Description of how the results of the validation will be documented for the product users.
- Definition of differences between validation and verification issues.

Reconciliation with user requirements

Suggested Content:

- Description of how the products or results will be reconciled with criteria defined by the data user or decision maker.

- Description of how reconciliation with user criteria will be documented and how issues will be resolved.
- Discussion of limitations on the use of the final data product and how these limitations will be documented for data users or decision makers.

Discussion

Application of a structured quality plan facilitates subsequent assessment, not only by scientists, but by courts. A structured quality plan communicates that the basic scientific method is being applied. This in turn ensures that judges have a basis that they can relate to. Specifically the U.S. Supreme Court's concept of "sound science," as related to environmental programs and their supporting data, requires an assessment of exactly what the legal concepts are and what are the actual processes to which they apply in an environmental program. The "Daubert Rule" looks specifically at the theory or technique and some areas associated with the theory or technique (for example, peer review, error rates, standards for control, and general acceptance) (Brilis, 2000).

A critical question might be, "What are the science-related theories or techniques involved in environmental programs?" Theories and techniques may be based on one or more disciplines, such as:

- experimental design
- engineering design
- sampling
- chemistry/biology
- quality assurance
- statistical analysis
- risk assessment
- risk management

When does the Daubert Rule come into play? Maybe not at all. The Daubert Rule would most likely apply to novel situations where a standard approach to performing the operation does not exist. For example, if the investigation activity is predetermined according to a known method and the analytical work is a known method (i.e., EPA and ASTM methods), then discussions about what might constitute needed proof for a hypothetical situation may be totally unnecessary.

For much of the environmental work performed on a routine basis, this approach is simply not necessary. However, when the activity requires the application of scientific expertise, the criteria outlined in the Daubert Rule makes sense when looking at admissibility of scientific evidence.

How should scientists respond to the complex implication of law on the process of science? Scientists should focus on the overlying charge that forms the basis for all credible work, that is, "to produce data of known and acceptable quality that is usable for its intended purpose." The intended purpose is key to the establishment of clear objectives for the project, the associated measurements, and their associated quality control criteria (Maney and Wait, 1991; Wait and Douglas, 1995). Each of the criteria mentioned here are not requirements and the end result is not good or bad, depending on the objective; the resulting information can be considered good, better, or best for assisting lawyers in using the overall result to support the original objectives.

From 1993 to 1999 more than 2000 cases cite the Daubert decision. As such, it behooves the scientist conducting defensible testing to consider the following:

Planning Criteria

- persons planning this work are knowledgeable (expert and trained)
- planning was performed
- planning was documented
- the plan was reviewed
- the plan included a clear objective(s)
- the plan included readily identifiable measurements to achieve the objectives
- the plan stated specific QC criteria for the measurements
- the plan referenced sampling and analytical procedures

Implementation criteria

- changes to the plan were noted and approved
- the activity was implemented as planned
- there was documented management overview of the implementation
- there was documented quality assurance overview of the implementation
- corrective action regarding problems noted during overview was taken and documented
- the personnel performing the work were trained
- the records that were kept were accurate
- the supplies used met requirements
- measurement devices were calibrated
- problems encountered were recorded
- problems were resolved (and documented)

The result and assessment criteria

- quality control criteria were met
- report conclusions are supported by data

- the data were validated
- the report was reviewed
- review comments were addressed
- results are comparable to results from similar work

Sample authenticity criteria

- chain of custody was maintained
- sample identity was maintained
- sample integrity was not compromised
- sample records are all consistent

Data integrity criteria

- data output records were well maintained
- computer hardware and software was controlled
- the quality of any secondary data used is known

The above information resembles the body of items one might consider in either a quality management plan or a project-specific technical specifications document. Scientists and lawyers have similar interests which are based on the overall objectives of the scientific effort. In some cases, quality control needs to focus on a single sample, when that sample might be used to prove the need for enforcement. In other cases, quality control needs to focus on a larger process such as the characterization of a site and potential cleanup. Still in other cases, quality control needs to focus on the proof of a research experiment which looks at a single technology application on a very small area or amount of material. In all cases, planning should consider the overall objective of the process considered during application of scientific techniques or theories.

Conclusion

The future holds many changes and challenges for geospatial data, image interpreters and the geospatial scientist. For example, the demand by the legal profession for GIS experts has increased since the GIS software has left the UNIX format and found its' way to more user-friendly software. This demand has been and will be intensified by the problems of environmental industrial contamination and the lawsuits brought against individuals and corporations by citizens, employees, and public agencies.

We predict that geospatial scientists, using advanced image analysis and GIS techniques, will become more adept at gathering data from complex problems. They will use this data in increasingly sophisticated ways to answer the numerous questions that surround legal cases.

The state of quality of geospatial science in the courtroom is still evolving as the courts continuously consider the quality of evidence. This is particularly true in cases where novel scientific techniques are used. Recent trends towards the use of remotely-sensed images, especially those using wavelengths outside the visible spectrum, beg the users to ensure that quality assurance and quality control policies and procedures are in place to ensure defensible evidence.

However, policies and procedures alone are not enough. Policies and procedures must be implemented and their use must be documented. The case of Brocklesby v. U.S. and Jeppesen & Co., highlights this fact. In this case, Jeppesen claimed that the defective data was obtained from the Federal Aviation Administration (FAA), and therefore no liability should be placed on Jeppesen. The court held that it was incumbent upon Jeppesen to verify the FAA's data by following its own Standard Operating Procedures which require Jeppesen to verify the integrity of the data (Ninth Circuit Court, 1985).

Additionally, the use of qualified experts that can translate complex and novel images or GIS products is becoming increasingly important. Indeed, litigators may increase the use of geospatial experts to help "translate" the technicalities of a case. While one may have highly defensible data, the communication of evidence to the lay persons (jurists) is critical in making a convincing presentation.

Image interpreters and GIS specialists are first and foremost analysts and their unique abilities will have an increasingly extensive applicability in the environmental arena. Therefore it is appropriate and necessary that geospatial scientists be involved from the beginning of the project. That is, "Plan the investigation, and investigate the plan."

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