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METADATA ANALYSIS OF THE MONTANA DEPARTMENT OF ENVIRONMENTAL QUALITY'S REFERENCE STREAM PROJECT DATASETS

By

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Metadata Analysis of the Montana DEQ's Reference Stream Project Datasets

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This Master's Thesis examines certain aspects of the frequently incongruous relationship in the State of Montana between the natural science of water quality measurement and the actual practices to which water quality management research is put. These discordances can be the source of misunderstandings about the purposes and uses for which data were collected. Moreover, miscues regarding the sharing of information among stakeholders have become more significant as adaptive and shared management programs continue to expand. At the core of this study are assessments of the value of water quality data generated by the Montana Department of Environmental Quality (DEQ) and surveys of some of the potential consumers of water quality data generated by the Montana DEQ. Datasets examined are part of an ongoing project at the Montana DEQ known as the "Reference Stream Project."

Research was framed using two basic questions: (1) Are Reference Stream Project data supported by an appropriate metadata framework?; and (2) In general, are water quality data produced by the Montana DEQ socially and politically useful or relevant to consumers of water quality information? Question 1 is addressed using a structural analysis of existing metadata from the Reference Stream Project to infer overall reliability and usefulness of data quality for these types of water quality data. Question 2 is examined using social inquiry of water resource stakeholders who are potentially interested in water quality data, in order to evaluate the usefulness and relevance of state generated water quality data. Question 1 is the primary focus of the study. The research identified a noteworthy demand among stakeholders to collaborate and share data with each other, which can be accomplished, in part by the following steps: (1) increasing metadata structure; and, (2) encouraging joint fact finding processes to be undertaken by the greater cohort of water quality stakeholders in Montana. This study reaffirmed the need for water resource managers to be critical of how water quality data are stored and described, in order to create reliable, useful, and inclusive management processes.

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INTRODUCTION

The State of Montana invests millions of dollars every year to collect, analyze and store water quality data (Montana State Legislature [updated 2010]). This information resource is used by the Montana Department of Environmental Quality (DEQ) to decide whether water bodies support their beneficial uses, whether discharges are in compliance with permits, whether water quality is improving or declining, and what are the causes and sources of impairment of water bodies. This information is potentially useful to citizen groups working to restore and maintain water quality; however for many this information is not accessible or understandable.

This study examines how the Montana DEQ stores and uses its water quality data, and what factors affect how easy it is to access, understand, and use that data. The intent of this study is to recommend to the Montana DEQ how it can make its data more useful to other users, but especially watershed groups. In the interest of making this thesis understandable to watershed groups, a glossary of technical terms is provided at the end.

The following metadata analysis was performed to present additional assessment methods that the Montana DEQ project planners and managers can consider when evaluating metadata associated with water quality projects. In general terms, metadata provides the information that describes any document or object in both digital and traditional formats. Such structured information describes, explains, locates or otherwise makes it easier to retrieve, use, or manage an information resource (Zeng and Qin 2008). A crucial component of database structure, metadata can make the difference between a well understood data resource and a worthless set of numbers. Two different evaluative frameworks for structuring metadata were applied to a case study of metadata from the

Montana DEQ, known as the "Reference Stream Project" (RefPro). The methods were designed to help understand how water resource data are stored and used.

Metadata serve not only to describe content of a set of data, but also to connect potential end-users to a valuable data resource. Hence, I surveyed watershed groups in Montana to improve the understanding of the relationship between water quality stakeholders and water quality data created by the Montana DEQ. This research not only analyzed the technical aspects of how water quality data are used by the Montana DEQ, but also evaluated its usefulness to citizen groups involved in water quality planning and management in Montana.

The target audience of this research includes all stakeholders involved with water quality management in Montana, especially the Montana DEQ[1] and watershed group coordinators within the state. Recommendations from a "third party" review of Montana DEQ metadata can help with future project design and database management (Cornell University Metadata Services [updated 2011]). Additionally, this study presents an opportunity for those engaged with water quality management in Montana to better understand some of the technical aspects of water quality data storage, and demonstrates how water quality stakeholders (including the Montana DEQ) can improve their ability to share and disseminate water quality data and information.

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[1] The Montana DEQ can be considered a water quality "stakeholder" at times, but for the purposes this paper will often be referred to independently of other water quality stakeholders in Montana.

SECTION 1 – PRESENTING WATER RESOURCE INFORMATION ISSUES

National Significance of Montana Water Resources

In a recent letter to the United States Secretary of Agriculture, the Western Governors Association requested that public involvement continue to be increased in the natural resource planning processes with regard to federal resources (Otter and Gregoire 2011). This request from the Western Governors Associations is in line with the current trend for more local and regionalized management processes to occur, because so many of the natural resources in the Western United States require significant human planning to be cultivated to their full potential. The Rocky Mountain West is a region rich in natural resources that depend on water, including great quantities of arable soils, ores, fuels, timber and wildlife. In my view, no other resource is more important than water to the health & prosperity of Montana citizens. Montana waters flow downstream to serve millions of Americans on both sides of the Continental Divide. Although it has fewer than 1-million constituents, the Montana DEQ, compared to other state environmental agencies, has a disproportionate amount of responsibility to protect the water quality within its jurisdiction.

Water Resource Information Issues in Montana

There are a host of state and federal agencies within Montana that are involved with water resource management; their responsibilities range from allocating water rights to permitting services for oil and gas development (Montana Watercourse [Updated 2011). The Montana DEQ is charged with evaluating restoring and maintaining the quality of Montana’s water resources (Montana DEQ 2010a). However, recent history has revealed that confronting the issues of water quality in Montana is as much a policy issue as it is an issue of understanding how to measure human impacts on water resources (Water Policy Interim Committee 2010).

Natural resource managers can often be left wondering why a plan or a management scheme was unsuccessful or did not achieve the intended goal, and that is why it can be crucial to identify willing stakeholders who need technical assistance to correct environmental issues (Susskind *et al.* 2005). Technical assistance for monitoring water quality can take on a variety of forms (Lanfear *et al.* 2004). One customary method of providing technical assistance is data sharing among stakeholders (Conservation Technology Information Center [updated 2011]).

Sharing data involves developing databases that are rooted in well structured metadata schemas (Foulonneau and Riley 2004). Environmental resource datasets described by appropriate metadata schemas help support the immediate intended use of the data (Fegraus *et al.* 2005). Moreover, metadata can help make datasets, more widely accessible to a broad spectrum of stakeholders and other secondary end-users, a characteristic known as "interoperability" (Shreeves *et al.*2006). If interested water quality stakeholders are given technical assistance and encouraged to participate in fact finding, then they will be more likely to collaborate and share their unique sets of knowledge, including knowledge in the form of data (Rofougaran and Karl 2005).

Balancing Science and Politics in Water Quality Management

Policy dictates what natural resource issues are actively managed, because political demands are a reflection of the demands placed on natural resources (MIT-USGS Science Impact Collaborative 2009). Therefore, scientific research is often organized to facilitate specific management goals (Bingham 2003). Water policy can be viewed as an interpretation of both the law and the circumstances of water resources, both of which are assumed to be predicated on trustworthy data and information (Bryan *et al.* 2009; Ozawa 1991). And while reliable information is supported by credible data, credible data requires well organized metadata (Baca 2008).

The data describing information we call metadata is a forum for acknowledging the reality that not all data are created equal, because data collection, summarization and interpretation methods differ (Field *et al.* 2007). In addition, the value of data should not only be determined by how it is organized, but also by the demands of potential end-users (Foshay *et al.* 2007). Water quality data illuminate ecological implications of water use by humans, and need to be accessible to all stakeholders whether top down or ground up governance is taking place (Matso *et al.* 2008). Developing metadata schemas is a part of the process of data sharing (Zeng and Qin 2008). And when trying to do conservation and be aware of the socio-political issues that underpin water quality management, being able to share information can be the difference between success and failure when managing water quality (Zeng and Qin 2008; McKinney and Harmon 2004).

Scientific Management of Water Quality

One key role of scientific management is to provide information and data that support reasoned decision making (McKinney and Harmon 2004). Obtaining a strong information base to serve a working management environment is crucial, because the information base is the center of the entire management process (see Figure 1) (Modified from Kohler and Hubert 1999).

There are four main factors that influence any natural resource management process. All of them, except the ecological factor, are related to dimensions of human behavior (see Figure 2) (Modified from Kohler and Hubert 1999). Integrating science and citizen based stakeholder groups can increase the likelihood for more broadly acceptable outcomes and encourage active resource management (McKinney and Harmon 2004). The process of gathering public input in scientific management is difficult, and requires tailored approaches for each instance of natural resource planning and management (MIT Science Collaborative [updated 2011]). One process for facilitating citizen involvement is to employ joint-fact finding (Amengual 2010).

The Case for Joint Fact Finding in Water Resource Management

Contentious natural resource issues in the Western United States often involve "complex information" (see Display 1) (Modified from McKinney and Harmon 2004). The theory behind joint fact finding is based on a set of best practices that attempt to ensure that science and politics are given equal voices in natural resource decision making processes (Karl *et al.* 2007). Joint fact finding is a procedure that encourages a conversation between those engaged in answering natural resource policy questions, and those who have specialized insight into a given issue from a political, social, or scientific standpoint (see Figure 3) (Modified from Rofougaran and Karl 2005). Building this interface can advance better decision making processes and reduce conflict (Modified from Rofougaran and Karl 2005; Scarlett 2004).

The process of joint fat finding is an opportunity for stakeholders to address information gaps and scientific uncertainty as well as produce credible, creative, and more durable management decisions (Ehrmann and Stinson 1999). Joint fact finding is most likely to be used as a component of a consensus building process, and demonstrates that inclusive forums for natural resource management can work (see Figure 4) (Modified from Rofougaran and Karl 2005 originally from CBI, Cambridge, Mass.). Because joint fact finding promotes shared learning, it helps to create knowledge that is reliable, useful to decision makers, and publicly legitimate (Karl *et al.* 2007). Moreover, joint fact finding allows for the consideration of local and cultural knowledge as well as expert knowledge (Karl *et al*. 2007).

During the process of consensus building, local knowledge can support scientific knowledge to create preferable outcomes for stakeholders (Adler and Birkhoff 2002). In addition, accounts of non-experts making large contributions to the identification and understanding of environmental problems exist throughout the literature **(**Amengual 2010). In Montana, joint fact finding is occurring among stakeholders involved with natural resource management, including in the management of water quality (Montana DEQ 2010b). Citizen and quasi-government driven stakeholder groups are beginning to undertake the process of joint fact finding more regularly (Kohler and Hubert 1999). As processes and models are refined, water quality can theoretically be adaptively managed in perpetuity (Montana DEQ 2007; Watson 2011). Joint fact finding is also occurring within consensus building processes for independent large-scale water quality related projects in Montana (Upper Clark Fork River Basin Remediation and Restoration Advisory Council 2010).

Metadata as a Tool for Joint Fact Finding

Making inquiries using joint fact finding needs to be done based on a common understanding regarding the research methods being used (Ehrmann and Stinson 1999). Being able to interpret available water quality data from agencies like the United States Environmental Protection Agency (U.S. EPA) can be crucial to supporting a management environment predicated on shared knowledge (U.S. EPAOffice of Environmental Information [updated 2010]). Credible water quality information is also a valuable resource for other state government stakeholders beyond the Montana DEQ, such as Montana Fish, Wildlife and Parks (Land Use Clinic 2009).

The U.S. EPA predominantly uses geospatial metadata schemas to share data, but they are developing a sense of the importance of metadata for ecologically related datasets as well, and have encouraged state agencies to do the same (U.S. EPA Data User Corner [updated 2010]; Lazorchak *et al*. 1998; Montana DEQ *et al.* 2009). Digital databases with well structured metadata are crucial not just for sharing geospatial data, but ecological data as well (Fegraus *et al*. 2005). In response to an increased demand for interoperability of water quality data, the U.S. EPA Environmental Information Exchange Network has undertaken the development of the national Water Quality Exchange (WQX) (Environmental Information Exchange Network [updated 2011]). Essentially, data exchanges like the WQX function through the use of an electronic interface (i.e., a web-page). Metadata created by a schema that all participants use supports the sharing of water quality data in a standard format (see Figure 5) (Modified from Environmental Information Exchange Network [updated 2011]).

SECTION 2 – FRAMING THE ISSUES ASSOCIATED WITH WATER QUALITY METADATA

Montana DEQ-Managers of Water Quality Data

Located within the Montana DEQ's Planning Prevention and Assistance Division (PPA), the Water Quality Planning Bureau (WQPB) is the branch of the DEQ responsible for assuring that water quality is maintained and improved so that state waters can support all their beneficial uses (Montana DEQ Quality Assurance Program [updated 2010]). The Montana DEQ WQPB manages two types of data in large database systems that are made available to the public (Montana DEQ Water Quality Standards and Classifications [updated 2010]). Data structure and management at the Montana DEQ are the responsibility of the Information Management and Technical Services Section (Montana DEQ Information Management and Technical Services [updated 2010]). All of the data that the Montana DEQ collects have to be properly managed so they can be interpreted by stakeholders who are becoming more involved in the planning process (Mathieus *et al.* 2005b; Watson and Brick 2002).

Data flow through a series of mediums, formats and quality checks from the planning phase through the completion of the field collection, lab analyses and final entry (see Figure 6) (Modified from Mathieus *et al*. 2005a). Through processing, data should become more reliable, useful and relevant from the standpoint of Montana DEQ (Mathieus *et al.* 2006). Moreover, the synthesis of watershed information to determine if "sufficient credible data" exists to make a "beneficial use-support determination" regarding a water body, depends largely on whether an adequate metadata structure for a given data resource is in place (see Figure 7) (Modified from Mathieus *et al*. 2006).

Current Water Quality Databases in Montana-STORET/WQX

The Clean Water Act (CWA) is a relevant example of a democratic legislative product that combines significant scientific standards with political demands (Montana Watercourse Guide to Montana water management [updated 2011). The act legally holds the U.S. EPA responsible for managing water quality in the United States. Responsibility for Montana's water has been formally delegated to the Montana DEQ (Bryan *et al.* 2009). With respect to water quality data governance, the U.S. EPA maintains a national water quality database known as STORET/WQX, which is an evolving attempt to help states organize and share water quality metric data on a national scale (U.S. EPA Web Guide-Metadata Frequently Asked Questions [updated 2011]). The U.S. EPA has developed a loose structural framework for metadata in the original STORET that has existed in several forms since the 1965. WQX components began being added as of September 2009 in an attempt to improve metadata structure for improved data preservation and data sharing capabilities (U.S. EPA Web Guide-Metadata Frequently Asked Questions [updated 2011]; Environmental Information Exchange Network [updated 2011]). The relationship between the federal government and states regarding water quality management is diverse and varies regionally, but states will continue to rely on federal assistance to pool data resources to achieve management goals (U.S. EPA Pacific Northwest Water Quality Data Exchange [updated 2009]). National and state forums, like the Pacific Northwest Water Quality Exchange, are being developed to share water quality data, and to increase stakeholder involvement in managing water quality (U.S. EPA Pacific Northwest Water Quality Data Exchange [updated 2009]; National Water Quality Monitoring Council [updated 2010]).

All data collected or received from collaborating partners of the Montana DEQ are uploaded to the U.S. EPA's STORET/WQX data warehouse (Montana DEQ Information Management and Technical Services [updated 2010]). The Montana DEQ has its own unique process for uploading water quality data to STORET/WQX called Montana-eWQX (Montana DEQ EQuIS Water Quality Exchange Support [updated 2010]). Montana-eWQX is partially the product of models designed for the U.S. EPA to encourage interoperability (enfoTech & Consulting 2005). This process is an attempt to standardize the way that all water quality data are submitted to STORET/WQX, and also how these data are structured in the warehouse (Environmental Information Exchange Network [updated 2011]).

Other Relevant Water Quality Interfaces and Databases in Montana

The Clean Water Act Information Center (CWAIC) is an electronic interface that is supported by the Montana DEQ, which generates reports of available water quality assessment data and decisions based on Montana Water Quality Standards (Clean Water Act Information Center [updated 2011]). These data form the basis for reports required by the Clean Water Act, namely the state's 303(d) list and 305(b) water quality integrated report. These reports are provided to the EPA under explicit delegated authority to implement the federal Clean Water Act in Montana (CWA 33 U.S.C. §§1251 et seq.; Montana DEQ 2010a). In addition, information in CWAIC is also provided to the public at the direction of Montana's Water Quality Act (Bryan *et al.* 2009). CWAIC provides query based access to water body specific data, Montana's 303(d) lists, integrated reports, a public comment web application for commenting on draft reports and documents, and a web-based mapping application to view assessment units and listings of interest (Clean

Water Act Information Center [updated 2011]). A chart for understanding citizen participation in natural resource planning can be helpful when describing the governance structure of an agency (McKinney and Harmon 2004). So, based on the intent of CWAIC, which is largely used in the TMDL planning process, it would appear in Table 1 that Montana DEQ's Water Quality Planning Bureau encourages roughly a medium "Degree of Citizen Influence" (Modified from McKinney and Harmon 2004; Montana DEQ 2007; Montana DEQ 2010a).

Other databases exist in Montana that are designed to encourage participation from water quality stakeholders (Montana Watercourse 2009 annual report [updated 2011]). In addition to CWAIC, the Montana DEQ (and the U.S. EPA) in conjunction with Montana Watercourse support the Montana Volunteer Water Monitoring Project (MVWMP), which maintains a database for citizen volunteers to store and access water quality data from participating stakeholder groups or individuals (Montana Watercourse Water Monitoring [updated 2011]; Montana Watercourse 2009 annual report [updated 2011]). Volunteers in the MVWMP are required to become certified participants, and are educated on the importance of using quality assessment methods that support the development of reliable metadata (Montana Watercourse Volunteer Monitoring Training and Certification [updated 2011]). The MVWMP's database was recently reconfigured to make submitting data easier and to make data interactive; both of which are also priorities of other government agencies dealing with water quality (Montana Watercourse Water Monitoring [updated 2011]; Isaak 2011).

SECTION 3 – THE MONTANA DEQ REFERENCE STREAM PROJECT AS A CASE STUDY OF DATA ACCESIBILITY AND QUALITY

Nonpoint Source Pollution Created the Need for the Reference Stream Project

Nonpoint source pollution (NSP) is increasingly recognized as a major threat to the long term sustainability of healthy water quality in Montana (Montana DEQ 2010b). NPS management is at the intersection of various branches of ecology including aquatic, landscape and human (Turner *et al.* 2001). Methods for analyzing NPS require that the surveying of water quality reach beyond political boundaries, to perform regional risk assessments that are based on interactions between terrestrial and aquatic systems at the landscape-scale (Montana DEQ 2010b; Turner *et al.* 2001)

The Montana DEQ's NPS Management Program has the responsibility of protecting and restoring water quality from the impacts of nonpoint sources of pollution in order to provide a clean and healthy environment (Montana DEQ Nonpoint Source Program [updated 2011]). The program is required to provide two reports to the U.S. EPA for the federal Clean Water Act: a five year management plan and an annual report (see Table 2) (Modified from MT DEQ et al. 2009). Part of the process of evaluating nonpoint source pollution includes developing both numeric and narrative water quality standards that the Montana DEQ must substantiate and uphold (Montana DEQ Water Quality Standards and Classifications [updated 2010]). In order to maintain narrative water quality standards, the Montana DEQ must compare existing water quality to what "naturally occurs" or is"normal" (Bryan *et al.* 1999; Suplee *et al.* 2005).

The RefPro

The "Reference Stream Project" (RefPro) is an ongoing study at the Montana DEQ that began collecting data in the early 1990's, with the initial report published in

1992 (Bahls *et al.* 1992). The project is an outgrowth of the reference condition concept that is widely applied throughout the United States and the world (Suplee *et al.* 2005; Doyle *et al.* 1999). The purpose of the RefPro is to develop a system of reference stream reaches of first through fifth order streams classified by Level III (coarse scale) and Level IV (fine scale) eco-regions so as to provide a benchmark “normal” condition to set goals for restoring water quality, and to set criteria for fully supporting certain uses (Bahls *et al.* 1992; Suplee *et al.* 2005).

The project collects a wide range of data on the physical, biological and chemical stream conditions that can be site specific (Montana DEQ 2009a). Both qualitative and quantitative measurements are screened against seven different tests, some of which are directly related to the quality of data reported (Suplee *et al.* 2005). The sampling methods used for the RefPro are particular to Montana’s wadeable streams and require a high level of quality assessment and quality control to ensure that the collected data are credible; and this includes a need for well structured metadata (Lazorchak *et al.*1998; Montana DEQ 2009b; Mathieus *et al.* 2005b; Montana DEQ 2005). The variety of water quality indicators collected for the RefPro demand the use of an integrated database such as STORET/WQX to hold raw data (Montana DEQ Information Management and Technical Services [updated 2010]). For this reason the RefPro provides an interesting case study with regard to metadata quality assessment, because there is such a variety of data collected for the project, making data challenging to describe (Margaritopoulos *et al*. 2008; Park 2009).

RefPro Data Management

The protocol for gathering and structuring metadata for the RefPro is a process unique to the project that combines approaches from the Montana DEQ Quality Assurance Project Plan (QAPP), Sampling and Analysis Plan, and specific contractual agreements with partnering entities such as the University of Montana Watershed Health Clinic (Mathieus *et al.* 2005a; Montana DEQ 2009a; Montana DEQ 2009b; Montana DEQ 2005). Appropriate field forms and chain of custody forms are essential for adequately describing the data being gathered and need to be filled out with consistent language (see Displays 2-5) (Montana DEQ 2009; Bostrom *et al.* 2008). In addition, water quality metric data management at Montana DEQ's WQPB is also a highly defined process where the RefPro dataset (that is initially gathered, see Displays 2-5) is maintained in the local MT-eWQX data system (Montana DEQ EQuIS Water Quality Exchange Support [updated 2010]).

Scientifically valid methodologies for collecting physical, chemical, and biological data are crucial components of planning and managing water quality (Mathieus *et al.* 2006). Long term monitoring has been difficult to sustain, but there have been large strides made recently with regard to the technology available to perform remote sensing, which can digitally record environmental conditions and automatically relay information to a database (Connell and Miller 1984; Turner *et al*. 2001). Also, it is worthwhile to mention that current methods of river classification similar to those used in the RefPro (i.e., Rosgen methodologies for stream classification) are controversial in some geomorphic communities (Snelder and Biggs; Omernik and Bailey; Doyle *et al.* 1999). Nevertheless, these different approaches to water quality planning and research should not have an effect on the way metadata are structured for a given project (Caplan 2003).

Capabilities of the RefPro Dataset

The Montana DEQ is adamant about ensuring that full and complete metadata are made available for all its metric data (Montana DEQ *et al.* 2009). While the Montana DEQ does seek to provide all critical metadata about the data and information they produce to secondary data end-users, potential data consumers such as academia, industry or other stakeholders are responsible for assessing data quality and the appropriateness of data for their business or project needs (Montana DEQ Information Management and Technical Services [updated 2010]; Conservation Technology Information Center [updated 2011]; Foshay *et al.* 2007). Furthermore, the Montana DEQ gathers data for specific project objectives, which are defined in each project's Sampling & Analysis Plan, and they do not have the resources to understand and provide all possible data and information products conceived by interested parties, nor would they be expected to even with available resources (Montana DEQ Information Management and Technical Services [updated 2010]; Lanfear *et al.* 2004; Bryan *et al.* 2009). Even so, the metadata structure used by the Montana DEQ for the RefPro still provides a valid case study for examining how state generated water quality data rates in terms of its reliability, usefulness and relevance, based on the fact that similar frameworks for metadata structure are used throughout the Montana DEQ. By examining the RefPro, there are valuable lessons to be learned regarding interoperability (Montana DEQ *et al.* 2009; Bruce and Hillmann 2004).

RefPro Quality Assessment and Quality Control

Quality assessment and quality control (QA/QC) procedures are critical to establishing integrity for any dataset, and the scale at which RefPro data are collected imposes a need for particularly strict QA/QC measures, which can be done in part by evaluating project metadata (Mathieus *et al*. 2005b; Montana DEQ Quality Assurance Program [updated 2011]; Turner *et al.* 2001; Hughes *et al*. 2005). The practical framework used by the Montana DEQ's WQPB for managing the quality of water quality data collection, generation, and use is referred to as a "quality system" (Montana DEQ Quality Assurance Program [updated 2011]). Within Montana DEQ's WQPB is the Quality Assurance Program that requires all metric data without adequate metadata be rejected "quality data" are defined as those data that enable the end-user to make a timely decision with an acceptable risk of decision error (Montana DEQ Quality Assurance Program [updated 2011]). When determining whether sufficient credible data exist to make a beneficial use-support determination, the Montana DEQ will "score" pertinent data relevant to the particular decision (Mathieus *et al.* 2006). This is done using a numeric and narrative method that accounts for several factors including metadata characteristics of the data (see Tables 3-5) (Modified from Mathieus *et al.* 2006; Mathieus *et al*. 2005b)

SECTION 4 – METHODS OF EXAMINING METADATA

The Purpose of Metadata

Metadata are often defined as “data about data,” and meant to facilitate the understanding, use and management of an individual data item or a collection of data items (Dublin Core Metadata Initiative [updated 2011]; Foulonneau and Riley 2008). There are serious consequences that are associated with inadequate metadata practices (Bruce and Hillman 2004). At the forefront of these concerns is the information content associated with data-this will inevitably change and degrade overtime without proper structural support from metadata (see Figure 8) (Modified from Michener *et al.* 1997). Metadata based on a framework of well characterized descriptions are critical to upholding high quality datasets such as the one that the RefPro maintains, as well as ensuring that datasets are accessible to potential end-users (Foulonneau and Riley 2008).

RefPro Metadata

Illustrated information pathways work best to describe the importance of metadata (Bui and Park 2006; Ma 2007; U.S. EPA Web Guide-Metadata...[updated 2011]). Without an understanding of potential end-users, it is difficult to determine an appropriate metadata structure for a given project (see Table 6) (Modified from Michener *et al.* 1997). The Montana DEQ regularly publishes data and endures audits of its data, which are some of the most critiqued uses of an information resources; moreover, based on Table 6 there is no excessive amount of structure that can occur for a “Level III/publishable and auditable” use of data (Michener *et al.* 1997; Montana DEQ *et al.* 2009; Suplee *et al.* 2005; Montana DEQ 2010b). During the initial construction of a metadata framework, the format (or type) of the metadata has to be in line with audience expectations (see Table 7), the RefPro uses almost exclusively definitional and lineage based metadata structures to convey characteristics of the data (Modified from Foshay *et al.* 2007; Bahls *et al.* 1992; Suplee *et al.* 2005). Additional, and more in depth concepts of format and type can be seen in Table 8, with RefPro metadata fitting into administrative, descriptive and use types (Modified from Baca 2008; Bahls *et al.* 1992; Suplee *et al.* 2005).

Metadata structure is in part determined by data type and structure, because metadata quality assessment is part of the data quality assessment process discussed above. This explains why it is so crucial for the RefPro (and other water quality monitoring projects) to maintain a basic set of metadata attributes regarding structure, characteristics and examples that can describe a wide range of data types (see Table 9) (Modified from Baca 2008; U.S. EPA Data User Corner [updated 2010]; King *et al.* 2005; Lanfear *et al.* 2004). RefPro metadata consist of a large groups of "elements" embedded within files called "Regular Files" or Biological Files" (which are determined by Sampling and Analysis Plans mentioned above) and "descriptive" metadata files (formally known as "application profiles") that stand alone (Montana DEQ STREFPRO 2011a; Montana DEQ STREFPRO 2011b). These metadata do not abide by a specific structural program that is organized to serve on a broad vocational basis (i.e. librarians, ecologists, etc.), but rather are intended to be used by a distinct community of agency personnel (Dublin Core Metadata Initiative [updated 2011]; Fegraus *et al.* 2005; Montana DEQ Information Management and Technical Services [updated 2010]).

Need for this Analysis of Montana DEQ Water Quality Metadata

Overall, this research was performed to try to better understand the way water quality data generated by the Montana DEQ are structured, and how potential end-users are interacting with water quality data. In the interest of examining how well RefPro metadata are organized, the following research was designed to see if end-user community-based conceptual models for metadata could be successfully applied to the RefPro as evaluative frameworks (Bui and Park 2006; Margaritopoulos *et al.* 2008). The RefPro, like many projects in the environmental sciences, has specific objectives and requires a specialized metadata structure or schema (Park 2009; Caplan 2003). Therefore, the following metadata quality assessment compares existing metadata to broadly applicable evaluative frameworks to determine the Montana DEQ's ability to disseminate information, distinguish the value of data from the standpoint of different communities, and to briefly look at the possibility of employing a common metadata structure at the Montana DEQ as a basic schema (Zeng and Qin 2008).

The RefPro is an ongoing project at the Montana DEQ, and being able to preserve the value of its water quality data into the foreseeable future is largely a function of metadata structure (Michener *et al.* 1997). Furthermore, the RefPro is a relatively long-term project, and as such can illustrate for potential end-users (i.e. those stakeholders involved with water quality planning and management) that the value of data resources can vary with their metadata structure over time; this will be addressed by looking at pre-1999 and post-1999 RefPro metadata (Montana DEQ 2010b; Field *et al.* 2007; Michener *et al.*1997). Moreover, although no legal precedent was discovered to indicate poor metadata structure has been used as grounds for dismissing water quality data from a trial, this does not completely discount the notion that metadata could be used as grounds for dismissing data as evidence in a courtroom (Westlaw Research Trail [updated 2011]). Even without this legal concern, there are still significant reasons to develop a reliable metadata structure for internal purposes (Bruce and Hillmann 2004; Land Use Clinic 2009).

SECTION 5 – METHODS

Three Potential Problems Associated With Inadequate Metadata

1. Adequate metadata structure is necessary for all Montana DEQ projects to accomplish their objectives (Mathieus DEQ). Without proper metadata structure, the RefPro would be unable to aid in the development of narrative water quality standards (Suplee *et al.* 2005)
2. If data are not well described and adequately supported by well structured metadata, the value of data will degrade over time as the information resource will be difficult to understand to future end-users (Michener *et al.*1997).
3. Identifying secondary audiences for water quality research, and subsequently applying research and monitoring water quality can present significant challenges for water resource managers (Johnson and Host 2010; Juracek and Fitzpatrick 2003; Field *et al.* 2007).

This study was designed to examine whether data quality assessment and quality control by the Montana DEQ result in adequate metadata “scores” for the “Reference Stream Project” based on the “Bruce- Hillmann Framework” and the “Dublin Core Metadata Element Set” metadata quality assessments. The scope of this work is to serve as an initial analysis of the “Reference Stream Project” metadata using methods of metadata quality assessment that differ from those used by the Montana DEQ. Narrative (not numeric) based metadata evaluative frameworks were used because they are more in line with the procedures employed by the Montana DEQ. There are more technical issues that can arise with regard to computer coded metadata than the three listed above; but, for the purposes of looking at the metadata that Montana DEQ creates for the

"Reference Stream Project," a relatively coarse level of quality assessment was adequate to address the issues (Zeng and Qin 2008).

Three Main Questions Based on Metadata Quality Concerns:

The following questions are based on the three main issues listed above:

Question 1: Is there an adequate metadata structure to support the immediate use of data by the Montana DEQ for the RefPro's intended purpose based on two metadata frameworks for quality assessment?

Question 2: How well will metadata associated with the RefPro preserve data value through time?

Question 3: How can metadata facilitate applying research and data sharing?

Researching Methods for Assessing Metadata Quality

Broadly, four approaches to researching the topic of metadata and water quality data in Montana were used: (1) literature review, (2) harvesting metadata/metadata analysis, (3) interviewing and surveying, and (4) participation in the Reference Stream Project as a field technician for the 2009 and 2010 field seasons. While researching the topic, I noted two issues of interest that relate to the majority of metadata literature to Montana DEQ water quality data: (1) the rise of commonly used metadata has coincided with the rise of the internet, and therefore little literature exists on the topic roughly pre-1995, especially with regard to scientific communities outside of computer science (Caplan 2003; Baca 2008); and (2) metadata and related concepts have been slow to be integrated into the thought process of the natural resource community, but exposure and aptitude for the average non-information/technology savvy natural resource professional seems to be increasing (Fegraus *et al.* 2005; Caplan 2003).

Literature and Web-based Resource Review

This study reviewed the state-of-the art of metadata structure for water quality information, but found ecologically based metadata to be the primary searchable body of literature. Water resource and metadata related journals such as the *Journal of the American Water Resources Association* and *Cataloging and Classification Quarterly* respectively, were among the peer reviewed journals examined. University library systems were also fruitful places to search for information regarding metadata structure, as these systems were some of the first communities to be heavily involved with the use of metadata (Caplan 2003). In addition, professional consultants marketing metadata services provided a business/industry perspective on the value of metadata structure; in some cases these ventures were related to university libraries (Cornell University Metadata Services [updated 2011]). Reviewing of reports and web based information at federal and state water related agencies was a useful process, and was absolutely necessary to acquire the information to complete this study. Reviewing documents produced by the Montana DEQ Water Quality Planning Bureau was particularly worthwhile, as were interviews of agency personnel at the Montana DEQ Water Quality Planning Bureau and the Oregon DEQ. Also, web based searches for water quality related stakeholders in Montana, and examining case studies of joint fact finding for technical information contributed to building the discussion.

Overview of Metadata Analysis Methods

This portion of the methods addresses the types of methods that were used to address the reliability and usefulness of state generated water quality data and methods used to answer Questions 1 and 2. Methodologies for analyzing metadata are varied and approaches differ based on what type of information is being stored as data (Bruce and Hillmann 2004). A variety of "loose fitting" methods for quality assessment do exist and are intended to be applied to a wide range of resources (Foulonneau and Riley 2008; Zeng and Qin 2008). These methods are based on conceptual models that use statistical *procedures* (not tests) and narrative indices for checking the quality of metadata (Park 2009). The purpose of this portion of the study is to evaluate how the Montana DEQ is delineating and describing the water quality data that they are producing. Two metadata standards were employed to assess metadata quality for the RefPro: a "conceptual" metadata approach used by the Bruce-Hillmann Framework (BHF), and the "firm" metadata approach used by the Dublin Core Metadata Element Set (DCMES). These two methods will be described in a later section.

Querying STORET/WQX

STORET/WQX is where data and associated metadata for the RefPro are housed, and made publically accessible. Data are ordered in the database by "organization" and the Montana DEQ maintains nine organizations. However, only two organizations contain data that are owned by the Montana DEQ, meaning that they only assume QA/QC responsibilities for data and associated metadata for those organizations (Montana DEQ Information Management and Technical Services [updated 2010]). "MDEQ_WQ_WQX" is the name of the organization that houses current water quality data, and it is complemented by a collection of historic data collected before 1999, in "MONT_DEQ_WQX." Display 6 illustrates the formal queries submitted to STORET/WQX for all files associated with the RefPro.

Using R to Evaluate Metadata

Once data have been placed in STORET/WQX by the Montana DEQ, the expectation exists that it has undergone all of the QA/QC measures associated with the RefPro's Sampling and Analysis Plan (Montana DEQ Information Management and Technical Services [updated 2010]; Montana DEQ *et al.* 2009). The flowchart in Figure 9 provides a common procedure for managing, curating and storing data in the ecological sciences (Modified from Gotelli and Ellison 2004). The top half of the figure illustrates how this process generally occurs to create a finished product (i.e. the data resource) that is then archived in STORET/WQX. Moreover, in this model which can be viewed as a generalized version of the data management and statistical procedures used at the Montana DEQ, metadata are generated initially, and then are reviewed based on QA/QC procedures to develop an informative structure that is accurate in describing the specific data resource (Montana DEQ Information Management and Technical Services [updated 2010]; Montana DEQ Quality Assurance Program [updated 2011]; Gotelli and Ellison 2004).

As this study was an analysis of RefPro metadata and not RefPro data, the queried files were not thoroughly checked for outliers or specific errors in preparation for a formal statistical analysis. Instead the statistical program "R" was used to look at some conceptual aspects of metadata structure (Bolker 2008). R is a software package used for statistical computing and generating graphical displays; R-commander is a supplemental interface that can run in conjunction with R. R can help organize metadata elements, and create outputs for indices of basic quality assessment (Verzani 2004). One advantage of using R to aid in evaluating metadata is its ability to process large data files, such as those associated with the RefPro, in a relatively short amount of time (Bolker 2008).

R was employed in this study to measure completeness of the RefPro files on an elemental basis, meaning objects (i.e., the values of individual measurements taken in the field) were counted separately for each element (i.e., the measurements being taken in the field). The intention was to quantify the number of absent data values for each element. The process for doing this was as follows:

1. Data were changed from a text format in Notepad to a spreadsheet format in Excel.
2. Appropriate options for converting the file were necessary to be able to use the Excel file in R; the following are options as they appear in Excel:
   (i) text delimited for no spaces (ii) tab delimiter (iii) generally format column data
3. R-Commander received data via the functions: Import → Data from Excel
4. Code was developed using the features: Statistics → Summaries → Count missing objects.

Deciding On Standards for Metadata Quality

Although numeric based frameworks can be used to analyze metadata, as is evidenced by the use of statistical procedure in R, narrative frameworks rooted in the concepts of data description and sharing can be applied to a wider range of data resources and can still act as a common method of assessing data durability and interoperability (Bruce and Hillmann 2004; Dublin Core Metadata Initiative [updated 2011]; Margaritopoulos *et al.* 2008; Park 2009). Other models for quality assessment were considered besides the BHF and the DCMES. Ma (2007) presents results from a survey that gathered information on metadata demand and structure at university libraries in the United States. A spectrum of options for models to use in this study were laid out here, but many of them were not conceptually based and focused on the needs of cataloging and library professionals. Hughes *et al.* (2005) present an example of quality evaluation using open language archives; however, this approach is far more appropriate for metadata in a web-based format. Table 10 illustrates an Ecological Metadata Language (EML) record used by Fegraus *et al.* (2005) to evaluate natural resource based metadata (Modified from Caplan 2003 as retrieved from http://knb.ecoinformatics.org). While similar in format to the DCMES, EML does not encourage the same level of interoperability that the DCMES does and is designed to serve a narrower community of end-users (Baca 2008; Caplan 2003; Zeng and Qin 2008).

Challenges in approaching questions of metadata quality include the fact that new metadata standards are arising quickly; quality standards and measures can be overlooked in metadata creation; and specialist communities who often see their work as unique, frequently resist the notion that there may be strategies available to them that could enable their metadata to interoperate (Baca 2008; Foulonneau and Riley 2004; Zeng and Qin 2008). No one metadata standard can serve every type of dataset; theories and practices differ considerably, because of varying cultural and professional purposes for storing information (Baca 2008). In addition, metadata can relate to more than just the description of an object, they can designate context, management, processing, preservation, uses of the data, and can originate from different sources, experts and non-experts (Baca 2008). For these reasons, two different standards were employed for this study.

RefPro metadata were compared against “conceptual” and “firm” metadata standards. “Conceptual standards” refer in part to a reasoned narrative framework of standards recommended by the BHF. While the DCMES provides “firm standards” to compare the specific elements provided for description in a given Montana DEQ dataset to a set of element types, there is still a conceptual foundation that underlies the fifteen core elements of the of the Dublin Core Metadata Initiative (Dublin Core Metadata Initiative [updated 2011]; Cornell University Metadata Services [updated 2011]).

Bruce-Hillmann Framework Methods

The BHF is an attempt at a systematic, domain- and method- independent discussion of quality indicators for metadata (Bruce and Hillmann 2004). The approach is touted by its creators as being, “pragmatic and managerial, rather than idealistic,” because it is understood that projects like the RefPro operate under resource constraints (Bruce and Hillmann 2004). The primary reason for choosing the BHF for this study is its ability to effectively evaluate information resources across a variety of disciplines (Beall 2005). In addition, Park (2009) acknowledges in “Metadata quality in digital repositories: A survey of the current state of the art,” the refined nature of the BHF and how it emphasizes the use of functional metadata structures. The BHF is based on a set of seven characteristics that are intended to act as places to look for quality in a database-specific schema, and should not be used as a checklist or contribute to a quantitative metadata evaluation (Bruce and Hillmann 2004).

Metadata characteristics that can be isolated using the BHF include: completeness, accuracy, provenance, conformance to expectations, logical consistency and coherence, timeliness, and accessibility. The original BHF is illustrated in Table 11, but is summarized in Table 12 for the purposes of creating a meaningful narrative “score” for each category based on metadata from the RefPro (Both Modified from Bruce and Hillman 2004). The following explanations of the seven characteristics are modified and abbreviated from the framework presented in Bruce and Hillmann’s *The Continuum of Metadata Quality: Defining, Expressing Exploiting*, which was published as a section of Hillmann and Westbrook’s 2004 compilation “Metadata in Practice.” Each characteristic was applied to the metadata queried for the RefPro, and a narrative “score” was produced.

“Completeness” determines whether there is sufficient information quality to answer a given question. The element set should describe the data as completely as is economically feasible, and the element sets should be applied as completely as possible. It is less effective to prescribe a particular set of elements if most of them are never used, because most end-users will expect uniformity across the collection. However, this may improve interoperability by creating a wide range of elements to satisfy the needs of a variety of end-users.

“Accuracy” is defined by whether metadata are factual in the way they describe objects. At a basic level this is determined by whether information provided is correct; and at an advanced level accuracy pertains to the ability to perform high quality editing for typographical errors. In large heterogeneous databases such as the RefPro’s, accuracy may not be directly verifiable, and alternatives to labor intensive inspection may be necessary (this is where R has a variety of potential applications).

“Provenance” relates to the preparer and origin of the resource. This characteristic is based on judgment, experience, as well as expertise of the creator in the relevant domain (here this would be water quality), and general metadata standards. Provenance should also include records about transformations made to the dataset that have occurred over time, detailing whether value has been added or subtracted since the dataset's inception.

"Conformance to expectations" is an indicator of whether the elements are relevant, and are those that an end-user community would reasonably expect to find in a collection. To fully satisfy this characteristic, the end-user community should be considered when developing metadata structure, so as not to include elements that are not likely to be used. In addition, it is recommended that a common and well defined language be used to encourage cooperative standards, rather than an approach that tries to satisfy demands from all end-users.

"Logical consistency and coherence" are particularly important characteristics for collections like the RefPro's, which are joined together over time. The use of standard mechanisms such as application profiles (see Glossary) and common crosswalks (see Glossary) are important for tracking the record of intent over time. An overreliance on computer generated default values for some elements can cause issues with consistency and coherence; and it is within the realm of reason for this to be occurring in RefPro datasets, because there are elements that are populated with objects that have little or no variation between them. This characteristic is crucial for a common and reliable end-user experience to occur.

There are two different aspects of "timelines:" (1) "currency" refers to when objects change, but the metadata do not; and (2) "lag," is when objects are disseminated before some or all of the metadata are made available. Cultural differences among different professions can also contribute to timeliness, and should prompt project teams to not only ask what metadata are good for the end-user, but what structures yield the most utility, the fastest, and over the long term.

Lastly, "accessibility" as a characteristic refers to the ability of metadata to be read and understood by end-users. Physical obstacles to accessibility include technical or organizational barriers where metadata are not directly associated with objects. For example, RefPro files are separated in STORET/WQX by "organization," as well as within the zip files that are delivered from the STORET/WQX query. Intellectual obstacles to accessibility are difficult to overcome, because both objects and elements can be employed by a wide range of potential end-users, and the extent to which data are disseminated can be unpredictable. If a project has a diverse end-user base in mind, there needs to be an interface created for a broad audience, and there should be practice guides and other content rich forms of documentation available.

Dublin Core Metadata Element Set Methods

The DCMES is a basic and universally applicable approach to metadata structure, developed by a committee of professionals in Dublin, Ohio in the mid-1990's and is managed by the "Dublin Core Metadata Initiative" (Dublin Core Metadata Initiative [updated 2011]). It was originally created to be a "catalog card" for networked resources, but has expanded to be able to describe nearly any information resource (Baca 2008; Caplan 2003). DCMES was chosen for this study because it provides an approach to metadata that can be applied across disciplines due to its ability to offer simple and generic resource descriptions that are accessible to experts and non-experts alike (Dublin Core Metadata Initiative [updated 2011]; Baca 2008). Moreover, DCMES was an appealing standard for this study, because it is inexpensive to create and maintain, but can be complimented by other metadata elements or profiles to meet the needs of a particular project or end-user (Baca 2008; Zeng and Qin 2008).

The DCMES, as a standard, allows a quality assessment to look for holes in data based on a set of fifteen elements (see Table 13) (Modified from Dublin Core Metadata Initiative [updated 2011]). These fifteen elements are considered to be the fundamental terms that should be satisfied to create minimally adequate metadata structure (Dublin Core Metadata Initiative [updated 2011]. Their necessity can be best understood by placing the terms in specific groups (see Figure 10) (Modified from Zeng and Qin 2008). Tables 14-16 are lists of elements reported from three different files queried from STORET/WQX. They were used to identify one “robust” element that exemplified a given term, for as many of the fifteen DCMES terms as could be satisfied. This approach to using the DCMES was taken because the categorization of elements into term groups is subject to a certain degree of interpretation, and some elements could satisfy more than one category (Dublin Core Metadata Initiative [updated 2011]; Caplan 2003; Foulonneau and Riley 2004). Furthermore, attempting to populate the fifteen terms of the DCMES with the complete list of all elements from each RefPro data file would not have been possible. Some elements in the RefPro data files were not completely populated by objects, thus their meaning or context could not be completely deciphered; this is noted as having a negative contribution in the “scoring” process in the sub-section below “Using R to Evaluate STORET/WQX Metadata.”

Overview of Stakeholder Survey Methods

This portion of the methods describes methods used to answer Question 3 by examining the utility and political/social relevance of state generated water quality data, based on a survey that tried to address the relationship between water quality stakeholders, and the data resources generated by the Montana DEQ. The survey was primarily designed to provide insight into how water quality stakeholders are organized in Montana (Frey *et al.* 1991). Combining the methods used in the metadata analysis (the primary purpose of this study) with looking at social aspects of water quality data, had the intention of allowing issues regarding water quality data to be approached from the perspective of water quality data producers as well as end-users in various watersheds in Montana (Foshay *et al.* 2007).

Water quality stakeholders are entities that inherently require certain types of water quality information to operate (Montana Watershed Coordination Council [updated 2011]; (Conservation Technology Information Center [updated 2011]; Montana Watercourse 2009 annual report [updated 2011]). Watershed groups that are members of the Montana Watershed Coordination Council (MWCC), provided an actively engaged stakeholder group focused on water quality in Montana to survey (McKinney and Harmon 2004; Susskind *et al.* 2005; Montana Watershed Coordination Council [updated 2011]). The MWCC is a statewide information and support network created to advance local watershed work (see Displays 7 and 8) (Modified from Montana Watershed Coordination Council [updated 2011]; Montana DEQ 2010b).

An organizational survey (see Display 9) was designed to capture how watershed groups involved with Montana Watershed Coordination Council are interacting with the

Montana DEQ and state generated water quality data (Frey *et al.* 1991). Surveys were distributed to watershed coordinators via email over the course of six weeks.

The survey was also conducted to better understand the potential that metadata structure has to increase accessibility of state generated water quality for stakeholder groups outside of the Montana DEQ (Foshay *et al*. 2007; Frey *et al.* 1991). Sharing information and encouraging collaboration in natural resource disputes, particularly those related to water in the Western United States, can be difficult (Rofougaran and Karl 2005). Strategies can vary to obtain technical information that collaborative groups need; the MWCC is a forum related to consensus building that is capable of engaging in the process of "joint fact finding" (Montana DEQ 2010b; Karl *et al.* 2007). This also made the member watershed groups of the MWCC a viable target response group for the survey (Frey *et al.*1991).

SECTION 6 – RESULTS

Query of STORET/WQX for RefPro Data

Querying STORET/WQX yielded five raw data files for the RefPro. Two files were produced from the pre-1999 sampling done for the project: one “Regular File” and one “Metadata File” (also known as an application profile). Three files were produced from post-1999 sampling done for the RefPro: one “Regular File, one “Biology File,” and one “Metadata File.” Based on the RefPro Sampling and Analysis Plan there is the possibility that there should have been a “Habitat File” included, but the shift from STORET to WQX may have eliminated querying potentially empty files (Montana DEQ 2009a; Montana DEQ 2009b; Montana DEQ Information Management and Technical Services [updated 2010]). When initially queried, all files are presented in a text file format. The Regular and Biology Files contain field measurements, and metadata elements are located within these files. The Metadata Files are application profiles and serve as the way that the Montana DEQ (a specialized community) interacts with the greater community of those who use metadata (Baca 2008). Displays 10 and 11 contain abbreviated versions of the metadata records (also known as application profiles) queried from STORET/WQX for the pre-1999 and post-1999 RefPro data (Modified Montana DEQ STREFPRO 2011a; Montana DEQ STREFPRO 2011b). Not all entries were included, and the entries that are displayed are either common between Montana DEQ projects or are specific to the RefPro. The application profiles in Displays 10 and 11 have missing values that are not justified with any explanation of why an entry is omitted. This in turn contributes negatively during the “scoring” process. Also, abbreviations and other open-ended language are used throughout, but are not explained by any defined language; this also has a negative impact during scoring.

An Evaluation of STORET/WQX Metadata by R

Importing the raw data into Excel and then into R were major victories for this study. It allowed the metadata to be sorted and examined in an easy to use format. Completeness was the only variable from the BHF or the DCMES that was measured using R, and did not contribute extensively to the completeness term analysis when applied to the BHF. Displays 12-14 contain the R code and the output for the pre-1999 Regular File, post-1999 Regular File, and the post-1999 Biology File. Each series of code entered in R illustrates how to find out the number of missing objects for each element; each element is listed above its respective number of missing entries. The important point to recognize here is that the pre-1999 structure supported a much more completely filled in set of elements, than the post-1999 structure, probably because there were fewer elements to satisfy in the pre-1999 framework (i.e., fewer measurements were being taken in the field at the time). Additionally, as noted above many elements in all RefPro files are not completely populated by objects, and the extent to which this is occurring can be gauged based on the output from R that gives a numeric value for the number of missing objects for each element. These objects could have been omitted for either of two reasons: one, data was accidentally omitted during entry in the field or during electronic entry, or two, the element (i.e. the field measurement, in the case of the RefPro) did not apply to the site being sampled (i.e. the reference stream, in the case of the RefPro).

Bruce-Hillmann Framework Analysis of RefPro Metadata

The application of the BHF allowed the post-1999 Regular and Biology Files to be analyzed together. Using the standard produced a narrative analysis that can be viewed in Tables 17 and 18 for the pre-1999 RefPro metadata and the post-1999 metadata respectively. These tables serve as the formal results for the narrative scoring process and present direct questions and answers regarding quality criteria for each metadata characteristic as well as where to locate the criteria indices among documents associated with the RefPro metadata.

Dublin Core Metadata Element Set Framework Analysis of RefPro Metadata

As previously mentioned, an initial examination of the Regular and Biology Files yielded “element reports” displayed in Tables 14-16 for the pre-1999 Regular File, the post-1999 Regular File, and the post-1999 Biology File respectively. Similar to the BHF standard, applying the DCMES allowed files to be grouped together for analysis, because there was significant overlap between the Regular and Biology Files for the post-1999 data. When applied to the element reports and the Metadata Files, the DCMES evaluative framework produced Tables 19 and 20 for all pre-1999 files and all post-1999 files respectively. A robust (i.e. exemplary) element was selected from an element report (see Tables 14-16), and is listed next to the given file name(s) from which it was drawn.

Results of Survey of Potential End-users of Montana DEQ Water Quality Data

Responses to the organizational survey are presented in two ways. Questions 1-5b were “yes or no” questions and were quantified and are presented in Table 21. For the extended response questions (5c-8), relevant and interesting quotations were chosen from those provided by respondents and are presented in Display 15. Survey responses were received from 24 of 39 watershed groups who were asked to participate.

Display 15 presents a mixed message from respondents regarding use of water quality data from the Montana DEQ, ease of use of that data, and what additional information resources would be beneficial. It seems that while some groups are relying on technical advisors to understand information, others are relying on the Montana DEQ to provide technical assistance and interpret which water quality data are appropriate to use. Across the board, responses indicated that watershed groups are trying to use water quality information that the Montana DEQ creates, but the ease-of-use responses for database accessibility varied from “easy enough” to “very difficult.” While some respondents seem quite satisfied with the interactions occurring among water quality stakeholders, the following response illustrates the level of frustration that can occur among those involved with managing water resources:

> If you want to address a real problem you need to get DNRC and DEQ together and have one of them in charge of Montana Water. DNRC is interested in Quantity and keeps allowing "exempt wells" even in closed basins while DEQ is interested in "quality" while the availability is being reduced. You also might help these folks fund the Ground Water Information Program (GWIP) so we can have, at least, some idea how much ground water is available in these closed basins before DNRC gives it all away. Water quality becomes meaningless when there is no water!

Multiple respondents offered an opportunity to squelch confrontation, and promote constructive dialogue, by expressing their demand for a centralized location to access information. Essentially, this would enable all stakeholders involved with the management of water quality in a particular basin to be on the same page regarding what information is available to them.

Respondents also indicated that they are knowledgeable about, "…raw data out there that goes beyond the TMDL's and 303d lists…," and how they would appreciate having this information made available to them through a single interface. So, while it appears that TMDL related information is more immediately relevant to watershed groups, data from the RefPro would also be of interest, and even possibly helpful in planning. In addition, respondents articulated a need for more consistency between datasets as well as increased types of data such as temporal, spatial, and pollutant specific (i.e., heavy metals, pharmaceuticals, personal body care products, etc.) information. As water quality databases are set up now by the Montana DEQ, end-users may need to sift through multiple data repositories to query the right information. Also, respondents recognized the cost of acquiring water quality data, and as a result it seems they understand why it is crucial to build working relationships with the Montana DEQ and collaborate with stakeholders in seeking the appropriate technical information to plan for and manage water quality.

SECTION 7 – DISCUSSION

How RefPro Metadata Scored Based on the Bruce-Hillmann and Dublin Core Metadata Element Set Frameworks

Application of these two standards suggested that the RefPro data are described well and deserve an overall positive "score" for their intended purpose. The two analytical standards clearly conveyed that the objects describe the field measurements taken at the reference streams, and the elements selected for the RefPro illustrate the stream project as a whole (Zeng and Qin 2008; Foulonneau and Riley 2004; Hughes *et al*. 2005). However, even with the adequate narrative metadata scores provided in Tables 17-20, improvements can be made in the metadata if for no other reason than metadata concepts are evolving rapidly (Zeng and Qin 2008).

Question 1 asks: is there an adequate metadata structure to support the immediate use of data by the Montana DEQ for the RefPro's intended purpose based on two alternative frameworks? Results from the application of the BHF and the DCMES found that, based on these standards, Montana DEQ provides more than adequate fundamental metadata structure to support the immediate use of RefPro data by the Montana DEQ. Both standards were able to be completely applied to the RefPro metadata, and all characteristics scored well. The only glaring omission that was discovered from use of the BHF was the lack of basic standards documents such as explanations of vocabularies that should accompany best practice guidelines for data management, and exemplary templates for how metadata are created. Without these files, the RefPro data are missing information that could benefit monitoring, data preservation, and data sharing (Fegraus *et al.* 2005; Shreeves *et al*.2006).

Question 2 asks: how well will metadata associated with the RefPro preserve data value through time? Data are often best protected from decay by including a highly descriptive “Data Content Standard” as part of the metadata structure. This gives end-users the opportunity to look up reasons for discrepancies in the data, have terminology explained, or simply to read about the general metadata framework being used for the dataset. Results from the application of the BHF and the DCMES research found that, the data files associated with the RefPro in STORET/WQX from pre-1999 and post-1999 are not equal in terms of their metadata structure, meaning that fewer elements are made available to be populated for the pre-1999 file than the post-1999 files. In addition, the pre-1999 Metadata File (application profile) is less extensive in what it describes about the RefPro than the post-1999 metadata file. This is most likely because fewer measurements were being taken in the field during the pre-1999 years of the RefPro. Unfortunately, even if this is the case, no documentation exists to bring these older data up to current standards used in the post-1999 files. As a result there may be issues preserving or assessing their value through time. Moreover, drawing distinctions between pre-1999 metadata and post -1999 metadata only provides a snapshot of variation over time. Elements currently required to describe the array of measurements taken for the RefPro will inevitably change again, whether because of fluctuations in project resources or some other reason(s) related to project objectives. If metadata structure is not improved with more descriptive documents detailing the contents of an older dataset to support changes and discuss variations that have occurred through time, the context and value of older data can be lost (Michener *et al*. 1997). Furthermore, since metadata concepts are evolving rapidly, it is difficult to draw too many conclusions when comparing pre-1999 and post-1999 files (Caplan 2003; Bui and Park 2006).

As seen in Tables 19 and 20, there are significant differences in the way that pre-1999 and post-1999 metadata match up with the “firm” metadata standard provided by the DCMES. In the pre-1999 analysis, more DC-Elements were satisfied by the Metadata File than by actual reported elements from the Regular File; and in the post-1999 analysis, one can see that the Regular and Biology Files satisfy the majority of DC-Elements, and do not rely as heavily on the Metadata File to perform simple descriptions of elements. This indicates that pre-1999 files may be relying too heavily on the use of an application profile to describe the data, which can potentially be confusing for end-users as core elements are generally expected to be embedded within the files that contain the objects (Baca 2008).

Based on the DCMES standard, some robust elements (i.e., elements that portray the DC-Element well) exist in both the pre-1999 and post-1999 files, which are indicative of a set of variables that are readily available to be analyzed (Baca 2008). Moreover, metadata elements are a static structure, but only temporarily static, because they can change based on project priorities, available resources and other outside influences that impact project design (Dublin Core Metadata Initiative [updated 2011]; Bui and Park 2006; Montana DEQ Information Management and Technical Services [updated 2010]). The pre-1999 metadata, for reasons most likely related to the RefPro being in its initial stages of development, are not nearly as well populated with elements as their post-1999 counterparts (Bahls *et al.* 1992).

The BHF (see Tables 17 and 18) provides an excellent standard for the Montana DEQ to use in trying to build a common set of metadata elements and types. It has the structure needed to capture the crucial aspects of a metadata configuration and the flexibility to handle the large volume of information present in project data files such as those found in the RefPro. It would seem that while the BHF provides an excellent resource for most any data resource, the DCMES has fewer applications as a metadata standard for ecologically relevant data resources such as the RefPro (Park 2009; Caplan 2003). The RefPro is a project that has a relatively high level of complexity with regard to the elements (i.e. field measurements at different streams) needed to describe the data objects (recorded information). And even though the DCMES has 15 term elements to satisfy and can act as a good standard for some types of data; in comparison to the BHF, which is based on seven *conceptual* metadata characteristics, it is too simplistic to assess the quality of metadata for a project such as the RefPro. Even so, the DCMES was preferred when comparing the pre-1999 and post-1999 files, because it produces results that are based on less interpretation of the metadata than the BHF. The DCMES is either satisfied by existing metadata, or it is not, the results from the BHF are not as clear cut, and do not lend themselves to the same type side-by-side comparisons that the DCMES standard does.

The “conceptual” standard formed predominantly by the BHF and partly by the DCMES revealed areas where the Montana DEQ can improve the way it relates data to specific projects or end-user requests (Bruce and Hillman 2004; Bui and Park 2006; Margaritopoulos *et al*. 2008). Some metadata specialists argue that: “specialists tend to consider only the attributes that matter to them, neglecting those that make their data more useful to dimly imagined, and hence easily dismissed, groups of outsiders" (Bruce and Hillman 2004). Even though the RefPro is a government project, and therefore a public resource, there is still a culture among many data managers to avoid sharing internal practices and material for others to use. In addition, it is not unusual for projects to not budget time or resources for metadata documentation for internal purposes, much less external purposes (Bruce and Hillman 2004; Baca 2008). Isolation and specialized solutions can create barriers for coordinated thinking about metadata quality and other resource issues (Baca 2008). In Montana, there are examples of where interoperating has been a large part of collaborative ventures, and demands for data from future projects, especially collaborative projects, simply cannot be predicted (Montana Consensus Council 2002).

Encouraging widespread approaches to water quality management across communities can promote practical solutions to cross-discipline issues (Environmental Information Exchange Network [updated 2011]; MIT-USGS Science Impact Collaborative 2009). One way of doing this is by encouraging "interoperability" among stakeholders; which is a conceptual initiative that adds significant value to datasets via metadata structure (Baca 2008). Though data are usually generated for a specific purpose, that dataset can still have potential value beyond that immediate purpose; therefore, it would seem worthwhile to reinvest in "curating metadata" to keep datasets valuable and relevant well into the future (Foulonneau and Riley 2004). An estimated cost of how much "reinvesting" could add to the Montana DEQ's "data management budget" was not acquired for this study; however, hiring, training, or paying an hourly wage to personnel with the appropriate skills would most likely be a significant expense for a state agency already under tight fiscal constraints.

Creating interoperability is expensive, and for an agency such as the Montana DEQ, quality that serves unspecified projects is what Bruce and Hillmann (2004) would refer to as an ”unaffordable altruism.” Moreover, in addition to any self-directive to encourage interoperability, projects like the RefPro have to contend with a high rate of change in technology and metadata standards (U.S. EPA Office of Environmental Information [updated 2010]). However, while it is not the responsibility of the primary project entity to ensure that all possible uses of the data are supported, it is to the Montana DEQ’s advantage to encourage public involvement in water quality management in any way they can (Montana DEQ Information Management and Technical Services [updated 2010]; Rofougaran and Karl 2005; Kohler and Hubert 1999)

By providing metadata elements based on a standard structure, similar to the 15 core elements in DCMES, moving data between computer software programs can take place more easily, and encourage end-users to perform self-directed analyses of objects of interest (Shreeves *et al*.2006; Dublin Core Metadata Initiative [updated 2011]). This may be particularly important for watershed groups trying to do basic analysis of local water quality data (Conservation Technology Information Center [updated 2011]; USGS Science in Your Watershed [updated 2011]). Despite resource constraints at agencies like the Montana DEQ, recent developments in electronic interfaces such as the Montana Natural Resource Information System and the rise of the Environmental Information Exchange Network, are promising advances in terms of enabling water quality data to reach a wider audience of potential end-users and stakeholders (Environmental

Information Exchange Network [updated 2011]; enfoTech & Consulting 2005; Foshay *et al*. 2007).

Organizational Feedback Survey Discussion

Integrated Resource Management-Connecting Managers and Stakeholders

The RefPro has specific purposes for the data it collects, and it may not necessarily be the type of information that watershed groups would be interested in using (Montana Watercourse Guide to Montana water management 2011). However, the metadata structure used for the RefPro is a fairly common set of criteria used across water quality projects at the Montana DEQ. Therefore, this study has not asked the RefPro data to “be all things to all people" interested in water quality, but considered how metadata can increase usefulness of data to more end-users (Montana DEQ *et al.* 2009). Moreover, it is important for natural resource managers to build connections between research priorities and information that is in demand from stakeholders involved with applied water resource management (Kohler and Hubert 1999).

Question 3 asks: how can metadata facilitate applying research and data sharing? Metadata can help facilitate applying research and data sharing by providing end-users with well developed metadata with sufficient descriptions of the water quality data that help them understand exactly what a dataset contains (Foshay *et al.* 2007). Based on responses to survey questions 1-5b (see Table 21), the majority of watershed groups revealed that they do all of the following: (1) use water quality data in decision making processes, (2) communicate with the Montana DEQ, (3) use a technical advisor to gather water quality data, (4) use the process of “joint fact finding” or collaborate with other stakeholders, and (5) are aware of, and use water quality data generated by the Montana

DEQ. These responses are indicative of the enormous potential for the MWCC to continue to act as a forum for watershed groups and other water quality stakeholders in Montana, as well as to implement best practices for and engage in joint fact finding with the Montana DEQ to develop relevant water quality information (see Display 16) (Modified from McKinney and Harmon 2004).

In general, if water quality metadata are scored favorably, water quality data end-users will have an easier time gathering and using water quality data (Lanfear *et al.* 2004; Shreeves *et al*.2006; Foulonneau and Riley 2004). Also, it is crucial for the Montana DEQ to encourage public participation from water quality stakeholders in a constructive forum, and metadata can help facilitate discussions regarding available water quality information (Montana DEQ 2010b; Lanfear *et al.* 2004). Water resource managers need to communicate with constituents just as any natural resource manager does, and metadata structure is one pathway of communication that can improve working relationships among stakeholders (Shepard *et al.* 2011; Fegraus *et al.* 2005).

The Montana DEQ has initiated efforts to help stakeholders understand the TMDL planning process and other aspects of water quality management (Montana DEQ 2007; Montana DEQ 2010b). Nevertheless, based on selected survey responses (see Display 15) the MWCC can continue to act as an effective mediating force between the Montana DEQ (i.e. data generators, inspectors, and primary end-users) and water quality stakeholders (i.e., secondary consumers of the data) to improve their relationship (Montana DEQ 2010b). Collaboration and consensus building are both two way streets (MIT-USGS Science Impact Collaborative 2009). Therefore, the Montana DEQ and water quality stakeholders need to engage each other, but the responsibility to provide education and technical assistance to stakeholders must be the charge of the Montana DEQ (Matso *et al.* 2008; Montana DEQ 2010b). If the Montana DEQ can improve metadata structure to facilitate interoperability, they can make the sharing of water quality data increasingly possible for a growing number of secondary end-users (King *et al*. 2005; Lanfear *et al.* 2004). Furthermore, metadata structure can be used to support web-based interfaces that provide statistical summaries of water quality data; in turn these summaries can help make water quality data more understandable for non-expert end-users (Baca 2008).

Integrated Resource Management-Joint Fact Finding

Well defined forums and procedures create high-quality decision making processes, which then result in the best quality science being used (Kohler and Hubert 1999). Joint fact finding is a process that integrates science and policy; it is intended to produce a package of technical information that is: scientifically credible and socially/politically relevant/useful (Amengual 2010). As environmental resources become more intensively managed, public involvement in natural resource management must continue to increase, and joint fact finding is a way to encourage this (Kohler and Hubert 1999; Montana DEQ Nonpoint Source Program [updated 2011]). Web-based technologies supported by well developed metadata structures can increase public participation in environmental decision making processes and make joint fact finding easier (Yao 2006). In turn, by creating a prescriptive joint fact finding process that is developed for a specific natural resource conflict, adaptive management becomes far easier and promotes better resource management through integrated approaches (Matso *et al.* 2008; Watson 2011).

Oregon DEQ and the Pacific Northwest Water Quality Exchange

Like the Montana DEQ, the Oregon DEQ, has many projects that collect a wide range of data that create a blend of datasets under one water quality domain (Mrazik 2009; U.S. EPA Pacific Northwest Water Quality Data Exchange [updated 2009]). Also, like the Montana DEQ, the Oregon DEQ also has a “Reference Stream Project,” which collects, checks and stores water quality data much the same way that the Montana DEQ does for its RefPro (Drake 2004; Cude 2001). The web-based data retrieval tool used by the Oregon DEQ is outdated and not relatively accessible to secondary end-users compared to some applications on the internet (Environmental Information Exchange Network-Pacific Northwest Water Quality Data Exchange [updated 2010]). Furthermore, technological advances have established a certain expectation from the general internet user, and since the Oregon DEQ stores raw data, their data architecture currently does not accommodate an online retrieval tool that is simple (Pacific Northwest Water Quality Data Exchange 2005).

The Pacific Northwest Water Quality Exchange is a contemporary example of how improved data management and metadata structure can begin to serve the demands and needs of applied water resource managers (Pacific Northwest Water Quality Data Exchange 2005). Through the use of a common metadata schema, data submitted to the Pacific Northwest Water Quality Exchange are organized in a similar format which makes submitting queries to the data exchange straightforward, for a broad base of end-users (Pacific Northwest Water Quality Data Exchange 2005). When data are submitted to the Pacific Northwest Water Quality Exchange, they are all uploaded using the same guidelines, so when data arrive in the database, they are all uniform in structure and are able to be queried and manipulated using fairly simply functions from web-based interfaces or software packages. For these reasons the Pacific Northwest Water Quality Exchange has the potential to help the Network of Oregon Watershed Councils (NOWC, a collaborative effort similar to the MWCC), and other water quality stakeholders in participating states (e.g., Alaska, Idaho, and Washington) (Network of Oregon Watershed Councils [updated 2011]). The NOWC, like the MWCC can be viewed as a model for the country and the world in terms of their ability to use joint fact finding to build consensus regarding water resource disputes (Network of Oregon Watershed Councils [updated 2011]; Montana Watershed Coordination Council [updated 2011]). And with the use of interfaces supported by well structured metadata, joint fact finding can be increased and made easier. The Pacific Northwest Water Quality Exchange, is an advanced project in data sharing, but is not the standard for interoperability. As more states and regions begin to see value in integrating information resources, there will probably be an increased number of projects like the Pacific Northwest Water Quality Exchange.

SECTION 8 – CONCLUSIONS AND RECOMMENDATIONS

Conclusion

Answers are provided below for the three questions raised by this thesis:

Question 1: Based on the BHF and DCMES standards, it seems that adequate metadata structure is in place to support the immediate use of data for the RefPro's intended purpose by the Montana DEQ. From the standpoint of other standard frameworks or purposes, no conclusions can be inferred.

Question 2: Based on the BHF and DCMES standards, it was found that the pre-1999 and post-1999 data associated with the RefPro in STORET/WQX are not equal in terms of their metadata structure. This made it difficult to compare data from the two different eras.

Question 3: Well designed metadata can help to facilitate applying research through data sharing thereby making joint fact finding more efficient and end-user friendly.

Successful natural resource management and conservation practices depend on documenting the social aspects of the natural resource issues (Mascia *et al.* 2003). This study was designed with the purpose of not only examining issues regarding water quality data storage, but also the public's use of water quality data. Metadata structure is a strategy to make data more understandable and useful, provide data descriptions and relay any data discrepancies that may exist. As citizen involvement in water resource management increases, the demand for water quality data in Montana will also most likely increase.

Even though metadata “scores” for the RefPro are good based on the two standards, this still does not support the notion that watershed groups are being properly informed. Montana’s Department of Environmental Quality has many public servants who are committed to engaging water groups and other water quality stakeholders. As water resource use intensifies in the future, developing inclusive processes to connect these stakeholders to planning and management processes is crucial to generating positive outcomes. These outcomes, positive or not, are reflected in the water quality in lakes, rivers and streams, and also in the policy based decisions that are made.

Recommendations

Based on the findings from this initial search, a further investigation into the problem would track metadata over long periods of time since the RefPro is an ongoing project. Future work should also look at the potential for the Montana DEQ to create a formal narrative of their metadata structure. This would be a valuable resource for two primary reasons: (1) it would ensure that there is always a reference for metadata structure through time, and (2) could push the concepts of ecological metadata forward and improve resource management by making monitoring and data sharing easier. Metadata frameworks vary, and a database specific option can be selected or developed, but it should contain a set of universal attributes to facilitate interoperability for potential end-users.

Increasing metadata structure can in turn facilitate joint fact finding among a diverse group of stakeholders in Montana by fostering their ability to collaborate and share information. As a seasonal technician for two summers with the Reference Stream Project, I was educated on the specific purposes for the measurements being taken. Still, I believe that because the data gathered are so resource intensive to acquire, the Montana DEQ should broadcast these data to as many potential end-users as possible. Particularly since there is such a well developed cohort of stakeholders in the Montana water quality management community that are willing to participate in planning and managing water quality.

Recommendations for Montana DEQ:

1. Based on the results from comparing RefPro metadata against the BHF and the DCMES standards, the Montana DEQ should more directly address the methods they use for developing metadata in a "Data Content Standard." This should be done in order to: (1) track information over time, (2) prepare metadata to contribute to a wider audience of end-users, and (3) to help end-users better understand the value of data at a glance. The current standard is not explained clearly enough and does not lend itself to be understood to many outside of the Montana DEQ. Also, developing consistency between datasets generated by the Montana DEQ was a concern of some respondents to the survey and can be made possible through developing metadata schemas that are in-part built on a universal structure that can be moved from one project to another. This would still allow for specific project parameters to be recorded using an application profile or other "basic standard document."

2. Consider increasing input from water resource stakeholders when determining research priorities and develop metadata structure to be inclusive of constituents. Without knowing what information each watershed group needs to be successful, a management plan really has no direction. By developing a common metadata schema, watershed

groups and other stakeholders could potentially be interacting more efficiently with information that the Montana DEQ generates.

3. Increase data interoperability by building an interactive regional database like the Pacific Northwest Water Quality Exchange. Again, through the use of a common metadata schema as a template for sharing data, information can be broadcast and shared freely. This also may help to encourage participation in water quality management, if stakeholders are given the proverbial “reins” over *how* they seek out technical information. This could be a “one stop shop for state data,” that makes information on a variety of water quality indices available from all state agencies. This was a recommendation provided by multiple respondents to the survey (see Display 15). Based on survey responses it seems that watershed coordinators are being relied on heavily to interpret technical information, but by making technical information more interactive in a web-based “point-and-click” format the ordinary internet user (or watershed group member) could participate in the process of joint fact finding. Therefore, they could hopefully take more ownership of the water quality management process. The Montana Natural Resource Information System (NRIS) does provide a web-based user-friendly clearinghouse for many kinds of natural resource data; however, water quality data is not made available via NRIS.

4. Refine metadata quality assessment methods by standardizing them further, possibly by linking them to an established community of metadata professionals. One again, this would accompany the building of a metadata schema that is based on providing a common end-user experience.

Recommendation for data consumers (stakeholders):

1. Be critical of how natural resource data are stored and described.

2. Objectively consider the role of the researcher in the process of joint fact finding. Montana DEQ personnel are aware of their role in providing technical assistance, but also certainly have a firm grasp of agency priorities as dictated by the law and policy. They have two needs to satisfy, one internally at the agency, and one externally for the public

3. Be constructive when trying to engage the decision making body, and articulate information and data needs. The Montana DEQ is resource limited and does not have the ability to monitor every basin; they need direction with regard to where water quality issues are arising.

4. Support adequate funding of the Montana DEQ water monitoring and data management programs.

5. The Montana Watershed Coordination Council holds educational workshops for watershed coordinators several times per year. Workshops on water quality data collection, and particularly storage and sharing would be helpful in preparing watershed coordinators to better use Montana DEQ data. As approaches to management and planning evolve, it will most likely become increasingly important for natural resource stakeholders (water quality included) to be given the technical assistance to able to use electronic data and information resources.

GLOSSARY

303(d) list: under section 303(d) of the 1972 Clean Water Act, states, territories, and authorized tribes are required to develop lists of impaired waters

305(b) water quality integrated report: this document characterizes water quality, identifies widespread water quality problems on a state-by-state basis, and describes various programs implemented to restore and protect waters

Accessibility: a metadata characteristic; refers to the ability of metadata to be read and understood by end-users

Accuracy: as a metadata characteristic; refers to whether metadata are factual in the way they describe objects

Adaptive management: a process for administering the governance of a resource with the use of a flexible approach that can change as issues or demands change

Application profile: is a set of metadata elements, policies, and guidelines defined for a specific dataset

Basic Standards Documents: literature associated with metadata that often refer to the framework used to structure metadata

Beneficial Use Determination: gauging the extent to which a water body is impaired to evaluate which valuable uses of the water resource can still take place

Bruce-Hillman Framework: a metadata standard used to assess the quality of metadata structure

Coherence: a metadata characteristic; the ability of information to be understood based on its logic, order and consistency

Common crosswalks: digital pathways that allow information resource end-users to share data or other information

Completeness: a metadata characteristic; explains if there is sufficient information of a certain quality to answer a given question

Conceptual standards: evaluative frameworks that are narrative based and do not refer to specific metadata elements

Conformance: a metadata characteristic; refers to whether elements contained in a metadata structure are relevant to potential end-users

Consistency: a metadata characteristic; the same throughout in structure or composition

Clean Water Act: the primary federal law in the United States governing water pollution

Clean Water Act Information Center (CWAIC): an end-user friendly interface used to find information about the quality of Montana's rivers, streams, lakes and wetlands in relation to Montana's Water Quality Standards

Curating metadata: the act of organizing and maintaining metadata

Currency: an aspect of the metadata characteristic of timeliness; the property of belonging to the present time

Data Content Standard: rules that determine the vocabulary, syntax or format of content entered into data fields or metadata elements (Baca 2008)

Data governance: relates to decisions that define expectations, grant power, or verify performance when managing data

Descriptive metadata: information describing the content of a data resource

Dublin Core Metadata Element Set (DCMES): a metadata standard developed by the Dublin Core Metadata Initiative to promote interoperation of data resources; also can be used to assess the quality of metadata structure

Durability of Use: whether an information resource can endure through time

Ecological Metadata Language (EML): a metadata structure developed for use in the ecology discipline

Element profile (see DCMES analysis tables): a report of the elements included in a metadata scheme

End-user community based conceptual models of metadata: methods of structuring metadata, which are designed with a specific community of data end-users in mind

Evaluative Framework: a metadata standard for quality assessment

Firm standards: evaluative frameworks that are based on reporting elements present in a given metadata scheme

Governance (top down and ground up): a top down management process does not encourage citizen input, and reflects the decision making authority of an individual or select group in charge; a ground up management process allows input from citizens when making decisions

Interoperability: the ability of information to be readily shared between end-users

Joint fact finding: an inclusive process used in natural resource governance to aid in resolving disputes; used as part of a consensus building process

Lag: an aspect of the metadata characteristic of timeliness; refers to delays in information transmission between network nodes

Metadata: encapsulates the information that describes any document or object in both digital and traditional formats

Metadata attributes: specific qualities of a metadata schema

Metadata element (as used in database management): an individual division of a metadata structure or schema, which contains a particular category of information that relates to the information resource; for example, “Organization ID,” which could describe the creator of the data

Metadata element type: a categorization of individual metadata elements into groups to aid in organizing a schema

Metadata scheme: a rational structure of Metadata features that makes the organization of data attributes, and the entry of data easier for end-users

Metadata score: a numeric or narrative rating of the value of a metadata structure based on a comparison of that structure to a standard

Metadata standard: framework used to assess the quality of metadata

Metadata term (with regard to the DCMES): a term is an element or a qualifier from a controlled vocabulary maintained by the Dublin Core Metadata Initiative

Montana DEQ: the state environmental agency in Montana that plans and manages air and water quality

Montana DEQ Water Quality Planning Bureau (WQPB): is the division within the Montana DEQ that is responsible for maintaining and improving water quality so that state waters can support their beneficial uses

Montana Natural Resource Information System: also known as “NRIS,” this wide-ranging program is used to acquire store, and retrieve existing natural resource data in the state of Montana

Montana Volunteer Water Monitoring Project (MVWMP): focuses on teaching water quality and water monitoring procedures to citizens in order to provide them with technical assistance so that they can make knowledgeable decisions about local water quality issues

Montana Watershed Coordination Council (MWCC): is a collaborative effort made up of governmental and non-governmental stakeholder groups that are involved with the management of water quality on a basin wide scale

Montana-eWQX: is the chief storehouse for water quality monitoring data in Montana; includes physical, chemical, and biological data from various projects across the state

Objects (target or information objects): a resource in storage, such as a field measurement in a dataset, which can be addressed and manipulated as a discrete entity; it is made up of content, context and structure

Pacific Northwest Water Quality Exchange: includes a collection of related information management projects that collectively seek to facilitate the aggregation of and access to a comprehensive source of data related to water quality in the Pacific Northwest (Pacific Northwest Water Quality Data Exchange 2005)

Potential end-user: a possible consumer of an information resource

Primary end-user: is the consumer for which an information resource was chiefly designed

Provenance: a metadata characteristic; a record of the source of an information resource that can include a historical record

Quality Assessment: refers to a plan for the orderly examination and monitoring of different aspects of a project

Quality Control: a process by which the value of all factors involved in the production of an information resource are reviewed

Reference Condition: a benchmark state of a water body, usually a stream, used to gauge the health of potentially impaired waters

Reference Stream Project (RefPro): an ongoing study at the Montana DEQ that collects data and information on streams throughout Montana's eco-regions to use as benchmarks for developing water quality standards and restoration plans

Robust element (in reference to the Dublin Core Metadata Element Set): an element from a list of reported elements that exemplifies the metadata term being described

Secondary end-user: a possible consumer of an information resource, but not the audience that the resource was initially intended to serve

Statistical Procedure: a method of analyzing or representing data before they are used in a statistical analysis

STORET/WQX: STORET is a digital warehouse used by the U.S. EPA as a repository for water quality data collected by various groups across the nation; the Water Quality Exchange (WQX) is a structural component of the warehouse that makes it easier for States, Tribes, and others to upload and share water quality data

Sufficient Credible Data: data subject to specific guidelines that are used to assess the legitimacy and dependability of available data for making a beneficial use-support determination

Timeliness: a metadata characteristic; reflects the length of time between when data are made available and the event they describe; measured in the context of the duration of time that allows the information resource valuable and used

Total Maximum Daily Load (TMDL) Plan: a plan developed by water quality regulators (such as the U.S. EPA or state environmental agencies) that explains the calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources

Water quality: refers to the physical, chemical and biological characteristics of water; often relates to a water resource based on how water is impacted by natural processes and/or human activities

Watershed coordinator: an individual (or sometimes a panel of individuals) that is responsible for representing a watershed group at the Montana Watershed Coordination Council

Watershed group: a citizen driven initiative that is involved with the planning and management of water quality in a specific basin; the Montana Watershed Coordination Council is made up of watershed groups

Westlaw: an internet based legal research service

Water Quality Exchange (WQX): is a new framework being developed to make it easier for States, Tribes, and others to submit and share water quality monitoring data over the internet

Water Quality Planning Bureau (WQPB): plays a central role at the Montana DEQ in the protection, maintenance and restoration of Montana’s water quality; they establish and maintain water quality standards, monitor and report on water quality, manage data and develop watershed restoration plans

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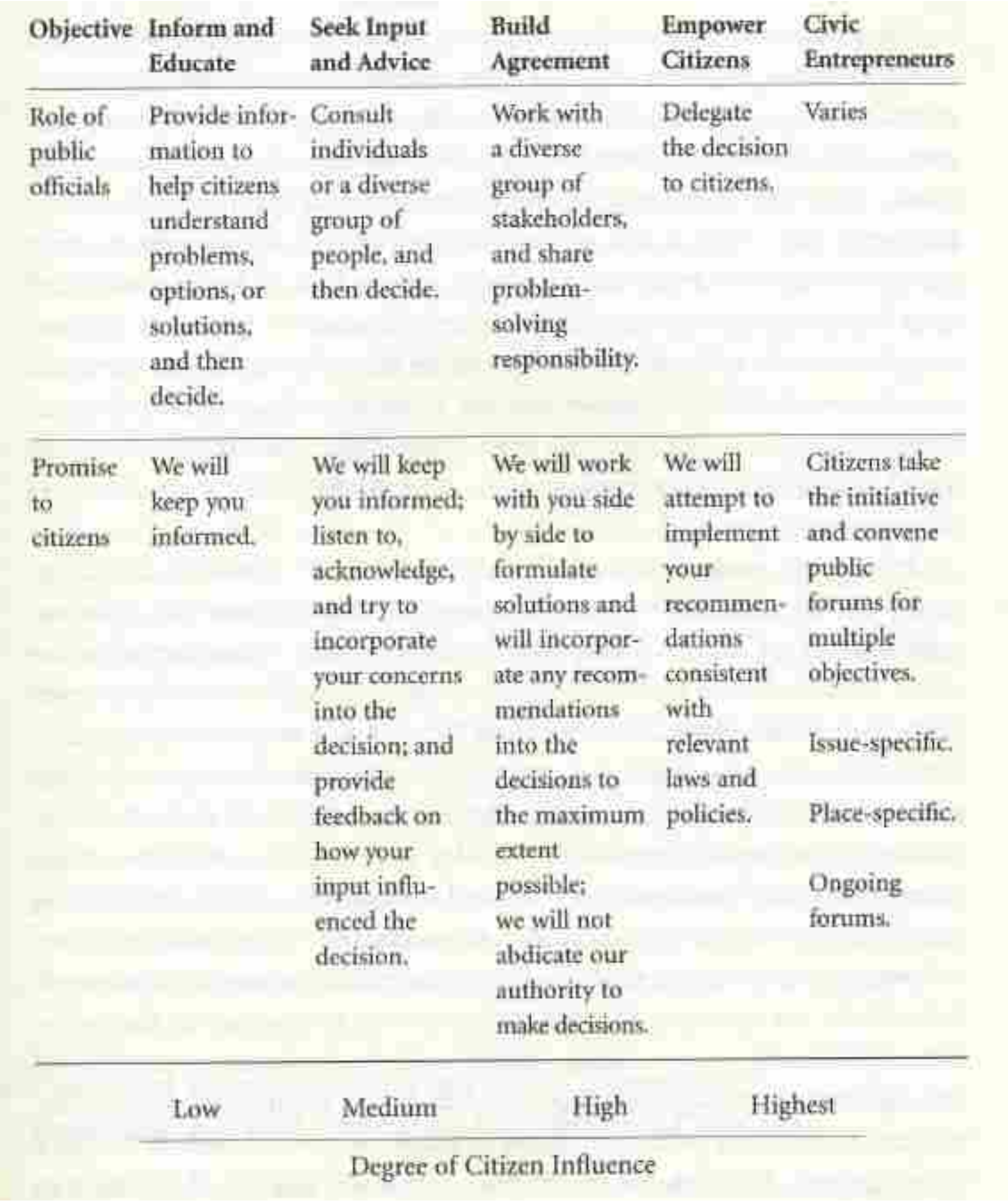
Table 1. A Continuum of Citizen Participation. the Montana DEQ-Water Quality Planning Bureau has roughly a medium "Degree of Citizen Influence," but because of the way decision making processes are structured by law, this is often the highest degree of influence citizens may obtain in water quality planning and management.

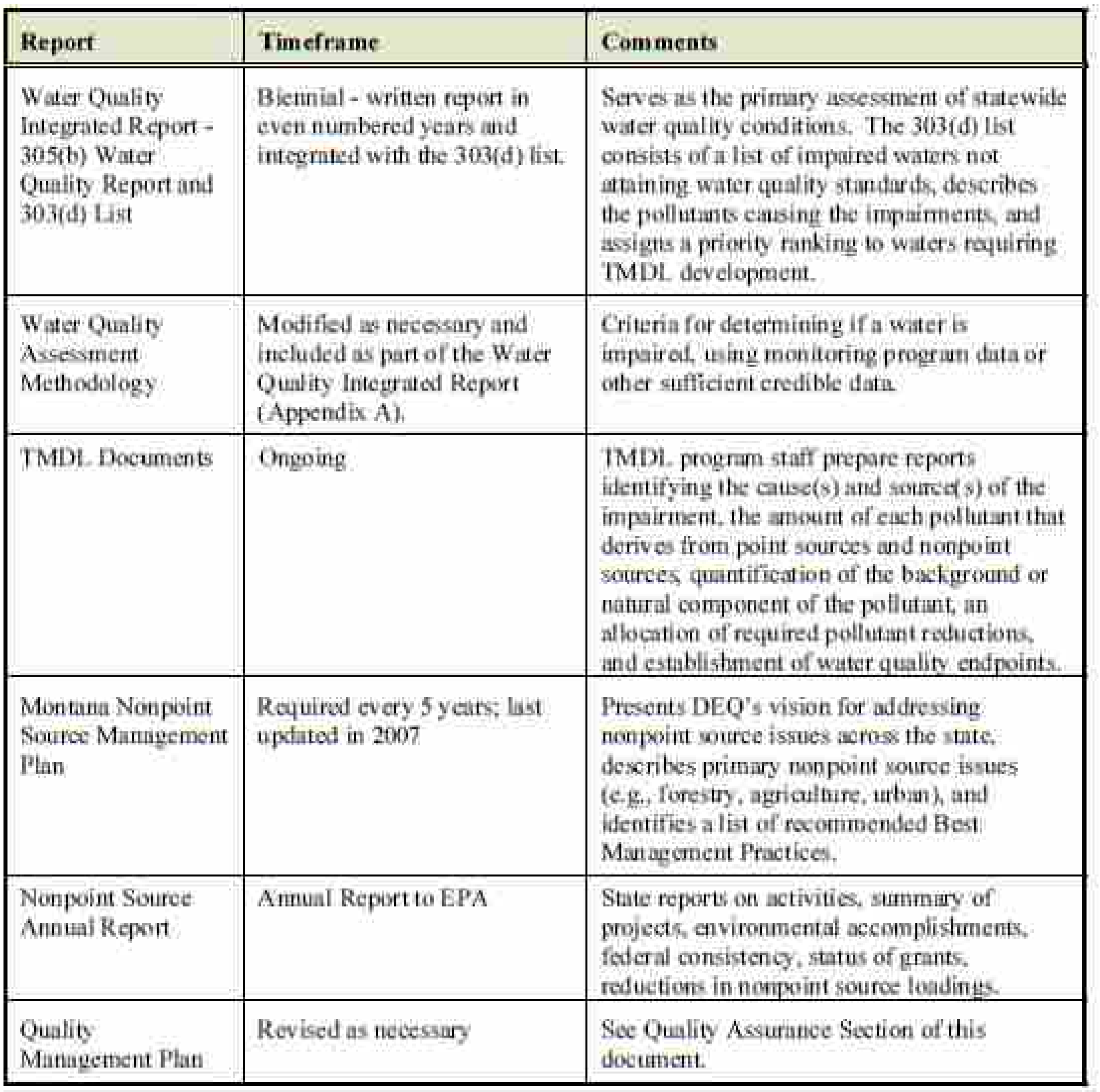


Objective	Inform and Educate	Seek Input and Advice	Build Agreement	Empower Citizens	Civic Entrepreneurs
Role of public officials	Provide information to help citizens understand problems, options, or solutions, and then decide.	Consult individuals or a diverse group of people, and then decide.	Work with a diverse group of stakeholders, and share problem-solving responsibility.	Delegate the decision to citizens.	Varies
Promise to citizens	We will keep you informed.	We will keep you informed; listen to, acknowledge, and try to incorporate your concerns into the decision; and provide feedback on how your input influenced the decision.	We will work with you side by side to formulate solutions and will incorporate any recommendations into the decisions to the maximum extent possible; we will not abdicate our authority to make decisions.	We will attempt to implement your recommendations consistent with relevant laws and policies.	Citizens take the initiative and convene public forums for multiple objectives. Issue-specific. Place-specific. Ongoing forums.
	Low	Medium	High	Highest	

Degree of Citizen Influence

(Modified from McKinney and Harmon 2004)

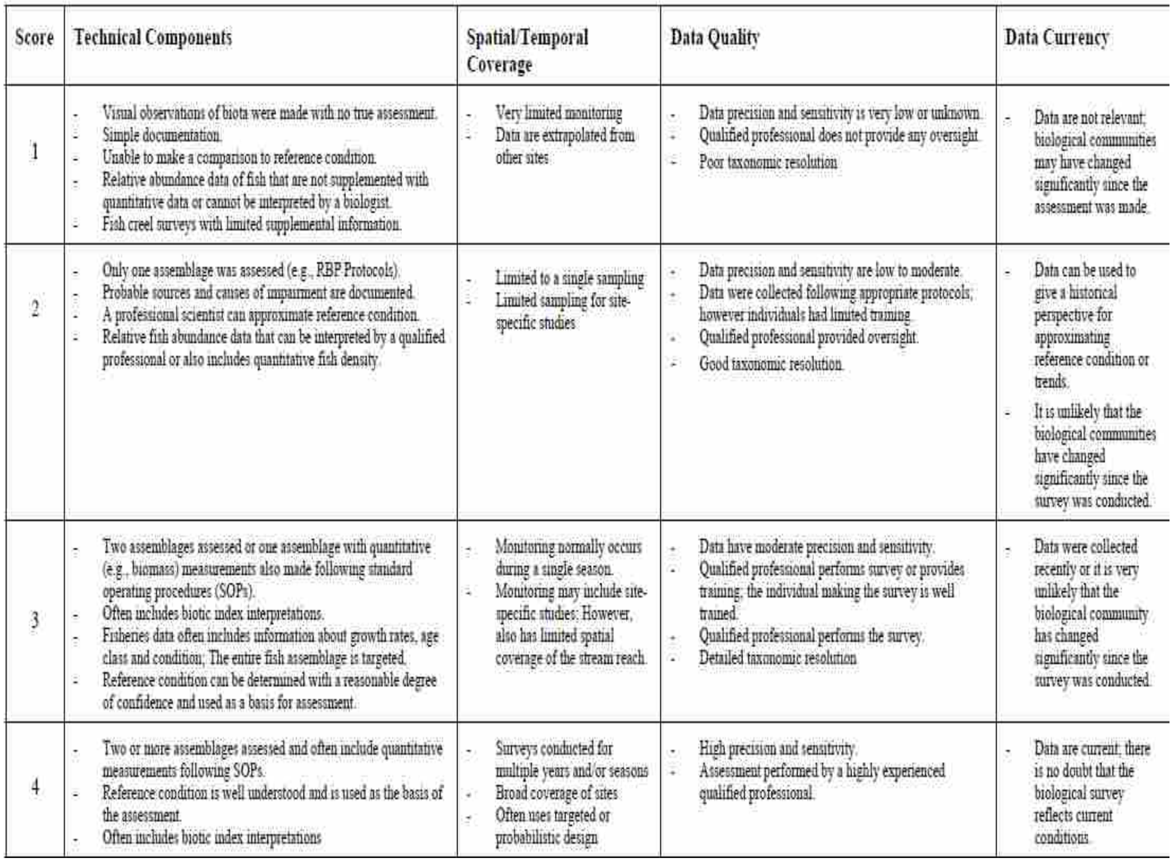
Table 2. State Generated Clean Water Act Documents. This table outlines a list of reports that the Montana DEQ must produce to fulfill their responsibilities as delegated by the U.S. EPA under the authority of the federal Clean Water Act.



Report	Timeframe	Comments
Water Quality Integrated Report - 305(b) Water Quality Report and 303(d) List	Biennial - written report in even numbered years and integrated with the 303(d) list.	Serves as the primary assessment of statewide water quality conditions. The 303(d) list consists of a list of impaired waters not attaining water quality standards, describes the pollutants causing the impairments, and assigns a priority ranking to waters requiring TMDL development.
Water Quality Assessment Methodology	Modified as necessary and included as part of the Water Quality Integrated Report (Appendix A).	Criteria for determining if a water is impaired, using monitoring program data or other sufficient credible data.
TMDL Documents	Ongoing	TMDL program staff prepare reports identifying the cause(s) and source(s) of the impairment, the amount of each pollutant that derives from point sources and nonpoint sources, quantification of the background or natural component of the pollutant, an allocation of required pollutant reductions, and establishment of water quality endpoints.
Montana Nonpoint Source Management Plan	Required every 5 years; last updated in 2007	Presents DEQ's vision for addressing nonpoint source issues across the state, describes primary nonpoint source issues (e.g., forestry, agriculture, urban), and identifies a list of recommended Best Management Practices.
Nonpoint Source Annual Report	Annual Report to EPA	State reports on activities, summary of projects, environmental accomplishments, federal consistency, status of grants, reductions in nonpoint source loadings.
Quality Management Plan	Revised as necessary	See Quality Assurance Section of this document.

(Modified from MT DEQ *et al*. 2009)

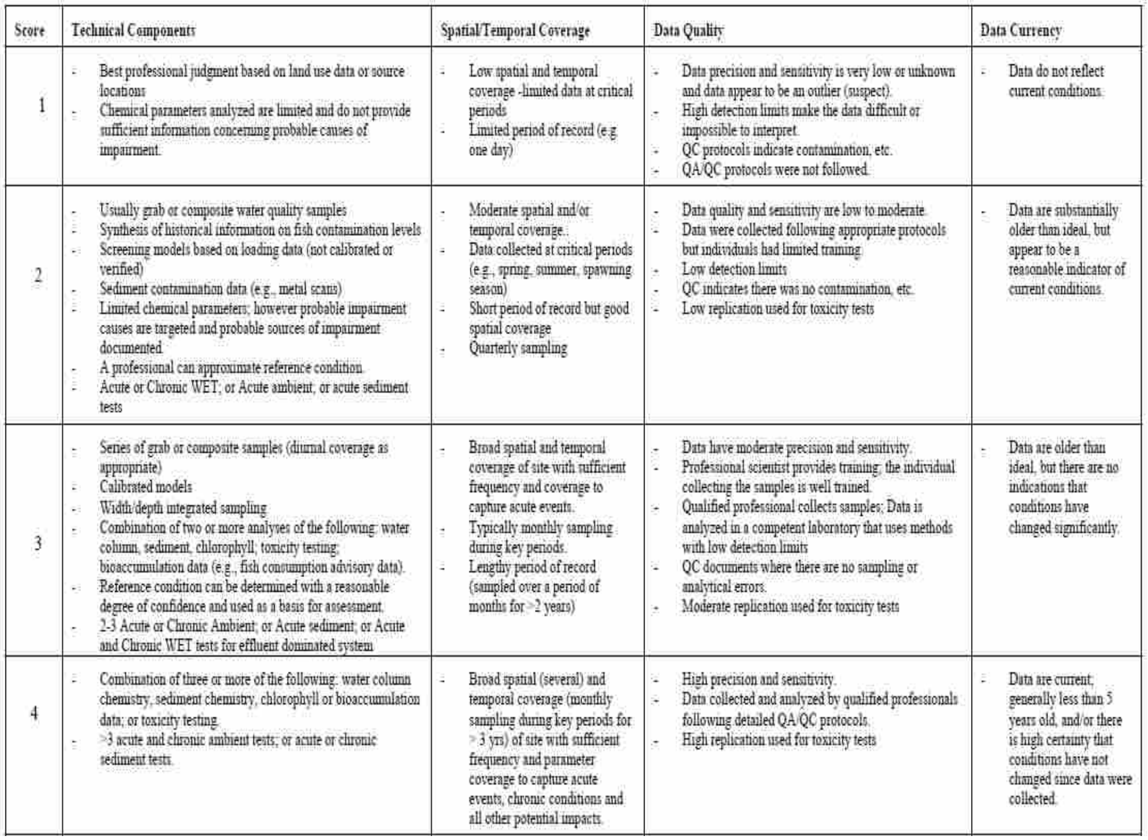
Table 3. Biology Sufficient Credible Data Decision Table for Aquatic Life Use (Streams) as seen in the Montana DEQ publication "Standard Operating Procedure-Water Quality Assessment Process and Methods."



Score	Technical Components	Spatial/Temporal Coverage	Data Quality	Data Currency
1	- Visual observations of biota were made with no true assessment. - Simple documentation. - Unable to make a comparison to reference condition. - Relative abundance data of fish that are not supplemented with quantitative data or cannot be interpreted by a biologist. - Fish creel surveys with limited supplemental information.	- Very limited monitoring - Data are extrapolated from other sites	- Data precision and sensitivity is very low or unknown. - Qualified professional does not provide any oversight. - Poor taxonomic resolution	- Data are not relevant; biological communities may have changed significantly since the assessment was made.
2	- Only one assemblage was assessed (e.g., RBP Protocols). - Probable sources and causes of impairment are documented. - A professional scientist can approximate reference condition. - Relative fish abundance data that can be interpreted by a qualified professional or also includes quantitative fish density.	- Limited to a single sampling - Limited sampling for site-specific studies	- Data precision and sensitivity are low to moderate. - Data were collected following appropriate protocols; however individuals had limited training. - Qualified professional provided oversight. - Good taxonomic resolution.	- Data can be used to give a historical perspective for approximating reference condition or trends. - It is unlikely that the biological communities have changed significantly since the survey was conducted.
3	- Two assemblages assessed or one assemblage with quantitative (e.g., biomass) measurements also made following standard operating procedures (SOPs). - Often includes biotic index interpretations. - Fisheries data often includes information about growth rates, age class and condition; The entire fish assemblage is targeted. - Reference condition can be determined with a reasonable degree of confidence and used as a basis for assessment.	- Monitoring normally occurs during a single season. - Monitoring may include site-specific studies: However, also has limited spatial coverage of the stream reach.	- Data have moderate precision and sensitivity. - Qualified professional performs survey or provides training; the individual making the survey is well trained. - Qualified professional performs the survey. - Detailed taxonomic resolution	- Data were collected recently or it is very unlikely that the biological community has changed significantly since the survey was conducted.
4	- Two or more assemblages assessed and often include quantitative measurements following SOPs. - Reference condition is well understood and is used as the basis of the assessment. - Often includes biotic index interpretations	- Surveys conducted for multiple years and/or seasons - Broad coverage of sites - Often uses targeted or probabilistic design	- High precision and sensitivity. - Assessment performed by a highly experienced qualified professional.	- Data are current; there is no doubt that the biological survey reflects current conditions.

(Modified from Mathieus *et al.* 2006)

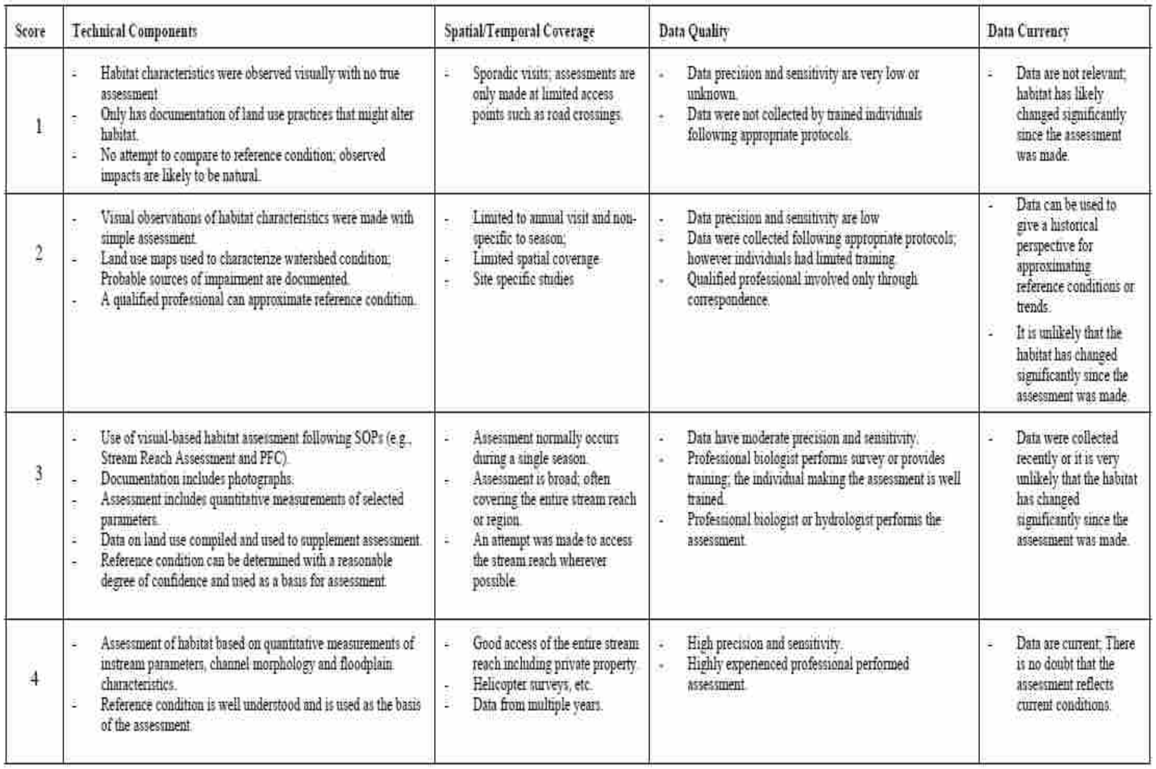
Table 4. Chemistry/Toxicity Sufficient Credible Data Decision Table for Aquatic Life Use (Streams) as seen in the Montana DEQ publication "Standard Operating Procedure-Water Quality Assessment Process and Methods."



Score	Technical Components	Spatial/Temporal Coverage	Data Quality	Data Currency
1	- Best professional judgment based on land use data or source locations - Chemical parameters analyzed are limited and do not provide sufficient information concerning probable causes of impairment.	- Low spatial and temporal coverage -limited data at critical periods - Limited period of record (e.g one day)	- Data precision and sensitivity is very low or unknown and data appear to be an outlier (suspect). - High detection limits make the data difficult or impossible to interpret. - QC protocols indicate contamination, etc. - QA/QC protocols were not followed.	- Data do not reflect current conditions.
2	- Usually grab or composite water quality samples - Synthesis of historical information on fish contamination levels - Screening models based on loading data (not calibrated or verified) - Sediment contamination data (e.g., metal scans) - Limited chemical parameters; however probable impairment causes are targeted and probable sources of impairment documented. - A professional can approximate reference condition. - Acute or Chronic WET; or Acute ambient, or acute sediment tests	- Moderate spatial and/or temporal coverage. - Data collected at critical periods (e.g., spring, summer, spawning season) - Short period of record but good spatial coverage - Quarterly sampling	- Data quality and sensitivity are low to moderate. - Data were collected following appropriate protocols but individuals had limited training. - Low detection limits - QC indicates there was no contamination, etc. - Low replication used for toxicity tests	- Data are substantially older than ideal, but appear to be a reasonable indicator of current conditions.
3	- Series of grab or composite samples (diurnal coverage as appropriate) - Calibrated models - Width/depth integrated sampling - Combination of two or more analyses of the following: water column, sediment, chlorophyll; toxicity testing; bioaccumulation data (e.g., fish consumption advisory data). - Reference condition can be determined with a reasonable degree of confidence and used as a basis for assessment. - 2-3 Acute or Chronic Ambient; or Acute sediment; or Acute and Chronic WET tests for effluent dominated system	- Broad spatial and temporal coverage of site with sufficient frequency and coverage to capture acute events. - Typically monthly sampling during key periods. - Lengthy period of record (sampled over a period of months for >2 years)	- Data have moderate precision and sensitivity. - Professional scientist provides training; the individual collecting the samples is well trained. - Qualified professional collects samples; Data is analyzed in a competent laboratory that uses methods with low detection limits - QC documents where there are no sampling or analytical errors. - Moderate replication used for toxicity tests	- Data are older than ideal, but there are no indications that conditions have changed significantly.
4	- Combination of three or more of the following: water column chemistry, sediment chemistry, chlorophyll or bioaccumulation data; or toxicity testing. - >3 acute and chronic ambient tests; or acute or chronic sediment tests.	- Broad spatial (several) and temporal coverage (monthly sampling during key periods for > 3 yrs) of site with sufficient frequency and parameter coverage to capture acute events, chronic conditions and all other potential impacts.	- High precision and sensitivity. - Data collected and analyzed by qualified professionals following detailed QA/QC protocols. - High replication used for toxicity tests	- Data are current; generally less than 5 years old, and/or there is high certainty that conditions have not changed since data were collected.

(Modified from Mathieus *et al.* 2006)

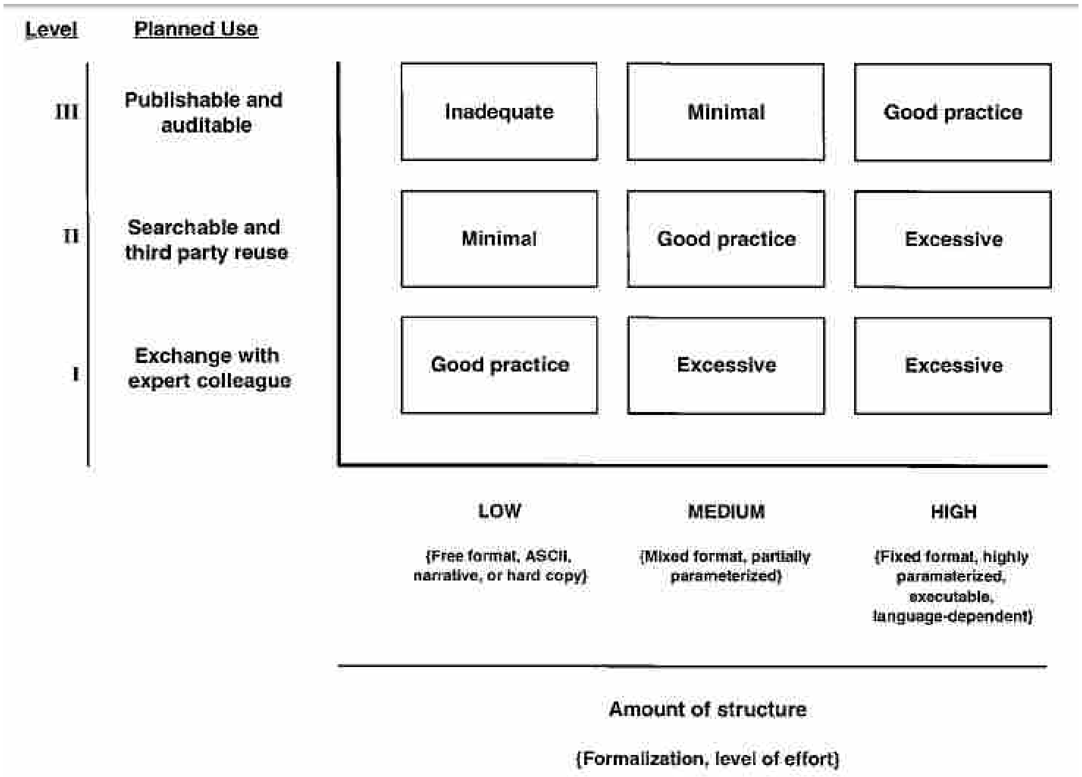
Table 5. Habitat/physical Sufficient Credible Data Decision Table for Aquatic Life Use (Streams) as seen in the Montana DEQ publication “Standard Operating Procedure-Water Quality Assessment Process and Methods.”



Score	Technical Components	Spatial/Temporal Coverage	Data Quality	Data Currency
1	- Habitat characteristics were observed visually with no true assessment. - Only has documentation of land use practices that might alter habitat. - No attempt to compare to reference condition; observed impacts are likely to be natural.	- Sporadic visits; assessments are only made at limited access points such as road crossings.	- Data precision and sensitivity are very low or unknown. - Data were not collected by trained individuals following appropriate protocols.	- Data are not relevant; habitat has likely changed significantly since the assessment was made.
2	- Visual observations of habitat characteristics were made with simple assessment. - Land use maps used to characterize watershed condition; Probable sources of impairment are documented. - A qualified professional can approximate reference condition.	- Limited to annual visit and non-specific to season; - Limited spatial coverage - Site specific studies	- Data precision and sensitivity are low - Data were collected following appropriate protocols; however individuals had limited training. - Qualified professional involved only through correspondence.	- Data can be used to give a historical perspective for approximating reference conditions or trends. - It is unlikely that the habitat has changed significantly since the assessment was made.
3	- Use of visual-based habitat assessment following SOPs (e.g., Stream Reach Assessment and PFC). - Documentation includes photographs. - Assessment includes quantitative measurements of selected parameters. - Data on land use compiled and used to supplement assessment. - Reference condition can be determined with a reasonable degree of confidence and used as a basis for assessment.	- Assessment normally occurs during a single season. - Assessment is broad; often covering the entire stream reach or region. - An attempt was made to access the stream reach wherever possible.	- Data have moderate precision and sensitivity. - Professional biologist performs survey or provides training; the individual making the assessment is well trained. - Professional biologist or hydrologist performs the assessment.	- Data were collected recently or it is very unlikely that the habitat has changed significantly since the assessment was made.
4	- Assessment of habitat based on quantitative measurements of instream parameters, channel morphology and floodplain characteristics. - Reference condition is well understood and is used as the basis of the assessment.	- Good access of the entire stream reach including private property. - Helicopter surveys, etc. - Data from multiple years.	- High precision and sensitivity. - Highly experienced professional performed assessment.	- Data are current; There is no doubt that the assessment reflects current conditions.

(Modified from Mathieus *et al.* 2006)

Table 6. Metadata structure depends on projected secondary data use. This table shows the level of format and structure necessary to support "good practices" for three levels of planned end-users. An entity like the Montana DEQ would need a "HIGH" level of metadata structure to support publications and audits that they perform, but it is predicted by the table that for "searching and third party reuse" this could be excessive. Too much structure, might make accessing the data too complicated for end-users like watershed groups who wish to reuse the data for their own purposes.



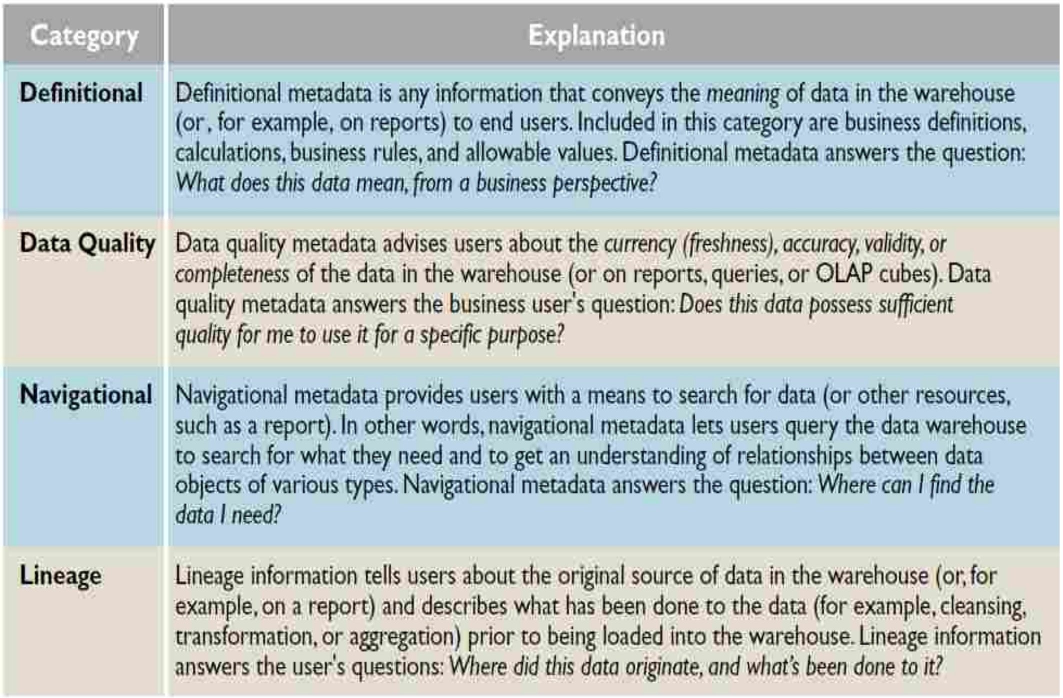
Level	Planned Use	LOW (Free format, ASCII, narrative, or hard copy)	MEDIUM (Mixed format, partially parameterized)	HIGH (Fixed format, highly paramaterized, executable, language-dependent)
III	Publishable and auditable	Inadequate	Minimal	Good practice
II	Searchable and third party reuse	Minimal	Good practice	Excessive
I	Exchange with expert colleague	Good practice	Excessive	Excessive

Amount of structure

(Formalization, level of effort)

(Modified from Michener *et al.* 1997)

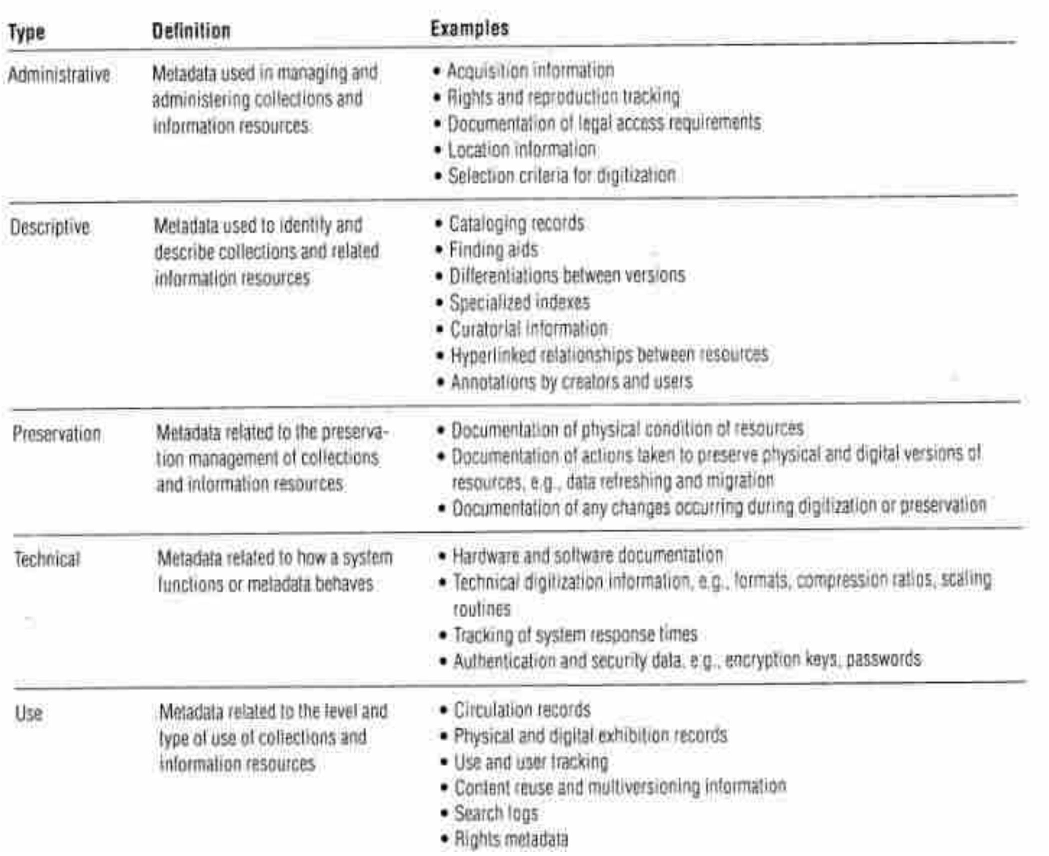
Table 7. End-user metadata types. What is referred to as the type or format of the metadata has to be in line with the expectations of the intended audience. The Reference Stream Project uses mostly definitional and lineage based metadata structures to convey data characteristics.



Category	Explanation
Definitional	Definitional metadata is any information that conveys the *meaning* of data in the warehouse (or, for example, on reports) to end users. Included in this category are business definitions, calculations, business rules, and allowable values. Definitional metadata answers the question: *What does this data mean, from a business perspective?*
Data Quality	Data quality metadata advises users about the *currency (freshness), accuracy, validity, or completeness* of the data in the warehouse (or on reports, queries, or OLAP cubes). Data quality metadata answers the business user's question: *Does this data possess sufficient quality for me to use it for a specific purpose?*
Navigational	Navigational metadata provides users with a means to search for data (or other resources, such as a report). In other words, navigational metadata lets users query the data warehouse to search for what they need and to get an understanding of relationships between data objects of various types. Navigational metadata answers the question: *Where can I find the data I need?*
Lineage	Lineage information tells users about the original source of data in the warehouse (or, for example, on a report) and describes what has been done to the data (for example, cleansing, transformation, or aggregation) prior to being loaded into the warehouse. Lineage information answers the user's questions: *Where did this data originate, and what's been done to it?*

(Modified from Foshay *et al.* 2007)

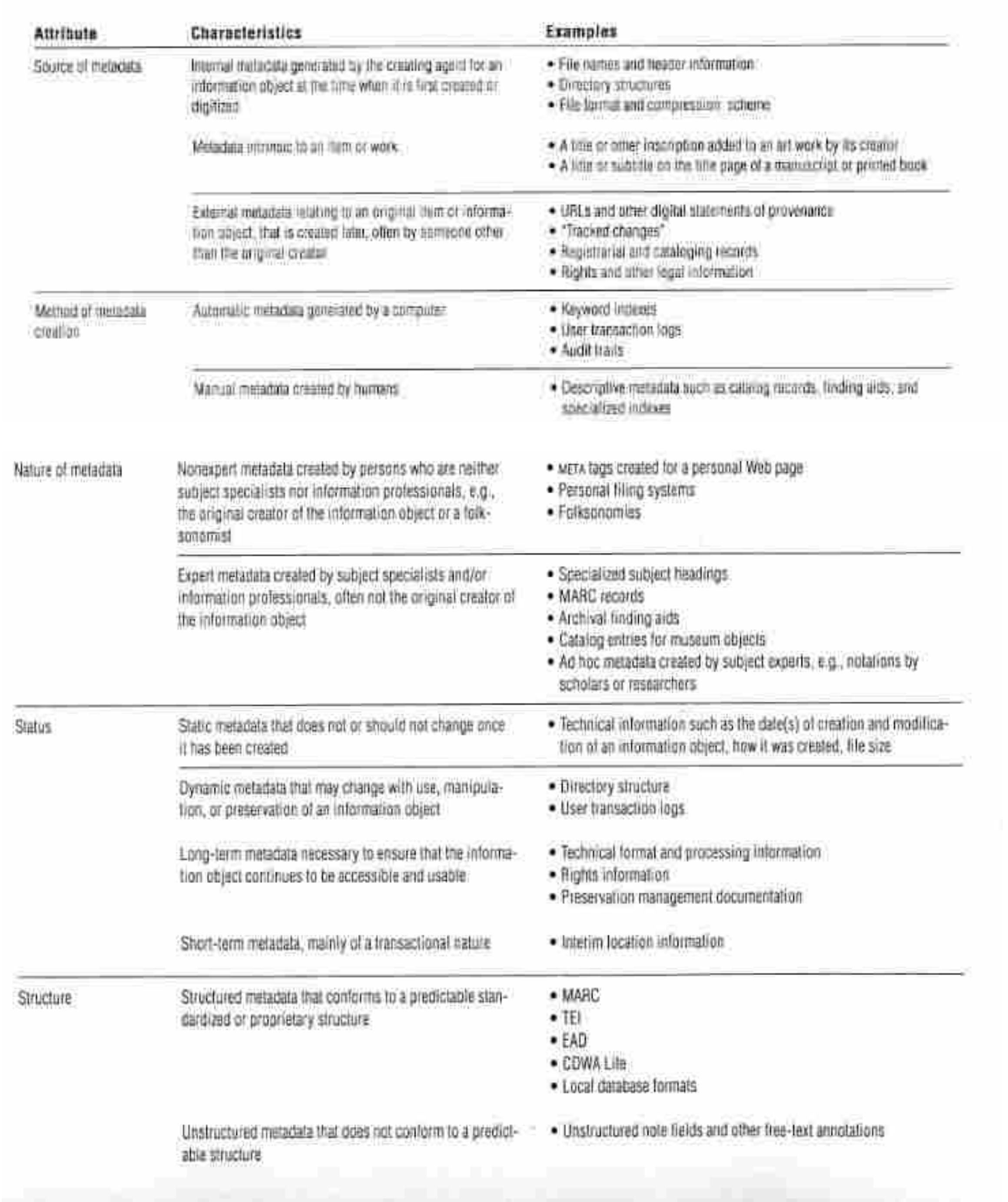
Table 8. Types of Metadata, Their Function and Examples. This table shows in depth concepts regarding format and type. RefPro metadata would fit into administrative, descriptive and use types.



Type	Definition	Examples
Administrative	Metadata used in managing and administering collections and information resources	• Acquisition information • Rights and reproduction tracking • Documentation of legal access requirements • Location information • Selection criteria for digitization
Descriptive	Metadata used to identify and describe collections and related information resources	• Cataloging records • Finding aids • Differentiations between versions • Specialized indexes • Curatorial information • Hyperlinked relationships between resources • Annotations by creators and users
Preservation	Metadata related to the preservation management of collections and information resources	• Documentation of physical condition of resources • Documentation of actions taken to preserve physical and digital versions of resources, e.g., data refreshing and migration • Documentation of any changes occurring during digitization or preservation
Technical	Metadata related to how a system functions or metadata behaves	• Hardware and software documentation • Technical digitization information, e.g., formats, compression ratios, scaling routines • Tracking of system response times • Authentication and security data, e.g., encryption keys, passwords
Use	Metadata related to the level and type of use of collections and information resources	• Circulation records • Physical and digital exhibition records • Use and user tracking • Content reuse and multiversioning information • Search logs • Rights metadata

(Modified from Baca 2008)

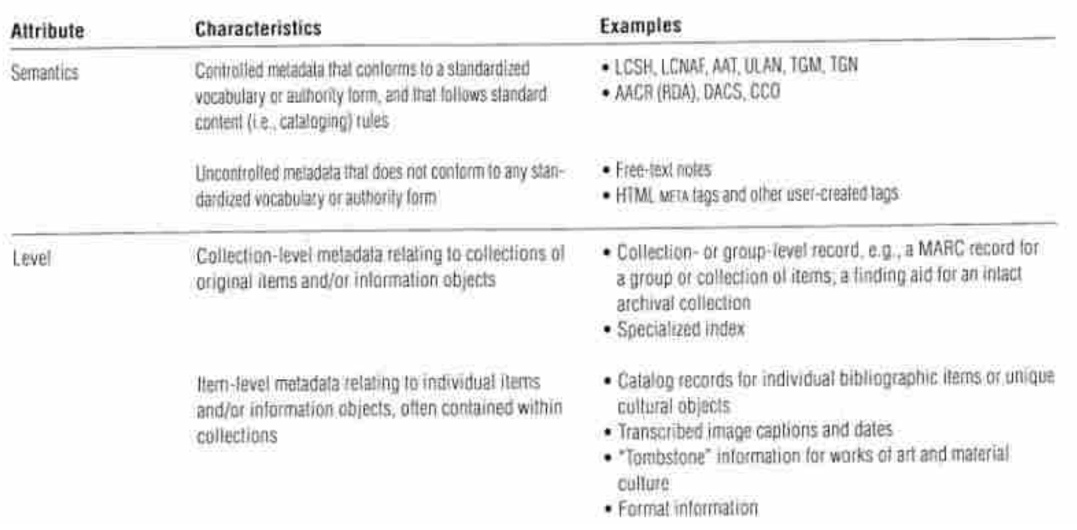
Table 9. Metadata Attributes, Characteristics and Examples. Explains the overarching need for the Reference Stream Project (and other water quality monitoring projects) to maintain a basic set of metadata attributes that can describe a wide range of data types.



Attribute	Characteristics	Examples
Source of metadata	Internal metadata generated by the creating agent for an information object at the time when it is first created or digitized	• File names and header information • Directory structures • File format and compression scheme
	Metadata intrinsic to an item or work	• A title or other inscription added to an art work by its creator • A title or subtitle on the title page of a manuscript or printed book
	External metadata relating to an original item or information object, that is created later, often by someone other than the original creator	• URLs and other digital statements of provenance • "Tracked changes" • Registrarial and cataloging records • Rights and other legal information
Method of metadata creation	Automatic metadata generated by a computer	• Keyword indexes • User transaction logs • Audit trails
	Manual metadata created by humans	• Descriptive metadata such as catalog records, finding aids, and specialized indexes
Nature of metadata	Nonexpert metadata created by persons who are neither subject specialists nor information professionals, e.g., the original creator of the information object or a folksonomist	• META tags created for a personal Web page • Personal filing systems • Folksonomies
	Expert metadata created by subject specialists and/or information professionals, often not the original creator of the information object	• Specialized subject headings • MARC records • Archival finding aids • Catalog entries for museum objects • Ad hoc metadata created by subject experts, e.g., notations by scholars or researchers
Status	Static metadata that does not or should not change once it has been created	• Technical information such as the date(s) of creation and modification of an information object, how it was created, file size
	Dynamic metadata that may change with use, manipulation, or preservation of an information object	• Directory structure • User transaction logs
	Long-term metadata necessary to ensure that the information object continues to be accessible and usable	• Technical format and processing information • Rights information • Preservation management documentation
	Short-term metadata, mainly of a transactional nature	• Interim location information
Structure	Structured metadata that conforms to a predictable standardized or proprietary structure	• MARC • TEI • EAD • CDWA Lite • Local database formats
	Unstructured metadata that does not conform to a predictable structure	• Unstructured note fields and other free-text annotations

(Modified from Baca 2008)

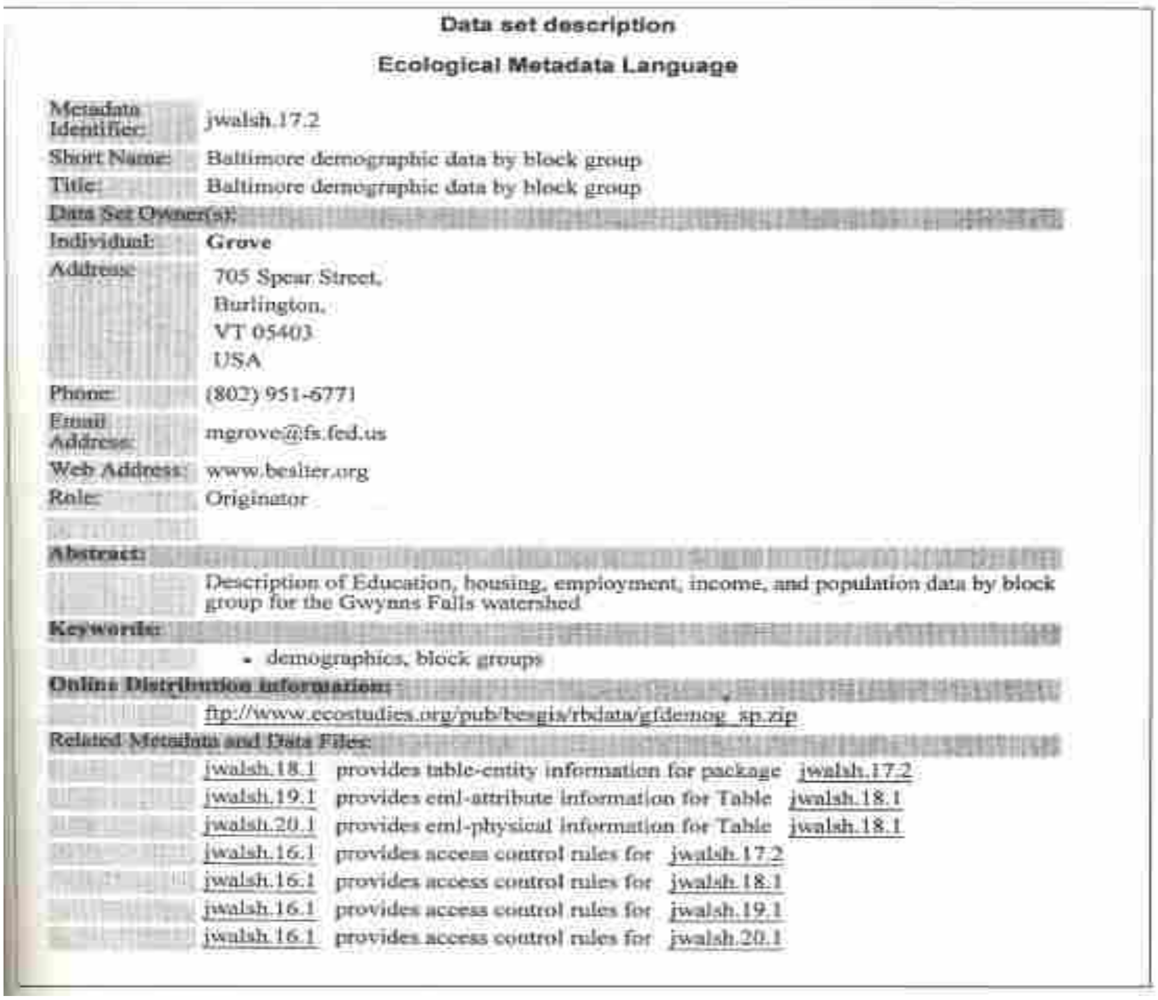
Table 9 cont.



Attribute	Characteristics	Examples
Semantics	Controlled metadata that conforms to a standardized vocabulary or authority form, and that follows standard content (i.e., cataloging) rules	• LCSH, LCNAF, AAT, ULAN, TGM, TGN • AACR (RDA), DACS, CCO
	Uncontrolled metadata that does not conform to any standardized vocabulary or authority form	• Free-text notes • HTML META tags and other user-created tags
Level	Collection-level metadata relating to collections of original items and/or information objects	• Collection- or group-level record, e.g., a MARC record for a group or collection of items; a finding aid for an intact archival collection • Specialized index
	Item-level metadata relating to individual items and/or information objects, often contained within collections	• Catalog records for individual bibliographic items or unique cultural objects • Transcribed image captions and dates • "Tombstone" information for works of art and material culture • Format information

(Modified from Baca 2008)

Table 10. Ecological Metadata Language (EML) Record; A metadata structure developed for use in the ecological sciences. EML is an example of a professional community collaborating to create a uniform metadata structure for their industry/discipline.



Data set description

Ecological Metadata Language

Metadata Identifier: jwalsh.17.2
Short Name: Baltimore demographic data by block group
Title: Baltimore demographic data by block group

Data Set Owner(s):

Individual: **Grove**
Address:
705 Spear Street,
Burlington,
VT 05403
USA
Phone: (802) 951-6771
Email Address: mgrove@fs.fed.us
Web Address: www.beslter.org
Role: Originator

Abstract:

Description of Education, housing, employment, income, and population data by block group for the Gwynns Falls watershed

Keywords:

- demographics, block groups

Online Distribution information:

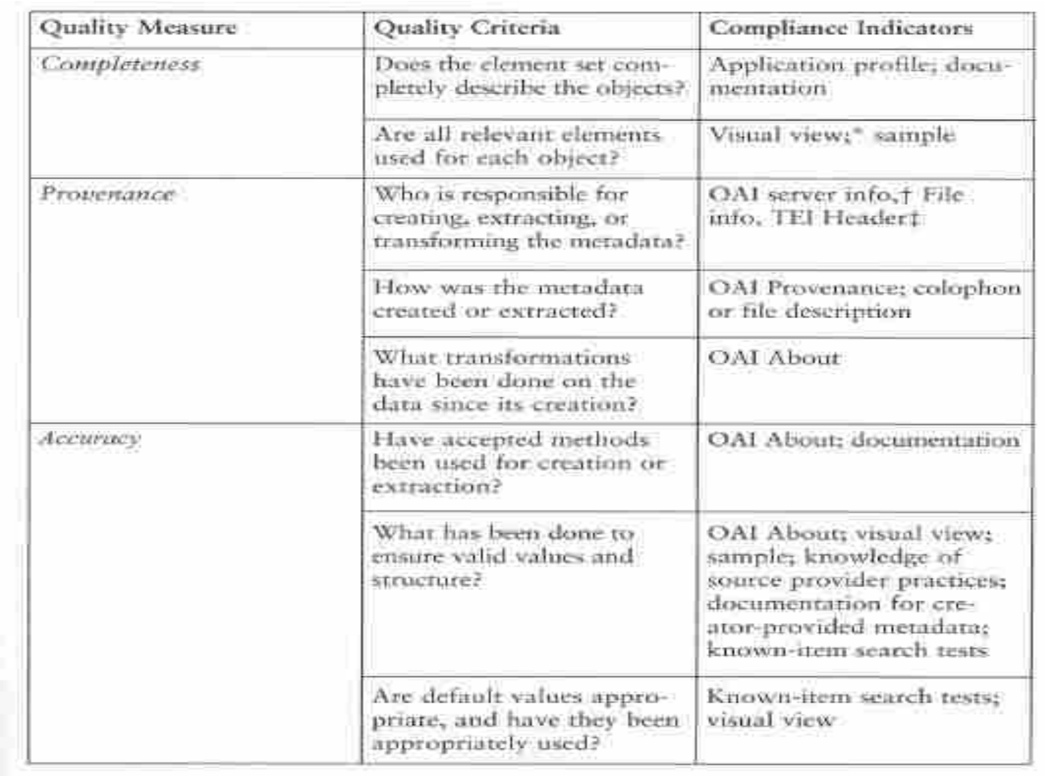
ftp://www.ecostudies.org/pub/besgis/rbdata/gfdemog_sp.zip

Related Metadata and Data Files:

jwalsh.18.1 provides table-entity information for package jwalsh.17.2
jwalsh.19.1 provides eml-attribute information for Table jwalsh.18.1
jwalsh.20.1 provides eml-physical information for Table jwalsh.18.1
jwalsh.16.1 provides access control rules for jwalsh.17.2
jwalsh.16.1 provides access control rules for jwalsh.18.1
jwalsh.16.1 provides access control rules for jwalsh.19.1
jwalsh.16.1 provides access control rules for jwalsh.20.1

(Modified from Caplan 2003 as retrieved from http://knb.ecoinformatics.org)

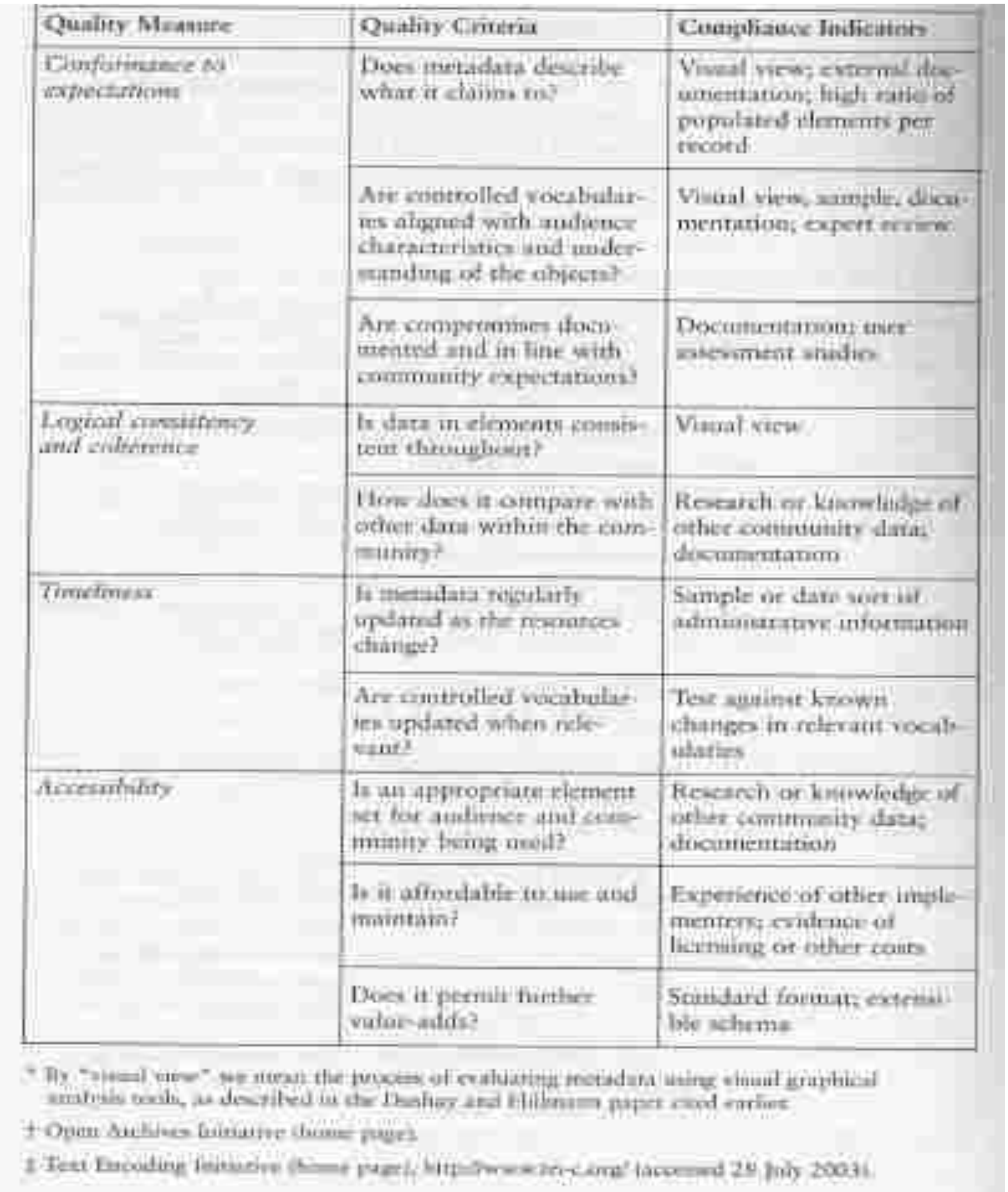
Table 11. Bruce and Hillman Framework; provides seven conceptual quality measures, quality criteria and compliance indicators to assess the quality of metadata on a narrative basis.



Quality Measure	Quality Criteria	Compliance Indicators
Completeness	Does the element set completely describe the objects?	Application profile; documentation
	Are all relevant elements used for each object?	Visual view;* sample
Provenance	Who is responsible for creating, extracting, or transforming the metadata?	OAI server info,† File info, TEI Header‡
	How was the metadata created or extracted?	OAI Provenance; colophon or file description
	What transformations have been done on the data since its creation?	OAI About
Accuracy	Have accepted methods been used for creation or extraction?	OAI About; documentation
	What has been done to ensure valid values and structure?	OAI About; visual view; sample; knowledge of source provider practices; documentation for creator-provided metadata; known-item search tests
	Are default values appropriate, and have they been appropriately used?	Known-item search tests; visual view

(Modified from Bruce and Hillman 2004)

Table 11 cont.



Quality Measure	Quality Criteria	Compliance Indicators
Conformance to expectations	Does metadata describe what it claims to?	Visual view; external documentation; high ratio of populated elements per record
	Are controlled vocabularies aligned with audience characteristics and understanding of the objects?	Visual view, sample, documentation; expert review
	Are compromises documented and in line with community expectations?	Documentation; user assessment studies
Logical consistency and coherence	Is data in elements consistent throughout?	Visual view
	How does it compare with other data within the community?	Research or knowledge of other community data; documentation
Timeliness	Is metadata regularly updated as the resources change?	Sample or date sort of administrative information
	Are controlled vocabularies updated when relevant?	Test against known changes in relevant vocabularies
Accessibility	Is an appropriate element set for audience and community being used?	Research or knowledge of other community data; documentation
	Is it affordable to use and maintain?	Experience of other implementers; evidence of licensing or other costs
	Does it permit further value-adds?	Standard format; extensible schema

* By "visual view" we mean the process of evaluating metadata using visual graphical analysis tools, as described in the Dushay and Hillmann paper cited earlier.

† Open Archives Initiative (home page).

‡ Text Encoding Initiative (home page), http://www.tei-c.org/ (accessed 28 July 2003).

(Modified from Bruce and Hillman 2004)

Table 12. Summarized version of the Bruce-Hillman Framework used to analyze RefPro metadata

Abbreviated Version of Bruce-Hillman Framework

Metadata Characteristics	**Definition**	**Quality Criteria**
Completeness	Metadata delineate and describe the entire resource.	~Element set describes the data as completely as possible given project resources ~The element set should be applied as completely as possible
Provenance	The source of metadata is thoroughly described and documented.	~The origin and preparer of the metadata are identified ~Metadata standards are based on sound judgment, past experience, as well as expertise in the relevant domain and general metadata standards ~Dataset transformations that have occurred over time are documented, and describe whether value has been added or subtracted since the resource's inception
Accuracy	Metadata "hit the bull's-eye" with regards to how they delineate and describe the resource.	~Metadata should be accurate in the way they describe objects ~Basic Level: information provided is correct and factual ~Advanced Level: high quality editing for typos
Conformance to Expectations	Metadata describe what they intend to for the potential audience.	~Elements are those that the community of relevance would reasonably expect to find ~Should not contain elements that are not likely to be used ~Syntax is appropriate and standardized
Logical Consistency and Coherence	Objects are reliably described based on a dependable metadata structure	~Use of standard mechanisms such as application profiles and common crosswalks are present
Timeliness	Metadata updates are documented and kept current	~Currency: target object changes but the metadata do not ~Lag: target object is disseminated before some or all of the metadata is available
Accessibility	Metadata are able to be viewed and comprehended	~Physical and intellectual obstacles are kept to a minimum ~Basic standards documents, practice guides, and other descriptive information is available

(Modified from Bruce and Hillman 2004)

Table 13. Set of 15 elements that make up the Dublin Core Metadata Element Set (DCMES).

Dublin Core Metadata Element Set (DCMES)		
	Term Name	**Description**
1	**Contributor**	The entity responsible for making contributions to the resource. Examples: a person, an organization, or a service. Name of a contributor should be used to indicate the entity.
2	**Term Name: coverage**	The spatial or temporal topic of the resource; the spatial applicability of the resource. Spatial topic and spatial applicability may be a named place or a location specified by its geographic coordinates. Temporal topic may be a named period, date, or date range. A jurisdiction may be a named administrative entity or a geographic place to which the resource applies. Recommended best practice is to use a controlled vocabulary.
3	**Term Name: creator**	The entity primarily responsible for making the resource. Examples: a person, an organization, or a service.
4	**Term Name: date**	A point or period of time associated with an event in the lifecycle of the resource. Date may be used to express temporal information at any level of granularity.
5	**Term Name: description**	An account of the resource. Description may include but is not limited to: an abstract, a table of contents, a graphical representation, or a free-text account of the resource.
6	**Term Name: format**	The file format, physical medium, or dimensions of the resource. Examples of dimensions include size and duration. Recommended best practice is to use a controlled vocabulary.
7	**Term Name: identifier**	An unambiguous reference to the resource within a given context. Recommended best practice is to identify the resource by means of a string conforming to a formal identification system.

Table 13 cont.		
8	**Term Name: language**	The language of the resource. Recommended best practice is to use a controlled vocabulary.
9	**Term Name: publisher**	An entity responsible for making the resource available. Examples: a person, an organization, or a service.
10	**Term Name: relation**	A related resource. Recommended best practice is to identify the related resource by means of a series of linkages conforming to an identification system.
11	**Term Name: rights**	Information about rights held in and over the resource. Typically, rights information includes a statement about various property rights associated with the resource, including intellectual property rights.
12	**Term Name: source**	A related resource from which the described resource is derived. The described resource may be derived from the related resource in whole or in part. Recommended best practice is to identify the related resource by means of a series of linkages conforming to an identification system.
13	**Term Name: subject**	The topic of the resource. Typically, the subject will be represented using keywords, key phrases, or classification codes. Recommended best practice is to use a controlled vocabulary. To describe the spatial or temporal topic of the resource, use the Coverage element.
14	**Term Name: title**	A name given to the resource. Typically, a “Title” will be a name by which the resource is formally known.
15	**Term Name: type**	The nature or genre of the resource. Recommended best practice is to use a controlled vocabulary. To describe the file format, physical medium, or dimensions of the resource, use the Format element.

(Modified from Dublin Core Metadata Initiative [updated 2011])

Table 14. Elements associated with pre-1999 Regular File. These are term names that were used to describe actions taken during sample collection and analysis for the Reference Stream Project prior to 1999.

26 Elements Reported for “STORET Data Request - Request_ID: 859362” – pre-1999 data
1.Org Name
2.Station ID
3.State
4.County
5.HUC
6.Generated HUC
7.Station Latitude
8.Station Longitude
9.Station Horizontal Datum
10.Visit Num
11.Activity ID
12.Activity Start
13.Activity Start Zone
14.Activity Medium
15.Activity Type
16.Activity Category-Rep Num
17.Activity Depth
18.Activity Depth Unit
19.Characteristic Name
20.Sample Fraction
21.Value Type
22.Statistic Type
23.Result Value Status
24.Result Value as Text
25.Units
26.Analytical Proc ID

Table 15. Elements associated with post-1999 Regular File. These are term names that have been used to describe actions taken during sample collection and analysis for the Reference Stream Project since 1999.

117 Elements Reported for "STORET Data Request - Request_ID: 859093" – post-1999 data-Regular File	
1.Org ID	60.Activity Depth Ref Point
2.Beach ID/Project ID	61.Sample Collection ID
3.Org Name	62.Field Gear ID
4.Station ID	63.Field Gear Config ID
5.Station Name	64.Container Desc
6.State	65.Temp Pres Type
7.County	66.Pres Storage Proc
8.HUC	67.Portable Data Logger
9.Generated HUC	68.Characteristic Name
10.Station Latitude	69.CAS Num
11.Station Longitude	70.EPA Registry Num
12.Station Horizontal Datum	71.ITIS Num
13.Converted Station Latitude	72.Sample Fraction
14.Converted Station Longitude	73.Value Type
15.Converted Station Horizontal Datum	74.Statistic Type
16.Primary Type	75.Result Value Status
17.Secondary Type	76.Result Value as Text
18.S/G/O Indicator	77.Result Value as Number
19.Visit Num	78.Units
20.Visit Start	79.Converted Result Value
21.Visit Start Zone	80.Converted Result Unit
22.Visit Stop	81.Activity Comment
23.Visit Stop Zone	82.Result Comment
24.Trip ID	83.Result Measure Qualifier
25.Trip Name	84.Result Free Text
26.Project Name	85.Weight Basis
27.Project Description	86.Temperature Basis
28.Project Document/Graphic	87.Duration Basis
29.Project Document/Graphic URL	88.Particle Size Basis
30.Activity ID	89.Distance Measured From
31.Activity Start	90.Distance Measured To
32.Activity Start Zone	91.Analytical Proc ID
33.Activity Stop	92.Detection Limit
34.Activity Stop Zone	93.Detection Limit Descript
35.Activity Medium	94.Lower Quantification Limit
36.Activity Matrix	95.Upper Quantification Limit
37.Activity Type	96.Lab Remark
38.Activity Category-Rep Num	97.Dilution Ind
39.Activity Intent	98.Recovery Ind
40.Field Set	99.Correction Ind
41.Actual Location Point Type	100.Lab ID
42.Actual Point Sequence Num	101.Lab Name
43.Actual Point Name	102.Lab Cert
44.Actual Activity Latitude	103.Lab Batch ID
45.Actual Activity Longitude	104.2004
46.Actual Activity Horizontal Datum	105.Analysis Date Zone
47.Converted Actual Activity Latitude	106.Num of Reps
48.Converted Actual Activity Longitude	107.Precision
49.Converted Actual Activity Horizontal Datum	108.Bias

Table 15 cont. Elements associated with post-1999 Regular File

50.Well Number
51.Pipe Number
52.Geopositioning Method
53.Map Scale
54.Activity Depth
55.Activity Depth Unit
56.Activity Upper Depth
57.Activity Rel Depth
58.Activity Lower Depth
59.Upr Lwr Depth Unit
109.Conf Level
110.Correction for Bias Ind
111.Result Document/Graphic Name
112.Result Document/Graphic URL
113.Activity Document/Graphic Name
114.Activity Document/Graphic URL
115.Last Change Date
116.User ID Last Change
117.Last Transaction ID

Table 16. Elements associated with post-1999 Biology File. These are term names used to describe actions during sample collection and analysis for the RefPro since 1999.

	178 Elements Reported for "STORET Data Request - Request_ID: 859093"-post-1999 data-Biology File		
1	Org ID	48	Actual Activity Horizontal Datum
2	Beach ID/Project ID	49	Converted Actual Activity Latitude
3	Org Name	50	Converted Actual Activity Longitude
4	Station ID	51	Converted Actual Activity Horizontal Datum
5	Station Name	52	Well Number
6	State	53	Pipe Number
7	County	54	Geopositioning Method
8	HUC	55	Map Scale
9	Generated HUC	56	Activity Depth
10	Station Latitude	57	Activity Depth Unit
11	Station Longitude	58	Activity Upper Depth
12	Station Horizontal Datum	59	Activity Rel Depth
13	Converted Station Latitude	60	Activity Lower Depth
14	Converted Station Longitude	61	Upr Lwr Depth Unit
15	Converted Station Horizontal Datum	62	Activity Depth Ref Point
16	Primary Type	63	Sample Collection ID
17	Secondary Type	64	Field Gear ID
18	S/G/O Indicator	65	Field Gear Config ID
19	Visit Num	66	Container Desc
20	Visit Start	67	Temp Pres Type
21	Visit Start Zone	68	Pres Storage Proc
22	Visit Stop	69	Characteristic Name
23	Visit Stop Zone	70	Characteristic Description
24	Trip ID	71	CAS Num
25	Trip Name	72	EPA Registry Num
26	Project Name	73	ITIS Num
27	Project Description	74	Sample Fraction
28	Project Document/Graphic	75	Value Type
29	Project Document/Graphic URL	76	Statistic Type
30	Activity ID	77	Result Value Status
31	Activity Start	78	Result Value as Text
32	Activity Start Zone	79	Result Value as Number
33	Activity Stop	80	Units
34	Activity Stop Zone	81	Converted Result Value
35	Activity Medium	82	Converted Result Unit
36	Activity Type	83	Activity Comment
37	Activity Category-Rep Num	84	Result Comment
38	Activity Intent	85	Result Measure Qualifier
39	Community Sampled	86	Result Free Text
40	Subject Taxon	87	Weight Basis
41	Biopart	88	Temperature Basis
42	Field Set	89	Duration Basis
43	Actual Location Point Type	90	Particle Size Basis
44	Actual Point Sequence Num	91	Distance Measured From
45	Actual Point Name	92	Distance Measured To
46	Actual Activity Latitude	93	Analytical Proc ID
47	Actual Activity Longitude	94	Detection Limit

Table 16 cont.

95	Detection Limit Descript	140	Current Type Code
96	Lower Quantification Limit	141	Amperage Measure
97	Upper Quantification Limit	142	Pass Count
98	Lab Remark	143	Pass Length Measure
99	Dilution Ind	144	Pulse Rate Measure
100	Recovery Ind	145	Electroshock Comment
101	Correction Ind	146	Total Energzd Time
102	Lab ID	147	Sampling Duration
103	Lab Name	148	Orientation to Current
104	Lab Cert	149	Trap/Net Rel Current Dir
105	Lab Batch ID	150	Trap/Net Rel Wind Dir
106	Analysis Date	151	Trap Net Comment
107	Analysis Date Zone	152	Bio Result Group ID
108	Num of Reps	153	Bio Result Group Type
109	Precision	154	Bio Result Group Subj Txn
110	Bias	155	Bio Result Group Desc
111	Conf Level	156	Feeding Group
112	Correction for Bias Ind	157	Pollution Tolerance
113	Result Document/Graphic Name	158	Trophic Level
114	Result Document/Graphic URL	159	Habit
115	Activity Document/Graphic Name	160	Voltinism
116	Activity Document/Graphic URL	161	Cell Shape
117	Trawl Start Point Name	162	Cell Form
118	Trawl Start Latitude	163	Number in Group
119	Trawl Start Longitude	164	Group Count Type
120	Trawl Start Datum	165	Phys/Bio Ind
121	Conv Trawl Start Latitude	166	Bio Result Group ID (sex)
122	Conv Trawl Start Longitude	167	Bio Result Group ID (lifestage)
123	Conv Trawl Start Datum	168	Bio Result Group Class Var
124	Trawl Start Depth	169	Class Prim Desc
125	Trawl Stop Point Name	170	Class Sec Desc
126	Trawl Stop Latitude	171	Class Lower Bound
127	Trawl Stop Longitude	172	Class Upper Bound
128	Trawl Stop Datum	173	Class Units
129	Conv Trawl Stop Latitude	174	Number in Class
130	Conv Trawl Stop Longitude	175	Bio Individual Number
131	Conv Trawl Stop Datum	176	Last Change Date
132	Trawl Stop Depth	177	User ID Last Change
133	Fished Duration Measure	178	Last Transaction ID
134	Boat Speed		
135	Fished Distance		
136	Trawl Rel Current Dir		
137	Trawl Rel Wind Dir		
138	Trawl Comment		
139	Voltage Measure		

Table 17. Pre-1999 RefPro metadata analysis using the Bruce-Hillman Framework

Bruce-Hillman Framework Analysis of Pre-1999 RefPro Metadata			
Metadata Characteristics	**"Quality Criteria Questions" from Bruce-Hillman Framework**	**RefPro Pre-1999 Files - Narrative Metadata Score Based on "Quality Criteria Questions" from Bruce-Hillman Framework**	**Location**
Completeness	1. Does the element set completely describe the objects? 2. Are all relevant elements used for each object?	1. No, not all measurements (objects) noted in the report are expressed as elements. 2. Yes, there are sufficient elements to describe the objects present in the dataset; all objects are described by elements.	1. (Bahls et al. 1992) 2. Visual view
Provenance	1. Who is responsible for creating, extracting, or transforming the metadata? 2. How was the metadata created or extracted? 3. What transformations have been done on the data since its creation?	1. Contains information on the generator and end-user. 2. Contains no information on documents pertaining to the project protocols. 3. Notes that the data are historic and are from a "pre-1999" era.	1-3. Application profile
Accuracy	1. Have accepted methods been used for creation or extraction? 2. What has been done to ensure valid values and structure? 3. Are default values appropriate, and have they been appropriately used?	1. Yes, there are series of protocols offered by the contributor and publisher. 2. QA protocols exist for field, lab, and database management; they are not mentioned in the metadata. 3. Yes, and yes; QA protocols have been developed for older datasets.	1. (Bahls et al. 1992) 2. (Bahls et al. 1992) 3. Montana DEQ external sources

Table 17 cont. Pre-1999 RefPro metadata analysis using the Bruce-Hillman Framework

Metadata Characteristics	**"Quality Criteria Questions" from Bruce-Hillman Framework**	**RefPro Pre-1999 Files - Narrative Metadata Score Based on "Quality Criteria Questions" from Bruce-Hillman Framework**	**Location**
Conformance to Expectations	1. Does metadata describe what it claims to? 2. Are controlled vocabularies aligned with audience characteristics and understanding of the objects? 3. Are compromises documented and in line with community expectations?	1. Yes 2. Yes, but syntax is not outlined or defined in the queried files. 3. Yes and no: primary end-users are satisfied; potential end-users are generally not satisfied.	1. (Bahls et al. 1992) 2. Visual view and application profile 3. User assessment study (see joint fact finding section)
Logical Consistency and Coherence	1. Is data in elements consistent throughout? 2. How does it compare with other data within the community?	1. No, object values change in some cases. 2. Elements vary based on project and when data was generated.	1. Visual view 2. Comparing files on a temporal scale.
Timeliness	1. Is metadata regularly updated as the resource changes? 2. Are controlled vocabularies updated when relevant?	1. Yes, but what is changed is not documented. 2. Yes, documentation exists for correcting metadata files.	1. Visual View 2. Montana DEQ external source
Accessibility	1. Is an appropriate element set for audience and community being used? 2. Is it affordable to use and maintain? 3. Does it permit further value-adds?	1. Yes and no. 2. Yes and no. 3. Yes, data is accessible and can be manipulated	1. User assessment study, immediate audience is satisfied; community is generally not. 2. Experience of U.S. EPA, database changed recently because of resource constraints; new system is being implemented. 3. Standard format

Table 18. Post-1999 RefPro metadata analysis using the Bruce-Hillman Framework

Bruce-Hillman Framework Analysis of Post -1999 RefPro Metadata			
Metadata Characteristics	**"Quality Criteria Questions" from Bruce- Hillman Framework**	**RefPro Post-1999 Files - Narrative Metadata Score Based on "Quality Criteria Questions" from Bruce-Hillman Framework**	**Location**
Completeness	1. Does the element set completely describe the objects? 2. Are all relevant elements used for each object?	1. Yes, all measurements (objects) described in the report are expressed as elements. 2. Yes, there are sufficient elements to describe the objects present in the dataset; all objects are described by elements.	1. (Suplee et al. 2005) 2. Visual view
Provenance	1. Who is responsible for creating, extracting, or transforming the metadata? 2. How was the metadata created or extracted? 3. What transformations have been done on the data since its creation?	1. Contains information on the generator, user, and curator of the metadata. 2. Contains information on documents pertaining to the project protocols. 3. Updates are noted using element fields.	1. Application profile 2. Application profile 3. Visual view
Accuracy	1. Have accepted methods been used for creation or extraction? 2. What has been done to ensure valid values and structure? 3. Are default values appropriate, and have they been appropriately used?	1. Yes, there is a series of protocols offered by the contributor and publisher. 2. QA protocols exist for field, lab, and database management; they are mentioned in the metadata. 3. Yes, and yes; QA protocols have been developed.	1. Montana DEQ external source 2. U.S. EPA and Montana DEQ external sources 3. Montana DEQ external sources

Table 18 cont. Post-1999 RefPro metadata analysis using the Bruce-Hillman Framework

Metadata Characteristics	**"Quality Criteria Questions" from Bruce- Hillman Framework**	**RefPro Post-1999 Files - Narrative Metadata Score Based on "Quality Criteria Questions" from Bruce-Hillman Framework**	**Location**
Conformance to Expectations	1. Do metadata describe what it claims to? 2. Are controlled vocabularies aligned with audience characteristics and understanding of the objects? 3. Are compromises documented and in line with community expectations?	1. Yes 2. Yes, but syntax is not outlined or defined in the queried files 3. Yes and no: primary end-users are satisfied; potential end-users are generally not satisfied.	1. (Suplee et al. 2005) 2. Visual view and application profile 3. User assessment study (see joint fact finding section)
Logical Consistency and Coherence	1. Are data in elements consistent throughout? 2. How does it compare with other data within the community?	1. No, object values change in some cases. 2. Elements vary based on project and when data was generated.	1. Visual view 2. Comparing files on a temporal scale.
Timeliness	1. Is metadata regularly updated as the resource changes? 2. Are controlled vocabularies updated when relevant?	1. Yes, but what is changed is not documented. 2. Montana DEQ external source	1. Visual View 2. Montana DEQ external source
Accessibility	1. Is an appropriate element set for audience and community being used? 2. Is it affordable to use and maintain? 3. Does it permit further value-adds?	1. Yes, but some elements are superfluous and do not pertain to every site sampled. 2. Yes, for its intended use. 3. Yes, data is accessible and can be manipulated	1. User assessment study, immediate audience is satisfied; community is generally not. 2. Experience of U.S. EPA, database changed recently because of resource constraints; new system is being implemented. 3. Standard format

Table 19. DCMES analysis for Pre-1999 RefPro files queried from STORET/WQX.

	Dublin Core Metadata Element Set (DCMES) Analysis of Pre-1999	
	DC-Elements	**(Pre-1999 File)-reported element**
1	Contributor	(Regular File)-Org Name
2	Coverage	(Regular File)-HUC
3	Creator	(Metadata File)
4	Date	(Regular File)-Activity Start
5	Description	(Metadata File)
6	Format	(Regular File)-Activity Medium
7	Identifier	(Regular File) Station ID
8	Language	(Metadata File) (Regular File)-Units
9	Publisher	(Metadata File)
10	Relation	(Regular File)-Characteristic Name
11	Rights	(Metadata File)
12	Source	(Metadata File); (Regular File)-Analytical Proc ID
13	Subject	(Metadata File); (Regular File)-Activity ID
14	Title	(Metadata File)
15	Type	(Metadata File)-Activity Type

Table 20. DCMES analysis for Post-1999 RefPro files queried from STORET/WQX.

	Dublin Core Metadata Element Set (DCMES) Analysis of Post-1999	
	DC-Elements	**(Post-1999 File)-reported exemplary element**
1	Contributor	(R/B Files)-Org ID
2	Coverage	(R/B Files)-HUC
3	Creator	(R/B Files)-Project Name
4	Date	(R/B Files)-Acitivity Start
5	Description	(R/B Files)-Project Description
6	Format	(R/B Files)-Activity Medium
7	Identifier	(R/B Files)-Station ID
8	Language	(Metadata File); (R/B Files)-Units
9	Publisher	(R/B Files)-Org Name
10	Relation	(R/B Files)-Characteristic Name
11	Rights	(Metadata File)
12	Source	(Metadata File); (R/B Files)-Analytical Proc ID
13	Subject	(Metadata File); (R/B Files)-Activity ID
14	Title	(Metadata File)
15	Type	(Metadata File); (R/B Files)-Activity Type

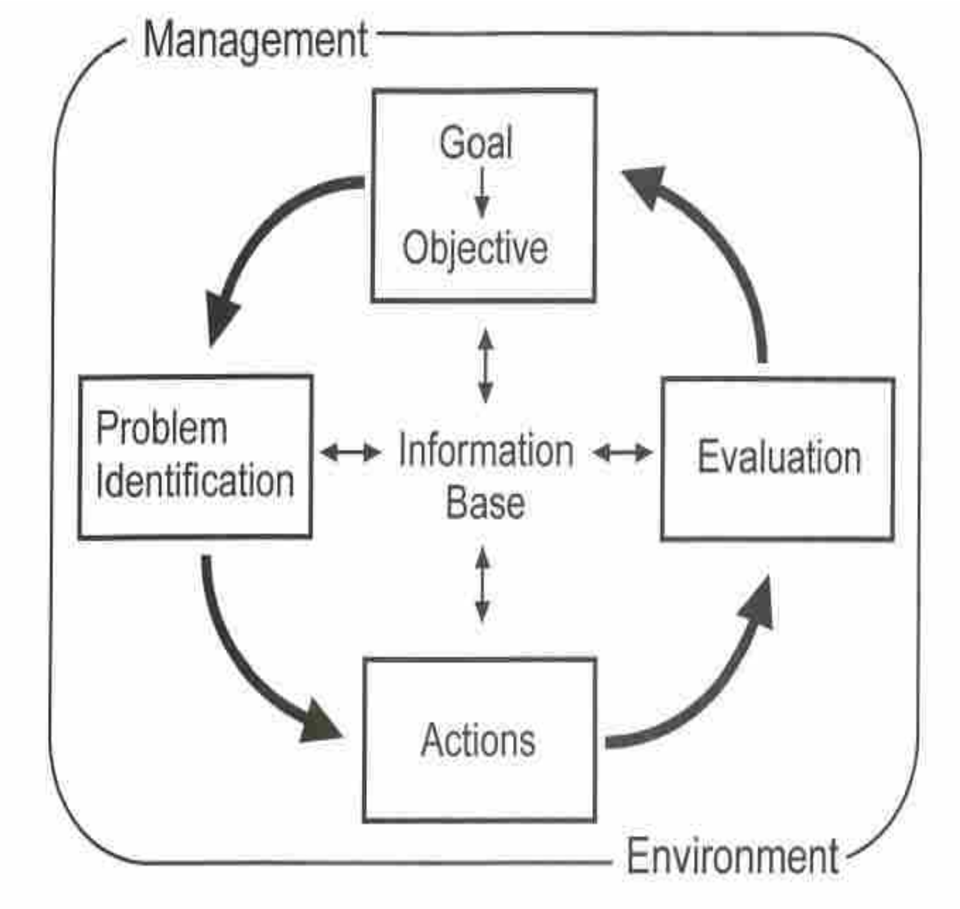
Notes for Tables 19 and 20:

Note: the Regular and Biology files share a metadata file (also known as an application profile), but the Pre-1999 file has its own.
--(Regular File)-file queried from STORET/WQX that contain actual data described by traditional elements, robust examples from the element report (see Table 14) are listed.
--(R/B Files)-Regular/Biology files queried from STORET/WQX that contain actual data described by traditional elements, robust examples from the element report (see Table 15 and 16) are listed.
--(Metadata File)-or application profile, is a file queried from STORET/WQX that contains narrative metadata and not traditional elements.

Table 21. Survey responses for questions 1-5b; “Unidentified /Non-response” indicates the respondent did not select an organization type on the survey; “Other/2+ Groups” indicates that the respondent selected two or more groupings on the survey, or wrote in a self-selected organization type

	Question 1. Does your organization use water quality data in decision making processes?		**Question 2.** Does your organization communicate with the Montana DEQ?		**Question 3.** Does your organization use a technical advisor to gather water quality data?		**Question 4.** Does your organization use the process of “joint fact finding” or collaborate with other stakeholders?		**Question 5.** Does your organization know about the water quality data that the Montana-DEQ generates?		**Question 5b.** If yes, does your organization use any Montana DEQ data?	
MWCC Organization Type	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
Watershed Group	15	2	15	2	13	4	13	4	17	0	15	2
Unidentified/Non-response	4	0	4	0	3	1	4	0	4	0	2	2
Other/2+ Groups	2	1	3	0	3	0	3	0	3	0	3	0
TOTAL	20	2	21	1	17	5	19	3	22	0	18	4

Figure 1. The importance of obtaining a strong information base to serve a working management environment. A strong information base needs to be able to support the management environment as processes are refined. This figure shows how adaptive management is fed by the available information base.

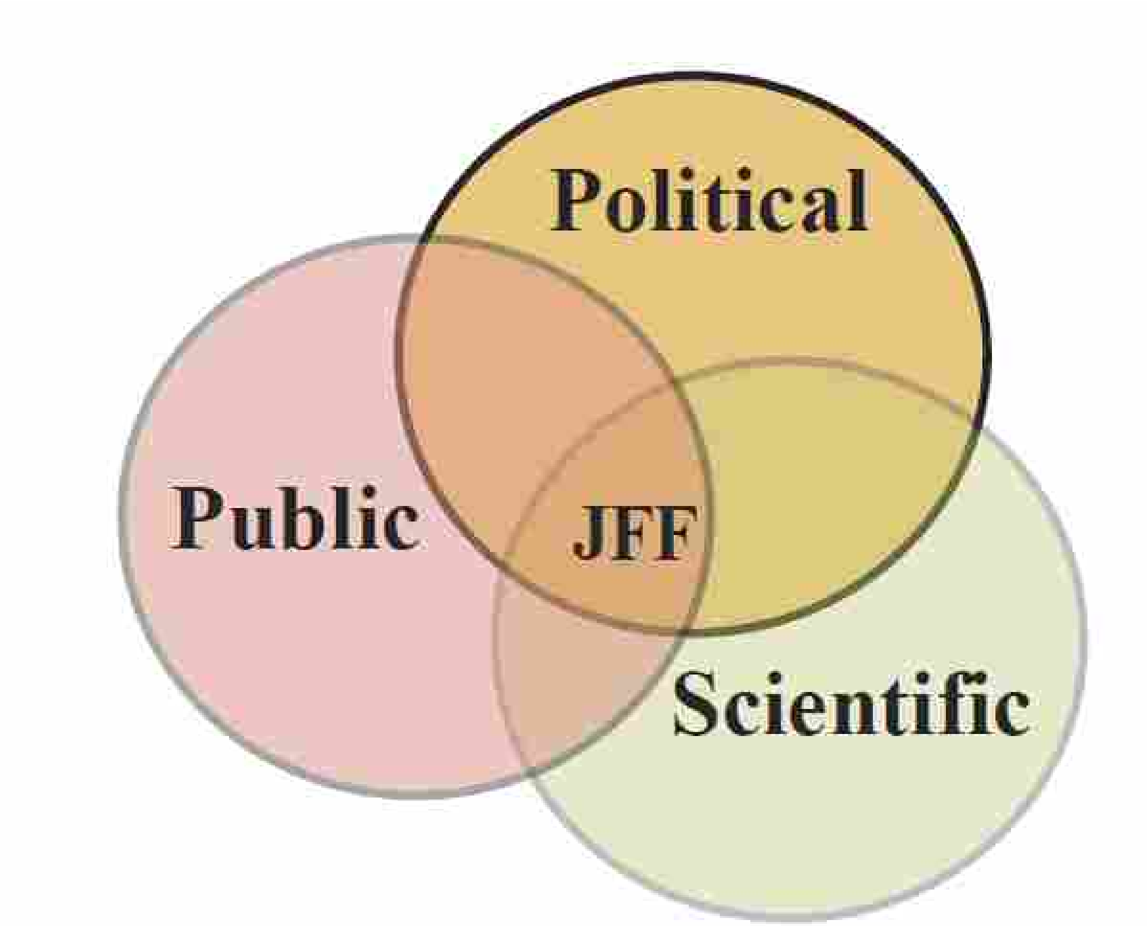


(Modified from Kohler and Hubert 1999)

Figure 2. Factors influencing the process of natural resource management. This figure shows the components that contribute to the management process in time and space; and is used to help natural resource managers understand the various factors that influence a given management process.

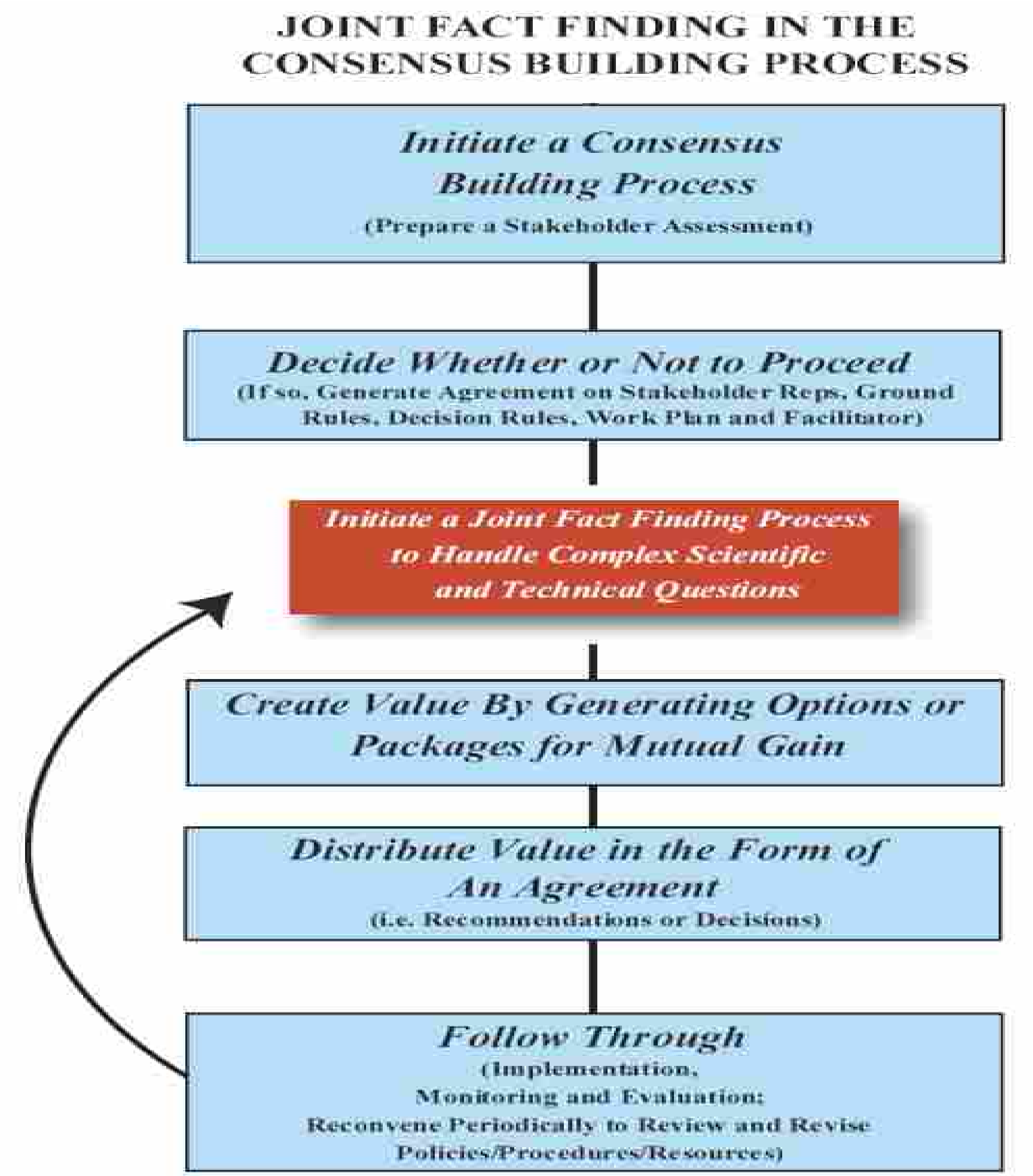
(Modified from Kohler and Hubert 1999)

Figure 3. A model for interpreting the purpose of joint fact finding. This Venn diagram shows the overlap between the three major stakeholder groups in a natural resource context. Joint fact finding is located in the middle of the diagram where groups' interests intersect and where collaboration can take place.



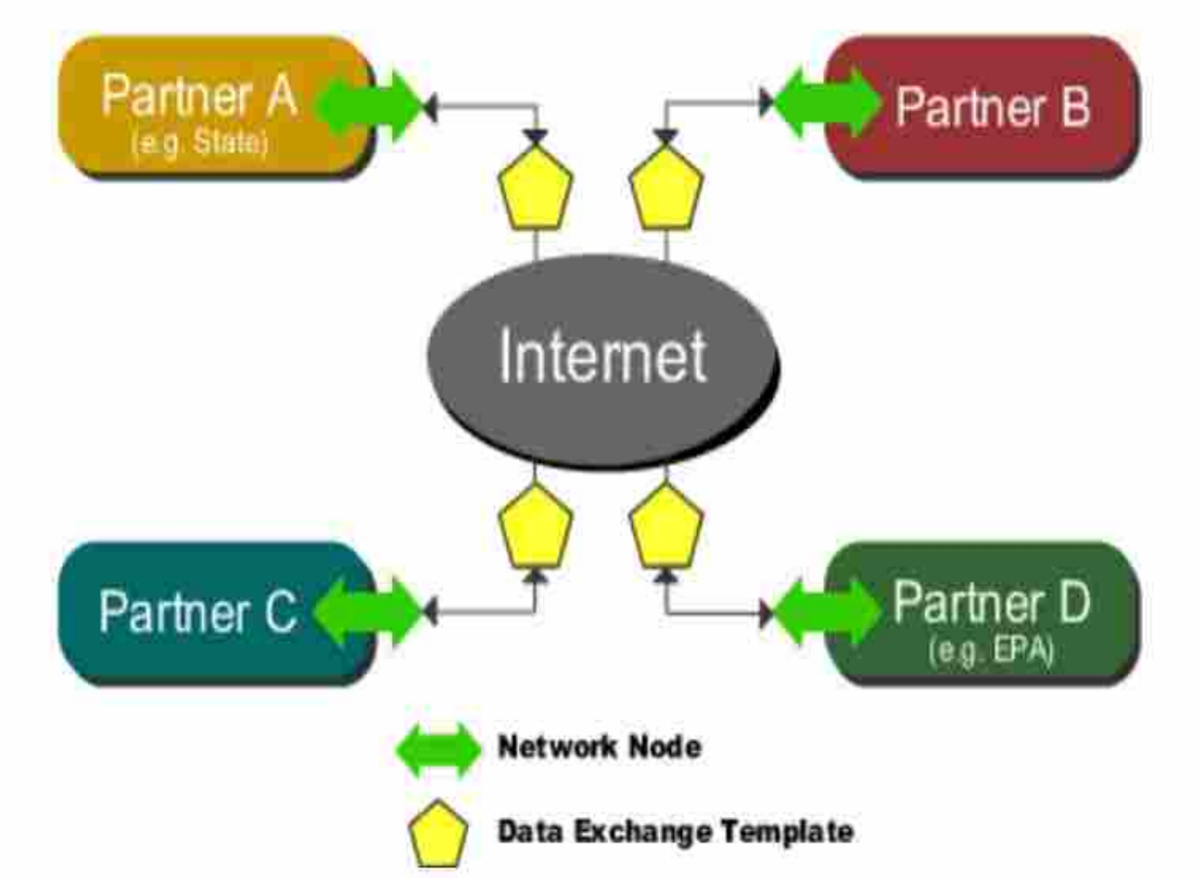
(Modified from Rofougaran and Karl 2005)

Figure 4. A model for using joint fact finding as part of the consensus building process. Joint fact finding is a prescribed procedure that can help to build consensus regarding the technical aspects of water quality planning and management. It is a prescriptive process, but has a basic framework that should be adhered to.



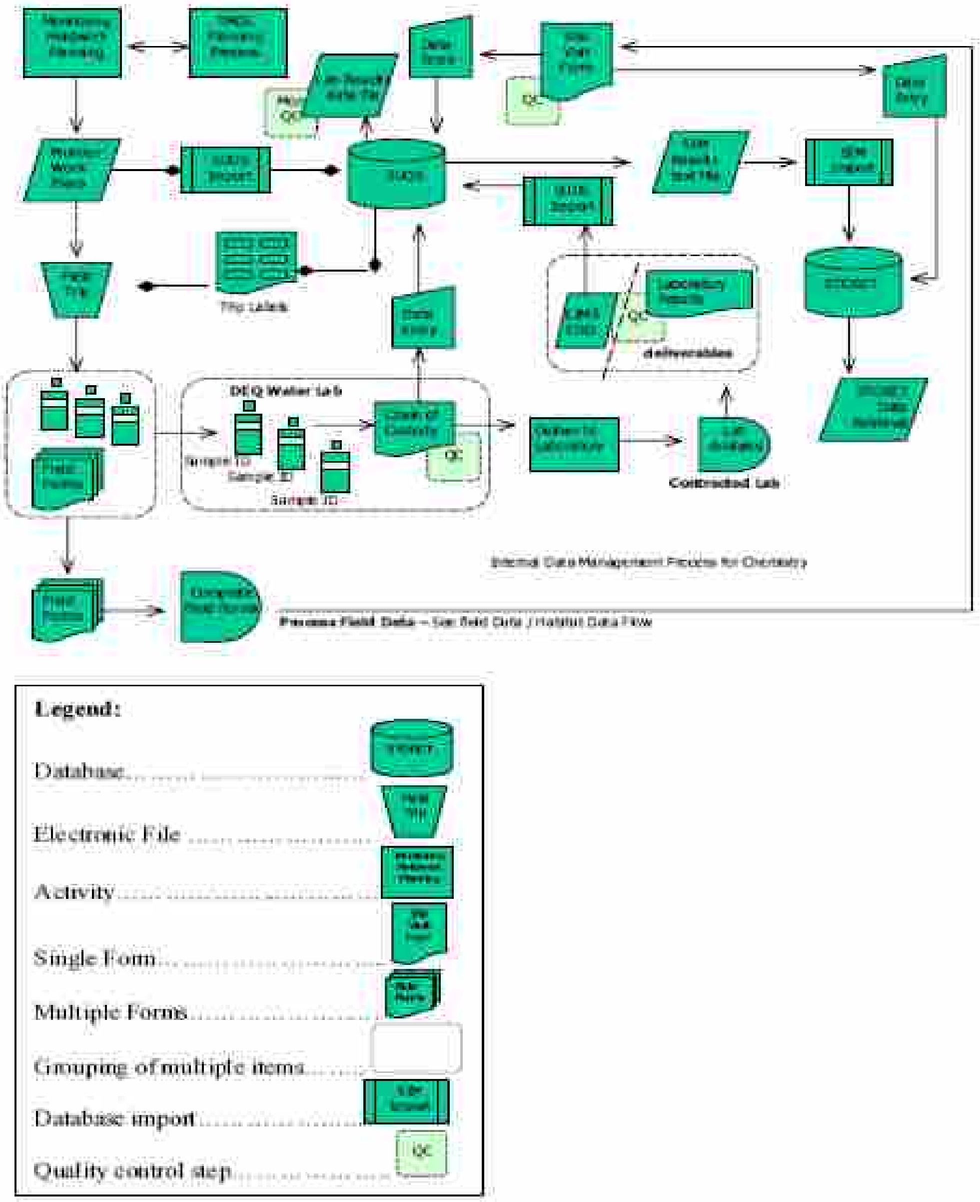
(Modified from Rofougaran and Karl 2005 from CBI, Cambridge, Mass.)

Figure 5. Illustrates how the Environmental Information Exchange Network operates. This figure shows how a web-based interface can be used to share data between multiple partners. The exchange network uses "data exchange templates" (i.e., metadata schemas) to link end-users together, enabling them to share information.



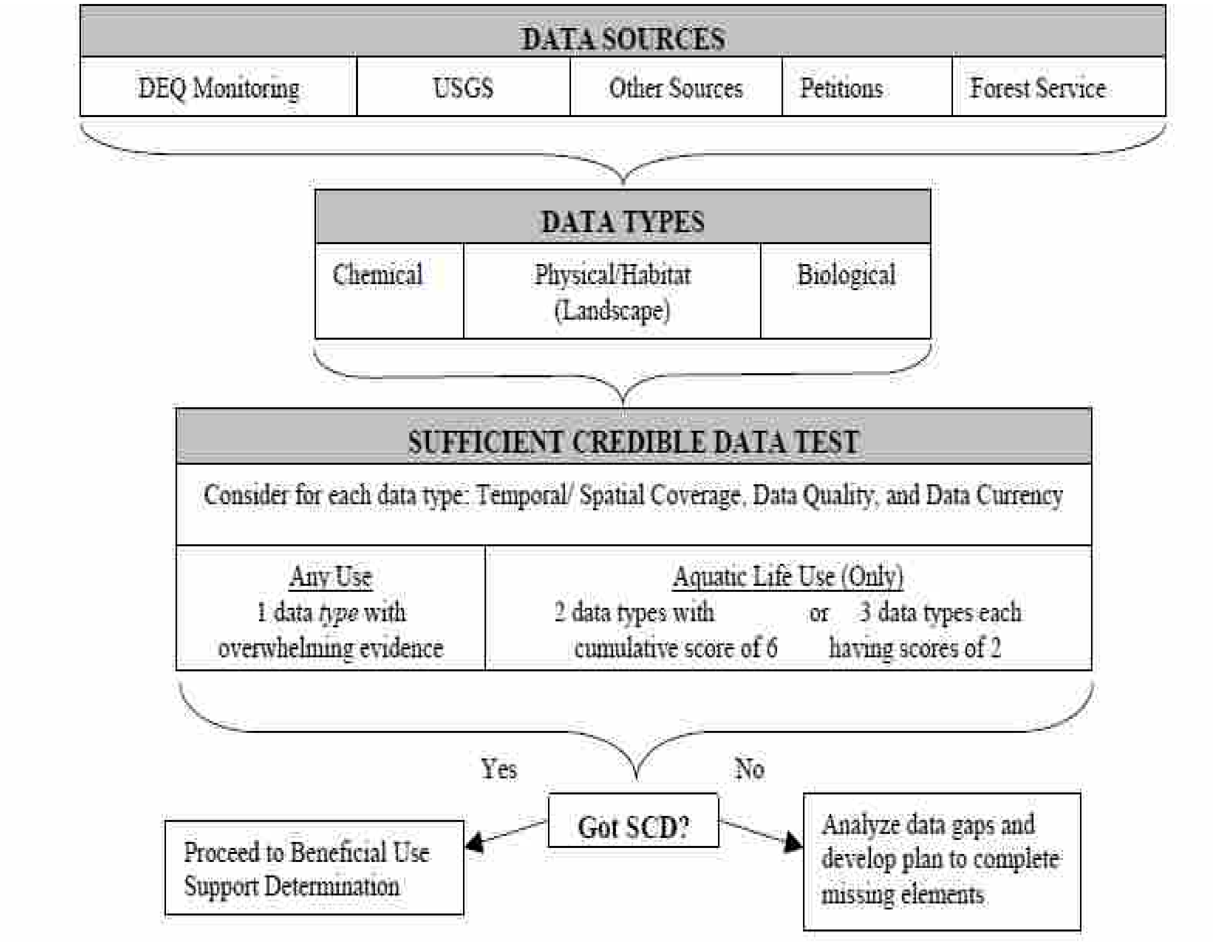
(Modified from Environmental Information Exchange Network [updated 2011])

Figure 6. Flow of data at the Montana DEQ; covers from the planning phase through the completion of the analyses and final entry. It is a comprehensive process that is best understood in an illustrated format. Metadata are gathered throughout the process at critical points including in the field forms, chain of custody forms and during lab analysis.



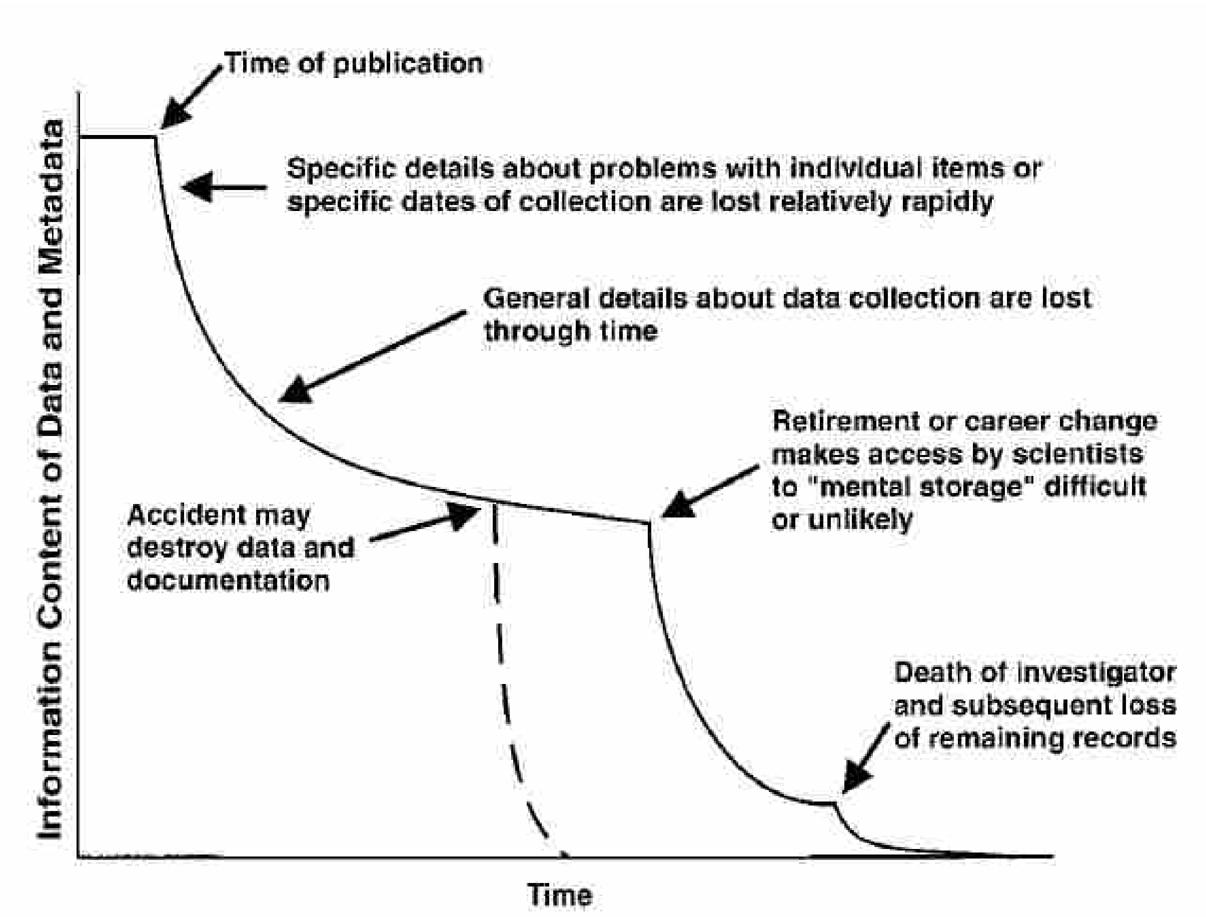
(Modified from Mathieus *et al.* 2005a)

Figure 7. Montana DEQ sufficient credible data flowchart. In order to proceed with a beneficial use determination, data need to be tested for coverage, quality, and currency. Without adequate metadata, performing these tests would not be possible. Sufficient credible data should have a limited number of data gaps and few missing elements or they will be deemed unfit to inform a beneficial use support determination.



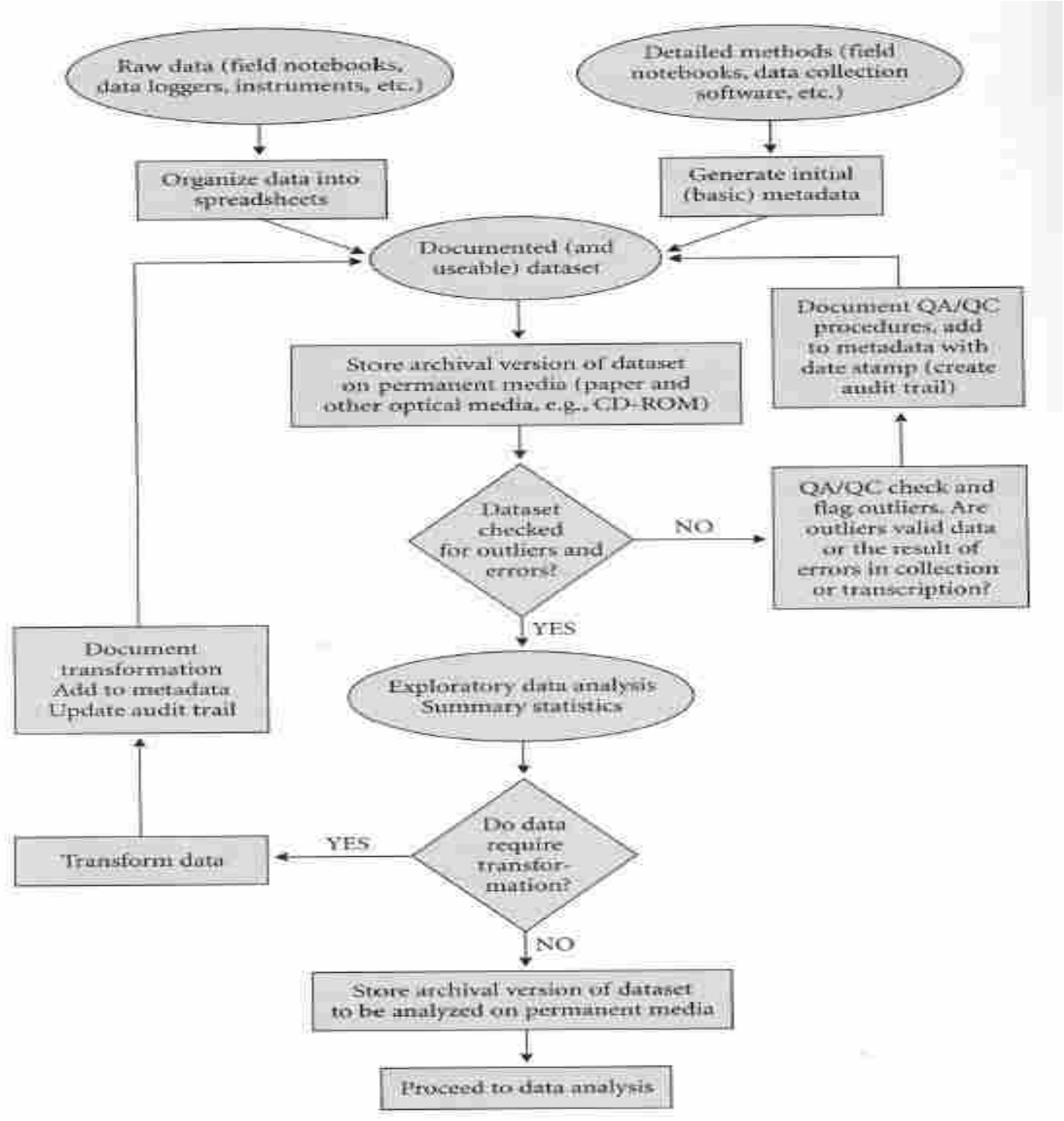
(Modified from Mathieus *et al.* 2006)

Figure 8. Information entropy; this figure is an example of how information connected with data and metadata degrades over time. Accidents or changes in storage technology (dashed line) may eliminate access to remaining raw data and metadata at any time.



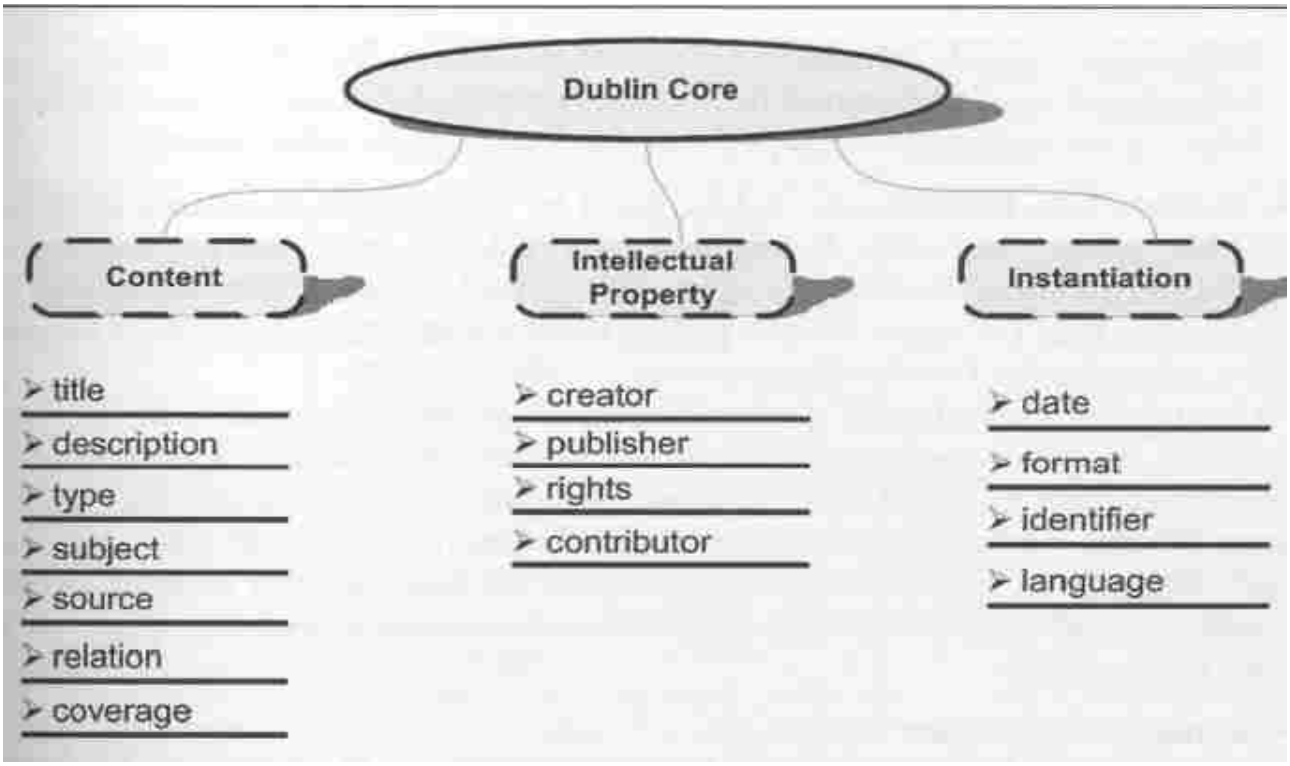
(Modified from Michener *et al.* 1997)

Figure 9. Flowchart of procedures for managing, curating and storing data. This is a valuable figure for understanding how metadata structure contributes to statistical procedure. There are several key nodes in the diagram, particularly in the QA/QC procedures, where adequate metadata are critical to proceeding with a meaningful analysis.



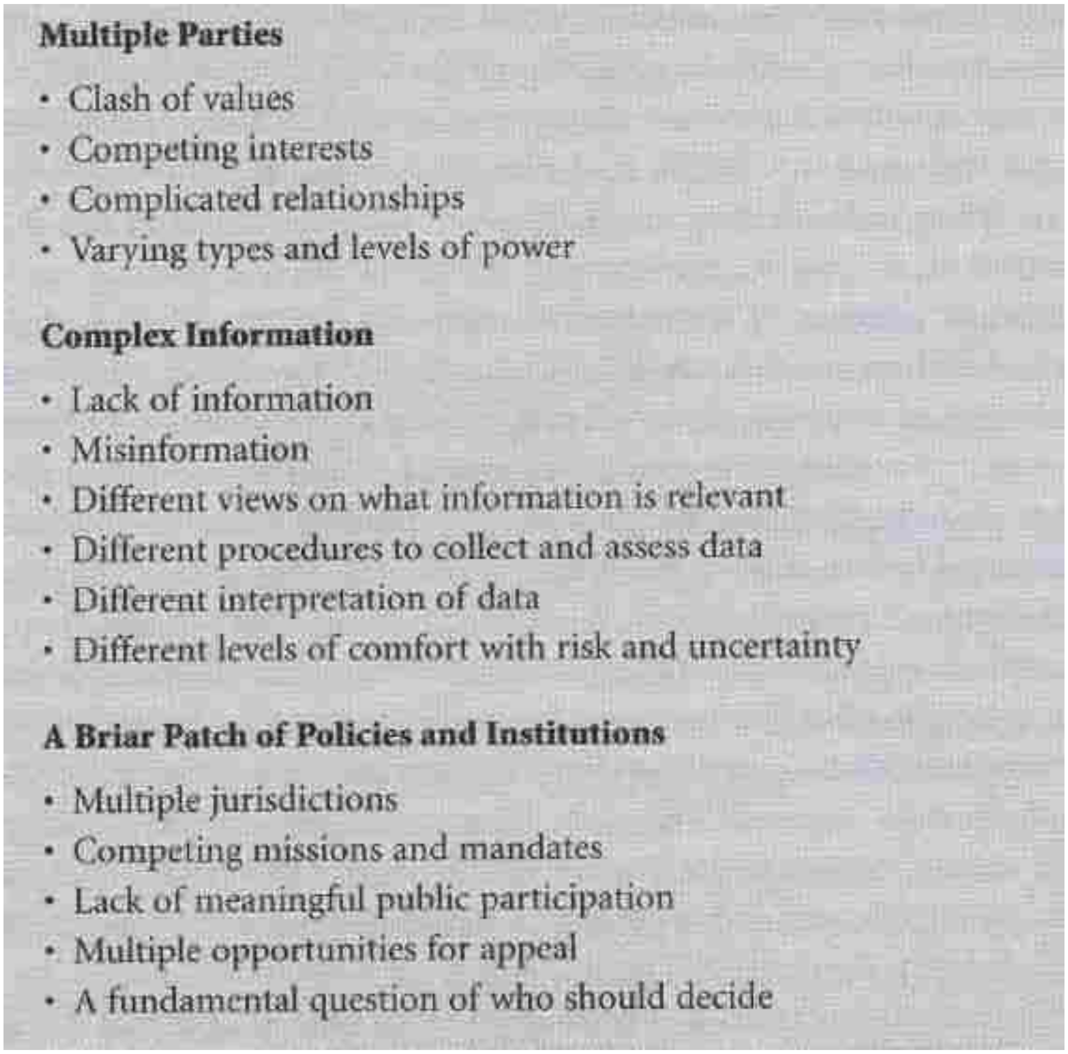
(Modified from Gotelli and Ellison 2004)

Figure 10. The 15 elements of the Dublin Core Metadata Element Set (DCMES) grouped by category. The Dublin Core Metadata Initiative is an endeavor to categorize metadata elements to create a common metadata structure for use across disciplines. These categories are presented by Zeng and Qin (2008) to demonstrate how element descriptions are related, and how they can rely on each other to support overall metadata structure.



(Modified from Zeng and Qin 2008)

Display 1. Commonalities among resource disputes in the Western United States.



Multiple Parties

- Clash of values
- Competing interests
- Complicated relationships
- Varying types and levels of power

Complex Information

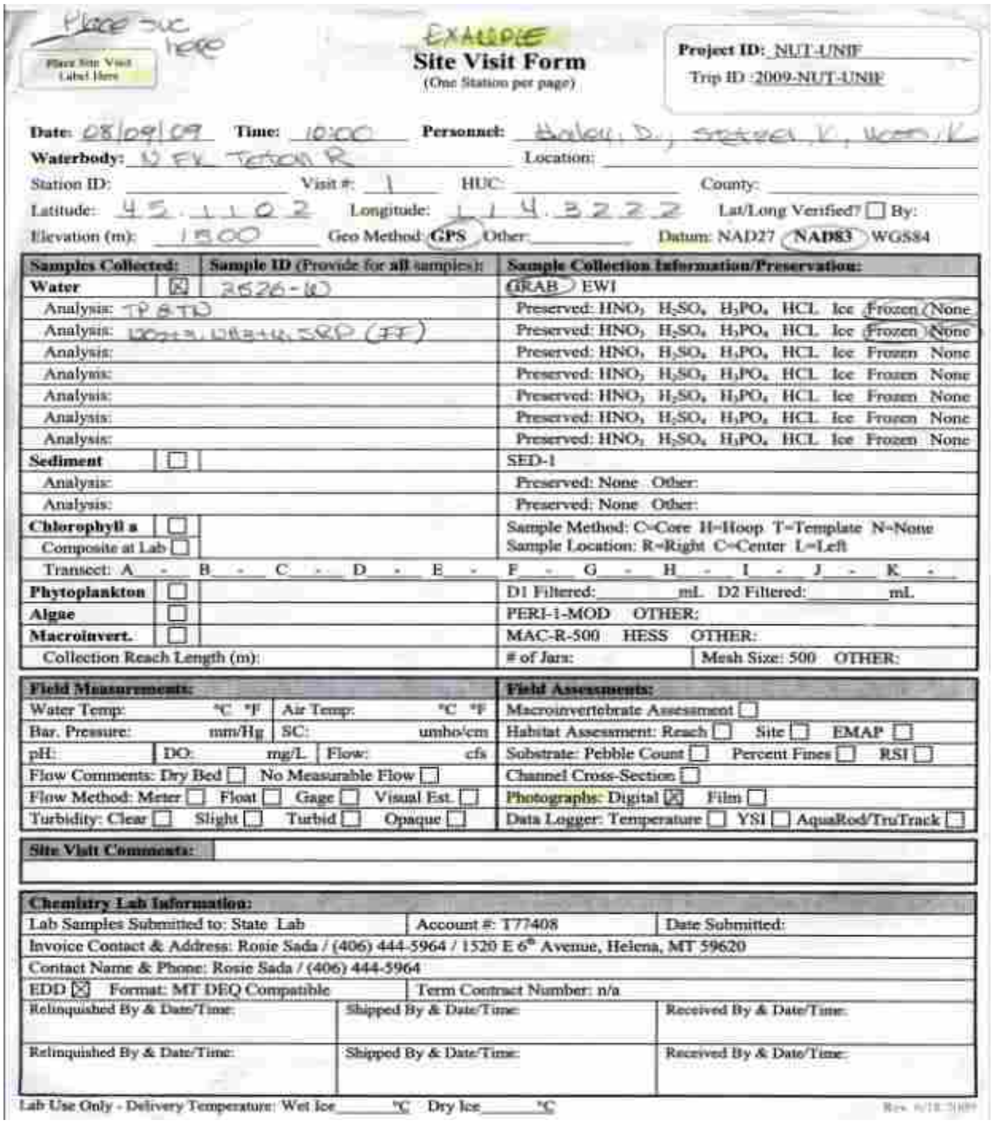
- Lack of information
- Misinformation
- Different views on what information is relevant
- Different procedures to collect and assess data
- Different interpretation of data
- Different levels of comfort with risk and uncertainty

A Briar Patch of Policies and Institutions

- Multiple jurisdictions
- Competing missions and mandates
- Lack of meaningful public participation
- Multiple opportunities for appeal
- A fundamental question of who should decide

(Modified from McKinney and Harmon 2004)

Display 2. Site Visit Form contributing metadata to files queried for the RefPro 2009 field season from STORET/WQX.



Place SVC here

Place Site Visit Label Here

EXAMPLE

Site Visit Form
(One Station per page)

Project ID: NUT-UNIF
Trip ID :2009-NUT-UNIF

Date: 08/09/09 **Time:** 10:00 **Personnel:** Haley, D., Stetzel, K, Woods, K
Waterbody: N FK Teton R Location:
Station ID: Visit #: 1 HUC: County:
Latitude: 45.1102 Longitude: 114.3222 Lat/Long Verified? ☐ By:
Elevation (m): 1500 Geo Method: [✓ GPS] Other: Datum: NAD27 [✓ NAD83] WGS84

Samples Collected:		**Sample ID** (Provide for **all** samples):	**Sample Collection Information/Preservation:**
Water	☒	2526-W	[✓ GRAB] EWI
Analysis: TP & TN			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice [✓ Frozen] [✓ None]
Analysis: NO2+3, NH3+4, SRP (FF)			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice [✓ Frozen] [✓ None]
Analysis:			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice Frozen None
Analysis:			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice Frozen None
Analysis:			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice Frozen None
Analysis:			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice Frozen None
Analysis:			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice Frozen None
Sediment	☐		SED-1
Analysis:			Preserved: None Other:
Analysis:			Preserved: None Other:
Chlorophyll a Composite at Lab ☐	☐		Sample Method: C=Core H=Hoop T=Template N=None Sample Location: R=Right C=Center L=Left
Transect: A - B - C - D - E -			F - G - H - I - J - K -
Phytoplankton	☐		D1 Filtered: mL D2 Filtered: mL
Algae	☐		PERI-1-MOD OTHER:
Macroinvert.	☐		MAC-R-500 HESS OTHER:
Collection Reach Length (m):			# of Jars: Mesh Size: 500 OTHER:

Field Measurements:			**Field Assessments:**
Water Temp: °C °F		Air Temp: °C °F	Macroinvertebrate Assessment ☐
Bar. Pressure: mm/Hg		SC: umho/cm	Habitat Assessment: Reach ☐ Site ☐ EMAP ☐
pH:	DO: mg/L	Flow: cfs	Substrate: Pebble Count ☐ Percent Fines ☐ RSI ☐
Flow Comments: Dry Bed ☐ No Measurable Flow ☐			Channel Cross-Section ☐
Flow Method: Meter ☐ Float ☐ Gage ☐ Visual Est. ☐			Photographs: Digital ☒ Film ☐
Turbidity: Clear ☐ Slight ☐ Turbid ☐ Opaque ☐			Data Logger: Temperature ☐ YSI ☐ AquaRod/TruTrack ☐

Site Visit Comments:

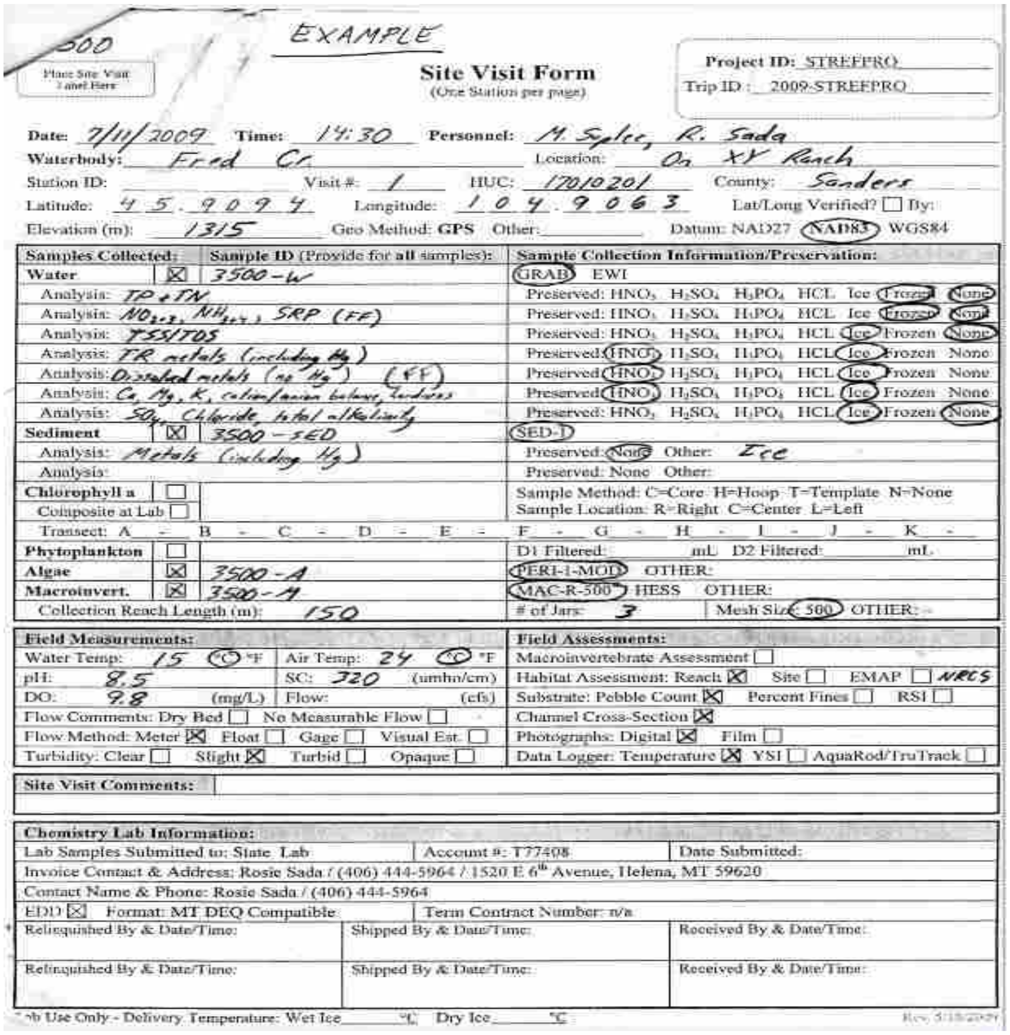
Chemistry Lab Information:		
Lab Samples Submitted to: State Lab	Account #: T77408	Date Submitted:
Invoice Contact & Address: Rosie Sada / (406) 444-5964 / 1520 E 6th Avenue, Helena, MT 59620		
Contact Name & Phone: Rosie Sada / (406) 444-5964		
EDD ☒ Format: MT DEQ Compatible	Term Contract Number: n/a	
Relinquished By & Date/Time:	Shipped By & Date/Time:	Received By & Date/Time:
Relinquished By & Date/Time:	Shipped By & Date/Time:	Received By & Date/Time:

Lab Use Only - Delivery Temperature: Wet Ice ____ °C Dry Ice ____ °C

Rev. 6/18/2009

(Montana DEQ, Sampling Protocol, 2009)

Display 3. Site Visit Form contributing metadata to files queried for the RefPro 2009 field season from STORET/WQX.



500

Place Site Visit Label Here

EXAMPLE

Site Visit Form

(One Station per page)

Project ID: STREFPRO
Trip ID : 2009-STREFPRO

Date: 7/11/2009 **Time:** 14:30 **Personnel:** M. Sylee, R. Sada
Waterbody: Fred Cr. Location: On XY Ranch
Station ID: Visit #: 1 HUC: 17010201 County: Sanders
Latitude: 45.9094 Longitude: 104.9063 Lat/Long Verified? ☐ By:
Elevation (m): 1315 Geo Method: **GPS** Other: Datum: NAD27 [✓ NAD83] WGS84

Samples Collected:		**Sample ID** (Provide for **all** samples):	**Sample Collection Information/Preservation:**
Water	☒	3500-W	[✓ GRAB] EWI
Analysis: TP + TN			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice [✓ Frozen] [✓ None]
Analysis: NO_{2+3}, NH_{3+4}, SRP (FF)			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice [✓ Frozen] [✓ None]
Analysis: TSS/TDS			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL [✓ Ice] Frozen [✓ None]
Analysis: TR metals (including Hg)			Preserved: [✓ HNO_3] H_2SO_4 H_3PO_4 HCL [✓ Ice] Frozen None
Analysis: Dissolved metals (no Hg) (FF)			Preserved: [✓ HNO_3] H_2SO_4 H_3PO_4 HCL [✓ Ice] Frozen None
Analysis: Ca, Mg, K, cation/anion balance, hardness			Preserved: [✓ HNO_3] H_2SO_4 H_3PO_4 HCL [✓ Ice] Frozen None
Analysis: SO_4, Chloride, total alkalinity			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL [✓ Ice] Frozen [✓ None]
Sediment	☒	3500-SED	[✓ SED-1]
Analysis: Metals (including Hg)			Preserved: [✓ None] Other: Ice
Analysis:			Preserved: None Other:
Chlorophyll a	☐		Sample Method: C=Core H=Hoop T=Template N=None
Composite at Lab ☐			Sample Location: R=Right C=Center L=Left
Transect: A - B - C - D - E -			F - G - H - I - J - K -
Phytoplankton	☐		D1 Filtered: mL D2 Filtered: mL
Algae	☒	3500-A	[✓ PERI-1-MOD] OTHER:
Macroinvert.	☒	3500-M	[✓ MAC-R-500] HESS OTHER:
Collection Reach Length (m):		150	# of Jars: 3 Mesh Size: [✓ 500] OTHER:

Field Measurements:		**Field Assessments:**
Water Temp: 15 [✓ °C] °F	Air Temp: 24 [✓ °C] °F	Macroinvertebrate Assessment ☐
pH: 8.5	SC: 320 (umho/cm)	Habitat Assessment: Reach ☒ Site ☐ EMAP ☐ NRCS
DO: 9.8 (mg/L)	Flow: (cfs)	Substrate: Pebble Count ☒ Percent Fines ☐ RSI ☐
Flow Comments: Dry Bed ☐ No Measurable Flow ☐		Channel Cross-Section ☒
Flow Method: Meter ☒ Float ☐ Gage ☐ Visual Est. ☐		Photographs: Digital ☒ Film ☐
Turbidity: Clear ☐ Slight ☒ Turbid ☐ Opaque ☐		Data Logger: Temperature ☒ YSI ☐ AquaRod/TruTrack ☐

Site Visit Comments:

Chemistry Lab Information:		
Lab Samples Submitted to: State Lab	Account #: T77408	Date Submitted:
Invoice Contact & Address: Rosie Sada / (406) 444-5964 / 1520 E 6th Avenue, Helena, MT 59620		
Contact Name & Phone: Rosie Sada / (406) 444-5964		
EDD ☒ Format: MT DEQ Compatible	Term Contract Number: n/a	
Relinquished By & Date/Time:	Shipped By & Date/Time:	Received By & Date/Time:
Relinquished By & Date/Time:	Shipped By & Date/Time:	Received By & Date/Time:

ab Use Only - Delivery Temperature: Wet Ice ____ °C Dry Ice ____ °C

Rev. [illegible]

(Montana DEQ, Sampling Protocol, 2009)

Display 4. Site Visit Form contributing metadata to files queried for the RefPro 2009 field season from STORET/WQX.

SOC

Place Site Visit Label Here

EXAMPLE

Site Visit Form
(One Station per page)

Project ID: STREFPRO
Trip ID : 2009-STREFPRO

Date: 7/13/09 **Time:** 10:00 **Personnel:** Smith, K., Cook, P., Sada, R.
Waterbody: Elk Cr Location:
Station ID: Visit #: 1 HUC: 170102 County: Sanders
Latitude: 45.9094 Longitude: 104.9092 Lat/Long Verified? ☐ By:
Elevation (m): 500 Geo Method: [✓ GPS] Other: Datum: NAD27 [✓ NAD83] WGS84

Samples Collected:		**Sample ID** (Provide for **all** samples):	**Sample Collection Information/Preservation:**
Water	☐		GRAB EWI
Analysis:			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice Frozen None
Analysis:			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice Frozen None
Analysis:			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice Frozen None
Analysis:			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice Frozen None
Analysis:			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice Frozen None
Analysis:			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice Frozen None
Analysis:			Preserved: HNO_3 H_2SO_4 H_3PO_4 HCL Ice Frozen None
Sediment	☐		SED-1
Analysis:			Preserved: None Other:
Analysis:			Preserved: None Other:
Chlorophyll a	☒	3500-C	Sample Method: C=Core H=Hoop T=Template N=None
Composite at Lab	☐		Sample Location: R=Right C=Center L=Left
Transect: A T-R B T-L C T-C D H-R E C-L F C-C G H-R H T-L I T-C J H-R K H-L			
Phytoplankton	☒	3500-PHY	D1 Filtered: 600 mL D2 Filtered: 600 mL
Algae	☐		PERI-1-MOD OTHER:
Macroinvert.	☐		MAC-R-500 HESS OTHER:
Collection Reach Length (m):			# of Jars: | Mesh Size: 500 OTHER:

Field Measurements:		**Field Assessments:**
Water Temp: °C °F	Air Temp: °C °F	Macroinvertebrate Assessment ☐
pH:	SC: (umho/cm)	Habitat Assessment: Reach ☐ Site ☐ EMAP ☐
DO: (mg/L)	Flow: (cfs)	Substrate: Pebble Count ☐ Percent Fines ☐ RSI ☐
Flow Comments: Dry Bed ☐ No Measurable Flow ☐		Channel Cross-Section ☐
Flow Method: Meter ☐ Float ☐ Gage ☐ Visual Est. ☐		Photographs: Digital ☐ Film ☐
Turbidity: Clear ☐ Slight ☐ Turbid ☐ Opaque ☐		Data Logger: Temperature ☐ YSI ☐ AquaRod/TruTrack ☐

Site Visit Comments:

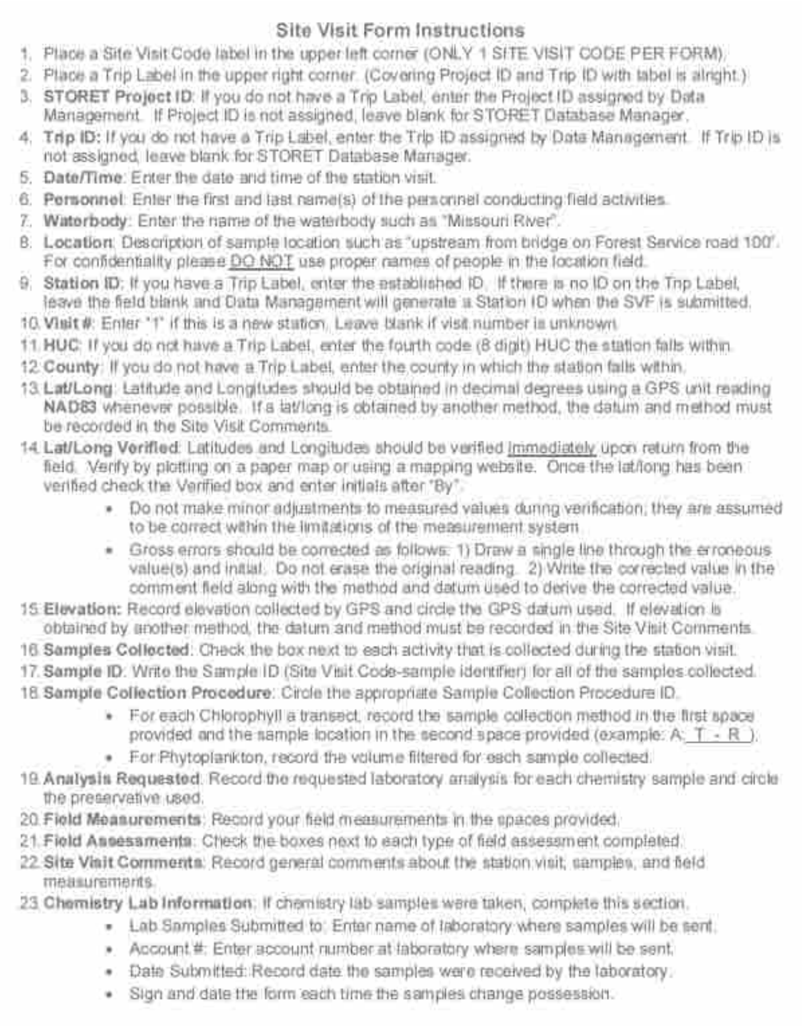
Chemistry Lab Information:		
Lab Samples Submitted to: UM	Account #: n/a	Date Submitted:
Invoice Contact & Address: Watershed Clinic-UM c/o Vicki Watson, Missoula, MT 59812		
Contact Name & Phone: Vicki Watson / (406) 243-5153		
EDD ☒ Format: MT DEQ Compatible	Term Contract Number: n/a	
Relinquished By & Date/Time: 07/13/09 10:00 AM	Shipped By & Date/Time:	Received By & Date/Time:
Relinquished By & Date/Time:	Shipped By & Date/Time:	Received By & Date/Time:

Lab Use Only - Delivery Temperature: Wet Ice______°C Dry Ice______°C

Rev. 5/18/2009

(Montana DEQ, Sampling Protocol, 2009)

Display 5. Reverse side of standard Site Visit Form with instructions for how to interpret metadata elements



Site Visit Form Instructions

1. Place a Site Visit Code label in the upper left corner (ONLY 1 SITE VISIT CODE PER FORM).
2. Place a Trip Label in the upper right corner. (Covering Project ID and Trip ID with label is alright.)
3. **STORET Project ID**: If you do not have a Trip Label, enter the Project ID assigned by Data Management. If Project ID is not assigned, leave blank for STORET Database Manager.
4. **Trip ID:** If you do not have a Trip Label, enter the Trip ID assigned by Data Management. If Trip ID is not assigned, leave blank for STORET Database Manager.
5. **Date/Time**: Enter the date and time of the station visit.
6. **Personnel**: Enter the first and last name(s) of the personnel conducting field activities.
7. **Waterbody**: Enter the name of the waterbody such as "Missouri River".
8. **Location**: Description of sample location such as "upstream from bridge on Forest Service road 100". For confidentiality please DO NOT use proper names of people in the location field.
9. **Station ID**: If you have a Trip Label, enter the established ID. If there is no ID on the Trip Label, leave the field blank and Data Management will generate a Station ID when the SVF is submitted.
10. **Visit #**: Enter "1" if this is a new station. Leave blank if visit number is unknown.
11. **HUC**: If you do not have a Trip Label, enter the fourth code (8 digit) HUC the station falls within.
12. **County**: If you do not have a Trip Label, enter the county in which the station falls within.
13. **Lat/Long**: Latitude and Longitudes should be obtained in decimal degrees using a GPS unit reading **NAD83** whenever possible. If a lat/long is obtained by another method, the datum and method must be recorded in the Site Visit Comments.
14. **Lat/Long Verified**: Latitudes and Longitudes should be verified Immediately upon return from the field. Verify by plotting on a paper map or using a mapping website. Once the lat/long has been verified check the Verified box and enter initials after "By".
    - Do not make minor adjustments to measured values during verification; they are assumed to be correct within the limitations of the measurement system.
    - Gross errors should be corrected as follows: 1) Draw a single line through the erroneous value(s) and initial. Do not erase the original reading. 2) Write the corrected value in the comment field along with the method and datum used to derive the corrected value.
15. **Elevation:** Record elevation collected by GPS and circle the GPS datum used. If elevation is obtained by another method, the datum and method must be recorded in the Site Visit Comments.
16. **Samples Collected**: Check the box next to each activity that is collected during the station visit.
17. **Sample ID**: Write the Sample ID (Site Visit Code-sample identifier) for all of the samples collected.
18. **Sample Collection Procedure**: Circle the appropriate Sample Collection Procedure ID.
    - For each Chlorophyll a transect, record the sample collection method in the first space provided and the sample location in the second space provided (example: A: T - R).
    - For Phytoplankton, record the volume filtered for each sample collected.
19. **Analysis Requested**: Record the requested laboratory analysis for each chemistry sample and circle the preservative used.
20. **Field Measurements**: Record your field measurements in the spaces provided.
21. **Field Assessments**: Check the boxes next to each type of field assessment completed.
22. **Site Visit Comments**: Record general comments about the station visit, samples, and field measurements.
23. **Chemistry Lab Information**: If chemistry lab samples were taken, complete this section.
    - Lab Samples Submitted to: Enter name of laboratory where samples will be sent.
    - Account #: Enter account number at laboratory where samples will be sent.
    - Date Submitted: Record date the samples were received by the laboratory.
    - Sign and date the form each time the samples change possession.

(Bostrom et al. 2008)

Display 6. Query performed in STORET/WQX for Reference Stream Project Data. Directive is followed by contents of "processing" and "completion" electronic notifications for pre-1999 and post-1999 data.

1. Go to: http://www.epa.gov/storet/dw_home.html
2. Select "Results by Project" query.
3. Select the following organization ID from the drop-down list depending on the data queried:
   - →"MONT_DEQ_WQX" - will query pre-1999 data
   - →"MDEQ_WQ_WQX" - will query post-1999 data
4. Select "Look Up" and select the following project ID from the drop-down list: "STREFPRO"
5. Before selecting "Continue" at the bottom of the screen, choose "Select All" for each data element of the report. This will include all available fields in the exported files. There will be some blank fields, but the default fields can leave out some important elements out, so it is usually best to "Select All" and then narrow down the fields once the files have been imported into Excel (or Access). [To query specific dates, media, characteristics or other parameters, narrow the search before selecting "Continue." For example: A "Results by Geographic Query" can be performed that searches for a specific "HUC," but this would produce more data that would need to be narrowed down down by organization and project.]
6. In the next window, it will display how many results were found; enter an email address and a three character report prefix to identify the data when it is forwarded via email.
8. After doing that select "Immediate" and wait for the results to arrive at the submitted email address.
9. A "Processing" email will arrive first and say "STORET data request submitted (PROCESSING)". Then a group of text files will arrive in a second email as a zip file; this email should say "STORET data request status (COMPLETED)"
10. When the "Completed" email arrives, it will have a link to a zip file. In the zip file will be three data files: one for regular results, one for bio results, and a metadata file.
11. Import these files into Excel (or Access) and then data can be filtered based on elements of interest such as HUC, or other elements.

Display 6 cont.

“STORET Data Request - Request_ID: 859362” – pre-1999 data

[Contents of the “Processing Email”- STORET data request submitted (PROCESSING). Request_ID: 859362]

```
Your request for Result Download is submitted for Immediate batch
processing.
Following is your request information:
Request ID     :  859362
Request Type   :  Result Download
Record Count   :  1570
Request Mode   :  Immediate batch
File Name      :  P99_20110328_110721.zip
URL            :
http://www.epa.gov/storpubl/modern/downloads/P99_20110328_110721.zip
Email provided:  jonathan.leiman@umontana.edu
You will be notified when the request is processed.
List of Filters: ~Organization~Project~
Query Parameter Values:
Organization(s):        MONT_DEQ_WQX<br>
Project(s):      10 - REFERENCE STREAM STUDY
```

Contents of the “Completed Email”- [STORET data request status (COMPLETED). Request_ID: 859362]

```
Your request for STORET Results download is completed via Immediate
batch processing.  The Request_ID is 859362.  You can download your
file (size : 20.9 KB) using the hyperlink
http://www.epa.gov/storpubl/modern/downloads/P99_20110328_110721.zip
```

“STORET Data Request - Request_ID: 859093” – post-1999 data

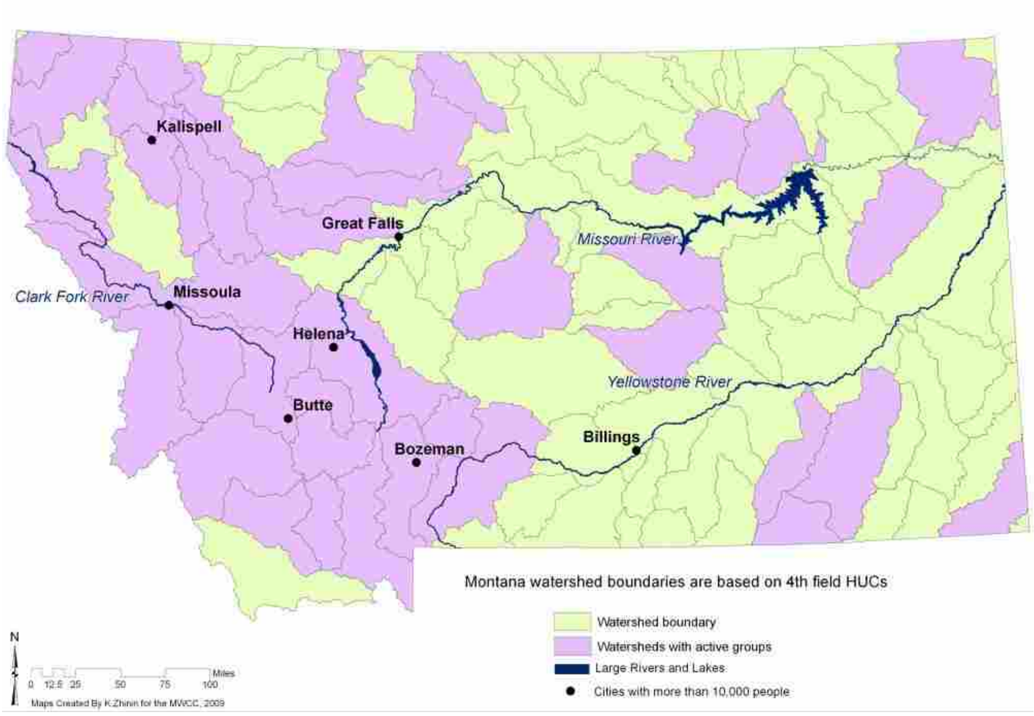
Contents of the “Processing Email”- [STORET data request submitted (PROCESSING). Request_ID: 859093]

```
Your request for Result Download is submitted for Immediate batch
processing.
Following is your request information:
Request ID     :  859093
Request Type   :  Result Download
Record Count   :  53520
Request Mode   :  Immediate batch
File Name      :  jsl_20110320_163712.zip
URL            :
http://www.epa.gov/storpubl/modern/downloads/jsl_20110320_163712.zip
Email provided:  jonathan.leiman@umontana.edu
You will be notified when the request is processed.
List of Filters: ~Organization~Project~
Query Parameter Values:
Organization(s):        MDEQ_WQ_WQX<br>
Project(s):      STREFPRO - Stream Reference Project Monitoring
```

Contents of the “Completed Email”- [STORET data request status (COMPLETED). Request_ID: 859093]

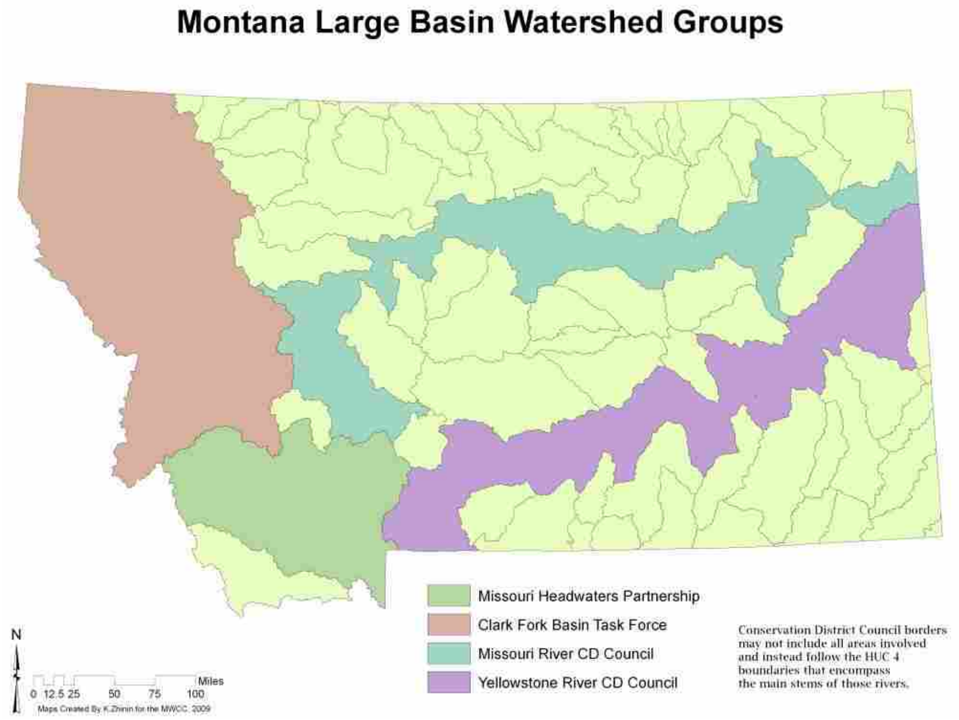
```
Your request for STORET Results download is completed via Immediate
batch processing.  The Request_ID is 859093.  You can download your
file (size : 2016.4 KB) using the hyperlink
http://www.epa.gov/storpubl/modern/downloads/jsl_20110320_163712.zip
```

Display 7. Locations of Montana Watershed Coordination Council (MWCC) member watershed groups



(Modified from Montana Watershed Coordination Council [updated 2011])

Display 8. Locations of Montana Watershed Coordination Council (MWCC) member watershed groups from large basins



(Modified from Montana Watershed Coordination Council [updated 2011])

Display 9. Survey given to members of the Montana Watershed Coordination Council

Organizational Feedback Survey: Utilization of Water Quality Data Generated by the
Montana Department of Environmental Quality (MT DEQ)

The following questionnaire intends to gather information regarding how organizations involved with water resource management in Montana are interacting with information generated by the MT DEQ (Montana Department of Environmental Quality). The results from this survey will be used in a sub-section of a master's thesis project and will contribute to a discussion regarding state generated water quality data. Please provide answers to the best of your ability, circling or filling out the appropriate response. If you need to detail your response beyond "Yes/No," please write below the question.

Organization name and location (optional):
Type of organization (circle): watershed group gov't agency for-profit other

1. Does your organization use water quality data in decision making processes? **Yes / No**

2. Does your organization communicate with the MT DEQ? **Yes / No**

→If yes, who does your organization communicate with at MT DEQ (i.e. bureau/program/staff)?

3. Does your organization use a technical advisor to gather water quality data? **Yes / No**

4. Does your organization use the process of "joint fact finding" or collaborate with other stakeholders? **Yes / No**

5. Does your organization know about the water quality data that the MT-DEQ generates? **Yes / No**

→If yes, does your organization use any MT-DEQ data? **Yes / No**

→If yes, please list the dataset(s) used AND note how easy it is to use
(i.e. very easy, easy enough, difficult, very difficult)?

6. How could the water quality data used/needed by your organization be made easier to use/obtain?

7. What additional water quality data would your organization like to have available?

8. Please provide any further feedback you may have on your organization's use of water quality data/information in their planning and decision making processes; use the back of this sheet if necessary.

Display 10. Metadata record for pre-1999 RefPro metadata; reported from query **“STORET Data Request - Request_ID: 859362” – pre-1999 data}** in STORET/WQX; ### signifies new summary; yellow highlights example(s)

STORET Results Metadata Report   Result Report Name:SDR20110328_110728.txt   Date:03/28/2011

###
Organization Summary

Organization:MONT_DEQ_WQX   MONT_DEQ_WQX - Montana DEQ - Pre-1999 Data
Type: US Government/State
Description: The MONT_DEQ_WQX organization is a static, historic dataset with the majority of data originating from the Storease database.
Parent Organization:
Electronic Addresses:
Internet http://deq.mt.gov/
Office 406-444-5304

###
Cooperating Organization Summary

Organization:MONT_DEQ_WQX   MONT_DEQ_WQX - Montana DEQ - Pre-1999 Data

###
Project Summary

Organization:MONT_DEQ_WQX   MONT_DEQ_WQX - Montana DEQ - Pre-1999 Data
examples of RefPro entries:
Project: 10   REFERENCE STREAM STUDY
Start Date: Planned Duration:Unknown
Purpose:
Study Area:
Project Design:
Obtain Plan:
Quality Assurance:
Quality Objectives:
Assigned Stations
Station ID   Station Name

Project: 12   ECO-REGION REFERENCE STREAM MONITORING PROGRAM
Start Date: Planned Duration:Unknown
Purpose:
Study Area:
Project Design:
Obtain Plan:
Quality Assurance:
Quality Objectives:
Assigned Stations
Station ID   Station Name
###
Program Summary

Organization:MONT_DEQ_WQX   MONT_DEQ_WQX - Montana DEQ - Pre-1999 Data

Display 10 cont.

###
Sample Collection/Creation Procedure Summary
____
Organization:MONT_DEQ_WQX MONT_DEQ_WQX - Montana DEQ - Pre-1999 Data
ProcedureID:HISTORIC
Procedure Name:Unknown, Historic Data, Migrated from STOREASE
Gear Group Name:Miscellaneous/Other
Description:
Citation:

###
Sample Gear And Equipment Configuration Summary
____
Organization:MONT_DEQ_WQX MONT_DEQ_WQX - Montana DEQ - Pre-1999 Data
Gear Group Name: Miscellaneous/Other
Field Gear ID:
Gear Name: Miscellaneous (Other)
Config ID:
Config Name:
Specification:

###
Sample Preservation And Handling Profile Summary
____
Organization:MONT_DEQ_WQX MONT_DEQ_WQX - Montana DEQ - Pre-1999 Data

###
Laboratory Summary
____
Organization:MONT_DEQ_WQX MONT_DEQ_WQX - Montana DEQ - Pre-1999 Data

###
Analytical Procedure And Equipment Detail Summary
____
example of RefPro entry:
Procedure Source: USEPA
Procedure ID: 200.7(W)
Procedure Name: Metals in Water by ICP-AES
Citation:
Equipment:
Comparable National Procedure ID: USEPA200.7(W)

###
Lab Sample Preparation Procedure Summary
____
Organization:MONT_DEQ_WQX MONT_DEQ_WQX - Montana DEQ - Pre-1999 Data

###
Bibliographic Citation Summary
____
Organization:MONT_DEQ_WQX MONT_DEQ_WQX - Montana DEQ - Pre-1999 Data

(Modified STREFPRO 2011a)

Display 11. Metadata record for post-1999 RefPro metadata; reported from query {**“STORET Data Request - Request_ID: 859093” – post-1999 data}** in STORET/WQX; ### signifies new summary; yellow highlights RefPro samples

STORET Results Metadata Report Result Report Name:SDR20110320_163810.txt Date:03/20/2011

###
Organization Summary

Organization:MDEQ_WQ_WQX MDEQ_WQ_WQX - Montana DEQ WQPB
Type: US Government/State
Description: The MDEQ_WQ_WQX organization is for data collected by DEQ’s Water Quality Planning Bureau (WQPB).
Parent Organization:
Electronic Addresses:
Internet http://deq.mt.gov/
Office 406-444-5304
Internet http://deq.mt.gov/
Office 406-444-5304 --------

###
Cooperating Organization Summary

Organization:MDEQ_WQ_WQX MDEQ_WQ_WQX - Montana DEQ WQPB

###
Project Summary

Organization:MDEQ_WQ_WQX MDEQ_WQ_WQX - Montana DEQ WQPB

Project: STREFPRO Stream Reference Project Monitoring
Start Date:
Planned Duration: Unknown
Purpose:
Study Area:
Project Design:
Obtain Plan:
Quality Assurance:
Quality Objectives:
Assigned Stations
Station ID
Station Name

###
Program Summary

Organization:MDEQ_WQ_WQX MDEQ_WQ_WQX - Montana DEQ WQPB

###
Sample Collection/Creation Procedure Summary

Organization:MDEQ_WQ_WQX MDEQ_WQ_WQX - Montana DEQ WQPB

Display 11 cont.

example from RefPro:
ProcedureID:HOOP
Procedure Name:Chlorophyll-a Hoop Sample
Gear Group Name:Miscellaneous/Other
Description:
Citation:

###
Sample Gear And Equipment Configuration Summary

____
Organization:MDEQ_WQ_WQX MDEQ_WQ_WQX - Montana DEQ WQPB
example from RefPro:
Gear Group Name: Water Sampler
Field Gear ID:
Gear Name: Water Bottle
Config ID:
Config Name:
Specification:

###
Sample Preservation And Handling Profile Summary

____
Organization:MDEQ_WQ_WQX MDEQ_WQ_WQX - Montana DEQ WQPB

###
Laboratory Summary

____
Organization:MDEQ_WQ_WQX MDEQ_WQ_WQX - Montana DEQ WQPB
example RefPro:
/University of Montana Watershed Health Clinic Laboratory
Electronic Addresses:
###
Analytical Procedure And Equipment Detail Summary

____
Organization:MDEQ_WQ_WQX MDEQ_WQ_WQX - Montana DEQ WQPB
example from RefPro:
Procedure Source: USEPA
Procedure ID: 447.0
Procedure Name: Chlorophyll a and b in phytoplankton by HPLC/UV
Citation:
Equipment:
Comparable National Procedure ID: USEPA447.0
###
Lab Sample Preparation Procedure Summary

____
Organization: MDEQ_WQ_WQX MDEQ_WQ_WQX - Montana DEQ WQPB
example from RefPro:
Procedure Source: USEPA
Procedure ID: USEPA 200.2
Procedure Name: Preparation for Water, Soil, or Waste Samples
Citation:

(Modified from STREFPRO 2011b)

Display 12. R code for checking completeness of 26 Elements Reported for “STORET Data Request - Request_ID: 859362” – pre-1999 data

```
> Dataset <- sqlQuery(channel = 1, select * from
+   [Data_P99_20110328_110721_RegRes$])

> names(Dataset) <- make.names(names(Dataset))

> library(relimp, pos=4)

> showData(Dataset, placement='-20+200', font=getRcmdr('logFont'),
+   maxwidth=80, maxheight=30)

> sapply(Dataset, function(x)(sum(is.na(x)))) # NA counts
           Org.Name          Station.ID                   State
                  0                   0                       0
             County                 HUC           Generated.HUC
                  0                   0                       0
   Station.Latitude   Station.Longitude  Station.Horizontal.Datum
                  0                   0                         0
        Activity.ID      Activity.Start     Activity.Start.Zone
                  0                   0                       0
    Activity.Medium       Activity.Type  Activity.Category.Rep.Num
                  0                   0                         0
Characteristic.Name     Sample.Fraction              Value.Type
                  0                 561                       0
Result.Value.Status  Result.Value.as.Text                 Units
                  0                 479                     479
  Analytical.Proc.ID
                  0
```

Display 13. R code for checking completeness of 117 Elements Reported for “STORET Data Request - Request_ID: 859093” – post-1999 data-Reg File

```
> reg <- sqlQuery(channel = 3, select * from
+   [Data_jsl_20110320_163712_RegRes$])
> names(reg) <- make.names(names(reg))
> library(relimp, pos=4)
> showData(reg, placement='-20+200', font=getRcmdr('logFont'), maxwidth=80,
+   maxheight=30)
> sapply(reg, function(x)(sum(is.na(x)))) # NA counts
                  Org.ID             Beach.ID.Project.ID
                    0                      0
                Org.Name                 Station.ID
                    0                     686
            Station.Name                    State
                   686                    686
                  County                     HUC
                   686                    686
           Generated.HUC             Station.Latitude
                   686                    686
       Station.Longitude        Station.Horizontal.Datum
                   686                    686
Converted.Station.Latitude      Converted.Station.Longitude
                   686                    686
Converted.Station.Horizontal.Datum                Primary.Type
                   686                    686
            Project.Name             Project.Description
                    0                      0
             Activity.ID             Activity.Start
                    0                      0
     Activity.Start.Zone             Activity.Medium
                    0                      0
         Activity.Matrix             Activity.Type
                  3689                     0
Activity.Category.Rep.Num        Actual.Location.Point.Type
                    0                     686
   Sample.Collection.ID                Field.Gear.ID
                  2819                   2819
   Portable.Data.Logger            Characteristic.Name
                 18003                     0
                CAS.Num              Sample.Fraction
                  8954                   7939
              Value.Type            Result.Value.Status
                    0                      0
    Result.Value.as.Text             Result.Value.as.Number
                  5808                   5808
                   Units        Converted.Result.Value
                  5808                   5808
   Converted.Result.Unit               Activity.Comment
                  5808                   6977
          Result.Comment          Result.Measure.Qualifier
                  8069                  17366
     Particle.Size.Basis            Analytical.Proc.ID
                 17416                     0
         Detection.Limit        Detection.Limit.Descript
                  6982                   4203
                Lab.Name                    F104
                  2997                   5159
      Analysis.Date.Zone     Activity.Document.Graphic.Name
                 13580                  17553
        Last.Change.Date             User.ID.Last.Change
                    0                   14961
     Last.Transaction.ID
                 14961
```

Display 14. R code for checking completeness of Biology File; 178 elements reported for "STORET Data Request - Request_ID: 859093" – post-1999 data-Bio File

```
> bio <- sqlQuery(channel = 1, select * from
+   [Data_jsl_20110320_163712_BioRes$])
> names(bio) <- make.names(names(bio))
> library(relimp, pos=4)
> showData(bio, placement='-20+200', font=getRcmdr('logFont'), maxwidth=80,
+   maxheight=30)
> sapply(bio, function(x)(sum(is.na(x)))) # NA counts
                  Org.ID           Beach.ID.Project.ID
                       0                             0
                Org.Name                    Station.ID
                       0                             0
            Station.Name                         State
                       0                             0
                  County                           HUC
                       0                             0
           Generated.HUC              Station.Latitude
                       0                             0
       Station.Longitude      Station.Horizontal.Datum
                       0                             0
Converted.Station.Latitude    Converted.Station.Longitude
                       0                             0
Converted.Station.Horizontal.Datum            Primary.Type
                       0                             0
            Project.Name           Project.Description
                       0                             0
             Activity.ID                Activity.Start
                       0                             0
     Activity.Start.Zone               Activity.Medium
                       0                             0
           Activity.Type     Activity.Category.Rep.Num
                       0                             0
         Activity.Intent            Community.Sampled
                       0                             0
           Subject.Taxon     Actual.Location.Point.Type
                       0                             0
   Sample.Collection.ID                  Field.Gear.ID
                       0                             0
     Characteristic.Name    Characteristic.Description
                       0                          1845
                ITIS.Num                    Value.Type
                    1845                             0
     Result.Value.Status          Result.Value.as.Text
                       0                          1613
  Result.Value.as.Number                         Units
                    1613                          1613
  Converted.Result.Value          Converted.Result.Unit
                    1613                          1613
        Activity.Comment                Result.Comment
                    6468                          7262
     Analytical.Proc.ID                       Lab.Name
                       0                         31921
      Analysis.Date.Zone              Last.Change.Date
                   33761                             0
```

Display 15. Selected responses from “watershed group” respondents for questions 5c-8

Question 5c. Does your organization know about the water quality data that the MT-DEQ generates; if yes, please list the dataset(s) used AND note how easy it is to use.
→ Use STORET, TMDL info and DEQ web site- STORET data is not user friendly, so <u>difficult</u>

→303d list for GIS (we contact usually DEQ directly for this), and the Clean Water Act Information Database (easy enough) –watershed group

→TMDL data, and monitoring data from our restoration projects. It is all DEQ data, but we contracted and collected it and gave it to DEQ. We then use it to help chart our course of action and set priorities. It is not user friendly, and I am the only one in the group that can understand it.

→This past year we performed sampling runs in cooperation with Montana DEQ, the resultant data will become part of: MDEQ_WQ_WQX - MDEQ_WQ_WQX - Montana DEQ WQPB data in STORET. At this point the datasets are easy enough to use.

→Past use of STORET, very difficult to use.

Question 6. How could the water quality data used/needed by your organization be made easier to use/obtain?
→This might be a little "pie in the sky", but it would be wonderful to have a one stop shop for state data - flows, aquatic life, water quality, findings, etc. -- a super-site between DEQ, Natural Heritage, FWP, DNRC, GWIC, ...

→Without me functioning as the watershed coordinator it is unlikely that the data would be used by the group. They do not understand the science, and are unable to recognize what information is relevant/important. Nor would they even know where to look. They rely on contractors or me to “translate.” A huge effort would be necessary to turn the data into something usable for the “common person.” It is way above their heads.

→No recommendation I find it useful now & easy to obtain –watershed group

→The --- River Watershed has developed their own water quality monitoring strategy and database to make the data easier to analyze and use for decision-makers in the watershed. The database that DEQ uses is very difficult to use and is largely a deterrent for non-agency people to access.

→ The data could be made simpler to find and use if it was somehow attached to a watershed map, with points to click on and then data behind it. Similar to the USGS map/data. –watershed group

→Point and click on map on website. Simplicity in excel spreadsheet- currently overcomplicated last time I checked. There is probably good reasoning behind spreadsheet organization but it is not user friendly.

Display 15 cont.

Question 7. What additional water quality data would your organization like to have available?

→There is a lot of raw data out there that goes beyond the TMDL's and 303 lists where applicable. We know this partially from a reporting standpoint. The information might not be relevant to the categories
listed, but would be to other projects. Many of these reports can be found on their own, but the data in the database with the stream listing would be great. Even a reference to alternative data sets under the stream name would be great.

→Regular sampling of lakes and 303 Streams. Nutrient Loading estimates for main lakes.

→Consistent water quality data for --- Lake (monitoring is critical), site specific information about water quality impacts on Flathead Lake, prevention measures for --- Lake and upstream rivers (i.e. locally relevant information about riparian buffers (width, species composition, density, etc) to prevent nutrients and other pollution from entering lake and rivers).

Water quality data for shallow alluvial aquifer (--- Aquifer) over time; specific impacts on aquifer's ecological integrity and its ability to maintain clean water in the aquifer and --- River; impacts of specific land use on aquifer's water quality that might help guide recommendations for various land use densities/intensity (farming, residential housing densities, etc.)

→Both temporal and spatial water quality data on the --- River mainstem, major tributaries, and irrigation return flows. The --- has developed an extensive baseline, but lack the funds to extend it much beyond this calendar year. It would also be helpful if the data collected in the headwaters by the --- Tribe was available.

→I wish there was an easy way to keep all data in one place for each watershed group. So what would be nice if we each had a web site that could easily import USGS data, DEQ data and our own data to overlay onto one map and one database.

→Not sure if there are fields for specific pollutants like mercury or pharmaceuticals and personal care products.

Question 8. Additional feedback.

→Water quality data is great but getting harder to obtain due to smaller budgets. And is hard to get each agency and/or group to agree on what is best to monitor so have consistency between data sets.

→We find the best way to access state generated data reliably is to access a state employee. In our work we invite state agency representatives to work out our projects. When we need information generated by their agency, we ask them for help rather than trying to interpret and search on our own. The results are much more fruitful that way and helps us to know that the information we are using is accurate.

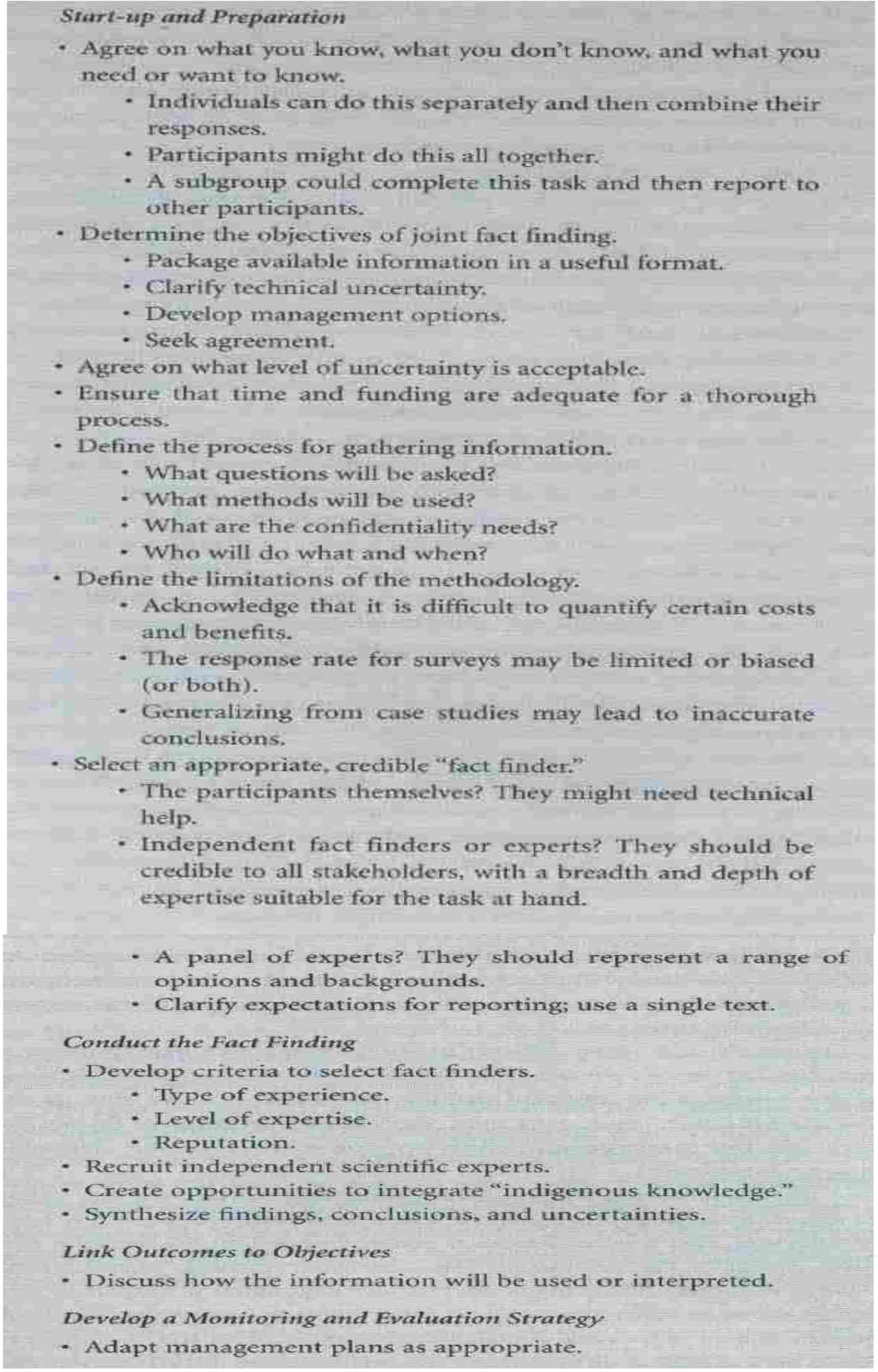
→We use information in education, outreach, BMPs education, restoration planning, lake levels and drought planning, legislation advocacy

Display 15 cont.

→Our organization is in the pre-TMDL planning process. We are gathering our own water quality data thru volunteer monitoring. Working with the DEQ is both helpful and challenging.

→If you want to address a real problem you need to get DNRC and DEQ together and have one of them in charge of Montana Water. DNRC is interested in Quantity and keeps allowing "exempt wells" even in closed basins while DEQ is interested in "quality" while the availability is being reduced. You also might help these folks fund the Ground Water Information Program (GWIP) so we can have, at least, some idea how much ground water is available in these closed basins before DNRC gives it all away. Water quality becomes meaningless when there is no water!

Display 16. Suggested best practices for using joint fact finding



Start-up and Preparation

- Agree on what you know, what you don't know, and what you need or want to know.
    - Individuals can do this separately and then combine their responses.
    - Participants might do this all together.
    - A subgroup could complete this task and then report to other participants.
- Determine the objectives of joint fact finding.
    - Package available information in a useful format.
    - Clarify technical uncertainty.
    - Develop management options.
    - Seek agreement.
- Agree on what level of uncertainty is acceptable.
- Ensure that time and funding are adequate for a thorough process.
- Define the process for gathering information.
    - What questions will be asked?
    - What methods will be used?
    - What are the confidentiality needs?
    - Who will do what and when?
- Define the limitations of the methodology.
    - Acknowledge that it is difficult to quantify certain costs and benefits.
    - The response rate for surveys may be limited or biased (or both).
    - Generalizing from case studies may lead to inaccurate conclusions.
- Select an appropriate, credible "fact finder."
    - The participants themselves? They might need technical help.
    - Independent fact finders or experts? They should be credible to all stakeholders, with a breadth and depth of expertise suitable for the task at hand.
    - A panel of experts? They should represent a range of opinions and backgrounds.
    - Clarify expectations for reporting; use a single text.

Conduct the Fact Finding

- Develop criteria to select fact finders.
    - Type of experience.
    - Level of expertise.
    - Reputation.
- Recruit independent scientific experts.
- Create opportunities to integrate "indigenous knowledge."
- Synthesize findings, conclusions, and uncertainties.

Link Outcomes to Objectives

- Discuss how the information will be used or interpreted.

Develop a Monitoring and Evaluation Strategy

- Adapt management plans as appropriate.

(Modified from McKinney and Harmon 2004)