

DISSERTATION

A GENERAL FRAMEWORK FOR A WATER QUALITY KNOWLEDGE
AND INFORMATION NETWORK

Submitted by

Fernanda Dalcanale

Department of Civil and Environmental Engineering

In partial fulfillment of the requirements

For the Degree of Doctor of Philosophy

Colorado State University

Fort Collins, Colorado

Spring 2010

Copyright by Fernanda Dalcanale 2010

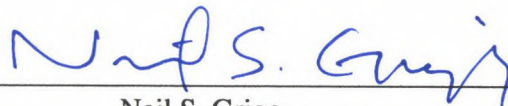
All Rights Reserved

COLORADO STATE UNIVERSITY

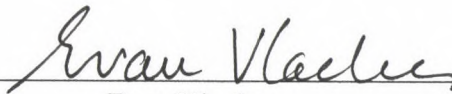
January 22, 2010

WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY FERNANDA DALCANALE ENTITLED A GENERAL FRAMEWORK FOR A WATER QUALITY KNOWLEDGE AND INFORMATION NETWORK BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

Committee on Graduate work



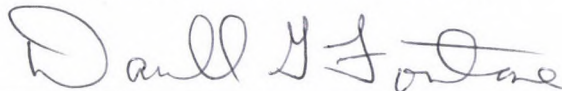
Neil S. Grigg



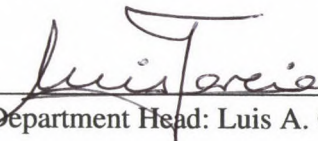
Evan Vlachos



Monica Ferreira do Amaral Porto



Advisor: Darrell G. Fontane



Department Head: Luis A. Garcia

ABSTRACT OF DISSERTATION
A GENERAL FRAMEWORK FOR A WATER QUALITY KNOWLEDGE AND
INFORMATION NETWORK

The increasing pressure on water resources worldwide, due to growing demand, scarcity, and pollution, are leading to a shift from top-down models of management to interdisciplinary approaches and participatory processes, highlighting the need for collaborative work. As a result, the evolution in regulations and management practices and the forging of new partnerships are creating the need for unprecedented amounts of data and knowledge exchange, adding to the complexity of managing information on water resources.

Regarding water quality management in particular, the interdependency with the land and the environment and the uncertainty around sources of contamination and chemical interactions can add to the problem. Furthermore, information and knowledge are produced by many different water quality management entities, and efficient means to communicate them are an important part of the process.

Technology has provided some excellent tools for sharing information in all branches of science, including water resources. The latest developments go beyond static formats, allowing for the creation of online communities that can provide the necessary tools for information and knowledge exchange.

In this project, a search for the available technology for collaboration, methods of community filtering, and community-based review was performed and the possible implementation of these tools to create a general framework for a collaborative “Water Quality Knowledge and Information Network” was evaluated. The main goals of the network are to advance water quality education and knowledge; encourage distribution and access to data; provide networking opportunities; allow public perceptions and concerns to be collected; promote exchange of ideas; and, give general, open, and free access to information. A reference implementation was made available online and received positive feedback from the community, which also suggested some possible improvements.

Fernanda Dalcanale
Department of Civil and
Environmental Engineering
Colorado State University
Fort Collins, CO 80523
Spring 2010

Acknowledgments

During the course of this PhD program, I received immense support from a number of institutions and people. I would like to thank CAPES, IIE and AAUW for their invaluable financial and logistical support. I also owe my gratitude to Colorado State University and its incredible faculty and staff. A very special thanks to Ms. Marilee Rowe for taking such good care of the international students.

I would like to express my respect and gratitude to my committee members: Dr. Neil Grigg, for your insights, advice and willingness to be so helpful; Dr. Evan Vlachos, for your kindness and for sharing your absolute pansophy; and Dr. Monica Porto, for whom my admiration goes beyond words.

To my advisor, Dr. Darrell Fontane, thank you for being so accessible, interested, and enthusiastic. For bearing with me for all these years and for all the knowledge you are able to transfer to us in such a seamless way.

I also owe my gratitude to Dr. Rubem La Laina Porto for all the advice, kindness, and wisdom through the years and to Dr. Robert Ward for inspiring me and strengthening my resolve to work in water quality management.

Even before I started this program, I was guided and encouraged by my professors André Fabiani, Dr. Benedito Braga, Dr. Fábio Ramos (*in Memoriam*), Dr. Marcos Tozzi, and Dr. Ruy Sant'Ana.

So many people have to admire their heroes from a distance; I feel completely privileged for having been able to work and learn from mine.

To all the colleagues who answered the surveys that helped to improve the

concept of the framework of this dissertation, thank you for taking an interest in the project and for taking the time to answer the questionnaires.

Friends and family provided me with comfort and care. My parents, grandparents, brother, sister and mother-in-law have also supported me through this process in more than one way, and I need not only to thank them but also to apologize for unilaterally imposing a 6,000-mile distance between them and their grandson and nephew.

Last, and surely not least, to Yuri. Your passion for open source gave me the idea for this project. Your guidance and hard work helped me to develop it. Your willingness to follow me across the continent only made the journey more fun. Your kindness, integrity, correctness, curiosity and (why not?) geekiness inspire me to be a better person. We make a good team. *Wani ra yana ro aisha.*

This dissertation is dedicated to *Mario Dalcanale-Csapo*, the living proof
that the whole can be greater than the sum of its parts.

Table of Contents

| | |
|--|----|
| 1. Introduction..... | 1 |
| 2. Literature Review..... | 7 |
| 2.1 Water Quality Management Process..... | 7 |
| 2.2.1 The World Wide Web..... | 21 |
| 2.2.2 The Open Source Model..... | 23 |
| 2.2.3 User Generated Content and Knowledge Networks | 25 |
| 2.2.4 Peer Review & Trust Networks..... | 29 |
| 2.3 Water Resources Knowledge on the Web..... | 34 |
| 3. Methodology..... | 39 |
| 3.1 Phase I - Search for Collaborative Technologies..... | 43 |
| 3.2 Phase II – Development and Application of the Exploratory Questionnaire..... | 47 |
| 3.2.1 Analysis of the Responses..... | 52 |
| 3.2.2 Conclusions from the Search and Questionnaire Responses..... | 60 |
| 3.3 Phase III – Reference Implementation..... | 63 |
| 3.3.1 WQIN..... | 65 |
| 3.4 Phase IV – Beta Testing and Analysis of the Results..... | 72 |
| 4. Final Conclusions..... | 81 |
| 5. References List..... | 87 |
| 6. Appendices..... | 95 |
| 6.1 Appendix I – Responses from the Exploratory Questionnaire..... | 96 |

| | |
|--|-----|
| 6.2 Appendix II – WQIN Technical Specifications..... | 107 |
| 6.3 Appendix III – Website Traffic Data..... | 110 |
| 6.4 Appendix IV..... | 114 |

1. Introduction

Water Resources worldwide are under increasing pressure. Population growth, growing industrial and urban consumption rates, and climate change are just a few of the factors contributing to that pressure. Scarcity and pollution create transboundary issues that may contribute to local, regional, and international conflicts. Recognition of the need for interdisciplinary concepts and public awareness and participation all point to a need for a collaborative approach to Water Resources Management.

In response, for every level of government and civil society in countries around the World, there is a growing effort to develop regulations, create and test new management practices, establish new partnerships and negotiate with neighboring regions to deal with common issues.

While this comes as good news, the management of information in water resources is, as a result, becoming more complex. The cost of building and maintaining Water Resources Information Systems is increasing, which may discourage developing countries from making their data accessible or even collecting the data in the first place. The increase in all elements of uncertainty in time and space, combined with the decrease of data availability, leads to an uncertainty paradigm (Simonovic 2009). In addition, there is an evolving need for sharing not only data, but also knowledge and experiences.

For water quality management in particular, the interdependency with the land and

the environment and the uncertainty around sources of contamination and chemical interactions can add to the problem. As complexity grows, so does the demand for information. The push for integrated approaches, combining physicochemical, social and political disciplines (Perry and Vanderklein 1996), only underscores the need for knowledge exchange.

The 2nd World Water Development Report (WWDR) calls for integrated water resources management as the means for sharing resources and responsibilities. It also concluded that this will only be possible with “focus on better water governance that embraces all stakeholders and civil society, in both the public and private sectors...” (UNESCO 2006). Similarly, the European Water Framework Directive's key principles include “sharing information and experiences, the development of common methodologies and approaches, and the involvement of experts and stakeholders from candidate countries” (NADDEO et al. 2005). These calls imply the need for intense communication at all levels due to the number of factors and different interests involved in the process.

While calls for collaboration and information sharing are many, some obstacles still prevent it from happening. On the technology side, proprietary, closed source applications can prevent databases from being able to communicate. Different systems and sources can make it difficult to navigate and sort through the available information. On the organizational side, there may be some resistance from certain groups to sharing data. On all fronts, inertia and resistance to change and innovation can halt collaboration

efforts.

In terms of water quality, the organizational resistance to exchanging information is deepened by the fact that some groups might fear potential liabilities. While monitoring water quantity information may not be exceptionally risky—since it is difficult to control—the sharing of water quality information can lead, depending on the case, to a range of pressures, from local conflicts to international litigation. As a result, organizations that could be collecting and publishing large amounts of data and information are only distributing the amount of information required by law, while extra information is either quietly collected, or not collected at all.

Data and information on water quality can serve different objectives, and the difference between information gathered for management purposes and for scientific purposes can be substantial (Ward 2002). However, any data can be valuable, despite the purpose of its initial collection. The existence of information on the data sets (metadata)—how it was collected, under which protocols it was analyzed, etc.—is crucial for consistency and comparability (Peters and Ward 2003). Furthermore, intrinsic knowledge or experience accumulated from a field worker, a manager, or a scientist could also be an important asset to others working on similar programs or similar regions. This is why ways of publishing all this knowledge, in an organized and multidirectional way, need to be made more widely available. And while some organizations view sharing information as potentially risky, the need for this exchange is widely recognized. Among academia, research institutions, industry, government, professionals and citizen advocacy groups,

there has been an increasing effort to improve the level of communication (Vansteenkiste et al. 2008), even in poor and remote communities (Mulenga 2008; Liniger and Lynden 2005).

Technology has provided some excellent tools for sharing knowledge in all branches of science, including water resources. The Internet and the World Wide Web are significant advances, with applications from discussion lists and fora to web pages.

Most online resources for the Water Sector, however, are still limited to static pages and links to data sources or single databases. Although useful, these are restricted to material that a handful of editors are able to collect, check, and publish. Sources usually include a limited number of institutions and collaborators, and information may not be frequently updated. Most importantly, communication is usually restricted and unidirectional.

E-mail lists, the most user-inclusive application, are widely used, but very often lack efficient moderation. At the same time, the ephemeral nature of this type of discussion results in continuous information loss. After a few days, information posted is seldom recoverable. This usually means that a particular piece of information will only be able to grab the attention of a user who has an immediate use or particular interest in it. And to get to the information, users have to read through a daily list of several other messages that are of no interest to them.

The web has certainly made it easier to share information, and collaborative tools

abound. The latest developments go beyond the static information format, allowing for the creation of online groups where the user is empowered to build the community. This may be in the form of a side contribution, such as a product rating or a news comment, or in a more essential contribution to the application, like the videos posted on You Tube.

Online-accessible databases (STORET-EPA, AQUASTAT-UN, NWIS-USGS and others) are increasingly advancing the ways we electronically share data. These databases are a collaborative effort, with several agencies collecting and feeding the database. The next logical step is to allow, in a similar way, for water professionals, researchers, agencies, and stakeholders to disseminate other kinds of information that could benefit the community, such as methods, experiences, models, metadata, water quality assessments, opinions and any other relevant knowledge related to the field.

But the number of applications and amount of information on the web can be overwhelming. In order to promote collaboration, there is a need for more efficient communication tools that will enable information, while keeping it reliable, to be published faster. Such tools would make it possible to cut costs, prevent replication of work, and enable a focus on community-building. These new tools should address most, if not all, of the deficiencies of the existing ones, and at the same time, should allow the system to evolve and grow as the necessity arises.

A combination of these technologies and methods, along with collaborative filtering techniques (decision methods based on user's inputs, members' relationships and assessments), could be used to create a web-based Knowledge and Information Network.

The network would provide the basic environment for a community of practitioners to virtually congregate in a way that would facilitate and promote the exchange of information and experiences (Seufert, von Krogh and Bach 1999), as well as to convene the different inputs necessary for the decision-making process. The main concept of such a network is that it would be community-controlled and have community generated content. This means that any member could contribute a piece of news; introduce models, methodologies or developments in the field; or discuss projects and their results, resulting in a more flexible and dynamic way of sharing information. With the addition of collaborative filtering methods, the network could be used to transform scattered information into structured knowledge. Before a full effort in this direction is conceived, the potential for these elements to be utilized in a water quality online community should be investigated. This project assesses existing technology for collaborative potential and methods of community filtering and community-based reviews, compares this technology to technology that has already been implemented in the field of water quality, analyzes possible improvements to the implementation, surveys the water quality community, and proposes an initial framework for a collaborative Water Quality Knowledge and Information Network. After a reference implementation was made available online, the final responses and feedback from the community were reviewed and final conclusions and improvements were drawn.

2. Literature Review

2.1 Water Quality Management Process

Water Quality Management involves dealing with a number of environmental factors that interact and affect the state and flow of a water body. It also involves the manipulation of the supplementary tools designed to collect and analyze data as well as methods to transform data sets into useful information and convey this information to managers, decision makers, and the public in general. In addition, management of water quality also includes the implementation, evaluation, and compliance to the set of regulations, practices, and programs designed to keep, or bring, the quality of water to desired levels.

The management process continues to evolve. Ward, Loftis, and McBride (1990) argue that the processes and the science involved are “necessarily broad and complex” and laws, regulations, and goals are in constant change (Ward 2002) as political and social changes take place.

From the establishment of a link between water quality and human health – through a command and control and structural measures approach – to a more comprehensive “Integrated Management” (Dixon and Easter 1996), the faces of the players have changed as well. While previously left to engineers, today, new managers come from a diversity of disciplines. Ward (2002) notices that “a growing awareness of the fragmentation of the environment, for purposes of management, is leading to a desire to reconnect the various elements of our efforts to control water quality into a more 'holistic' or 'integrated' approach to water resources management focused on the watershed. Grigg (1996) argues that systematic approaches, largely preferred by engineers, cannot be used exclusively to describe the complexity and conflict in today's issues.

Technical work is usually followed by “governmental meetings, public hearings, appeals to regulators and lawsuits.” Water Management is unique because of the different links to human health, development, and the environment.

Porto and Lobato (2004) defined Modern Environmental Management as the articulation of four types of mechanisms:

“i) the traditional instruments of Command and Control (C&C), specific to centralized operation in the State Apparatus, and which, within the scope of water resources management are disciplinary instruments, usually defined as granting the right to use water resources and as standards established by environmental legislation, through granting permits for activities.

ii) building social consensuses, used in establishing objectives and defining intervention plans – such as water resources plans, whose objectives are reflected in the framework and classification of water bodies, indicating objectives for water quality – consensuses that require institutional models for the shared management of responsibilities between the State and the other agents of society;

iii) the sphere of the so-called economic management instruments, whose nature as decentralized induction to environmental behavior also implies institutional arrangements of shared responsibilities; and,

iv) the field of voluntary adherence mechanisms, in general, based on circumscribing markets, fields of action and/or sources of resources, by means of certifications of the quality of processes and environmentally correct forms of productions which characterize decision spaces more appropriate to private agents, but that also can be applied to public entities, both in the sphere of water resources management and of environmental management.”

Furthermore, several world fora “recommendations” (Dublin 1992; World Water Forum Ministerial Statements 2003, 2006, 2009; Stockholm World Water Week 2008; Istanbul Water Consensus 2009) contain more than a few common themes. Among these are that water is a finite and essential resource for human development and requires integrated management, sustainable development, and participatory processes. The World Water Assessment Programme, in its first report (UNESCO 2006, 3) argues that “The key challenges of contemporary water management

can only be understood within the very broad context of the world's socio-economic systems. ”

This change in approach has, in turn, been reflected in almost every legislative review in the last two decades. The terms 'public good', 'sustainability', 'integrated management' and 'public participation', or their equivalents, are a constant in several reviews of countries' “Water Management Principles.” Countries like Brazil, South Africa, Australia, New Zealand and the European Union have set, explicitly or not, some similar lists of principles for Water Resources Management. Table 2.1 presents and highlights some of the similarities among these regulations.

| Brazil 1994 | Australia 1996 | South Africa 1998 | European Community 2000 | Western Water USA 1998 |
|---|--|---|--|---|
| <ul style="list-style-type: none"> • Water is a public good; • Water is a finite resource that has economic value; • The use of water required to meet people's basic needs shall have priority, especially in critical periods; • Water management shall comprise and induce multiple uses; • The river basin is the appropriate unit for water management; • Water management shall be decentralized, with the participation of government, stakeholders and society. | <ul style="list-style-type: none"> • All water pricing is to be based on the principles of full cost recovery and transparency of cross-subsidies; • Any future new investment... only after appraisal indicates it is economically viable and ecologically sustainable; • "... comprehensive systems of water allocations ... specification of entitlements in terms of ownership, volume, reliability, transferability and, if appropriate, quality;" • "... allocations for the environment as a legitimate user of water;" • "Trading,..., of water allocations...within the social or physical and ecological constraints of catchments; • An integrated catchment management approach to water resource management be adopted; • Greater responsibility at the local level for the management of water resources; greater public education about water use and consultation in the implementation of water reforms. | <ul style="list-style-type: none"> • "...the ultimate aim of water resource management is to achieve the sustainable use of water for the benefit of all users;" • "Water management strategies must therefore be based on the principle of integrated management in order to achieve sustainability, equity and efficiency;" • "...the nation's water resources are managed through a public trust which is created to replace private ownership;" • "Bases comprehensive protection of all water resources on the need to protect basic human and ecological needs;" • "... de-links water rights and land ownership. It replaces the previous riparian system of allocation, which linked water rights to land ownership, with a compulsory licensing regime to achieve more equitable water redistribution in the population." | <ul style="list-style-type: none"> • The setting of ambitious objectives to ensure that all waters meet "good status" by 2015; • Use of water resources must be sustainable throughout Europe • The protection of all categories of waters; • The requirement for waters to be managed at river basin level by formulating a River Basin Management Plan. In the case of transboundary water bodies, this needs co-operation between countries; • Ensuring the active participation of all stakeholders, including NGOs and local communities, in water management activities; • Requiring water pricing policies based on the "user pays" principle; • Balancing the interests of the environment with those who depend on it. | <ul style="list-style-type: none"> • Sustainable use of Resources; • maintain National goals and standards; • Emphasize local implementation, innovation and responsibility; • Incentives; • Respect existing rights; • Social equality; • Organize around hydrologic systems; • Measurable objectives, sound science and adaptive management; • Participatory decision making; • Innovative funding. |
| (Porto and Kelman, 2002) | (Department of the Environment, of Australia. Website.); OZH2O website. | (Gowlland-Gualtieri2007) | (Water Framework Directive - 2000/60/EC) | (Ward 2002) |

Table 2.1 - Excerpts from newly reviewed water legislation in several countries and their similarities.

In light of this change in paradigm, from specific to integrated and from hierarchical to heterarchical, what are the main elements of the Water Quality Management Process and how do these elements interact? Previous representations for Water Resources and Water Quality Management usually focus on a quasi-rigid flow of information and actions. An example of this kind of “work flow” is shown in Fig. 2.1, while Fig. 2.2 shows one effort to better represent the integrated and adaptive system.

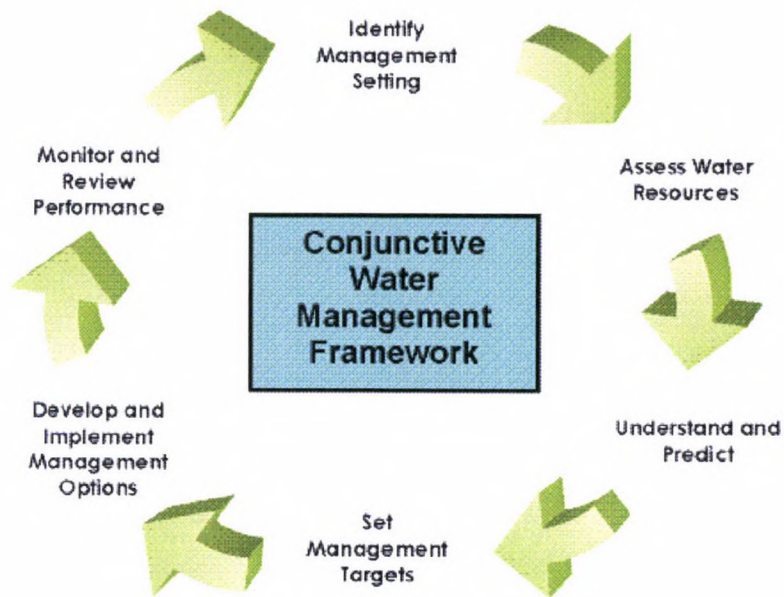


Figure 2.1: Managing Connected Water Resources Project - Australian Government (2009)

<http://www.connectedwater.gov.au/framework/index.html>

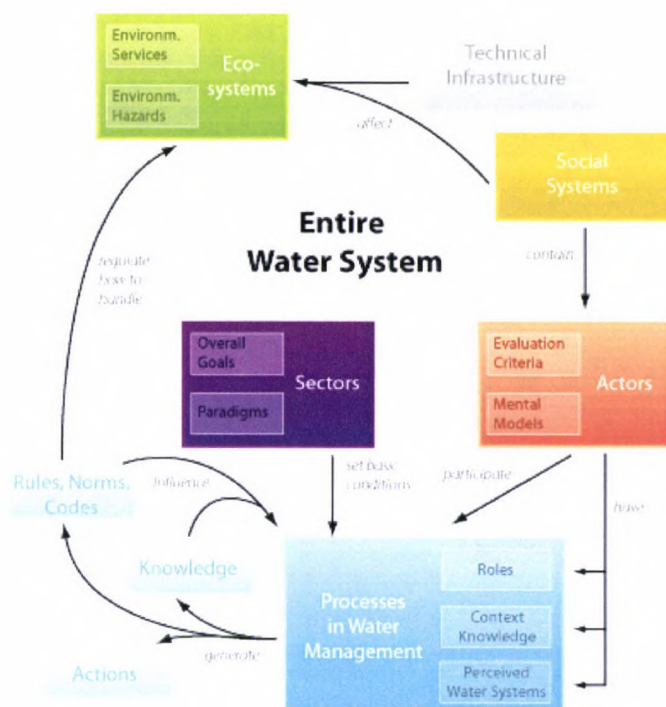


Figure 2.2: Adaptive Implementation of Water Policies. European project © NeWater 2008.

In reality, the classification of these elements is not completely clear cut. Many, if not all, are interdependent, and interaction between them is all but linear.

In building a more general Water Quality Management Framework, it may be necessary to start with the elements considered endogenous to the process. These elements can be grouped and represented as “main blocks” of knowledge, processes, and actions in water quality management, the so-called traditional set of management “tools.” These tools are fairly common elements in Water Quality Management systems worldwide. Fig. 2.3 proposes a possible representation.

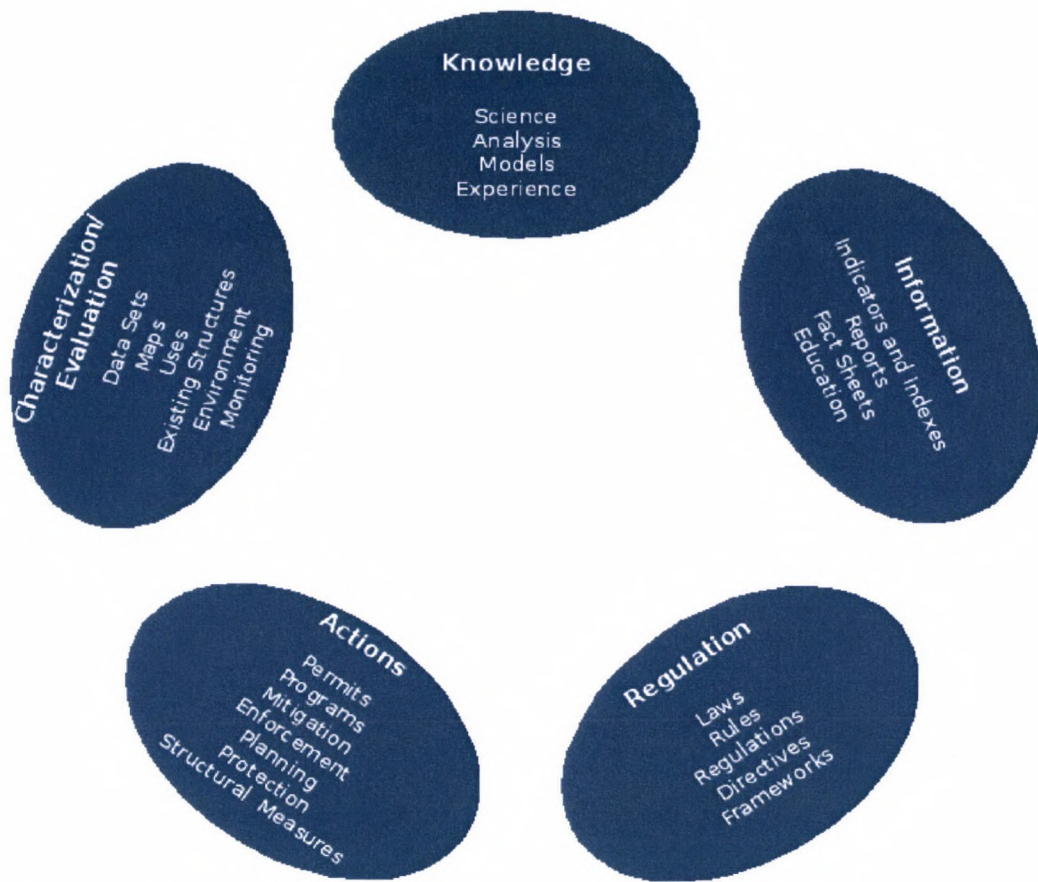


Figure 2.3: Water Quality Management Tools

In addition to the management tools, there are exogenous factors, such as cultural practices, political processes, new knowledge and best practices, social and political pressure and funding. These components should not be overlooked. As noted by Vlachos (1982, 256), “Social-political considerations are a major reality that confronts every planner”. In fact, most decisions in environmental management are made not based on pure science, but on some combination of these external factors. (And often, these decisions do not reflect or address the priority set of objectives and concerns). Budget constraints, ideologies, and uneven stakeholder pressure are only a few of the factors that could tip the scale to decisions that do not move the set of goals

forward. Fig. 2.4 shows the main exogenous factors added to the process.

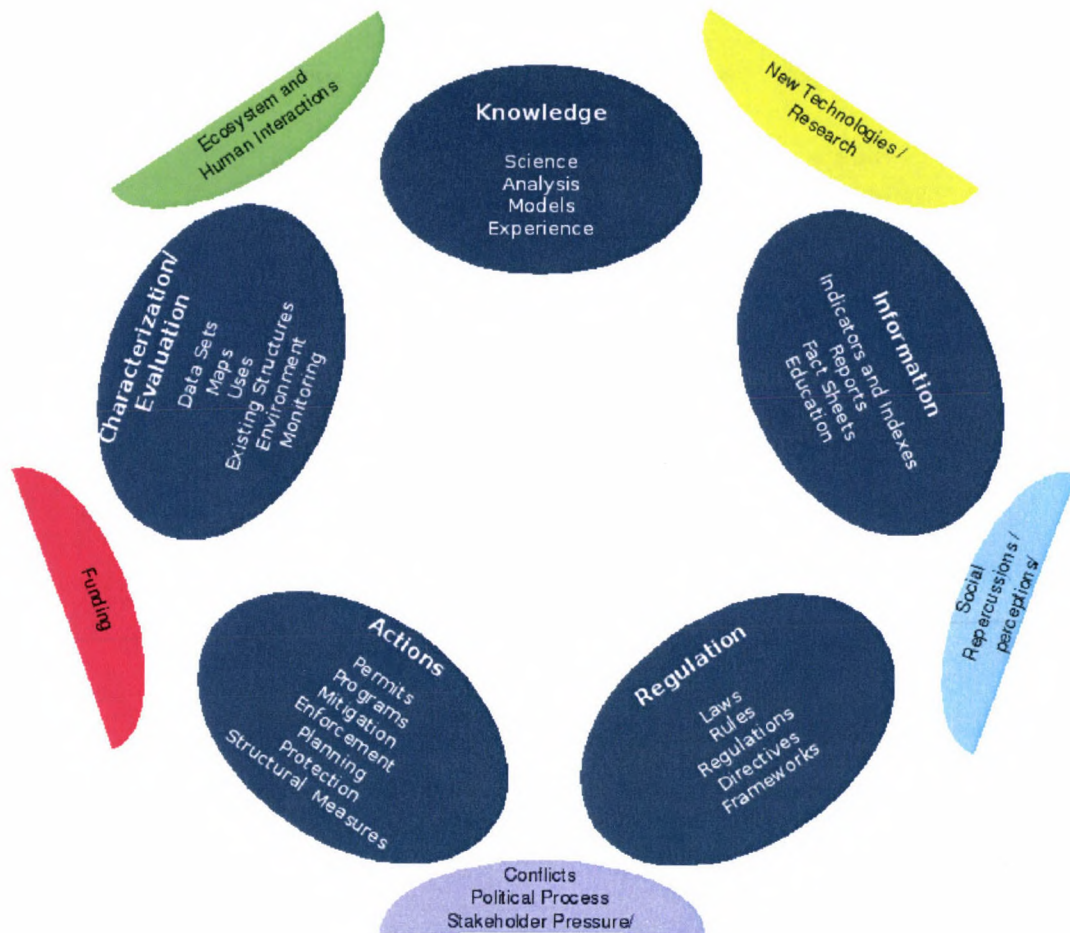


Figure 2.4: Endogenous and Exogenous factors in Water Quality Management

Finally, the integration of the process must be considered. The elements of integration, such as collaboration, interdisciplinarity, and adaptive management, are at the core of the process. The definitions for Integrated Water Resources Management are many, but most include a somewhat comprehensive (or holistic) approach: viewing water as a part of the environmental system, dealing with quantity and quality as a whole, and taking social and political issues into consideration. A definition by the Global Water Partnership (2000) is widely accepted: “IWRM is

a process which promotes the coordinated development and management of water, land, and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.” The same document warns that this definition is to be used just as a common framework and that there is no “universal blueprint” for IWRM. On the other hand, the concept has been criticized for being too vague, difficult to implement, and therefore, unlikely to produce the desired results (Biswas 2004).

Although the complexity of the system is not in dispute, it is also practically impossible – and certainly unwise – to ignore the external pressures, as they are an inherent part of the process. So assuming that a new paradigm will include all of these elements, the next question is: how do all of them interact? How should one account for uncertainties and interdependency?

Even if a main and intuitive flow of information-action exists, it surely does not tell the whole story. The inputs the system receives are continuously altered by some of its outputs, sometimes unexpectedly and certainly not in any organized, linear way. In other words, any new movement in the system will reflect directly or indirectly in some or all of its elements.

In the same way, the decision-making process, once linear and centralized, yet segmented for every different discipline, has become more difficult to characterize. Integrated management and participatory processes imply a holistic view, resulting in a decision-making process that is localized and distributed.

So while it is safe to anticipate that the traditional data-information-action-evaluation loop (Simonovic 2009) will be present in the process, it is also necessary to recognize that the reflections for each and every movement will occur in all directions, and the information flow needs to be represented in a manner that indicates that interdependency.

Taking a cue from information technology and its own evolution to multidirectional, multi-dimensional information flow, a new representation that connects and integrates the main elements in a Water Quality Management Framework is proposed in Fig. 2.5.

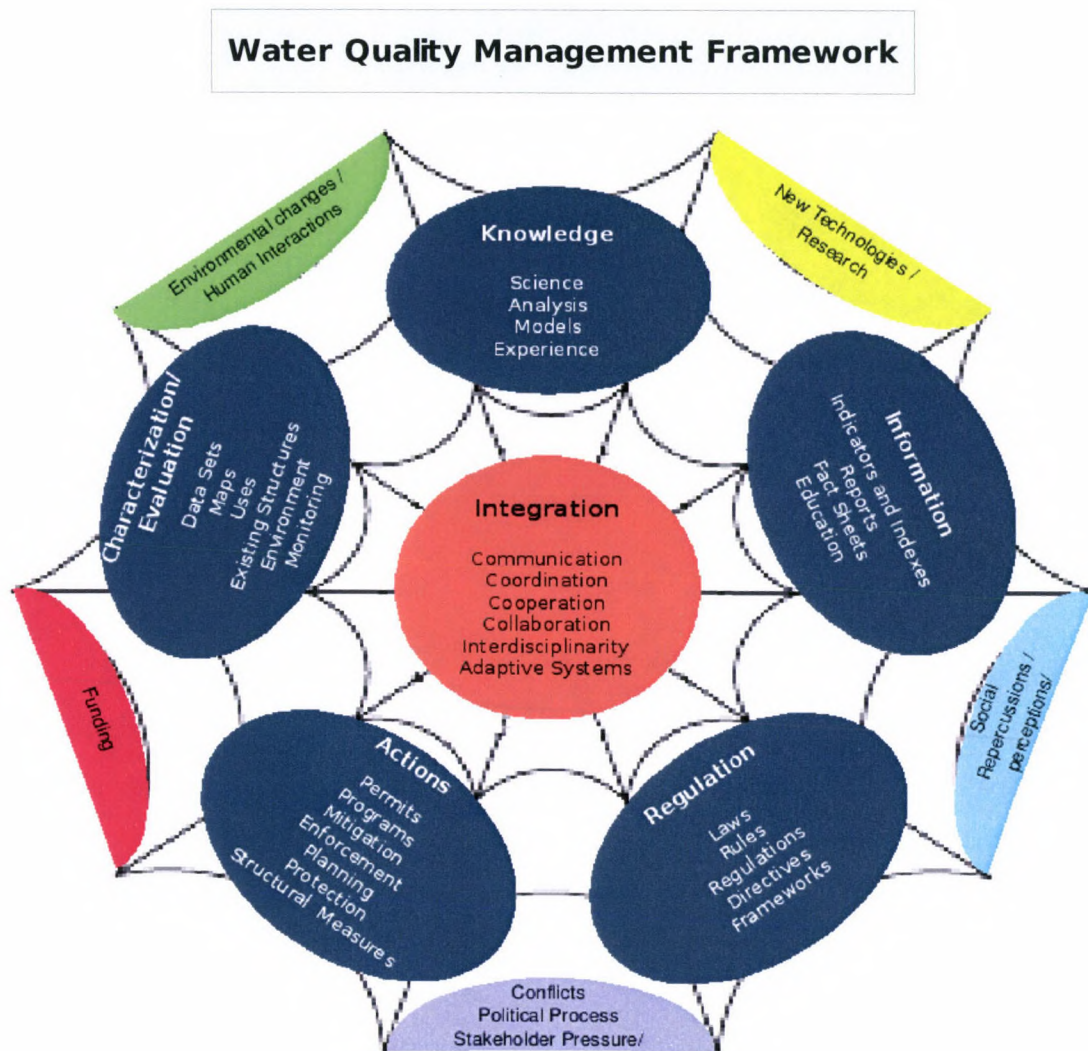


Figure 2.5: Proposed Representation for a Water Quality Management Framework

2.2 Data, Information, and Knowledge

Information and data exchange are crucial to any science, but are particularly important when the subject of research, such as water, cannot be contained within local, regional, or national boundaries. The complex interactions with the environment leads to uncertainty levels difficult to surpass without adequate information. Djordjevic (1993, 461) argues that “The water resources system (WRS) control is basically a struggle with entropy... it is essential to collect, process, and use the necessary information for making control decisions”. Nevertheless, much data is collected without regard to its ability to be comparable to existing information, or even coordinated to be comparable to data being collected downstream (Ward 2002).

Local, national, and international laws and regulations, in addition to integrated management and transboundary issues, add complexity. Simonovic (2009, 43) noted that the system analysis “must involve trade offs among multiple objectives in a multidisciplinary and a multi-participatory decision-making process”. That leads to an increasing need for adequate collection and use of information, as well as integration and collaboration among the parties involved (Ganoulis 1999).

The growing concern about the environment and more readily available monitoring techniques has generated an incredible amount of stored data (Vansteenkiste 2008). Data is the primary level of information, the one that is collected and stored without any interpretation or manipulation (Djordjevic 1993).

Very often, collected data is not appropriately converted into useful information, a state characterized by Ward, Loftis, and McBride (1986) as a “data rich but information poor” syndrome. The assertion attests to the fact that data is useless until it reaches its intended

audience and is communicated in a meaningful, understandable way. It also reflects that the task is not trivial since the target audience could be a combination of a wide variety of users, including government officials, engineers, scientists, researchers, land developers, and consultants (Fitsik et al. 2008, 23) as well as the general public. Many of these groups could also be providers of data as well as end users.

Time is also an issue. Information may lose its value as time passes (Djordjevic 1993), so timely processing and conveyance is essential.

As knowledge and regulations evolve, so do the methods of collecting and analyzing data. For this reason, metadata is an essential part of the information. Data sets, however, very often are not accompanied by information about the data itself. The amount of data and the fact that a broad number of agencies that collect information also pose a problem by making coordination of several sources difficult and costly.

In a report to the General Accountability Office in 1995 (GAO/T-RCED-95-174), EPA admitted: “Many of (the agency's) scientific data sets are either incomplete, obsolete or missing altogether, a problem that extends across all media areas. These problems have made it difficult for the agency to conduct scientifically based risk assessments and to measure the results of environmental programs. The agency's problems in obtaining quality data are exacerbated by difficulties in managing the data that are available. In particular, EPA's data management systems have been designed to track or manage information about environmental conditions and results for each environmental medium, thus making scientific assessments of risk across media areas cumbersome and costly.”

If this is true for a country like the United States, it is possibly even harder for developing

countries to collect and manage data and to make the information accessible to all stakeholders. Established common ground is necessary so different players can have a mutual understanding of their goals and the means to achieve them.

In their introduction to the series of papers: A Framework For 'Constructing' Water Quality Monitoring Programs (Impact - September, 2003, p.3), Peter and Ward noted that “To meet the data and information challenges facing Water Quality Management today, across agencies and disciplines, requires a common view of water quality monitoring and a common vocabulary to facilitate collaboration and communication”

In the same issue, Markowitzet, Green, and Laine (2003), introduce the National Water Quality Monitoring Council's (NWQMC) Proposed Framework for Water Quality Monitoring Programs (Fig. 2.6), where the 3 C's – Communicate, Coordinate, Collaborate – take central stage, and describe short term (enhanced, and more widely applicable, assessment tools, increased quality and quantity of data and information, potentially less cost and reporting consistency) and long term (monitoring is consistent, comparable and scientifically defensible; information is accessible and facilitates sound decision making by all stakeholders) monitoring needs.

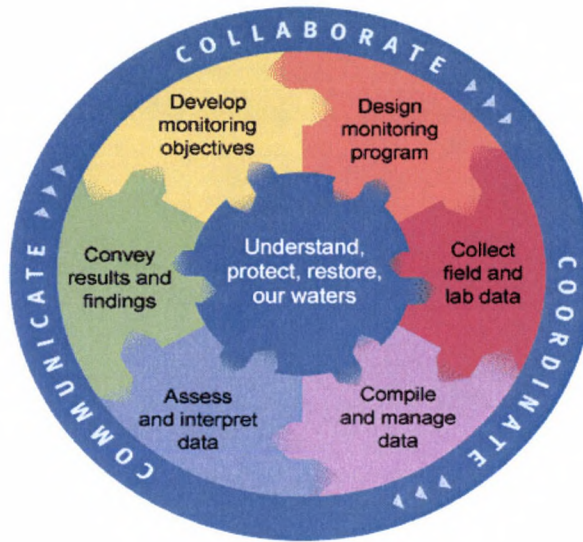


Figure 2.6: NWQMC's Proposed Framework for Water Quality Monitoring Programs

Although monitoring data is a very important piece of water quality knowledge, it is not the only one worthy of being electronically available. Furthermore, while today there is a great push to integrate databases, the bulk of the knowledge is being somewhat neglected as a valuable and sharable resource.

Before electronic communications were possible and widely accessible, most information and knowledge was transmitted in three ways: (1) Formal education and training; (2) Paper publications; and (3) Conferences and seminars (Wenger 1998). With the World Wide Web now available, the same models are being applied. Universities are making web courses a part of their curricula; journals are becoming available online (for subscribers), and associations are making it easier for conferences and seminars to be attended.

While those developments are welcome, there is no reason to simply adapt those models; instead, new ways to make use of the technology now available should be explored. The new

paradigm in Water Resources Management has undoubtedly added to the complexity of the process and, regardless of their background, current water managers need a significantly broader set of information sources than their previous counterparts (Pahl-Wostl 2006; Fontane 1999).

A document from the World Bank (1993, 71) highlights this necessity and advocates for training in “ cross-sectoral analysis; legal, regulatory, and privatization issues; and river basin management, environmental protection, project formulation and evaluation, demand forecasting, and participatory management. ”

In the same way, the inclusion of different disciplines, stakeholders, and the community in decisions also requires that these players be educated and understand enough of the process to participate effectively. As Grigg (1996, 19) notes “The prescription for dealing with complexity is competence, to be built through education, training and professional development.”

New approaches to technology and the adoption of information flowing in all directions – as opposed to top-down models – can be part of the solutions for this problem, bringing the possibilities for sharing and disseminating knowledge to a new level.

2.2.1 The World Wide Web

Even before the creation of the Web, electronic communication was booming. Researchers, nonprofits, corporations, and others were using bulletin boards (BBS), to disseminate their work and collaborate on projects (Cisler 1993). E-mail facilitated communication. Usenet newsgroups appeared at Duke University in the late 1970s (Daniels, Ellis and Truscott 1980) and spread throughout the academic and research world as a tool to electronically exchange information with threaded text messages (all messages are grouped by

topic and hierarchically linked to the original message and subsequent replies) among a group of people interested in the same subject (Golder 2003).

In 1989, Timothy John Berners-Lee and his team at the *Organisation Européenne pour la Recherche Nucléaire (CERN)* proposed the concept of the World Wide Web, writing the first browser and the early version of HyperText Markup Language (HTML) (Berners-Lee 1989, 1990). The main objective of HTML was to allow knowledge sharing and communication among fellow researchers.

Although the concept for Hypertext had been developed decades before (Nelson 1992), the breakthrough was the use of unidirectional links, which allowed users to link to other information without any action from the other part – and the fact that the system was not proprietary, allowing it to grow quickly as users could write their own code depending on their necessities.

One of the earliest efforts to take advantage of this new technology in the Water Resources field was made by the USGS, sponsoring the project for the Universities Water Information Network (UWIN) in 1992 (Anderson and Wade 1995).

In 1994, Martin brought up the need for an information exchange network in water resources and noted some existing electronic networks, such as the Groundwater database for the State of Wisconsin and the National Gulf of Mexico and Chesapeake Bay Programs' Bulletin Boards, but no single national system was available at the time.

In the next 10 years, several similar efforts to publish water resources information were developed. The online resources range is broad, consisting of online databases (STORET (EPA), GRDC, HIDROWEB, WISE), e-publications (Impact, E-WATER (EWA)), news and discussion

lists (waterlaw.org, ABRH-GESTAO), GIS linked data and applications and websites to water agencies, projects and programs (NAWQA, ANA, EPA, USGS) to name a few. Some of these websites combine different resources and also link to several other sources of relevant information.

With electronic resources readily available and broadband capacities increasing, the efficiency of the information exchange is mostly limited by the inability to organize and publish such information so that it is not only easily retrievable, but also fosters contributions from the entire community.

2.2.2 The Open Source Model

In 1991, an unpretentious message fired up a revolution in the software world. Although the idea of open code was not new (GNU project), Linus Torvalds, posting on a newsgroup (Fig. 2.7) his idea for a new operational system (OS), initiated a big-scale collaboration project (Linux). He would be followed by several similar efforts to produce software with open code.

In having the open code available to the community, Torvalds started receiving not only suggestions for his OS, but also written code for the desired features and solutions for fixing bugs. Instead of waiting for a suitable change to be made, users would build on the accessible code, implement the code themselves, and make the changes available to their peers.

```
From: Linus Benedict Torvalds
(torvalds@klaava.Helsinki.FI)
Subject: What would you like to see most in minix?
Newsgroups: comp.os.minix
Date: 1991-08-25 23:12:08 PST
Hello everybody out there using minix -
I'm doing a (free) operating system (just a hobby,
won't be big and professional like gnu) for
386(486) AT clones. This has been brewing since
april, and is starting to get ready. I'd like any
feedback on things people like/dislike in minix, as
my OS resembles it somewhat (same physical layout
of the file-system (due to practical reasons) among
other things).
I've currently ported bash(1.08) and gcc(1.40), and
things seem to work. This implies that I'll get
something practical within a few months, and I'd
like to know what features most people would want.
Any suggestions are welcome, but I won't promise
I'll implement them :-)
```

Linus (torvalds@kruuna.helsinki.fi)

PS. Yes - it's free of any minix code, and it has a
multi-threaded fs. It is NOT protable (uses 386
task switching etc), and it probably never will

support anything other than AT-harddisks, as that's
all I have :-)

Figure 2.7: Linus Torvald's original message to the Usenet Newsgroup

According to Seybold (2006, 200), “the more profound breakthrough represented by the open source model...(are) complex products that are co-created and evolved by a community of practitioners”

In the following years, Linux grew into a very reliable OS and the applications for the OS are continuously being developed. Despite, or maybe because of, being developed in an almost organic form, Linux made open source software into a viable, and very often, better alternative than their traditionally closed source counterparts (Augustin, Bressler and Smith 2002).

As observed by Raymond (2000, 55), “The strongest argument the open-source community has is that decentralized peer review trumps all the conventional methods for trying to ensure that details don't get slipped.”

2.2.3 User Generated Content and Knowledge Networks

From the time of its creation until the beginning of the 21st century, the content of the web has been mostly static – with information posted by website owners and a handful of contributors and then accessed by users looking for such data. As the number of individuals and amount of data on the web grew exponentially, web site editors started to look for other ways to manage and update their data. Why not let their own virtual community help to improve it?

The first participatory web technologies include: electronic fora, wikis, newsgroups and blogs. An improved and timelier version of the bulletin boards, these allow people to not only post questions but also to interact more directly with fellow members.

User generated content is a relatively new concept on the web with a great potential to support collaborative learning and exchange of ideas (Wheeler, Yeomans, and Wheeler 2008). The applications for this trend go beyond discussion groups, as users are now able to generate and upload any form of digital work as opposed to simple text messages (You Tube is a well known example; Wikipedia, a collaborative encyclopedia, is another). Online stores allow consumers to rate their products; online product search engines ask them to rate the online stores. News shows are soliciting viewers to comment on their pieces and upload their own photos and videos of current events. Social networks are playing an essential part in how people communicate – even when (or maybe because) closed regimes try to stop them.

Participation is essential for this new approach, and several authors have studied the role users play in online discussions and their motivations for contributing to online groups and websites. Welsler et. al. (2007,1) found that “People contribute to these conversations for a variety of reasons: for debate, to express appreciation or affiliation, to build a sense of community, to provide and receive social support, to collect information, and to provide answers to questions”

In a number of cases, user contributions started quasi by accident, as a byproduct of more open designs of the websites. Seybold (2006) describes how, once their bug report database was made available online, the technical support at Cisco Systems started seeing their own customers collaborating online and posting the answers to other customer's questions. Other collaborative sites were developed with user's contributions in mind, such as the Wiki concept, created based on some of the open source community experience and aimed at being a simple database that should be easy to use, yet sufficiently organized so information will be readily accessible. Wikipedia (<http://www.wikipedia.org>) is the most famous application for the concept. This online encyclopedia has about two million articles in English, plus an average of four hundred thousand articles in other main languages, totaling about eight million articles.

Knowledge Networks, also called Communities of Practice (CoPs), are nontraditional, nonstructured ways to exchange extrinsic and tacit information. According to Wenger (1998) and Smith, M. K. (2003), a community of practice is characterized by: (1) what it is - a joint enterprise as understood and continually renegotiated by its members; (2) how it functions - by mutual engagement that bind members together into a social entity; and (3) its results – a shared repertoire of communal resources (routines, sensibilities, artifacts, vocabulary, styles, etc.) that members have developed over time. Allee (2000, 6) argues that “The primary purpose of informal knowledge networks is to collect and pass along information” and “relationships are

always shifting and changing as people have need to connect”. While on CoPs : “Communities require a sense of mission: there is something people want to accomplish or do together that arises from their shared understanding.”

The rise of social networking sites (Facebook, MySpace ,and Twitter) has also given a new life to knowledge exchange. The advancements in technology, mostly created to facilitate the development of blogs and social sites can also be used to improve knowledge-based communities. CoPs are largely used in business, usually for intra-corporation knowledge management. But with the proliferation of these applications, many of them open source, the CoPs are freed to move outside corporations and, more importantly, outside a formal structure and any top-bottom control (Wenger 2002).

These types of communities are characteristically heterogeneous in their memberships and are typically formed within corporations or shared-interest groups (Ardichvili, Page, and Wentling 2003). Broad levels of expertise among the membership leads to different patterns of participation and contributions within the community (Johnson 2001).

As the discussion evolves, individual roles take shape. As adoption grows, most participants will assume a well defined position in the community (Turner et al. 2005). Some research was done in order to identify a pattern in user participation that defines those roles. Among those, Viegas (2004, 1) uses a method called visualization to reveal “temporal patterns of thread initiation and reply that can broadly characterize the roles authors play in Usenet” while Golder (2003) traces the disparity in the levels of participation and argues that it can be explained by the different goals, needs, and skills of the participants of the community. Common roles are: users who create original content, users who share and forward existing content, users that critique and comment on the content, and finally, users who consume all the information.

Ardichvili, Page and Wentler (2003) identified some of the reasons and benefits for and barriers to participation. Table 2.2:

| Reasons and Benefits | Barriers |
|--|--|
| Members view their knowledge as a public good, belonging not to them individually, but to the whole organization. | Knowledge seen as an individual's private asset and competitive advantage. |
| Need to establish themselves as experts. | Approval or moderation process and unclear rules |
| Several managers and experts felt that they had reached a stage in their lives when it was time to start giving back, sharing their expertise, mentoring new employees; they felt that the participation in the community provided them with this opportunity. | Fear that what they post may not be important (may not deserve to be posted), or may not be completely accurate, or may not be relevant to a specific discussion. |
| Useful problem-solving tool: Useful for keeping informed of general developments in their profession; Access to Best Practices; Access to a Lessons Learned Database. | Fear of possible criticism or ridicule of what they might post. This last group is concerned that they may receive responses belittling the importance of their contributions. Some are concerned that questions they might post deal with matters to which they should already know the answer. |
| The system provides a space for jointly generating new knowledge, not just capturing the existing knowledge; The system's ability to provide benefits beyond specific solutions to immediate problems. | |
| Timeliness of the Information; An easy link not only to one's own community, but to other related communities and topics; Increased efficiency of one's work. | |

Table 2.2 Reasons and benefits for and barriers to participation in a CoP.

Collaborative websites are not without criticism. A number of problems can occur when malicious users edit an article, which anyone, anonymously, can do. A number of self-serving edits have also been detected (Seybold 2006). Eventually, the community detects and corrects these outliers, but some damage can be done before that happens.

Knowledge networks change the speed and increase the volume of information that can be published. They shift the control of the information flow from the insiders to the end users. That, alone, can make information publishing more efficient, but it certainly does not guarantee to make it accurate.

Copyright is also an issue. The legal system is still wrestling with matters such as fair use, and the jury is still out on if and how websites can be made responsible for content posted by their users. While liability is a concern, according to the Citizen Media Law Project (2009, paragraph 3) “Bare facts and ideas, government documents, and items in the public domain are not subject to copyright, and some materials may be published under a Creative Commons license or other license that permits reuse. In addition, the doctrine of fair use provides that copyrighted materials may be used without the consent of the original owner in certain situations, such as when using excerpts for criticism or news reporting.”

As a result, some practices of this new “open web” are changing, and peer review will play a part in that. Validation and classification of online content are increasing, but the volume of data makes it impossible for website managers to do it alone. In addition, active users are eager to help, as they see themselves as a part of the community. As Golder (2003, 1.3) found, “Over time, individuals (who) demonstrate responsibility, gain the respect of their peers and their investment of time in the community yields a sense of ownership”.

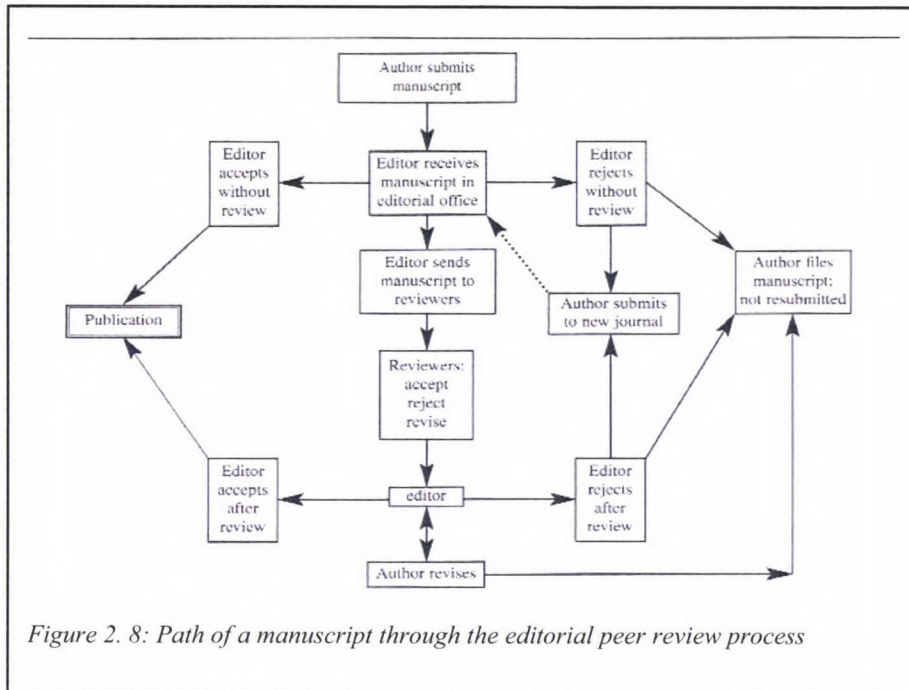
2.2.4 Peer Review & Trust Networks

Peer review, a process in which one's professional peers review one's scientific work, is often described as the way by which the scientific community regulates itself, preserves its autonomy, and practices quality control.

Several authors (Weller 2001; Chubin and Hacket 1990) attribute the earliest use of peer review to the founding of the *Philosophical Transactions* of the Royal Society in 1665. The practice was established as a means to give the council, which conducted the review, some control over the publication. In the 19th century, *Nature* and the *British Medical Journal* were among the first journals to adopt some form of peer review (Weller 2001).

Since then, the model has evolved and extended. Modern peer review was widely adopted in the mid 1900s. While studying the evolution of peer review, Burnham (1990, 3) noted that “Institutionalization of the process...took place mostly in the 20th century, either to handle new problems in the numbers of articles submitted or to meet the demands for expert authority and objectivity in an increasingly specialized world”

Benos et al (2007, 145) asserts that peer review “In general,... now embodies a process of systematically distributing, evaluating, and reaching a consensus on the merits of submitted manuscripts as evidenced by publication acceptance or rejection. The cornerstones of this process are the editors and expert reviewers”. Weller (2001) identifies editorial peer review as “...fairly well defined,”and describes the path of a manuscript through the process as shown in Fig. 2.8.



Peer review today is not only used for publications, where it is also called by some “journal refereeing,” but also for approval of research proposals, deciding the distributions of grants, and review of projects.

While 'referees' are considered helpful to filter through manuscripts and identify the ones that are worthy of publication, and also contributing to the final quality of the articles by suggesting changes or improvements, some argue that the peer review process, as it is employed today, has gained strength in detriment of the concept of 'free flow of information'.

Issues such as anonymity of referees, vested interests, politics, ideology, censorship and lack of openness to new, ground-breaking ideas, have brought intense criticism to what is now a very well established practice in the scientific community. In an analysis of the peer review

process, Moran (1998, 4) notes its deficiencies and calls for “Academic peer review authorities to live up to the rhetoric of openness, open discussion, open debate and free exchange of ideas among scholars”.

Future practices in peer review may incorporate the technology advances in the process. With changes in publications’ practices and exchange of information in the electronic era, there is hope for great improvement to a process that is described as saturated by a growing number of scientists and scientific fields. On the other hand, the potential for a steep increase in number of publication titles could also create confusion, and therefore, necessitates improvement in the way people find and access publications, data, and resources relevant to their work.

Currently, most web communities have moderation to ensure quality. The moderator's task is, similar to a peer reviewer, to ensure quality of the material posted. According to Resnick et al. (1994, 2), “A moderated group employs a primitive form of collaborative filtering, choosing articles for all potential readers based on evaluations by a single person”. But that amounts, as in the peer review process, to not only placing great trust in the moderator's judgment, but also to potentially losing information due to either bias or simple lack of resources and time.

That is why ratings are an essential part of today's web. To filter and navigate over extensive amounts of resources and information, users are increasingly relying on their peers to indicate the way. Online stores (Amazon, Buy.com) have buyer reviews for their products; travel sites (Travelocity, Expedia) have ratings and comments on hotels and other amenities; You Tube has their best videos, as chosen by their viewers, on the front page. News are rated by aggregators like Reddit.com and Digg.com. In these cases, even if not all the reviews are trustworthy, the volume of reviews ensures that the average should be at least a good indicator of consensus.

Collaborative content filtering can be as simple as an average of single ratings, or in the case of a smaller community or when accuracy is at the core, a reputation mechanism can be combined to the ratings in order to increase confidence in the filtering process (Zacharia, Moukas and Maes 1999). This can be accomplished by either (a) declared trust: users can declare confidence in other user's reviews or articles; (b) interest sub groups: the system can automatically establish relationships by examining which articles users read and comment upon and how they rate them; (c) declared level of confidence in the author's institution; (d) declared interest in certain subjects; and (e) a combination of those factors (Fig. 2.9).

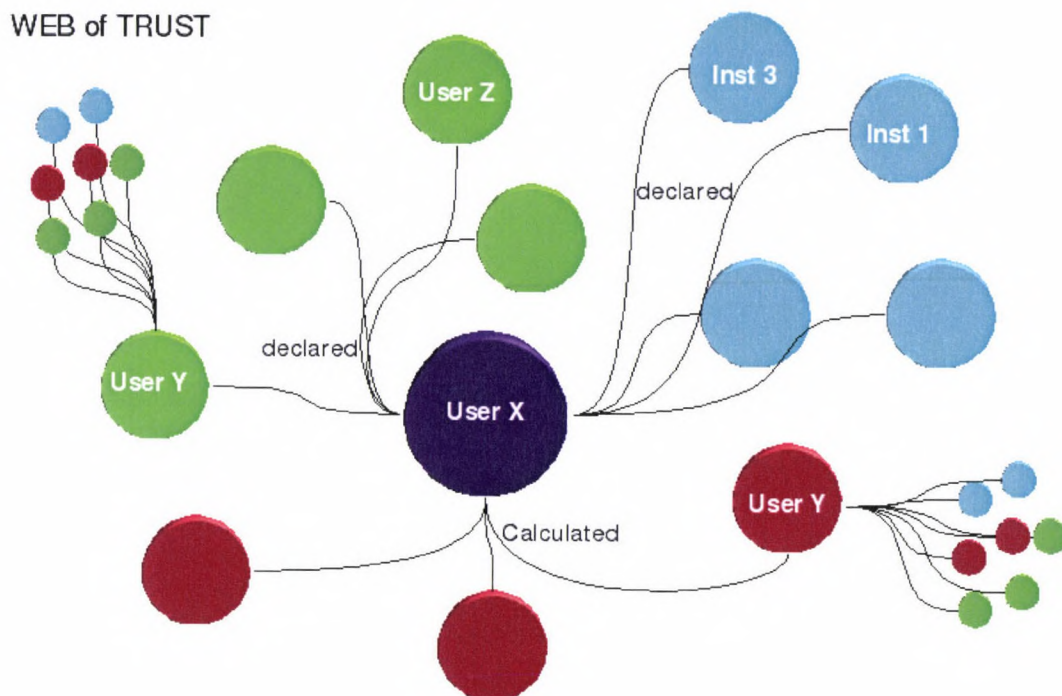


Figure 2.9: Web of Trust. Example of relationships within the network.

Once the “declaration of trust” and the relationships are established, a number of filtering queries can be electronically set up. For instance, user X has declared confidence in users Z and Y and in the institutions 1 and 3. So user X can give priority to articles that were reviewed by

those users or authored by people from those institutions. They can also get articles reviewed by people that are trusted by users Z and Y. But the system also finds that user X and user W have common interests, either by the articles they read or how they rate them. So the system can also suggest to user X the material that was highly rated or commented upon by user W.

This kind of “web of trust” can be set up to be as personalized as necessary. Users can either let the system run a standard query based on a combination of factors above or they can run their own queries on the system. Another possibility is to query the user database. If the user is interested in networking, he can easily find people interested in the same subjects as those on which he is working, or query for a completely different subject.

Combining reputation systems and collaborative filtering, the relationships and ratings elements can be constructed and used as an indicator of the reliability of the material published. As Judson (1994, 94) foresaw “The transformation will open up the processes by which scientists judge each other's work, making them less anonymous, capricious, rigid, and subject to abuse, and more thorough, responsible, and accountable. It will oblige the readers of journals – even journals of clinical research – to take a more active part in the intellectual assessment of published work.”

2.3 Water Resources Knowledge on the Web

The World Wide Web is replete with, among other things, small pieces of knowledge, all scattered in different resources and sources. Depending on the subject, one can find thousands or even millions of sources of information, some reliable, some not. The problem is, how to sort them out? How can one check sources and decide what information is useful and reliable?

For Water Quality, this is not any different. In a search for water quality on Google, the dominant search engine, some general terms yield a few million results. The more specific the search, the narrower the results, but there is no guarantee on the quality of the sources. Although most search engines do a good job ranking their results, one must be very specific about what one is looking for to get to information quickly. Furthermore, the ranking of the results on Google is based on the analysis of pages that link to that specific website, which may not reflect the source's expertise on that particular subject.

“PageRank relies on the uniquely democratic nature of the web by using its vast link structure as an indicator of an individual page's value. In essence, Google interprets a link from page A to page B as a vote, by page A, for page B. But, Google looks at more than the sheer volume of votes, or links a page receives; it also analyzes the page that casts the vote. Votes cast by pages that are themselves “important” weigh more heavily and help to make other pages “important.”

Google's Description of Page Rank. (<http://www.google.com/corporate/tech.html>)

That may be the reason Wikipedia, and not EPA or USGS, is first ranked in the results of the search for Water Quality. It is because Wikipedia is a more popular site, in general, than the other two, so even if you expect EPA or USGS to be more “linked to” when talking about water quality, the popularity of Wikipedia weights the results so that it is very likely to be on top. Table 2.3 shows some common search terms for water quality and their search results:

| Search Term | Number of Results | Top results |
|------------------------------------|--------------------------|---|
| Water Quality | 132,000,000 | Wikipedia en.wikipedia.org/wiki/Water_quality EPA www.epa.gov/safewater/ USGS ga.water.usgs.gov/edu/waterquality.html |
| Water Quality News | 91,900,000 | <i>Medical news Today</i> www.medicalnewstoday.com/sections/water_quality/ <i>US Water News</i> www.uswaternews.com/archives/arcquality/arcquality.html <i>Microbe World</i> www.microbeworld.org/news/water_quality/news_water_quality.aspx |
| Water Quality Information | 90,200,000 | Water Quality Information Center www.nal.usda.gov/wqic/ USGS water.usgs.gov/owq/ EPA www.epa.gov/safewater/ |
| Water Quality Information Colorado | 1,580,000 | Water Quality Control Division for the State of Colorado www.cdphe.state.co.us/wq/ USGS Colorado Water Center co.water.usgs.gov/ Colorado Water Quality Association www.cwqa.org/home.html |
| Water Quality Big Thompson | 268,000 | Big Thompson Watershed Forum www.btwatershed.org/ USGS Role in the BTWF Monitoring Program (presentation, ppt) acwi.gov/monitoring/ppt/denver0702/rob_julianne.pp Coyote Gulch coyotegulch.wordpress.com/...water/.../big-thompson-watershed/ |

Table 2.3 Search results for water terms, in English, on July 15th 2009.

In terms of Water Resources knowledge, the information is found on:

1. Water Agencies websites: usually contains data, news (from the agency), documents, regulations, and publications;
2. Projects' and programs' websites: can be related to agencies or not, but have the information about those specific projects or programs (e.g., monitoring, clean up programs in specific rivers);
3. Water Professionals Associations: have information about conferences, their own publications (usually restricted to members) and other events. Some have discussion lists associated with them.

4. Basin organizations: basin committees, forums, or other types of organizations centered on a watershed. Usually have information restricted to their programs. Some are organized by citizen groups, some by stakeholders and water users' groups.

5. Discussion lists, fora: The discussion and fora lists are the most “democratic” kind of information since users can post their own information. Usually delivered by e-mail to subscribed users. Retrieval of information, on the other hand, is not trivial.

Most of these resources do not allow – or envision – much collaboration or user content. Official agencies, like EPA or EEA, may have a legitimate concern about liability. Their information needs to be 100% verifiable, so they are reluctant to take any content that is not checked by their offices. Also, when allowing user content, there is certainly a trade off: more information, better efficiency – for some lower degree of accuracy.

On the other hand, collaborative websites could be the answer for the increasing lack of funding and person power for these kinds of projects. Relying on the community to publish and classify information cuts cost and increases the efficiency of the process. Concerns about accuracy may be solved by the use of trust networks and other forms of review; the technology for solving accuracy issues is evolving rapidly.

Table 2.4 presents a sample of current websites containing Water Resources' knowledge. The sites were chosen for being representative of the kind of knowledge and information currently available on the web. Some of the resources have been grouped according to similarity in content.

| Website | Type of Resource | Type of information | Access | User comments / content? | Sources | Comments |
|--|------------------|---|--------------------------|--------------------------|----------------------------------|---|
| EPA USGS USDA | Website | News Data Sets Newsletter Programs Projects Legislation Reports | public | No | Mostly internal | Governmental - USA http://www.epa.gov/ow/ http://water.usgs.gov/owq/ http://www.nal.usda.gov/wqic/ |
| EEA | Website | News Data Newsletter Programs Projects Legislation Reports | public | No | | Governmental – Europe http://www.eea.europa.eu/themes/water |
| AWRA www.awra.org | | News Publications Events | Mostly member | No | Mixed | Professional Association |
| NWQMC http://acwi.gov/monitoring/ | website | News | Public | No | Internal, from council's members | Government supported |
| EWA | website | News Journal Newsletter Legislation Reports | Some public, some member | | | European Water Association http://www.ewaonline.de |
| GIWA | website | Newsgroups Reports | | | | UNEP - Global International Waters Assessment http://www.unep.org/dewa/giwa/ |
| Water Wiki | website | Information knowledge collaboration Case Studies Projects | Public | Some | UNDP UNESCO WHO Members | http://waterwiki.net/ |
| Water Forum ABRHGestao(BR) Water Quality Forum | Discussion lists | | Public | Yes, yes | members | http://tech.groups.yahoo.com/group/waterforum/ http://br.groups.yahoo.com/group/ABRH-Gestao/ http://groups.yahoo.com/group/wqf/ |
| WATERSisweb | website | News | Public | Yes, yes | mixed | Http://www.sisweb.org/water |

Table 2.4 Sample of available knowledge on Water Resources on the Web as of July 21st 2009.

3. Methodology

The question this research sought to answer is: would the application of new technologies and methods in virtual collaboration help improve the exchange, use, and interpretation of data, information, and knowledge within the water quality community?

In order to answer this question, an examination of the use of water quality information and knowledge and a search of existing online resources was conducted.

To better understand how information is produced, used, and transferred, an exploratory questionnaire was posted to different professionals involved in water quality management. A preliminary search of existing water resources and water quality communities, combined with the identification of existing community building technologies, led to the design of the second part of the questionnaire, which was intended to collect impressions on the usefulness of these new technologies for water quality information exchange.

Each of the communities selected for examination was chosen because at least one unique aspect identified as a possible component for the network framework.

After visiting and analyzing several collaborative resources and websites, a compilation of possible useful tools and methods was produced. Since a questionnaire was to be posted to the water community in Phase II, the objective of this initial search was to catalog and examine the methods that could potentially be applied in the context of a water quality community. Subsequently, strengths and weaknesses of the main applications for water resources were assessed.

The next step was the development and application of the exploratory questionnaire, in

order to request input from the water community, while identifying, for determined groups such as government, education, and research entities as well as citizen groups, which capabilities and tools would be in demand and how the different groups would use those resources.

With data from the technology searches and exploratory questionnaire, a basic framework and reference implementation was developed, consisting of the implementation of the main concepts identified from the analysis of the data collected by the searches and the questionnaire. The website for the network was then published online and initially populated.

A final questionnaire was drafted to collect feedback from the community. The responses, along with traffic data from the site, was used to add understanding and draw the final conclusions. Fig. 3.1 shows the methodology chart.

The main objective in the design of the framework is to identify key tools and information that would attract water quality professionals to the network and foster collaboration among them. The goal is not to build a fully workable database with complete resources and data. Even so, a reference implementation was deemed necessary. Because this is a new concept in communication, the pilot will demonstrate and test the basic features and their usability. Once a user base is established, the demand for new resources should arise from the community itself.

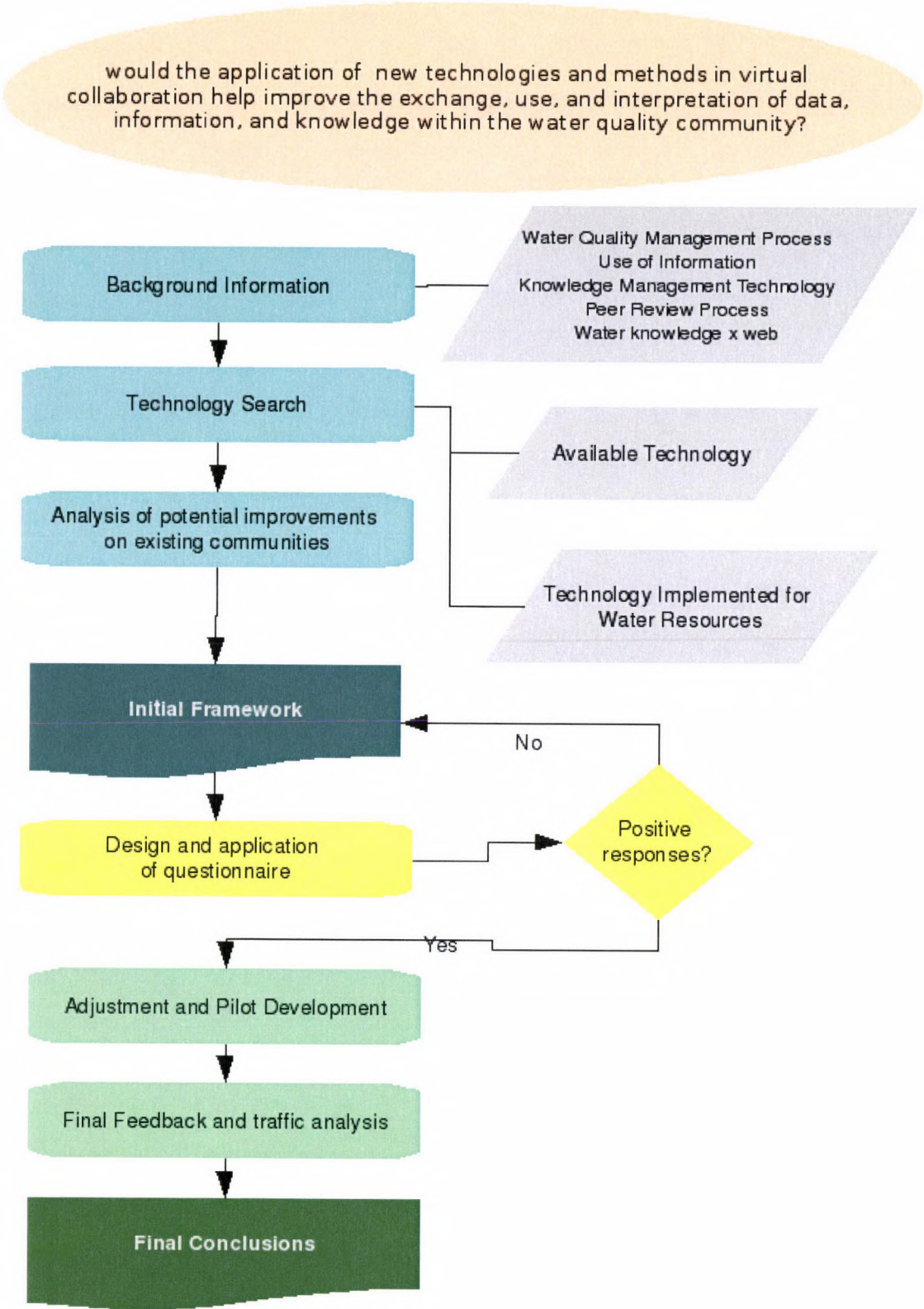


Figure 3.1: Methodology Chart

For this reason, the search for technology was driven by the feasibility of the application to be utilized and manipulated by regular professionals in the water quality field, as well as what would be a good, useful means to “jump start” such a community. Notably, every contribution from the users would require a different level of experience with the technology: a single entry for a water quality project or program in the database or a news article should require no more effort than filling out a single form, while building a model that would run directly from the network would require considerably more skill.

The concept of the network was designed to achieve these main goals:

- Advance Water Quality education and knowledge in several levels;
- Encourage distribution and access to data and information;
- Provide networking opportunities;
- Allow public perceptions and concerns to be collected;
- Promote exchange of ideas;
- Give general, open, and free access to information.

The project consisted of four separate phases. The first phase focused on the search for possible applications and the design of a preliminary framework; the second was the development and collection of responses of a exploratory questionnaire; the third was the design and development of the pilot system following the responses from the questionnaire, and finally, the fourth phase consisted of several beta tests aimed to further evaluate the project. Membership and participation in online communities are typically slow in initial phases. The results expected from the final evaluation are positive responses to the concept of the network, not broad adoption.

3.1 Phase I - Search for Collaborative Technologies.

The main sources of information for this phase were collaboration websites for other areas of knowledge. The field of Computer Science, as expected, is the area that has taken the most advantage from what the World Wide Web has to offer in terms of exchanging information while the Water Resources community is still looking for ways to improve collaboration. Most websites only offer static pages and editorial content. The trend for community generated content is still very much absent from Water Resources networks. On the other hand, discussion groups (e-mail lists) are thriving, which indicates that the will and the need to collaborate exists, and once presented with the right tools, the community could come to adopt the improved means of communication. An examination of these groups can provide a picture of what types of information is being circulated. Additional examination will render some clues of how and where this information is used. Table 3.1 shows the most common types and uses of information in water quality. A list of the most relevant communities reviewed and their description is shown in Table 3.2.

| Information Type | Information Uses |
|--------------------------|----------------------------------|
| Monitoring Data | Research |
| Indicators & Indexes | Management |
| Knowledge, Science (I&E) | Decision Making |
| Regulatory Framework | Regulators |
| Funding | Engagement |
| Opinion and Q&A | Public and community information |

Table 3.1 Information type and uses

In the search for useful tools, there are many considerations. Data, information and knowledge are only valuable when there is a perceived trust in their sources. The confidence in the provider of the information, as assessed by the recipient, is essential. On the other hand, there is a danger of stated opinions to become *de facto* knowledge, especially in environments where dissent is not encouraged.

Based upon visiting collaboration websites and community networks, the following activities were identified as the ones that would likely be used within the Water Resources community. The main method for selecting these activities was to compare their potential to improve on the activities already performed by the community with the objective of exchanging information. The activities range from providing information sources (a,b and c), models and data (d and e), information processes (f, g, and h, i), to collecting feedback (j). Accessing the believability of each kind of information was an important consideration, as the benefits of those tools would only be in place if the network members know they can rely on it.

For an initial guide, a tentative assessment (Table 3.3) for these activities was constructed, with potential improvements and/or complements identified for each one. The results from this search were used to build the online questionnaire for phase II.

The search for technology resulted in a preliminary framework that was used in the design of the questionnaire and the draft design of the reference implementation. The main goal of the design was to explain the concept so it could be evaluated and commented upon by different segments of the water quality community.

| Website / Network | Description |
|---|---|
| Slashdot Slashdot.org | A pioneer in UGC, slashdot is a site for news and information, mainly in information technology. Although the content is user generated, it has an editorial system that will screen the stories users submit. Users can comment on the stories or ask/answer questions regarding technology. There is a user moderation system in place to keep discussions civil. |
| Water Forum http://tech.groups.yahoo.com/group/waterforum/ | Basically, an e-mail discussion list. Users send news, questions, and announcements; others comment and offer input. |
| ABRH-Gestão yahoogroups | A discussion list for water resources in Brazil. Same procedures. Main discussions are technically or politically oriented. |
| Wikipedia www.wikipedia.org | A user-based encyclopedia. Users can alter content and edit articles. Works well and information is mostly very reliable. |
| Knol http://knol.google.com | Google's knowledge database. It is new and not yet very popular. While Wikipedia will have one single article per subject that users can contribute to, Knol users will write an entire article in their area of expertise and may or may not accept contributions from others. |
| Naymz.com | Professional Network. Interesting reputation system that includes personal references and background checks. |
| LinkedIn.com | Professional Network. Relies on user recommendations to assess reputations. |
| WQF – yahoo groups | Water Quality Forum on yahoo groups. They describe themselves as a “Consortium of government agencies, nonprofit groups, private businesses, and individuals who have joined together in Knoxville/Knox County to improve the health of the local waterways.” |
| Big Thompson Watershed Forum (btwatershed.org) | A forum for stakeholders that coordinates collaborative monitoring and projects in the Big Thompson Watershed. |
| Colorado Watershed Assembly (coloradowater.org) | Nonprofit advocate for citizen conservation groups. The group relays information from several sources through a weekly newsletter and occasional announcements by e-mail. |
| Amazon.com; Buy.com CNET; Travelocity.com | Online stores with customer reviews and ratings of the products. |
| Drupal.org | Community building development tool. |
| Twitter.com; Facebook.com; Myspace.com; Orkut.com | Social networking sites. |
| LinkedIn.com; XING.com Naymz.com | Professional networking sites with user reputation schemes. |
| Ebay.com Kasbah.com | Sales and auction sites with user reputation systems. |
| Water Sisweb | Water news site with collaborative filtering |

Table 3.2 - Main Collaboration Sites and Networks visited

| Activity | Possible improvement or complementary tool | Advantages, Strengths | Possible conflicts | Possible solutions |
|---|---|---|--|--|
| (a) Publications: books, seminars, journals, and online resources | A database where users could submit their own publications or any other resource available online | Time frame, a unique database to find a great number of publications | Copyright control, quality control | An external reference library, a rating system, trust network |
| (b) News articles | User submitted news with real time posting | Time frame, possibility of every agency / organization to divulge their own news without waiting for editorial approval | High volume of information Quality, reliability of information. | Filtering information by area and or region; rating system |
| (c)Funding information | User submitted, allow agencies to announce their funding opportunities, real time posting, funding alerts | Time frame, user could receive alerts for funding as soon as they are posted; agencies do not need to rely on e-mail lists and edited content | Reliability, especially for dates and criteria | Brief description of funding with links to the agency's website; to ensure accurate information. |
| (d) Datasets | Database for datasets | Searchable, metadata required | Copyrights, liability for agencies, quality control, CoP | External reference library, optional fields, rating and metadata |
| (e) Software and models | Database and announcements for availability | Time frame, more visibility for models and software | Copyrights, quality control | External reference library, with indication for paid or free software, rating system |
| (f) Professional networking | User database with resumes, job announcements | More visibility for users and for employers | Reliability of credentials | A trust system were users can "vouch" for others |
| (g) Educational resources | Database for educational tools and methods. | Exchange of techniques, presentations, exams, materials, etc. | Reliability of information | Rating system and trust network |
| (h) Communications | Embedded chat, conference calls, forum | Instant access to colleagues when online. | Unwanted contacts, spam | User can control if he/she is shown online and from whom she/he wants to receive calls/material |
| (I) Collaboration | Online work processor and other collaboration documents / tools | Can be edited by more than one person at the same time while keeping track of revisions and back-ups | Control, very complex | Several free solutions that can be integrated |
| (j) Public perception | Integrated forum, public educational resources, discussion tools | Two way communication, yet informal | Posting control and moderation made more difficult, levels of complexity | Community filtering, designated areas for non-technical information |


Table 3.3 - Common activities for use and exchanging information within the Water Resources community and suggested improvements.

3.2 Phase II – Development and Application of the Exploratory Questionnaire

The goal for the exploratory questionnaire was to identify what kind of knowledge the community was interested in sharing as well as the various interests of different groups of organizations on their need and use of information.

The first part of the questionnaire was built in order to identify these different groups, with questions about their country of origin, type of organization, main focus, and position of the respondent within the organization (Fig. 3.2). The second part had specific questions about how they thought the reliability of the information could be assessed, what resources they would find useful, what information they would be willing to share, and how the community could self moderate (Fig. 3.3, 3.4 and 3.5).

[Exit this survey](#)



Water Quality Indicators Network

1. WQIN Survey -

We are going to ask you just a few questions about:
Where and what do you work on.
How would you use the Network.

1. Demographics:

Select...

Select Your Country

2. Organization Type:

Education Government (Federal) Private Company
 Government (local) Non-profit Other
 Government (State) Private Practice

Name of Organization (optional):

3. What is the main focus of your organization, as it relates to Water Quality? Check all that apply.

Citizen group High-ED Research
 Consulting Laboratory Stakeholder
 Development Monitoring Utilities
 Education Planning Vendor
 Enforcement Regulation

Other (please specify)

Figure 3.2: Exploratory Questionnaire, First Part.

4. What is your main function on the organization?

Executive Researcher Planner
 Middle Management Professor Lab Technician
 Engineer Student Operator
 Scientist Educator

Other (please specify)

5. Do you participate in any online groups? (Forum, e-mail lists, etc.)

Yes, I subscribe and frequently contribute
 Yes, I subscribe and sometimes contribute
 Yes, I subscribe but do not contribute
 No

6. How would you like an online network to better assess the confidence level or the reliability of the information posted by a user? Please assign each factor a level of importance.

| | not important | somewhat important | important | very important |
|-----------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Author's number of contributions | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Rating of previous contributions | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Author's seniority on the Network | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Author's institution | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Author's credentials | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Other (please specify) | | | | |

Figure 3.3: Exploratory Questionnaire, Second Part.

7. In order to promote the exchange of information and collaboration between peers, what features and resources do you think would be useful in a water quality indicators network and how would your organization use them? (check all that apply).

| | would contribute frequently | would post/sometimes contribute | would check the information frequently | would use the information sometimes | would comment or rate the information frequently | would comment or rate the information sometimes | would probably not contribute or use the feature | Don't know |
|--|-----------------------------|---------------------------------|--|-------------------------------------|--|---|--|--------------------------|
| News articles and comments | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Conferences/ Events/ Announcements | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Funding Opportunities | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Job Announcements | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Raw Data Sharing | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Organized Data Sharing | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Water Quality Assessments / Reports | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Forum / Threaded Discussion | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Publications viewing and downloads | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Model Publication /Sharing | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Images Database | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Laws and Regulation Section | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Users database / Profiles/ Resume | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Trust or Confidence Levels for Information | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Ability to select specific topics and/or regions of interest | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Collaborative Article / Project tools | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Integrated Chat/ Conference Call | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| RSS feed see definition in new window | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Figure 3.4: Exploratory Questionnaire, Second Part (cont.).

8. Which do you think is the best way to manage the information on the Network and control inappropriate (out of topic, spam) in this kind of online community?

The users would flag inappropriate content and after a certain number of flags, the post would be removed
 One or several users would be chosen to moderate postings and remove inappropriate content
 Users would flag content, but a few moderators would check the postings and arbitrate disputes
 Other (please specify)

9. Should anonymous posts be allowed ?

Yes
 No
 Not sure
 Other (please specify)

10. Can we contact you? Your e-mail address would only be used to send you a few follow up questions, if necessary. We will not share your e-mail with absolutely anyone else, no exceptions.

Yes
 No
 e-mail address:

11. If you have any other comment or suggestion, please let us know (Additionally, comments may be sent to wqin.email@gmail.com):

Figure 3.5: Exploratory Questionnaire, Second Part (cont.).

The questionnaire was then posted to water quality communities as a case study in order to determine their use of online resources. The water groups that received the questionnaire are listed in Table 3.3. The reason for choosing these groups was that they already have some online interaction and are already familiar with some of the web resources. Although some of

these Water groups have a broader interest than just water quality, the people expected to answer were the ones who either concentrate on the subject or have a special interest in the technology itself.

| Water group | Note |
|------------------------------|---|
| Big Thompson Watershed Forum | Questionnaire was posted to board of directors |
| Colorado Watershed Assembly | Questionnaire was sent in their weekly newsletter |
| ABRH-Gestão | Questionnaire was posted to the list |
| Water Forum | Questionnaire was posted to the list |

Table 3.4 Water groups receiving the questionnaire

The information obtained by the responses to the questionnaire and the analysis of tools was classified and organized in order to allow a qualitative evaluation of these systems. The complete set of graphical results is presented in appendix I.

There were 67 valid responses to the questionnaire, with a good distribution of demographics and different areas of activities. Responses came from 12 countries and represented the following distribution of organizational type: educational (46%), governmental (37%), nonprofit (10%), private and other organizations (5%). Of these respondents, less than 10% do not participate in some kind of online forum.

3.2.1 Analysis of the Responses

The information obtained by the responses can be divided into three categories: usage and contribution of information, factors to consider when rating the information posted, and ways to moderate postings and control improper use of the network.

The features proposed on the questionnaire were ranked according to the response in usage of the information (Fig. 3.6), contribution of information (Fig. 3.7) and both criteria

combined (Fig. 3.8).

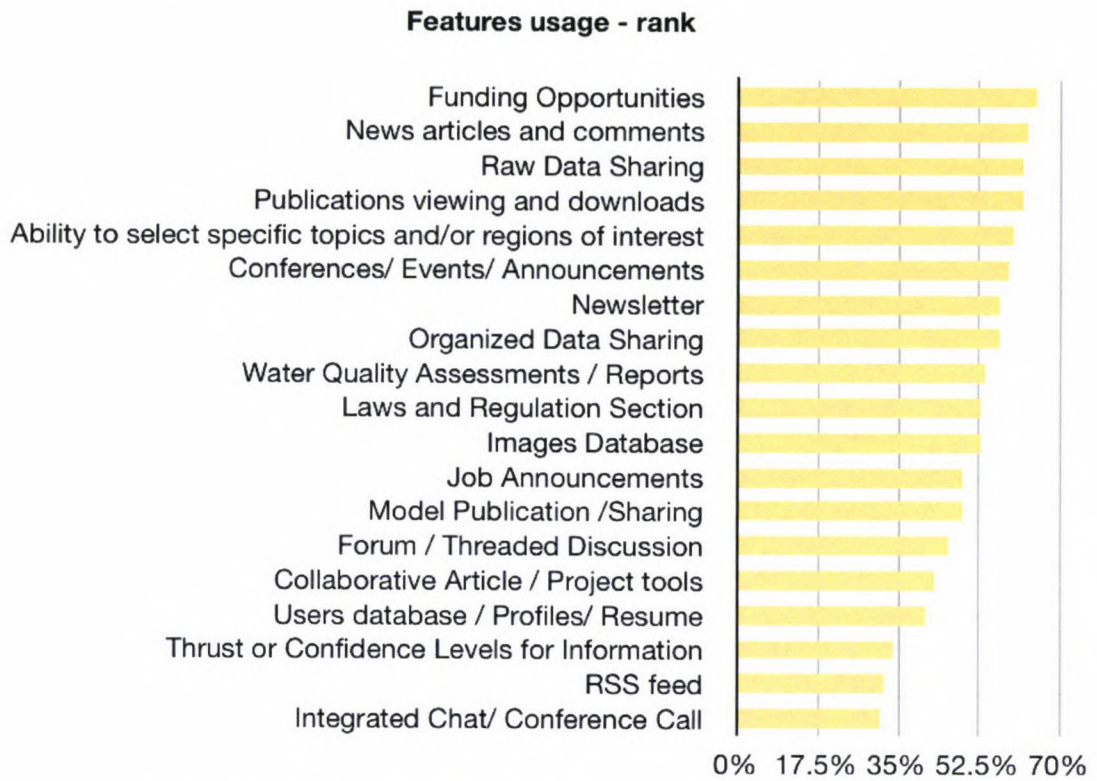


Figure3.6: Rank of Usage of Information.

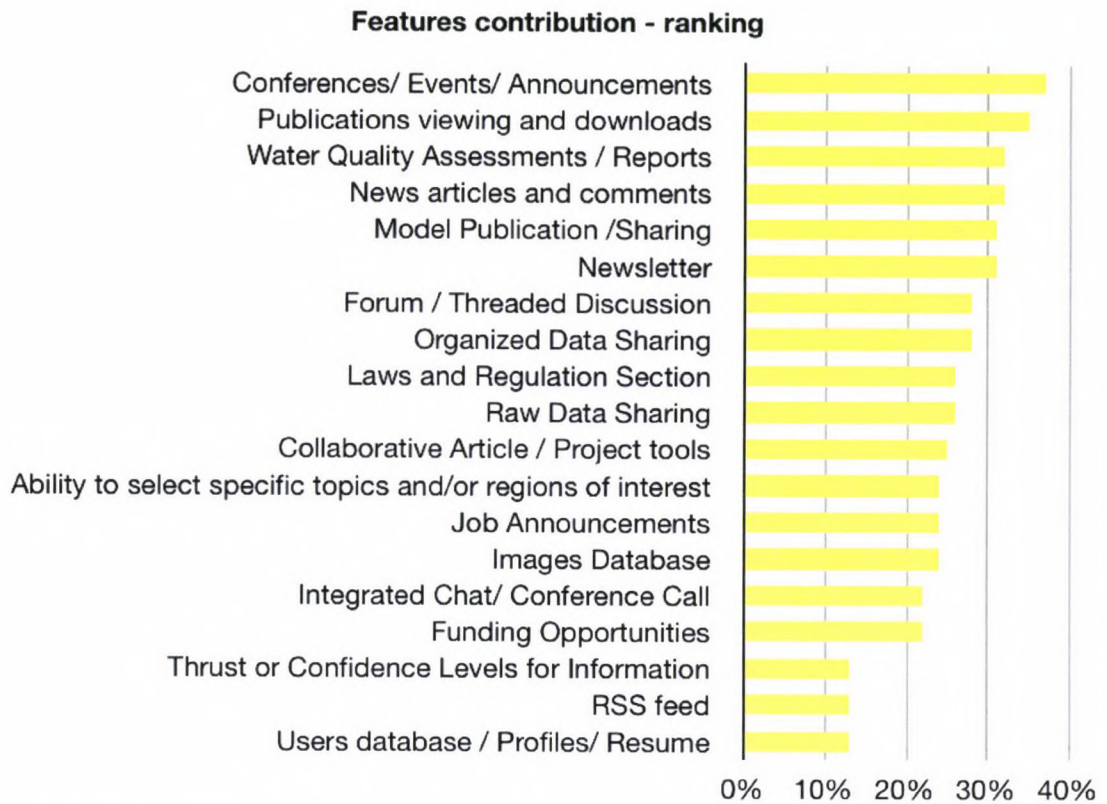


Figure 3.7: Contributions Rank

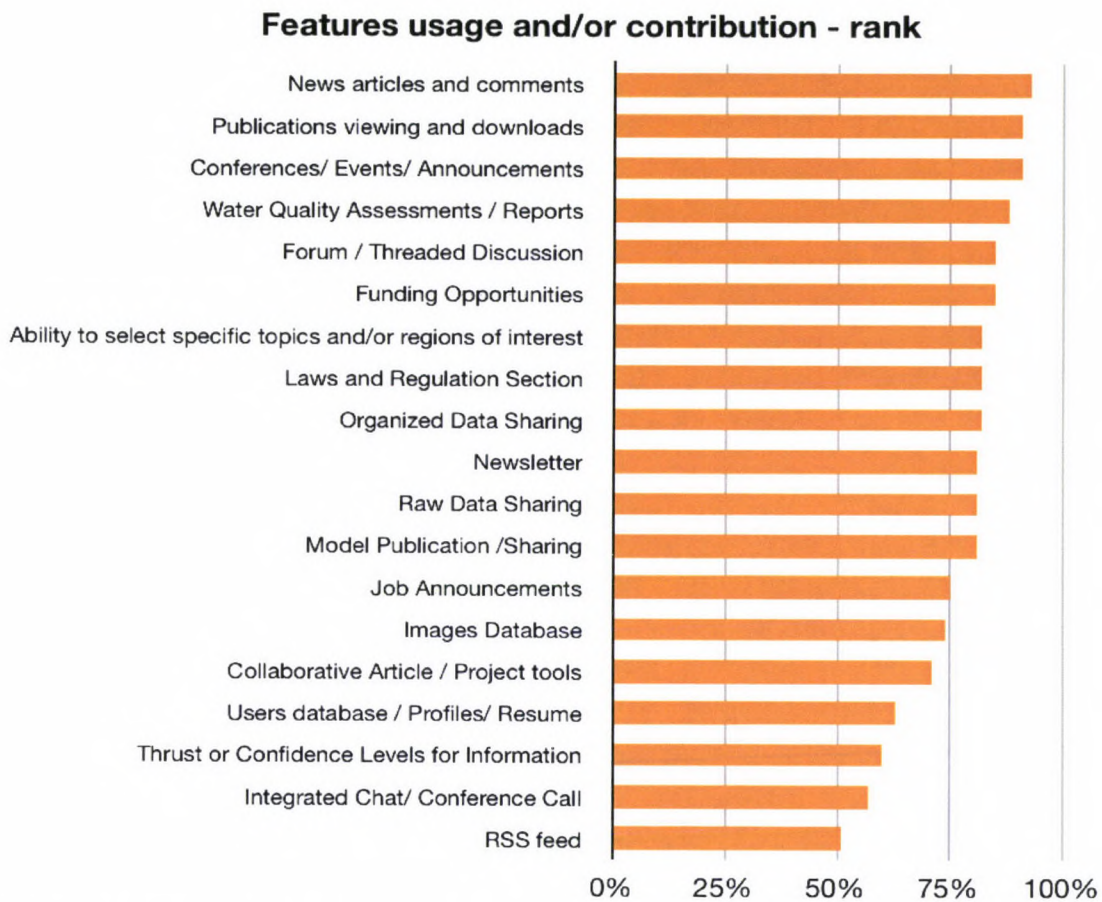


Figure 3.8: Rank for Usage and/or Contribution.

When asked about the tools and information on the network, different types of organizations indicate a significant variation in their use (Fig. 3.9 and 3.10). As expected, government organizations would be a major source of information. Education and research institutions are both providers and users of information, while other groups indicate more usage than contribution. But it is important to note that for every feature presented, the majority of the respondents said they would either contribute to the feature and/or use the information available. Almost every respondent indicated that they could contribute to the network at some point (Fig. 3.11).

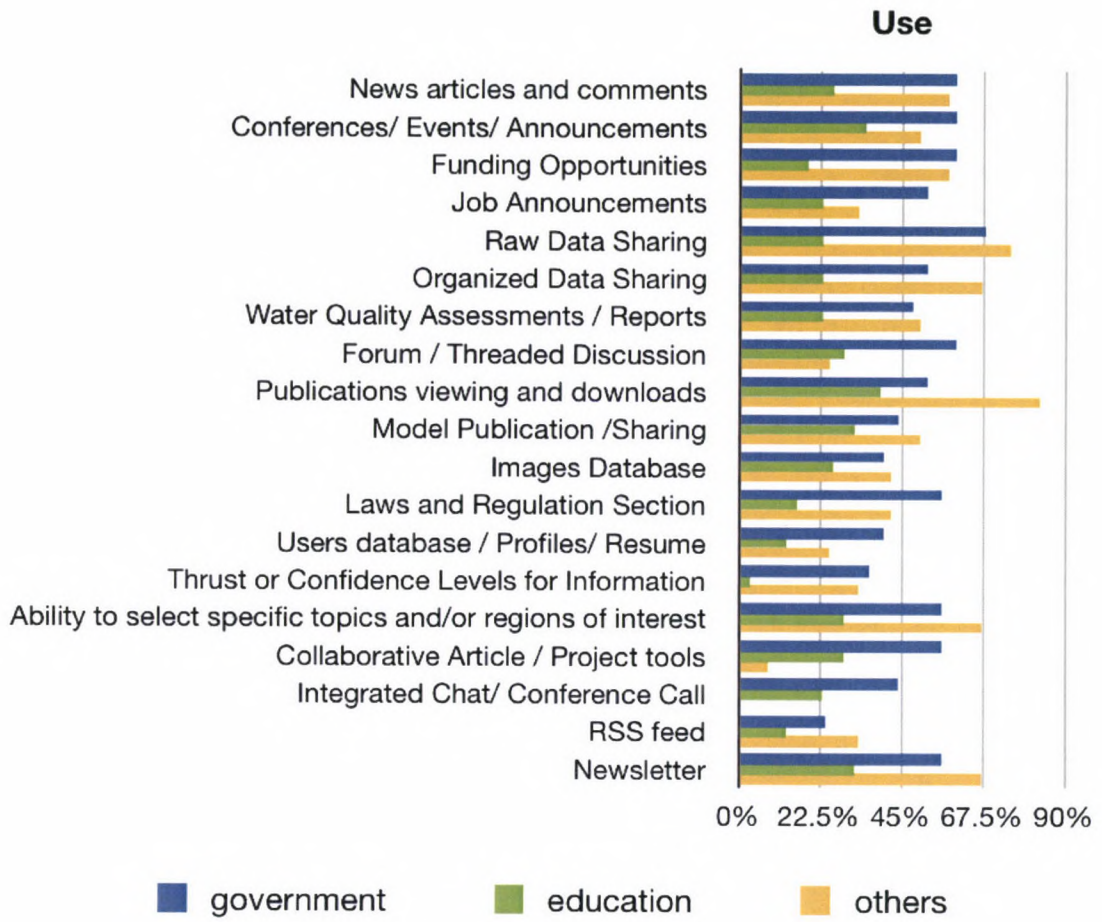


Figure 3.9 - Usage by type of Organization.

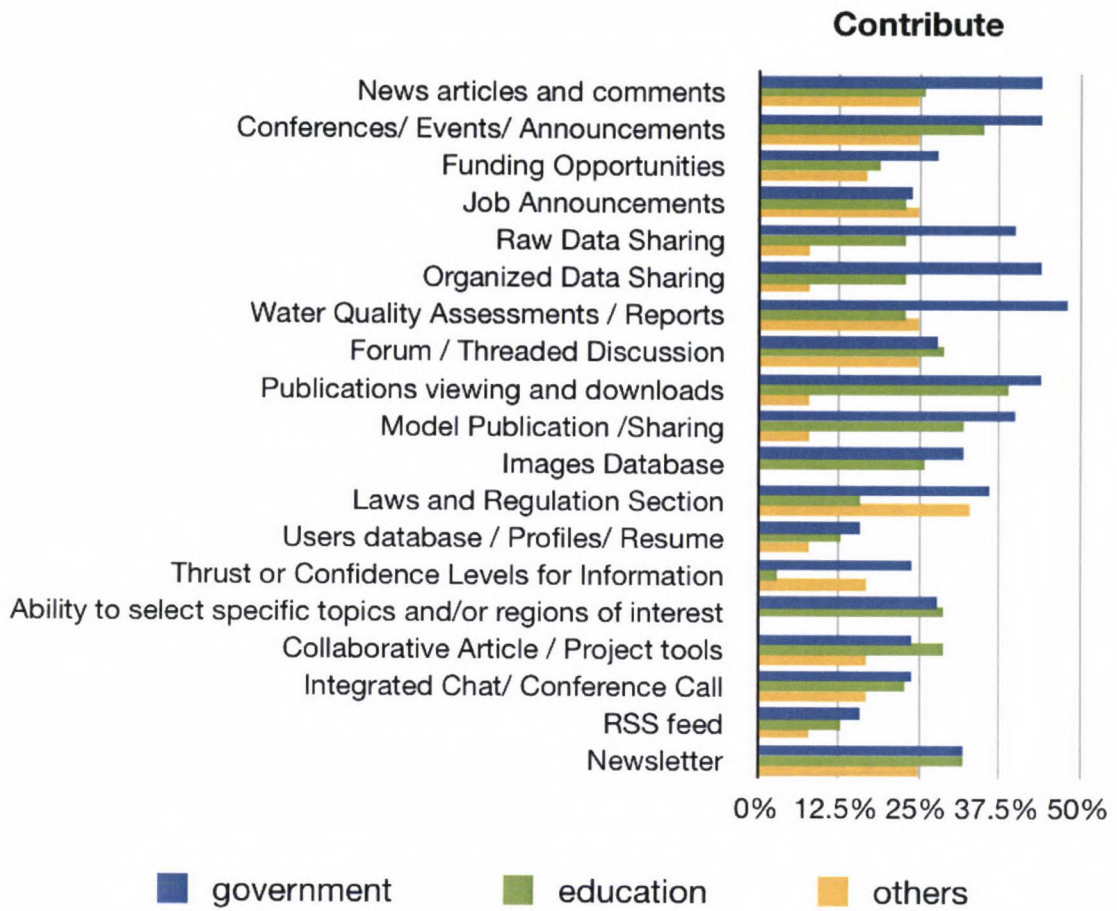


Figure 3.10 -Contributions by type of Organization.

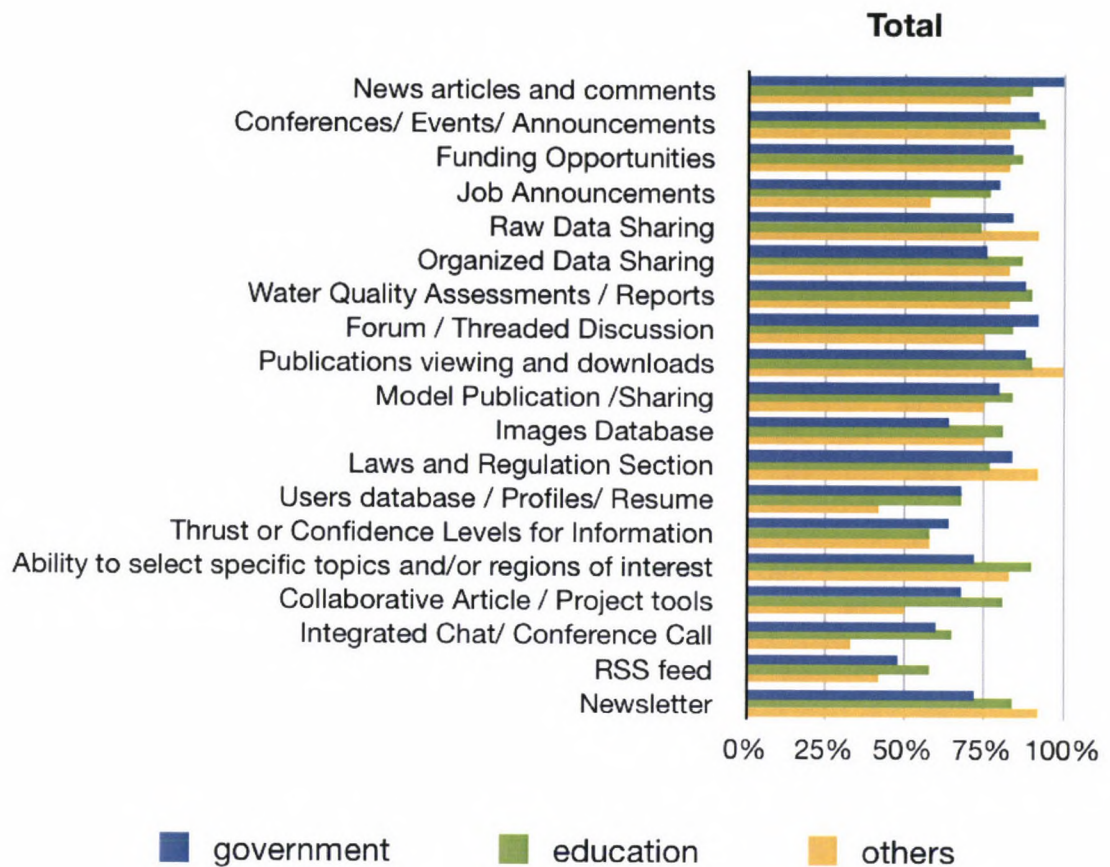


Figure 3.11 -Total Usage by type of Organization.

Respondents said that the most important factors when assessing the confidence level of each piece of information should be the author's credentials and the author's institution, indicating that the usage of a trust network would be desirable. Also, the ratings of previous contributions was considered important. These responses indicate that a rating system for postings, something that has become somewhat common for user generated content and has been proven effective to sort high volumes of data, would be desirable. These results will be particularly useful for the construction of the collaborative filtering and the web of trust. Figure 3.12 shows the results for the reliability question.

| | Author's Number of Contribution | Ratings of Previous Contribution | Author's Seniority on the Network | Author's Institution | Author's Credentials |
|---------------------------|--|---|--|---------------------------------|---------------------------------|
| Not Important | 22.10% | 2.90% | 23.50% | 5.90% | 1.50% |
| Somewhat Important | 45.60% | 27.90% | 45.60% | 30.90% | 25.00% |
| Important | 27.90% | 44.10% | 25.00% | 36.80% | 32.40% |
| Very Important | 2.90% | 20.60% | 2.90% | 25.00% | 39.70% |

Figure 3.12 - How to assess the confidence level for the information.

Finally, the questionnaire asked about moderation of postings within the community. One great problem of online communities is that anonymity sometimes allows for bad behavior. Spam is also a problem, and the majority of the respondents indicated that anonymous posts should not be allowed.

Moderation in this kind of community is becoming more difficult, so the trend is to allow the community to flag posts that are inappropriate, having a few moderators chosen to resolve conflicts. The respondents seem to agree with the trend, as shown in Fig. 3.12.

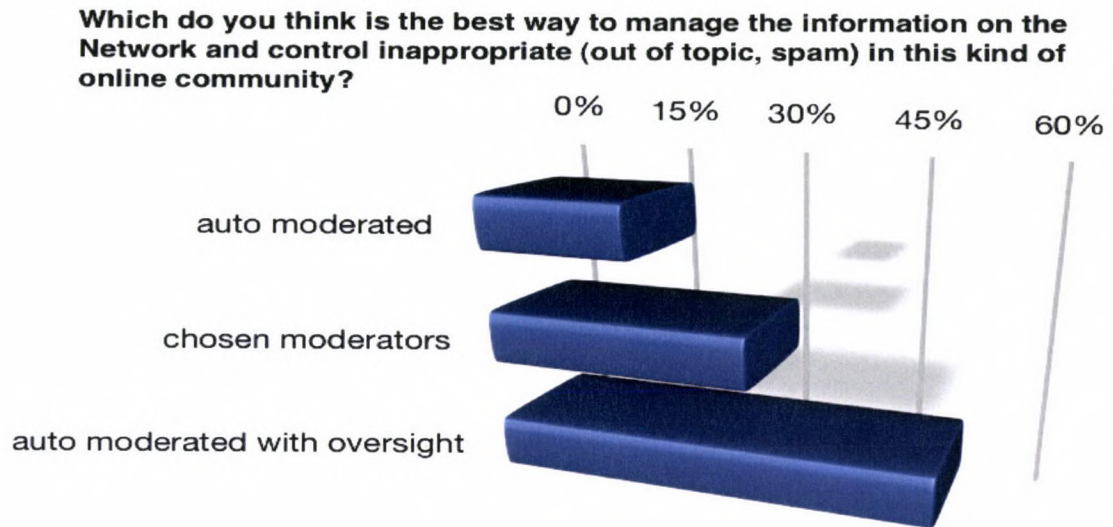


Figure 3.13 - Moderation of the Community

3.2.2 Conclusions from the Search and Questionnaire Responses

The search for methods and tools for online collaboration provided a broad view of what is available today for general communities and what has already been explored by water resources groups. The main observation from the search is that while there is a diverse range of tools for user participation available on the web, and these types of groups have been thriving in several areas, the water resources community is still very much relying on e-mail lists and static web pages for information exchange.

The answers from the questionnaire show that there is a need for greater interaction. Most, if not all, of the suggested features were well received, and the responses indicate a high demand for them. The possibility of adding content empowers the user so that they are more likely to participate when they have a real time system that does not depend on editorial approval.

The results also show that respondents are willing to share and contribute information to

the network, and all groups have, at different levels, indicated that the suggested content would be populated and used by distinct groups of users. Respondents working in government and education have indicated a high level of contributions for almost all suggested items of content. Fig. 3.13 shows how major groups, government, education and others (mostly private consultants and professionals) intend to use or contribute information. Since all respondents have indicated some level of contribution and usage of the information and features proposed, the analysis indicates that the initial proposed framework is viable.

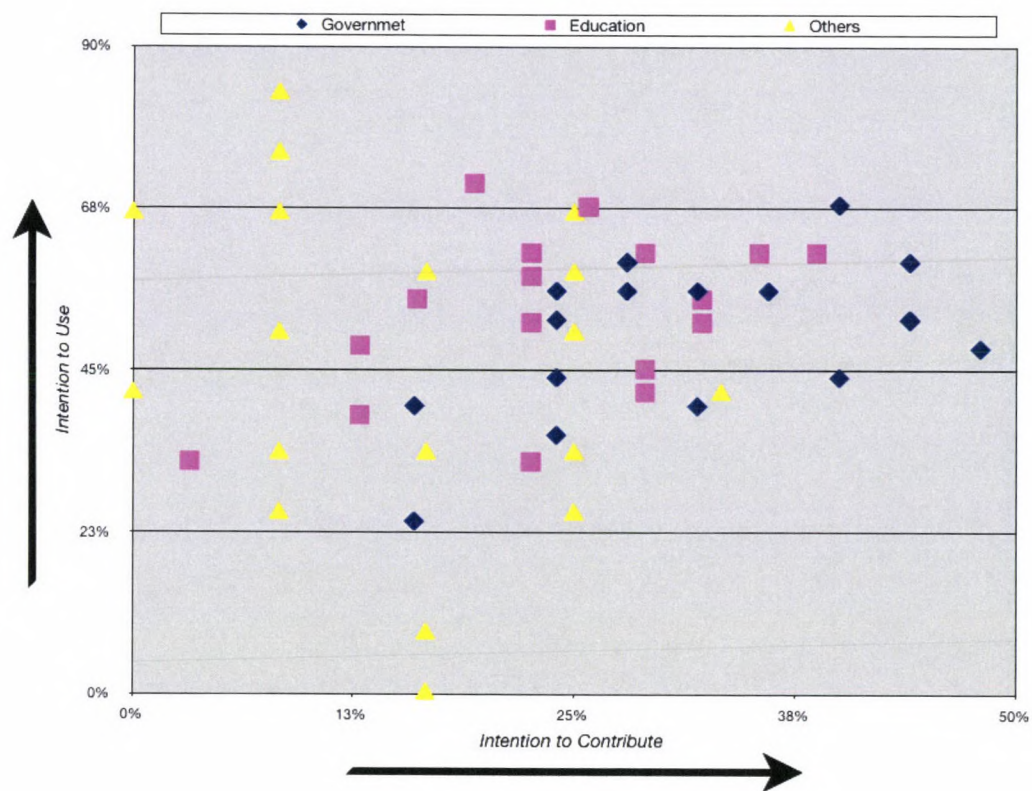


Figure 3.14: Intention to make contributions or use items of information suggested on the questionnaire.

Based on the results of the search and the questionnaire, the following aspects were

identified as the main guidelines for the Water Quality Knowledge and Information Network.

a. Follow the demand: The community should guide the construction of the network; priority should be given to features identified in the questionnaire as being most useful. Also, choosing some of the most popular features will boost the membership; the early adopters can then be used as an “expert panel” to help to improve and grow the network.

b. Reliability is essential: The road to success passes through the user's confidence of the information. A combination of a trust network, where users can “declare their confidence” in others and a rating system for postings should be able to achieve such a goal.

c. Keep it clean: A flag system for quickly identifying “out of topic” posts and spam can keep the network clean of unwanted material. A few moderators can help to resolve possible conflicts as they arise.

d. Configurable is better: While users of e-mail groups have to deal with a large volume of information they do not need, the community filtering system, where users can select their sources, get recommendations based on previous readings, ratings, and peers, by topic, region, or other criteria should keep users interested instead of overwhelmed.

Fig. 3.14 represents a general concept for the system. It highlights the main groups of users and contributors of content, the system interface, and the aspect of continuous and dynamic flow of information. The framework also represents the collaborative filtering and trust network at the heart of the process. This will allow the collaborative building of the network and allow users to have confidence in the system.



Figure 3.15: Collaborative Network Framework

3.3 Phase III – Reference Implementation

In order to further examine the potential of the proposed network, a reference implementation was developed. The system for the network has three basic functions: the database, the collaboration tools, and the user interface. While the database and applications are the reason for the community to exist, the interface plays a crucial part. Since the interface will provide access to the information, it needs to be very well organized so its use will be as intuitive as possible.

Using the guidelines identified in chapter 3.2, a few features were selected for the reference implementation. The choice was based on factors such as innovation, preferred features identified on the questionnaire and feasibility of development. Table 3.4 shows the identified priorities:

| Feature | Description |
|--|---|
| Announcements | Any short, time sensitive piece of news. |
| Events Calendar | Conferences, Meetings, etc. |
| Forum | Communication tool. Threaded discussion. |
| Images Gallery | A database to share water related images. |
| Jobs & Funding | Source for grants and work opportunities |
| News | Any news article that has been published. |
| Publications, Models, and other References | Also includes: educational resources, data, reports, etc. |
| Users Database | So users can communicate. Privacy levels can be set. |
| Water Quality Projects and Programs Database | Description and links to projects and programs worldwide. |

Table 3.5 Selected basic features for the Reference Implementation

Although the base technology for the network is beyond the scope of this research, it is important to note that the use of a Content Management System (CMS) was selected so the network could be developed quickly. The open source CMS DRUPAL was selected as the base for development. A CMS is a software package that facilitates the management of information and content. In DRUPAL's case, it provides built-in functionality, such as user accounts, forum and administration, add-ons modules, such as news blogs, and rating systems, as well as the possibility of self-developed modules, when none of the existing ones will satisfy the need. The development, building, and coding of the system was made in collaboration with a Computer Science professional. A description of the system's technical specifications for the Reference Implementation (WQIN) is presented in appendix II.

The development and debugging was completed after nine months of work. The network is live online under the url: <http://www.wqin.org>.

3.3.1 WQIN

WQIN is the reference implementation for a Collaborative Water Quality Knowledge and Information Network. Its goal is to provide and to evaluate the basic tools for this new and dynamic way to exchange information. The system is completely open, meaning users can not only contribute information on Water Quality but can also suggest and even write new applications for the network itself. To address information reliability, a community filtering process was implemented, and every piece of information will be rated and linked to its source.

The network was developed based on responses from the questionnaire that was distributed to professionals from different segments of the water resources community. Below is a description of the main features and characteristics of the network.

Resources and Contributions are the main topics of the menu. Under Resources, the current types of information available are listed, such as News Articles, Forum, Indicators Database, Announcements, Calendar, Publications, Jobs and Funding Sources. An aggregation page for web feeds¹ from relevant water blogs is also included. Under Contribute, the same categories are listed so the user can submit information to any one of the topics. For instance, if a member has an agency press release to post, he or she opens the “contribute – news article” link and pastes the contents of the press release. It will be published immediately to the News Section. If the press release refers to a permanent publication or model, for instance, it can also be posted

¹ A **web feed** is a way to automatically get updated content from other sources on the web. Content providers allow clients to subscribe to feeds. An aggregation page makes content from different feed sources available in one page.

as such, so when someone in the community is searching for that, it will be listed under the appropriate category.

In an effort to broadcast the content on the site, a web feed was implemented, as well as automatic updates on Twitter when news or announcements are posted. The following snapshots (Fig. 3.16 to Fig. 3.20) from the website show some of the main Features and Resources already implemented, along with a brief description.

WQIN Water Quality Knowledge and Information Network

Search
Search this site:

Home

- News
- About WQIN
- Overview

Resources

- Announcements
- Events Calendar
- Forum
- Images Gallery
- Jobs & funding
- News Search
- Publications, Models and other References
- Users Database
- Water Quality Projects Database
- Water Blog Log

Reducing Some Water Flow Rates May Bring Environmental Gains
Tue, 01/05/2010 - 20:04 — dalcanele

Although conservationists have often concentrated on increasing water flow through ecosystems to bring about more natural conditions in altered landscapes, increasing flows can have unfavorable consequences in some situations, notably those where invasive species or pollution are problematic.
Full story at American Institute of Biological Sciences.

Source: NSF
Region: Worldwide
Average: Average: 4.11 votes
Your rating: Your rating: 4

Water - The Epic Struggle for Wealth, Power, and Civilization
Tue, 01/05/2010 - 19:46 — dalcanele

Take the WQIN feedback Survey
Let us know what you think about WQIN, it takes less than 5 min. [Click Here](#)

Subscribe:

Follow us
[twitter](#)

Announcements

Webinar: Putting Maps and Geographic Data on the Web
Jan 21, 2010

Help Select America's Top 40 Research Priorities for Conservation Policy
brief survey

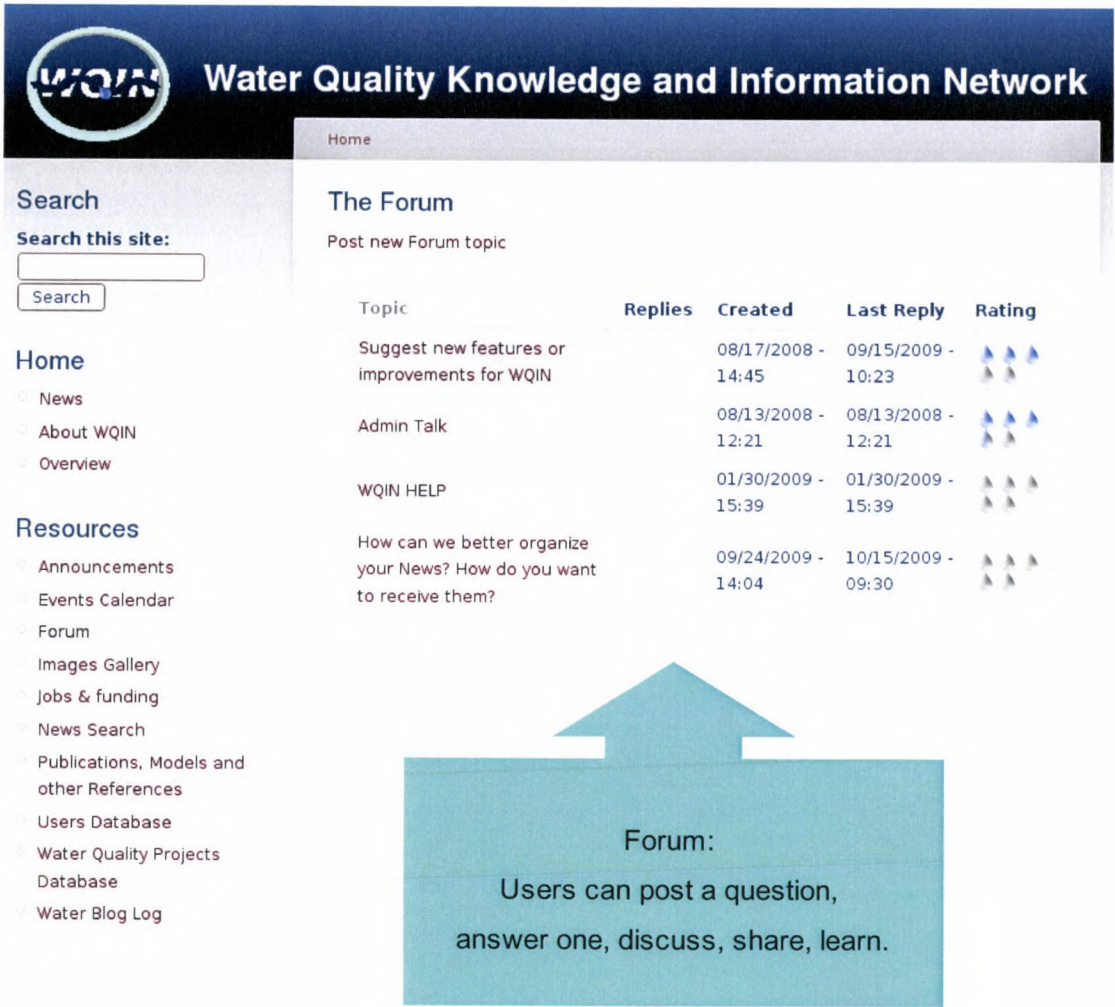
Nutrient Reduction Workshop
12th to 14th January

Diversity & Convergence: Planning in a World of Change
Anglia Ruskin University, Chelmsford, Essex 7-9 April 2010

News section: Users will post latest news and any newsworthy article related to Water Quality. A feature for leaving comments on news articles is also available on this section.

Left menu: Announcements: call for papers, courses, grants, deadline sensitive information

Figure 3.16: WQIN's Main Page



WQIN Water Quality Knowledge and Information Network

Home

Search
Search this site:

Home

- News
- About WQIN
- Overview

Resources

- Announcements
- Events Calendar
- Forum
- Images Gallery
- Jobs & funding
- News Search
- Publications, Models and other References
- Users Database
- Water Quality Projects Database
- Water Blog Log

The Forum
Post new Forum topic

| Topic | Replies | Created | Last Reply | Rating |
|--|---------|--------------------|--------------------|--------|
| Suggest new features or improvements for WQIN | | 08/17/2008 - 14:45 | 09/15/2009 - 10:23 | ▲▲▲ |
| Admin Talk | | 08/13/2008 - 12:21 | 08/13/2008 - 12:21 | ▲▲▲ |
| WQIN HELP | | 01/30/2009 - 15:39 | 01/30/2009 - 15:39 | ▲▲▲ |
| How can we better organize your News? How do you want to receive them? | | 09/24/2009 - 14:04 | 10/15/2009 - 09:30 | ▲▲▲ |

Forum:
Users can post a question, answer one, discuss, share, learn.

Figure 3.17: Forum

WQIN Water Quality Knowledge and Information Network

Home

Search
 Search this site:

Home

- News
- About WQIN
- Overview

Resources

- Announcements
- Events Calendar
- Forum
- Images Gallery
- Jobs & funding
- News Search
- Publications, Models and other References
- Users Database
- Water Quality Projects Database
- Water Blog Log

Publications, Models and other References

Resource Type

- CD/DVD/Video
- Educational Resource
- Legislation/ Regulations
- Publication (Book, Article)
- Publication (Periodical)
- Raw Data
- Organized Data
- Software/Model

Region

- Africa
- Asia
- Central America and Caribbean
- Europe
- Middle East
- North America (Canada, USA, Mexico)
- Oceania (Australia, New Zealand and South Pacific)
- South America

Keyword

Access

| Title | Region (Only shows first) | Access | Rating |
|--|---------------------------|--------|--------|
| Publication, Models and Other References: Publications, Educational Resources, Legislation Data, Reports, Software and more.... | | | |

Figure 3.18: Publications, Models and other References

WQIN Water Quality Knowledge and Information Network

Home

Search
 Search this site:

Home

- News
- About WQIN
- Overview

Resources

- Announcements
- Events Calendar
- Forum
- Images Gallery
- Jobs & funding
- News Search
- Publications, Models and other References
- Users Database
- Water Quality Projects Database
- Water Blog Log

Water Quality Projects and Programs Database
 Use CTRL key (Command on Mac) to select multiple values

Water Uses

- Agricultural
- Energy
- Environmental Protection
- Industrial
- Recreation
- Urban/Water Supply

Project Region

- Africa
- Asia
- Central America and Caribbean
- Europe
- Middle East
- North America (Canada, USA, Mexico)
- Oceania (Australia, New Zealand and South Pacific)
- South America

Category

- Biological
- Chemical
- Compliance
- Economic
- Environmental
- Physical
- Social
- Sustainability

| Rating | Title | Water Uses | Parameters | Project Region |
|--------|--|--------------|------------------------------------|--|
| | Water quality indicators in Queensland | Agricultural | Biological Chemical Physical | Oceania (Australia, New Zealand and South Pacific) |

Water Quality Projects and Programs database:
 Users can contribute some information and the project website, share experiences, and information, contact other professionals and agencies working in the same area.

Figure 3.19: Water Quality Projects and Programs

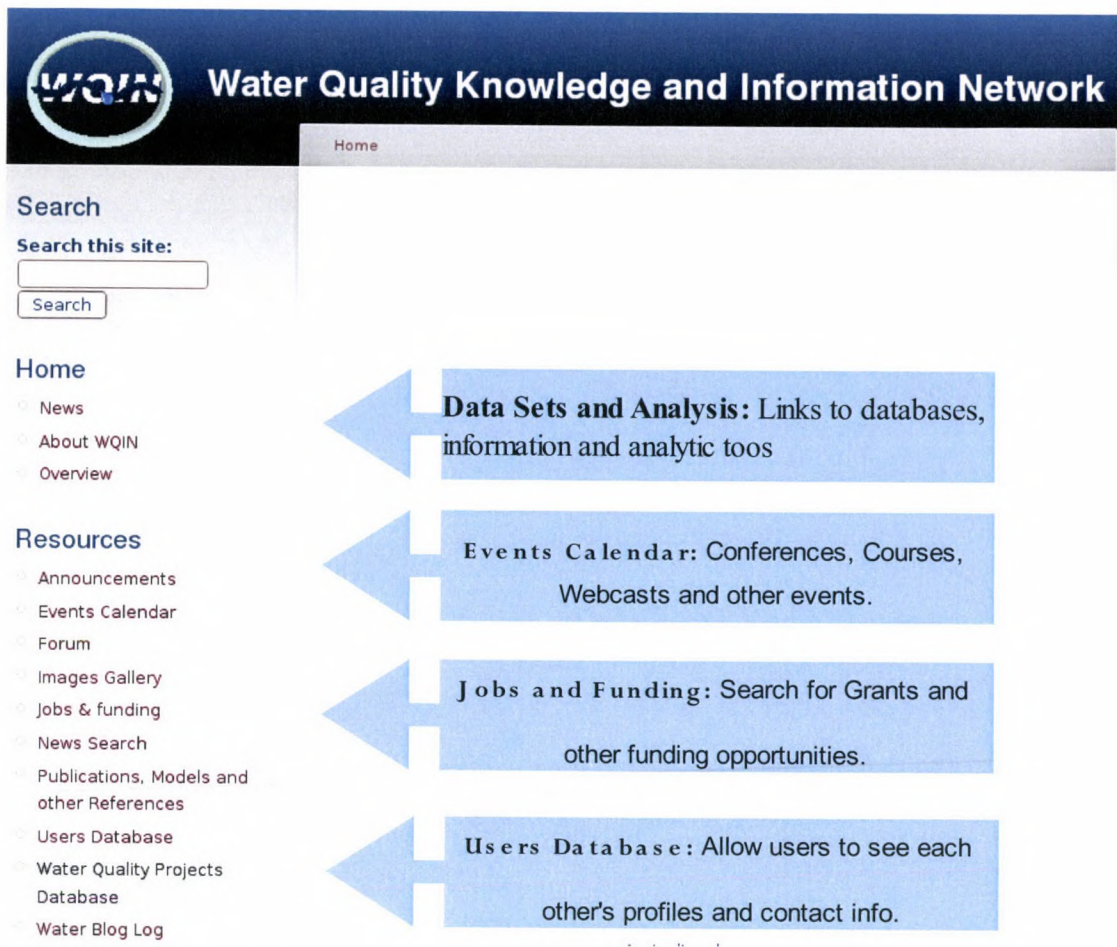


Figure 3.20: Additional Resources

The Network also features a “Relevance Rating System”, where nearly every piece of information will have a relevance level. This is the beginning of the implementation for the collaborative filtering and the trust network. It will help users to sort through the database and find reliable information and resources. It will also give users the opportunity to have their input on the content of the site, while the comment feature can be used to justify their rating as well as to add more information about the subject.

3.4 Phase IV – Beta Testing and Analysis of the Results

While the ultimate test for the success of an online community is its mainstream adoption, for this reference implementation, the expected adoption is considerably lower. The analysis of Rogers curve (Fig. 3.21) for the adoption of new technology (Rogers 1995) shows that slow adoption is to be expected in the beginning, and communities will emerge very slowly, with very weak-ties between its members (Abrams, Maloney-Krichmar, and Preece 2003). But investigations on successful and unsuccessful communities show that there is no certain formula for this process (Surry and Ely 2001).

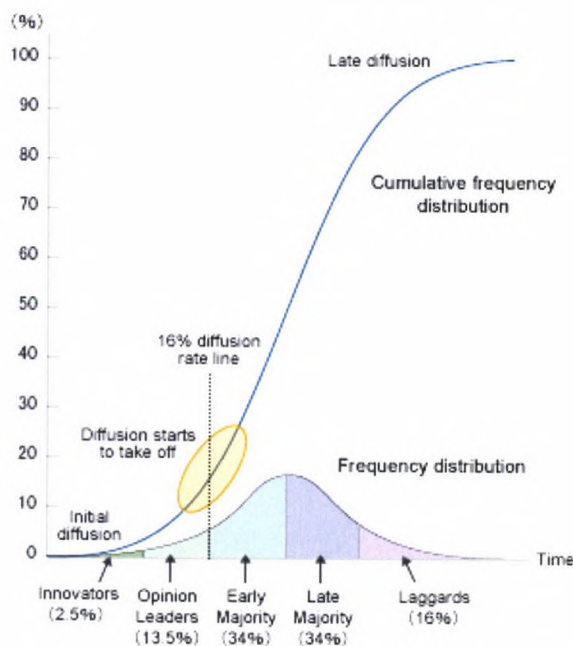


Figure 3.21: Rogers curve of new technology adoption (source: <http://www.sustain.co.uk/resource/insight-articles/the-value-chain.aspx>)

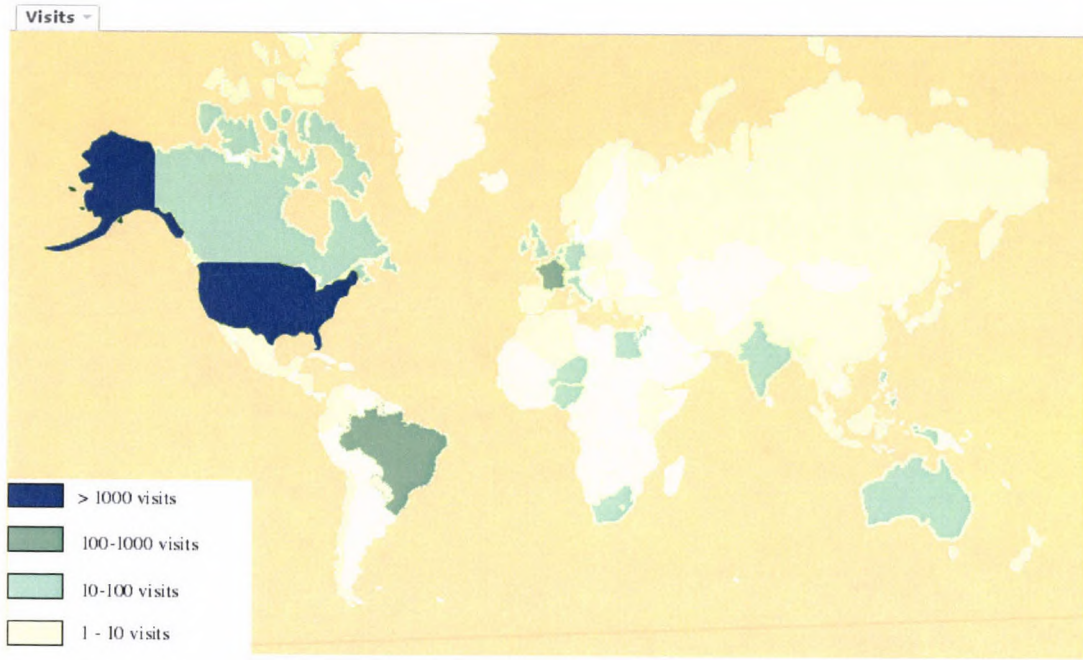
The main goals of this phase are to test the system, to bring content to the network, to market the concept, and to analyze the responses obtained.

For testing of the system, an initial population of the database was performed. The exercise was important not only for jump starting the network, but also for testing the stability of the system. Since main debugging was performed during the development, only small problems were encountered and quickly solved. The initial content was uploaded to the network with the intent to attract membership, to demonstrate how the system works, and to exemplify the format of the desirable information to be contributed.

Once the system was proven stable, the network was open to beta users anywhere. Announcements were sent via discussion lists and groups on social networks. Analytical data of the traffic on the website was collected. Site visits in the first three months were over 1300 unique visitors, with over 1000 returning visits. Visits came from more than 70 countries, but most of them were from the United States, where the site was mostly marketed. While slow adoption is expected for these kinds of networks, the release of the site for beta users resulted in a total of about 100 memberships over the period, which was very encouraging. Fig. 3.22 shows the map overlay of site visits, and Fig. 3.23 show the overview of traffic on the site, after it was announced on September 24, 2009, until December 24, 2009. Detailed information for unique visitors is included in appendix III.

Map Overlay

Sep 24, 2009 - Dec 24, 2009 ▾



2,388 visits came from 71 countries/territories

Figure 3.22: Map Overlay

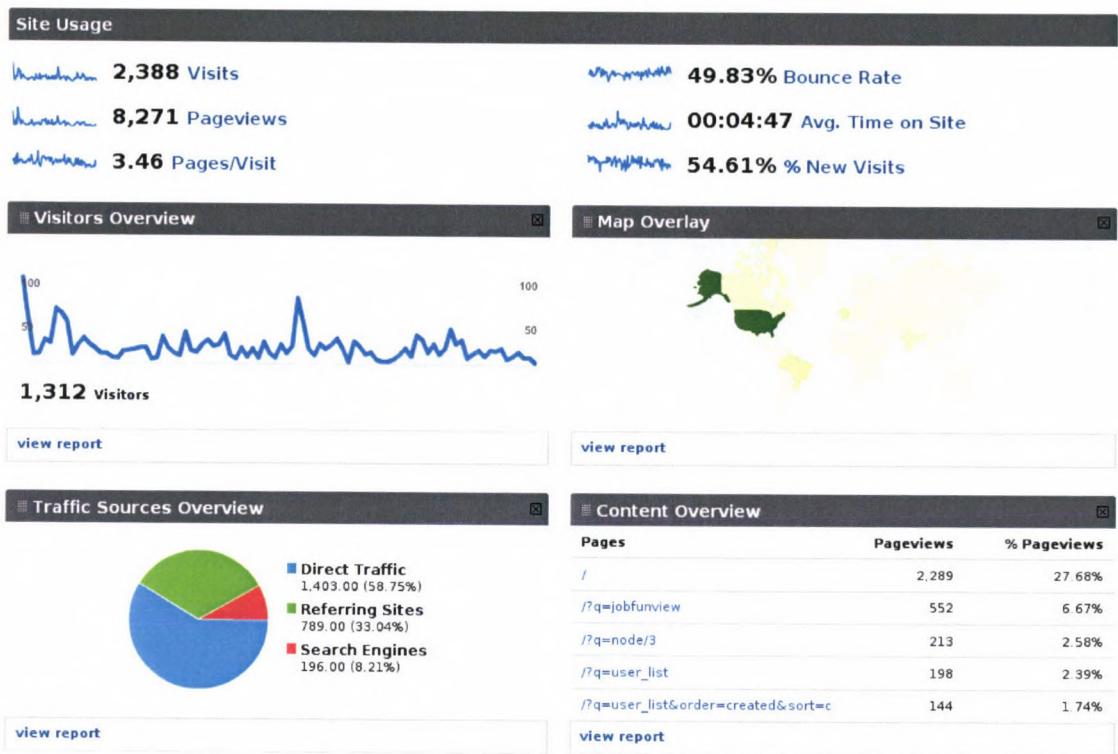


Figure 3.24: Traffic Analysis on WQIN website

While the membership and traffic results are very encouraging, the number of contributions was, not unexpectedly, low. One probable explanation for this is that most users will only contribute to a network once it becomes part of their usual sources of information. As user's confidence in the network increases, the level and number of contributions should increase as well.

A final evaluation was performed using feedback from a second questionnaire posted on the network's website. The questionnaire was designed to answer the following questions: (1) Is the concept potentially useful?; (2) Could it be widely adopted? and (3) Who would benefit from it? The questionnaire, as posted to the users, is presented in appendix IV.

The final conclusions of the study are based on the traffic on the website, the number of memberships obtained, and the final responses on the feedback questionnaire as well as on the entire experience of designing and implementing the network. The analysis also generated a number of recommendations for further improving the network. Fig. 3.25 to Fig. 3.31 show the answers obtained.

The first three questions were designed to collect data on the area of interest of respondents and their use of information. Responses to question 1 and 2 show a good distribution among interests and use of information in the field of water quality. Responses from question 3 indicate that while respondents use a variety of sources, only a few sources (23%) let them comment upon or contribute information, which are key characteristics of the proposed framework.

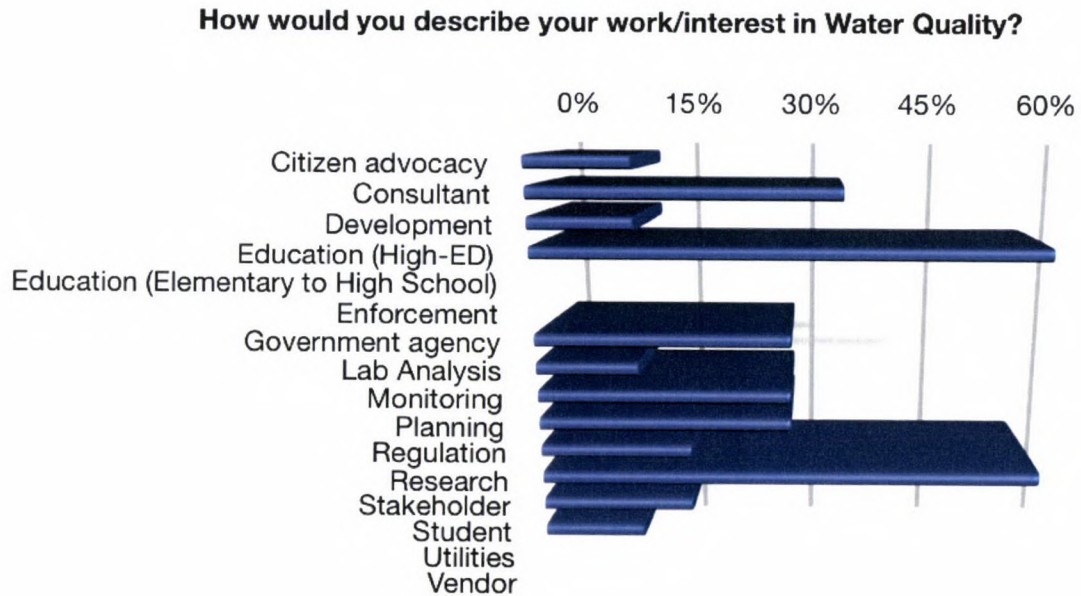


Figure 3.25: Responses from the feedback questionnaire, question 1.

What are your main three uses of Water Quality information?

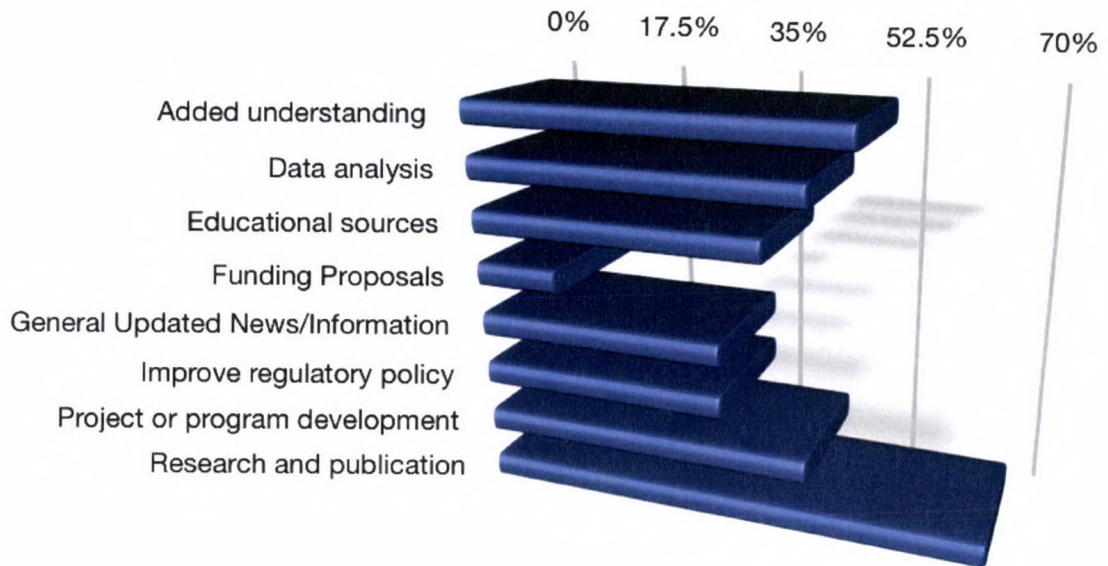


Figure 3.26: Responses from the feedback questionnaire, question 2.

How do you use online resources for publishing or getting Water Quality Information and/or participate in any online groups? (Forum, e-mail lists, etc). Check all that apply.

0% 17.5% 35% 52.5% 70%

Considering the means you know or use to exchange information on Water Quality, for each feature, **CONCEPT of WQIN is:**

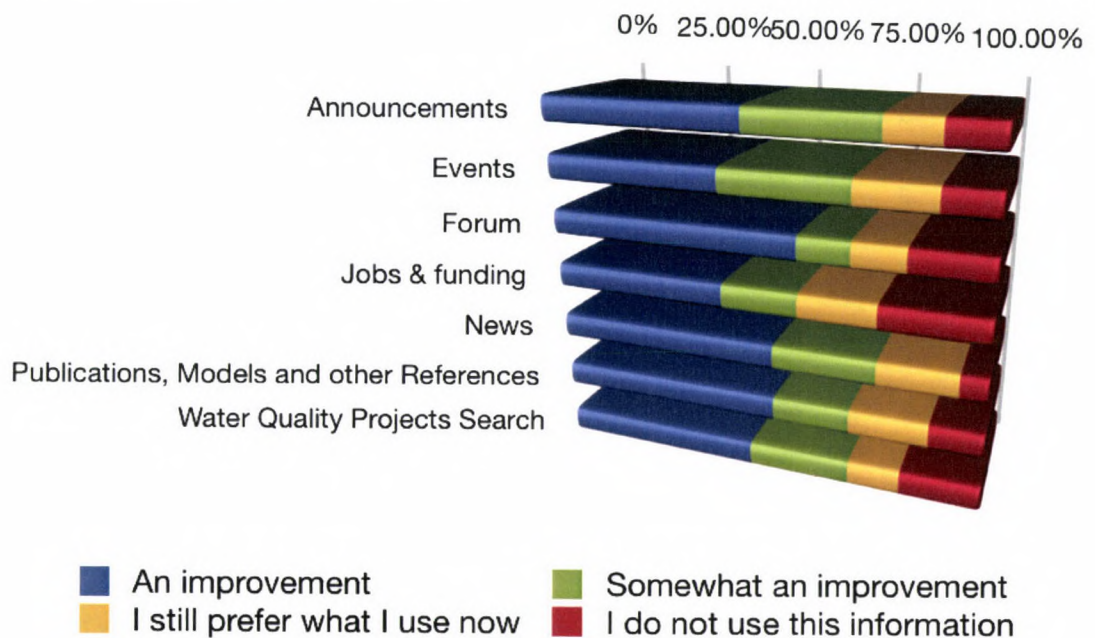


Figure 3.28: Responses from the feedback questionnaire, question 4.

What kind of organizations and professionals would benefit from the collaborative way WQIN works? Check all that apply

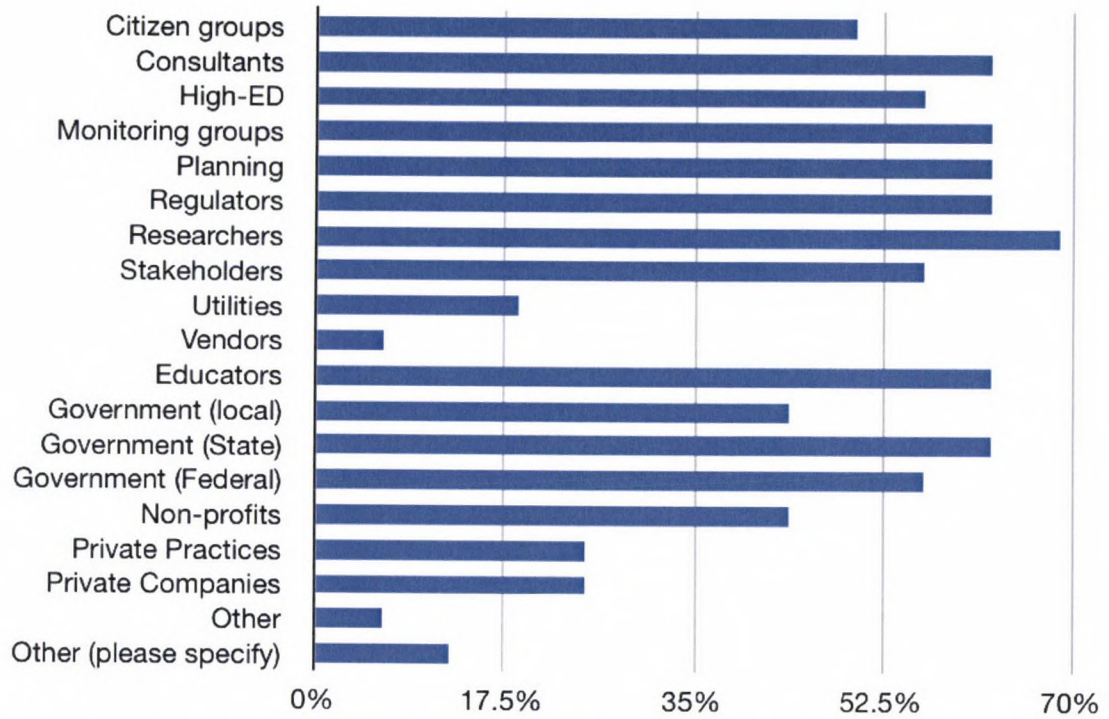


Figure 3.29: Responses from the feedback questionnaire, question 5.

Do you think WQIN's format could be adopted by the water community as a means to exchange information?

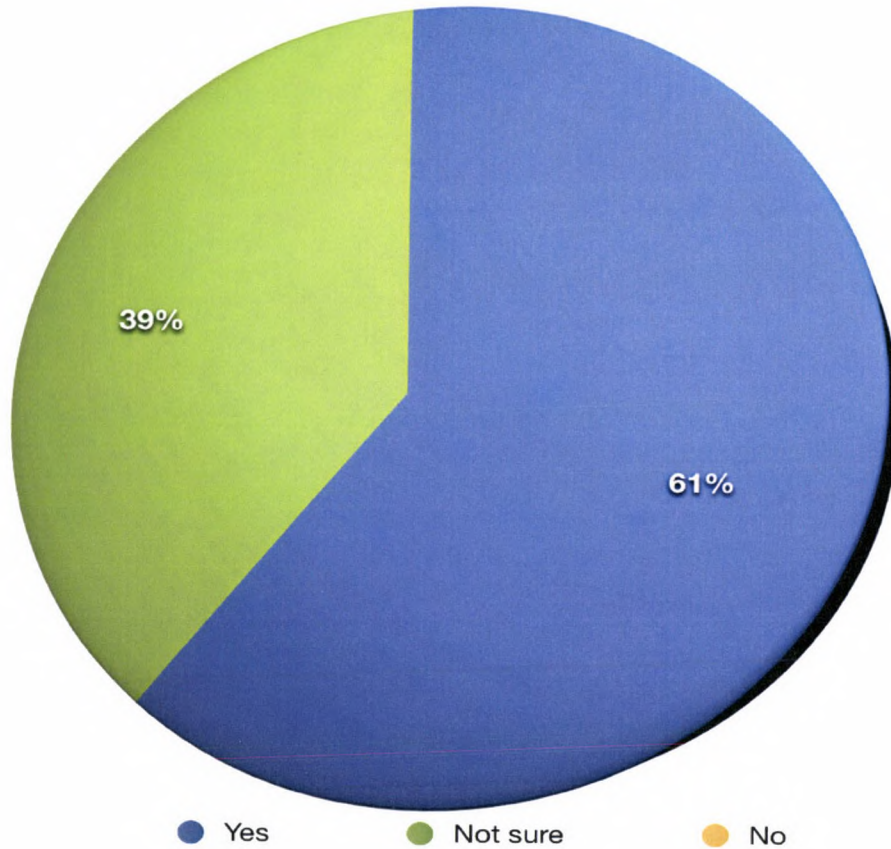


Figure 3.30: Responses from the feedback questionnaire, question 6.

Finally, question 7 asked about future development and how to improve the pilot implementation. An interesting aspect of the responses is that they confirm the demand for some of the features indicated in the responses from the first questionnaire but which were either not yet or only partially implemented, such as the trust network. Local information was also indicated to be a priority. The responses will help to guide future implementations using this framework as well as to improve WQIN.

What improvements could we make to WQIN so it would make it more widely adopted? Check all that apply.

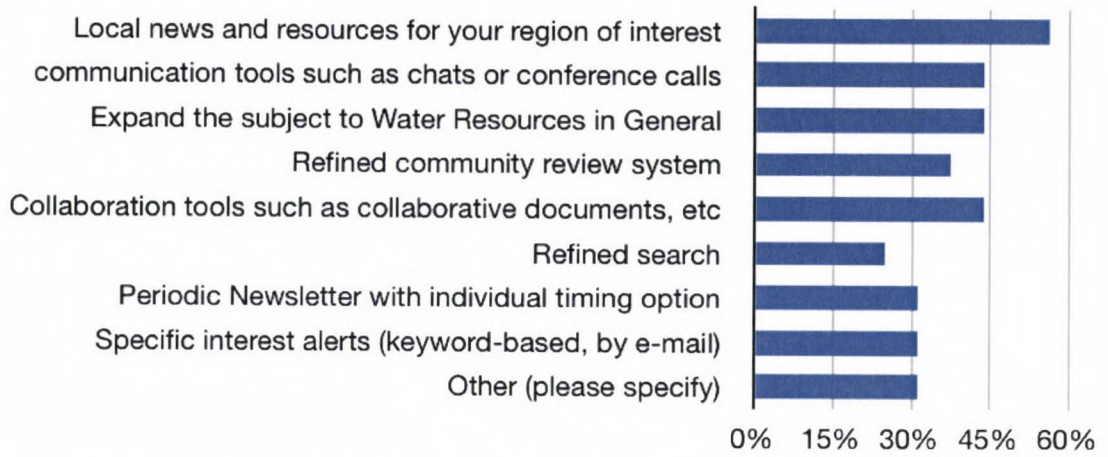


Figure 3.31: Responses from the feedback questionnaire, question 7.

4. Final Conclusions

This project proposes a new and more efficient way to achieve collaboration, knowledge exchange, and information dissemination and usage through a virtual community of practice. The general framework offers an overall concept for an open, multidisciplinary and multidirectional network. The reference implementation exemplifies the concept with an online, collaborative “Water Quality Knowledge and Information Network”, where any member can contribute a piece of news, introduce models, methodologies, or developments in the field, discuss projects and their results, resulting in a more flexible and dynamic way of sharing information and obtaining feedback.

The data collected through the questionnaire supports the concept of the framework by showing that a significant number of community members agree that such a design would improve their access to information and allow for a better exchange of knowledge; a significant number of community members agrees that the reference implementation helps solve some of the problems identified by the research.

There are several benefits a framework of collaboration could bring to the different players of Water Quality Management. Some of these benefits are identified below.

All groups:

- Allow for one stop shopping for a number of different resources;
- Disseminate information quickly;
- Provide a forum to raise water quality issues with local and state agencies;

- Reduce time-consuming information gathering, links to direct channels and tracing information to the source;

- Enhance the participatory process;

- Facilitate a forum for effectively communicating water quality issues.

Organizations, agencies or companies:

- Increase communication with public, donors, or stakeholders;

- Establish partnerships with similar entities for cost effectiveness;

- Adopt tested practices using experiences from others;

- Increase access to information in the decision-making process;

- Provide more and better information, leading to faster and more accurate assessments and decisions;

- Eliminate duplicate work;

- Identify information and knowledge need;

- Identify experts and professionals to recruit;

- Evaluate stakeholder and public perceptions in order to increase communication and establish priorities;

- Find resources and funding;

- Raise awareness support for local, regional, and global water quality efforts;

- Decrease uncertainty while designing and planning projects and programs.

Consultants and other professionals, individually:

- Identify possible partners;
- Provide opportunities to help others and establish relationships, networking;
- Find professional advancement and employment opportunities;
- Showcase projects.

Public and citizen groups:

- Allow better access to information;
- Provide better quality of reporting directed to the public;
- Increase opportunities to participate on the discussion and the decisions;
- Create opportunities to congregate, communicate and to forge alliances.

Some of the challenges when designing and administering the network would include:

- Determine the adequate technology and resources for the expected level of members' expertise;
- Find an acceptable balance between security and free flow of information;
- Define the control of copyrighted materials;
- Maintain the Network up to date;
- Bring representation for every player in order to have balanced discussions;
- Promote and facilitate collaboration and communication;
- Follow suggestions for new features or to improve existing ones;
- Identify and delete out of topic posts quickly;
- Keep the interest levels and the relevance of the information posted;

- Maintain professional level discourse;
- Keep the independence of network while still making it financially viable. The sources of financial support cannot interfere with the freedom of discourse nor with the topics covered and highlighted.

Some of the ways the network could be improved were identified using the data from the questionnaire as well as the results from the beta testing. Many of these improvements, while identified a priori, require a significantly larger effort to implement so were not selected for the beta build. Others were results from the comments received from beta users. In both cases, the following features could further enhance usability of the network:

- Integrate with communication tools, allowing chat and teleconferencing should provide members of the network a better level of communication;
- Develop a better repository and interface for Water Quality Data links;
- Provide further layers of filtering to provide for state and local levels to be added to the regions' capability;
- Increase the customization, so users can chose what kind of information they want to see every time they visit the site.
- Implement a full collaborative filtering;
- Implement a trust network score and customized queries for filtering information.
- Improve methods of integration with existing sources of information and the use of automated feeds may be beneficial.

The project demonstrates the potential of a virtual Water Quality community and suggests

applications that could lower costs, shorten time, and promote communication among peers and the public. It also demonstrates that data, information, and knowledge can be generated and used anywhere inside the community. A digital network will never be able to capture all of the information generated, but it can and should facilitate the access to knowledge and information. As it grows, such a network is expected to improve the way information and knowledge is disseminated, used, and interpreted.

The proposed framework was designed to be adaptable and scalable. The use of open source technology can cut costs and would also guarantee the continuity, independence, and compatibility of the database and modules within the foreseeable future. As the information on the network is shared, so will be the technology behind it. Improvements of one system can immediately be made available for similar implementations.

The framework and the technology identified during this project could be used to implement a community based system for a specific watershed or for solving a specific problem. The system could help to improve the participatory processes being proposed and implemented around the world. While every country, if not region, has implemented different management systems, the trend toward decentralized management leads to decentralized decisions. The possibility of sharing content and different views and the potential to help stakeholders to construct their perception about a complex problem with many variables may lead to a better and more civilized discussion and to better conclusions and decisions at the end of the process.

One example of a possible use for the framework would be a basin committee. In some countries such as France or Brazil, most decisions are made in participatory committees, with representations from stakeholders, government and the civil society. An implementation of this framework could improve the communication among the members, and increase public's access

to the information and the decisions produced by the committee. Similar groups exist in other countries, in different levels of decision making powers, could also benefit from such implementations.

The same framework could also be adapted for communities revolving around a similar set of disciplines, such as Integrated Water Resources Management or Ground Water.

Fully implemented, WQIN, or a similar project, could enhance collaboration among water managers at all levels as well as provide opportunities to learn from previous experiences. An organically grown network could have a great impact on how quickly the system would publish and manage its resources since these would be grassroots contributions emanating from the community itself, as opposed to mandated or dictated information.

5. References List

- Abras, C., Maloney-Krichmar, D., Preece, J. 2003. Evaluating an online academic community: Purpose is the key. In *Human-Computer Interaction, Theories and Practice*. Edited by C. Stephanidis & J. Jacko. (Part 1) Volume 2, 829-833. HCI International, Crete, Greece.
- Allee, V. 2000. Knowledge Networks and Communities of Practice. *OD Practitioner*, Fall/Winter 2000.
- Anderson, Faye and Greg A. Wade. 1995. The Development of the Universities Water Information Network. *Water Resources Update*. Vol. 99. pp. 30-33.
- Ardichvili, Alexander, Vaughn Page, and Tim Wentling. 2003. Motivation and barriers to participation in virtual knowledge-sharing communities of practice. *Journal of Knowledge Management*. V7.Issue 1: 64 - 77
- Augustin, Larry, Dan Bressler and Guy Smith. 2002. Accelerating software development through collaboration. International Conference on Software Engineering archive. Proceedings of the 24th International Conference on Software Engineering, Orlando, FL. 559-563
- Benos D.J., E. Bashari, J.M. Chaves , A. Gaggar, N. Kapoor, M. LaFrance, R. Mans, D. Mayhew, S. McGowan, A. Polter, Y. Qadri, S. Sarfare, K. Schultz, R. Splittgerber, J. Stephenson, C. Tower, R.G. Walton, A. Zotov. 2007. The ups and downs of peer review. *Advances in Physiology Education*. 2007 Jun; 31(2):145-52.
- Berners-Lee, Tim. 1990. Information Management: A Proposal. CERN. March 1989, May 1990
- Biswas, Asit K. 2004. Integrated Water Resources Management: A Reassessment. *Water International*, 29:2, 248- 256
- Blöch H. 1999. The European Union Water Framework Directive: Taking European Water Policy into the Next Millennium. *Water Science and Technology*. 40(10): 67-71.
- Burnham J. C. 1990. The evolution of editorial peer review. *JAMA* 263: 1323–1329.
- Chubin, Daryl E. and Hacket, Edward J. 1990. Peer Review and U.S Science Policy. Albany, NY. State University of New York Press.
- Cisler, S. 1993. Community Computer Networks: Building Electronic Green Belts. In *What Does Your Community Need?*. Edited by A. Bishop. Champaign-Urbana. Graduate School of Library and Information Science. University of Illinois.

- Citizen Media Law Project. 2008. Primer on Copyright Liability and Fair Use. [html]. Accessed 23 September 2009. Available from <http://www.citmedialaw.org/blog/2008/primer-copyright-liability-and-fair-use>
- Daniel, Stephen, James Ellis, and Tom Truscott. 1980. USENET - A General Access UNIX Network. Durham, NC: Duke University.
- Department of the Environment Australia. Water, Heritage and the Arts. [html]. Accessed on 12 August 2007. Available from <http://www.environment.gov.au>
- Dixon, J.A. and K.W. Easter. 1986. Integrated watershed management: an approach to resource management . Westview Press Publisher. Boulder, CO.
- Djordjevic, Branislav. 1993. Cybernetics in Water Resources Management. Highlands Ranch, CO. Water Resources Publications.
- Fitsik, R., Quigley, M., Strecker, E., Jones, J., Clary, J. and O'Brien , J. 2008. Managing the International BMP Database. Water Resources Impact. V10-N6. pp. 22-24
- Fontane 1999. Monitoring Water Systems: The USA Experience. In *Transboundary Water Resources in the Balkans: Initiating a Sustainable Co-operative Network*. Edited by Ganoulis, J., Irene Lyons Murphy, and Mitja Brilly. Netherlands. NATO Science series . Kluwer Academic Publishers.
- Ganoulis, J. 1999. Sharing Transboundary Water Resources: The role of Regional Partnerships in the Balkans. In *Transboundary Water Resources in the Balkans: Initiating a Sustainable Co-operative Network*. Edited by Ganoulis, J., Irene Lyons Murphy, and Mitja Brilly. Netherlands. NATO Science series . Kluwer Academic Publishers.
- GAO 1995. EPA's Problems with Collection and Management of Scientific Data and Its Efforts To Address Them. GAO/T-RCED-95-174
- Global Water Partnership. 2000. "Integrated Water Resources Management." TAC Background Papers No. 4. Stockholm: GWP Secretariat.
- Golder, S. A. 2003. A Typology of Social Roles in Usenet. Unpublished Senior Honors, Harvard University, Cambridge, MA.
- Gowlland-Gualtieri , Alix. 2007. South Africa's Water Law and Policy Framework - Implications for the right of Water. IELRC Working Paper. Geneva, Switzerland. International Environmental Law Research Centre.

- Grigg, Neil S., Criswell, Marvin E., Fontane, Darrell G., Saito, Laurel, Siller, Thomas J., Sunada, Daniel K. 2004. Integrated Civil Engineering Curriculum: Five-Year Review. *Journal of Professional Issues in Engineering Education & Practice*; Jul 2004, Vol. 130 Issue 3, p160-165.
- Grigg, Neil S., Criswell, Marvin E., Fontane, Darrell G., Siller, Thomas J. 2005. Information Technology in Civil Engineering Curriculum. *Journal of Professional Issues in Engineering Education & Practice*; Jan2005, Vol. 131 Issue 1, p26-31, 6p.
- Grigg, Neil. 1996. *Water Resources Management. Principles, Regulations, and Cases*. New York, NY. McGraw Hill.
- Istanbul Water Consensus. 2009. 5th World Water Forum. Istanbul, Turkey. Water Resources Council.
- Johnson, Christopher M. 2001. A Survey of Current Research on Online Communities of Practice. *The Internet and Higher Education*. Volume 4, Issue 1, 1st Quarter 2001, Pages 45-60
- Judson H.F. 1994. Structural transformation of the sciences and the end of peer review. *JAMA*. 272:92-94.
- Lave j. and E Wenger. 1999. *Situated learning: Legitimate peripheral participation*. Cambridge. Cambridge University Press
- Liniger, H., and G. van Lynden. 2005. Building Up and Sharing Knowledge for Better Decision-Making on Soil and Water Conservation in a Changing Mountain Environment – The WOCAT Experience. In *Renewable Natural Resources Management for Mountain Communities*. Edited by Stocking, M., Helleman, and H. Roger White. 2005. International Centre for Integrated Mountain Development, UK. Department for International Development.
- Markowitz, Abby, Green, Linda T. Laine, James. 2003. The 3 C's: Communicate, Coordinate, Collaborate. Doing Together What We Can't do Alone. *Water Resources Impact*. Vol. 5, No 5, September, 2003 – AWRA.
- Markowitz, Abby, Linda T. Green, and James Laine. The 3 C's: Communicate, Coordinate, Collaborate - Doing Together What We Can't Do Alone. *Water Resources Impact* 5(5): 8-10.
- Martin, Quentin W. 1994. Alternative Designs for a Water Resources Planning and Management Electronic Information Exchange Network in *Water Policy and Management: Solving the Problems*. In *Proceedings of the 21st Annual Conference*. Water Resources Planning and Management Division, ASCE, Denver, Colorado, May 23-26.

- Ministerial Declaration. 2003. 3th World Water Forum. Kyoto. Water Resources Council.
- Ministerial Declaration. 2006. 4th World Water Forum. Mexico City. Water Resources Council.
- Ministerial Declaration. 2009. 5th World Water Forum. Istanbul, Turkey. Water Resources Council.
- Moran, Gordon. 1998. *Silencing Scientists and Scholars in Other Fields: Power, Paradigm Controls, Peer Review And Scholarly Communication*. Ablex Publishing Corporation. Greenwich, CT.
- Mulenga, Martin. 2008. Improving water and sanitation provision globally through information sharing. *Waterlines*, Volume 27, Number 2, April 2008 , pp. 104-115(12). Practical Action Publishing.
- Naddeo V., T. Zarra, and V. Belgiorno. 2005. European Procedures To River Quality Assessment. Selected from papers presented in 9th International Conference on Environmental Science and Technology (9CEST2005) 1-3 September 2005, Rhodes island, Greece *Global NEST Journal*, Vol 7, No 3, pp 306-312.
- Nelson, Theodor H. 1992. *Literary Machines* 93.1. Sausalito, CA. Mindful Press.
- OZH2O. Water Resources and Use in Australia. [html]. Accessed on 12 August 2007. Available from <http://www.ozh2o.com/h2use4.html>.
- Pahl-Wostl, C. 2006. The importance of social learning in restoring the multifunctionality of rivers and floodplains. *Ecology and Society* 11(1): 10. [online]. Accessed on 25 October 2009. Available from <http://www.ecologyandsociety.org/vol11/iss1/art10/>
- Perry, J.A., Vanderklein E. 1996. *Water quality: Management of a Natural Resource*. Blackwell Science.
- Peters, C.A. and R.C. Ward. 2003. A framework for ‘constructing’ water quality monitoring programs. *Water Resources Impact* 5(5): 3-7.
- Porto M., F. Lobato. 2004. Mechanisms of water management: command & control and social mechanisms. *REGA- Revista de Gestão de Água da América Latina*. Available from <http://www.bvsde.paho.org>

- Porto, Monica, and Jerson Kelman. 2000. Water Resource Policy In Brazil. [pdf]. Brasília, Brazil. Agência Nacional de Águas. Accessed 14 July 2007. Available from http://www.ana.gov.br/AcoesAdministrativas/CDOC/Catalogo_imgs/WaterResourcesPolicyinBrazil.pdf
- Raymond, Eric S. 2000. The Cathedral and the Bazaar. [html]. Accessed 28 September 2008. Available from <http://catb.org/~esr/writings/cathedral-bazaar/cathedral-bazaar/index.html>
- Resnick P, Iacovou N., Suchak M., Bergstrom, and Riedl J. 1994. GroupLens: An open architecture for collaborative filtering of netnews", Proceedings of ACM 1994 Conference on Computer Supported Cooperative Work, Chapel Hill, NC: ACM, 175-186.
- Rogers, E.M. 1995. Diffusion of innovations (4th ed.). New York: The Free Press.
- Seufert, A., G. von Krogh, and A. Bach. 1999. Towards knowledge networking. *Journal of Knowledge Management*. Volume:3Issue:3Page:180 - 190
- Seybold, Patricia B. 2006. Outside Innovation – How Your Customers Will Co-Design Your Company's Future. New York, NY. HarperCollins.
- Simonovic, Slobodan P. 2009. Managing Water Resources: Methods and Tools for a Systems Approach. Paris, France. UNESCO.
- Smith, M. K. 2003. Communities of Practice. The encyclopedia of Informal Education. Accessed on 25 October 2009. Available from http://www.infed.org/biblio/communities_of_practice.htm. Last updated: 30 January 2005 .
- Surry, Daniel W. and Donald P. Ely. 2001. Adoption, Diffusion, Implementation, and Institutionalization of Educational Technology. [html]. University of South Alabama. Accessed 25 November 2009. Available from <http://www.usouthal.edu/coe/bset/surry/papers/adoption/chap.htm>
- The World Bank. 1993. Water Resources Manangement - World Bank Policy Paper (1993). International Bank for Reconstruction and Development / THE WORLD BANK . 1818 H Street, N.W. Washington, D.C. 20433 U.S.A.
- Turner, T. C., Smith, M. A., Fisher, D., and Welser, H. T. 2005. Picturing Usenet: Mapping computer-mediated collective action. *Journal of Computer-Mediated Communication*, 104, article 7.
- UNESCO. 2006. 2nd UN World Water Development Report. WWAP. [pdf]. WWAP. Accessed 25 April 2007. Available from <http://www.unesco.org/water/wwap/wwdr1/>

- UNESCO. 2003. 1st UN World Water Development Report - Water for People, Water for Life. [pdf]. WWAP. Accessed 25 April 2007. Available from <http://www.unesco.org/water/wwap/wwdr1/>
- Vansteenkiste, T., G.Vaes², P. Willems¹, W.J. de Lange³, J. Plyson⁴, F. Provost². 2008. WISE-RTD WEB Portal as a Tool for Sharing Water Related Research Information. UNESCO-INWEB. Accessed 20 August 2009. Available at <http://www.inweb.gr/twm4/abs/VANSTEENKISTE%20Thomas.pdf>
- Viegas, F. B., Smith, M. A. 2004. Newsgroup Crowds and Author Lines: Visualizing the Activity of Individuals in Conversational Cyberspaces. Big Island, HI: IEEE.
- Vlachos, Evan. 1982. Social politics aspects of Urban Hydrology. in *Water resources and land-use planning*. By Pierre Laconte and Yacov Y. Haimes. North Atlantic Treaty Organization
- Ward, R. C., JC Loftis, and GM McBride. 1986. The "Data Rich but Information-Poor" Syndrome in Water Quality Monitoring. *Environmental Management* Vol. 10 No. 3, 10:29 1-297
- Ward, R. C., JC Loftis, and GM McBride. 1990. *Design of Water Quality Monitoring Systems*. Hoboken, NJ. John Wiley & Sons, Inc.
- Ward, Robert. 2002. *Management and Monitoring of Water Quality – Class Notes*. Fort Collins, CO. Colorado State University.
- Water Framework Directive. 2000. WISE - Water Information System For Europe. (2000/60/EC). [html]. Accessed on 12 August 2007. Available from http://ec.europa.eu/environment/water/water-framework/index_en.html.
- Weller, Ann C. 2001. Editorial Peer Review : Its Strengths and Weaknesses. Medford, N.J.: Information Today Inc. American Society for Information Science and Technology.
- Welser, Howard T., Gleave, Eric, Fisher, Danyel Smith, Marc. 2007. Visualizing the Signatures of Social Roles in Online Discussion Groups. In *Journal of Social Structure* Vol. 8 2007. <http://www.cmu.edu/joss/>
- Wenger, Etienne. 1998. *Communities of practice: Learning, meaning, and identity*. Cambridge, U.K. and New York, NY. Cambridge University Press
- Wenger, Etienne. 2002. *Communities of practice: Learning, meaning, and identity*. Cambridge, U.K. and New York, NY. Cambridge University Press

Wheeler, Steve, Peter Yeomans, and Dawn Wheeler. The good, the bad and the wiki: Evaluating student-generated content for collaborative learning. *British Journal of Educational Technology* 39, No 6 2008: 987–995 doi:10.1111/j.1467-8535.2007.00799.x

WMO, UNEP. 1992. Dublin Principles. The Dublin statement on water and sustainable development. In: International Conference on Water and the Environment : development issues for the 21st century, 26-31 January 1992, Dublin, Ireland.

6. Appendices

6.1 Appendix I – Responses from the Exploratory Questionnaire

Country Demographics

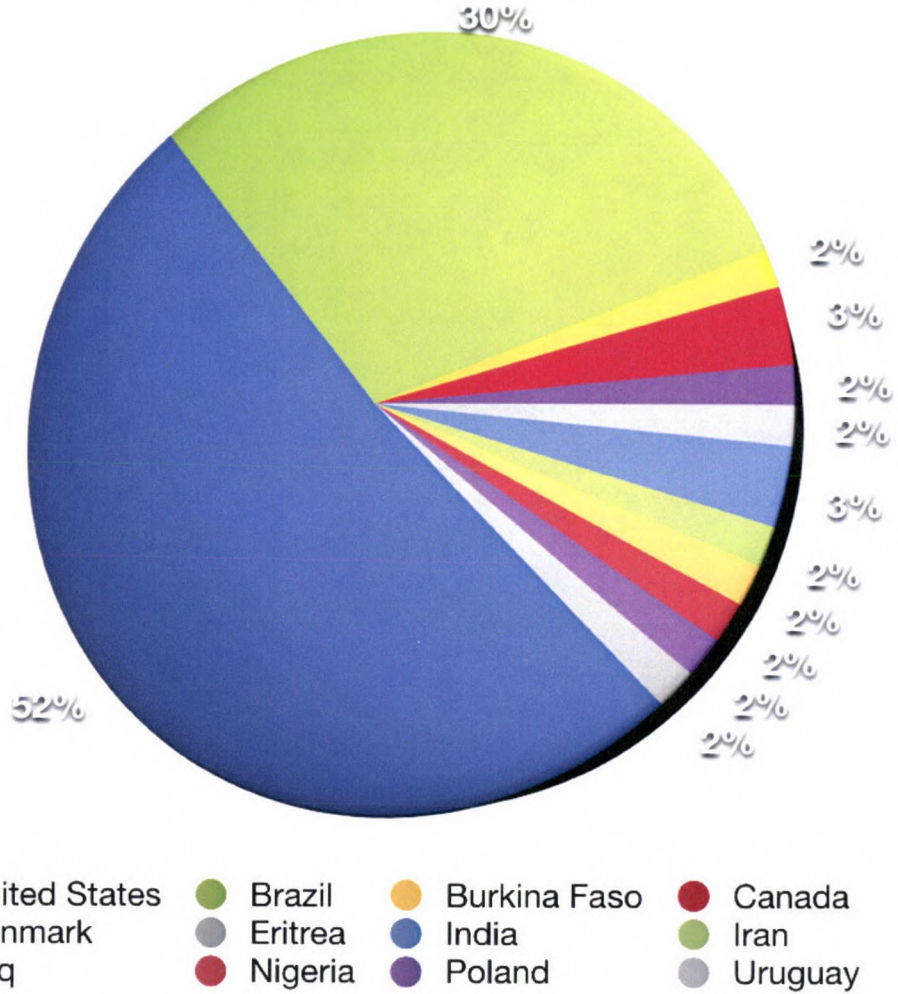


Figure 6.1: Country Demographics

Organization Type

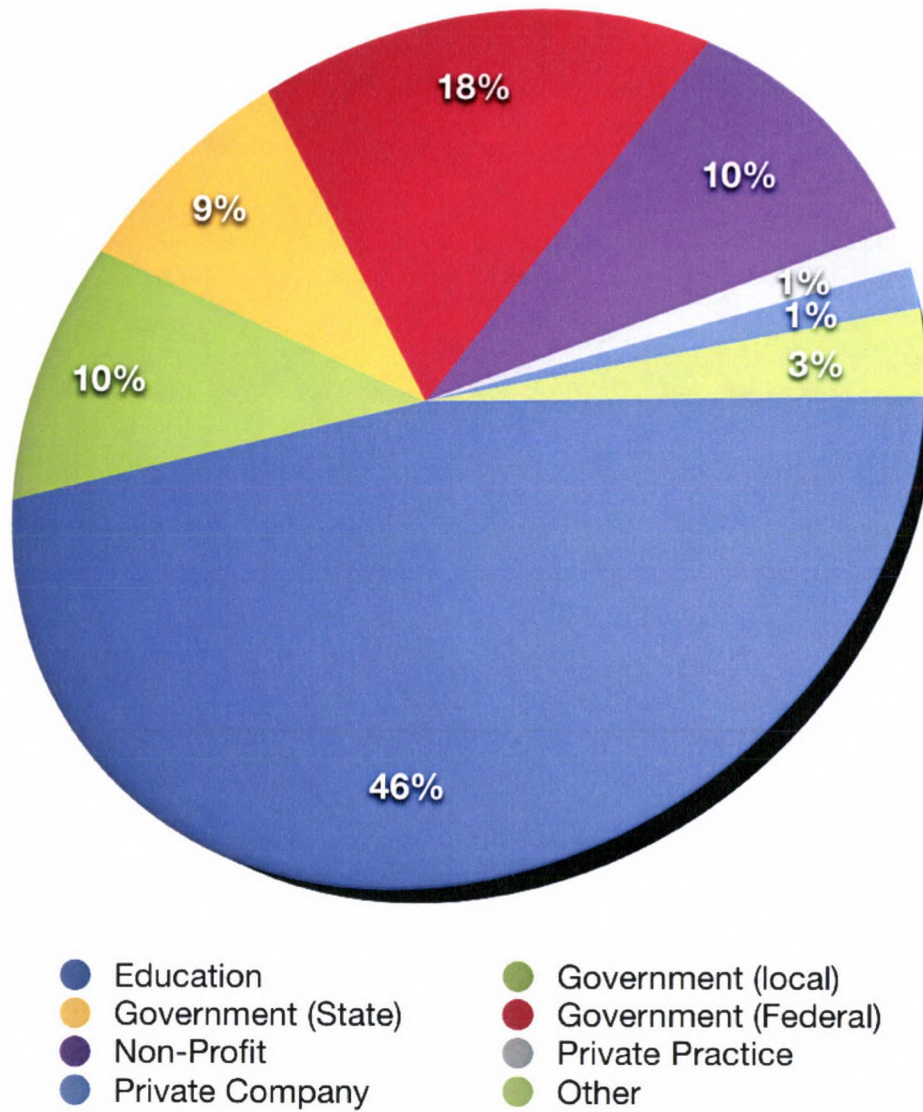


Figure 6.2: Organization Type.

**What is the main focus of your organization, as it relates to water quality?
Check all that applies.**

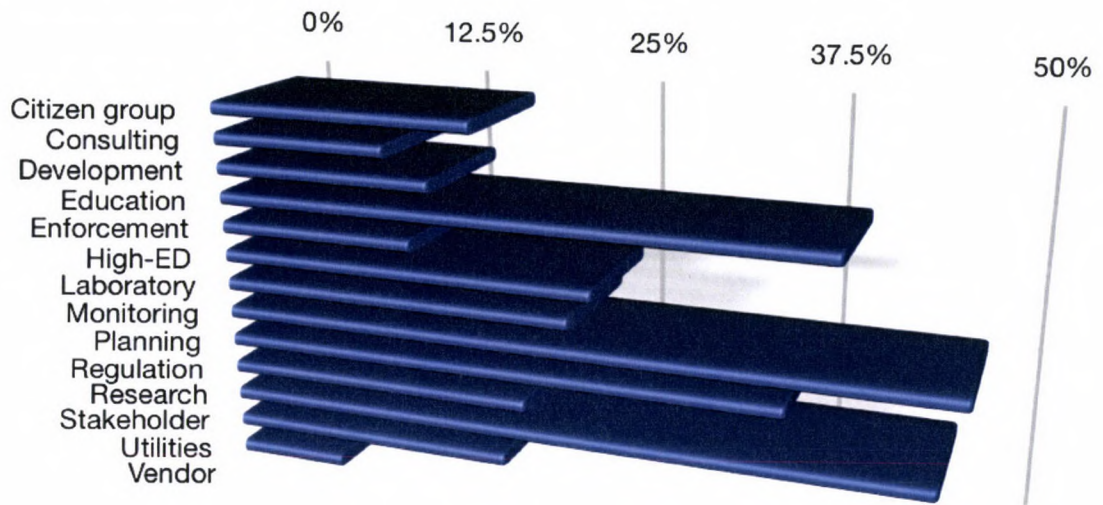
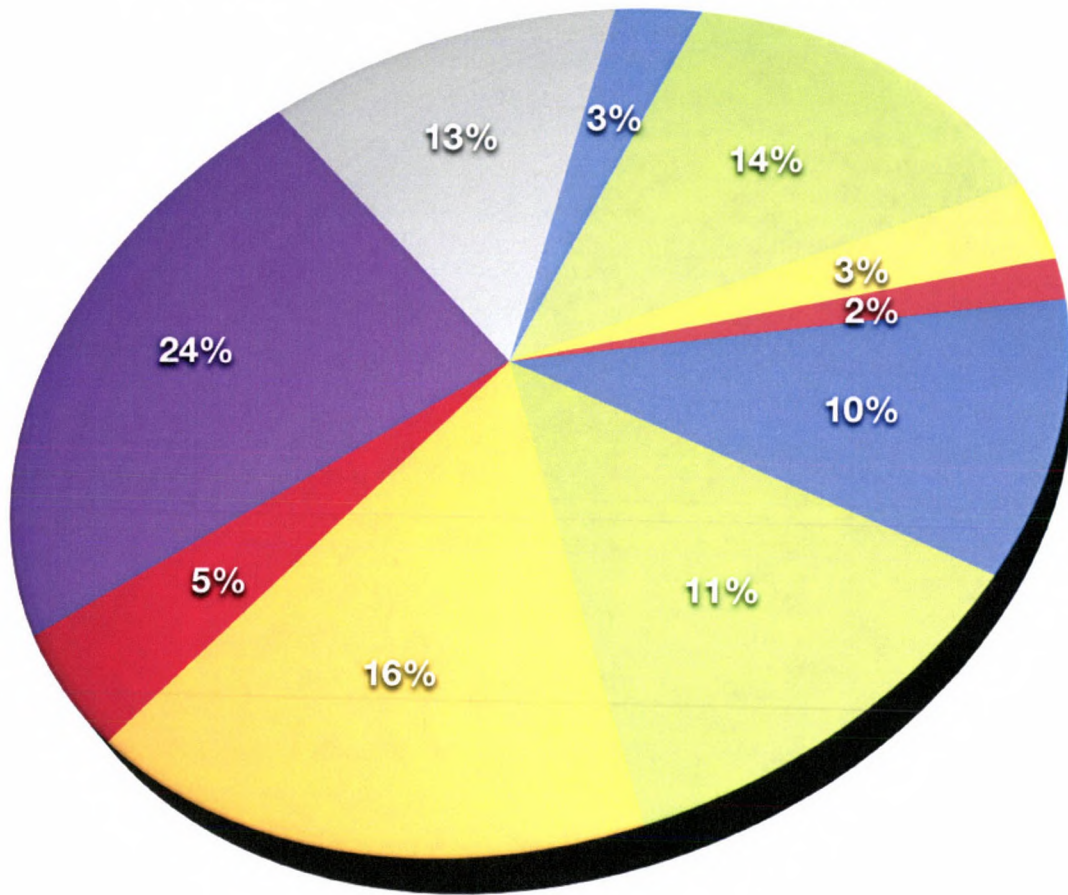


Figure 6.3: What is the main focus of your organization, as it relates to Water Quality? Check all that apply.

What is your main function in the organization?



- Executive
- Scientist
- Student
- Lab – technician
- Middle-Management
- Researcher
- Educator
- Operator
- Engineer
- Professor
- Planner

Figure 6.4: What is your main function on the organization?



Figure 6.5: Do you participate in any online groups?

| | Author's Number of Contribution | Ratings of Previous Contribution | Author's Seniority on the Network | Author's Institution | Author's Credentials |
|---------------------------|---------------------------------|----------------------------------|-----------------------------------|----------------------|----------------------|
| Not Important | 22.10% | 2.90% | 23.50% | 5.90% | 1.50% |
| Somewhat Important | 45.60% | 27.90% | 45.60% | 30.90% | 25.00% |
| Important | 27.90% | 44.10% | 25.00% | 36.80% | 32.40% |
| Very Important | 2.90% | 20.60% | 2.90% | 25.00% | 39.70% |

Figure 6.6: How would you like an online network to better assess the confidence level or the reliability of the information posted by a user? Please assign each factor a level of importance.

Question 7. *In order to promote the exchange of information and collaboration between peers, what features and resources do you think would be useful in a water quality indicators network and how would your organization use them? (check all that apply).*

The answers were divided to reflect usage (Fig. 6.7), contribution (Fig 6.8) and totals (Fig. 6.9).

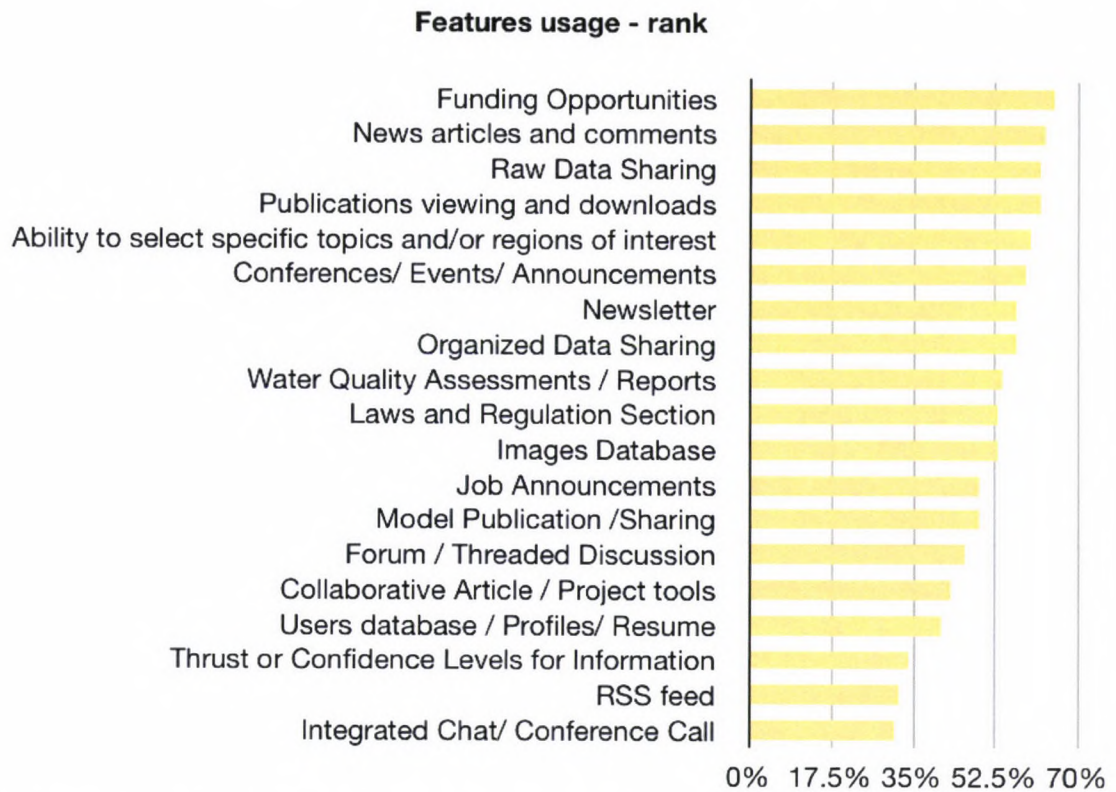


Figure 6.7: Features usage - Rank

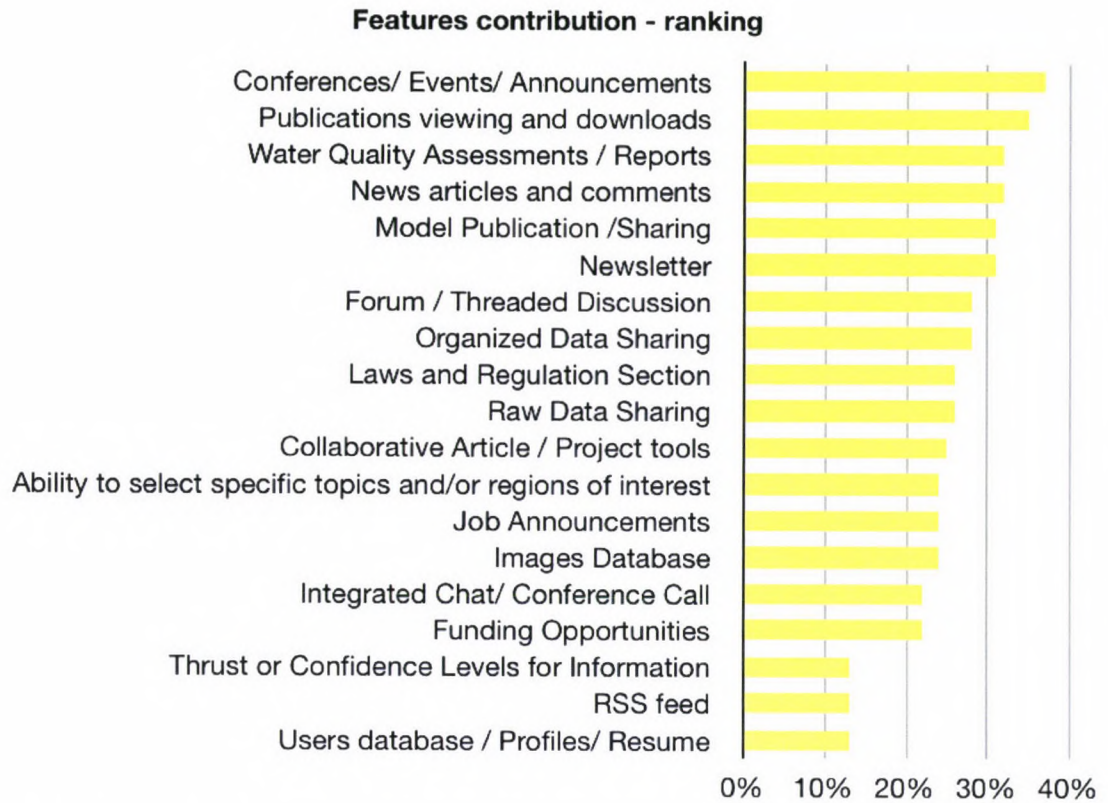


Figure 6.8: Features Contribution

Features usage and/or contribution - rank

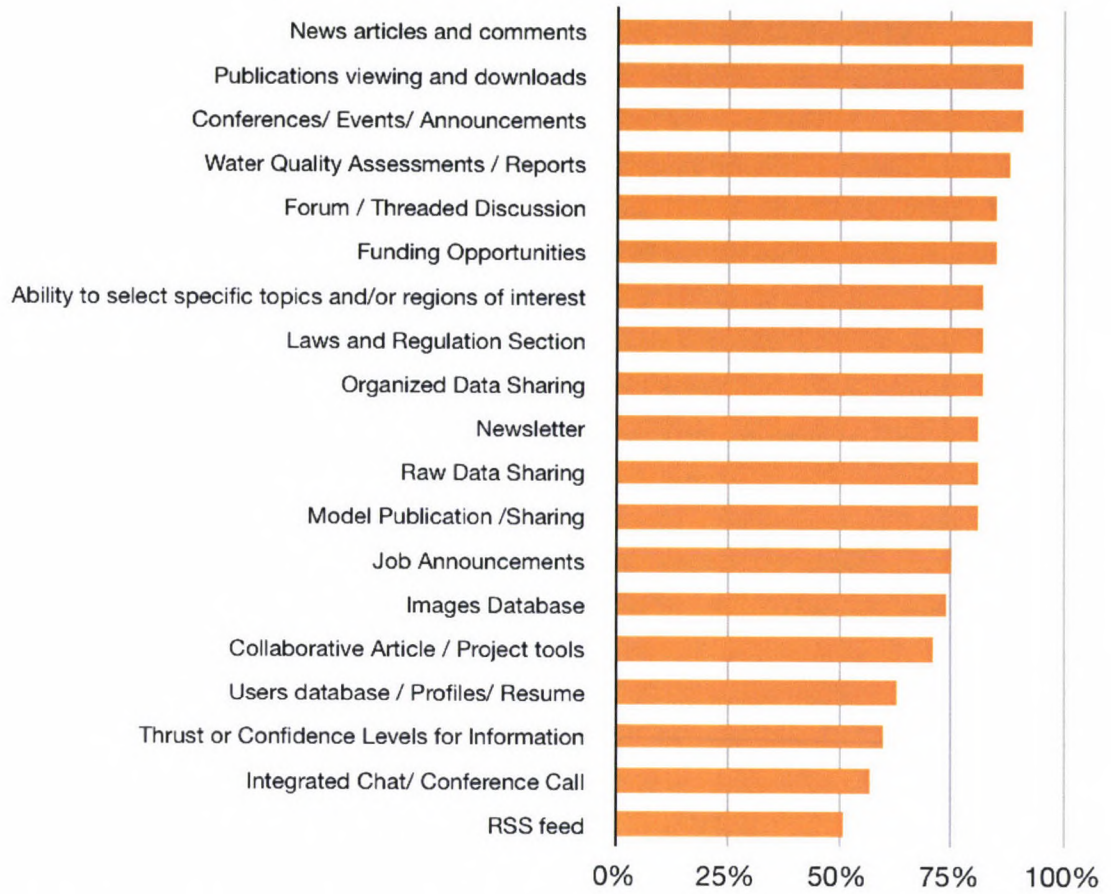


Figure 6.9: Features Usage and/or Contribution Rank

Which do you think is the best way to manage the information on the Network and control inappropriate (out of topic, spam) in this kind of online community?

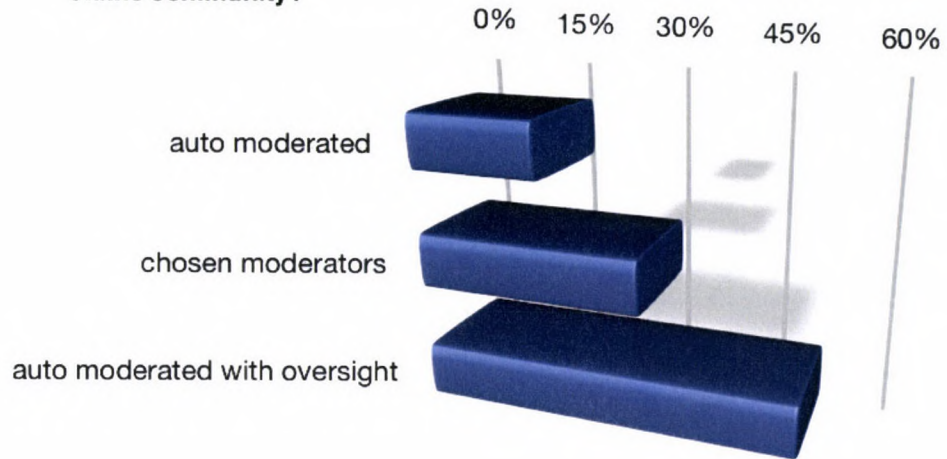


Figure 6.10: Which do you think is the best way to manage the information on the Network and control inappropriate (out of topic, spam) in this kind of online community?

Should anonymous posts be allowed?

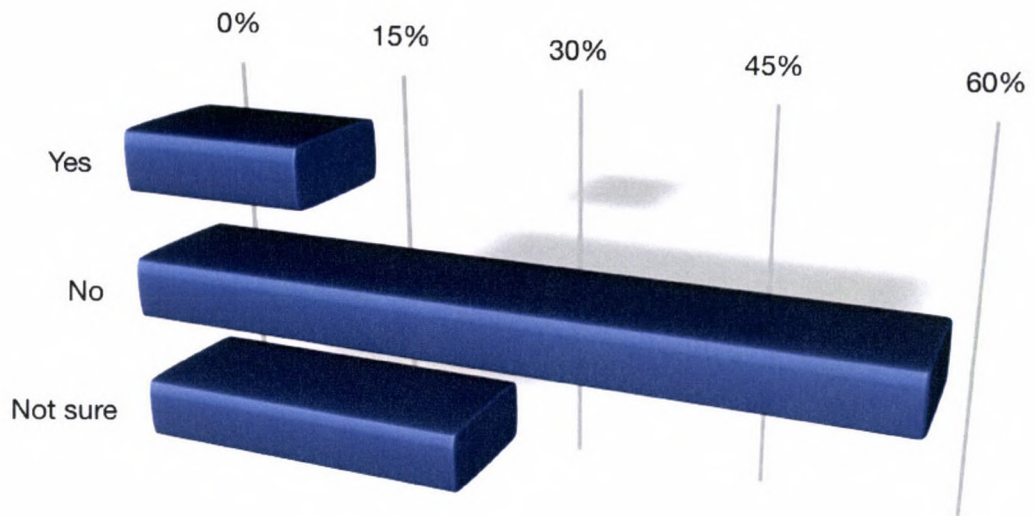


Figure 6.11: Should anonymous posts be allowed ?

6.2 Appendix II – WQIN Technical Specifications

6.2.1 Requirements and Technical Specifications for WQIN

The requirements for building WQIN were for the system:

- To be open, in the sense that it must be possible, at least in theory, for anyone in the community to contribute changes and enhancements. The community must be allowed to contribute even to the source code base if they so desire;
- WQIN needs to be scalable. It must be able to support the kind of growth that may potentially be seen in collaborative networks of all kinds, from Wikipedia to Google, where a relatively simple infrastructure may be required to deliver a similar experience regardless of the number of users, be it in the dozens or in the millions;
- To be inexpensive. In the best of times any such effort will need to support itself during the long phase of community building.

6.2.1.1 Software Solutions

Free/Open Source Software (FOSS) was a natural match to the openness philosophy behind WQIN and was used throughout. This assures that it is technically possible to change and customize every single aspect of the system at all levels. At the top-most level, that of the web interface, WQIN is as easy to provide content to as social networks like Facebook. It requires no special training. At the deepest level, it is possible to implement changes and modify the behavior of every single component of the system, should this be required.

WQIN is built on five FOSS projects: Linux (Ubuntu Server 8.04), the operating system; Apache 2.2, the web server; MySQL 5.0, the relational database; PHP 5, the HTML-embedded scripting language; and Drupal 6, the Content Management System (CMS).

Linux is probably the best known FOSS project and one of the flagships of the Open Source movement. One of the reasons for its selection is that it runs on an extensive range of hardware, from cell phones such as Google's Android to Roadrunner, the world's fastest supercomputer (Top500 Project, www.top500.org, rank for June/09).

Linux, Apache, MySQL and PHP together form what is known as "L.A.M.P.", an extremely popular web platform.

Drupal's mission statement from their website (<http://drupal.org/mission>) is the best reference as to why it was chosen for WQIN: "To develop a leading edge open-source content management system that implements the latest thinking and best practices in community publishing, knowledge management, and software design."

WQIN has been implemented as extensive customization to Drupal. Drupal and the Apache web server run on the same server while the MySQL database runs on a separate server. This division of labor provides flexibility to adapt to changing demands from the community. There is a full duplicate of the system running on independent servers for development. This allows experimenting with the platform without negatively impacting the community. All servers run Linux.

6.3 Appendix III – Website Traffic Data

Visitors Overview

Sep 24, 2009 - Dec 24, 2009 ▾



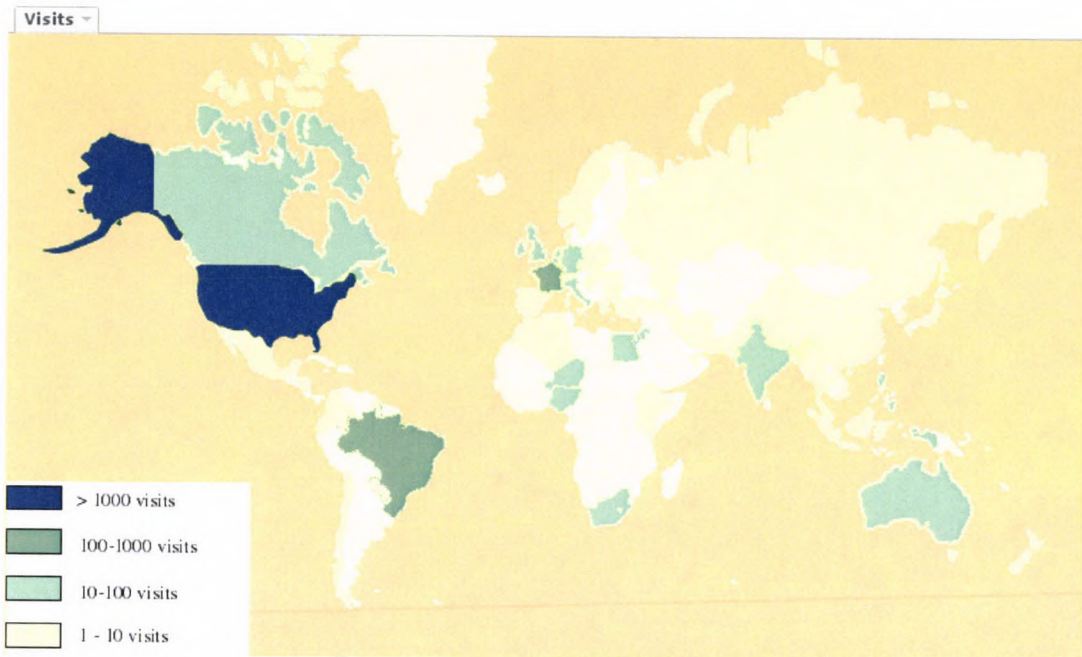
1,312 people visited this site

| | |
|--|---------------------------------------|
| | 2,388 Visits |
| | 1,312 Absolute Unique Visitors |
| | 8,271 Pageviews |
| | 3.46 Average Pageviews |
| | 00:04:47 Time on Site |
| | 49.83% Bounce Rate |
| | 54.61% New Visits |

Figure 6.12: Visitors Overview

Map Overlay

Sep 24, 2009 - Dec 24, 2009 ▾



2,388 visits came from 71 countries/territories

Figure 6.13: Map Overlay

Content by Title

Sep 24, 2009 - Dec 24, 2009 ▾



544 page titles were viewed a total of 8,271 times

| Content Performance | | | | | | | |
|---|--------------------------|----------------------------|--------------------------|--------------------------|--------------------------|--------|----------|
| Pageviews | Unique Pageviews | Avg. Time on Page | Bounce Rate | % Exit | \$ Index | | |
| 8,271 | 5,676 | 00:01:56 | 49.92% | 28.82% | \$0.00 | | |
| % of Site Total: 100.00% | % of Site Total: 100.00% | Site Avg: 00:01:56 (0.00%) | Site Avg: 49.92% (0.00%) | Site Avg: 28.82% (0.00%) | Site Avg: \$0.00 (0.00%) | | |
| Page Title | None ▾ | Pageviews ↓ | Unique Pageviews | Avg. Time on Page | Bounce Rate | % Exit | \$ Index |
| 1. Water Quality Knowledge and Informa | | 3,139 | 2,033 | 00:02:25 | 50.16% | 34.21% | \$0.00 |
| 2. Announcements Water Quality Know | | 312 | 238 | 00:01:11 | 32.35% | 18.59% | \$0.00 |
| 3. Jobs and Funding Water Quality Kno | | 307 | 174 | 00:01:45 | 52.83% | 33.55% | \$0.00 |
| 4. Jobs & Funding Water Quality Knowl | | 243 | 147 | 00:01:27 | 85.71% | 29.22% | \$0.00 |
| 5. Events Water Quality Knowledge and | | 226 | 185 | 00:00:23 | 0.00% | 3.54% | \$0.00 |
| 6. Welcome to the Water Quality Knowle | | 201 | 142 | 00:01:31 | 77.78% | 27.36% | \$0.00 |
| 7. User account Water Quality Knowlec | | 162 | 113 | 00:01:15 | 0.00% | 8.64% | \$0.00 |
| 8. Water BlogLog Water Quality Knowle | | 119 | 61 | 00:03:31 | 5.56% | 19.33% | \$0.00 |
| 9. Publications, Models and other Refer | | 113 | 83 | 00:01:30 | 25.00% | 19.47% | \$0.00 |
| 10. White House CEQ Releases Revised F | | 111 | 89 | 00:04:04 | 78.38% | 68.47% | \$0.00 |

Figure 6.14: Top Content by Title

6.4 Apendix IV

WQIN - Feedback Questionnaire

The image shows a screenshot of a web-based survey titled "WQIN - Feedback Questionnaire". At the top left is the WQIN logo, and at the top right is a link that says "Exit this survey". Below the header, the text "WQIN feedback" is displayed, followed by the section title "1. WQIN feedback". The main content area begins with the text "We need your feedback to evaluate WQIN".

1. How would you describe your work / interest in water quality? Check all that apply.

| | | |
|--|--|--------------------------------------|
| <input type="checkbox"/> Citizen advocacy | <input type="checkbox"/> Government agency | <input type="checkbox"/> Stakeholder |
| <input type="checkbox"/> Consultant | <input type="checkbox"/> Lab Analysis | <input type="checkbox"/> Student |
| <input type="checkbox"/> Development | <input type="checkbox"/> Monitoring | <input type="checkbox"/> Utilities |
| <input type="checkbox"/> Education (High-ED) | <input type="checkbox"/> Planning | <input type="checkbox"/> Vendor |
| <input type="checkbox"/> Education (Elementary to High School) | <input type="checkbox"/> Regulation | |
| <input type="checkbox"/> Enforcement | <input type="checkbox"/> Research | |

2. What are your main three uses of water quality information?

- Added understanding
- Data analysis
- Educational sources
- Funding Proposals
- General Updated News/Information
- Improve regulatory policy
- Project or program development
- Research and publication

Other (please specify)

Figure 6.15: WQIN - Feedback Questionnaire

3. How do you use online resources for publishing or getting Water Quality Information and/or participate in any online groups? (Forum, e-mail lists, etc). Check all that apply.

- I use only specific sources
- I have some preferred sources and also search for additional information
- The resources I use also let me contribute information
- The resources I use let me comment or rate the information
- I subscribe to at least one discussion list or Forum
- I have contributed to a discussion list or Forum before
- I seldom/do not use online resources

4. Considering the means you know or use to exchange information on Water Quality, for each feature, the **CONCEPT of WQIN is:**

| | An improvement | Somewhat an improvement | I still prefer what I use now | I do not use this information |
|---|-----------------------|-------------------------|-------------------------------|-------------------------------|
| Announcements | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Events | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Forum | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Jobs & funding | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| News | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Publications, Models and other References | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Water Quality Projects Search | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

Comments

Figure 3.16: WQIN - Feedback Questionnaire (cont.)

5. What kind of organizations and professionals would benefit from the collaborative way WQIN works? Check all that apply

- | | | |
|---|---|---|
| <input type="checkbox"/> Citizen groups | <input type="checkbox"/> Researchers | <input type="checkbox"/> Government (State) |
| <input type="checkbox"/> Consultants | <input type="checkbox"/> Stakeholders | <input type="checkbox"/> Government (Federal) |
| <input type="checkbox"/> High-ED | <input type="checkbox"/> Utilities | <input type="checkbox"/> Non-profits |
| <input type="checkbox"/> Monitoring groups | <input type="checkbox"/> Vendors | <input type="checkbox"/> Private Practices |
| <input type="checkbox"/> Planning | <input type="checkbox"/> Educators | <input type="checkbox"/> Private Companies |
| <input type="checkbox"/> Regulators | <input type="checkbox"/> Government (local) | <input type="checkbox"/> Other |
| <input type="checkbox"/> Other (please specify) | | |

6. Do you think WQIN's format could be adopted by the water community as a means to exchange information?

- Yes
- Not sure
- No

Please tell us why

Figure 6.17: WQIN - Feedback Questionnaire (cont.)

7. What improvements could we make to WQIN so it would make it more widely adopted? Check all that apply.

- Local news and resources for your region of interest
- Implement communication tools such as chats or conference calls
- Expand the subject to Water Resources in General
- Refined community review system (collaborative filtering and trust network)
- Collaboration tools such as collaborative documents, etc
- Refined search
- Periodic Newsletter with individual timing option
- Specific interest alerts (We would send you an e-mail when something is posted with a specific keyword)
- Other (please specify)

8. Can we contact you? Your e-mail address would only be used to send you a few follow up questions, if necessary. We will not share your e-mail with absolutely anyone else, no exceptions.

- Yes
- No

e-mail address:

9. If you have any other comment or suggestion, please let us know (Additionally, comments may be sent to wqin.email@gmail.com):

Figure 6.18: WQIN - Feedback Questionnaire (cont.)