Identifying and Prioritising Water Research Questions for South Africa

Report to the

WATER RESEARCH COMMISSION

by

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EXECUTIVE SUMMARY

BACKGROUND AND RATIONALE

Limited historical data are available to describe water research in South Africa over the first half of the 20th century. Many authors recognise that this period was dominated by technological developments, breakthrough research and projects in water storage and transfer, and frequently characterised by a positivist approach to nature and development (Tempelhoff et al., 2009; Tewari, 2009; Tempelhoff et al., 2007; Tempelhoff, 2006; Turton et al., 2006; Allan, 2004; Turton and Meissner, 2002; Allan, 1999).

A new era in water research in South Africa began with the promulgation of the Water Research Act No. 34 of 1971. The Act led to the formation of the Water Research Commission (WRC) and the Water Research Fund with the purpose of initiating, managing and financing water research. The objectives of the WRC, as stated in the Act, were to co-ordinate, promote, and encourage research in respect of a wide range of purposes and activities (Republic of South Africa, 1971).

A shift in the political landscape, marked by the first democratic elections in South Africa in 1994, contributed to a major shift in the existing water resource management paradigm. Legislative reform coincided with growing concerns about the state of the country's waterways and the rising capital expenses in supply schemes, coupled with the growing environmental concerns globally (Herold, 2009; Funke et al., 2007; Schreiner, 2006). The legislative reform in South Africa is lauded as being the first country in the world to have promulgated national water legislation which uses water to achieve societal transformation and focusing attention on environmental and social justice (Funke et al., 2007).

This study commences with the identification of the prevailing paradigms that have influenced the history of water research in South Africa by analysing the publication output over the last four decades and in identifying research questions proposed by a range of researchers active in the water sector in South Africa.

AIMS AND OBJECTIVES

The overall aim of this project is to generate research questions capable of addressing immediate and medium-to-long term water-related issues and challenges facing South Africa, and to do so with some assurance that these questions will be acceptable to researchers and practitioners alike.

The aim is met by addressing the following objectives which:

- Explore the prevailing paradigms that have influenced the history of water research in South Africa
- Identify and evaluating research questions proposed by a range of researchers active in the water sector in South Africa
- Critique past and present paradigms of South African water research in order to develop insight into future water research questions and approaches.

LITERATURE

A paradigm can identify a conceptual framework that is composed of a class of common elements, theories, laws and generalisations that is widely acknowledged within a scientific school of thought or discipline. Paradigms also shift for a variety of reasons and under various influences. According to Kuhn (1962), when enough significant anomalies have accrued against a current paradigm, then the scientific discipline is thrown into a state of crisis. During this crisis, new ideas, and even those previously discarded, are tested further. A change of worldview begins when a significant anomaly is recognised within an existing paradigm. The signals and changes in paradigms, with attention to paradigm changes in water resource management, provides the context from which to explore corresponding changes in the water research enterprise in South Africa.

One of the earliest paradigms in water resource management began at the start of the 20th century and is most often acclaimed as the hydraulic mission because it is characterized by major engineering activities involving the construction of water infrastructure to capture, store and distribute water. The majority of water projects in this period were concerned with supplying more water, more efficiently to more areas (Tempelhoff et al., 2009; Van Vuuren, 2009). The demand-side of water resource management focuses attention on how to manage water demand and use. This shift is influenced to an extent by various social advocacy movements, but is also influenced by increasing recognition of resource scarcity, heightened interest in sustainable development considerations, post-modern philosophies and increased prominence of environmental justice, equity and democratisation of resources (Tempelhoff et al., 2009; Ohlsson and Turton, 2000).

Global changes in water resource management are explained further in observing the shift in paradigms (Allan, 2005). His work focuses on the development of analytical methods to address the problem of water resource allocation. Allan's contribution lies in identifying paradigms that are reliant on economic, legal and political factors that influence the water sector in semi-arid countries. These shifts are observed in a transition of five water management paradigms, each with its own distinct focus and function. The third paradigm in

Allan's (2005) framework is particularly pertinent to this study because it coincides with the period immediate prior to and after the promulgation of the Water Research Act No. 34 of 1971 in South Africa. During this same period, Allan identifies a general global shift towards sustainable resource management and a concerted effort to redress the damage done by previous paradigms. The fourth paradigm is characterised by a period of economic expansion (particularly in the North), and in smart economic decisions that offer several environmental advantages. Finally, the fifth paradigm is dominated by political and institutional change which becomes increasingly aligned with global shifts towards sustainability and also a rapid decline in the hydraulic mission.

In this study, observations of shifts in water management paradigms provide an interesting point of departure from which to consider how the scientific output, measured in terms of publications of water research in South Africa, are characterised by their response to the various paradigmatic changes.

Scientometric methods are used to collect a series of appropriate publications or reference material. Sets of keywords and/or noun-phrases amongst the journal articles are analysed with respect to their frequency to each other within the article and towards other articles. This is known as a topic/word/concept co-occurrence network. Scientometrics of published works provides an interpretative account that is used to identify patterns of change and to understand the relationships that influence these trends. However, scientometrics is not an appropriate method for determining future water research questions. For this purpose the study uses a form of horizon scanning to identify future research questions and strategies similar to studies undertaken by Sutherland and Woodroof (2009, pp. 525) which are to: (i) scope the issue; (ii) gather information; (iii) spot signals; (iv) watch trends; (v) make sense of the future; and (vi) agree on the response. This study uses a similar approach which is supported by a collaborative, multi-stakeholder process to identify and examine threats or trends in society, the environment or a sector, and identify needs that will enable appropriate management (Shackleton et al., 2011; Sutherland and Woodroof, 2009).

METHODOLOGY

Scientometrics analysis

A conceptual narrative on water research in South Africa is central to the discussion on water research paradigms, knowledge and appropriate adaptive capacity. Many authors (for example, LaRowe et al., 2009; Herr et al., 2008; Hood and Wilson, 2001; Van Raan, 2003; Todrov, 1989) have discussed how these approaches provide an objective and evidence-

based means of assessing the state of a research or scientific field. The key data for this method are research outputs, either in the form of publication, collaboration, intellectual property, policy influence and application.

Locating relevant water-related publications objectively and comprehensively is a challenge within itself. This challenge stems from the definition of water research used herewith. In this study, the journal search set comprised a two-fold approach: firstly, journals that had five or more articles in searching the terms: *water* and *South Africa* (or derivatives thereof). Secondly, snap polls and pilot surveys undertaken towards the end of 2011 that included questions asking practitioners where they published and read South African water-related research. The results from the significant publication count criteria and stakeholder input resulted in 171 publications forming part of the journal search set. These journal titles were then added to the query and searched further. The final search query searched for journal articles that contained *water* and *South Africa* in their topic within the *journal search set*.

There are limitations in the use and interpretation of scientometric maps since the output only provides a representation of relationships between terms found in published content. The results should be interpreted with caution even though the evolution of scientometric methods represents the most effective known method of simply representing scientific relationships, output or developments on a particular scale.

The search for water research questions

A form of horizon scanning is used to identify and evaluate research questions that are currently being asked by researchers. There are three main methodological steps that are typically used: 1) identify and create a collaborative stakeholder network; 2) collect data from this network regarding their research expertise, opinions on research considerations and research questions; and 3) analyse this data by allowing the network to deliberate the results and produce a final set of results of research opinion and questions.

Sutherland and Woodroof (2009) provide a substantial taxonomy of horizon scanning methods used in identifying and prioritising future research questions, scenarios and needs. They follow a combination of open forums, trend analysis, questionnaire and expert consultation. Arguably a strength, and at the same time a weakness of the current study, was the desired intention to involve a wide variety of stakeholders with an interest in water and water research, and to engage these participants through the ‘voice’ of a research initiative, rather than through that of the researchers.

RESULTS AND DISCUSSION

The number of journal articles and research reports published per year shows an increase in annual publication counts; a rise in *Water SA* articles; and a marked increase in WRC research reports. South Africa's water-related research output has steadily increased and the research is found in more diverse, international journals.

Scientometric maps created using Sci2 and VOSviewer comprises five year time-slices from 1977 to 2011 and is graphically depicted in label or density format. Label format presents more prominent words in the network as larger spheres.

Elements of the map using keywords for the period 1977 to 2011 shows the dominance of research output that focus on management, development, models, water quality and system treatment. The first time-slice of 1977 to 1981 shows a small, but scattered research effort with an emphasis on water quality. The map from 1982 to 1986 indicates further scattering of research output with a small shift to natural biological systems and the first elements of approaching water affairs at a catchment scale. Treatment systems and industrial water present the major focus in the time-slice for 1987 to 1991. In the early post-apartheid years from 1992 to 1996, shows how disciplines start to connect with one another. While treatment systems still dominate, management, development and urban research begin to show prominence within water research. These emerging areas of inquiry increase their presence during and following the country's major water policy reconstruction in the period from 1997 to 2001. At this point the research is at its most polarised, with treatment systems and basic science dominating one area while development, assessment and management sciences dominate another. The penultimate time-slice from 2002 to 2006 shows emerging research fields which relate to the increase in overall publications in which the word 'management' becomes more pronounced and more social science orientated terms such as community, impact and application make an appearance. The final time-slice from 2007 to 2011 shows management as the current dominant research area of prominence. While engineering sciences such as treatment systems are present, they are dominated by assessment research, modelling and community related research.

Question gathering

The stakeholders captured by the research signed up and engaged in the process for numerous reasons. Some simply wanted to remain informed of the process and results. Others saw an opportunity to participate in the surveys and discussions, while others used

the portal to ask further information about water research. When the study was completed in December 2012, there were 2260 unique stakeholder contacts on the database.

The stakeholders contained within the database were diverse in their involvement in the South African water sector but appeared well connected within the water sector networks. Overall, stakeholders in the database were affiliated to 572 organisations or institutions. By the time the *main survey* closed in December 2012 there were 641 completed responses. Of the 1674 questions submitted, 4629 keywords/categories were provided of which 844 of these were unique. The most striking result is that of 245 occurrences of the keyword *management*. A large proportion of the submitted questions had a management-oriented line of inquiry.

Following further refinements, including the removal of duplicates, quality control of questions and suitability of questions, a total of 401 questions were presented as the input data to the *Water research horizon scanning workshop* in October 2012 in Cape Town. Delegates were asked to reduce the list of 401 questions to approximately a quarter of the theme totals. The final dataset amounted to 59 priority water research questions across the six themes.

Research output and links to paradigms

South Africa has undergone significant changes in the output and structure of water research over the past four decades. There has been substantial growth in output with a total relevant sample publication record of 6007 articles and research reports and a current annual output of over 350 articles and reports per year. The number and different sources of journal articles over this period have increased and diversified while WRC research report output has also increased, albeit at a slower rate.

The emergence of two main areas of research or fields of specialisation in the democratic transition (1992-1996) period is supported by greater diversity of publications than in previous years. The engineering or technical research outputs cluster together and again focus on treatment systems, processes and evaluation. This time the clustering is associated with management-based and planning oriented research.

A transition period in water research occurred over a period that became increasing focused on quality constraints, fields of management and planning. It also indicates that the 2nd transition of Turton and Meissner (2002) was occurring with a new social contract around water that came not only from a new political regime and democratic transition that focused on redistribution, but also one that was spurred on by a movement of South African

environmentalism, the beginning of the global sustainability debate and the rise of civil society activism.

The period 1997-2001, around the major transformation of South Africa's water laws and post establishment of the national Constitution, shows a strong polarisation between the main technical and management orientated disciplines. Researchers began to focus further on understanding the broader water context, use systems approaches and were beginning to plan for more than just engineering solutions. These results support the view that a transition was still underway with regard to the dominant paradigms but the word system had shifted noticeably towards the management and development related research disciplines and away from the technical.

The most recent decade of water research represents the greatest change in water research paradigms. It represents over half (3456 of 6007) of the collected and analysed publications, and constitutes the most representative sample of current recent water research. In this period, words become clustered and centralised, with the images being most clustered in their centres and with few stand-alone concentration areas. This indicates how research has become more diverse yet interconnected and a shift towards other disciplines.

The research effort in South Africa appears to have evolved into a new set of paradigms, albeit it tentative and uncertain, in which some emphasis is given to the social sciences disciplines and to concepts of governance and management. There is also evidence of research that focuses more attention on demand-side applications and interests, and integrated management. However, a third or reflexive transition phase (Allan, 2005) does not appear just yet. Keywords that relate to the green economy or risk awareness are not yet prominent. What is obvious is an increase in the prominence of collaboration across multiple disciplines over the last decade.

Identifying and prioritizing questions: the link to paradigms

The launch and strategies undertaken through the Aqua d'UCT initiative far surpassed expectations with regards to participation, uptake and response. The robust and yet diverse nature of the results and community interaction during the study was shown by the steady growth of interest from approximately 600 to over 2000 stakeholders on the research contact database by the time the study was completed in 2012.

While many respondents wanted longer and more substantial research projects to be funded and established, the majority of research questions were categorised as short- to

medium-term projects taking only one to three years, or ten years and more to complete respectively. Nevertheless, these questions reflect the diverse research disciplines and specialisations as suggested by the keywords such as management, governance, planning, education, policy, planning and alternatives being most prominent. However, those questions of a more technical nature relating to treatment, quality and pollution, hydrology, climate, supply and ecology dominate the input dataset.

In general, the final list of questions confirms three important observations: (a) over 78% of the questions that were offered and refined at the workshop seek to address short- to medium term research questions, typically questions dealing with service delivery, sanitation, access to water, pricing and water quality; (b) the majority of the questions confirm the existence of a transition paradigm, similar to what was identified earlier in the scientometrics analysis, and (c) there is a small a set of questions that are arguably more closely aligned with issues and concerns that feature some elements of Allan's (2005) 3rd, 4th and 5th paradigm. Here the questions deal with medium to long-term critical concerns of sustainability, establishing green economies, and implementing new forms of integrated, adaptive governance. These kinds of questions pose extraordinary challenges necessitating considerable financial and institutional support.

Delegates acknowledged that the workshop was an energising and interesting collaborative exercise. While there were some obvious gaps in the representation of participants, delegates were pleased to interact with diverse leaders in the field. Most delegates appreciated the quality of exchange and interaction during the formal and informal activities. However, strongest criticism was that the approach and methods used at the workshop were not designed to identify horizon scanning research questions *per se*. Rather delegates said that they felt coerced into responding to the questions that were put before them. Moreover, delegates felt that it was difficult to develop new questions that were of an horizon scanning, long-term nature for a number of reasons: the groups were too diverse; there was insufficient time to consider and develop meaningful questions; and the process was too demanding for the facilitators resulting in tasks being carried out in a mechanistic manner against a tight timeframe.

CONCLUSIONS

Scientometric results show that the publication record for water related research in South Africa contained 6007 from 1977 to 2011. Water Research Commission (WRC) research reports amounted to 1760 (29.30%) of this total. The remainder were peer-reviewed journal articles published in *Water SA* accounting for 1829 (30.45%) articles. The publication record

also increased in number dramatically since 1990 with more articles being published annually than each previous year before throughout the dataset.

Paradigms were identified through the scientometric mapping methods using the publication record to show a history of water research from 1977 to 2011. Overall, the research output focused predominantly on management, development, models, quality and system treatment. Technical matters dominant the historical record but other paradigms such as allocative efficiency, uncertainty and risk are also present. The change in paradigms is observed when these results are examined over successive time periods.

Two major paradigm approaches were observed in the analysis of water research publications along with one significant transition period. The first set of paradigms, from 1977-1991, emphasises the hydraulic mission that sought to secure supply, understand basic natural systems. In the following ten years (1992-2001) there is transition in which quality constraints and fields of management and planning become prominent. This paradigm is in response to changes in water deficits and focus on end-use efficiency. A second transition occurs with a new social contract around water at a time when the new political regime enters government in a period of democratic transition, growing environmentalism and a rise of civil society activism. The need to plan, model catchments and include other disciplines is becoming evident in the research environment.

The question prioritisation activities using horizon scanning methods provided an opportunity for the study to engage with a wide and diverse population of water research stakeholders and practitioners. The survey resulted in a substantial collection of research questions from water stakeholders and researchers. Many questions deal with immediate- to medium-term concerns while only a few aim to tackle long-term or systemic problems. Others are coupled or integrated questions that cover a number of disciplines.

RECOMMENDATIONS FOR FUTURE RESEARCH

It is recommended that further detailed mapping and analysis be performed on publications to explore the reasons that might cause paradigm shifts as well as understand what is missing in the existing body of knowledge. Horizon scanning has many inappropriate elements for the South African context as it is limited to a degree by its reach and participation. It is recommended that further prioritisation activities are undertaken to guide research but that these are expert lead and informed at the earliest stage before taking the results to a wider audience for consultation. In the study, the questioning does, however, provide an overall perspective of what a large and diverse group of research stakeholders

and practitioners believe is important even if these may not deal with long-term challenges but rather, more situated in addressing current and pressing research needs.

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LIST OF ABBREVIATIONS

AHCI	Arts and Humanities Citation Index
DWA	Department of Water Affairs
NWRS	National Water Resource Strategy
R&D	Research and Development
RSA	Republic of South Africa
SCI	Science Citation Index
WOS	Web of Science
WRC	Water Research Commission

1. INTRODUCTION

More people now place a high value on maintaining the integrity of water resources and the flora, fauna, and human societies that have developed around them. There are growing calls for the costs and benefits of water developments to be distributed in a more equitable manner and for unmet basic human needs to be addressed. And more and more, efforts are being made to understand and meet the diverse interests and needs of all affected stakeholders. If the next generation of water planners continues to try to integrate these principles, the present stalemate and paralysis on how to move forward will ease and a new era of innovative water management will ensue.

(Gleick, 2000 pp. 130)

1.1 Project Overview

The first effort to co-ordinate water research in South Africa began with the promulgation of the Water Research Act No. 34 of 1971 (RSA, 1971) resulting in significant development of water research in the country. The Act also led to the establishment of the Water Research Commission (WRC), which falls under the national Department of Water Affairs (DWA) and is responsible for managing the allocation of public funds to support water research. The results of this public initiative are found in the plethora of water research activities and related benefits that directly acknowledge the support and services of the WRC. While the national research output of the WRC accounts for a substantial proportion of research publications, other institutes such as government departments, national science councils, universities, private consultancies, civic groups and non-governmental organisations also contribute to the water research field. Since 1971 over 9000 peer-reviewed articles on the theme and topic of water in the South Africa have been published in various scientific journals.

The conceptualisation of this project (the WRC Report No. K5/2170) began with two primary assumptions in mind. The first is that directions in water research, albeit partially, is found in a combination of evidence generated from a scientometric analysis of peer reviewed water research publications and in the prevailing paradigms in water resource management that could influence various trends in research. Moreover, it is possible to extend the assumption further by using published research and paradigms to guide the identification of new research questions.

The second assumption is that researchers themselves are best suited to identify research questions that are capable of addressing critical issues and challenges facing the water sector and water resource management in the short- to long-term. Researchers in academic institutions and private enterprise are expected to identify questions that are

relevant and acceptable to funding agencies, and will contribute broadly to the construction of knowledge and innovation.

These assumptions are tested later in this study together with their respective influence in shaping the research objectives and methods. The project begins with a brief contextual analysis of the history of water research in South Africa, followed by a description of the process involved in identifying and prioritising water-related research questions, and finally in a discussion on a set of water research questions which is the main outcome of the research study.

1.1.1 Setting the research context: a water stressed country

South Africa is classified as a water *stressed* country. This classification is determined by a water stress index system (based on the Falkenmark Water Stress Indicator) that calculates an index for a given area using various measures for water availability, water quality, water demand, water affordability and service coverage. In addition, the World Water Assessment Program places South Africa in the *extreme risk* category (Water Systems Analysis Group, 2012). Some of the most frequently cited data used to describe South Africa's water balance includes the fact that it receives an average rainfall of 497 mm/annum (well below the global terrestrial average of 860 mm/annum), and an annual freshwater availability of less than 1700 m^3/person (Institute for Futures Research, 2009). In addition, it has one of the lowest mean annual conversion rates of precipitation to runoff with less than 10% of input that eventually flows as surface water (O'Keeffe et al., 1992). Researchers and multiple scientific reviews have warned that South Africa faces a growing water-related environmental, economic and social crisis (Herold, 2009; Bond and Dugard, 2008; Turton et al., 2006; Turton and Meissner, 2002).

In South Africa water stress and water insecurity are recurring themes in the history of water resources. Briefly told, the demand for large volumes of water began during the gold rush and mining boom of the late 19th century on the Highveld of South Africa - present day Gauteng (Turton et al., 2004). A reliable water supply had to meet the demands of the mining and manufacturing industry. Water supply was piped into this industrial and mining hub of the country, characterised as a semi-arid region, on a grand scale. This marked era of the 'national hydraulic mission', a phase that was characterised by so-called 'heroic engineering' projects of dam building, inter-basin transfers and large scale inter-catchment exchanges (Turton and Meissner, 2002).

The 'water supply' paradigm dominated this era. It was also characterised by political and institutional interventions that controlled the political power and socio-economic injustice

over the majority. However, soon after the demise of the apartheid government in 1994, the new political realities presented South African lawmakers and politicians with an opportunity to reform existing water policies and legislation, an opportunity that few countries ever get. Far-reaching reforms gave attention to pressing issues including social and economic redress, social equity and the right to access water. The National Water Act No. 36 of 1998 (Republic of South Africa, 1998) was widely recognized worldwide as one of the most progressive legislations promulgated to address water resources management (Tewari, 2009). Many of the principles in the Act represented both a mix of modernist and post-modernist paradigms as suggested in the quote below:

> *In many ways this shift in water policy mimics the shift in thinking in certain progressive research circles: from one which focuses on the physical laws of nature and the principles that drive society and what we are capable of doing through technological intervention, toward one which is driven by a strong set of values and the question of "what ought we do?"*
>
> (Funke et al., 2007 pp. 66)

1.1.2 Key arguments and considerations for the research

The approach to this study is summarised by the following key arguments:

- There exists a dominant argument that science and research should be undertaken to benefit society
- Research and Development (R&D) is a strong indicator of progress and innovation, an enabler of development, and a method to solve challenges and overcome problems
- The management, organisation and implementation of R&D is complex. It is underpinned by the power of politics, political will or lack thereof. It is most often discipline specific (as seen through research-derived research questions), lacks integration and is fragmented (evident worldwide and in South Africa)
- The water research enterprise in South Africa needs to urgently address current threats and give attention to opportunities, as well as attend to future risks, threats and opportunities
- Adaptive co-management is an approach that seeks to understand and adapt to uncertainty and complexity, in which collaborative networks are emphasised in this approach
- Paradigms and scientometrics are necessary to generate strategic thinking as well as to clarify positions from which to consider research futures
- Collaboration and consultation methods are required to build an adaptive, relevant, appropriate, efficient and strategic research practice.

1.1.3 Research question

The overall research question is straightforward:

- What are the immediate and medium to long-term water research questions that need attention in South Africa?

The challenge lies in finding acceptable methods of identifying these questions and then determining the research priorities. The methods of determining the questions are as important as the questions themselves.

1.1.4 Aim and objectives

The overall aim of this project is to generate research questions capable of addressing immediate and medium-to-long term water-related issues and challenges facing South Africa, and to do so with some assurance that these questions will be acceptable to researchers and practitioners alike.

The overall aim of the study will be met by:

- Exploring the prevailing paradigms that have influenced the history of water research in South Africa
- Identifying and evaluating research questions proposed by a range of researchers active in the water sector in South Africa
- A critique of past and present paradigms of South African water research in order to develop insight into future water research questions and approaches.

1.1.5 Study limitations

There were significant limitations to the study on two accounts. The first is the simplification of scientometrics which can cause a potential loss in detail and context. The result is that the interpretations of output maps remain subjective, although in defence, the method does provide powerful, macro perspectives of a research area. Moreover, the methods used in the field of scientometrics are repeatable and are not dependent on the choice of experts and their opinions which may vary as the choice of the participants changes in peer reviews (Pouris, 1988).

The second limitation is that the study uses a form of horizon scanning to identify and evaluate research questions that are currently being asked by researchers. The strongest criticism from delegates was that the approach and methods used at the final workshop were not designed to identify horizon scanning research questions *per se*. Rather delegates said

that they felt coerced into responding to the questions that were put before them. Moreover, delegates felt that it was difficult to develop new questions that were of an horizon scanning, being of a long-term nature for a number of reasons: the groups were too diverse; there was insufficient time to consider and develop meaningful questions; and the process was too demanding for the facilitators resulting in tasks being carried out in a mechanistic manner against a tight timeframe. To counter this perspective, the study sought raise water research questions from as wide a range of researchers and practitioners as possible rather than the voice of ‘experts’. Horizon scanning has many inappropriate elements for the South African context as it is limited to a degree by its reach into the community of practitioners and in the quality of participation. Further prioritisation activities may need to begin with expert input and then be informed by a wider audience at the earliest stages of the process.

2. LITERATURE

The evolution and state of water research in South Africa highlights potential shortfalls and prominent changes over the last four decades. This section introduces a metrics analysis method for studying research in a quantitative manner as well as a futures method for planning strategic research movements.

The discussion continues with global water perspectives, paradigms and approaches over the past century with reference to the South African water history. It explores the influence of water resources on societal and developmental change, and the evolution of paradigms.

In the final section, the literature discusses a selection of theoretical principles of sustainability and how these differ from the current approaches to water research in South Africa. Theoretical arguments about understanding and managing complex systems are outlined, with special attention to adaptation, capacity, collaboration and horizontality. Adaptive management within research, the necessity for horizon scanning and planning will form the central conceptual framework of this research project.

2.1 Reflections on research: emerging paradigms

> *Many believe that science and technology (S&T) must play a more central role in sustainable development, yet little systematic scholarship exists on how to create institutions that effectively harness S&T for sustainability.*
>
> (Cash et al., 2003 pp. 8086)

The rationale for scientific enquiry, as described by Bortolotti (2008) and Losee (2004), is to further the progress of humankind and improve livelihoods and benefits to society in general. Progress itself is the dominant feature of scientific endeavour that shapes much of the overall research intent, resulting in an improvement in the standards of living, dignity, intellectual and spiritual capabilities and knowledge of a group, society or nation. This is a view of 'development' which is often closely associated with the idea of progress. However, even though research contributes to society, it still needs to be accepted by society (Cash et al. 2003). Research needs to be credible and legitimate as explained below:

> *Credibility involves the scientific adequacy of the technical evidence and arguments. Legitimacy reflects the perception that the production of information and technology has been respectful of stakeholders' divergent values and beliefs, unbiased in its conduct and fair in its treatment of opposing views and interests.*
>
> (Cash et al., 2003 pp. 8086)

The foregoing sets the tone and scope from which to consider the purpose of scientific research. It is not possible to enter into a philosophical debate about the purpose in much detail, suffice to remind the reader that water resources and management thereof have reached a critical stage in South Africa. A new, urgent and effective response is now necessary. Thus, this study pursues a narrowly defined explanation of scientific research being that of "a human activity that aims at contributing to a coherent body of knowledge in a novel way by adopting a critical method" (Bortolotti, 2008 pp. 15). One reason for taking this view is that research is a form of development that contributes to the progress of humanity which is material, spiritual, relational and intellectual. Some commentators and researchers concur in recognising a shift towards research activities that apply more directly towards policy needs and concerns, and provide evidence and innovation in support of development (Pullin et al., 2009; Turton, 2009; Barbier and Homer-Dixon, 1996; Homer-Dixon, 1995). These authors suggest that solving challenges, particularly those wicked problems and complex issues, is through innovation, and the generation of ideas and knowledge (Barbier and Homer-Dixon, 1996; Homer-Dixon, 1995). Strengthening ideas, problem solving and, importantly, managing development directives as well as societal and environmental challenges, depends on the application of the human capital collective. The latter is termed 'adaptive capacity' (Turton, 2009) which is the capacity or ability of a sector or society or nation to solve problems, meet demands and enable appropriate development. If adaptive capacity is diminished, or grows at a slower rate than the emergent needs and problems, then development could easily regress and progress declines. The emphasis here lies in how knowledge gaps, research resources and adaptive capacity are measured, planned and implemented. Homer-Dixon (1995) aptly states:

> *I do not have precise measures for ingenuity; the argument here is heuristic and illuminative, not quantitative. But I believe researchers can eventually operationalize the key variables and specify the general shapes of the key functions. In time, on the basis of measurable data, we should be able to predict when and where ingenuity gaps will appear.*
>
> (Homer-Dixon, 1995 pp. 589)

Paradigms, used in this study, explain the dominant approach and underlying features of water research or scholarship. A paradigm comprises, and is identified by a number of different research domains each with differing relative significance over time. According to Kuhn (1962), when enough significant anomalies have accrued against a current paradigm, then the scientific discipline could be thrown into a state of crisis. During this crisis, new ideas, and even those previously discarded, are tested further. A paradigm shift occurs only after a given discipline has changed, and only when this change is widely recognised can it

be called a scientific revolution or a paradigm shift. New paradigms are part of the scientific revolution although there is often a delay before the scientific community accepts the change. Paradigms often only gain ground because of some dramatic and unforeseen verification, or for personal or aesthetic reasons in which they may appear neater, simpler or more elegant than their older counterparts do. A sudden moment in the shifting of paradigms can be likened to a Gestald switch, with sudden changes in perception, when that which was previously hidden now becomes visible, even obvious (Kuhn, 1962).

When new paradigms appear, however, they are rarely complete. More often they are the products of relatively sudden and unstructured events that arise from an enlightened moment in which previously hidden components of knowledge suddenly come into view because of a variety of factors including new discoveries from research (Kuhn, 1962). New knowledge sometimes has the power to cause an anomaly that leads to unexpected change in the worldview of those holding one or another paradigm. Thus, a change of worldview is initiated when a significant anomaly is recognised within an existing paradigm. The challenge is often to identify the anomaly and then to recognise the significance or importance of the phenomenon. Kuhn (1962) explains that anomalies are the ingredients of "scientific revolutions" and that these revolutions cause a shift in the dominant paradigm.

2.2 Shifting foci in South African water research

Literature describing the current state of research in South Africa is found largely in detailed analytical research undertaken by the Human Sciences Research Council (Blankley and Moses, 2009). In an assessment of South Africa's publication and citation standing, Jeenah and Pouris (2008) conclude that South Africa is certainly the most published and cited scientific nation on the continent and has shown remarkable increases in international importance and exposure for certain scientific disciplines in the past decade (also Pouris, 2005). However Erwin et al. (2005, pp. 14) state that "the respect for our universities and their distinction in the world of knowledge is timid..."

Central to the debate about the state and purpose of science includes an acknowledgement of a number of structural changes that have taken place during the post-apartheid period within higher education in South Africa. Institutions underwent substantial change in personnel, especially with the departure of intellectuals and the introduction of previously excluded ones. Funding structures were dramatically altered and political influence in the structure of all universities and science councils increased (Sooryamoorthy, 2010; De Villiers and Steyn, 2009; Erwin et al., 2005). Research agendas were encouraged to focus on the greatest needs in the nation, providing substantial challenges to researchers

and their associated human, financial and institutional capital. Habib and Morrow (2006, pp. 25) argue that "the intellectual scene was set by an intolerant and racist orthodoxy, and even the radical and liberal players, protest as they might, had to perform on this stage". It is therefore ironic that contemporary South Africa is now, in research terms, less productive than the isolated and provincial country of the apartheid era. It is possible that greater coordination and strategic management of research in South Africa is necessary since this is the 'lynchpin' of the entire research process and enables development. Shackleton et al. (2011) state that researchers or institutions should be better at anticipating research needs and challenges in South Africa in order to produce more appropriate and timely research. With reference to the role of universities, Shackleton et al. (2011, pp. 7) argue that identification and prioritising of research needs is paramount and that "in prioritising the … challenges facing the nation for the next decade, universities can consider their curricula and research programmes to produce the necessary knowledge and skills to address these challenges. Some of these are already apparent, but are likely to intensify in the coming years".

2.3 Scientometrics: analysis of research

> *Painting the big picture of an ever-evolving scientific discipline is akin to the situation described in the widely known Indian legend about the blind men and the elephant. As the story goes, six blind men were trying to find out what an elephant looked like. They touched different parts of the elephant and quickly jumped to their conclusions. The one touching the body said it must be like a wall; the one touching the tail said it was like a snake; the one touching the legs said it was like a tree trunk, and so forth. But science does not stand still; the steady stream of new scientific literature creates a continuously changing structure. The resulting disappearance, fusion, and emergence of research areas add another twist to the tale - it is as if the elephant is running and dynamically changing its shape.*
>
> (Borner et al., 2003 pp. 180).

Scientometrics is the field of analysing science and scientific output. It was founded on the works of Derek de Solla Price and Eugene Garfield in the mid-twentieth century. Garfield established the Institute for Scientific Information in 1960, effectively the Thompson ISI, Journal Citation Reports and Web of Science databases and platforms of today. The term scientometrics was first coined in the 1960s by Vassily V. Nalimov and is today often used interchangeably with those of bibliometrics and informetrics (Hood and Wilson, 2001). The three fields all refer to the study of science, knowledge and knowledge management and production. In a review of the concurrent literature on these subjects, Hood and Wilson (2001) even observe that "much of scientometrics is indistinguishable from bibliometrics, and much bibliometric research is published in the journal, *Scientometrics*" (pp. 293).

Bibliometrics however focuses on the literature and content of research, while scientometrics explore author relationships, geographic differences, socio-political considerations and other attributes of literature outputs. Informetrics is the study of the flow of knowledge and information from one use to another. This project uses scientometrics which is considered as the “study of the quantitative aspects of science as a discipline or economic activity. It is part of the sociology of science and has application to science policy-making. It involves quantitative studies of scientific activities, including, among others, publication, and so overlaps bibliometrics to some extent” (Tague-Sutcliffe, 1992 pp. 1). Since the project aims are to analyse the evolution and academic output of water research within a socio-political and historical context, it is appropriate to use scientometrics as a concept and term.

Within the quantitative analysis of research output and products, “a research field can be defined by various approaches: on the basis of classification codes and/or selected keywords in a specific database, selected sets of journals, a database of field-specific publications, or any combination of these approaches” (Van Raan, 2003 pp. 26). These indicators of research fields or classifications can then be applied to the research literature using scientometric (statistical, algorithmic and visual) methods. A detailed explanation follows in a later section of this report.

Small (1993) identifies a fundamental premise in that knowledge can be represented as a network of concepts and ideas and that these can be combined or aggregated to form a ‘macro-structure’. He goes further to argue that “it is not important that this network resemble a geographic map, or cleanly separate individual topics, any more than a map of the brain’s neuron connections would neatly organize human knowledge, but rather that the network is represented as truly and accurately as possible” (Small, 1993 pp. 295). Here the author is suggesting that a structured method, sound statistical and content analysis, and appropriate processing and visualisation of data are required to analyse knowledge.

The scientometric method begins with the collection of a series of appropriate publications or reference material and then performing network analysis thereon. Sets of keywords and/or noun-phrases amongst the journal articles are analysed with respect to their frequency to each other within the article and towards other articles. This is known as a topic/word/concept co-occurrence network. This analysis uses statistical algorithms such as cluster analysis and multidimensional scaling and forms the foundation of scientometrics. This also enables a research field or sub-field to be categorised, analysed and mapped as a collection of keywords. These are the ‘fingerprints’ of publications and hold the key to relevant similarities. The method is based upon the principle that the more (relevant) keywords or key-phrases two documents have in common, the more similar they are and therefore the more likely they are to be from the same research topic. These explanations

are expanded upon in the significant literature of Noyons et al. (1999), Van Raan (2000), Borner et al. (2003), Mane and Borner (2004), and Rafols et al. (2010).

Further studies have tested the strength of accepted scientometrics methods. They show that scientometrics, as an analysis of a scientific or discipline outline or description, is robust and reliable even on a coarse level (Klavans and Boyack, 2009; Rafols and Leydesdorff, 2009). A concern beyond this is whether they are indeed relevant in research planning and understanding. Arguably the main societal impact of scientometrics has been the creation of the impact factor and analysis of research, researchers, publications and journals. It is directly from certain scientometric methods that citation counts, impact factors and research indices have been developed and are now used as a mainstream analysis tool for research in most environments (Lane, 2010; Rafols et al., 2010; Campbell, 2008; Lautrup, 2006; Van Raan, 2003).

These debates enter the realm of value-based research philosophy and have added further fuel to the tension between performance management and academic freedom within institutions. Nevertheless, the purely objective methods themselves have been shown to be replicable, reliable and comprehensive enough in evaluating a research field from the 'topic' or categorisation approach. This project does not attempt to address water research from a researcher performance or institutional assessment approach but, as explained earlier, uses scientometrics to map research domains and changes within water research based on content and outputs.

The use of scientometric maps in displaying results has a number of advantages in research analysis. Researchers such as Roessner (2000), Stirling (2008) and Rafols et al. (2010) argue that scientometric maps are an important means of conveying the results of the method.

> [The maps]…*position units in a (two-dimensional [2D]) network instead of ranking them on a (one-dimensional) list. As in any data visualization technique, maps furthermore facilitate the reading of bibliometric information by non-experts with the downside that they also leave room for manipulating the interpretation of data structures. Second, maps allow for the representation of diverse and large sets of data in a succinct way. Third, precisely because they make it possible to combine different types of data, maps also enable users to explore different views on any given issue. This interpretive flexibility induces reflexive awareness about the phenomenon the user is analysing and about the analytical value (and pitfalls) of these tools. Implicitly, science maps convey a key message: bibliometrics cannot provide definite, 'closed' answers to science policy questions, such as 'picking the winners'. Instead, maps remain heuristic tools to explore and potentially open up plural perspectives in order to inform decisions and evaluations.*
>
> (Rafols et al., 2010 pp. 1873).

These maps are the main means of representing results in this research and will be accompanied by associated statistics and interpretations.

2.4 Horizon scanning

Initially, horizon scanning was identified as a method and activity that could be used to identify future research questions and strategies. Discussion in the analysis of this report will turn to the limitations of the method or at least in the way it was conducted within this project.

There are three fundamental stages to the method of horizon scanning: question collection, categorisation and prioritisation. These are most often classified according to fields, disciplines and prioritised according to their urgency and relevance towards society (Sutherland et al., 2011b). Moreover, and because this method is pertinent to embracing ongoing and widespread social transformation in South Africa, the approach is developed through collaborative, multi-stakeholder processes that identify and examine threats or trends in society, the environment or a sector, and identify needs that will enable the appropriate management (Shackleton et al., 2011; Sutherland and Woodroof, 2009).

Sutherland and Woodroof (2009, pp. 525) have documented the use and application of horizon scanning which "...include strategy making, policy making, risk management, threat identification and research prioritisation...although it is increasingly finding applications in government, industry and business". They also identify the main challenges of horizon scanning being that of obtaining credible and reliable evidence, and designing and adopting objective, collaborative, scalable, transparent and efficient methods. As an overall approach, they emphasise that "the objective is not to predict the future but to assist current decision-makers to produce strategies and plans that are sufficiently flexible and adaptable to remain robust in a range of possible plausible futures that have been identified."

Shackelton et al. (2011, pp. 3) argue that "in order to participate in global debates and research programmes to understand and solve environmental challenges, both at home and abroad, environmental scientists in South Africa need to be constantly anticipating the next challenge and how they may best play a role. Horizon scanning is a potentially useful tool for this purpose." The use of forecasting and science planning and horizon scanning are therefore relevant methods and activities in the arenas of knowledge management, strategic research planning and sustainable research management (King and Thomas, 2007). In hindsight, the European Environment Agency (2001) identified two key lessons in its analysis of how preventable environmental problems or issues could have been avoided, mitigated or managed through appropriate and timely research. These lessons were to

research and monitor for early warnings and *search out and address blind spots and gaps in scientific knowledge*.

In this project the focus on horizon scanning in the South African water sector follows the methodological elements that are detailed in Sutherland and Woodroof (2009, pp. 525) which are to (i) scope the issue; (ii) gather information; (iii) spot signals; (iv) watch trends; (v) make sense of the future; and (vi) agree on the response. A more detailed discussion on these concepts and methods is presented in the section on research methodology. A similar research method and process is followed by Brown et al. (2010) where the identification of water research questions for the United Kingdom was performed using horizon scanning. The researchers state that "several recent studies have emphasised the need for a more integrated process in which researchers, policy makers and practitioners interact to identify research priorities" and detail "how questions were developed through inter-disciplinary collaboration using online questionnaires and a stakeholder workshop" (pp. 256). As an output, they publish the key research questions and comment on their scale and scope while prioritising them into research themes and categories.

This research aims to produce a similar output and motivate for a system as seen in Pretty et al. (2010) and Sutherland et al. (2011a) where annual or regular horizon scanning activities are undertaken, reviewed and published. This could arguably enhance the water research and water management futures of South Africa by providing a co-ordinated, evidence based approach towards water research and aid in the sustainability of research as an undertaking as well as address the pressing water research needs in the country.

2.5 Reflections on evolving paradigms in water research

2.5.1 Global water paradigms over the past century

> *We are now living between past and the future. With our knowledge of the past, we have to look into the future and try to forecast the possible and, especially, the desirable options and strategies for them. The relevance of our decisions - whether minor or major - will be assessed by future generations. Understanding of the past is also a basic requirement for any useful strategic and visionary thinking of preferable futures.*
>
> (Katko et al., 2010 pp. 230)

The history of water entwines within the complex history of human development and society (Tempelhoff et al., 2009). In general, modern and largely urban societies have shifted through various paradigms including phases of water abundance through to water scarcity. Turton and Meissner (2002) capture this transition in a single schematic (Figure 1).

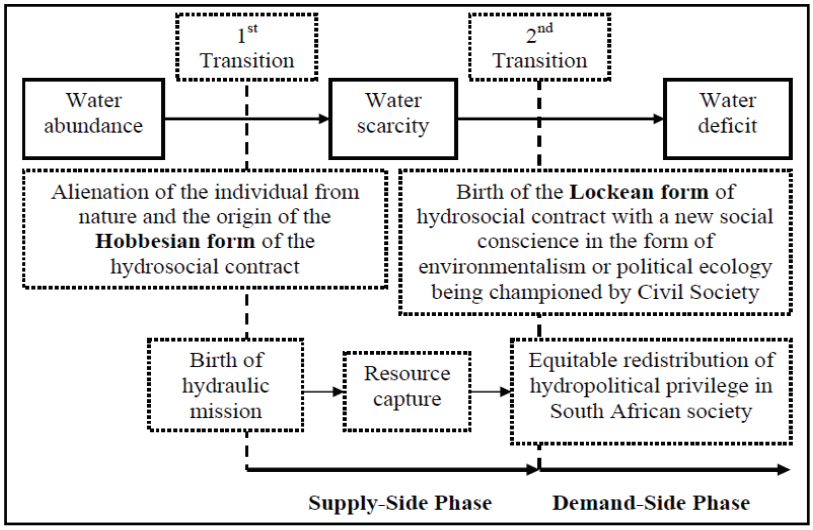

FIGURE 1: Transitions in the hydrosocial contract (Turton and Meissner, 2002)

The shift in hydro-social contract from the Hobbesian form of contract (between government and the public) to the Lockean form (where civil society groups become actors) reflects the change in hydro-political privilege (Turton and Meissner, 2002). These two forms of hydro-social contract are the beginnings of the hydraulic mission and water sustainability approaches respectively.

The hydraulic mission is characterized by major engineering activities that began at the start of the 20th century by constructing the infrastructure to capture, store and distribute water. This represented the 'heroic engineering' phase (Turton, 2009) noted for the immense scale of projects and plans, and also because it was supported by modernist or positivist belief that it was possible to control and manage nature. This period of major construction is also referred to as the supply-side phase of water management since the majority of water affairs projects were concerned with supplying more water, more efficiently to more areas (Tempelhoff et al., 2009; Van Vuuren, 2009).

The demand-side of water resource management, which in itself represents a paradigm, focused attention on how to manage water demand and use. This shift was influenced to an extent by various environmental movements, but was also driven by increasing recognition of resource scarcity, the growth of sustainable development considerations, post-modern philosophies and increased prominence of environmental justice, equity and democratisation of resources (Tempelhoff et al., 2009; Ohlsson and Turton, 2000).

Ohlsson and Turton (2000) describe how the predominant phases of water management do not only result from technological change, but also in response to water scarcity as a result of increased consumption. They explain that these paradigms have

developed as a progression from the need for more water, to more or better use of the water, to obtaining more value from the water as illustrated in Figure 2.

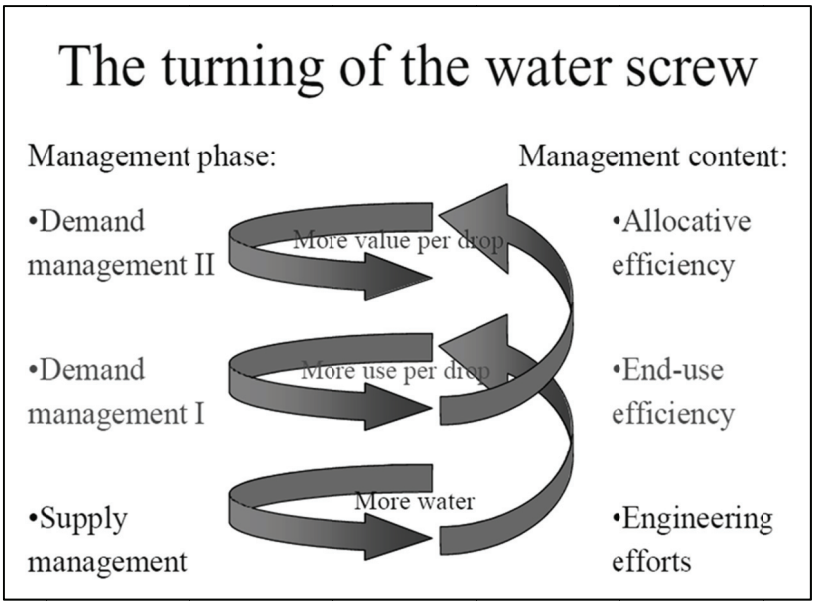

FIGURE 2: The shifting paradigms in management of water resources (Ohlsson and Turton, 2000)

Ohlsson and Turton (2000) describe how the predominant phases of water management are not caused by technological innovation alone, but are also in response to water scarcity. They show how paradigms have shifted and changed from the need for more water, to more or better use of the water, and then to obtaining more value from water. Here different management approaches are used which include that of the engineering efforts, end-use efficiency and allocative efficiency. With each progression, more technical and adaptive solutions are required to meet the challenges.

Allan (2005) offers a further paradigmatic study on water resource management. His work focuses on the development of an analytical method to address the problem of water resource allocation. While Ohlsson and Turton (2000) emphasised the social reactions and expectations required to overcome water challenges, Allan's contribution lies in identifying paradigms that are reliant on economic, legal and political factors that influence the water sector in semi-arid countries. This shift in paradigms is represented in a transition through five water management paradigms, each with its own distinct focus and function (Figure 3).

The first of the five paradigms is referred to as the 'pre-modern paradigm' which is dominated by a general increase in supply and water usage and occurs in an era of the "hydraulic mission" where ingenuity and engineering efforts abound. The second paradigm is characterised by industrial modernity and again features an increase in activity in the hydraulic mission. In this phase, water demand increases because agriculture activity shifts

from subsistence to commercial-based, followed by further demands on water resources due to the rapid increase in industrial activity. This period represents the era of the “golden age”, since it is the longest period in the survival of any of the five paradigms.

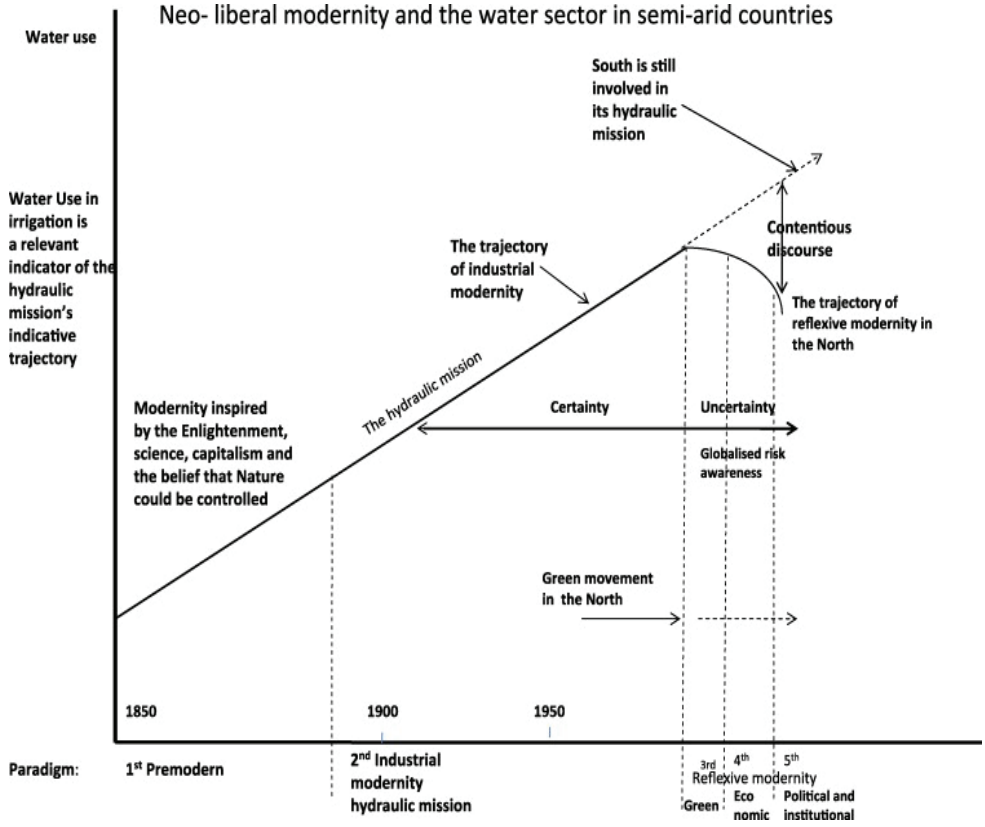

FIGURE 3: Five water management paradigms (Allan, 2005)

The third paradigm shows a shift towards sustainable resource management and a concerted effort to redress the damage done by previous paradigms. The fourth dimension is characterised by a period of economic expansion (particularly in the North), and in smart economic decisions that offer several environmental advantages but is also characterized by a general decline in the hydraulic mission. Finally, the fifth paradigm is dominated by political and institutional change which becomes increasingly aligned with global shifts towards sustainability and a rapid decline in the hydraulic mission.

Allan’s work is instructive in that it suggests how paradigms account for past trends in water resource management, but can also be used as a predictive tool to advance future prospects and problem solving. There are elements within Allan’s thesis that are applicable to the interpretation of the history and development of South Africa’s water resource management and these will be considered in more detail in the discussion section of this project report.

2.6 South African water approaches and paradigms

> *According to the National Water Resource Strategy of 2004, the total annual demand for freshwater in South Africa in 2000 amounted to 12 871 million m^3, just slightly less than the available yield of freshwater of 13 227 million m^3. This means that 98% of the national water resource was already allocated or in use in 2000, with little surplus water left.*
>
> (Institute for Futures Research, 2009 pp. 31)

As already mentioned, severe water constraints mark the present and future management challenges in South Africa, however the nation is still lauded as the first country in the world to have promulgated national water legislation which uses water as a means to achieve societal transformation based on environmental and social justice (Funke et al., 2007). The current legislation replaced many previous, inconsistent acts that focused on water security, supply-side interventions and water as an economically exploitable resource. The degradation of many of the nation's waterways in the 1980s and the rising capital expenses in supply schemes, coupled with the growing environmental concerns globally, spurred legislators to rethink water paradigms (Herold, 2009; Funke et al., 2007; Schreiner, 2006).

The change in water resource management in South Africa is reflected in the principles of the National Water Act No. 36 of 1998 (Republic of South Africa, 1998). These focus on the decentralisation of management and decision making, participatory decision making, the adoption of a new paradigm towards the commons, efficiency, cost recovery, environmental justice, the adoption of an environmental reserve, enabling underlying sustainability and ensuring equitable access (Funke et al., 2007). These authors go further to state that the shift towards the post-modern philosophical approach of new-environmentalism is evident in the global paradigm shifts:

> *In many ways this shift in water policy mimics the shift in thinking in certain progressive research circles: from one which focuses on the physical laws of nature and the principles that drive society and what we are capable of doing through technological intervention, toward one which is driven by a strong set of values and the question of 'what ought we do?' This shift is well articulated in descriptions of the emerging sustainability science research field, which seeks to overcome disciplinary myopia by focusing on social-ecological systems as interconnected, complex functioning wholes.*
>
> (Funke et al., 2007 pp. 21)

According to Ashton et al. (2006), governance should be undertaken through the use of a *trialogue* model in order to build relationships between government, civil society and science in a "set of partnerships, and that promotes close collaboration and interactions between

each of these sectors" (Ashton et al., 2006 pp. 31). They argue that science should be relevant not only to governance and decision making but also to the public. In other words, the contribution of science should be that of providing society with the tools and knowledge to overcome water challenges. In addition, Ashton et al. (2006 pp. 33) state that "the key role of the science cluster within the proposed trialogue model...is to gather, interrogate, and integrate knowledge and information into forms that provide useful and practical guidance to society and government."

Presently, South African institutions, government, leaders and communities are not able to meet the demands and stipulations of the National Water Act. The Act introduces a paradigm shift towards a socially equitable and just resource management society (Fallenmark and Rockstrom, 2006; Turton et al., 2006; Beukman, 2002), but in the meanwhile the country is experiencing a period of water deficit that requires urgent management and mitigation interventions.

2.7 The evolution of South African water research

Some ideas take off quickly, others take longer to grow and develop.

(Water Research Commission, 2010 pp. 2)

Limited historical data are available to describe water research in South Africa over the first half of the 20th century. Many authors discuss the dominant scientific and engineering approach and it can be assumed that this was period was informed by technological developments, breakthrough research and projects in water storage and transfer, as well as the positivist philosophical approaches towards nature and development (Tempelhoff et al., 2009; Tewari, 2009; Tempelhoff et al., 2007; Tempelhoff, 2006; Turton et al., 2006; Allan, 2004; Turton and Meissner, 2002; Allan, 1999). It was observed for example that "irrigation development played a major role in the moulding of early water policy, infrastructure, economic and social development in South Africa" (Tewari, 2009 pp. 696) and that this was founded on imported skills, knowledge and training from Europe.

With the promulgation of the Water Research Act No. 34 of 1971, in part a reaction following a severe period of intense drought, initiated a new era in water research and management in South Africa. The Act resulted in the formation of the Water Research Commission (WRC) and the Water Research Fund to support water-related research in the country. The objectives of the WRC, as stated in the Act, are: "to co-ordinate, to promote, to encourage...research in respect of...the occurrence, preservation, conservation, utilisation,

control, supply, distribution, purification, pollution or reclamation of water supplies and water...the use of water for agricultural purposes; - industrial purposes; or - urban purposes" (Republic of South Africa, 1971). These objectives are now refined in the quoted mandate of the WRC as:

- *Promoting co-ordination, co-operation and communication in the area of water research and development;*
- *Establishing water research needs and priorities;*
- *Stimulating and funding water research according to priority;*
- *Promoting effective transfer of information and technology; and*
- *Enhancing knowledge and capacity building within the water sector.*

> *The Mandate of the WRC clearly links the organisation to both the water and knowledge cycle...The WRC serves as South Africa's water-centred knowledge hub providing the nation with knowledge for sustaining its most precious resource, i.e. water.*
>
> (Water Research Commission, 2010 pp. 29)

The Act established the mechanisms with which to finance the then bold new research drive. Effectively, through consultation with other ministers and relevant departments, the Minister of Water Affairs may "(a) levy rates on land which may be irrigated by means of water supplied or made available by the State, an irrigation board or a water board; (b) levy charges on water supplied or made available for use for agricultural purposes, urban purposes, industrial purposes or any other purposes by the State, an irrigation board, a water board, a local authority, the Rand Water Board or any other body" (Republic of South Africa, 1971). The majority of state funding for water research originates from these levies. When the WRC was established, it too resulted in many formal water research organisations being established at universities mainly to perform the research requirements of the WRC and to enhance their own capacity.

Water-related research is now undertaken by every state university and a number of science councils, private companies, non-profit/government organisations and research institutes. Major capacity and strategic focus changes occurred in the research and science council environments in the 1980s and 1990s due to political and economic instability and changes. Studies have shown that different funding models, management structures and policies within these organisations have mostly negatively affected research output (Turton, 2009; Walwyn and Scholes, 2006). The WRC is the largest contributor towards water-related research in South Africa as a single institution, with an annual operating budget of over R150 million (Water Research Commission, 2010), supporting, funding or leading around 300

research projects of lengths ranging from 1 to 5 years on average and building human capital of over 500 graduate students at any given time through its projects.

The WRC is the most significant national institution in water research as confirmed in a recent report commissioned by the WRC to investigate the extent of R&D in water-related agricultural research. The report (Water Research Commission, 2011) shows that around R210 million was spent in 2010/2011 on water-related agricultural research, with the WRC itself funding approximately R130 million. These results show that just less than 40% of research funding (and subsequent research outputs) originated from other sources in this research area. Major contributors include universities, donors and other state institutions.

2.8 Summary

A dominant argument is that science and research should develop in the service of the betterment of society and its members. R&D is a strong driver of this progress and innovation. It is an enabler of development and a means towards solving challenges and overcoming problems. The management, organisation and implementation of this R&D are complex and also highly political. It is often very discipline specific, un-integrated and fragmented (both internationally and in South Africa).

Water research in South Africa has urgently to address the threats and opportunities that exist presently or could exist into the future. To do so requires an adaptive co-management approach, such that it will result in improved understanding and adaptation towards uncertainty and complexity, and use a collaboration of networks, and should not only be applied towards water resources as prescribed in IWRM principles, but also towards research resources (human capital, funding planning etc.).

Creating a context through scientometrics and generating strategic research futures and questions through horizon scanning (as defined and used in this research) are the proposed methods and these require collaborative support from, among others, the research practitioners themselves. The discussions in this chapter have attempted to stimulate and develop debate around research in society, research strategy, water scenarios and futures for water research in South Africa.

3. METHODS AND APPROACHES

3.1 Overview

The discussion begins with the scientometric methods used to gather data and to construct the tool, followed by a detailed account of the methods used to collect, analyse and evaluate research questions currently being asked by a broad range of research stakeholders in South Africa. The final section describes how the results were processed in order to critique water research questions and priorities.

3.2 Scientometrics

3.2.1 Conceptual basis, definitions and key methodological literature

A conceptual narrative on water research in South Africa is central for the discussion on water research paradigms, knowledge and appropriate adaptive capacity. To date, no quantitative assessment of research histories has been performed across the water sector in South Africa.

Many authors (for example, LaRowe et al., 2009; Herr et al., 2008; Hood and Wilson, 2003; Van Raan, 2003; Todrov, 1989) have discussed how these approaches provide an objective and evidenced-based means of assessing the state of a research or scientific field. Scientometrics is "the study of the quantitative aspects of science as a discipline" (Hood and Wilson, 2001 pp. 299). These methods are based on two assumptions. Firstly, that "scientific knowledge can be represented as a network of concepts or ideas, and that these elementary entities can be aggregated to form macro-structures" and secondly, if mapped or represented in a structured manner then "it is assumed that each map is a snapshot at a distinct point in time of what is actually a changing and evolving structure of knowledge" (Small, 1993 pp. 295). The key data for this method are research outputs, either in the form of publication, collaboration, intellectual property, policy influence and application.

Scientometrics is usually applied to the examination of networks and clustering in publications. This is a combination of content analysis and network science. Examples of these are author citation networks, geographic networks of publication, topic or content networks, and the temporal evaluation and evolution of these. These networks are created by analysing the different attributes (title, author, institution) of research publications and using statistical clustering to develop network matrices based on the original criteria of analysis. In this project, scientometrics is used to analyse publication data for a number of different queries. The queries asked in these methods are:

- What are the dominant research topics or areas of specialisation in the dataset and how are these related to other topics or areas of specialisation over the entire timeframe?
- What topics or areas of specialisation have emerged or disappeared from the dataset?
- What are the dominant research topics in given time periods and how do these relate to other topics or areas of specialisation within the same time period?
- What are the most recent and dominant topics or areas of research interest?

Many examples of topic evolution and analysis can be found in the literature, particularly in the journal of *Scientometrics* which is the main publication for these methods and analyses. Janssens et al. (2006, pp. 1615) discuss the discipline and state that:

> *The extension of co-word analysis towards the...texts of large sets of publications was possible as early as large textual databases became available in electronic form. The descriptive power of controlled terms or of the vocabulary used by authors to summarise their work in title and abstract, makes it possible to use text mining and co-word analysis as sophisticated tools both in structural...and dynamic bibliometrics.*

The growth of scientometrics has resulted in the development of many different commercial and open-source research endeavours and initiatives to refine algorithms, create software and standardise methods and processes within scientometric study. Cobo et al. (2011) provide a comprehensive review of the development of these initiatives and also assess different software tools that have been created for scientometric analysis and processing. Their analysis supports the use of the software *Science of Science Tool* (*Sci2 Tool)* (http://sci.slis.indiana.edu) for co-word or co-occurrence analysis of publication data and the *VOSViewer* (http://www.vosviewer.com) software for the mapping and visualisation.

A comprehensive review of literature on database platforms and testing supports this projects' use of the Web of Science (WOS) (operated by Thompson Reuters) as the search platform for peer-reviewed journal literature as it is considered to be the most comprehensive, reliable and integrated platform available (Adriaanse and Rensleigh, 2011). The majority of scientometric studies searching for journal publication data use the WOS (Leydesdorff and Rafols, 2011; Borner et al., 2010; Sooryamoorthy, 2009; Herr et al., 2008; Boyack et al., 2007; Borner and Mane, 2004;). This database "currently indexes more than 6,000 of the world's leading scholarly scientific and technical journals, approximately 1,800 social sciences journals, and 1,150 titles from the arts and humanities journals. All journals indexed by ISI are peer reviewed" (Inglesi-Lotz and Pouris, 2011).

South Africa produces other significant and relevant water related research, published formerly by the primary research funder (the WRC), that is not necessarily published in the peer-reviewed international journal realm. Instead these are published as research reports or technical reports by the organisation for all to access. Research output for South African water-related research is therefore defined in this study as:

- Water-related peer-reviewed journal articles as far as covered by the Science Citation Index (SCI), the Social Science Citation Index (SSCI), or the Arts & Humanities Citation Index (AHCI) found in the WOS database search platform. An 'article' falls under the following publication-types: normal articles (including proceedings papers published in journals), letters, notes, and reviews (but not meeting abstracts, obituaries, corrections, editorials).
- Formally published research reports (RR) of the Water Research Commission of South Africa.

It was decided not to include other possible outputs of scholarly work e.g. conference proceedings, notes, discussion papers and symposia briefings in the dataset. The main reason for this, although these could still be considered relevant, was that it offers a significant challenge to comprehensively collect and analyse data presented in these forms. These items of data exist in many different repositories and are often not standardised let alone collated. Their collection and analysis would have included significant bias towards easier accessible data. The defined research outputs above are sufficient in providing a significant historical narrative of water research and are the most recognised outputs of water-related research in South Africa.

3.3 Method

3.3.1 Data collection

Locating relevant water-related publications objectively and comprehensively is a challenge within itself. This challenge stems from the definition of water research used herewith. The authors have purposely avoided defining water-related research in a narrow sense in order to gather a macro perspective of the field. It then follows logically that any publications mentioning *water* and *South Africa* would to a certain degree be appropriate and relevant. A search of in the WOS identified over 13 000 individual journal papers but many of these were irrelevant or dealt with completely unrelated topics. Further refinement of this method was therefore based on the scientometric literature and methodological debates.

Journal articles within a database have a number of searchable attributes assigned to them such as the author name, geographic location, title, abstract, author-assigned keywords, database-assigned keywords, full-text, references and citations. The techniques and methods of extracting relevant data must be rigid and justified due to the large number of variables that exist.

The *journal search set* (Annexure A) comprised of a two-fold approach: firstly, journals that had five or more articles in them when searching *water* and *South Africa* (or derivatives thereof) were selected (five being the rounded standard deviation of article count per journal in the initial record of 13 000). Secondly, snap polls and pilot surveys undertaken towards the end of 2011 included asking practitioners where they published and read South African water-related research. The results from the significant publication count criteria and stakeholder input resulted in 171 publications forming part of the *journal search set*. These journal titles were then added to the query and searched further. The final search query searched for journal articles that contained *water* and *South Africa* in their topic within the *journal search set*. The verbatim query used in the WOS can be found in Annexure B - only 140 publications in the *journal search set* had relevant matches to the search.

The preliminary investigations into journal queries were performed over the entire database records' chronology. While it was initially decided to analyse publications since the promulgation of the Water Research Act in 1971 (as logical starting date), it was discovered that there is almost no relevant journal publication record before the year 1977 (seven journal articles in total and 47 *Water SA* articles) and almost none were available from the WRC. Publication records from the years 1977 to 2011 (35 years) were therefore analysed.

The results from the search query provide lists of journal articles in the database. These articles have extractable attributes that were then exported as text files and contain (amongst others) details on the articles including title, author(s), publication year and abstract. The most important data is the publication name, the title, the publication year and abstract. No attempt was made to analyse citations and author networks and the author, reference and institution attributes are ignored along with the journal title itself as these were predefined in the *journal search set*. These exported attributes were then combined with the WRC research report publication dataset of the same timeframe.

3.3.2 Data analysis

Scientometric queries require that the content or topic of research outputs must be analysed. The most widely used method here is the co-word analysis of research publications, particularly within their title and abstract (Janssens et al., 2006; Wallin, 2005; Borner and

Mane, 2004; Noyons and Van Raan, 1998; Todrov, 1989). The methodological foundation of co-word analysis is the idea that the co-occurrence of words describes the contents of documents. By measuring the relative intensity of these co-occurrences, it is possible to establish a simplified representation of a field's concept networks (Janssens et al., 2006).

Co-word analysis examines the frequency of individual words or word-phrases within a *data point* (publication) and concurrently across the dataset. The more frequently a word or phrase appears in a data point, the more relevant that topic becomes within the data-points. If similar frequencies of words or phrases appear across different data-points, the more these publications are related towards each other and become more related within the network. Borner et al. (2003, pp. 194) provide the most holistic definition of the statistical calculations related towards co-word analysis. The *tf*idf* model (term frequency by inverse document frequency) is the central equation in all scientometric analysis and is detailed as follows:

> *The discriminatory power of a term is determined by the well-known tf*idf model, in which tf denotes the term frequency and idf represents the inverse document frequency. Each document can be represented by an array of terms T and each term is associated with a weight determined by the tf *idf model. In general, the weight of term $T_k$in document $D_i$is estimated as follows:*

$$w_{ik} = \frac{tf_{ik} \times \left(\frac{N}{n_k}\right)}{\sqrt{\sum_{j=1}^{T}\left(tf_{ij}\right)^2 \times \log\left(\frac{N}{n_j}\right)^2}}$$

> *where tf_{ik}, is the number of occurrences of term T_k in D_i, N is the number of documents in a given collection, and n_k represents the number of documents containing term T_k. The document similarity is computed as follows based on corresponding vectors D_i = (w_{i1}, w_{i2}, ... ,w^i_T) and D_j = (w_j1, w_{j2}, ... , W_{jT}):*

$$sim_{ij}^{content} = \sum_{k=1}^{T} w_{ik} \times w_{jk}$$

> *Document similarity can be used to group a large collection of documents into a number of smaller clusters such that documents within a cluster are more similar than documents in different clusters. The vector space model provides an easy way to assess document similarities based on word matches.*
>
> (Borner et al., 2003 pp. 194)

The *Sci2 Tool* was developed at Indiana University Bloomington under the group named the *Cyberinfrastructure for Network Science Centre.* The creators describe it as below and full documentation, notes and tutorials can be found through the *Sci2 Tool* portal:

A modular toolset specifically designed for the study of science. It supports the temporal, geospatial, topical, and network analysis and visualization of datasets at the micro (individual), meso (local), and macro (global) levels. Users of the tool can

- *Access science datasets online or load their own*
- *Perform different types of analysis with the most effective algorithms available*
- *Use different visualizations to interactively explore and understand specific datasets*
- *Share datasets and algorithms across scientific boundaries.*

The Sci2 Tool is built on the Cyberinfrastructure Shell (CIShell)...an open source software framework for the easy integration and utilization of datasets, algorithms, tools, and computing resources. CIShell is based on the OSGi R4 Specification and Equinox implementation.

(http://sci.slis.indiana.edu)

Using the *Sci2 Tool* to create the word co-occurrence network requires a number of methodological steps listed below which are provided in the software, amongst other tools (these steps are outlined and described in Borner et al. (2003) and Van Eck et al. (2010a) and have been adapted for this study and to the datasets accordingly):

a. The manual (search and replace) removal of unnecessary words from the *data-points'* (e.g. academic paper) *attribute* (e.g. title). Words removed here (as they would unnecessarily skew the frequency results as they are the most common words in South African water publication searches) are: *water, south, africa, 1, 2, 3, ..., 0, river, orange, tugela, vaal, limpopo, cape, west, north, east, result, study*). The search terms, geographic indicators and common related proper names were removed along with numbers.
b. Load the specific dataset into the *Sci2 Tool* (entire or time-slice dataset, abstract or titles).
c. Pre-process the data by removing all stop-words (*and*, *the* etc.), lemmatising all words (converting them to their stem e.g. *sustain* from *sustainable* or *sustainability*), convert them all to lowercase and removing token words (*then*, *about*, *because* etc.). The remaining dataset only includes nouns, verbs and certain adjectives that are descriptive and are not within the software's thesaurus dataset of stop or token words.
d. Calculate the word co-occurrence network. This step uses the statistical techniques as referenced, along with multidimensional scaling and normalisation (Van Eck and Waltman, 2009) to account for shorter/longer attributes (e.g. long and short titles have different strengths) and to assign fair weighting towards them, to create a

network relationship matrix for all words within the attributes (titles and abstracts) in the dataset and amongst the different publications in the dataset.

e. Remove isolated or non-networked nodes or data-points/words.
f. Create a visualisation network or cluster diagram matrix from the network matrix. This step uses mapping and distancing algorithms developed from the significant research on network visualisation as seen in Borner et al. (2003), Waltman et al. (2010), Noyons and Van Raan (1998); Van Eck and Waltman (2010); Cobo et al. (2011); Leydesdorff and Rafols (2011) and expanded on below.
g. Isolate and extract the significant or strongest nodes (or number of edges) within the network and their relationship towards other nodes.

The final output from this process is a network visualisation file (.net) for the most frequent key-words within the dataset and their relative frequency towards other key-words. This is the fundamental output of mapping and visualising networks within scientometrics. The strength and background of visualising these networks can be found in the literature referenced in (f) above while the process and settings for using the software can be found in Annexure C.

The most common method of visualising or representing these outputs is through network maps. These represent the strength of topics and their interrelationship (associated strength) towards other topics. These maps are simplistic representations of the networks themselves. While they may initially seem sparse of information they have the benefit of displaying a network relatively effectively. Further interest and interpretation can come through exploring the maps in a software package.

> *As is the case with all bibliometric indicators, the appropriate use of overlay maps should not be taken for granted, particularly because they are tools that can be easily used by non-experts...This validation is about not just accuracy of representation but also, crucially, utility for practitioners, which depends on transparency and parsimony. Because there is generally a trade-off between accuracy, on the one hand, and transparency and parsimony, on the other, we argue that for a wide range of users, the most useful maps are not necessarily the most accurate, but are those that satisfy their needs with the most clarity and the least burden.*
>
> (Rafols et al., 2010 pp. 1877)

The majority of network maps use size and distance as indicators of certain attribute properties or relationships. As compared by Butter and Noyons (2002, pp. 1), the use of these maps is "the same as that for an ordinary street map: both are intended to guide the reader through a landscape." These maps can be defined as scaled dimensional representations of relations between scientometric results and are often based on an

association matrix. The matrix itself is used as the basis for a “hierarchical clustering system” (Butter and Noyons, 2002) which has specific criteria and then most often mapped onto a two-dimensional surface. Importantly, a bibliometric map has no axes. It is relative distance from other attributes on the map and attribute size that represents the relationships and properties. The statistical clustering techniques are applied to the relationship matrix created in the co-word analysis so as to create these relationships in the map as outlined in Butter and Noyons (2002) and Borner et al. (2003).

The use of *VOSViewer* (http://www.vosviewer.com), which stands for *visualisation of similarities*, as the visualisation software in is motivated and strength tested by Van Eck et al. (2010), Cobo et al. (2011) and Leydesdorff and Rafols (2011). Here the network file, created in the *Sci2 Tool,* is imported into the visualizer which applies similarity calculations to all the given attributes and maps them in the manner outlined in the previous paragraph. Mathematically, instead of applying multidimensional scaling only, the basic function of this software is to “minimize a weighted sum of the squared distances between all pairs of items. The squared distance between a pair of items is weighted by the similarity between the items” (Van Eck et al., 2010 pp. 2047). This technique was tested as being a better representation method and as being more accurate in mapping a cluster network.

The final outputs from *VOSViewer* are maps of topic size-distance relationships or density maps of colour-distance relationships. The visualizer software allows the user to zoom in and out of the map and change viewer properties such as to increase the strength weight size or colour formats or number of connector lines. The software and input files are made available on the research website (as introduced below) for download, use and comparison. As summarised by Marshakova-Shaikevich (2005, pp. 1543), these maps help in solving two scientific enquiries: “monitoring dynamics of scientific terminology and to visualize the conceptual links between terms and accordingly between science fields.”

Results from this method will be reported in a number of formats. Database query definitions and counts of papers are in either annexures or figures. Publication volumes over time will be plotted along with journal popularity. Co-word networks will be represented through bibliometric maps, these being displayed over the entire time series but also in shorter selected intervals of analysis.

3.4 Substantive assumptions and limitations

An important consideration when using the analysis and mapping software is the choice of parameters within the algorithms of the software. These are kept at their default values (Annexure C). The comparison and discussion of the mathematical and statistical

parameters is beyond the scope of this project, but the nature of the default values available within the software is intended to provide the most representative analysis and most commonly used methods within scientometric calculations. The specific discussion around these values can be found in Borner et al. (2003), Van Eck et al. (2010), Waltman et al. (2010), Cobo et al. (2011) and Leydesdorff and Rafols (2011).

Another limitation in the use of bibliometric maps is in the interpretation of the output. They only provide a representation of relationships between terms found in published content and the associated methods should be understood or at least recognised when using them. The results should be interpreted with caution yet are still the most effective method of simply representing scientific relationship, output or developments on a particular scale.

3.5 Scanning the horizon

3.5.1 Conceptual basis, definitions and key methodological literature

> *The practice of foresight plays an important role in science and technology policies...as it is supposed to enlarge the scope of the science and technology strategy to the longer term future.*
>
> (Treyer, 2009 pp. 353)

Horizon scanning methods are used to identify and evaluate research questions that are currently being asked by researchers. There are three main methodological steps that are typically used: 1) identify and create a collaborative stakeholder network; 2) collect data from this network regarding their research expertise, opinions on research considerations and research questions; and 3) analyse this data by allowing the network to deliberate the results and produce a final set of results of research opinion and questions.

Sutherland and Woodroof (2009) provide a substantial taxonomy of horizon scanning methods used in identifying and prioritising future research questions, scenarios and needs. They follow a combination of open forums, trend analysis, questionnaire and expert consultation. The majority of the horizon scanning process in this study focused on a catch-all principle of stakeholder identification and enlistment. This catch-all, however, is restricted to the water research sector and the subsequent questionnaires also attempt to extract participant expertise and research experience.

The motivation for attempting to engage a wide variety of stakeholders is multifold. As discussed earlier, collaborative networks are necessary for the adaptive co-management of the research resources (Pahl-Wostl et al., 2007b; Pahl-Wostl, 2009). This is because

research is often conducted and managed in isolation of other areas of specialisation and other institutions where there is limited coordination of activities and research thrust.

As mentioned earlier, the WRC is acknowledged as the main funding agency in the majority of water related research in South Africa, but there is also significant research activity and output that does not come under this influence. Thus the project accepted a need for involving marginalised, smaller, periphery or multi-disciplinary research stakeholders. Experts (as identified by the first data collection survey) were engaged electronically and during a specialist workshop to validate and comment on the wider results and to provide necessary credibility, a process that is well motivated in studies by Sutherland et al. (2011a), and Sutherland and Woodroof (2009).

It must be noted that while the central outcome in Sutherland et al. (2011a), Sutherland and Woodroof (2009) and Brown et al. (2010) was to create questions for evidence-based policy, this project is more interested in the methods of enabling research sustainability and in generating a substantial analysis of water research activities and the associated paradigms. The guiding principles for methods as listed in Sutherland et al. (2011a) are still applicable and will be followed in this project. These are: "(i) defining the project, (ii) organising the participants, (iii) soliciting and managing questions or issues, and (iv) disseminating results" (Sutherland et al., 2011b pp. 243). Overall, a three phase survey process was undertaken: firstly, a *pilot survey*; secondly, the *main survey* (data collection); and thirdly, *prioritisation and refinement*.

3.6 Method

3.6.1 Building a collaborative network

The project intended to involve a wide variety of stakeholders with an interest in water and water research and to engage participants through the 'voice' of a research initiative, rather than through the researcher's own. This would make communication more professional, allow for branding to be created, and to allow for a common identity if other researchers began working on or in association with the project. The research enterprise was named *Aqua d'UCT* with the tag-line of *Integrating Water Research*. The name stems from an *aqueduct*, which is a channel or bridge carrying water over a gap or valley, and was altered to mean 'water at the University of Cape Town (UCT)'. All communication with stakeholders would be driven through the 'voice' of *Aqua d'UCT* but also kept as 'human' and 'interpersonal' as possible.

A domain (www.aquaduct.org.za) was registered and a website built to establish an online presence for the study. Participants could sign up to contribute to surveys, receive newsletters or updates, view and download data, obtain results from the research, find more information about the research and communicate with the study team. The fundamental principle behind the creation of an online platform was that more stakeholders could be reached, at a faster rate and at a lower cost. While this would bias potential stakeholders without access to the internet, the stakeholders that were targeted (researchers, research managers or decision makers) were most probably all internet-active due to the nature of their careers and education.

An extensive marketing campaign was undertaken to inform and invite stakeholders to participate. These included conference presenting, networking, emailing key networks and social agents and linking the site to other water-related sites. A few pilot surveys, polls and communications were run in order to test the best method of engagement and response. The website was constantly updated and enhanced during this process to be made more appropriate for information access, project understanding and practical use. Stakeholders were able to register for the newsletter and participate in the research via a simple form on the website. More information on the research was constantly provided and the concept of brand and website management began to gain momentum from the launch day.

The *Water Research Futures Survey 2011-2012* was launched as the *pilot survey* and communicated to all registered parties on 1 November 2011. Stakeholders could opt out of the process and be deleted from all databases at all times.

To stimulate further interest and discussion in their research, a seminar was hosted at the University of Cape Town on 21 October 2011 entitled *Water research challenges in South Africa*. Two experienced water researchers gave keynote presentations which were followed by a panel debate with the panel consisting of further experienced researchers. The seminar was open to all and 110 water research stakeholders attended. All the presentations along with the debate were recorded and the podcasts published on the research website. These, along with the slideshow presentations and images of the seminar can be found at www.aquaduct.org.za/water-research-seminar-21-october-2011-at-uct.html. Guests were provided with a seminar pack with more information about the research, the seminar itself and the sponsors.

Communication with registered stakeholders was kept to a reasonable minimum in order to avoid email ‘fatigue’. This was done through formal email newsletters and contained updates or progress on the research, invitations/calls/reminders to participate in a specific survey or activity, water research related news and contact information.

A large number of stakeholders were captured for the research by *Aqua d'UCT* using branding and digital media methods. The research was communicated to a wide spread of institutions, water-related specialisations and sectors, networks and the research community in this manner in order to create as diverse, multi-discipline and as large a network as possible. The use of digital technology and effective communication with many other networks enabled a large number of stakeholders to be contacted at low cost and high scalability. The database continued to grow throughout and after the surveys.

3.6.2 Data collection: horizon scanning within the network

Formal surveys were used in order to elicit responses for opinions on water research and question gathering. The first formal pilot survey was conducted on paper at the *Aqua d'UCT* launch at the WRC 40-year Celebration Conference from 31 August 2011 to 1 September 2011 and was planned as a pilot for the survey method. The *Water Research Futures Survey: 2011-2012* was released to the stakeholder database and to other water networks on 1 November 2011.

These *pilot surveys* showed that a large proportion of research stakeholders were willing to participate in the activities of *Aqua d'UCT*. Almost all participants showed a willingness to provide their names, contact details and information about their career, provided they were not identifiable in publications and results/data distribution. This data was kept secure and confidential and was only intended to be used for stakeholder database capture, survey tracking and for the development of the researcher's professional profile. The survey questions were worded very specifically and tested on a few subjects before release. Full results of the *Water Research Futures Survey: 2011-2012* were made available on the research site.

Lessons learned and suggestions were incorporated in the production of the *main survey*. An online survey building and hosting service was used (www.surveymonkey.com). The design of the survey accounted for the desired outcomes of the research and the guidelines from the pilots. It was decided to use telephonic means of contact to alert potential participants to the survey and engage with them further on a more personal approach. Contacts on the database were phoned by a research team member. They were alerted of the study, its objectives and its length. The option of doing the survey over the phone or online was presented. Over 1700 phone calls were made from 21 May-15 June 2012. Principles of this survey were to gather the research/professional profile of the participant; conduct a scan on present and future challenges; and gather research questions and associated details to be researched.

The official, *main survey* entitled the *Priority Questions for Water Research 2012 (Aqua d'UCT & Water Research Commission)* (Annexure D) was released to the stakeholders on 21 May 2012 and closed on 6 July 2012. It was structured in three main parts: an introduction followed by brief questions to provide the research/professional profile of the participant; the central question gathering; and brief opinion seeking with opportunity to comment.

The data collected in the *main survey* was then analysed using statistical and graphic representation techniques. The submitted questions themselves (the key elements of this exercise) then underwent significant review first by a team of researchers to remove obvious duplicates, fix wording, grammar and spelling and improve basic style. This reduced the volume of question and allowed the questions to be categorised into six main integrated themes. These themes were decided upon through specialist consultation and included elements of the WRC impact areas and the National Water Resource Strategy 2012 priorities. These final lists of thematic questions were taken and used in the specialist workshop.

Specialists, who reflected experience in their field or within water related research, were identified from amongst the respondents using their profile of answers provided and through consultation with the project managers and WRC. Specialists were also selected based on their organisational and discipline diversity and their experience. This was done in order to have a representative group of specialists.

Questions from the *main survey* were distributed to the specialist group upon their acceptance of invitation to the *Water research horizon scanning workshop* which was held on 8-9 October 2012 in Cape Town. Substantial, early discussion with delegates and the workshop facilitators were held in order to create the appropriate workshop program and pre-event participation. This was aimed at eliciting comment and clarifying the study to delegates. The workshop invitation sample, the outline and discussion document and the pre-workshop delegate preparation exercise can be found in Annexures E, F and G respectively.

The opening workshop session constituted formal presentations on the project followed by a focused discussion on the method and activity. Delegates then were divided into four groups of three themes each and followed the prescribed processes. The central aim over the two days was to reduce the question dataset by prioritising questions within their themes. The first round saw the themes being reduced to roughly a quarter of their respective lengths. These results then went to the other groups who subsequently reduced the questions to around half of what they received. The brief was to maintain a set of priority questions (unranked) within the prescribed quantity that will remain as the final results.

Throughout the process delegates were encouraged to reword and edit the questions into appropriate or accurate forms.

The final list of questions became the main workshop output and was named the *Priority water research questions in South Africa 2012*. These were then distributed to delegates for comment and a discussion was encouraged as to how these can be published. The closing session included a formal review of the workshop, formal feedback forms and opportunity to comment along with open discussion on the process. A final distribution of the results and feedback was made to all delegates in December 2012 and further comment was allowed on the research website including prompts about where to take the study and these exercises in the future.

Certain annexures contain the large organisational representation list, counts and the different surveys used in the research. Stakeholder database communication records and database metadata are presented in lists and tables. The results from the *pilot survey* are presented online and certain plots are referred to in the results. Results from the *main survey* are presented in the following manner: plots for survey completion rates; certain quantitative research opinion data and certain stakeholder analysis data; tables for certain quantitative research opinion data and certain participant analysis data; tables of research question categorisation; the full question dataset as an online reference; the final *Priority water research questions for South Africa 2012*; and comprehensive feedback from stakeholders throughout.

3.7 Substantive assumptions and limitations

Horizon scanning is filled with potential limitations and opportunity for error due to the active, *action research* nature and complexity of the method. It must be recognised that this methodology exists within a social, political and cultural space where interaction with stakeholders occurs constantly, making the process and its successes unpredictable.

The single most significant limitation was that more stakeholders could have been involved in the research. This would have provided even more data and questions along with being even more representative of water research in South Africa. There was substantial marketing, engagement and participation with stakeholders in this method given the financial and time constraints of the research. The *main survey* and *specialist workshop* response rates were sufficient from which to draw significant results and analysis. It is assumed that participants submitted their responses to the best of their knowledge and ability; did not intentionally provide false answers; and were able to be as honest as possible. The use of electronic responses and guaranteeing data security and participant anonymity aided in this process.

4. RESULTS AND ANALYSIS

4.1 Scientometrics

The number of journal articles and research reports published per year as identified through the search is shown in Figure 4 and the *journal search set* is displayed in Annexure A. The stacked column graphic shows the proportion of WRC research reports, *Water SA* articles and other journal articles. In summary, there is an increase in annual publication counts; a rise in *Water SA* articles; and a marked increase in WRC research reports. The increase in the proportion of other journal articles from the early 1990s until the present is obvious. South Africa's water-related research output has steadily increased and the research is found in more diverse, international journals.

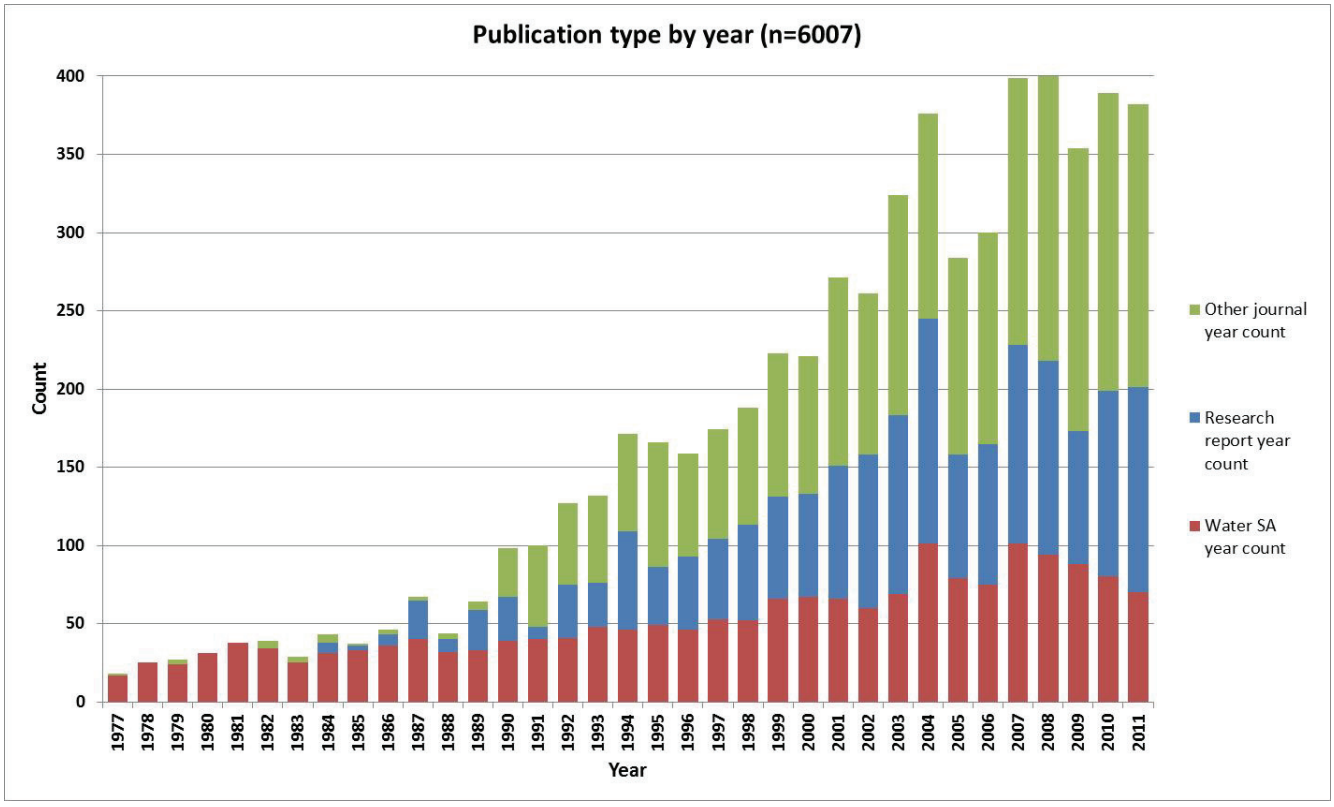

FIGURE 4: Publication type by year for all data points and all data sources

A description of the number of articles and research reports over time is listed in Table 1 and Figure 5. The number of associated abstracts is recorded and each entry or article is referred to as a *data point*. The WRC reports comprise 1760 (29.30%) of the 6007 data points over the entire dataset, while *Water SA* and other journal articles share 1829 (30.45%) and 2418 (40.25%) respectively.

A significant feature of these results are that other journal articles increase in their proportion of the time-slice from zero to low digits to almost half (47.04%) of the final time-slice, while the *Water SA* share reduces proportionally.

TABLE 1: Data points by type and time-slice

	1977-2011	***%***	***1977-1981***	***%***	***1982-1986***	***%***	***1987-1991***	***%***
Total data points	**6007**	*100.00*	**139**	*100.00*	**194**	*100.00*	**373**	*100.00*
All journal articles	**4247**	*70.70*	**139**	*100.00*	**177**	*91.24*	**278**	*74.53*
Water SA articles	**1829**	*30.45*	**135**	*97.12*	**159**	*81.96*	**184**	*49.33*
Other journal article	**2418**	*40.25*	**4**	*2.88*	**18**	*9.28*	**94**	*25.20*
WRC Research reports	**1760**	*29.30*	**0**	*0.00*	**17**	*8.76*	**95**	*25.47*
Available abstracts	**3670**	*61.10*	**0**	*0.00*	**0**	*0.00*	**100**	*26.81*
	1992-1996	***%***	***1997-2001***	***%***	***2002-2006***	***%***	***2007-2011***	***%***
Total data points	**755**	*100.00*	**1077**	*100.00*	**1532**	*100.00*	**1924**	*100.00*
All journal articles	**564**	*72.32*	**749**	*69.55*	**1020**	*66.02*	**1338**	*69.54*
Water SA articles	**230**	*30.46*	**304**	*28.23*	**384**	*24.85*	**433**	*22.51*
Other journal article	**230**	*30.46*	**445**	*41.32*	**636**	*41.17*	**905**	*47.04*
WRC Research reports	**209**	*27.68*	**238**	*30.45*	**252**	*33.98*	**586**	*30.46*
Available abstracts	**521**	*69.01*	**729**	*67.69*	**975**	*63.11*	**1302**	*67.67*

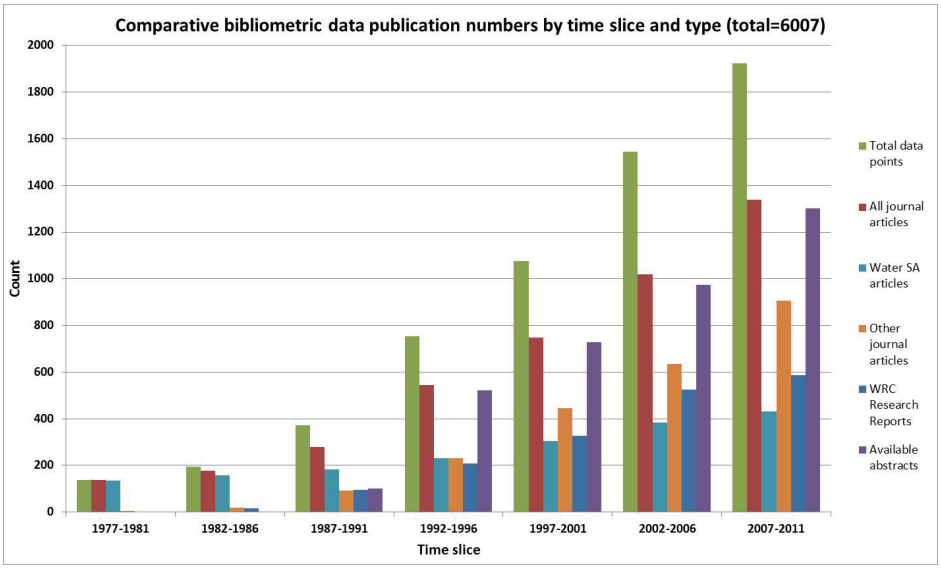

FIGURE 5: Comparative publication type by time-slice

Table 2 presents the data source titles with the most numerous publications or data points. *Water SA* and the WRC research reports comprise a significant proportion of the data. However, out of the 171 titles in the journal search set, 140 contained relevant articles. Apart from Water SA, there are only four titles containing more than 100 relevant data points, these being the *South African Journal of Science*, *Water Science and Technology*, *Physics and Chemistry of the Earth* and the *South African Journal of Botany*. The full database of data points (including source, title, authors, year and abstract where available) is available on the research website.

TABLE 2: Data-sources with 10 or more publications (n=66)

WATER SA	1829	SCIENCE OF THE TOTAL ENVIRONMENT	22	WATER POLICY	15
WRC RESEARCH REPORT	1760	JOURNAL OF BIOGEOGRAPHY	21	WATER RESOURCES MANAGEMENT	15
SOUTH AFRICAN JOURNAL OF SCIENCE	241	DIVERSITY AND DISTRIBUTIONS	20	AQUATIC BOTANY	14
WATER SCIENCE AND TECHNOLOGY	146	WATER RESEARCH	20	ENVIRONMENTAL POLLUTION	14
PHYSICS AND CHEMISTRY OF THE EARTH	107	AGRICULTURAL WATER MANAGEMENT	19	JOURNAL OF ENVIRONMENTAL MANAGEMENT	14
SOUTH AFRICAN JOURNAL OF BOTANY	103	AQUACULTURE	19	WATER RESOURCES RESEARCH	14
AFRICAN JOURNAL OF AQUATIC SCIENCE	97	FISHERIES RESEARCH	19	DESALINATION	13
SOUTH AFRICAN JOURNAL OF PLANT AND SOIL	92	APPLIED AND ENVIRONMENTAL MICROBIOLOGY	17	ECOLOGICAL ECONOMICS	13
ESTUARINE COASTAL AND SHELF SCIENCE	91	BULLETIN OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY	17	ECOLOGICAL MODELLING	13
HYDROBIOLOGIA	89	FRESHWATER BIOLOGY	17	ECOLOGY AND SOCIETY	13
JOURNAL OF ARID ENVIRONMENTS	77	NATURE	17	CONTINENTAL SHELF RESEARCH	12
SOUTH AFRICAN JOURNAL OF WILDLIFE RESEARCH	64	PLANT ECOLOGY	17	ENVIRONMENT DEVELOPMENT AND SUSTAINABILITY	12
KOEDOE	51	WATER AIR AND SOIL POLLUTION	17	ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY	12
JOURNAL OF HYDROLOGY	41	ECOTOXICOLOGY AND ENVIRONMENTAL SAFETY	16	GEOPHYSICAL RESEARCH LETTERS	12
BIOLOGICAL CONSERVATION	37	ENVIRONMENTAL MONITORING AND ASSESSMENT	16	MOLECULAR ECOLOGY	12
JOURNAL OF AFRICAN EARTH SCIENCES	37	FIELD CROPS RESEARCH	16	RIVER RESEARCH AND APPLICATIONS	12
AFRICAN JOURNAL OF ECOLOGY	33	INTERNATIONAL JOURNAL OF WATER RESOURCES DEVELOPMENT	16	AFRICAN JOURNAL OF AGRICULTURAL RESEARCH	11
MARINE AND FRESHWATER RESEARCH	33	AUSTRAL ECOLOGY	15	CONSERVATION BIOLOGY	11
EARTH AND PLANETARY SCIENCE LETTERS	28	FOREST ECOLOGY AND MANAGEMENT	15	ENVIRONMENTAL MANAGEMENT	11
ENVIRONMENTAL BIOLOGY OF FISHES	27	HYDROLOGY AND EARTH SYSTEM SCIENCES	15	ENVIRONMENTAL RESEARCH	11
CHEMOSPHERE	24	JOURNAL OF APPLIED ECOLOGY	15	HYDROLOGICAL PROCESSES	10
BIODIVERSITY AND CONSERVATION	22	WATER INTERNATIONAL	15	INTERNATIONAL JOURNAL OF ENVIRONMENTAL HEALTH RESEARCH	10

Figures 6 to 13 are the scientometric maps created using Sci2 and VOSviewer. Each figure comprises a specific time-slice and is shown in label or density format. Label format presents more prominent words in the network as larger spheres (i.e. to more often they were

mentioned). The closer spheres or words are to each other the more interrelated they are in the network (i.e. the more often they were mentioned together or 'near' each other). Colours represent clusters or sets of related words as they emerged from the network (i.e. more general relationships). Lines represent significant connections between words of the same or different clusters. Density format presents the identical map but uses warmer colours to display words and clusters of greater prominence with the colour contours conforming to how strong related clusters are. Word size represents general prominence as per label view.

During the preparation of the datasets and associated network files and maps, it was found that the networks or clusters using combined abstracts and titles or only abstracts produced maps that were scattered, undifferentiated and generally nonsensical (even with strong significance settings). This was a trend with all the time slices and the overall dataset. It was decided only to use the title attributes as these formed representative maps and weighted strengths.

Elements of the map using keywords for the period 1977 to 2011 (Figure 6) shows the dominance of research output that focus on management, development, models, water quality and system treatment. This is for the entire dataset and can be seen as the overall research effort strength in general for South African water research.

Figure 7 shows literature keywords for the first time-slice of 1977 to 1981. The image shows a small, but scattered research effort with an emphasis on water quality. The map for 1982-1986 (Figure 8) indicates the further scattering of research output. Here the emphasis has shifted to natural biological systems but indicate the first elements of approaching water affairs from a catchment scale and exploring the elements therein such as runoff, soils and irrigation.

Treatment systems and industrial water present the major focus areas when examining the time-slice for 1987-1991. This coincides with the beginning of the sharp increase in research publication output (Figure 9). In the early post-apartheid years from 1992-1996 (Figure 10) begin to show how disciplines start to connect with one another. While treatment systems still dominate, management, development and urban research begin to show prominence within water research. These emerging areas of inquiry increase their presence during and following the country's major water policy reconstruction in the period 1997-2001 (Figure 11). The research is at its most polarised, with treatment systems and basic science dominating one area while development, assessment and management sciences dominate another.

The penultimate time-slice of 2002-2006 (Figure 12) show emerging research fields which relate to the increase in overall publications that were analysed. Here the word

‘management’ becomes more pronounced and more social science orientated terms such as community, impact and application make an appearance. This is also when the word ‘integrate’ first appears and the overall research is connected and evenly distributed. The final time-slice of 2007-2011 (Figure 13) shows management as the current dominant research area of prominence. While engineering sciences such as treatment systems are present, they are dominated by assessment research, modelling and community related research.

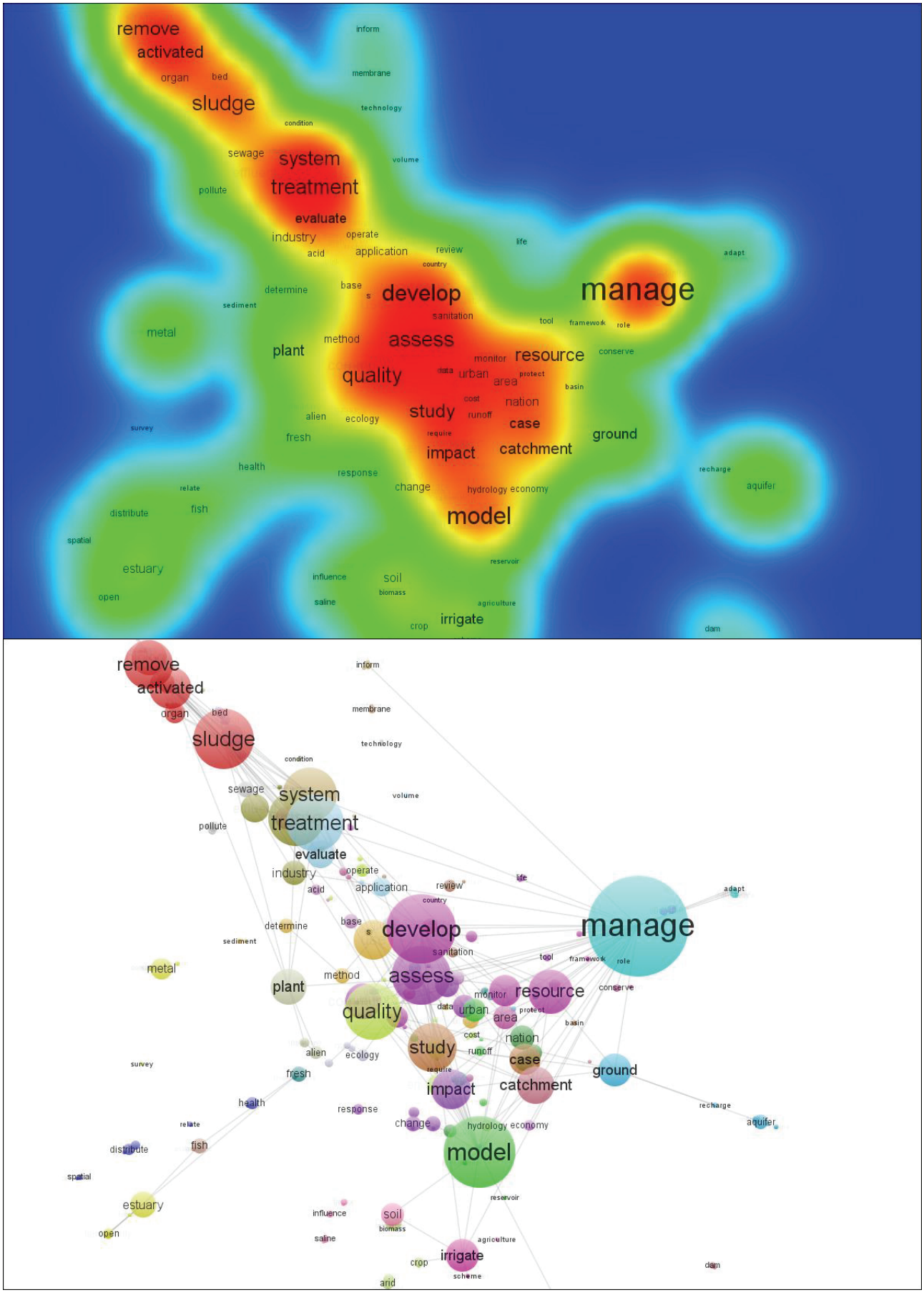

FIGURE 6: 1977-2011 publication bibliometric map (label and density) (n=6007)

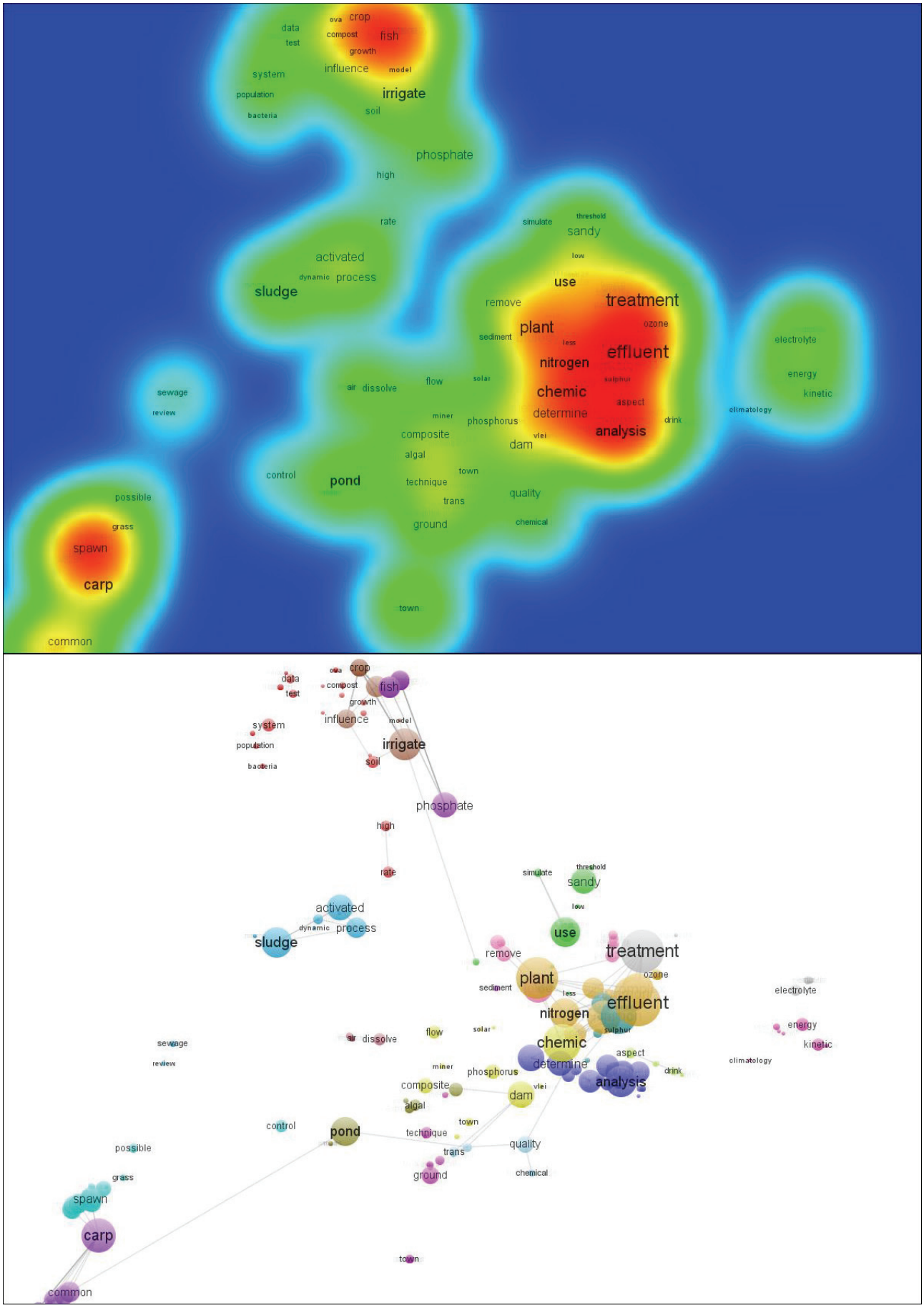

FIGURE 7: 1977-1981 publication bibliometric map (label and density) (n=139)

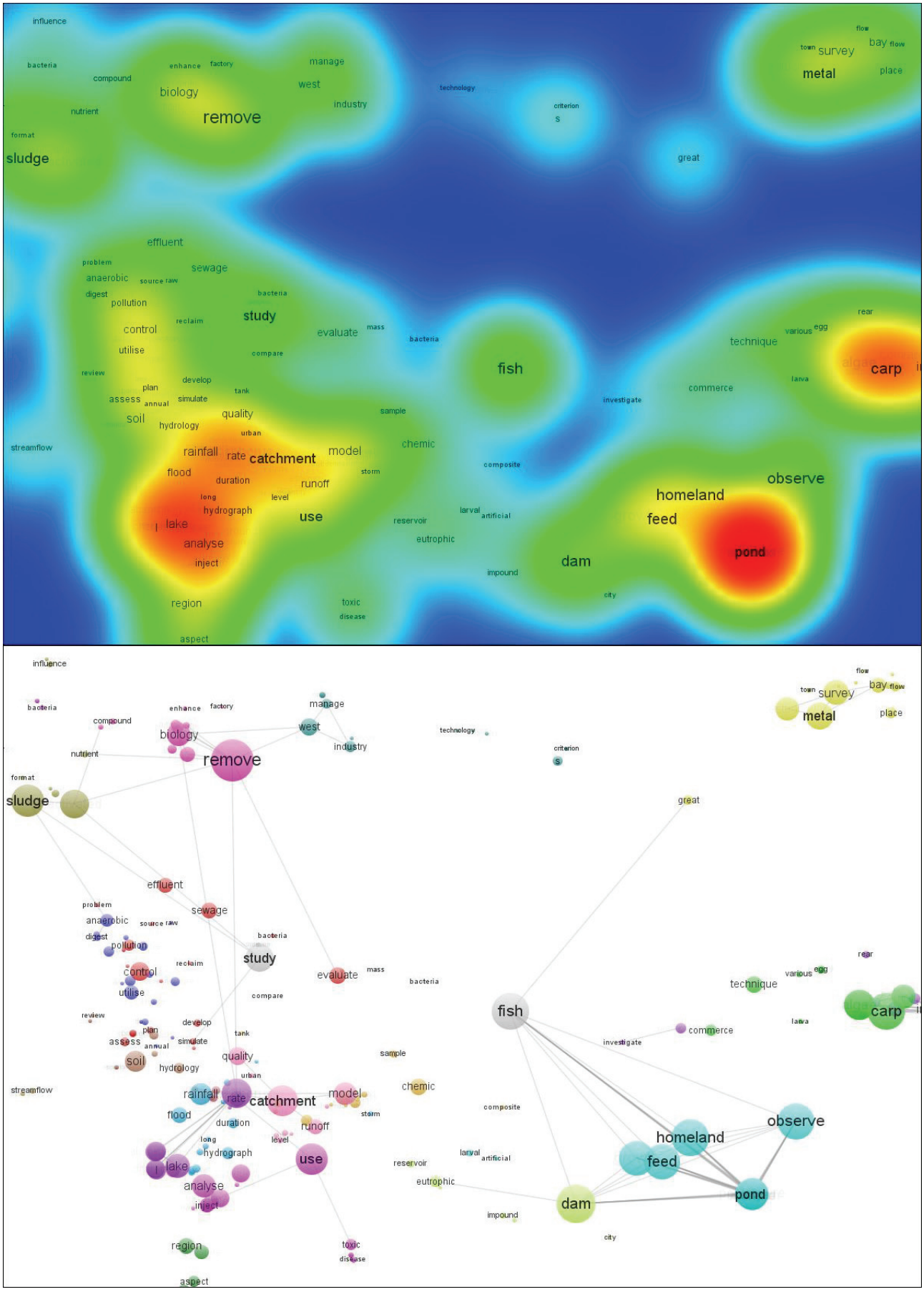

FIGURE 8: 1982-1986 publication bibliometric map (label and density) (n=194)

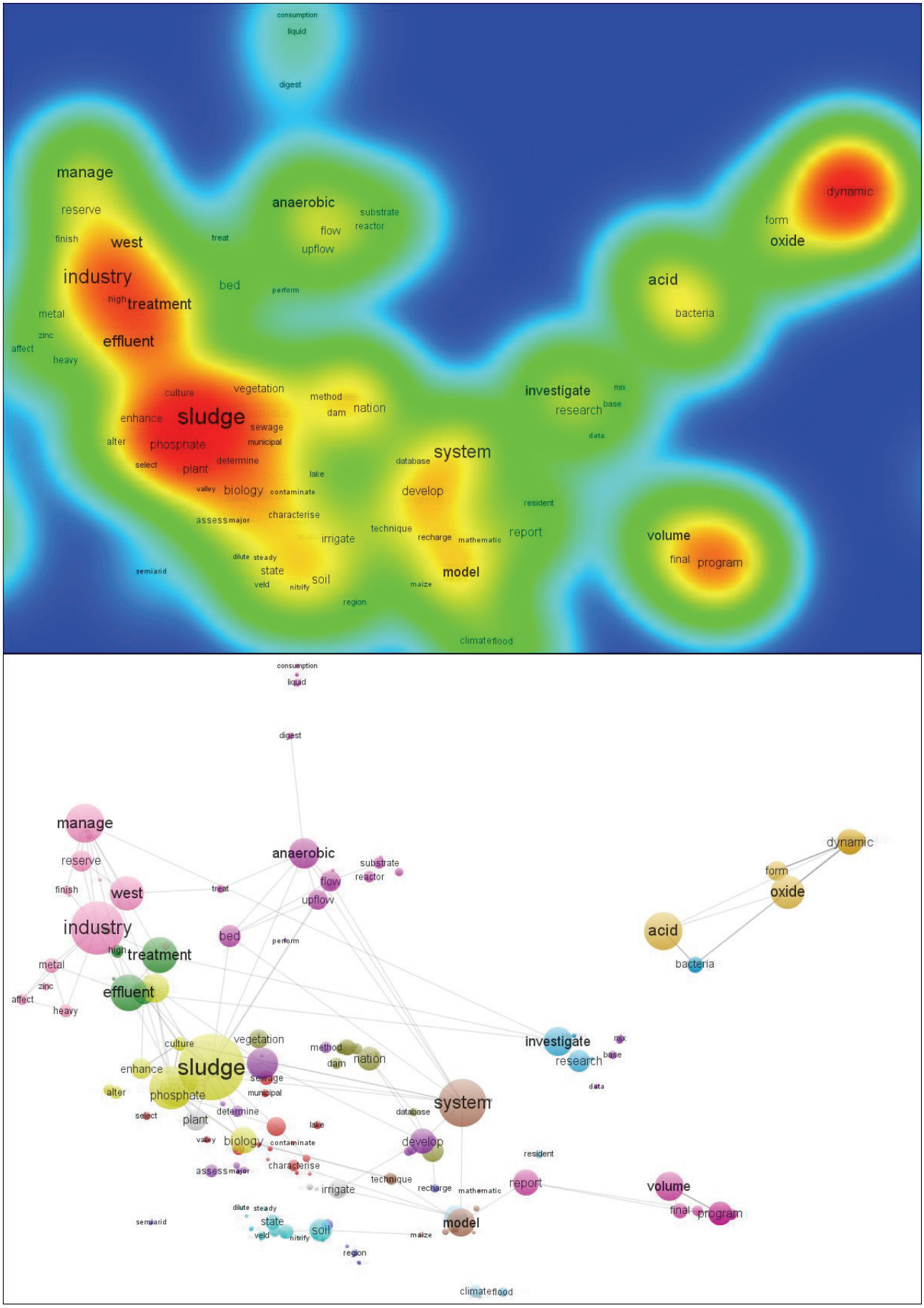

FIGURE 9: 1987-1991 publication bibliometric map (label and density) (n=373)

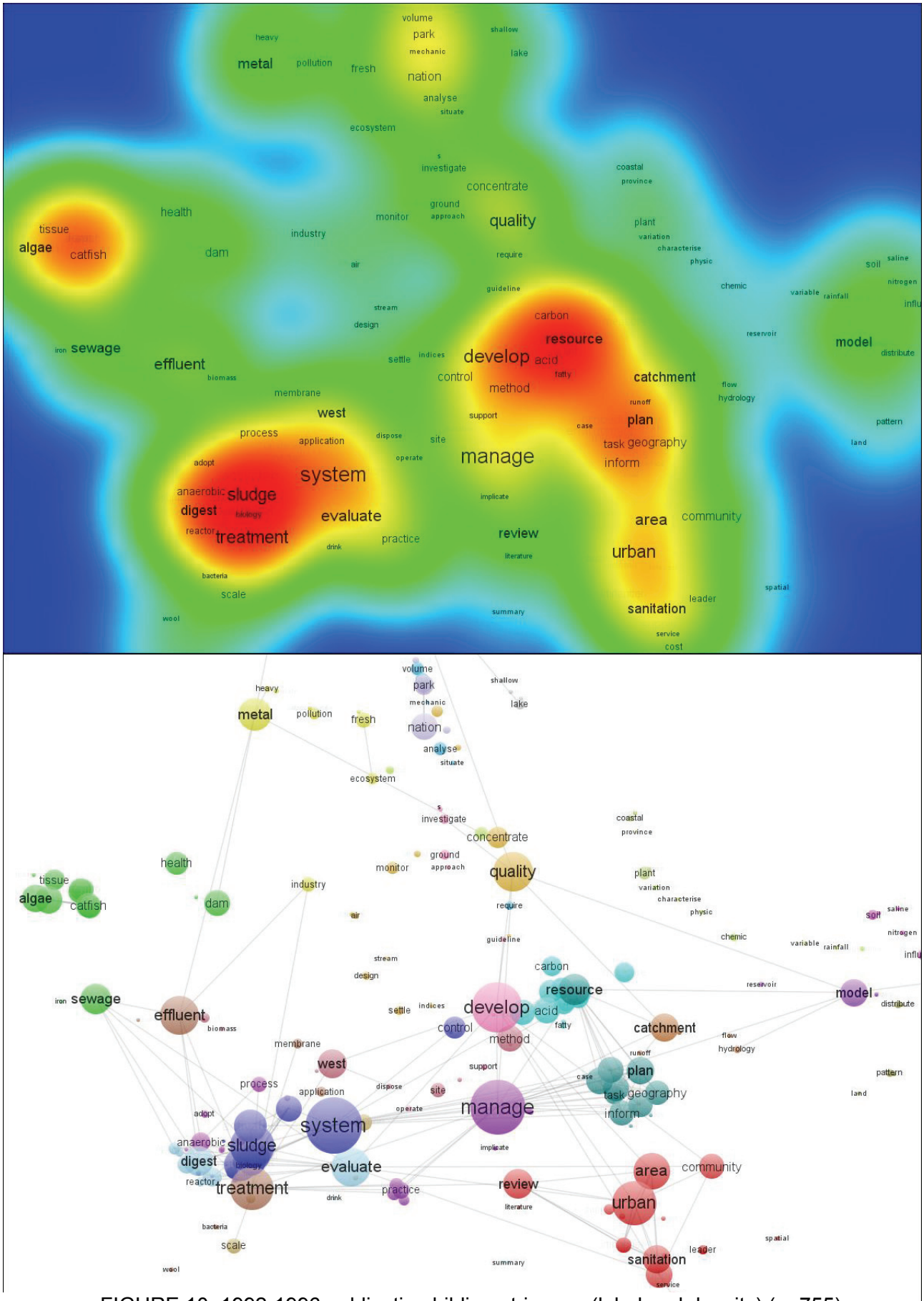

FIGURE 10: 1992-1996 publication bibliometric map (label and density) (n=755)

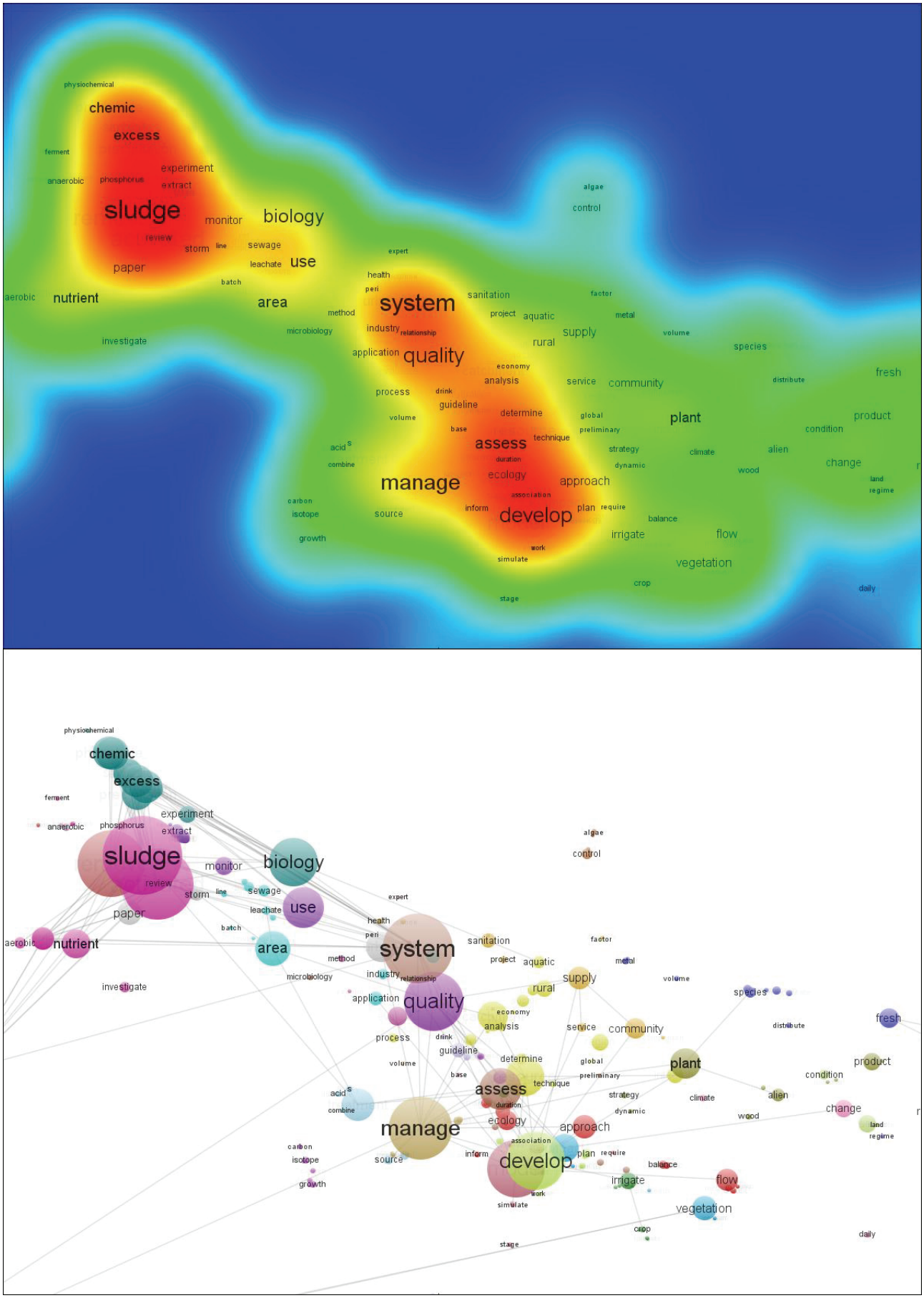

FIGURE 11: 1997-2001 publication bibliometric map (label and density) (n=1077)

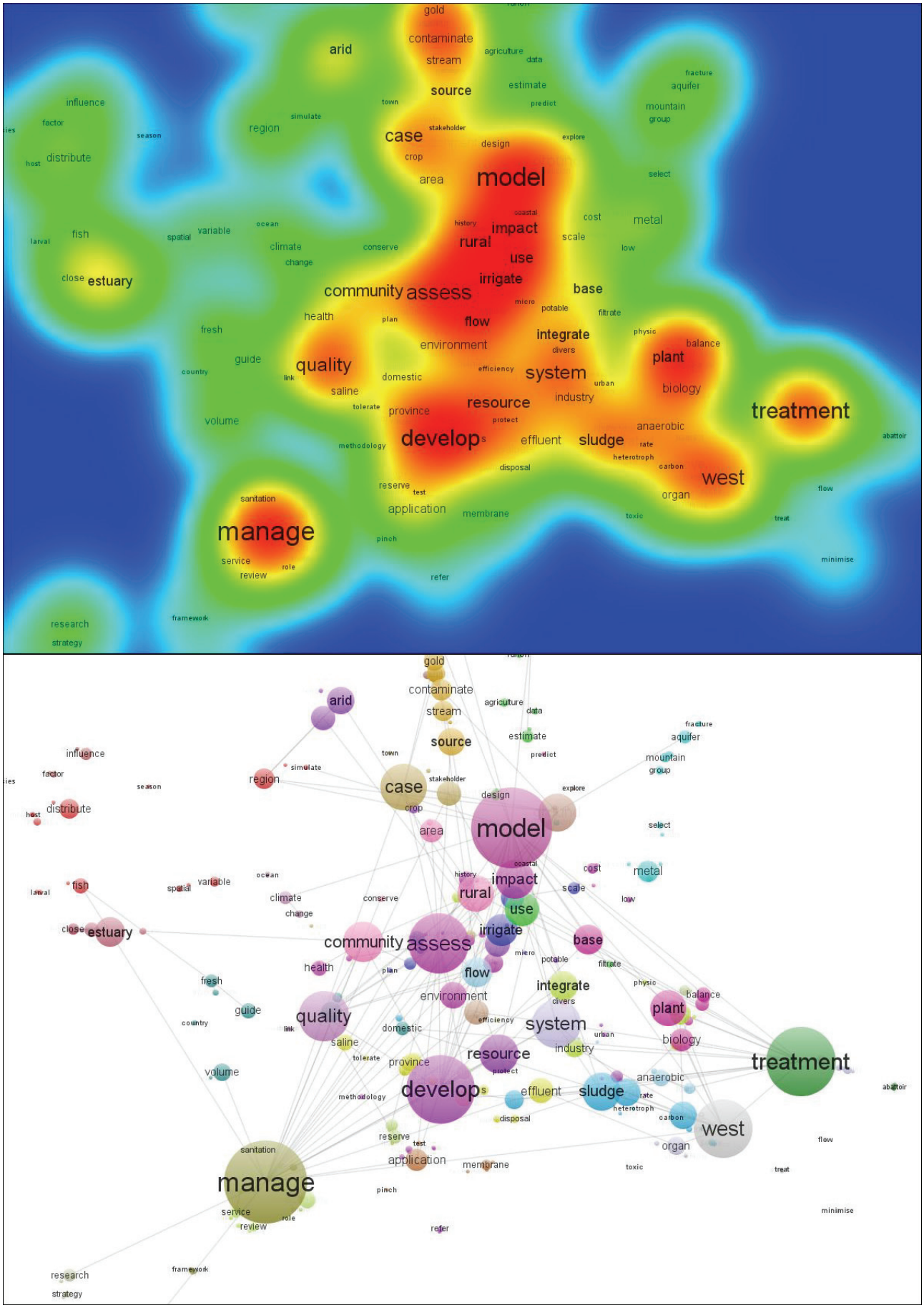

FIGURE 12: 2002-2006 publication bibliometric map (label and density) (n=1545)

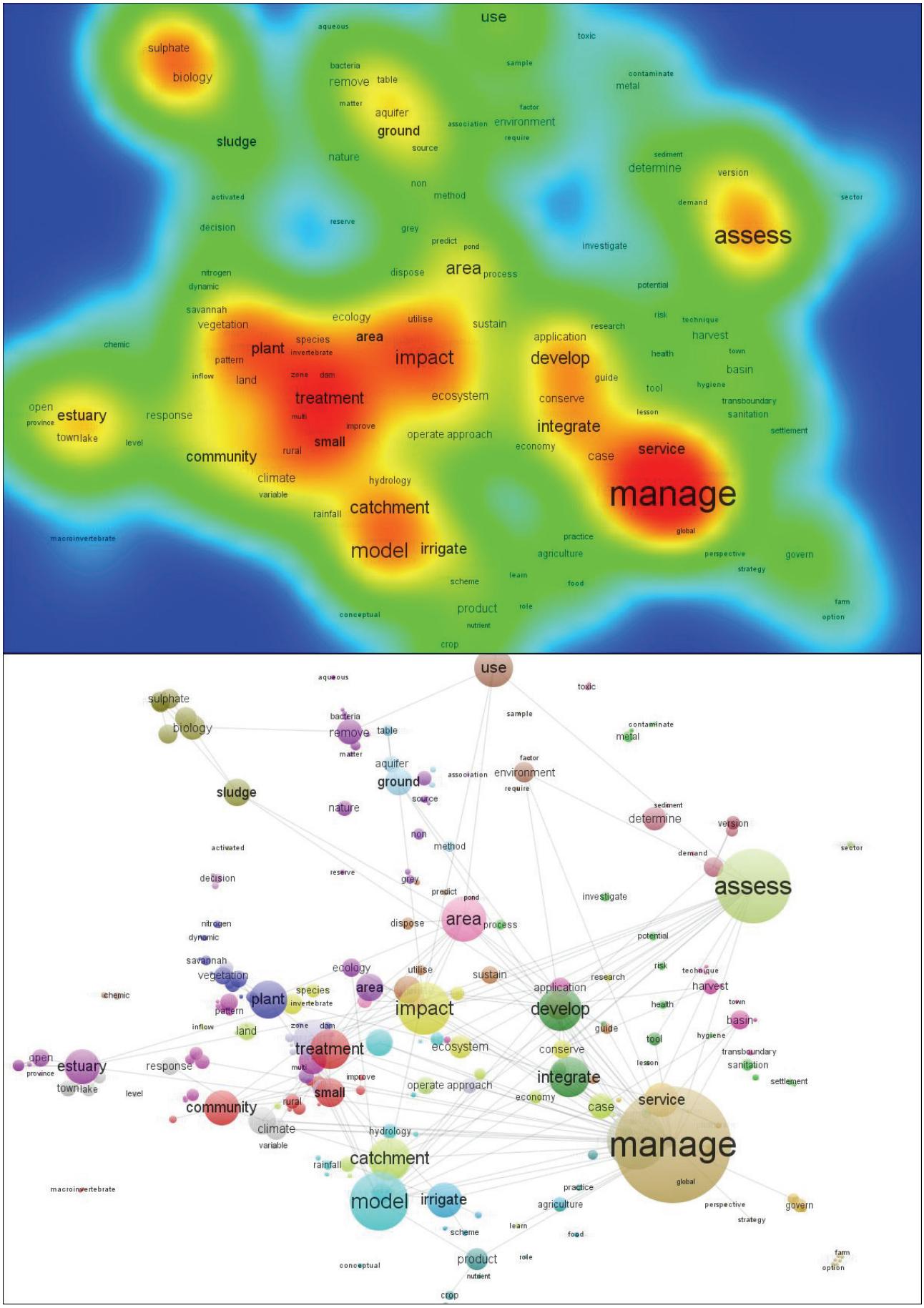

FIGURE 13: 2007-2011 publication bibliometric map (label and density) (n=1924)

4.2 The South African water research community

4.2.1 Stakeholders and participants: summary

Building a stakeholder and participant contact dataset involved many strategies as described in the method section. Table 3 summarises the stakeholder engagement processes and dates. The research reported here ended in December 2012 with 2260 unique stakeholder contacts on the database. These were gathered at minimal cost over the 15 months of operations.

TABLE 3: Aqua d'UCT stakeholder database engagement record

Activity	***Date***	***Number of stakeholders on the database***
Launch of Aqua d'UCT and www.aquaduct.org.za	August 2011	0
Extensive initial distribution of calls to sign-up to key networks and mailing lists and at key events	August 2011 - February 2012	0 to ~600
WRC 40th Anniversary conference and formal announcement of research	September 2011	~100
Water research challenges seminar at UCT	October 2011	~200
Launch of *Water Research Futures Pilot Survey*	November 2011	~400
Close of *Water Research Futures Pilot Survey*	February 2012	~600
Extensive collection of further contacts using networks, provided datasheets and at events	February 2012 - May 2012	~600 to ~1400
Launch of *Priority Questions for Water Research 2012* survey	May 2012	~1400
Close of *Priority Questions for Water Research 2012* survey	July 2012	~1700
Invitation and pre-event activities for specialist *Water Research Horizon Scanning Workshop*	August 2012 - September 2012	~1700
Water Research Horizon Scanning Workshop in Cape Town	October 2012	~1700
Presentation of preliminary results at key conferences	October 2012 - November 2012	~2200
Distribution of final results to all stakeholders and online	December 2012	2260
Formal update from Aqua d'UCT (emailed and published online)	08 / 09 / 11 / 12 2011 02 / 04 / 06 / 12 2012	
Survey reminders for *pilot* and *main surveys*	On-going while live	

The stakeholders in the database signed up and engaged with Aqua d'UCT for numerous reasons. Some simply wanted to remain informed of the process and results. Others saw

opportunity to participate in the surveys and discussions while others used the portal to ask further information about water research. The descriptive data of the participants are presented and discussed below: Table 4 presents the descriptive data for the entire database as of December 2012; and Figure 14 shows the distribution of titles of the various participants held within the database.

TABLE 4: Aqua d'UCT stakeholder descriptive data as of December 2012

Total number of stakeholders in the database	2260
Stakeholders who exercised their opt-out	24
Title of Professor	198
Title of Dr	251
Title of Miss / Mrs / Ms	420
Title of Mr	686
Unknown title	705
Captured stakeholder landline numbers	1407
Captured stakeholder mobile numbers	902
Stakeholders with captured company/affiliation	2080
Unique stakeholder companies or affiliations	573

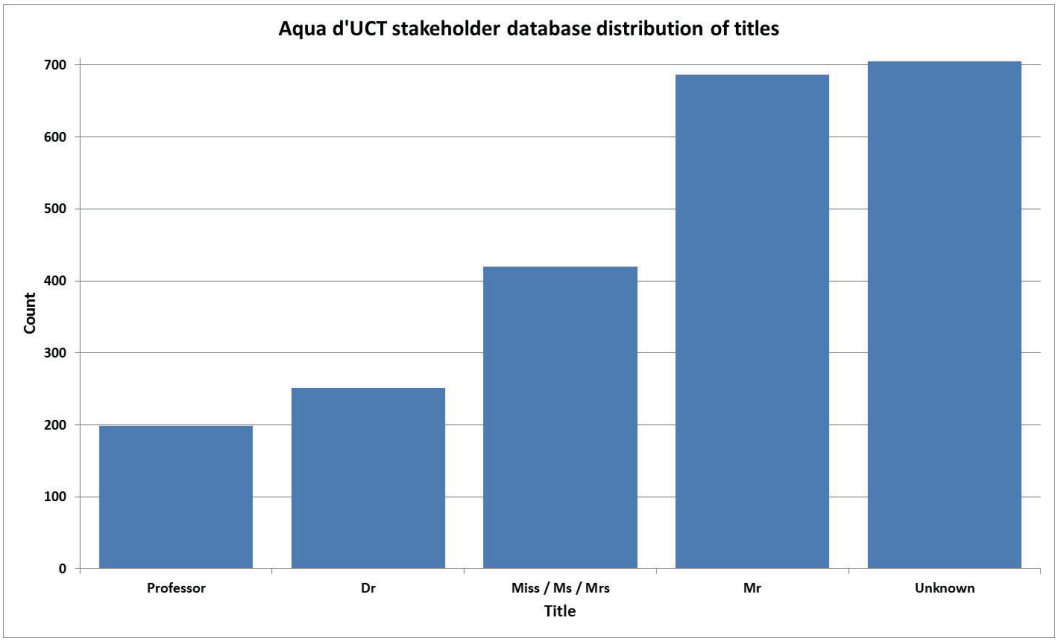

FIGURE 14: Distribution of titles of stakeholders within the database (December 2012)

The numerous strategies used to grow the network (some as listed in Table 3) each had varying amounts of success. Figure 15 shows the breakdown of where all contacts were gathered which varies from conference networking and delegate list; the use of the WRC metadata set; to sending invitations and calls through networks that resulted in site visits and contact forms being submitted. The latter activity generated the most significant amount of

contact acquisition resulting in 539 stakeholders visiting the site and completing the sign-up form directly. Another successful strategy was to ask participants at the end of the *main survey* to provide names and contacts of peers they would recommend complete the survey. This generated a further 350 unique contacts that were then added, called and emailed requesting their participation in the survey.

The stakeholders contained within the database were diverse in their involvement in South African water but appeared well connected within the water sector networks. Many of whom were recommended or were on another contact list, had attended a relevant water-related event or read and followed online calls.

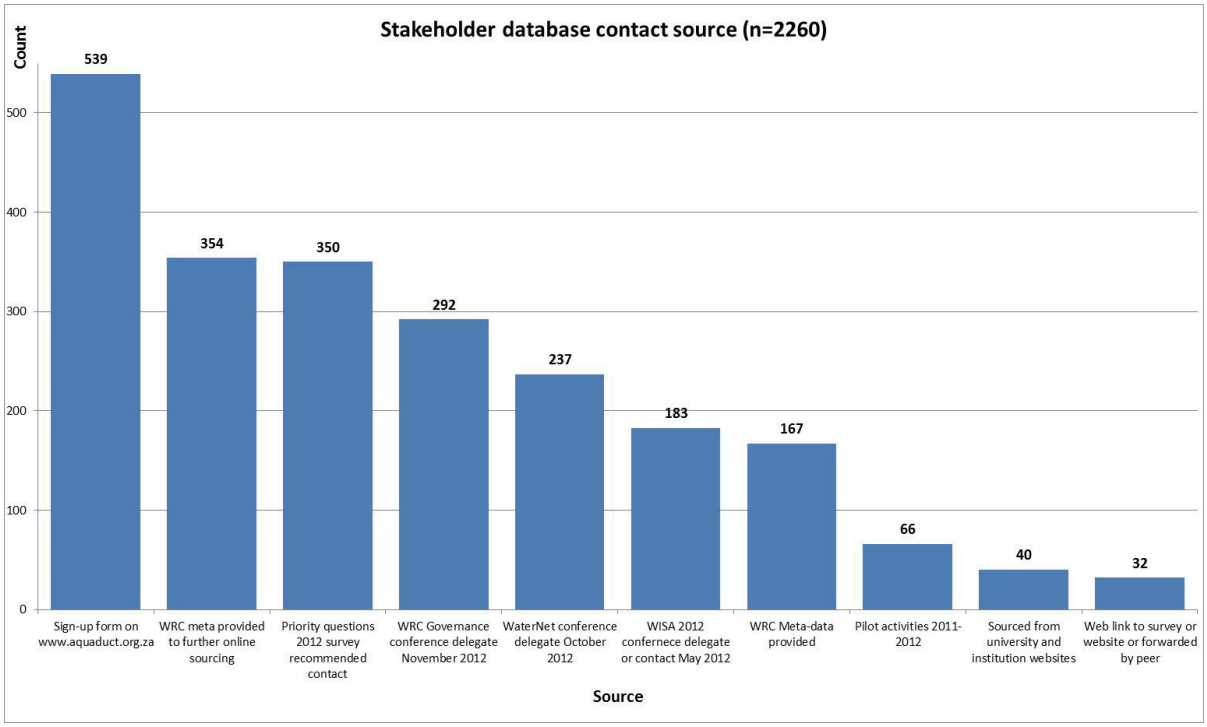

FIGURE 15: Distribution of stakeholder contact sources

The diversity of stakeholders within the database was seen in their involvement amongst a range of organisations or affiliations. Figure 16 presents the most represented organisations in the database. Overall, stakeholders in the database were affiliated to 572 organisations or institutions. (Annexure H).

The distribution of the sector affiliations is an important factor to consider. As stated in the methods and rationale, the intention was for the overall research to be as integrated, multi-disciplinary and inclusive as possible. The fact that research organisations or institutions (university or research council) hold places 2 to 11 (Figure 16) underscores the relevance of this study to these institutions but also to where the majority of research activity in South Africa occurs.

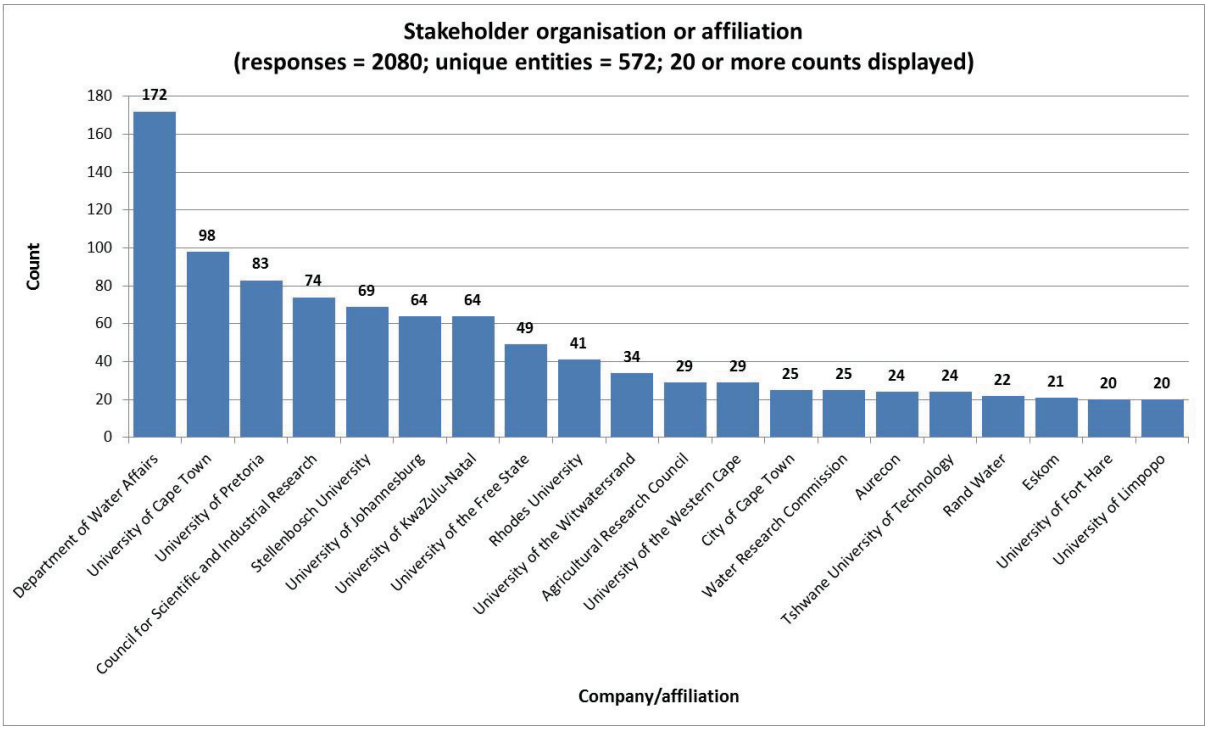

FIGURE 16: Distribution of stakeholder organisation or affiliation

4.2.2 Question gathering

Overall, 1075 stakeholders were contacted and spoken to directly via individual phone calls during May and June 2012 to be alerted about the survey. Along with these, 503 more were contacted only via email. The survey link was clicked on 1028 times during its live phase and there were 387 incomplete surveys (ones where at least the first input page was completed but not the entire survey). By the time the *main survey* closed in December 2012 there were 641 completed responses. While the survey was estimated to take 20 minutes to complete, feedback from participants suggested that an average survey completion time ranged from 30-40 minutes.

Survey participant information gives a detailed understanding of the type and range of respondents to the exercise in order to provide transparency and credibility to the results. Figure 18 presents the participant affiliations or organisations (592 responses, 221 unique organisations). The organisations with three or more survey respondents are shown, while the complete list is available in Annexure I.

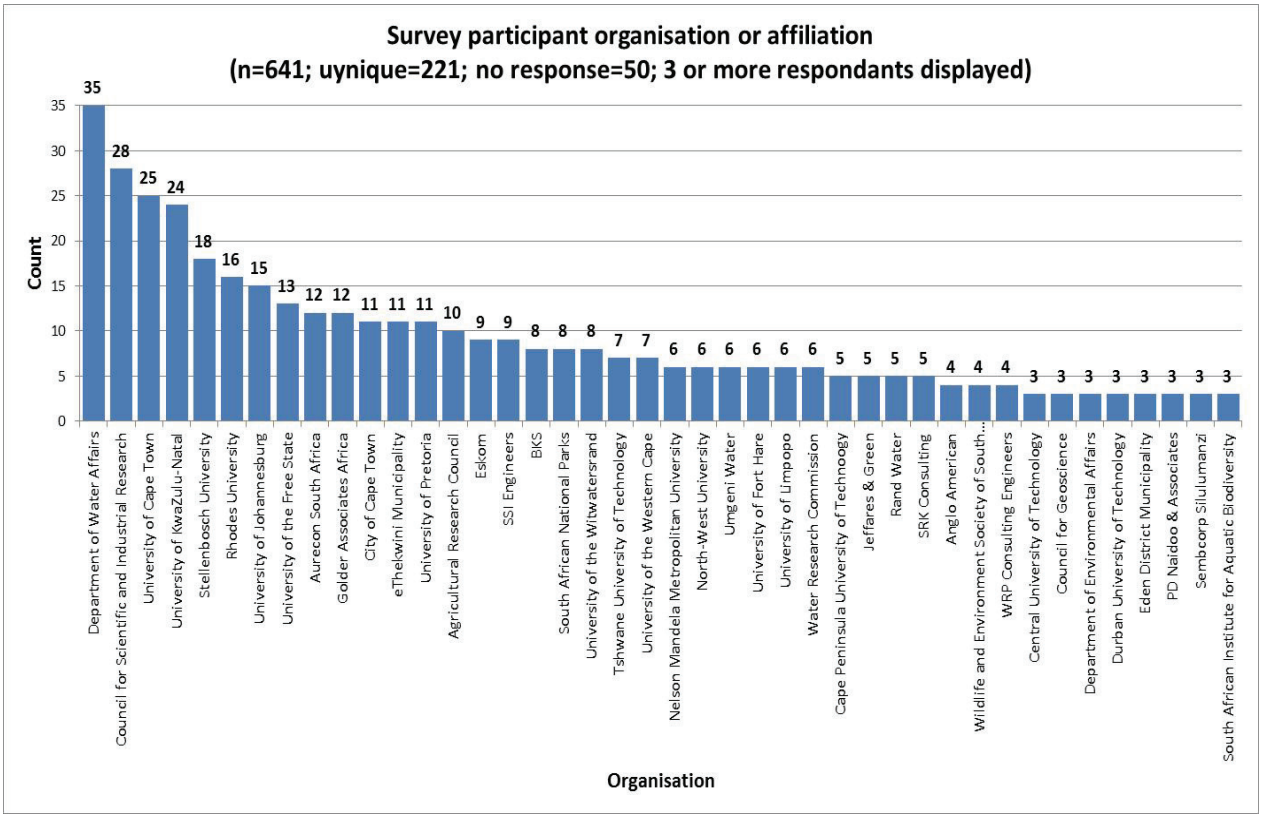

FIGURE 17: Distribution of survey respondent organisation or affiliation

The national authority provided the most survey respondents with universities and state research institutions taking 2nd to 6th place. There was fair diversity in the remaining top respondent affiliation with a few private entities and consultancies being represented along with other environmental organisations, other universities and utilities.

Participant position or type of work is another attribute of interest. Figure 18 shows these positions or occupations provided by the respondents. There was a good response to this question with 548 participant answers. It must be noted here that these are general occupations and one can, for example, be a manager of one single project or entire company and still state *manager*. Nevertheless, the results show that many respondents were in fact managers while a large number stated that they were researchers (59) or scientists (51) of some description. Overall 26 unique types of general occupations or positions were identified.

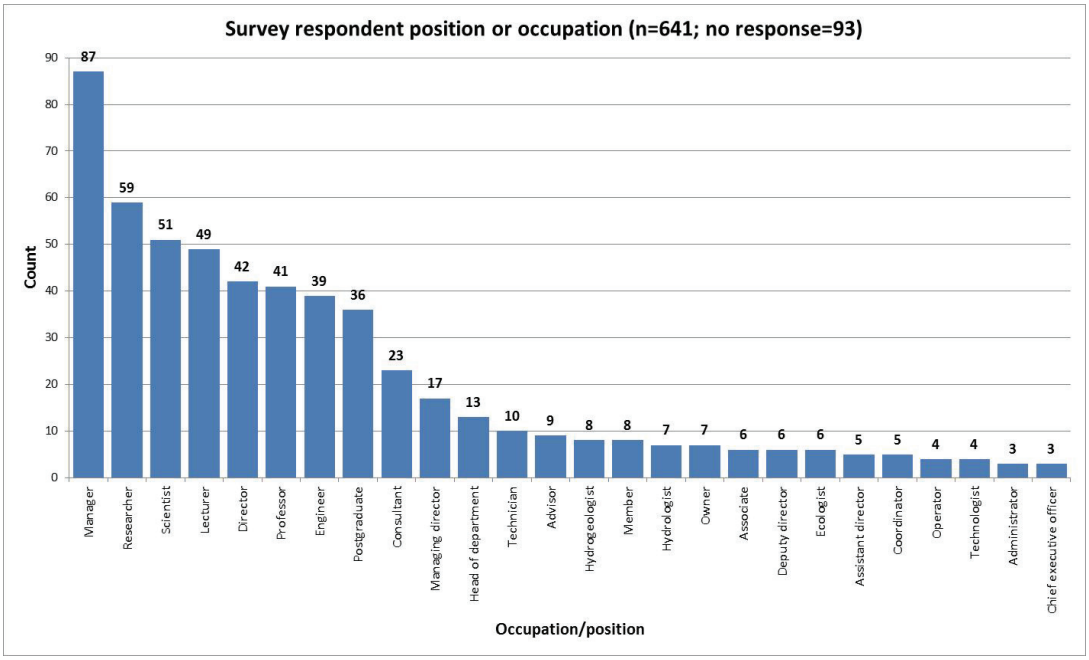

FIGURE 18: Survey respondent occupation or position

Respondents were asked to indicate their years of experience in the current discipline in which they practise Figure 19 shows how the top four counts were 5 (53), 15 (40), 2 (39), 10 (35) in years of experience. If decades were to be analysed then it is observed that the following decades of experience had the following respondent counts (in brackets): 0-1 (297), 1-2 (188), 2-3 (86), 3-4 (51) and 4 and more (19). The average years of experience are 14.38 years. The standard deviation from the mean is 11.54, while the sum of all respondent years' experience of 9220 years.

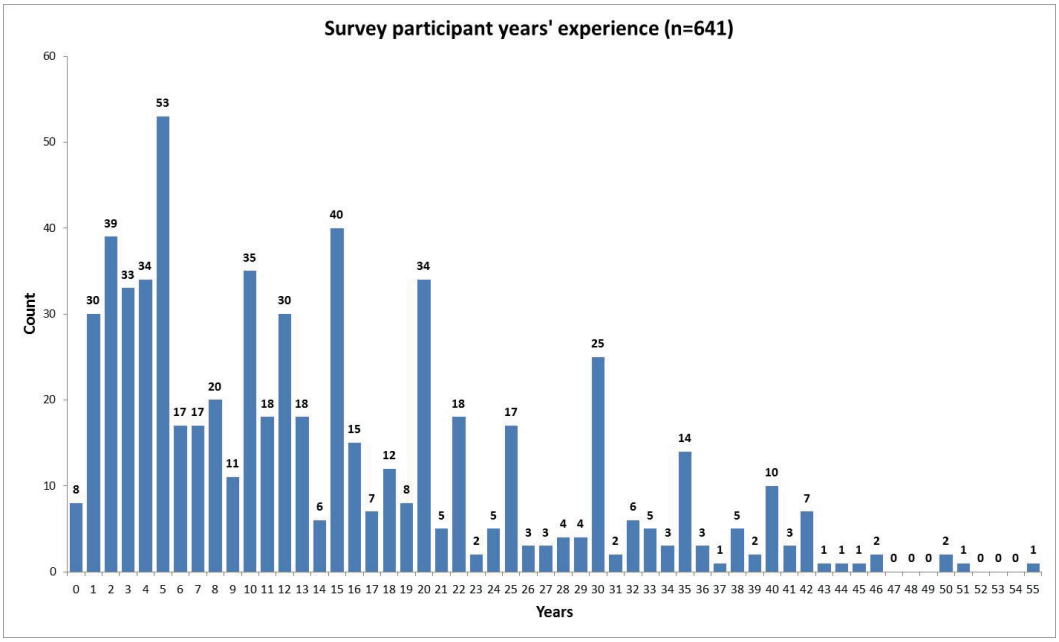

FIGURE 19: Survey respondent years of experience

Participants were given a choice of 20 different areas or specialisation across the water sector. These were selected originally from studying university research structure, water utility and state structures and association themes and groups. While some of the areas are very specific, others may be more general allowing for a mixture of responses. To ensure the level of specialisation was captured, along with the multi-disciplinary characteristics of many participants, three levels of specialisation were allowed in response (*partial understanding*, *partial specialist* and *specialist*) and multiple responses or areas of specialisations per respondent were allowed.

Figure 20 shows the number of responses in relation to each area of specialisation and the type of response in alphabetical order. For each area over 100, the respondents indicated they had a partial understanding while at least over 50 respondents stated that they considered themselves to be partial specialists in these areas. The largest reduction in responses from *partial understanding* to *specialist* is observed in the area of *economics* and it is in the following that the lowest overall response numbers are seen: *economics* (222), *transboundary waters* (231) and *drainage* (urban and rural) (250) indicating either less survey marketing and access to stakeholders in these specialisations or simply a reduced number of persons active in this field. *Environmental management* (425), *pollution* (403), *catchment management* (378) and *waste water treatment* (367) show the most consistently high number of responses in all types or specialisations. Total responses for all three types for each area are shown in the label brackets. Overall, there were 2713 responses of *partial* understanding, 2270 of *partial* specialist and 1274 responses of *specialist.*

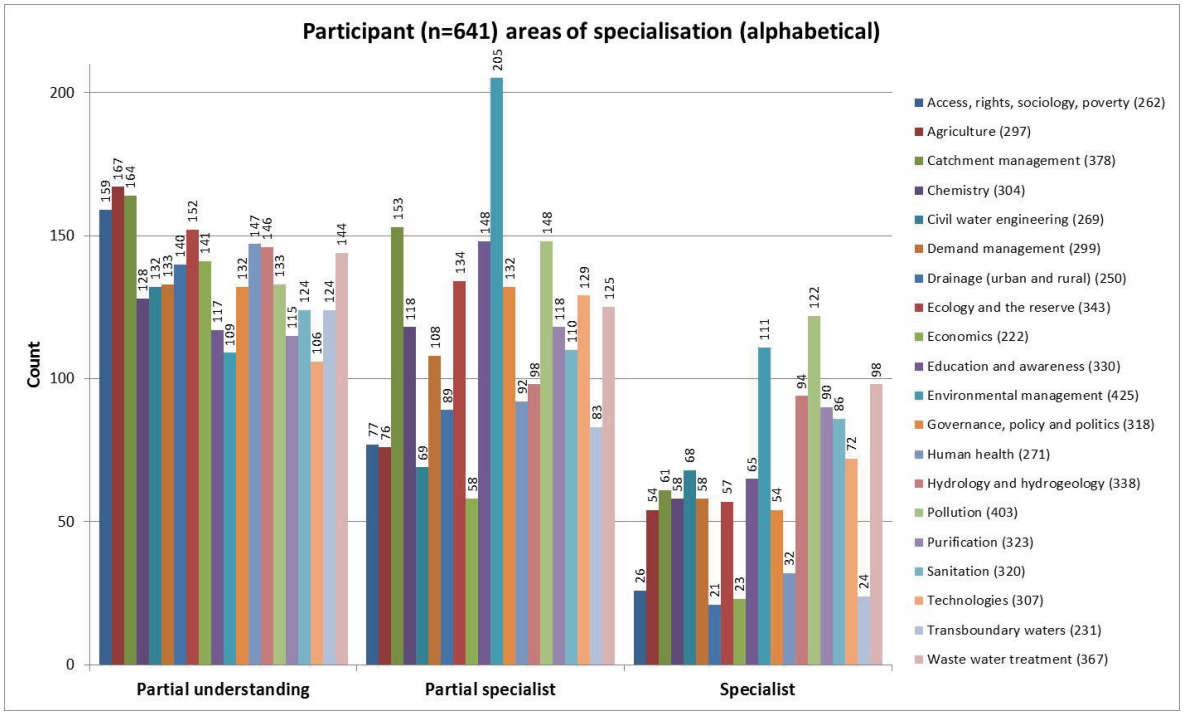

FIGURE 20: Survey respondent areas of specialisation

Figure 21 shows the ranked results for the respondent areas of specialisation while Figure 22 shows the total responses across all specialisation types (totalling to 6257 responses). Poor response numbers in the specialist category as stated from drainage (urban and rural), economics, transboundary waters, access, rights, sociology and poverty and human health can clearly be seen here with at least less than 32 respondents each.

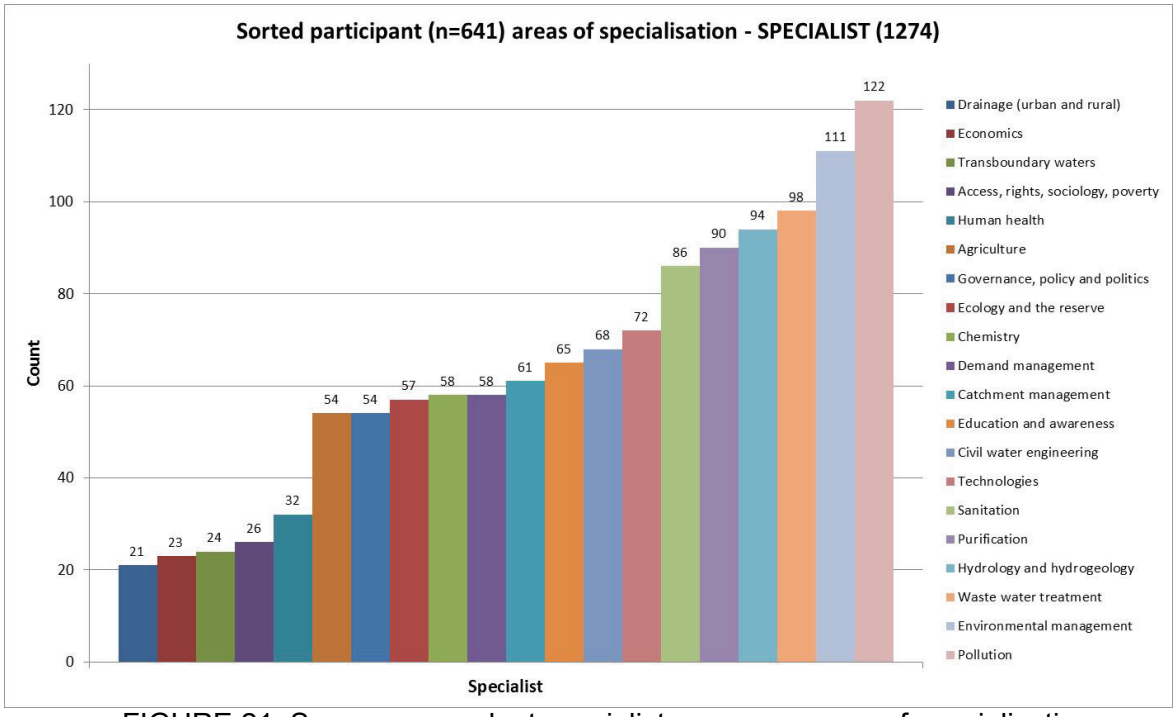

FIGURE 21: Survey respondent specialist response areas of specialisation

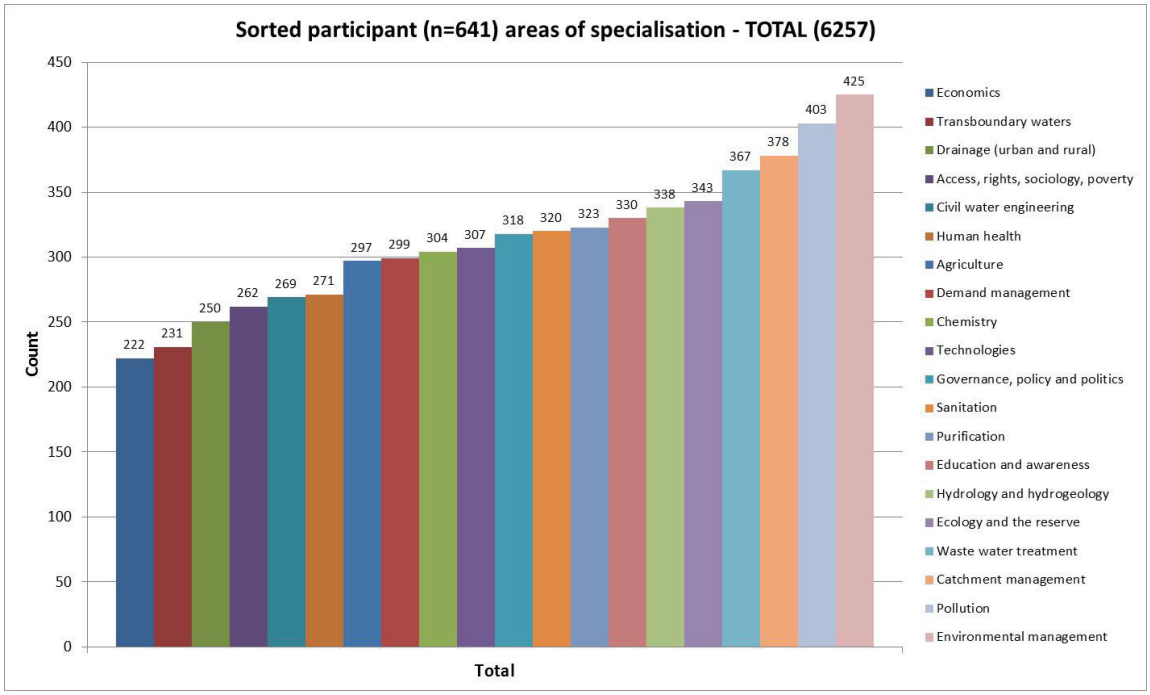

FIGURE 22: Survey respondent total responses areas of specialisation

A number of questions were presented to the stakeholder community on the Aqua d'UCT database during both the *pilot survey* and *main survey* regarding their opinions and perceptions of water research in South Africa. The majority of these reported here originate from the *pilot survey* which is not reported upon extensively. A detailed respondent analysis is not reported here as with the *main survey* but overall the *pilot survey* resulted in 534 unique respondents of which 156 completed the survey in its entirety. The full results can be found on the research website but participant profiles and attributes reflect those of the *main survey* in years' experience and occupational spread although there were significantly less completed responses.

One question asked respondents to choose what the role of science in society should be from three different choices. Figure 23 shows how the vast majority (149 or 195 responses) believe that science in society *should engage with society and the state to participate where there are research needs* while only 35 respondents answered that science *should have the absolute freedom to choose its research and activities* and 11 believed that it *should take its direction from the state as they provide most of the resources*.

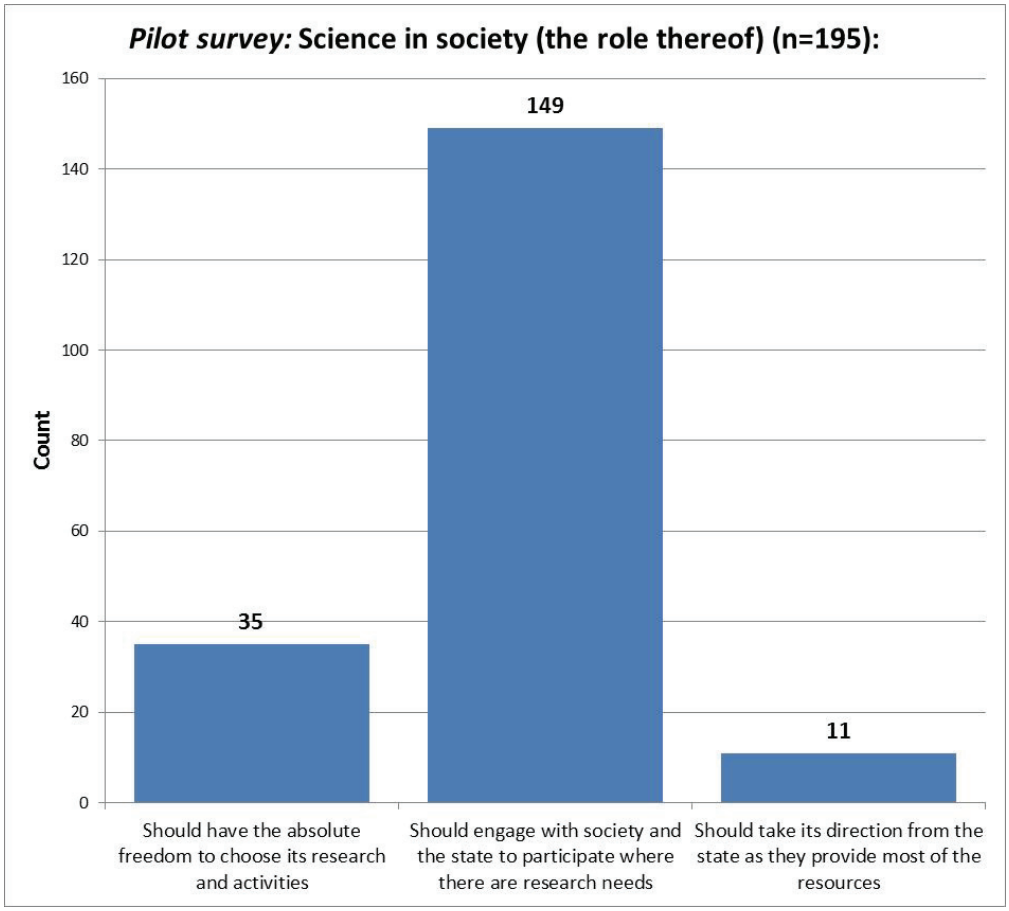

FIGURE 23: Pilot survey response to the role of science in society

Participants were asked elsewhere in the *pilot survey* their opinion on challenges in capacity development in the water sector. The challenges were listed as *funding/salaries, transformation, poor institutions, attracting the correct individuals to the sector* and *poor industry associations*. Figure 24 shows the results from 226 unique respondents where all the listed challenges record the large majority of being either significant or extremely significant.

The response options were scored and collapsed where extremely insignificant challenge = -2, insignificant challenge = -1, not a relevant challenge = 0, significant challenge = 1 and extremely significant challenge = 2. The results for the responses are as follows if sorted from most significant to least (numbers in brackets are for the number of individual responses per area of application): attracting the correct individuals to the sector **241** (222), funding/salaries **225** (226), poor institutions **196** (219) transformation **158** (218) and poor industry associations **140** (219).

All the response results show a positive result implying that all listed items are seen as challenges to capacity development. Of these significant challenges, industry associations and transformation are seen as the least significant while attracting the ideal candidates and funding or salaries are seen as the most significant.

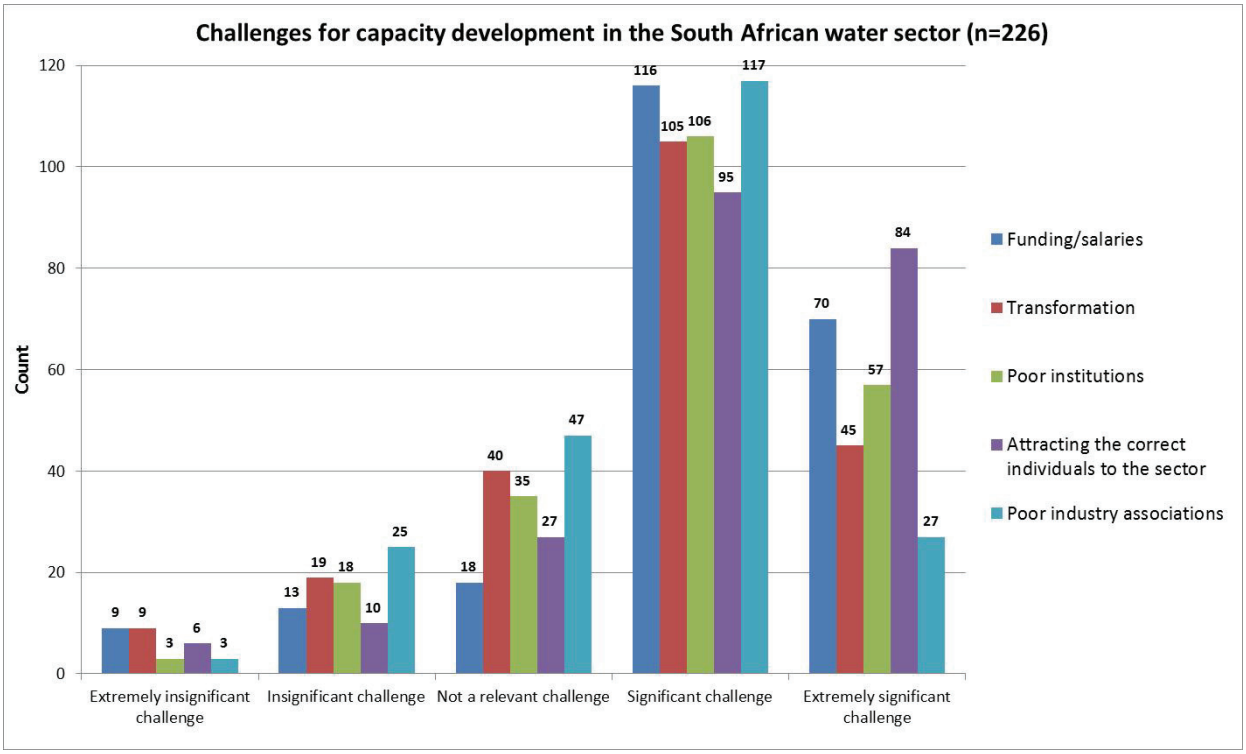

FIGURE 24: Pilot survey response to challenges for capacity development

Figure 25 shows the *pilot survey* average response from 145 respondents when asked where research funding should proportionally originate from. On average, 50.83% of funding should be from the state while the remaining sources are divided fairly evenly between private beneficiaries, commercial earnings and international donors.

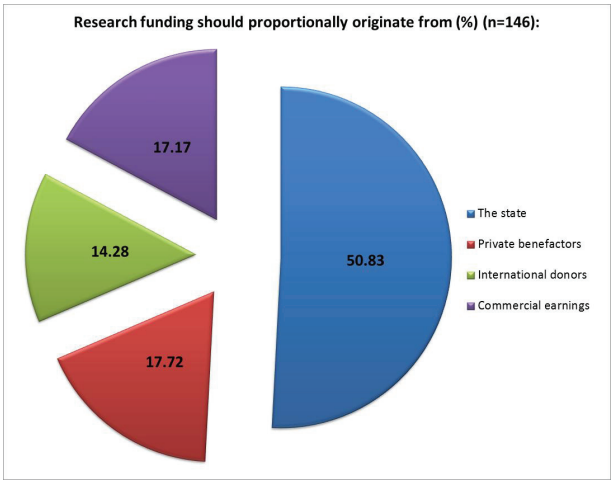

FIGURE 25: Pilot survey response on the origins or research funding

Participants of the *main survey* were asked a similar question to elicit a broader response to research funding in South Africa. Figure 26 shows how almost half (302 of 641 respondents) answered that water research was not adequately funded. Other significant responses were 127 for *maybe* and 112 for *yes* representing a mixed opinion towards funding. Annexure J lists all 120 comments to this question which is sorted as a list depending on the question response.

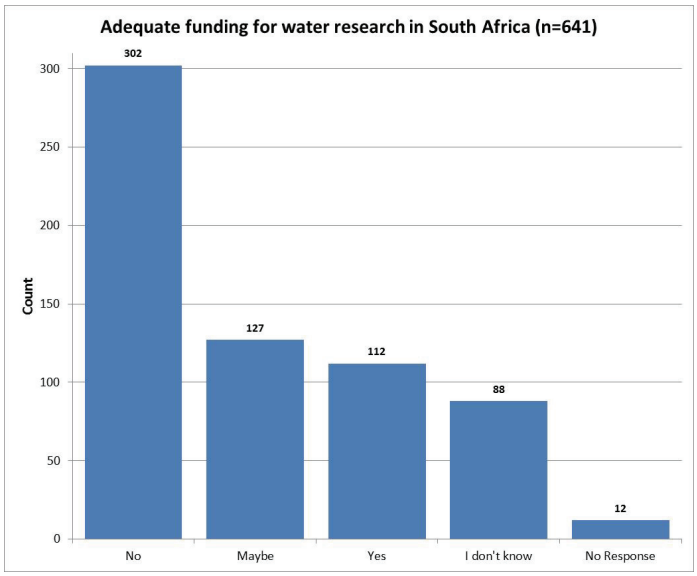

FIGURE 26: Main survey response to adequate funding for water research

Participants in the *main survey* were asked whether water research was effectively applied towards the following in South Africa: *policy, guidelines, practices, industry or business, relevant jobs* and *further research*. While none of the areas are mutually exclusive, the question ought to provide some insight into the opinion of research application in the country. Figure 28 shows how there are a spread of responses for all options. These range from *strongly agree* to *strongly disagree*. Many responses were neutral and there was more agreement for application towards guidelines and further research and less so for relevant jobs and practises.

The response options were scored and collapsed where *strongly disagree* = -2, *disagree* = -1, *neither agree nor disagree* = 0, *agree* = 1 and *strongly agree* = 2. The results for the responses are as follows if sorted from most agreement to least (numbers in brackets are for the number of individual responses per area of research application): *guidelines* **421** (629), *further research* **385** (615), *policy* **241** (627) *practises* **150** (621) and *relevant jobs*-**84** (623).Comment for this question was captured and there was significant input from participants through this means. Annexure K lists all 74 comments to this question.

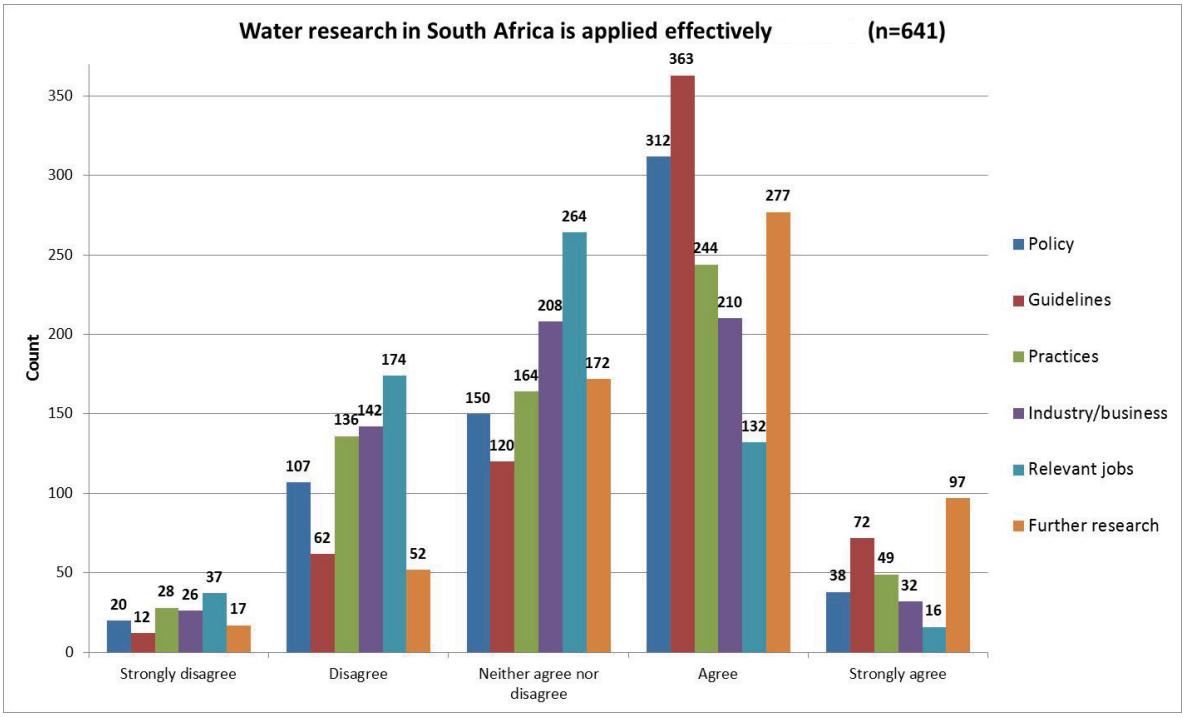

FIGURE 27: Main survey response to effective application of water research

4.3 Question gathering and prioritisation

4.3.1 Priority water research questions from the main survey

Respondents were asked to offer up to five water research questions as per the guidelines detailed in the survey. They were also asked to state how long they thought questions would take to answer, what keywords or categories the question related to, and to comment on their question. Of the 641 survey respondents, 125 provided five actual questions, 85 provided four, 104 provided three, 100 provided two, 197 provided one and 30 provided no questions. This resulted in a total of 1674 questions being captured for consideration during the *main survey*.

These questions were, as explained in the method, edited as certain stages for style, grammar, spelling and question construction. The keyword or category of entries and research lengths were then standardised.

Of the 1674 questions gathered, 1450 were submitted with an approximate research length of time. Figure 28 shows that the vast majority of the submitted questions (1014) fall within the one to three year category while the mean for the responses was 3.13, the median 2 and the standard deviation 2.32. 96 submitted questions have a research timeframe of over a decade and a fair amount of 323 are projected to take from four to six years to complete.

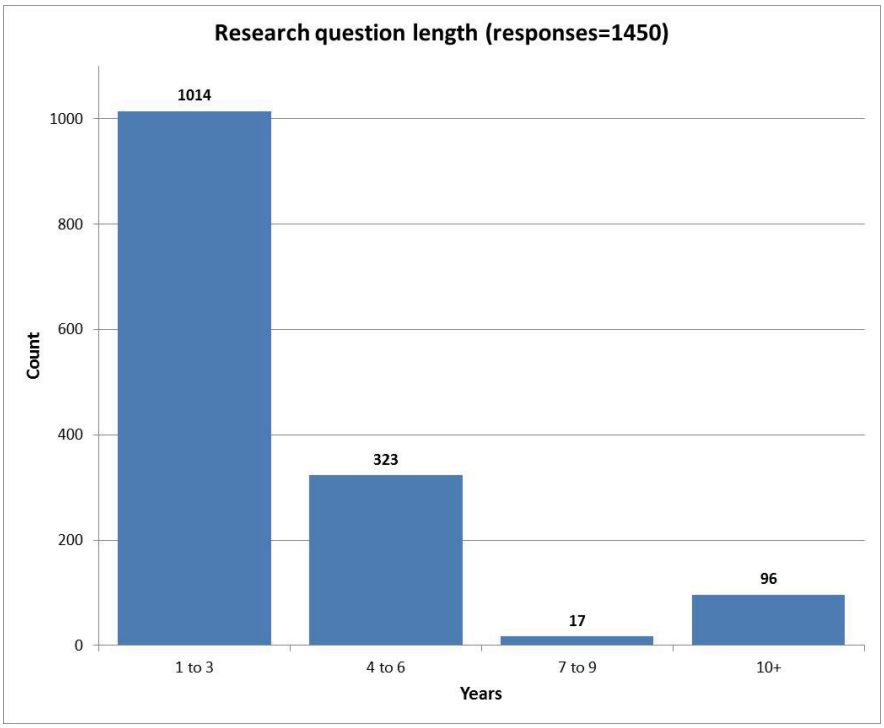

FIGURE 28: Submitted research question length in years

Of the 1674 questions submitted, 4629 keywords/categories were provided of which 844 of these were unique. These can be seen as the descriptive data of the submitted questions and is what guided the creation of the themes in for the workshop. Figure 29 displays the top 71 ranked counts of keywords in the responses while Table 5 shows the top forty keywords in the dataset along with the number of counts per keyword in brackets. The complete dataset of originally submitted questions, keywords and lengths (post-basic editing) is found on the research website along with the reduced lists discussed later in the results.

TABLE 5: Top forty research questions by keyword

management (245)	groundwater (79)	sanitation (54)	technology (44)	conservation (27)
treatment (136)	hydrology (73)	services (53)	policy (43)	capacity (26)
quality (118)	mining (73)	education (51)	rural (43)	energy (26)
supply (103)	health (72)	research (50)	use (37)	human (26)
wastewater (99)	economics (65)	monitoring (49)	wetlands (34)	planning (26)
agriculture (94)	catchment (55)	resources (49)	environmental (30)	urban (26)
pollution (83)	change (54)	ecology (47)	industry (30)	waste (25)
governance (80)	climate (54)	river (45)	demand (29)	alternatives (25)

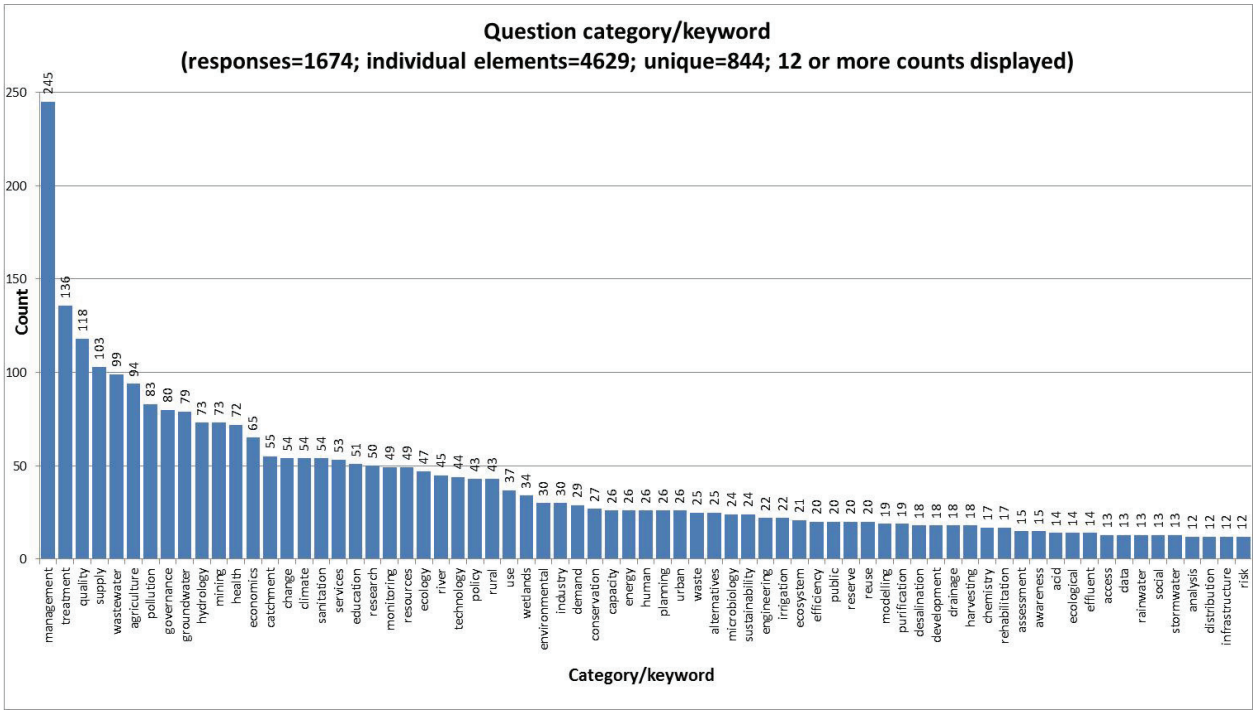

FIGURE 29: Submitted research question keywords showing 12 counts or more

The most striking result is the 245 occurrences of the keyword *management*. This would relate to many different disciplines and professions but it appears that a large amount of the submitted questions would have a management-orientated line of inquiry. The other top keywords of *treatment*, *quality* and *supply* which have over 100 counts are themselves very technically orientated keywords. The remainder of the top-count keyword represents the distribution of water-related research areas and disciplines and show a question dataset which is multi-disciplinary, integrative and covers the wider water sector.

Following a second review of the dataset, 71 questions were removed or merged into others as they were obvious duplicates of others. This left 1603 questions which were categorised into six themes for the workshop. The themes were created from a number of methods: a desktop study of the Water Research Commission research and funding structure, an analysis of the National Water Resources Strategy 2012 key strategic areas of intervention, a study of the submitted question keywords and in discussion with invited delegates to the workshop in their pre-event preparation.

Table 6 shows the six themes and their *descriptors* that were used to further categorise the 1603 questions. During the theme construction, 22 cross-cutting issues were identified that could not readily be placed in a theme but appeared in the dataset and analysis with prominence. Table 7 shows these cross-cutting issues and these were always displayed with the six themes to strengthen the consideration of integrated thinking and questioning.

TABLE 6: Six themes with descriptors used to categorise 1603 questions

Change Building socially resilient and adaptive responses to social, climate and general environmental change	**Innovation** Investment in infrastructure and research for innovation (R&D - appropriate technologies, capacity of human resources and infrastructure)
Ecosystems Protection, conservation, restoration and productive use of healthy ecosystem services	**Governance** Integrated, strategic adaptive management
Data Capturing of quality data through strategic monitoring, and with reliable analysis, modelling and scientific reporting	**Resources** Protection, conservation, treatment and management of water resources for equitable growth and development

TABLE 7: Twenty-two cross cutting issues

Allocative efficiency	Modelling	Socio-ecological responses
Culture	Multi-sector participation	Sustainable development
Education	Population growth	Technical and socio-technical
Equity	Poverty	Transdisciplinarity
Food security	Public information	Urbanisation
Gender	Rights	Water pricing
Goods and services	Risk and vulnerability	
Health	Sanitation	

The categorised 1603 questions along with the original 1674 can be found on the research website. Each question was placed into a theme depending on where its main focus or area of inquiry was. This resulted in the following numbers of questions (in brackets) per theme as ordered: *resources* (683), *innovation* (276), *governance* (245), *change* (204), *ecosystems* (158) and *data* (34).

This dataset, hereafter referred to as the *start-list,* constitutes the output from the survey and overall research effort. Questions that were highly specific to a geographic region or place were removed along with ones that were too broad, vague or generalist. Thereafter questions were tested using a primary rationale for theme acceptance of: (a) whether the question lends itself to an obvious research method and process; and (b) how important the question is for South Africa (either in the short or long term) and what level of knowledge is still required or already known about the issue. Overall, the initial reduction exercise remained fairly subjective, but some degree of support was found in identifying the themes. It was imperative to reduce the number of questions to a manageable volume.

Following this exercise, the dataset was reduced to a resulting 401 questions or 25.02% of the initial dataset and a few questions were moved to different themes upon review. The resulting number of questions in themes are as follows with the original number [] and the new number (): *resources* (103) [683], *innovation* (83) [276], *governance* (76) [245], *change* (55) [204], *ecosystems* (49) [158] and *data* (35) [34]. The total list of questions, hereafter referred to as the *long-list,* can be found in Annexure L where each question was given a unique number within its theme.

4.4 Water research horizon scanning workshop

The 401 questions in the *long-list* provided the input data into the *Water research horizon scanning workshop* on 8-9 October 2012 in Cape Town. Annexures E, F and G contain the workshop invitation, outline and pre-event delegate preparation exercise respectively. Following close consultation with the research supervisor, funders and other specialists in the field, 90 invitations were distributed in August 2012 to attend the workshop. All delegate travel and accommodation expenses were covered by the research budget and only delegates who could attend both complete days were accepted.

The workshop was attended by 34 delegates and was facilitated by a professional facilitator and mediator, Dr Laurie Nathan, of the University of Pretoria and London School of Economics and there were five graduate student assistants who ran the audio-visual systems, certain logistics and data collection including acting as rapporteurs. Table 8 lists the organisational affiliations of all delegates.

The 34 delegates followed the program as found in Annexure F in either plenary or in three smaller groups of three themes each. During the opening plenary a welcome and introduction was made and delegates were then given a comprehensive overview of the event, the study and the method to be followed. This was followed by discussion to clarify issues.

TABLE 8: Organisational affiliations of workshop delegates

Breede-Overberg Catchment Management Agency	South African Breweries
Counterpoint Development	South African Chamber of Mines
Department of Agriculture	Tlou Consulting
Department of Water Affairs (3)	Trans Caledon Tunnel Authority
Eskom	Tshwane University of Technology (2)
eThekwini Water and Sanitation	University of Cape Town (3)
Independent consultant	University of KwaZulu-Natal (2)
Inkomati Catchment Management Agency	University of Pretoria
Partners in Development	University of Stellenbosch
Rand Water	University of the Free State
Rhodes University	Virtual Consulting Engineers
Sasol	Water Research Commission (3)
See Saw Pro-Poor Solutions	World Wide Fund for Nature

In the smaller group sessions, delegates were asked to reduce the *long-list* of 401 questions to approximately a quarter of the theme totals. This resulted in 90 questions remaining as priority questions after the first day. These 90 questions are referred to as the *short-list* and underwent sometimes major review and editing by the groups regarding their wording, style

and question intent. The *short-list* can be found in Annexure M and the summary proportions of theme question numbers can be seen in Table 9. Each question still has a unique identifier to trace it to the original input question in the *long-list.* Delegates were encouraged to provide additional questions that were not represented in the data they received but were still seen as a priority given the input data. These are coded with 'ADD' in the dataset of the *short-list*.

Groups remained the same in the second day, but the data received was different. Each group received the results of the other two groups from the previous day (the *short-list*). Groups were then asked to reduce the theme lists again down to approximately half of what they were. This was effectively prioritising half the top half of the *short-list* questions received. Following this the final results were collated. If a *short-list* question received a priority vote from either of the day 2 review groups then it was included in the final dataset. This final dataset amounted to 59 priority water research questions across the six themes and is hereby referred to as the *final-list*. The count and proportional changes for questions in themes from the *start-list* (survey output: 1603) to *long-list* (workshop input: 401) to *short-list* (day 1 end: 90) to *final-list* (day 2 end: 59) can be seen in Table 9. Following this, the workshop question prioritisation *final-list* can be seen in Table 10 which constitutes the central output result from the workshop.

TABLE 9: Total and proportional question numbers

	Start-list	***Long-list***	***Short-list***	***Final-list***
CHANGE	**204**	**55**	**11**	**9**
Relative %	*12.73*	*13.72*	*12.22*	*15.25*
DATA	**34**	**35**	**8**	**5**
Relative %	*2.12*	*8.73*	*8.89*	*8.47*
ECOSYSTEMS	**158**	**49**	**13**	**7**
Relative %	*9.86*	*12.22*	*14.44*	*11.86*
GOVERNANCE	**245**	**76**	**16**	**11**
Relative %	*15.28*	*18.95*	*17.78*	*18.64*
INNOVATION	**276**	**83**	**21**	**14**
Relative %	*17.22*	*20.70*	*23.33*	*23.73*
RESOURCES	**686**	**103**	**21**	**13**
Relative %	*42.79*	*25.69*	*23.33*	*22.03*
TOTAL	**1603**	**401**	**90**	**59**
Relative %	*100.00*	*25.02*	*5.61*	*3.68*

It can be seen from Table 9 that the *long-list* contained a quarter (25.02) of the opening/input *start-list* dataset. This was further reduced to 5.61% in the *short-list* and 3.68% in the *final-*

list. The *final-list* consists of the priority 3.68% water research questions gathered during the *main survey.*

It can also be observed that the *resources* theme contained almost half (42.79%) of the *start-list* questions and that this was reduced to just under a quarter (22.03%) of the total in the *final-list.* The *innovation* theme increased slightly in proportional representation from 17.22% to 23.73% as was the case with *governance*, *ecosystems* and *change*. The largest proportional gain was in *data* increasing from 2.12% to 8.47%, mainly due to the large amount of additional questions added and deliberations on day one to revise most of the input data questions. Delegates did, however, respond that the *data* theme was underrepresented and voted to include more in the priority list.

TABLE 10: Final-list priority water research questions (59)

Theme	***Question***
CHANGE 1	How does global change impact water supply and demand, sustainable water services delivery and food security in South Africa?
CHANGE 2	What are the obstacles to achieving sustainable water and sanitation access for all?
CHANGE 3	How can integrated planning and development be implemented in order to deal with rapid rates of urbanisation?
CHANGE 4	What data and information is essential for monitoring hydrological responses to the change drivers for South Africa and how are these data best utilised in the sustainable development of South Africa?
CHANGE 5	In which ways can the efficiency of utilities and municipalities be improved in terms of water and wastewater services delivery?
CHANGE 6	What early warning and response systems need to be put in place to detect emerging waterborne contaminants?
CHANGE 7	How do we ensure that South African water research agenda is relevant and the outcomes adopted and implemented appropriately at a faster rate?
CHANGE 8	What is the strategic value of water and what changes need to be made in the South African economy to accommodate future water scarcity?
CHANGE 9	How can the social perception of the value of water be changed?
DATA 1	How can real time water data collection be used to act expediently?
DATA 2	How can the utility of monitoring systems and networks be optimised, maximised and explained to ensure sustainability of the resource and the monitoring system itself?
DATA 3	How and why could society at large contribute to and benefit from open access data related to water quality and availability?
DATA 4	How can rainfall, runoff and hydrological monitoring in South Africa be improved for better use in terms of decision making, planning, management and operations?
DATA 5	What is the current and desired state of data collection, use and data driven accountability in water services authorities?
ECOSYSTEMS 1	How can biological systems such as biofilters and wetlands be more effectively (re)used to treat all sources of pollution before it enters the freshwater and marine environment?
ECOSYSTEMS 2	What is the full ecosystem service value of our water resources and how can it be mainstreamed into the formal economy?
ECOSYSTEMS 3	What is extent and quantitative impact of alien invasive vegetation on a river's variable hydrology and water quality?
ECOSYSTEMS 4	What is the ecological impact on communities and the environment of not implementing the ecological reserve including over abstraction of water?
ECOSYSTEMS 5	What are the trends and effects of deteriorating water quality on the ecological function and associated risk and vulnerability of aquatic ecosystems?
ECOSYSTEMS 6	How can public education more effectively address the possible imbalances and trade-

	offs between ecological protection and use of water resources?
ECOSYSTEMS 7	What threats does economic development such as mining pose to the water-related environment?
GOVERNANCE 1	What has slowed the implementation of integrated water resource management in South Africa?
GOVERNANCE 2	How can effective regulation be achieved in South Africa?
GOVERNANCE 3	How can water resources within catchments be allocated to maximise sustainable economic, social and environmental benefits?
GOVERNANCE 4	How can sustainable business models for catchment management organisations be developed?
GOVERNANCE 5	How can South Africa's water information systems be improved in terms of collection, management and dissemination?
GOVERNANCE 6	What policy and practice mechanisms need to be put in place to successfully implement water demand management and conservation?
GOVERNANCE 7	How can the controls on municipal water treatment in South Africa be improved to reduce the risk to human health?
GOVERNANCE 8	What can be done to reduce river pollution in South Africa?
GOVERNANCE 9	What are the benefits of, and how effective is, ring fencing of water sales and waste water treatments costs for use in South Africa?
GOVERNANCE 10	What can be done to improve water quality monitoring, control, implementation and enforcement?
GOVERNANCE 11	How do we ensure effective implementation of co-operative governance and regulation specially inter departmental communication?
INNOVATION 1	What are the future skills gaps for professionals in the water sector and stakeholders and how can those be effectively addressed and the solutions monitored and integrated into planning and operations?
INNOVATION 2	What are the potential opportunities for energy savings in water and wastewater abstraction, treatment, distribution, collection, treatment and management without compromising quality?
INNOVATION 3	How can the role of monitoring and information systems assist in the management of the water and wastewater and well communicated to the public?
INNOVATION 4	How can the rural poor effectively access water including sanitised waste water for productive use?
INNOVATION 5	Which upstream and instream tools can be developed for the reduction into and evacuation of sediment out of rivers, wetlands and dams?
INNOVATION 6	To what extent can earth observation and related technologies be further operationalised for applications in agro-hydrological cycles in South Africa?
INNOVATION 7	How do we develop effective and efficient means of preventing, testing and treating drinking water and wastewater for emerging micropollutants and pathogens?
INNOVATION 8	How can innovative process technologies, including nanotechnology, be applied to benefit water and wastewater treatment process?
INNOVATION 9	How do we urgently, effectively and efficiently reduce water and wastewater losses in South Africa in a sustainably and socially just manner?
INNOVATION 10	How can we move towards sustainable urban drainage systems to accommodate flood events under present and projected climate change situations?
INNOVATION 11	What is the most cost effective and hygienic technology for treating sanitary waste, solid waste and greywater disposal in low-income and informal settlements?
INNOVATION 12	How can urban planning and implementation be used to provide cities and towns with safe, efficient and secure water wastewater and stormwater distribution and collection systems?
INNOVATION 13	What are the governance systems that need to be implemented in order to reduce and control eutrophication and how are they best implemented in the South African context?
INNOVATION 14	How should urban planning and implementation be used to provide efficient water, storm water, greywater and wastewater cascading and reuse considering separation at source including separation of solid waste?
RESOURCES 1	What are the policy and management approaches (agronomical, soil fertility management, water quality, nutrient reuse and greywater reuse) that can optimise water use efficiency in agriculture?

RESOURCES 2	To what extent is current water pricing policies not encouraging efficient resource utilisation?
RESOURCES 3	What systemic relationships exist between South African water quality, quantity and human diseases and how can these be addressed?
RESOURCES 4	What is the effect of large-scale hydraulic fracturing and related activities for gas extraction in the Karoo on the future groundwater quality and ecosystems in South Africa?
RESOURCES 5	What policies must be implemented to ensure effective water demand management?
RESOURCES 6	How can water footprinting tools and frameworks improve the knowledge and assessment of competing water uses and risk?
RESOURCES 7	How best should we quantify the economic value of water to address competing demands to ensure equitable and sustainable growth and development in the contexts of growing water scarcity?
RESOURCES 8	What are the life cycle and systematic impacts of acid mine water and how can these be managed, mitigated, remediated and beneficiated?
RESOURCES 9	How can urban South Africa transition towards water sensitive resilient cities?
RESOURCES 10	What mechanisms can be used to detect and address the current and future priority emerging contaminants in South Africa?
RESOURCES 11	How can groundwater resources be further developed, utilised, and managed in a sustainable manner?
RESOURCES 12	What are the health implications of irrigating various crops and watering of livestock with polluted water?
RESOURCES 13	What are the most effective methods in handling illegal water use?

Following the group prioritisation sessions, a final plenary was held at the end of the event. Each group reported back on their impressions of the event and the method using a strengths, weaknesses, opportunities, threats, way-forward and outcomes versus outputs analysis (SWOT-WO). The results of the SWOT-WO exercise can be found in Annexure N while selected direct quotes or discussion excerpts from the closing plenary as captured by the rapporteurs can be found in Annexure O.

In the formal feedback process (Figures 30-33), delegates were asked in Question 1 whether *identifying priority water research questions for South Africa through a collaborative process is useful*. The responses show that 13 delegates agreed and 6 strongly agreed indicating that question prioritisation is a valuable activity. Table 11 shows the comments to this question where collaboration is stressed and the nature of the input data is questioned. These responses identify the value of collaboration as an approach, and not necessarily that the workshop itself did or did not achieve a satisfactory level of collaboration. In Question 2 delegates were asked whether *horizon scanning is a useful methodology.* The response (Figure 31) shows that 10 delegates agreed while 8 were neutral indicating a hesitation to support this statement. The hesitancy may reflect issues including that horizon scanning methodologies were not clearly understood or that the form of horizon scanning that was carried out at the workshop was incomplete. Some support for this hesitancy can be seen in the comments in Table 1. Question 3 asked whether *a list of key water research questions for South Africa is a useful output.* Figure 32 shows that most respondents agreed or strongly agreed (14 in total), while 4 were neutral and 2 disagreed.

Question 4 asked for delegates to *comment on the horizon scanning method used in this workshop or elements thereof.* As can be seen in Table 11, delegates again found the process useful and interesting, particularly within the collaborative nature of the event but had certain misgivings around the input data, applicability of the method and how this could be better followed in South Africa. The responses here can be seen as mixed.

Question 6 asked whether *there was sufficient time for an appropriate outcome to be reached*. Figure 33 shows that there was a mixed to negative response to this statement as certain delegates responded that time-constraints were too stringent for them to make the decisions. Others said the tasks were too onerous and input data was too extensive to give meaningful comment. Finally, delegates were asked to provide any further comments on the event in (Table 11). Here there was again a mixed response towards the method applied and the input data while there was strong support for the open and collaborative nature of the event. Most delegates suggested that they would like further collaborative processes organised on the condition that addressed some of the concerns raised earlier. Most delegates also responded that question or research prioritisation and interrogation were useful activities that required further investigation and support.

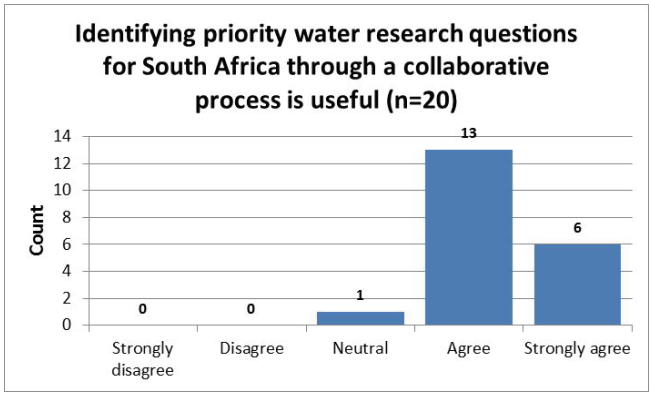

FIGURE 30: Workshop feedback Q1

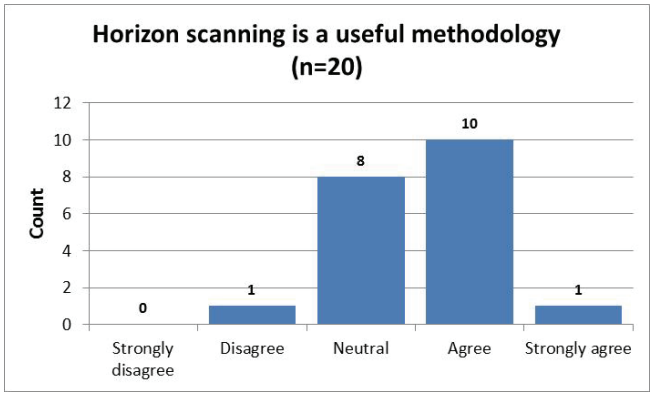

FIGURE 31: Workshop feedback Q2

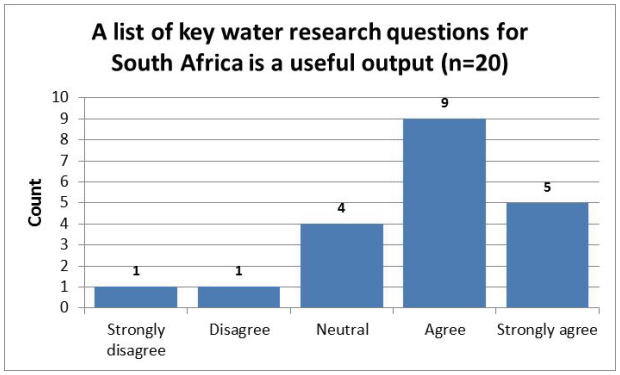

FIGURE 32: Workshop feedback Q3

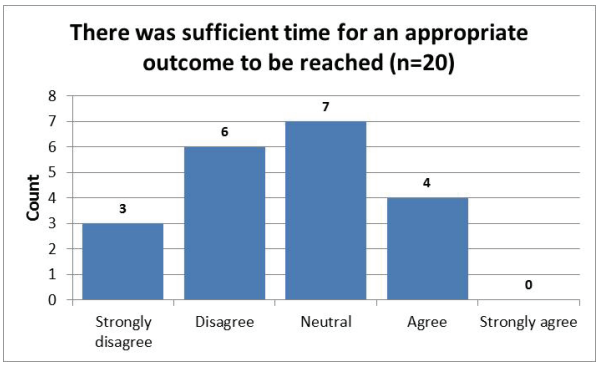

FIGURE 33: Workshop feedback Q6

TABLE 11: Formal feedback question responses and comments

1: Identifying priority water research questions for South Africa through a collaborative process is useful.
But are research questions the same as horizon scanning?
Good to identify focus areas.
Input is made by a variety of specialists to give a comprehensive picture of future research needs.
Priority research questions should be a collaborative process in which experts collaborate to define - not choose - the questions.
The priorities are interlinked and hence the collaborative process is key to uncovering and making these interlinkages explicit.
Yes, you obtain a larger group buy-in. The pre-questions and work is essential and is planning for success.
2. Horizon scanning is a useful methodology.
Current process has limitations - propose that future scenario scanning be done with participants first, then followed by formulation of questions.
Great idea; the process of distillation and prioritisation was very problematic. Key issues seemed to fall off the table because broader, more open questions got more votes in ways that reflected group dynamics as much as perceived importance.
Horizon scanning could be the most useful methodology but this was not achieved.
Horizon scanning is a necessity for proper governance and very little horizon scanning was done in the process.
Some challenges to implementing in a developing country context.
The methodology may be useful but the way it was applied did not provide a scenario based approach to the future.
Yes horizon scanning is key but we did not engage in much horizon scanning.
Yes if applied like this.
Yes it is but what other methodologies are there?
Yes, but the horizon scanning was not well explained and the "horizon" questions should have more themes.
3. A list of key water research questions for South Africa is a useful output
Certainly useful but the spectrum we worked on was inadequate. Too little exploration of economic/financial/institutional/management issues which drive traction, uptake and sustainability. Very little horizon scanning and it was rather about "what would be nice to know more about".
Collaborative approach will also hopefully help to get more and wider buy-in and application.
Research questions and horizon research questions are different.
The list of questions is the "same-old same-old".
Water is a critical resource in South Africa and issues of the future need to be researched with care and foresight.
Yes a list of key water questions is important but we were limited in the usefulness of our output by the weakness of the raw data we were presented with.
Yes, we adapted well and concluded on themes and questions.
4. Comment on the horizon scanning method used in this workshop or elements thereof
An interesting new approach compared with the more traditional blank sheet approach. A test of whether

we really believe in democracy or not!
Had we been presented with extremely wise and appropriate horizon scanning questions we could have done the method much more justice.
I must say that I was never really informed on the process itself during the workshop. I felt that what we did was questions scanning, not horizon scanning.
It should be appropriate to South Africa/developing countries.
Methodology needs significant rethink and more work.
Methodology too restricted and prevented horizon scanning and "out of the box" thinking.
Questions had lots of overlap and were unclear or constrained. Lots of discussion revolved around problems with particular questions and not on what the real problems were.
Remarkably disconnected from the real institutional issues underpinning many of the research questions identified. Undue and inappropriate focus on "hard science" questions rather than messier multi-variable questions and issues around what's really getting in the way of doing a better job.
Some elements of the methods were used. However it was not structured for the South African context.
There was very little organised horizon scanning.
Think through expectations vs. structure vs. assets in the room carefully each time.
We cannot easily see the horizon because of all the immediate problems in the foreground.
6. General comments on the workshop
Useful methodology - could be used for various collaborative processes for example strategic planning and project evaluation and prioritisation. Innovative, good timing, well facilitated, good opportunity, stimulated thought.
Assumed we were all coming from a shared understanding of issues and needs across the sector so that consensus was achievable and appropriate and voting was the appropriate tool. No process of seeing what's fallen off the table i.e. what remains in and what's been tossed - perhaps inappropriately. When do we get consensus on what the final list looks like?
Excellent exercise that brought experts together to discuss issues of primary priority in the country.
Generally a good process and good to interact with other water sector professionals at this event on this topic.
I think a brainstorming session to identify major issues and then focusing down on particular issues.
In short the Sutherland et al process is critically dependant on the quality of the questions. Unfortunately these were not present and were frequently commented on as being weak.
Not broad sectoral, representation good but enough academic representation.
The workshop format restricted free thinking but it was valuable as a learning experience. Think of a strategic workshop where we engage in future scenario planning and problem solving.
This was a very useful workshop. However there may be a need to redesign and continue the process.
Very well organised. Great opportunity and learned a lot. Great collaborative approach.
Worthwhile in order to focus our minds.

A workshop summary report was distributed to delegates two weeks after the workshop (Annexure P). While there was opportunity for delegates to comment further on the process, as called for at the end of the summary report, this data is not included or analysed due to the dispersed and delayed nature of the feedback that was received.

The *final-list* results, workshop summary, completed datasets and overall project report were placed on the research website in December 2012. All stakeholders in the database were notified via email of the posting of the final results at this time.

5. DISCUSSION

5.1 A contextual narrative through scientometrics

5.1.1 Research output and the beginning of publication

> *As the story goes, six blind men were trying to find out what an elephant looked like. They touched different parts of the elephant and quickly jumped to their conclusions. The one touching the body said it must be like a wall; the one touching the tail said it was like a snake; the one touching the legs said it was like a tree trunk, and so forth. But science does not stand still; the steady stream of new scientific literature creates a continuously changing structure. The resulting disappearance, fusion, and emergence of research areas add another twist to the tale-it is as if the elephant is running and dynamically changing its shape.*
>
> (Borner et al., 2003 pp. 180)

South Africa has undergone significant changes in the output and structure of water research over the past four decades. There has been substantial growth in output with a total relevant sample publication record of 6007 articles and research reports and a current annual output of over 350 articles and reports per year. The number and different sources of journal articles over this period have increased and diversified while WRC research report output has also increased, albeit at a slower rate.

While there are a large number of titles that reflect relevant journals (140), only 24 of these contained between 20 and 241 articles, four contained over 100 articles. There was one dominant journal, *Water SA (*containing 1829 articles), over the recorded history. This result can have a number of possible explanations: there are either too few relevant journals for South African researchers to publish in; the disciplines in the country are not diverse, integrated or trans-disciplinary enough; or there is skewed publication within disciplines. It is accepted that different disciplines have different publication outputs due to the nature of their research, so diversity within a publication database in any form must be recognised.

Before 1991 less than 100 relevant publications were being produced per year. The majority of these were WRC research reports supporting the argument that, although limited at the time, the WRC can be seen as the primary motivating factor in support of water research in the country. It is understood that many international journals were unavailable to South African researchers during the apartheid era and that peer-review publication may not have been as standard a global practise as it is today. During the period from 1977-1991 (15 years) only 706 data points were observed as opposed to the 755 in the five years after this period (1992-1996). Access to international publishing journals was restricted during the former period.

When the scientometric results for these formative fifteen years of water research publication are analysed, it is clear that the research disciplines or fields dealing with water were disconnected. The bibliometric maps display shows small pockets of specialisation such as in treatment systems, biological sciences, chemistry and some prominent words associated with the natural sciences including soils and sediment studies.

South African research and development over this period was more focused on the hydraulic mission that sought to secure supply, understand basic natural systems and was dominated by engineering and laboratory related science. Here the *getting more* and *supply management* paradigms of Ohlsson and Turton (2000) were typically found in the research output. The second industrial modernity paradigm identified by Allan (2005) appears to match the type of research was being produced in the late 80s and early 90s in South Africa.

5.2 Further research evolutionary transitions

The emergence of two main areas of research or fields of specialisation in the democratic transition (1992-1996) period is supported by a greater diversity of publications than in previous years. It is observed that the engineering or technical research outputs cluster together and again focus on treatment systems, processes and evaluation. This time the clustering is associated with management-based and planning orientated research which is found pronounced in the words ‘catchment’, ‘develop’ and ‘urban’. Although somewhat dispersed, water quality and algae also emerge as topics of research concern.

A transition period in water research occurred over a period that became increasing focussed on quality constraints, fields of management and planning. Words such as ‘review’, ‘model’, ‘community’ and ‘geography’ begin to appear in the research publications. This supports the beginning of paradigm changes due to water deficits towards end-use efficiency as outlined by Ohlsson and Turton (2000). It also indicates that the 2nd transition of Turton and Meissner (2002) was occurring where a new social contract around water was emerging that came not only from a new political regime and democratic transition that focused on redistribution, but also one that was spurred on by early South African environmentalism, the beginning of the global sustainability debate and the rise of civil society activism. Here marginal uncertainty begins to creep into the understanding of water affairs as described by Allan (2005) and the need to model, plan around catchments and include other disciplines (especially from the humanities) begin to become considerations in the research environment.

The period 1997-2001, around the major transformation of South Africa’s water laws and post establishment of the national Constitution, shows a strong polarisation between the

main technical and management orientated disciplines. Words such as develop, manage and asses become larger than more technical ones diminish. Researchers began to focus further on understanding the broader water context, use systems approaches and were beginning to plan for more than just engineering solutions. These results support the view that a transition was still underway with regards to the dominant paradigms but the word system had shifted noticeably towards the management and development related research disciplines and away from the technical.

5.2.1 Current water research approaches

The most recent decade of water research represents the greatest change in water research paradigms. It represents over half (3456 of 6007) of the collected and analysed publications, and constitutes the most representative sample of current recent water research. In this period, words become clustered and centralised, with the images being most clustered in their centres and with few stand-alone concentration areas. This indicates how research has become more diverse yet interconnected and a shift towards other disciplines. This is most prominent in the first series of the millennium analysed (2002-2006) with an emphasis on concepts such as management, modelling and development. These observations point to research that is directed towards dealing with current issues and societal benefits and needs.

'Treatment' and 'sludge' are dispersed (although still strong research areas) and exhibit many different linkages or connections with other keywords. The word 'community' is also prominent and this is the first time that the word 'integrate' makes a prominent appearance. This is not to suggest that these concepts had not emerged earlier, they find their way in many more water related publication. The research effort now evolves into a new set of paradigms that are focusing on social sciences and management. Arguably this new thrust supports a transition towards ideas of 'end use efficiency' and 'demand side solutions' as described by Ohlsson and Turton (2000), and that urban systems are seen through the lens of waterways as described by Brown et al. (2010).

The emergence of 'integration' signals another key approach in water research and water resource management. Here, multiple spheres of management and understanding are required in order to implement the principles of this approach. The broad clustering and interconnectedness of disciplines over this period, as seen in the map, as well as the greater prominence of management, are characteristics of this period.

Between 2007 and 2011 there appears to be a significant interconnectedness of specific keywords with many others. Here management has become a key research theme and this

is connected to almost every other keyword or area of interest. It is observed how all major areas of water research received fair attention and prominence in the results, from treatment systems to catchments, modelling, communities, development and biological concerns. The word integrated is increasingly prominent and linked to management, suggesting showing a dominant thrust in water research activity over this time. The growing prominence of climate related research also relates to the growing global interest in environmental change. Another interesting emerging field is ground-water research. While this has been present alongside general hydrological keywords and concepts, during this period the development and impact of the groundwater theme appears to becoming more independent than before.

5.2.2 A narrative summary

The research effort in South Africa appears to have evolved into a new set of paradigms, albeit it tentative and uncertain, in which some emphasis is given to the social sciences disciplines and to concepts of governance and management. There is also evidence of research that focuses more attention on demand-side applications and interests, and integrated management. However, a third or reflexive transition phase (Allan, 2005) does not appear just yet. Keywords that relate to the green economy or risk awareness are not yet prominent. What is obvious is an increase in the prominence of collaboration across multiple disciplines over the last decade. Collaboration across the disciplines might be a correct response in order to prepare to increase adaptive capacity and resource reconstruction in which allocative efficiency becomes a dominant management approach.

In brief, the scientometric analysis of South African published works on water research over the past four decades shows two reasonably distinct paradigms (Figure 34). The first paradigm occurs in a period dominated by the quest to supply water, which is interrupted dramatically by changes in the political landscape. The Constitution, the National Water Act, among others, and the shift in the balance of power, introduced the next paradigm shift and an emphasis on integrated water resource management. This new paradigm is characterised by a research effort that is centred on new themes and concepts such as sustainability, community, governance, and adaptation. The shift from the 1980s, once dominated by research efforts that focused on treatment, technical interventions and chemistry, and so forth, now features research interests and themes and approaches such as integrated water resource management and multi-disciplinary studies in water research.

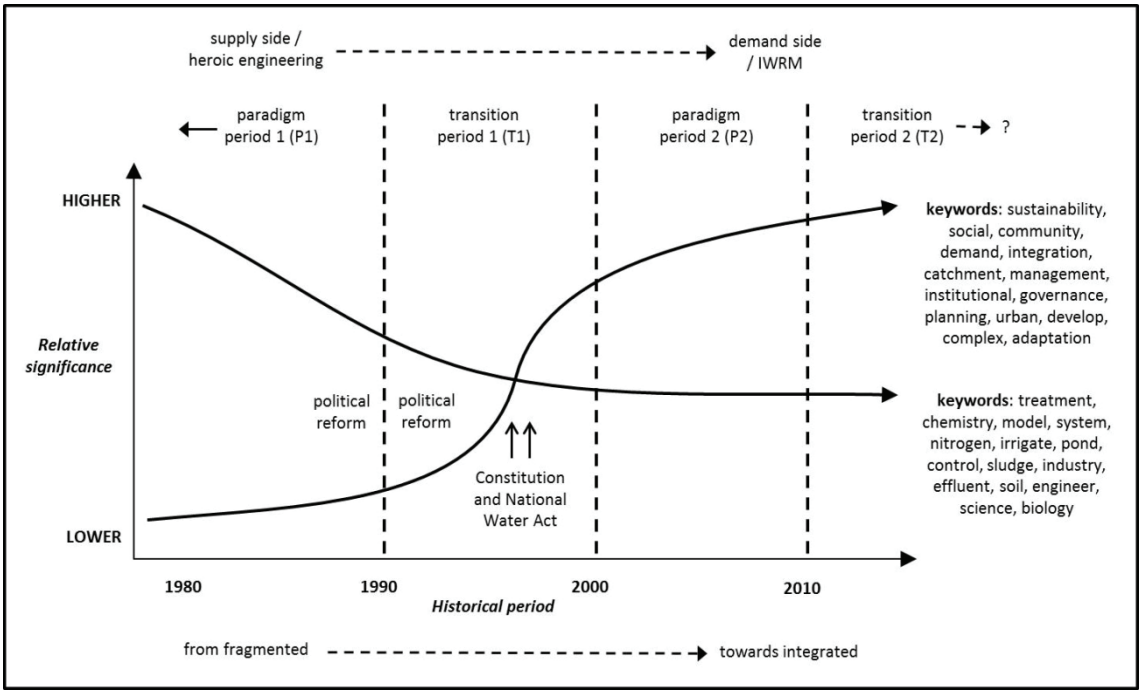

FIGURE 34: Paradigms and transitions emerging from scientometric analyses

It is interesting to observe what is not prominent seen in the scientometric results. Topics and themes such as data quality and integrity, law, rights, access, licencing and culture are noticeably absent from most of the scientometric outputs. This does not necessarily mean that they are being ignored by researchers, but rather that they are receiving less attention than other research disciplines and specialisations. The absence of these terms does not necessarily alter the observed paradigmatic shift, but may suggest that South Africa water research field is yet ready to move on to another water paradigm – at least not in the immediate future.

Paradigms take many forms and are shaped by a host of influences and changing context. For example, Ohlsson and Turton's (2000) allocative efficiency paradigm emphasises equity, rights and governance, while other contemporary paradigms emphasise adaptive co-management (Pahl-Wostl et al. 2007a). Figure 34 illustrates that the emerging paradigm appears too immature and embryonic to be categorised or described as an approach that might shape a particular research direction. At this stage, the future of an emerging paradigm looks uncertain.

5.3 Research prioritisation and the horizon

5.3.1 Water research communities, opinions, perceptions and paradigms

The launch and strategies undertaken through the Aqua d'UCT initiative far surpassed expectations with regards to participation, uptake and response. The robust and yet diverse

nature of the results and community interaction during the study was shown by the steady growth of interest from approximately 600 to over 2000 stakeholders on the research contact database by the time the study was completed in 2012. The largest proportion of stakeholders that were captured in the database were 'self-assigned', again pointing towards a genuine interest in the study and initiative.

Substantial feedback was gathered through the *pilot-survey* processes on how to manage and attract diverse stakeholders. Participants and respondents in the *main survey* represented diverse occupations or career types, from management, pure research to advisory. They were an interdisciplinary and mixed group of stakeholders broadly representative of the South African water research community. The dispersed and oftentimes substantial years of experience and high diversity in stated areas of specialisation strengthened the diversity. A large majority of *pilot survey* respondents (149/195) responded positively to the idea that *science in society should engage with society and the state to participate in identifying and addressing the research needs*.

Respondents in the *pilot survey* stated that at least half of the national research funding for water research should originate from the state while the remaining need should be divided by industry, benefactors and international supporters. The largest number of respondents (302/641) also said that water research funding is insufficient. They argued that more diverse funding options should be available that not only increase the overall output, but also increase the spread of disciplines and areas of interest or specialisation amongst the water research activities.

Commentary within the survey was extensive and varied. There was significant criticism around how national or public institutions manage, plan and spend research money, while a large amount of comments praised the WRC for the effective research funding it provides and the efficient systems that it has in place. There was also a strong call for more key, strategic and longer research projects to be supported which would involve more researchers with larger budgets. Another opinion that emerges is that more should be spent on research application and appropriate dissemination and that research grants from the state should become more competitive with industry standards.

Most respondents in the *main survey* were critical of the planning and nature of research activities and indicated that research outcomes do not account for post-project activities. Some argued that research is still not integrated and interdisciplinary enough. The list is indicative of a broad problem identification of water research challenges in South Africa and where major areas for improvement can be found.

5.3.2 Priority research questions and identified issues on the horizon

While many respondents called for longer and more substantial research projects to be funded and established, the majority of research questions submitted in response to the survey were labelled as short term projects taking only one to three years to complete. Nevertheless, these questions reflect the diverse research disciplines and specialisations as suggested by the keywords such as management, governance, planning, education, policy, planning and alternatives being most prominent. However, more technical questions relating to treatment, quality and pollution, hydrology, climate, supply and ecology dominate the input dataset.

The survey results are viewed as a substantial collection of research questions from water research stakeholders. The process of reducing the survey dataset into something manageable for prioritisation at the workshop was also a rigorous one. The reduction from 1603 initial to 59 priority research questions for water followed the methods of Sutherland et al. (2011b). The only significant change was to gather the initial dataset of questions from a broad and larger community rather than simply from key specialists. The workshop itself represented many different disciplines and sectors within water as seen by the delegate affiliations. This is reflected in the proportion of questions per theme in the *final list* with the following numbers and percentage of questions per theme constituting this final list (ranked): innovation (14; 23.73%), resources (13; 22.03%), governance (11; 18.64%), change (9; 15.25%), ecosystems (7; 11.86) and data (5; 8.74%) (Refer to Table 10). The set of research questions was categorised further (Figure 35). In this diagram the vertical axis represents time (i.e. nominal period in years required to address a research question); a horizontal axis identifying issues and concerns identified by the question that deals with immediate, pressing issues to those requiring a long-term view; and finally, the organisation of questions in relation to the paradigms identified earlier from the scientometric analysis of published works. All 59 questions were plotted against this matrix. The process of developing and plotting this matrix is a subjective one. It has not been tested with the stakeholders, but it is presented here as a contribution to thinking how best to incorporate multiple elements into the development and organisation of a research question bank. In Figure 35, the notation R1, for example, refers to the question in Resource 1 found in Table 10. In general the presentation (Figure 35) confirms three important findings: (a) many of the questions that were offered and refined at the workshop seek to address short term research questions and issues of immediate concern, e.g. questions about supply of service delivery, sanitation, access to water, and water quality; (b) the majority of the questions confirmed the existence of a transition period as identified earlier in the scientometrics analysis. These questions deal with issue of intermediate concern and were dominated by issues of integration; data

and information; social change; planning; improved legislation; health and communication; and finally, (c) a set of questions that are arguably more closely aligned with issues and concerns that are on the horizon or close to it, and also feature elements of Allan's (2005) 3rd, 4th and 5th paradigm. Here the questions deal with long-term critical concerns of sustainability, green economies, and new forms of integrated, adaptive governance. These kinds of questions pose extraordinary challenges and will necessitate long term support to be given to the South Africa scientific and research community. Two examples of these kinds of questions are:

How can innovative process technologies, including nanotechnology, be applied to benefit water and wastewater treatment process? (I8)

What are the life cycle and systematic impacts of acid mine water and how can these be managed, mitigated, remediated and beneficiated? (R8)

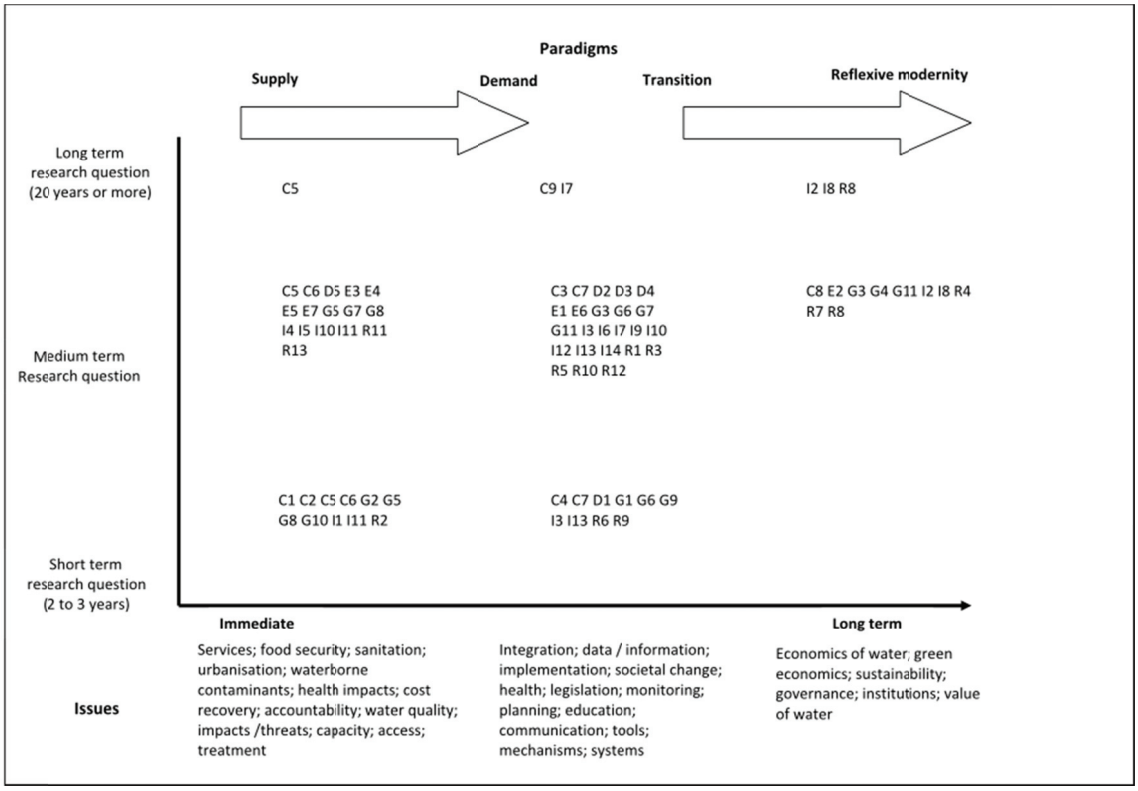

FIGURE 35: Organisation of questions in relations to the research challenge, issues and paradigms

The workshop was acknowledged by many delegates as an energising and interesting collaborative exercise. While there were some obvious gaps in the representation, delegates were pleased to interact with diverse leaders in the field. The quality and high level of

exchange and interaction during the formal and informal activities was appreciated by most delegates who identified this as a key feature of the experience. Positive comments were also received about the organisation, facilitation, the venue and structure of the workshop. Many said that the structured approach to the workshop made the best use of time in order to achieve the intended product.

The strongest criticism from delegates was that the approach and methods used at the workshop were not designed to identify horizon scanning research questions in themselves. Rather delegates said that they were coerced into responding to the questions that were put before them. Moreover, delegates felt that it was difficult to develop new questions that were of an horizon scanning nature for a number of reasons: the groups were too diverse; there was insufficient time to consider and develop meaningful questions; and the process was too demanding for the facilitators which tended to result in tasks being carried out in a mechanistic manner and all within a tight timeframe.

Delegates were critical of the fact that they had to work with a large number of questions that were poorly formulated. Problematic questions came in a number of forms: they were often about immediate issues; they could not be identified as a research question; they were too broad to be categorised in a chosen theme; were often limited to disciplines and fields within the natural sciences; and many did not show any insight into what might lie on the ‘horizon’. Delegates were frustrated by the pressure to modify a large set of questions that appeared to have limited value to them at the time.

Upon reassessment of the workshop method, feedback and the final list of questions, the results are, nevertheless, seen to have significant value as a collaboratively derived collection of national research priorities as motivated by most delegates. While the priorities may not be exclusively focused on the horizon, they still capture the knowledge needs within water through actionable questions. This is the first effort of its kind that has produced comprehensive and inclusive research priorities for water in South Africa.

These questions also indicate a current state of thinking amongst researchers and the broader water community. There is a move towards a new paradigm that accounts for a third paradigm transition as uncertainty and risk are being explored. However, the majority of the questions remain within paradigms which focus on end-use efficiency, demand-side management and technical solutions. Limited integrated thinking and management is pursued. This also explains the delegate frustration at the workshop as many were expecting to be able to provide these types of questions that would create a new set of paradigms and lead future thinking.

6. CONCLUSION

The intention of this study was to contribute to the understanding of South Africa's water research in two ways. Through an analysis of the history of water research in order to identify paradigms and associated shifts; and to identify and evaluate new water research questions and their associated paradigms that will meet the changing needs of the country in the medium to long term. The methods of scientometrics and horizon scanning are used to identify, analyse and critique these paradigms. Scientometrics provides the historical narrative to identify and discuss paradigm movements. Horizon scanning allowed for research question gathering and prioritisation through which paradigms and futures are analysed.

Scientometric results show that the publication record for water related research in South Africa contained 6007 articles. Water Research Commission (WRC) research reports amounted to 1760 (29.30%) of this total. The remainder were peer-reviewed journal articles published in *Water SA* accounting for 1829 (30.45%) articles. The publication record also increased in number dramatically since 1990 and more articles are published annually than the year before throughout the dataset. This scientometric analysis shows that water research has become more prolific and is found in more diverse publications, many of these being internationally distributed. The WRC plays a significant role in funding and publishing water research in South Africa.

Paradigms were identified through the scientometric mapping methods using the publication record show a history of water research from 1977 to 2011. Overall, the research output has predominantly focused on management, development, models, quality and system treatment. This shows a technical dominance in the historical record but other paradigms of allocative efficiency, uncertainty and risk are also present. The change in paradigms is observed when these results are examined over successive time periods.

Two major paradigm approaches are observed in the analysis of water research along with one significant transition period over the past four decades in which this study was conducted. The first set of paradigms, from 1977-1991, emphasises the hydraulic mission that sought to secure supply, understand basic natural systems and is dominated by engineering and laboratory related disciplines. The 'getting more' and 'supply management' paradigms are characterised by efforts to ensure water supply, drainage and the development of the sewered city - mainly engineering and biological related research efforts.

In the following ten years (1992-2001) there is transition in which quality constraints and fields of management and planning become prominent. This paradigm is in response to changes in water deficits and focus on end-use efficiency. A second transition occurs with a

new social contract around water at a time when the new political regime enters government in a period of democratic transition, growing environmentalism and a rise of civil society activism. The need to plan, model catchments and include other disciplines is becoming evident in the research environment.

The question prioritisation activities using horizon scanning methods provided an opportunity for the study to engage with a wide and diverse population of water research stakeholders and practitioners. Digital tools were used to increase the reach of the study and allow for faster communication and results dissemination. This resulted in a growth from 600 to over 2000 stakeholders on the research contact database by the time the study was complete in 2012.

The survey results are a substantial collection of research questions from water stakeholders and researchers. The process of reducing the survey dataset a final priority list was rigorous. Here the reduction from 1603 initial, to 59 priority research questions for water, represents many technical, social and interdisciplinary areas of questioning. Many questions deal with immediate concerns while others aim to tackle long-term or systemic problems. Others are coupled or integrated questions that cover a number of disciplines. These questions indicate present and future paradigms amongst researchers and the broader water community. There is a transition observed towards a new paradigm that accounts for a third transition shift (Allan, 2005) as uncertainty and risk are being questioned. However, the majority of the questioning still falls within paradigms that focus on end use efficiency, demand side management and technical solutions.

As mentioned in the earliest stages of this study report, there were significant limitations to the study. The simplification of scientometrics causes a potential loss in detail and context. The interpretations of output maps remain subjective but the method does provide powerful, macro perspectives of a research area. It is recommended that further detailed mapping and analysis be done on publications to tease out the reasons for paradigm shifts as well as understand what is missing in the existing body of knowledge. Horizon scanning has many inappropriate elements for the South African context as it is limited to a degree by its reach and participation. It is recommended that further prioritisation activities are undertaken to guide research but that these are more expert and leader initiated before a wider audience is consulted. The current state of questioning does, however, provide an overall perspective of what a large and diverse group of research stakeholders and practitioners are asking even if these may not be on the horizon.

The combination of the most recent scientometric and horizon scanning results provide a synthesised understanding of present and potential future paradigms. Elements of end-use efficiency and the end of the second paradigm transition are represented by both the

identified questions and scientometric results in the 2007-2011 results. Some of the question results in the final list also begin to ask further questions about water governance, allocation and how institutions should act in the water environment. This represents the beginning of a transition or paradigm shift that is occurring within South Africa towards the third paradigm of Allan (2005) or one that focuses now on allocative efficiency (demand management II). Here many questions exist within the paradigm of adapting to scarcity (Ohlsson and Turton, 2000).Questions relating to new urban approaches to water are also present, supporting a change in paradigms within Brown et al. (2010) towards waterways or water sensitive cities. For this to occur, adaptive capacity in research needs to be mobilised.

7. RECOMMENDATIONS

Two obvious recommendations arise from this project which could be considered for further research. The first is to undertake a comprehensive scientometric analysis and to connect the patterns and processes in the research output with the changing context. The current study was only able to map results for time slices extracted at a fairly high resolution, and these were based on two broad concepts, that of 'water' and 'South Africa'. The interpretation of scientometrics can also be enriched by supplementing the findings with complementary metadata which is part of value chain and will include information on capacity building, funding, patents and economics of publication of research. Scientometric presents an historical perspective which is useful in identifying processes from the past trends. It also provides a perspective on what could be learnt from these processes, and offers potential to evaluate the strengths and weaknesses of the research output.

A second recommendation is to test horizon scanning further using a variety of different methods. In this study, the priority was to establish a large database of questions offered by a range of researchers and practitioners across the country. The authors argued that it was important to start by getting a glimpse of the macro picture rather than commence by gathering questions from a small group of accomplished researchers only. This approach was criticised by some of the workshop participants principally because they felt that it did not do justice to full scope of horizon scanning methods. The current study offers a range of carefully chosen questions that were refined at the workshop and then considered against elements such as issues of concern, the scope of the research enterprise, and paradigms. It is logical that consideration should be given to horizon scanning methods for the South African water sector by following a more detailed, as suggested by Sutherland and Woodroof (2009, pp. 525), for example, which are to (i) scope the issue; (ii) gather information; (iii) spot signals; (iv) watch trends; (v) make sense of the future; and (vi) agree on the response. The method involves a consultation process involving visionaries who are capable of imaging a long term future.

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Annexure A: Journal search set

ADVANCES IN WATER RESOURCES	ENVIRONMENTAL SCIENCE AND POLLUTION RESEARCH	LAW ENVIRONMENT AND DEVELOPMENT JOURNAL
AFRICAN JOURNAL OF AGRICULTURAL RESEARCH	ENVIRONMENTAL SCIENCE AND TECHNOLOGY	LEAD LAW ENVIRONMENT AND DEVELOPMENT JOURNAL
AFRICAN JOURNAL OF AQUATIC SCIENCE	ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY	MARINE AND FRESHWATER BEHAVIOUR AND PHYSIOLOGY
AFRICAN JOURNAL OF ECOLOGY	ESTUARINE COASTAL AND SHELF SCIENCE	MARINE AND FRESHWATER RESEARCH
AFRICAN WILDLIFE	FIELD CROPS RESEARCH	MINE WATER AND THE ENVIRONMENT
AGREKON	FISHERIES RESEARCH	MITIGATION AND ADAPTATION STRATEGIES FOR GLOBAL CHANGE
AGRICULTURAL AND FOREST METEOROLOGY	FOREST ECOLOGY AND MANAGEMENT	MOLECULAR ECOLOGY
AGRICULTURAL SYSTEMS	FRESHWATER AND MARINE JOURNAL	NATURAL RESOURCES JOURNAL
AGRICULTURAL WATER MANAGEMENT	FRESHWATER BIOLOGY	NATURE
AGRICULTURE ECOSYSTEMS AND ENVIRONMENT	FRONTIERS IN ECOLOGY AND THE ENVIRONMENT	ORYX
AMBIO	GEOFORUM	PADDY AND WATER ENVIRONMENT
APPLIED AND ENVIRONMENTAL MICROBIOLOGY	GEOGRAPHICAL JOURNAL	PHYSICS AND CHEMISTRY OF THE EARTH
AQUACULTURE	GEOJOURNAL	PHYSICS AND CHEMISTRY OF THE EARTH PARTS A/B/C
AQUATIC BOTANY	GEOPHYSICAL RESEARCH LETTERS	PLANT ECOLOGY
AQUATIC CONSERVATION-MARINE AND FRESHWATER ECOSYSTEMS	GLOBAL AND PLANETARY CHANGE	POPULATION AND ENVIRONMENT
AREA	GLOBAL ECOLOGY AND BIOGEOGRAPHY	PROCEEDINGS OF THE INSTITUTION OF CIVIL ENGINEERS-WATER MANAGEMENT
AUSTRAL ECOLOGY	GROUND WATER	PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA
BIODIVERSITY AND CONSERVATION	GROUND WATER MONITORING AND REMEDIATION	PROGRESS IN DEVELOPMENT STUDIES
BIOLOGICAL CONSERVATION	HYDROBIOLOGIA	PROGRESS IN PHYSICAL GEOGRAPHY
BIOLOGICAL WASTEWATER TREATEMENT	HYDROGEOLOGY JOURNAL	REMOTE SENSING OF ENVIRONMENT
BIOSCIENCE	HYDROLOGICAL PROCESSES	RESTORATION ECOLOGY
BIOTECH AND BIOENGINEERING	HYDROLOGICAL SCIENCES JOURNAL	RIVER RESEARCH AND APPLICATIONS
BIOTECHNOLOGY RESOURCES	HYDROLOGY AND EARTH SYSTEM SCIENCES	SCIENCE
BULLETIN OF ENVIRONMENTAL CONTAMINATION AND TOXICOLOGY	ICHTHYOLOGICAL EXPLORATION OF FRESHWATERS	SCIENCE OF THE TOTAL ENVIRONMENT
CAPITALISM NATURE SOCIALISM	INLAND WATER BIOLOGY	SOIL AND TILLAGE RESEARCH
CHEMOSPHERE	INTERNATIONAL JOURNAL OF ENVIRONMENTAL HEALTH RESEARCH	SOUTH AFRICAN GEOGRAPHICAL JOURNAL
CIVIL ENGINEERING	INTERNATIONAL JOURNAL OF ENVIRONMENTAL SCIENCE AND TECHNOLOGY	SOUTH AFRICAN JOURNAL OF BOTANY
CLEAN-SOIL AIR WATER	INTERNATIONAL JOURNAL OF ENVIRONMENTAL STUDIES	SOUTH AFRICAN JOURNAL OF CHEMISTRY
CLIMATE AND DEVELOPMENT	INTERNATIONAL JOURNAL OF LIFE CYCLE ASSESSMENT	SOUTH AFRICAN JOURNAL OF PLANT AND SOIL
CLIMATIC CHANGE	INTERNATIONAL JOURNAL OF WATER RESOURCES DEVELOPMENT	SOUTH AFRICAN JOURNAL OF SCIENCE
CONSERVATION BIOLOGY	IRRIGATION AND DRAINAGE	SOUTH AFRICAN JOURNAL OF WILDLIFE RESEARCH
CONSERVATION LETTERS	IRRIGATION SCIENCE	SOUTHERN FORESTS
CONTINENTAL SHELF RESEARCH	JOURNAL AMERICAN WATER WORKS ASSOCIATION	SUSTAINABLE DEVELOPMENT
DESALINATION	JOURNAL OF AFRICAN EARTH SCIENCES	TRANSACTIONS OF THE ROYAL SOCEITY OF SOUTH AFRICA

DESALINATION AND WATER TREATMENT	JOURNAL OF APPLIED ECOLOGY	TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY
DIVERSITY AND DISTRIBUTIONS	JOURNAL OF APPLIED ICHTHYOLOGY	URBAN WATER JOURNAL
EARTH AND PLANETARY SCIENCE LETTERS	JOURNAL OF APPLIED PHYCOLOGY	WASTE MANAGEMENT AND RESEARCH
EARTH SURFACE PROCESSES AND LANDFORMS	JOURNAL OF ARID ENVIRONMENTS	WATER AIR AND SOIL POLLUTION
EARTH-SCIENCE REVIEWS	JOURNAL OF BIOGEOGRAPHY	WATER AND ENVIRONMENT JOURNAL
ECOLOGICAL ECONOMICS	JOURNAL OF CLEANER PRODUCTION	WATER ENVIRONMENT RESEARCH
ECOLOGICAL ENGINEERING	JOURNAL OF ENERGY IN SOUTHERN AFRICA	WATER INTERNATIONAL
ECOLOGICAL MODELLING	JOURNAL OF ENVIRONMENTAL MANAGEMENT	WATER POLICY
ECOLOGY AND SOCIETY	JOURNAL OF ENVIRONMENTAL MONITORING	WATER QUALITY
ECOLOGY OF FRESHWATER FISH	JOURNAL OF ENVIRONMENTAL QUALITY	WATER RESEARCH
ECOSYSTEMS	JOURNAL OF FRESHWATER ECOLOGY	WATER RESOURCES
ECOTOXICOLOGY	JOURNAL OF HYDROLOGY	WATER RESOURCES MANAGEMENT
ECOTOXICOLOGY AND ENVIRONMENTAL SAFETY	JOURNAL OF HYDROLOGY AMSTERDAM	WATER RESOURCES RESEARCH
ENERGY CONVERSION AND MANAGEMENT	JOURNAL OF SOIL AND WATER CONSERVATION	WATER SA
ENERGY FOR SUSTAINABLE DEVELOPMENT	JOURNAL OF SOUTHERN AFRICAN STUDIES	WATER SCIENCE AND TECHNOLOGY
ENERGY OXFORD	JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION	WATER SEWAGE AND EFFLUENT
ENVIRONMENT AND HISTORY	JOURNAL OF THE SOUTH AFRICAN INSTITUTION OF CIVIL ENGINEERING	WETLANDS ECOLOGY AND MANAGEMENT
ENVIRONMENT AND URBANIZATION	JOURNAL OF WATER AND ENVIRONMENT	
ENVIRONMENT DEVELOPMENT AND SUSTAINABILITY	JOURNAL OF WATER AND HEALTH	
ENVIRONMENTAL BIOLOGY OF FISHES	JOURNAL OF WATER CHEMISTRY AND TECHNOLOGY	
ENVIRONMENTAL CONSERVATION	JOURNAL OF WATER RESOURCES DEVELOPMENT	
ENVIRONMENTAL MANAGEMENT	JOURNAL OF WATER RESOURCES PLANNING AND MANAGEMENT-ASCE	
ENVIRONMENTAL MODELLING AND SOFTWARE	JOURNAL OF WATER SUPPLY RESEARCH AND TECHNOLOGY	
ENVIRONMENTAL MONITORING AND ASSESSMENT	KOEDOE	
ENVIRONMENTAL POLLUTION	LAND DEGRADATION AND DEVELOPMENT	
ENVIRONMENTAL RESEARCH	LANDSCAPE AND URBAN PLANNING	

ANNEXURE B: WOS QUERY

Topic based

Publication Name=(ADVANCES IN WATER RESOURCES OR AFRICAN JOURNAL OF AGRICULTURAL RESEARCH OR ... OR WETLANDS ECOLOGY AND MANAGEMENT) AND Topic=(water*) AND Topic=("south* africa*")

Refined by: Document Type=(ARTICLE)

Timespan=All Years.

Lemmatization=On

Title based

Publication Name=(ADVANCES IN WATER RESOURCES OR AFRICAN JOURNAL OF AGRICULTURAL RESEARCH OR ... OR WETLANDS ECOLOGY AND MANAGEMENT) AND Title=(water*) AND Title=("south* africa*")

Refined by: Document Type=(ARTICLE)

Timespan=All Years.

Lemmatization=On

ANNEXURE C: SOFTWARE SETTINGS

Sci2

.ini settings >-vmargs-Xms15m-Xmx1200m
Load >f ile.csv
Preprocessing> Topical > Lowercase, Tokenize, Stem, and Stopword Text (title)
Data Preparation > Extract Word Co-Occurrence Network (title, unique)
Preprocessing> Networks > Delete Isolates
Visualization > Networks >DrL (VxOrd) (Edge weight attribute: weight; New X-Position Attribute Name: xpos; New Y-Position Attribute Name: ypos; Do not cut edges; Edge cutting strength: 0.0)
Preprocessing> Networks > Extract Top Edges (1000)
Preprocessing> Networks > Delete Isolates
Save > (Pajek) file.net

VOSviewer

Open > Import > file.net
Show connected items
Lines: 200
Labels > size effect > 70%
Normalization method: 1
Mapping parameters > convergence 1E-8;maximum iterations 1000
Clustering parameters >resolution 1.00; random starts 1: 10; random starts 2: 50
Random seed: 0
Zoom and orientate
Save to file (label and density view) > file.jpg

ANNEXURE D: PRIORITY QUESTIONS FOR WATER RESEARCH 2012 SURVEY

Priority Questions for Water Research 2012 (Aqua d'UCT & Water

Welcome

THIS IS THE WELCOME PAGE. THE SURVEY BEGINS ON PAGE 4 AND IS 9 SHORT PAGES IN LENGTH.

Welcome to the "Priority Questions for Water Research 2012 Survey"

PAGE 1: WELCOME
PAGE 2: STUDY INTRODUCTION
PAGE 3: CONSENT PAGE
PAGE 4: SURVEY BEGINS (5-10 minutes maximum)

You have arrived at this page by being identified as a key participant. This is because you are either a water research stakeholder (e.g. water manager, policy maker etc.) or practitioner (e.g. researcher, research manager etc.). We are collecting important water research questions in this survey.

Many other smaller or pilot surveys have been conducted in the past few months. All results are on www.aquaduct.org.za and are being used to guide the project. This is the national-scale question gathering survey supported by the Water Research Commission. It aims to target 2000 key water professionals.

Please take a moment to think over your water-related field or your relevant experience and the research that is performed therein. Where are the research strengths and weaknesses? What areas should be focused on? In this survey you will be asked to provide important research questions for your field or any water related area that you know.

This survey should not take you more than 5-10 minutes to complete.

Click next to continue.

Visit www.aquaduct.org.za for more.

Introduction

THIS IS THE INTRODUCTION PAGE. THE SURVEY BEGINS ON PAGE 4.

The title of the overall study is 'An analysis of paradigms shaping water research in South Africa: questions for future research'. It is being conducted at the University of Cape Town (UCT) under the initiative name Aqua d'UCT (pronounced aqueduct and meaning 'water at UCT') and is supported by the Water Research Commission (WRC). The study runs from May 2012 until February 2013 but is anticipated to become an annual endeavour.

The driving force behind this project is to identify the 100 most important research questions in the water sector. The method behind this process is as follows: by gamering information from a wide number of water stakeholders (2000 people) we will be able to identify the main concerns and questions in the water sector. The information will be gathered through a series of telephonic and online surveys and will mainly target water researchers, research managers, decision makers, NGO leaders or active community groups in the water sector.

Through the perspectives of the participants we will be able to gather qualitative and quantitative data to identify, evaluate and prioritise new water research questions that seek to address the present and changing needs of the South Africa.

Please participate in the telephonic or online survey. Visit our website www.aquaduct.org.za for more background, methods, references, results, contacts and discussion.

The Aqua d'UCT Team

Consent

Page 1

Priority Questions for Water Research 2012 (Aqua d'UCT & Water

THIS IS THE CONSENT PAGE. THE SURVEY BEGINS ON THE NEXT PAGE.

Consent to Participate in a Study

Title: Priority Questions for Water Research 2012 Survey

Contact details:
Raymond Siebrits
Department of Environmental and Geographical Science
University of Cape Town
E-mail: raymond.siebrits@uct.ac.za
Phone: +27 82 587 0982
Postal: PO Box 199, Newlands, Cape Town, 7725, South Africa

Research Ethics Approval
This study has been approved by the Ethics in Research Committee of the Faculty of Science at the University of Cape Town with the approval code 'SFREC 006_2011'. If you have any questions, concerns, or reports regarding your rights as a participant of this research, please contact the researcher or the committee chair on michael.meadows@uct.ac.za.

Purpose and Description
The purpose of the study is to collect and evaluate important water research questions for South Africa. Your participation will require 5-10 minutes of your time.

Procedures
If you decide to participate you will be asked to take an online survey that includes providing research questions and opinions of research future scenarios. Overall in the study, we hope to gain information about water research preferences, opinions, questions, histories and futures in South Africa. Besides your time, there are no costs for helping us with this study. All results of this research will be fed back to you once the survey has closed and the analysis completed.

Voluntary Participation and Withdrawal
Participation in this research is voluntary. You do not have to be in this study. If you decide to be in the study and change your mind, you have the right leave out at any time. If you wish to opt out of communications, email raymond.siebrits@uct.ac.za.

Confidentiality
We will keep your records confidential. Only the research team will have access to the information you provide. Information may also be shared with those who make sure the study is done correctly, i.e. the research supervisor. The information you provide will be stored on a password protected secure database. Your name, email address, and other facts that might point to you will not appear when we present this study or publish its results.

Your answers will be confidential and they will be put together with those of the many other people who are participating to gather an overall picture.

Email follow-up
If you are willing to participate, you will be asked for your email address. This is so we can contact you with the survey link if you do not complete the survey and would like to return to it at a later date. You can opt-out of any participation at any stage.

***I have read the information above. I have had the chance to ask questions and receive answers about it by contacting the researcher on this page.**

***Are you willing to volunteer for this research?**

◯ I agree to participate

Occupation details

Priority Questions for Water Research 2012 (Aqua d'UCT & Water

1. *Please provide your current work details. This is so that we can identify which sectors are participating in this study.

No information published or distributed will be able to identify you.

Enter up to three affiliations/activities if you have multiple water positions.

Occupation:

Company/organisation/affiliation

*Current position/activity/occupation

Occupation:

Company/organisation/affiliation

Current position/activity/occupation

Occupation:

Company/organisation/affiliation

Current position/activity/occupation

2. *How many years experience do you have in the water sector?

Priority Questions for Water Research 2012 (Aqua d'UCT & Water

3. *My areas of specialisation are within (you may select multiple fields):

(note: this is the only question with a large number of fields)

	Partial understanding	Partial specialist	Specialist
Access, rights, sociology, poverty	◯	◯	◯
Agriculture	◯	◯	◯
Catchment management	◯	◯	◯
Chemistry	◯	◯	◯
Civil water engineering	◯	◯	◯
Demand management	◯	◯	◯
Drainage (urban and rural)	◯	◯	◯
Ecology and the reserve	◯	◯	◯
Economics	◯	◯	◯
Education and awareness	◯	◯	◯
Environmental management	◯	◯	◯
Governance, policy and politics	◯	◯	◯
Human health	◯	◯	◯
Hydrology and hydrogeology	◯	◯	◯
Pollution	◯	◯	◯
Purification	◯	◯	◯
Sanitation	◯	◯	◯
Technologies	◯	◯	◯
Transboundary waters	◯	◯	◯
Waste water treatment	◯	◯	◯

Other/comments

Priority questions for water research 2012: question submission

Priority Questions for Water Research 2012 (Aqua d'UCT & Water

Instructions:

Please submit up to 5 research questions below (contact us if you wish to submit more or use the link below). The extra information per question is recommended but not mandatory.

Please ensure your questions are sound, thoughtful and relevant to the best of your experience.

Link for more than 5 questions upon completion of this survey:
https://www.surveymonkey.com/s/aquaduct-wro-priority-questions-water-research-2012-additional-questions

This link provides some discussion around constructing a research question. Please visit the webpage to learn about this process if you are interested:
http://www.aquaduct.org.za/question-construction.html

1. *Draft or write a water research question

*Question	
Sector or research type category/keywords	
How long could this research realistically take?	
Comments	

2. Draft or write a water research question

Question	
Sector or research type category/keywords	
How long could this research realistically take?	
Comments	

3. Draft or write a water research question

Question	
Sector or research type category/keywords	
How long could this research realistically take?	
Comments	

4. Draft or write a water research question

Question	
Sector or research type category/keywords	
How long could this research realistically take?	
Comments	

Priority Questions for Water Research 2012 (Aqua d'UCT & Water

5. Draft or write a water research question

Question	
Sector or research type category/keywords	
How long could this research realistically take?	
Comments	

South African capacity

1. *Water research in South Africa is applied effectively toward:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Policy	◯	◯	◯	◯	◯
Guidelines	◯	◯	◯	◯	◯
Practices	◯	◯	◯	◯	◯
Industry/business	◯	◯	◯	◯	◯
Relevant jobs	◯	◯	◯	◯	◯
Further research	◯	◯	◯	◯	◯

Comments

2. *In your experience, do you think that water research is adequately funded in South Africa?

- ◯ Yes
- ◯ Maybe
- ◯ No
- ◯ I don't know

Comments

My details

Priority Questions for Water Research 2012 (Aqua d'UCT & Water

***Please provide your personal contact details.**

This is so we can keep track of your survey and send you updates. No information published or distributed will be able to identify you individually.

First name	
Surname	
*Email address:	
*Confirm email address:	
Landline:	
Mobile:	

Feedback, comments and closing remarks

1. Please write any comments on the study or survey here:

Priority Questions for Water Research 2012 (Aqua d'UCT & Water

2. Provide the name and phone number of any persons who would be interested in participating in the study or who is a key contact person (e.g. a colleague, contact, manager, supervisor, associate etc.).

1 Name	
1 E-mail	
1 Organisation	
1 Phone number	
1 Who are they / what do they do?	
2 Name	
2 E-mail	
2 Organisation	
2 Phone number	
2 Who are they / what do they do?	
3 Name	
3 E-mail	
3 Organisation	
3 Phone number	
3 Who are they / what do they do?	
4 Name	
4 E-mail	
4 Organisation	
4 Phone number	
4 Who are they / what do they do?	
5 Name	
5 E-mail	
5 Organisation	
5 Phone number	
5 Who are they / what do they do?	

Telephone contact feedback

Priority Questions for Water Research 2012 (Aqua d'UCT & Water

***Rate the overall telephone contact experience you had with a member of our research team:**

- ◯ Bad
- ◯ Average
- ◯ Good
- ◯ Other or comments

Thanks

Thank you for your input!

If you wish to add additional research questions at a later stage, visit www.aquaduct.org.za/surveys or go to this link:
https://www.surveymonkey.com/s/aquaduct-wrc-priority-questions-water-research-2012-additional-questions

Spread the word: tell others to visit www.aquaduct.org.za and participate or send them the survey link:
https://www.surveymonkey.com/s/aquaduct-wrc-priority-questions-water-research-2012

Follow us on Facebook or Twitter for the latest updates:
www.facebook.com/pages/Aqua-dUCT/205566342838109
www.twitter.com/aRAYofwater

Lookout for feedback and updates from the survey and post-analysis results.

Regards,

The Aqua d'UCT Team

ANNEXURE E: WORKSHOP INVITATION

INVITATION TO WATER RESEARCH HORIZON SCANNING WORKSHOP

Hosted by Aqua d'UCT, University of Cape Town and the Water Research Commission

8-9 OCTOBER 2012 | THE ALPHEN BOUTIQUE HOTEL | CONSTANTIA | CAPE TOWN

9 August 2012

Dear

As akey specialist and experienced practitioner in the water sector you are hereby invited to participate in the Aqua d'UCT ***Water Research Horizon Scanning Workshop*** on 8-9 October 2012. You are among 40 selected delegates who have been invited to attend this event which is funded by the Water Research Commission.

The workshop aims to refine and select waterresearch questions collectedfrom a larger list earlier in the year from over 600 participants. The outcome of the workshop is toidentify the100 water research questions that will contribute towards credible, relevant and legitimate institutional and policy solutions to meet the various water resource challenges in South Africa. These questions will be used towards an academic publication for which you will be invited and a contributing co-author. The input data for the event will be drawn from the successful*Questions for water research 2012* activities which can be found on www.aquaduct.org.za.

All reasonable travel costs and accommodation at the Alphen Boutique Hotel will be covered by the organisers of the workshop. Please indicate if you will require hotel accommodation on Monday 8 October. Guests who commit to attending and ultimately do not, without cancelling by 31 August 2012, will be invoiced for the full cost of their participation.

Further details about the event will be distributed upon acceptance of this invitation. Invitees will also be expected to partake in a two-houronline question prioritisation exercise two weeks prior to the event. See the attached Outline and Draft Program for more information on the workshop.

Please would you respond by no later than Friday 17 August 2012.

Yours sincerely,

Raymond Siebrits
Principal Researcher
raymond.siebrits@uct.ac.za

Dr Kevin Winter
Project Leader
kevin.winter@uct.ac.za

ANNEXURE F: WORKSHOP OUTLINE

WATER RESEARCH HORIZON SCANNING WORKSHOP

Hosted by Aqua d'UCT, University of Cape Town and the Water Research Commission

8-9 OCTOBER 2012 | THE ALPHEN BOUTIQUE HOTEL | CONSTANTIA | CAPE TOWN

OUTLINE AND DISCUSSION

The *Water Research Horizon Scanning Workshop* is a research event funded by the Water Research Commission of South Africa and coordinated by Aqua d'UCT, a strategic water research initiative at the University of Cape Town. Aqua d'UCT researches the water research environment in South Africa with the main objectives of understanding past dynamics of research as well as horizon scanning for futures research. Horizon scanning involves looking beyond the short-term challenges and needs to identify emerging areas of knowledge requirements. This activity is undertaken as objectively as possible and is informed through collaboration and established literature and methods. All activities and results seek to be transparent and to adopt the principles of political and institutional non-alignment. Visit www.aquaduct.org.za for more information.

Forty selected water specialists and research strategists from around South Africa have been invited to attend this high-level two-day workshop on **8&9 October 2012 at the Alphen Boutique Hotel in historic Constantia, Cape Town**. Delegates will engage in research question prioritisation, discussion and information-sharing opportunities.

The event will cover all reasonable transport and accommodation costs of visiting persons. While delegates are expected to participate throughout the event, the *Water Research Horizon Scanning Workshop* cannot provide them with participation fees. Delegates will also be expected to participate in an online prioritisation exercise before the event. Event discussion can be found below.

Firstly, delegates will participate in a collaborative horizon scanning method - the first of its kind in South Africa for water research. This will identify the 100 priority water research questions for South Africa from a large, nationally collected list of questions elicited from over 600 research practitioners earlier this year. Secondly, delegates will engage in facilitated debate and discussion around key research strategies and challenges in South Africa. The main outcomes of this workshop are a *Water Research Horizon Discussion Paper* which will identify key ideas that emerged from the event as well as key interventions and strategies for research and a publication concerning the *100 Priority Water Research Questions in South Africa 2012* for which delegates will be invited to contribute as co-authors.

The method of collaborative horizon scanning draws on work in the United Kingdom and Europe as described in Sutherland et al. (2011). Prioritised research questions in a number of fields have been published so as to contribute towards the research agenda and debate. Research questions as a means of issue identification have

been used and are what delegates will engage with during the workshop where they will participate in prioritisation sessions. Questions not only help identify future research areas but also stand as actionable items following horizon scanning.

The central objective of this workshop will be to reformulate and prioritise research questions that will **contribute towards credible, relevant and legitimate institutional and policy solutions to meet the various water resource challenges in South Africa**. This will be achieved using similar horizon scanning methods from Sutherland et al. (2011). The questions used were gathered earlier in the year from over 600 survey participants and delegates will have the opportunity to remove, reconstruct and refine these during the workshop. Further objectives of the workshop are:

- To contribute towards the research agenda and debate through an objective, neutral and rigorous academic method.
- To identify the extent of consensus within research prioritisation.
- To inform all participants, research practitioners, institutions, national authorities and funders of the outcomes of the large-scale question gathering and specialist prioritisation results.
- To identify potential areas for research synergy and collaboration as well as to identify knowledge gaps and intersections.

The method and program will allow for substantial and oftentimes facilitated dialogue around issues of values and interests and the extent of prioritisation consensus will be of academic and methodological interest.

The *Water Research Horizon Scanning Workshop* will be facilitated by Professor Laurie Nathan who is the Director of the Centre for Mediation at the University of Pretoria and Visiting Professor at Cranfield University. He is a member of the United Nations Mediation Roster and a member of the United Nations Roster of Security Sector Reform Experts. He joined the Department of Environmental and Geographical Science at the University of Cape Town as an Honorary Research Associate in 2005 and teaches graduate studies on Understanding and Managing Conflict. While Dr Nathan's expertise resides in conflict mediation and security studies, he has a passion for the water sector and is an experienced facilitator. Dr Nathan will play a pivotal role in facilitating dialogue during the workshop.

Reference

Sutherland W, Fleishman E, Mascia M, Pretty J and Rudd M (2011) Methods for collaboratively identifying research priorities and emerging issues in science and policy. *Methods in Ecology and Evolution* **2** (3) 238-247.

WATER RESEARCH HORIZON SCANNING WORKSHOP

Hosted by Aqua d'UCT, University of Cape Town and the Water Research Commission

8-9 OCTOBER 2012 | THE ALPHEN BOUTIQUE HOTEL | CONSTANTIA | CAPE TOWN

DRAFT PROGRAM

Monday 8 October 2012

09:30	Registration
10:00	Session 1 (plenary: welcome, keynote, purpose, method, program)
11:30	Morning break
12:00	Session 2 (4 venue parallel prioritisation sessions)
13:30	Lunch
14:30	Session 3 (4 venue parallel prioritisation sessions)
16:00	Afternoon break
16:30	Session 4 (4 venue parallel prioritisation sessions)
19:30	Dinner

Tuesday 9 October 2012

09:00	Session 5 (2 venue parallel prioritisation sessions)
10:30	Morning break
11:00	Session 6 (2 venue parallel prioritisation sessions)
12:30	Lunch
14:00	Session 7 (plenary: final prioritisation, summary, way forward, closure)
15:30	Afternoon break and farewell

ANNEXURE G: PRE-WORKSHOP DELEGATE PREPARATION EXERCISE

Horizon Scanning for Water Research Questions

Purpose of the pre-workshop preparation:

1. To confirm and strengthen the process to be carried out at the workshop: made efficient, collaborative and interesting so that a high level end product is achieved through concensus
2. To consider and refine the technical requirements of the end product:

a. Identifying themes
b. Establish the best means of identifying horizon type questions
c. Determine an effective means of prioritizing questions

1. Workshop process

Workshop principles and guidelines

*The central objective of this workshop will be to reformulate and prioritise research questions that were drafted over the past eight months by researchers, managers and interested parties involved in water research and the water sector in general.

These questions aim to potentially contribute towards credible, relevant and legitimate institutional and policy solutions to meet the various water resource challenges in South Africa.

*The workshop is focused on identifying key strategic opportunities and challenges that require knowledge development and research.

* Horizon scanning methods involve:

- discussion, debate and disagreement so as to ensure that the final results are achieved through transparent, democratic and an inclusive means.

- a data-intensive exercise requiring delegates to work in groups on lists of questions, in order to refine, edit and prioritise these questions.

*The Chatham House Rule will apply during the workshop i.e. no attribution

*Only the list of the final prioritised questions, the method and the rationale of the study will be submitted to a journal for publication. All delegates are invited to become co-authors in the final paper.

*Opportunity will be available for delegates during the workshop, during breaks and at the organised dinner to discuss broader research issues and strategic concepts in water research.

*There are two idealistic reasons for designing water research questions as opposed to identifying issues in water resource management:

(a) to identify what needs to be done to address the various issues / challenges / opportunities / needs and strategies in the water research field

(b) to focus attention on strategic thinking in water research that can become known or understood by research and to deliver measurable, realistic and a deliverable response.

*Methods of editing and prioritizing questions will be conducted in small groups:

-The opening sessions involve intensive editing, deleting, replacing and prioritising of an existing database of questions that were collected from a wide ranging community of water researchers

-In the latter part of the workshop, sessions will be conducted in larger groups involving further discussion and prioritisation.

-A final plenary will allow for delegates to comment and rework the final list.

2a Themes (Big issues) that need to be addressed by water research on the horizon*

**on the horizon – means that we can see it in the distance but it is not in direct sights not it is looming large. However it is apparent and we are moving towards it.*

Themes are used to categorise questions, to retain a measure of cross-cutting integrity, and also to focus on particular kinds of research endeavours required to answer the questions. How should be categories questions?

Core strategies of the National Water Resources Strategy 1012

Implementation of Equity Policy;
Putting water at the centre of integrated development planning and decision-making;
Ensuring water for equitable growth and development;
Contributing to a just and equitable South Africa;
Prioritising and ensuring the implementation of water conservation and demand management;
Optimizing and stretching of our available water resources (groundwater, water re-use, desalination (including seawater), water systems optimization and rainwater harvesting);
Committing to the protection of our water resources and ecosystems;
Achieving effective and smarter water governance;
Embedding sustainable business principles and practices in water resources and systems management;
Implementing a water sector investment framework for infrastructure, human resource capacity and institutions;
Engaging the private and water use sectors.

WRC Thrusts

Critical Issues

Impact of climate change
Food security
Water quality: contamination of ground and surface water

Political instability
Human Capacity
Investment in infrastructure and technology
Cost recovery
Water for equitable growth and development
Catchment management
Institutional failure to regulate water resources
Urbanisation
Exploitation and misuse of water resources by corporate enterprises

2b Identifying a horizon scanning questions

Identifying and designing water research questions that 'on the horizon' is a complex task requiring consideration of multiple factors. Sutherland et al (2011) suggest that a research question has some or all of the following features:

- answerable through a realistic research design,
- has a factual answer that does not depend on value judgments,
- is able to address important gaps in knowledge,
- has spatial and temporal scope that could be addressed by a research team,
- is not formulated as a general topic area,
- is not answerable with a "maybe" or "it all depends",
- should not involve too many variables as this tends to broaden the research scope to a point where it is too general,

- should not be answered simply by "yes" or "no"
- contains a subject, an intervention and a measurable outcome if the question relates to impacts and interventions.

2c Prioritising research questions

The following questions were extracted from the database as potential questions that could be considered in a horizon scanning activity. Rank these questions (number 1 = most critical as a water research question for South Africa, etc.):

2. What cost-effective treatment and remediation strategies are available for acid mine water?
3. What are the projected impacts of climate change on agricultural yields and crop behaviour?
4. Are agricultural production processes able to adapt to less supply given predicted climate change?
5. How can water pricing truly account for equity, efficiency and sustainability?
6. What is the water requirement for food security nationally and sub-nationally?
7. Is integrated water resource management an option given political obstacles?
8. How can capacity building be improved in the water research sector?
9. What are the estimated returns on investment from demand-side management interventions for different sectors?
10. What is required for the establishment of effective cost recovery in peri-urban areas?
11. How can water sensitive urban design principles and methods be translated into municipal policy?
12. How effective is the use of biogas produced by the Waste Water Treatment Works?
13. How can mechanisms and processes found in nature inform the development of more efficient, large-scale desalination systems?
14. Does reclaimed AMD Water pose a health threat to South Africans?

15. What is the viability of South Africa having a separate institution to integrate agriculture, water and land systems to ensure appropriate decisions?
16. What predominant learning processes and institutional factors can support and strengthen social change to improve catchment management?
17. What recovery methods can be developed for municipal water losses?
18. What are the potential effects of hydraulic fracturing on the water supply in the Karoo?
19. To what extent are artificial wetlands practical and sufficient as a buffer area around wastewater treatment plants?
20. What policy and practice mechanisms need to be put in place to successfully implement water demand management in urban residential areas?

ANNEXURE H: STAKEHOLDER AFFILIATION OR ORGANISATION

Alphabetical, where two or more stakeholders are represented (total = 182).

3S Media (2)	International Water Management Institute (6)	SRK Consulting (9)
Africa University Zimbabwe (2)	Itron (2)	SSI Engineers & Environmental Consultants (Pty) Ltd (15)
Agricultural Research Council (29)	IUCN South Africa (2)	Stellenbosch University (69)
Amatola Water (6)	IWR Water Resources (Pty) Ltd (2)	Stewart Scott (2)
Anatech Instruments (2)	Jeffares and Green (5)	Stockholm Environment Institute (3)
Anglo American (10)	JOAT Group (3)	Sud-Chemie Water & Process Technologies (2)
ARA Centro Mozambique (2)	Johannesburg Water (5)	Sulzer Pumps Wastewater SA (Pty) Ltd (2)
Arcus Gibb (2)	Komati Basin Water Authority (6)	SWADE (LUSIP) (2)
Aurecon (24)	Lawyers for Human Rights (2)	Swaziland Department of Water Affairs (2)
Australian National University (2)	Libertas (2)	Talbot & Talbot (Pty) Ltd (2)
Aveng Water (4)	Lindokuhle Engineering (2)	Technikon Natal Center for Water and Wastewater Research (2)
AWARD (2)	Magalies Water (5)	Tecroveer (Pty) Ltd (3)
Bigen Africa Services (Pty) Ltd (2)	Makerere University Uganda (5)	Trans-Caledon Tunnel Authority (9)
Binghamton University Institute for Global Cultural Studies (2)	Maluti GSM Consulting Engineers (3)	Tshwane University of Technology (24)
BKS (Pty) Ltd (10)	MBB Consulting Engineers (2)	UDSM Zambia (2)
Bloemwater (2)	Mbombela Local Municipality (2)	Umgeni Water (16)
Bosch Stemele (2)	Merck (2)	Umhlaba Consulting Group (Pty) Ltd (2)
Breede Overberg Catchment Management Agency (3)	Ministry of Water Tanzania (2)	Umvoto Africa (7)
BTW Consulting (3)	Mintails SA (Pty) Ltd (2)	United Nations Children's Fund (2)
Buckman Africa (3)	Mintek (4)	United Nations Educational, Scientific and Cultural Organization IHE (14)
Cape Peninsula University of Technology (17)	Mkhambathini Municipality (2)	United Nations Office for Project Services (UNOPS) (2)
Cap-Net UNDP (2)	Monash University (3)	University of Botswana (7)
Central University of Technology (5)	Moses Kotane Local Municipality (2)	University of Cape Town (98)
Chamber of Mines SA (3)	Mvula Trust (5)	University of Dar es Salaam Tanzania (4)
City of Cape Town (25)	Mzuzu University (2)	University of Fort Hare (20)
City of Tshwane (7)	N&Z Instruments (2)	University of Johannesburg (64)
Council for Geoscience (6)	Namibia Water Corporation (2)	University of KwaZulu-Natal (64)

Council for Scientific and Industrial Research (74)	National Research Foundation (2)	University of Limpopo (20)
CRA (2)	NCC Environmental Services (3)	University of Malawi (5)
Danish Institute for International Studies (3)	NCP Chlorchem (4)	University of Pretoria (83)
Department of Agriculture Forestry and Fisheries (4)	Nelson Mandela Metropolitan University (17)	University of South Africa (8)
Department of Environmental Affairs (4)	Nemai Consulting (2)	University of Swaziland (3)
Department of Rural Development and Land Reform (2)	North West Department of Agriculture, Conservation and Environment (11)	University of the Free State (49)
Department of Water Affairs (172)	North-West University (15)	University of the Western Cape (29)
Development Bank of Southern Africa (7)	Okavango Research Institute Botswana (14)	University of the Witwatersrand (34)
DHI (2)	Orange Senqu River Commission (3)	University of Venda (19)
Digby Wells Environmental (4)	Overberg Water (3)	University of Zambia (3)
Dow Water & Process Solutions (2)	Palmer Development Group (2)	University of Zimbabwe (11)
Durban University of Technology (8)	PD Naidoo& Associates (6)	University of Zululand (15)
East Rand Water Care Company (2)	Pegasys Strategy & Development (5)	Upper Manyame SCC Zimbabwe (2)
Eduardo Mondlane University Mozambique (2)	PLAAS (2)	USAID (2)
Emanti Management (2)	Polytechnic of Namibia (3)	Vaal University of Technology (4)
ERWAT (9)	Prentec (Pty) Ltd (2)	Vela VKE Consulting Engineers (2)
Eskom (21)	Pulles Howard & de Lange (5)	Veolia Water Solutions & Technologies (4)
eThekwini Municipality (17)	Rand Afrikaans University (8)	WAM Technology cc (5)
EWSETA (2)	Rand Water (22)	Water & Sanitation Services SA (Pty) Ltd (4)
Free State Technikon (2)	Rhodes University (41)	Water Institute of Southern Africa (2)
Freshwater Consulting Group cc (3)	Rural Integrated Engineers (2)	Water Research Commission (25)
Gauteng City Region Observatory (2)	SADC (3)	Water Research Institute of Mozambique (2)
Gauteng Department of Local Government and Housing (2)	SAPPI (2)	Water Rhapsody (5)
GCS Pty Ltd (2)	SASOL (2)	Water Solutions Southern Africa (Pty) Ltd (2)
GE Power and Water (2)	See Saw Pro-poor solutions (4)	WaterNet Secretariat (7)
GEOSS (2)	SembcorpSilulumanzi (6)	WEC Projects (Pty) Ltd (2)
GIZ Transboundary Water Management in SADC (2)	SigodiMarah Martin Development Consultants (2)	Wettech RSA (2)
GK Water (2)	South African Breweries (4)	Wildlife and Environment Society of South Africa (6)
Global Water Partnership (5)	South African Environmental Observation Network (3)	World Vision (2)

Golder Associates Africa (18)	South African Institute for Aquatic Biodiversity (7)	World Wildlife Fund for Nature (2)
Groundwater Africa (2)	South African Local Government Association (2)	WRP Consulting Engineers (3)
GrundfosAlldos (2)	South African National Biodiversity Institute (4)	ZAMCOM (2)
Inkomati Catchment Management Agency (3)	South African National Parks (10)	Zimbabwe Open University (2)
Institute for Natural Resources (2)	South African Weather Services (4)	

ANNEXURE I: SURVEY RESPONDENT AFFILIATION OR ORGANISATION (221)

ACER (Africa) Environmental Management Consultants (1)	Festo (1)	PICWAT (1)
African Institute for Mathematical Science (1)	Fiberpipe (1)	PLAAS (1)
Agricultural Research Council (10)	Fort Hare University (1)	Polytechnic of Namibia (1)
AL Abbott and Associates (1)	Free State Department of Agriculture (1)	Prei Instrumentation (1)
Albany Museum (2)	Friends of the Liesbeek (2)	Prime Africa Consultants (1)
Amatola Water (2)	Gabsie's Business Solutions (1)	Rand Water (5)
Anglo American (4)	Gauteng City-Region Observatory (1)	Renosterberg Municipality (1)
AOC Geomatics (1)	Gauteng Department of Agriculture and Rural Development (2)	Resource Ballast Technologies (1)
Atkins Ltd (1)	Gauteng Department of Local Government and Housing (1)	Rhodes University (16)
Aurecon South Africa (12)	GCS (1)	Sappi (1)
Aveng Water (1)	GE Water (2)	Scherman Colloty and Associates (1)
Balanced Environment (1)	GEOSS (1)	Schneider Electric (1)
Biomimicry South Africa (1)	GLS Software (2)	Seboka Manyabolo Management (1)
BKS (8)	Goba Consulting Engineers (1)	Sembcorp Silulumanzi (3)
Blue Science (1)	Golder Associates Africa (12)	Shared Energy Management (1)
Botshelo Water (1)	Grundfos (1)	SLR Consulting (1)
Breede-Overberg CMA (1)	H2Oasis (1)	Social justice Network (1)
BTW & Associates (1)	Haloflo (1)	Softchem (1)
Bufo Technology (1)	Hanna Instruments (1)	South Africa Weather Service (1)
Cape Peninsula University of Technology (5)	HHO Africa (1)	South African Association for Water User Associations (1)
Capricorn District Municipality (1)	Hitachi Power Africa (1)	South African Breweries (2)
Carifro Consulting Engineers (1)	Hlathi Development Services (1)	South African Environmental Observation Network (2)
Central University of Technology (3)	Hydrosol (1)	South African Institute for Aquatic Biodiversity (3)
Citrus Research International (1)	Ilifa Africa Engineers (1)	South African National Biodiversity Institute (1)
City of Cape Town (11)	ILISO Consulting (1)	South African National Parks (8)
City of Johannesburg (1)	Illovo Sugar Limited (1)	South African Sugarcane Research Institute (2)
City of Tshwane Municipality (1)	Imperata Consulting (1)	Square One Trust (1)
Coalition for Environmental Justice (1)	Informage (1)	SRK Consulting (5)
COBENG (1)	Inkwanca Local Municipality (1)	SSI Engineers (9)
Conservation South Africa (1)	Inkomati CMA (1)	Stellenbosch University (18)
Council for Geoscience (3)	Interwaste (1)	Steve Tshwete Local Municipality (1)
Council for Scientific and Industrial Research (28)	Jeffares& Green (5)	Stockholm International Water Institute (1)
Counterpoint Development cc (1)	JOAT Consulting (2)	Swellendam Municipality (1)
CRH Clanahan& Associates (1)	Johannesburg Water (2)	Talbot & Talbot (1)
CSV Water (1)	JOJO Tanks (1)	Tannery Environmental Consultancy (1)
Cwenga (1)	Krohne PTY Ltd (1)	Tecroveer (1)

Daveyton Environmental Youth Counsel (1)	KwaZulu-Natal Department of Environmental Affairs (1)	ToxSolutions (1)
De Beers (1)	Lanstar (1)	Trans-Caledon Tunnel Authority (1)
Dehteq (1)	Ledet (2)	Tshwane University of Technology (7)
Delta H Water Systems Modelling (1)	Limpopo Agrofood Technology (1)	Turner & Townsend International (1)
Dencon (1)	Malutigsm (1)	Uhambiso Consult (1)
Department of Agriculture, Forestry and Fisheries (2)	Mangosuthu University of Technology (1)	Umfula Consort (1)
Department of Co-operative Governance and Traditional Affairs (1)	MATI Africa (1)	Umgeni Water (6)
Department of Education (1)	MBB Consulting Engineers (1)	Umhlaba Consulting Group (1)
Department of Energy (1)	Mbombela Local Municipality (1)	Umkhanyakude District Municipality (1)
Department of Environmental Affairs (3)	Medical Research Council (1)	Umvoto Africa (2)
Department of Higher Education (2)	Mekong River Commission (1)	University of Cape Town (25)
Department of Public Works (1)	Merbombo Projects (1)	University of Fort Hare (6)
Department of Water Affairs (35)	Merck Millipore (1)	University of Johannesburg (15)
Development Bank of South Africa (1)	Microzone Polokwane (1)	University of KwaZulu-Natal (24)
DHI South Africa (1)	Midvaal Water Company (2)	University of Limpopo (6)
Dibgy Wells International (1)	Mintek (2)	University of Pretoria (11)
Dow Water & Process Solutions (1)	Mkhambathini Municipality (1)	University of South Africa (2)
DPI Plastics (1)	Modimolle Municipality (1)	University of the Free State (13)
Drakenstein Municipality (1)	Mogale City Local Municipality (1)	University of the Western Cape (7)
Dresser-Rand Guascor (1)	Moses Kotane Local Municipality (1)	University of the Witwatersrand (8)
DTK (1)	Mottram and Associates (1)	Vaal University of Technology (1)
Dube Ngeleza Wiechers Environmental (1)	Mpfuneko Community Support (2)	Vela VKE Consulting Engineers (2)
Dube Tradeport (1)	Mpumamanzi Group (1)	Veolia Water Solutions & Technologies (1)
Duncan Heard Environmental Consulting (1)	Mvula Trust (2)	WAM Technology cc (2)
Durban University of Technology (3)	Mzuzu University (1)	Water Research Commission (6)
EcoMonitor cc (1)	Narrative Lab (1)	Water Rhapsody (1)
EcoSmart Industries (1)	National Institute for Occupational Health (1)	Water Solutions Southern Africa (2)
Ecotone Freshwater Consultants (1)	National Research Foundation (1)	Waterscience (1)
Eden District Municipality (3)	NCC Environmental Services (1)	WATSUP Development (1)
Ekurhuleni Metropolitan Municipality (1)	NCP Chlorchem (1)	Webber (1)
Emanti Management (1)	Nelson Mandela Metro University (6)	WEC Projects (1)
Endangered Wildlife Trust (1)	North-West University (6)	West Coast District Municipality (1)
Environmental Monitoring Group (1)	One World Sustainable Investments (1)	Western Cape Department of Human Settlements (1)
ERWAT (1)	Overberg National Water Board (1)	Wettech SA (1)
Eskom (9)	Pam Golding Properties (1)	Wildlife and Environment Society of South Africa (4)
eThekwini Municipality (11)	Pamsa (1)	Winelands UV Technology (1)
EWSETA (1)	Partners in Development (1)	WRP Consulting Engineers (4)
Ez Flo (1)	PD Naidoo& Associates (3)	

ANNEXURE J: MAIN SURVEY COMMENTS - ADEQUATE WATER RESEARCH FUNDING

(edited for spelling, grammar, structure; personalised references omitted; n=120)

Response	*Comment*
Yes	Funds should not be allocated to projects which benefit individuals only where the public has to be a member of a certain organisation in order to access the research.
Yes	How about some of the money rather being used for the effective implementation of the provision of basic water and sanitation to the poor?
Yes	I believe that there is sufficient funding, but that it is given to people who (very often) do not have the expertise in the field that they choose to do the research in. Many research projects do not contribute towards effective change and improvement in water and sanitation - they simply provide 'paid projects' for researchers to dabble in while earning good money.
Yes	I think the WRC does an excellent job in funding water research.
Yes	I think there is probably enough money, but it's not necessarily oriented in the right direction - i.e. too much emphasis on technical or "academic" research, and not enough recognition of action and participatory research which informs on-the-ground changes and improvements in people's lives.
Yes	In view of the fact that limited effort is placed on promoting use of research to improve practice, I believe that research funding is adequate. I believe that a dedicated fund is required to promote use and application of the guidelines and tools already developed by the WRC during its 40 years of existence. When I do research in municipalities, I meet officials who don't know about the WRC and its products.
Yes	It's the involvement, uptake and implementation of this research by relevant government departments that is lacking.
Yes	Maybe the focus of research can somewhat be directed better: there is a lot of non-value-adding research
Yes	More funding will only be productive if the research capacity is improved. This is clearly a gradual process with one influencing the other.
Yes	Relative to the socio-economic condition of the country: yes. Relevant to our needs: maybe. Relevant to our ability and desire to do good research: no.
Yes	South Africa is the only African country that adequately supports research in the water sector.
Yes	Thank you to the WRC for providing an invaluable source of funding.
Yes	The concentration should also focus on the rural areas.
Yes	The establishment and continued support of the WRC by government indicates foresight and appreciation of the water related challenges that face the development of South Africa.
Yes	The technical aspects of research receive more attention than the softer issues. There is a need for the issues such as the capacity for governance and implementation to be addressed in a more focused way.
Yes	The WRC receives large amounts of money. A lot of it is used extremely usefully, but some is used to advance the idiosyncratic interests of individual research managers with inadequate accountability around why some research is funded and some is not.
Yes	There is a tax on all water users that is used to fund the Water Research Commission. The question is whether the WRC has used and is using this tax effectively. Has the WRC been effective over the years? Judged (perhaps superficially) on the recurrent demonstrations on service delivery in many towns and often about the lack of water, one can ask if the research focus of the WRC over the years has been correct. These type of questions need to be addressed.
Yes	There's a lot of money out there, it just needs to go in the right places. There's still a lot of protectionism and research funding going to people who know people - better market research on relevant questions may be needed by collaborating. The water industry at large, research and otherwise, needs to become more professional.
Yes	Water research is adequately funded however the education system does not allow us to make the best use of these funds. We need to address education urgently. This is not just in the water sector.

Yes	When I look at the levy consumers pay on each drop of water bought.
Yes	WRC and other institutions provide excellent research opportunities for water however budgets are often low and not big enough to allow bigger scope within projects.
Yes	WRC is proof of that, but research needs to be implemented.
Yes	WRC research in respect of aquaculture is good but there are too few researchers.
Yes	Yes but there is still so much more research that needs to be done that additional funding would be welcome.
Yes	Yes it is adequately funded at fundamental research level but there is no cradle to grave or market strategy. Money is re-invested in the same research and there is no legislation forcing implementation of sustainable remediation solutions.
Yes	Yes. The most disappointing part about research done by service providers is the implementation and the reporting of the results - it is not easy to access them. Sometimes one has to buy the booklet from the source of the research to get assistance.
No	A few sectors of the wider research field may attract sufficient funding, especially those fields dominated by the engineering profession, but the health-related impacts of even the engineering solutions are never determined for example. Then years later the health services have to cope with the 'unforeseen' problems. The other sectors are almost routinely underfunded.
No	A huge chunk of funding should be allocated to long term studies, rather than short projects that end up with decade gap in data before a follow up study is done.
No	Absolutely not. Notwithstanding that water is uniquely one of few 'renewable' natural resources, it remains the country's most precious one, and is becoming more so.
No	All possible water resources need be sustainably exploited and researched. It is important to identify priorities and adequately fund research in these. Research on possible new water sources must be supported provided these have a strong scientific base.
No	Although funds are availed, they are poorly utilised. There is too much fragmentation, low continuity and too much repetition.
No	As a country that would be categorised as semi-arid not enough research has been done on ensuring water security, or at least this information has not been displayed publically to educate our society.
No	As one of our most critical resources, the requirements for funding are unlikely to meet the actual need given the impact of water scarcity on our cities without a massive national initiative.
No	Considering that South Africa is a water scarce country more should be done.
No	Current experience is that a research question which is vital for the sector is being "diluted" and scaled down due to a lack of funds to support the initial scope of enquiry.
No	Current projects are funded over 2 or 3 years. It should be extended to cover long-term studies.
No	Definitely not. Considering that access to sufficient good quality water is of vital importance to everyone, the government should be spending more on securing water resources.
No	Definitely under-funded by a very large margin.
No	Despite the willingness by researchers to conducted water research, the need for further research in South Africa is constrained by limited funds.
No	Due to the limited funding many small projects exist that (though necessary) have little impact. More large multi-disciplinary projects are needed and these require more funding.
No	Due to the severity of the problem in the country more money should be allocated.
No	Funding has been limiting in mine waste treatment.
No	Generally in Africa as a whole funding is a problem.
No	Given that water is one of our most critical natural resources and underpins all our economic activities, research on it is underfunded. We must however look critically at where we direct the funding for research.
No	Given that we face huge challenges with water - we need to be doing much more.
No	I feel that there is a lot that needs to be done, however due to limited funds, this is not achieved.
No	In tertiary institutions you still find that only two or four students are funded by a water institution and at this pace there will never be enough water research conducted.
No	International funding is available if treasury regulations were less time consuming.
No	It is not adequately funded as people tend to research on issues that have funds even if these are not pressing issues.

No	It is only few NGO and Chapter 9 institutions that are funded - there has not been funding for grassroots projects.
No	It is relatively well funded once you are an established researcher, but not well funded for upcoming researchers.
No	It is simply not done sufficiently.
No	It might be on balance, but the questions would remain: "Are the right projects adequately funded?" or "Are some projects that are not very useful overfunded?"
No	It often seems that not enough funds are available to follow up or continue on the outcome of research or to study the effect of research that has been applied.
No	It seems to be "protected" by elite.
No	Many water projects, to be effective, require long term monitoring and this requires considerable amount of on-going research funding. It is often possible to set up the project initially and get one or two years' worth of results. However, longer term funding is much harder to secure but is necessary to see how seasonal fluctuations can influence the variation in different parameters.
No	More funding is required. One indicator of that the WRC does not pay rates for research at levels that are viable for many researchers.
No	More money is always better, especially for collecting data on the ground for monitoring purposes.
No	My observations are that in South Africa the water industry pyramid is upside down. There are too many policy frameworks and regulatory bodies that spend way too much time drafting policies, but at the bottom there is not much activity in terms of moving the industry towards addressing present and future challenges using a home grown approach. Most of the activity has been applying the 'plug and play' modular approach that is 100% suitable for industrialised nations, but quite costly for South Africa in terms of the extensive re-engineering that has to be done so that these technologies give a semblance of being effective.
No	No research is ever adequately funded in South Africa.
No	Not nearly enough research is being well funded in South Africa.
No	Not sufficient for groundwater.
No	Often research is directed at basic research (academic), with researchers having very little understanding of the real world problems and the implementation of research results. Very often research to focus around concepts without considering the practical application of ideas.
No	On-going research questions arise which cannot be answered because of limited funding.
No	Part of the problem is the state's co-operation with big business to hide the identities of polluters. Our understanding is that the locations, sizes, compositions and ownership of coal dumps is still confidential. We perceive that publications or proposals which 'name-and-shame' polluters are suppressed. When the output of such research does not allow the public identification of the polluting sources, the funding mechanism is by its nature also deficient.
No	Private industry and public enterprises should try come together as this will benefit all in the future.
No	Research is generally not adequately funded and the share for water is too little given the importance of the issue.
No	Research is ridiculously underfunded. The effective used of the small funding pool is further impaired as there is confusion about what we as a country want. Do we want the more traditional outcomes of international papers and PhDs? Do we want to learn how to enable research to drive society both towards economic innovation and towards public good in societal-ecological applications? We current try to do both - but if we want to be world class in both these arenas and get the best out of the interaction between them considerably more funding - and much more innovative use and leveraging of funding - is required.
No	Some areas are well funded especially in terms of guidelines, policy etc. but pure and applied research does not appear to be adequately funded.
No	Sound sociological and political science inquiry is highly needed to understand decision-making elites.
No	The average age of engineers and qualified artisans is getting higher at an alarming rate.
No	The challenges in the water sector are numerous, complex, and yet are poorly resourced. It is strange that water is deemed a human right yet research to ensure both its quantity and quality are minuscule and rapidly becoming less by the year. Can South Africa address its water challenges without well directed and resourced water research? This needs to be addressed. Short term solutions will remain problematic as has been seen in numerous cases in the country.
No	The funding often limits the benefit of research both in depth of research and inclusion of wider input.

No	The hourly rate paid by WRC is a loss leader for consulting firms and implies that researchers should subsidise personally in order to undertake research.
No	The problem is the quality of research is often doubtful and the same groups get funded over and over again and they refine small bits of research far beyond the ability of South Africa to implement.
No	The state and the water departments lag behind other departments in the allocation of monies to fund research.
No	The technical / scientific aspects of water management are well funded but the human aspect of water management and finding effective management strategies are not.
No	The WRC has a most effective system of research implementation i.e. proposal reviews and research committees that assist and criticise progress. It is a pity that there is not more money available for unsolicited research.
No	The WRC has saved water research in South Africa but considering the strategic importance of water it is a shame that there is a handful of top researchers in the country. This is a direct function of financial sustainability.
No	The WRC is pivotal in this area but their budget is a fraction of what is needed. Research cannot keep up with the issues associated with the rapidly growing human population and effects of climate change. In addition, there is a serious need for funds for long-term monitoring.
No	The WRC is the only funder that supports true research. Other funding institutions often only indirectly fund research by providing students that need a lot of hands-on training and perhaps equipment. Often only PhDs are eligible for such funds which hampers research. We are dependent on external funders (EU, USAID) that naturally also benefit the external partners more than the South Africa researchers.
No	There has been systematic disinvestment (in real terms) over the last 30-35 years.
No	There is funding, but there is no institutional structure. All initiatives are driven by individuals. This is because the whole society model (including academia, government, commerce) are driven from a self-centred model and not a group-centred model.
No	There is funding, which many other countries don't have, but we are water scarce and we have a huge water/energy/food nexus brewing which threatens our economy and social fabric. Compared to the risk of the nexus, the money invested in research is very low. I do think that there is a need to focus the funding on central themes and that many researchers should be jointly working to find solutions to these challenges. Many researchers are territorial and although they are very sound researchers may be causing more harm than good by not sharing ideas and data with the community.
No	There is never enough money to provide all of the answers needed.
No	There is never enough money, especially when it comes to human resources.
No	Using engineering consultants is efficient as the management and ownership of deliverables are better defined but it is more expensive.
No	Water is such a critically scare resource in South Africa and is under significant pressure and needs additional research funding. However, there needs to be cross-sectoral integration of such research initiatives (industry, agriculture, landuse planning, development zoning and authorisation, etc.) and the results, findings and leanings need to also spread beyond the water and/or research sectors.
No	Water research can play a much larger role if their funding could be increased. Water researchers should also be playing a much larger role as consultants to municipalities.
No	Water research is becoming less effective due to the pool of people available reducing and the willingness to do the research required.
No	Water research must be funded to the point of real impact for every South African. Often the wheel gets re-invented through parallel studies and funds very necessary for implementation never seem to be available.
No	Water research should be linked to conservation and management and major funding is required to deal with the high level of problems related to freshwater resources at catchment levels.
No	Water research should be the entity to be funded.
No	We need to understand the efficiency of our options far better.
No	We spend too much time and effort developing grand strategies and ignoring reality. As a result we spend too little time and effort quantifying reality.
No	WR2005 and WR2012 are going a long way thanks to the WRC but other organisations need to assist with funding.
Maybe	Again, it depends on the research topic and it also depends what is in the research findings for government. Government

	will not fund controversial or truth-exposing research because it would put them in a bad light. Such research is sometimes funded through private means - or it never comes off the desk into the field.
Maybe	Certain sectors especially applied research is probably adequately funded but some basic (continuous monitoring and evaluation) research is underfunded or has been discontinued.
Maybe	Disproportionate funding towards science and technology might be the way to go instead of the vast amounts spent towards policy and water management.
Maybe	Given all of the competing demands on public funds, public-funded water research is reasonable, particularly at a national level through the WRC. There is however much more scope for further partnerships at a more local level and from the private sector.
Maybe	I suspect that the competition for funds has intensified considerably over the past few years, while the research budget has remained fairly fixed. Water research funding is not available from a wide range of funders, with the WRC being the main funding source for a growing body of consultants and researchers.
Maybe	I think it would be very difficult to allocate funds to the plethora of attractive research proposals.
Maybe	I think water research funding is very narrow in South Africa i.e. there are few donor agencies.
Maybe	If one has a good, well-motivated project then it has a good chance of getting funding.
Maybe	If the types of investigations supported/undertaken by the WRC are helping to address key issues in the water sector that boost socio-economic conditions then more money is needed here.
Maybe	In general research is not well funded, but the WRC is doing great job compared to other sectors.
Maybe	In my opinion the biggest frustration is that when your proposal is accepted the budget is generally severely cut which means that several of the envisaged outcomes cannot be achieved.
Maybe	It is possible that research is adequately funded but it certainly is not adequately applied.
Maybe	Perhaps, because national funds are usually allocated and never utilised. Most research is driven primarily by organisations and/or parastatals and usually researchers face budget constraints due to the nature of the research.
Maybe	Some sectors are adequately funded but more funding could go to basic research which has not been nearly as adequately covered as seen in Europe, North America, Japan, Russia, Australia and New Zealand.
Maybe	South Africa, like other countries, seems to have moved away from a careful analytical approach to water research, carried out by a team at a permanent institution with advanced facilities. Much useful research and training takes place in spite of this, but it could be more efficient and directed if critical mass could be attained in one or more locations.
Maybe	There are many people working within water research, in various disciplines and there seems to be a sufficient amount of money going into research. There is not however nearly enough going into implementation, management initiatives etc. in almost all sectors of water.
Maybe	There is a lot done in term of technology and treatment practices, but institutional, social and economic research with respect to water should be funded.
Maybe	There is a lot of scientific knowledge that has been produced but not utilised or implemented as yet and the problem is always associated with a lack of funds. The implementation of such knowledge would open further areas of research in this field.
Maybe	There is reasonable funding for water research but given our water constraints this should perhaps be even higher.
Maybe	There will always be room for increased funding.
Maybe	This depends on the organisation responsible for water research. Some organisations are better funded than others.
Maybe	Water research certainly appears to be better funded than most sectors, whether it is enough or focussed enough with the most impact given the challenges we face in the water sector with a growing population and a developing economy with high demands is maybe the area for investigation.
Maybe	We need more quality researchers doing work of greater importance - the money is there, but is not always utilised optimally or for the most pressing needs.

ANNEXURE K: MAIN SURVEY COMMENTS -APPLICATION OF WATER RESEARCH

(edited for spelling, grammar, structure; personalised references omitted; n=74)

A lot of research and guidelines are published but this information is not always enforced.
A silo approach is still followed to do research. The statement has a bias towards governmental processes, but there are also non-governmental bottom-up processes, including actions by ordinary individuals, that can also impact on the issues mentioned above. When I say ordinary individuals, I don't mean scientists only, but also 'the man on the street'.
Academia and scientists within water research need to take a stance with regards to where they foresee research being done and not be influenced by political/institutional agendas. We know that some of these institutions provide funding and a platform to promote research to a political scene, but there should be some manner through which the political agenda and water research can complement one another.
Although policy and guidelines are reasonably well formulated, water research could be applied more effectively toward actual practice.
Although research is often directed towards policy, it is not applied as often as it possibly should be. There is a disconnect that needs to be addressed.
At a very general level much of the research being conducted is either not communicated effectively to potential users of the research or users, because of their own inadequacies, are unable to utilise the research results on offer.
Based at university and most of the time focused on my study, I cannot really tell much about this question.
Benefits of research are hard to come by in industry; perhaps we are reluctant to use new methods before they are proven beyond bench or pilot scale.
Blue prints are marvellous, because most of the time they are mostly copied from the developed countries. However, due to the reality that South Africa is a developing country, there is a huge chasm between the requirements and what is realistically possible.
Current status shows many of above aspects have little or no regard for research findings or the rate of producing relevant aspects is so poorly generated at a very low rate and outrun by the demands and challenges of the day.
From working with legislation and some policy, I find that much of our water quality and usage standards do not address short term activities like events and filming activities. The legislation is left to the interpretation and discretion of the local authority and in most cases the landowners/stakeholders. In my opinion research needs to focus on all uses and how this use is managed, or can be managed. Finally, all the research in the world cannot make the change; people need to make the change. Perhaps research needs to be done in terms of how much of the outcomes and suggestions that come from research projects are being taken up into all of the mentioned areas.
Government tends to make policy before finding out what works and then try to get researchers to justify the policy. This is not a good recipe for effectiveness.
Guidelines are not properly researched in terms of affordability.
Guidelines need to be implemented and currently there is no mechanism in place to enforce best practices.
I am a believer in a fine split between pedagogic scripture and implementation. In my mind there are far too many of the first and very little being done. We have to get tools to do work. The tools must be demonstrated and disseminated.
I believe that water research should be applied effectively toward all the above. I also believe that we should address these factors across inter-disciplinary bodies and organisations and not only focus them through the Department of Water Affairs. Integrated approaches are the solution.
I do not think research or research results are well communicated. A regular water program on radio of television could be very popular and informative.
I don't think the policy and guidelines developed are filtered down adequately to users like mining houses, developers, tourism establishments, municipalities, consultants, catchment management agencies etc. It all sits as reports undertaken in the scientific realm.
I see very little application of water research - the research is completed but taking it into practice seems to be a definite problem. I think that there needs to be some thought put into getting the people involved in water research and industry together to create joint projects.

I think much is still needed especially for rural areas.
I think there is a strong disparity between scientific knowledge/technology and application. This is mainly due to problems outside of the realm of pure water research e.g. lack of management capacity.
I think we are doing an appalling job of applying research.
I think we do use research - but not effectively - and certainly could use it more effectively - but consideration of how and where it will be used (context) needs to inform the research and we need to take co-learning and social learning seriously for effective application.
I think we have good water policies as a country however the application of those policies in not effective.
I think what is lacking is implementation especially in terms of lack of capacity.
I would like to see more action-research and research on the implementation process.
Industry and especially mining and agriculture still enjoy the privilege of using water and paying cheap tariffs.
It is all very well having excellent legislation but in South Africa this legislation is not being implemented and there is no law enforcement.
Knowledge is a difficult thing to acquire, especially in the present academic world where the objective is not knowledge but publishing. If the academics do not strive for knowledge, they do not acquire it. If they do not have it they cannot advise the government. Then political decisions are not driven by societal motives, but by commercial ones. Big business influences political decisions. Research on technical aspects will not change this. The political structure and mechanisms would need to change first.
More efforts should be made to increase the uptake of available research based knowledge. This means that all research should be directed and managed within the innovation process. Ensuring that research is applicable and socially beneficial requires time.
More research needs to be done together with the private sector and consultants in the water and wastewater field. These sectors have the skill and the abilities to assist but internal matters prevent the private sector from assisting.
Most research just develops guidelines and more guidelines without turning results into policy and practical solutions.
Municipalities will stifle any research done to conserve water as this is their income lies.
Not enough emphasis is placed on social research relating to communities and their water use and how they value and give meaning to water.
Not enough new technologies are being implemented as in developed countries.
Policy, strategies and guidelines are often not implemented. The research community is under tremendous pressure to do real research but funds and internal policies prevent this to a large degree. Incompetent people and practices hamper all of the above.
Policy and guidelines are mostly good - implementation of knowledge is clouded by many other factors.
Policy gaps are glaring and research should become focused at addressing issues of the day.
Research is not applied well towards industry and business.
Research is the basis for every strategic and operational decision that should be taken in the water services sector and should guide every policy-maker, business implementer, skills educator, trainer, employer and worker.
Some organisations do their own water research and yet command/dictate the cost of water, policy and their own research agenda.
Something can't be working well if we still have so much damage to all of our water systems. The interconnection between economic and political drivers and the lack of recognition for ecosystem services and the vital value of water over and above the value of mines etc. seriously needs to be researched. There is a lot to learn and entire new perspectives to realise.
Somewhere something is serious out of place if the poor water quality in this country is taken into account: we cannot afford the present situation to continue.
South Africa has developed some of the most advanced policies and guidelines with regards to managing water resources but there seems to be a serious lack of capacity within water-related fields.
South Africa is good with creating new policy and guidelines but these rarely get implemented properly on the ground and in the real world.
South Africa is rapidly approaching a crisis with respect to water resource management. This is widely known and widely reported yet poorly understood. Too much of our research is still devoted to telling clients - government and industry - that there are no problems. When effects become acute, we move into crisis management mode. Most of the problems we have now are actually well understood at a conceptual level and have been well understood for many years. The detail essential to address these is often missing and management seems to begin and end at a strategic level with inadequate practical application.
South Africa is trying to carry out water research but I feel we still have a long way to go before we have our water pollution under control. We have some guidelines but not covering all aspects of contaminants. Also some aspects of water research get funded

such as the acid mine drainage problem which has received much international coverage but there are other aspects of water research that must also be addressed such as the state of our rivers, lakes, water bodies and throughout South Africa.
The link between research outcomes and policy implementation needs to be strengthened.
The water services policy development directorate for the Department of Water Affairs has little interaction between the unit and research work and institutions. This is the unit that drives the policy decisions for water services in the country.
There are a lot of gaps in water research. What research is done is not easily accessible or in a format that can be used outside of the research community.
There are far too many reports and papers that are 'non-prescriptive' or regulatory - reports are not concise enough.
There is a concern for the lack of transparency within industry and business. In addition, there is a concern that professors have too large an impact on research, tend not to prioritise students and their agendas are often hidden. More transparency is needed to explain the relevance of some of the research undertaken.
There is a huge gap between the advance made in science and how it is applied and developed at a functional or practical level. The problem lies in our recruitment and training strategies - however, this has not been confirmed by means of an investigative research programme.
There is a lot of research, but implementation is slow; this would be expected of any change over large scales that would require changes to government systems - but we need to focus on relevance to specific area needs and find innovative solutions that are effective to meet basic human needs and preserve ecological functioning.
There is a point where further research should not continue, but actual implementation takes place. Also, the role of the private sector/industry is under-estimated - let business make their money, but provides solutions - that takes a load off the tax base where government offices want to provide the solutions with inadequate resources.
There is no strong framework directing wetland research in South Africa.
There is room for research to be more focussed on the realities associated with practical, affordable implementation.
Too much emphasis is on policy and too little on implementation. We also need better monitoring data to guide decision making.
Uptake of water research products is generally a challenge and not happening as extensively as it should.
Water research has been rather prolific, but the process is lacking the regular revisions aiming to select and promote relevant and long-term valid practices in a user friendly manner.
Water research in South Africa is applied effectively on the technology side - we ignore the human factor to a great extent. Very few research projects look at municipal management.
Water research in the urban context is severely limited - agriculture and catchment management are partly covered, but urban water cycles haven't had due attention.
Water research is positive in many respects, if not all, but it is the implementation thereof that is often seriously lacking. Also, where such research implicates government, then the intended outcomes of the research are never reached or implemented or taken seriously.
Water research is very strong in South Africa but its use for education is lacking.
Water research should do more about public awareness and implementation of solutions.
Water will probably become the major environmental and human resource need in the next 50 years. Much can be done to put research and systems in place to address this need.
We are doing great with the development of guidelines and policies however; there is a need for more compliance monitoring.
We are losing researchers faster than we can replace them and the replacements are not up to par on experience and ability.
We have written a lot of policy documents and guidelines, but very little implementation is seen.
We need more practical, applicable research that generates solutions to SA's water problems rather than the development of more policies and guidelines that never see the light of day or are never applied effectively.
We seem to lack generating further research from original research as the commercialisation interface is lacking.
While most researchers have a good idea of what they want to achieve, this is often tempered by the provider of the money to pay for the research, especially on large projects. Constraints in terms of references may limit effectiveness but this is necessary to obtain benefit from applied research.
While much of the research has been good, there is far too little funding and many urgent and far reaching needs are falling away. This leads to gaps in practice and loss of scarce research skills, either to emigration or moving out of the realm of research.

ANNEXURE L: LONG-LIST PRIORITY RESEARCH QUESTIONS BY THEME (401)

Theme	*Question*
CHANGE 01	What is the level of access by lower-income groups to water and sanitation services?
CHANGE 02	Where does the balance lie between water access being a human right and financially viable?
CHANGE 03	How can equitable access to water be achieved?
CHANGE 04	How can human-centred resilience be increased as water resources become scarcer?
CHANGE 05	What is the potential for and benefits of developing a multi-sector participatory agent-based social simulation modelling capability in South Africa?
CHANGE 06	What are the projected impacts of climate change on agricultural yields and crop behaviour?
CHANGE 07	Has the large scale establishment of irrigated crops along rivers influenced the local climate in any way?
CHANGE 08	Are agricultural production processes able to adapt to less supply given predicted climate change?
CHANGE 09	What monitoring methods can track climate-driven changes in hydrological processes within South Africa's catchments?
CHANGE 10	What predominant learning processes and institutional factors can support and strengthen social change to improve catchment management?
CHANGE 11	What suite of adaptation measures is required regarding the predicted increased variability of rainfall due to climate change?
CHANGE 12	How does climate change affect water availability and agricultural productivity in South Africa?
CHANGE 13	How will climate change impact South Africa's water demand and how can this be addressed?
CHANGE 14	How will global climate change affect water temperature and flow regimes in South Africa's rivers?
CHANGE 15	How will freshwater ecosystems be impacted by climate change in South Africa?
CHANGE 16	What effect will climate variability and infrastructure development have on groundwater recharge?
CHANGE 17	How can climate change scenarios become incorporated into the mainstream water resource analysis methods?
CHANGE 18	What are the impacts of projected climate change on long-term infrastructure planning?
CHANGE 19	How will water resource management change with and adapt to climate change?
CHANGE 20	What are the climate change and water security knowledge gaps?
CHANGE 21	Is it possible to predict the changes in water availability in South Africa over time?
CHANGE 22	What impact does climate change have on freshwater ecology in South Africa?
CHANGE 23	How can near real time to seasonal weather and climate forecasts be translated into operational hydrological forecasts?
CHANGE 24	What innovation processes are required to enhance community assessments of river health?
CHANGE 25	What framework can be developed to include cultural values in the development of water conservation planning initiatives?
CHANGE 26	What are the drought or flood damage functions for different sectors in agriculture?
CHANGE 27	What can be done to increase the public sense of ownership over water resources?
CHANGE 28	In what way can the efficiency of higher-level planning and utility operation in terms of skills in the water sector be improved?
CHANGE 29	What is the framework and origin of social life and understanding surrounding water use in rural communities?
CHANGE 30	How can sociology be integrated into the engineering framework to produce more efficient and effective development strategies?
CHANGE 31	What are the societal impacts towards addressing equity and access of poor infrastructure?
CHANGE 32	What is the projected influence of climatic change on groundwater recharge?
CHANGE 33	How can relevant human health topics be integrated within the water sector?
CHANGE 34	What is the potential impact of climate change on the frequency of floods in southern Africa?
CHANGE 35	How can indigenous knowledge help us better understand ways of conserving water with local communities?
CHANGE 36	How can communities improve self-management of water resources?
CHANGE 37	What are the solutions for mine water pollution that also have social benefits?
CHANGE 38	What are the impacts of water privatisation for South African communities?
CHANGE 39	What are the key leverage points and self-organising principles to communicate regarding the approaches of Pro-Poor design?
CHANGE 40	How can changes in rainfall distribution patterns be further improved?
CHANGE 41	To what extent is water research relevant and contributing towards sustainable decisions?
CHANGE 42	To what extent are research recommendations followed up on?
CHANGE 43	To what extent do rural communities benefit from research?

CHANGE 44	How can the water research community encourage more social scientists to be involved in water research?
CHANGE 45	How can sanitation services be used at a sustainable level?
CHANGE 46	How can the challenges of water use security be used to empower women?
CHANGE 47	How can development of water services be accelerated?
CHANGE 48	How can water system management encourage long-term social-learning?
CHANGE 49	What methods can be used to transition from a centralised to decentralised water supply scheme?
CHANGE 50	What are the main reasons for skill and capacity shortages in water supply systems?
CHANGE 51	In what way do cultural attitudes affect the amount the willingness to pay for water and sanitation services?
CHANGE 52	How can housing and water planning provisions be successfully and effectively integrated?
CHANGE 53	What are the potential impacts of climate change on the quality of drinking water, as well as on treatment strategies in South Africa?
CHANGE 54	How do people value and give meaning to water and water resources?
CHANGE 55	What is the role of values in building stewardship of social-ecological systems?
DATA 01	How can monitoring of wastewater effluent be captured online to ensure transparency and effective data access?
DATA 02	How can flood hydrology data sets and methodologies be improved?
DATA 03	How can borehole logging be used to determine water movement, direction and velocity within a borehole?
DATA 04	What baseline hydrologic information can be gained prior to hydraulic fracturing exploration?
DATA 05	What is required to improve groundwater monitoring?
DATA 06	How can a comprehensive database of groundwater research in South Africa be developed?
DATA 07	How can river flow and rain gauging structure maintenance be improved for long term use?
DATA 08	How can satellite data and information on water management be used optimally given the paucity of in-situ data?
DATA 09	What are the minimum data requirements to adequately model rainfall-runoff processes?
DATA 10	How can water resource management decisions be better made with incomplete information?
DATA 11	What historic rainfall records are held by private landowners and how can this be exploited?
DATA 12	How can monitoring methods for radio-active substances in water resources be improved?
DATA 13	How can the water quality monitoring process be streamlined in order to eliminate the current backlog and maintain updated registries of water users?
DATA 14	Can rainfall and runoff monitoring in South Africa be improved to ensure efficient reserve determination and better allocation of water resources?
DATA 15	How can rainfall and streamflow data be improved?
DATA 16	How can advanced control systems and remote monitoring improve water and wastewater treatment works' performance management?
DATA 17	How will the decreasing numbers of working flow gauges affect water resources management and planning?
DATA 18	What is the state of data collection by municipalities regarding water resources?
DATA 19	What is the feasibility of establishing a national water faults database?
DATA 20	Why are the results of municipal water tests no longer accessible to the public?
DATA 21	Are our current water quality testing standards appropriate to monitor all potentially pathogenic organisms in water systems?
DATA 22	How can the collation and co-ordination of the general monitoring of aquatic resources be implemented at a local scale?
DATA 23	How is water related research data managed and can it become more centralised and available?
DATA 24	How can research in academia be directed so as to acquire the correct data from all relevant parties in society, for the eventual use in government decision-making?
DATA 25	How can baseline or primary data pertaining to climate, water, soils and land cover in South Africa be improved?
DATA 26	How can researchers be motivated to input their data into existing databases or develop relevant databases to improve interdisciplinary communication?
DATA 27	How can water users access and contribute towards open access water databases?
DATA 28	How can we improve the quality and quantity of water related data in South Africa?
DATA 29	How can a centralised microbial database improve effective management of treatment and wastewater facilities?
DATA 30	How can daily rainfall databases in South Africa be updated, quality controlled and made more readily available?
DATA 31	What is the socio-economic value of hydrometric data collection?
DATA 32	Do the current hydrology models still accurately portray naturally observed data or should they be revised?
DATA 33	How should a database of geochemistry and potential contamination from different mining environments be formulated?
DATA 34	What are the best methods of obtaining water quality data for use in models?
DATA 35	What is the impact of using historical hydrological and use data for allocation determination over real-time data?
ECOSYSTEMS 01	How can cleared riparian zones be actively restored?

ECOSYSTEMS 02	What are the seed banks of selected invasive alien aquatic weeds?
ECOSYSTEMS 03	Is it biologically safe to farm fish in treated sewage water?
ECOSYSTEMS 04	To what extent is aquaculture feasible in South Africa?
ECOSYSTEMS 05	How can the diversity of aquatic biota in relation to the ecological status of the environment be evaluated?
ECOSYSTEMS 06	What collection of variables can be measured to determine the trophic status of an aquatic ecosystem?
ECOSYSTEMS 07	How we can better understand the effects of global climate change on South African rivers by understanding the ecology of aquatic insects?
ECOSYSTEMS 08	Which water-dwelling species are most resilient to climate change?
ECOSYSTEMS 09	Where are artificial wetlands being used to mitigate source-point pollution?
ECOSYSTEMS 10	How can species level information of freshwater fauna diversity be used to determine the conservation value of selected rivers?
ECOSYSTEMS 11	To what extent are rapid biological assessments effective in detecting environmental changes?
ECOSYSTEMS 12	How can biological systems, such as biofilters and wetlands, be used to effectively treat polluted runoff before it enters freshwater systems?
ECOSYSTEMS 13	How can bioremediation of acid mine drainage be integrated with existing chemical treatments?
ECOSYSTEMS 14	What is the return on investment for programmes that focus on the rehabilitation of freshwater ecosystems?
ECOSYSTEMS 15	How can the determination of the reserve be accelerated?
ECOSYSTEMS 16	What is the role of river inflow on the marine ecosystem?
ECOSYSTEMS 17	How much water does a wetland require for basic ecological functioning?
ECOSYSTEMS 18	What are the baseline economic values of aquatic ecosystems?
ECOSYSTEMS 19	What are the costs and benefits of ecological systems and protection within catchments?
ECOSYSTEMS 20	What is the full ecosystem service value of our water resources?
ECOSYSTEMS 21	What is the potential for ecosystem services to strengthen impoverished livelihoods?
ECOSYSTEMS 22	What are the main risks associated with estuarine health within the South African context?
ECOSYSTEMS 23	How can public education effectively communicate the ecological concerns and limitations of water supplies?
ECOSYSTEMS 24	To what extent is eco-classification successfully applied in the environmental management impact framework?
ECOSYSTEMS 25	How vulnerable are aquatic species to impacts from treated mine water according to environmental risk assessment?
ECOSYSTEMS 26	What are the effects of deteriorating water quality on the ecological function of an estuary?
ECOSYSTEMS 27	What is the health status of freshwater fisheries in South Africa?
ECOSYSTEMS 28	What is impact of alien vegetation in the riparian zone on a river's hydrology?
ECOSYSTEMS 29	What is the most effective method for management of invasive plants in waterways and estuaries?
ECOSYSTEMS 30	What threats does economic development (such as mining) pose to the ecology of water basins?
ECOSYSTEMS 31	What is the most efficient monitoring frequency for river ecosystems?
ECOSYSTEMS 32	What are the best early-warning biomarkers for metal pollution?
ECOSYSTEMS 33	What are the South African rehabilitation guidelines for wetlands and riparian zones and are they sufficient for implementation?
ECOSYSTEMS 34	How can reserve management and calculation become more accurate and responsive?
ECOSYSTEMS 35	How can ecological risk assessments be implemented in IWRM in South Africa?
ECOSYSTEMS 36	What is the ecological impact, on communities and the environment, of not implementing the ecological reserve (over abstraction of water)?
ECOSYSTEMS 37	What are the reference states for urban and intense agricultural riparian and wetland zones in South Africa?

ECOSYSTEMS 38	Is the eradication of alien fish in South Africa's freshwater systems a feasible option?
ECOSYSTEMS 39	What is the current geographical distribution of the intermediate host snails of schistosomiasis in South Africa?
ECOSYSTEMS 40	What are the lethal thermal limits and critical thermal thresholds of South Africa's aquatic invertebrates?
ECOSYSTEMS 41	Are the recommended buffer zone guidelines for wetlands and rivers sufficient and practical in urban residential zones?
ECOSYSTEMS 42	How can effective microorganisms aid in water treatment systems?
ECOSYSTEMS 43	What are the most appropriate methods of determining buffer zones for wastewater facilities?
ECOSYSTEMS 44	How can the efficacy of wetland and riparian buffer zones be improved?
ECOSYSTEMS 45	What is the aquatic invertebrate community structure and succession in newly inundated wetland systems?
ECOSYSTEMS 46	What is the impact of improved wetland management on water quality, quantity and flood attenuation?
ECOSYSTEMS 47	What climate-driven changes are occurring in the required ecological reserves?
ECOSYSTEMS 48	How can the benefits of ecosystem services be mainstreamed into the formal economy?
ECOSYSTEMS 49	Can the ecological function of engineered rivers be improved?
GOVERNANCE 02	What is the viability of South Africa having a separate institution to integrate agriculture, water and land systems to ensure appropriate decisions?
GOVERNANCE 03	What methodologies can be determined to accurately estimate domestic and agricultural water requirements?
GOVERNANCE 04	In what way can water allocation on a national scale between rivers, estuaries, groundwater and wetlands be balanced?
GOVERNANCE 05	How can the alteration of water allocation contribute to South Africa's transition into a steady-state (non-growth, low carbon) economy?
GOVERNANCE 06	How can catchments allocate their water resources to ensure maximum economic, social and environmental benefit?
GOVERNANCE 07	What alternative funding mechanisms are available for improved stormwater infrastructure and management?
GOVERNANCE 08	Are there viable alternatives available to replace CMAs in areas where the CMA is not implemented?
GOVERNANCE 09	How can a realistic asset-management plan be developed for the sanitation sector?
GOVERNANCE 10	What practical approaches can be adopted by municipalities to incorporate asset management into their planning and operational decision- making processes?
GOVERNANCE 11	How can sustainable business models for catchment management organisations be developed?
GOVERNANCE 12	What has slowed the implementation of integrated water resource management in South Africa?
GOVERNANCE 13	What is required for effective implementation of cooperative management in catchments?
GOVERNANCE 14	How is the disjunction between spatial town planning and water quality affecting the country economically?
GOVERNANCE 15	How can South Africa's water information systems be improved?
GOVERNANCE 16	How can the communication regarding water issues among communities and municipalities be improved?
GOVERNANCE 17	How can the implementation and management of water conservation schemes be improved?
GOVERNANCE 18	To what extent does corruption impact the South African water sector?
GOVERNANCE 19	What is required for the establishment of effective cost recovery in peri-urban areas?
GOVERNANCE 20	What effect does price elasticity have on water demand?
GOVERNANCE 21	Are there measures in place for managing first, second and third-order water scarcity in South Africa?
GOVERNANCE 22	What optimal water demand management tools are available to water allocation administrators?
GOVERNANCE 23	What policy and practice mechanisms need to be put in place to successfully implement water demand management in urban residential areas?
GOVERNANCE 24	Are South African water schemes economically sustainable?
GOVERNANCE 25	How can catchment management agencies effectively determine the price of water?

GOVERNANCE 26	To what extent are water users associations cost effective and sustainable?
GOVERNANCE 27	How can the real values of water be more effectively determined in South Africa?
GOVERNANCE 28	To what extent is the non-payment of services affecting the sustainability of water provision?
GOVERNANCE 29	What can be done on a municipal level to elevate the technical competence of process control staff?
GOVERNANCE 30	Who is responsible for the inspection and monitoring of effluent-producing factories and is this being performed?
GOVERNANCE 31	How do we benchmark coal-powered energy generation with regards to its water-use on an international and national level?
GOVERNANCE 32	How can we create a more rational approach to determining environmental water requirements and the associated impact on catchment yields?
GOVERNANCE 33	How can the determination of water-energy footprints be integrated into the environmental assessment and water use authorisation processes?
GOVERNANCE 34	How effective would the implementations of co-operative environmental authorisation be in South Africa?
GOVERNANCE 35	What are the advantages and disadvantages of doing on-site analysis rather than central-laboratory analysis?
GOVERNANCE 36	What are the minimum requirements for a groundwater protection zoning model?
GOVERNANCE 37	Is the Blue and Green Drop Programme generating the incentive to self-regulate and improve standards towards excellence within poorer municipalities?
GOVERNANCE 38	How can Department of Water Affairs become an effective regulator in the absence of an independent regulator?
GOVERNANCE 39	What is the role of traditional authorities in water policy formulations and governance?
GOVERNANCE 40	How can water law compliance be improved in South Africa?
GOVERNANCE 41	What role can the government play in maintaining the safety and security of the water sector?
GOVERNANCE 42	What are the most effective institutional arrangements for successful catchment management?
GOVERNANCE 43	What are the main constraints and hindrances to effective water resources governance?
GOVERNANCE 44	To what extent are local authorities financially prepared to implement the new water quality standards?
GOVERNANCE 45	What is a suitable institutional design for sustainable urban water management?
GOVERNANCE 46	What practical guidelines can be formed for the institutional arrangement of groundwater schemes?
GOVERNANCE 47	To what extent are industries compliant with their water use license requirements?
GOVERNANCE 48	How can private sector effluent producers monitor and record their wastewater quality to enable public access?
GOVERNANCE 49	What are the real barriers to multi-sector engagement in catchment management agency arenas created by legislation?
GOVERNANCE 50	How should the free basic water allocation be adjusted given future scarcity and cost predictions?
GOVERNANCE 51	To what extent is risk-based regulation working in South Africa for water services?
GOVERNANCE 52	How effective is current legislation and its implementation at ensuring long-term water sustainability?
GOVERNANCE 53	What viable options exist for community-based natural freshwater resource management?
GOVERNANCE 54	Why is there a lack of departmental integration in water utilities to move towards sustainability?
GOVERNANCE 55	How can authorities such as the Department of Water Affairs improve knowledge archive systems to enable better learning from past research and activities?
GOVERNANCE 56	How can institutional private-public partnerships address excess mine water challenges?
GOVERNANCE 57	How can water-use efficiency be increased at a municipal level?
GOVERNANCE 58	How can a framework for the governance of the use of nanotechnology in the water sector be established?
GOVERNANCE 59	How can participatory budgeting be strengthened at a municipal level in the water sector?
GOVERNANCE 60	To what extent do the South African National, Provincial and Local Government have the capacity to properly implement environmental policies?
GOVERNANCE 61	What policy changes and regulations are needed to effectively manage hydraulic fracturing?

GOVERNANCE 62	What policies should be implemented to improve citizen response to the discharge of polluted water and biomass into urban river systems?
GOVERNANCE 63	Are the controls on municipal water treatment in South Africa sufficient to keep the risk to human health within 'acceptable' bounds?
GOVERNANCE 64	What is South Africa's water security status?
GOVERNANCE 65	What are mechanisms and guidelines for the enforcement of stormwater regulations?
GOVERNANCE 66	How can water research be promoted to improve water resource use and management?
GOVERNANCE 67	What are the Municipal budgets and capacities available for operation and maintenance of sanitation facilities in informal settlements?
GOVERNANCE 68	To what extent do municipal human resources understand service delivery requirements?
GOVERNANCE 69	How can multiple stakeholder engagement for management purposes be improved?
GOVERNANCE 70	What do our decision makers understand by the concept of a sustainable water supply?
GOVERNANCE 71	How can the definition of a watercourse in terms of NEMA and the NWA be improved?
GOVERNANCE 72	How can utilities become financially self-sustainable without relying so heavily on the limited budget offered by taxes and government subsidies?
GOVERNANCE 73	What suitable legislation can be implemented to govern the reuse of non-potable water (e.g. greywater) in South African urban areas?
GOVERNANCE 74	What initiatives can the central government drive to improve infrastructure of wastewater treatment facilities?
GOVERNANCE 75	Does the awarding of Green Drop status to a waste water treatment works result in improved downstream water chemistry and biological integrity?
GOVERNANCE 76	How can the various wetland assessment protocols in South Africa be unified into one effective method?
GOVERNANCE 01	How can the issue of non-payment be minimised among water users?
INNOVATION 01	What economic benefits can be derived from acid mine drainage?
INNOVATION 02	What are the best passive treatment systems for acid mine water?
INNOVATION 03	How can the nutritional productivity and water efficiency of crops be improved?
INNOVATION 04	What is the potential role of organised agriculture in facilitating and initiating water research?
INNOVATION 05	Is there a potential to develop drought resistant indigenous food crops?
INNOVATION 06	Can we find more water-efficient irrigation technologies and practices?
INNOVATION 07	How can modern treatment technology-such as ARD- be used as a replacement source of water supply to communities and industry?
INNOVATION 08	What dyes can be used to stain anaerobic bacteria in order to determine population sizes from samples?
INNOVATION 09	What tools can be utilised to improve public awareness of drinking water quality issues?
INNOVATION 10	What are the best practises for cost effective measurement, logging and telemetry of borehole level monitoring and small channel flow measurement?
INNOVATION 11	Are there more cost effective solutions for managing the brine produced from membrane treatment processes?
INNOVATION 12	Which tools can be developed for mobilising the evacuation of sediment from bulk water storage facilities?
INNOVATION 13	What training is needed to develop the skills necessary for future wastewater managers?
INNOVATION 14	How can a standardised carbon footprint assessment methodology for the water sector be developed?
INNOVATION 15	What is the appropriate level of training and experience of catchment managers?
INNOVATION 16	What are the returns on investment from the improved management of watersheds and primary catchments?
INNOVATION 17	How much biogas can be produced by mesophically digesting thickened waste activated sludge with and without the implementation of a cell lysis system?
INNOVATION 18	What carbon reduction measures within water services provision are appropriate?
INNOVATION 19	What economic mechanisms can be used to improve the understanding of the true value of water?
INNOVATION 20	Is it possible to make desalination affordable and environmentally sustainable?

INNOVATION 21	Can the use of desalinised water supplement inter-basin transfers?
INNOVATION 22	Are water distribution efficiency solutions adequately incorporated into the current water-distribution design?
INNOVATION 23	How are water distribution systems being designed to minimise energy consumption?
INNOVATION 24	If dry sanitation is promoted, how can greywater be managed in urban areas?
INNOVATION 25	To what extent can Earth Observation be used for evapotranspiration monitoring in South Africa?
INNOVATION 26	To what extent can Earth Observation be used for water quality monitoring in South Africa?
INNOVATION 27	To what extent can Earth Observation be used for run-off calculation in South Africa?
INNOVATION 28	What economic benefits do high sanitation standards create?
INNOVATION 29	How can communication among scientists, policy makers, stakeholders, and the public be improved?
INNOVATION 30	How can public education on water use and conservation be improved?
INNOVATION 31	Where are the potential energy savings in water and wastewater treatment?
INNOVATION 32	How can sewerage biogas in wastewater treatment facilities be used to generate electricity in all municipalities?
INNOVATION 33	How can the national plan for water and sanitation be improved in order to increase its attractiveness to investors?
INNOVATION 34	How can municipalities be convinced that spending more on capital will save much more on operating expenses long term?
INNOVATION 35	What is the best way to ensure the maintenance of the water meters?
INNOVATION 36	Is the diversion and capturing of surface run-off an effective and sustainable means of improving flood control?
INNOVATION 37	What are the optimal design and materials for fog water harvesting in South Africa?
INNOVATION 38	How can national sediment yield be calculated?
INNOVATION 39	How can a greywater footprint be calculated for South Africa?
INNOVATION 40	What are the practical solutions for grey water management in dense informal settlements?
INNOVATION 41	What is the best means of testing drinking water for xenobiotics or substances such as anti-biotics?
INNOVATION 42	What is the best means of treating wastewater for endocrine disrupters?
INNOVATION 43	What new methods are available for heavy metal removal from waters based on their speciation?
INNOVATION 44	Can excess mine water be used to provide hydroelectricity?
INNOVATION 45	What are the most effective methods for enforcing industrial effluent discharge restrictions?
INNOVATION 46	What is the most effective role of ICT in the water and sanitation sector?
INNOVATION 47	How can smartphone and tablet applications contribute to water quality management and reporting in South Africa?
INNOVATION 48	How effective are online instrument analysers and how can this market grow?
INNOVATION 49	How can the concept of the green economy be used to manage water in a water-scarce country?
INNOVATION 50	How should the concept of transdisciplinarity inform water resources management?
INNOVATION 51	What are the obstacles involved in using microbes for water treatment?
INNOVATION 52	How can the sludge resulting from treatment of acid mine water be managed?
INNOVATION 53	Can nanotechnology benefit the water treatment process?
INNOVATION 54	How can effective biomarkers of pollution be determined?
INNOVATION 55	What is the level of importance placed on pipeline protection?
INNOVATION 56	Can a feasible method for instant water testing be developed?

INNOVATION 57	How should urban stormwater runoff be effectively filtered?
INNOVATION 58	How can water quality parameters be predicted by hyperspectral sensing?
INNOVATION 59	How can the research skills base in South Africa be increased?
INNOVATION 60	How can academic research become more responsive to industrial needs?
INNOVATION 61	How to implement latest trends in ecotoxicological methods in IWRM in SA
INNOVATION 62	How can water-energy nexus's be understood in the context of a changing climate?
INNOVATION 63	How can the rural poor effectively access water for productive use?
INNOVATION 64	Can a Salinity Hazard Index be created for South Africa using hydrosalinity models such as ACRU Salinity?
INNOVATION 65	How would it be best to optimise current infrastructure in the sanitation sector and identify alternative methods of wastewater treatment?
INNOVATION 66	How can the toilet designs and systems be reconsidered or re-approached?
INNOVATION 67	Can risk-based management of water utilities be implemented in South Africa?
INNOVATION 68	What is the level of compliance amongst municipalities in sludge disposal?
INNOVATION 69	What is the most cost effective process for managing highly polluted low flow stormwater runoff?
INNOVATION 70	How well do leak detection correlates work on local piping materials?
INNOVATION 71	How effective is the use of biogas produced by the Waste Water Treatment Works?
INNOVATION 72	How might new technologies affect the supply of drinking water?
INNOVATION 73	How can mechanisms and processes found in nature inform the development of more efficient, large-scale desalination systems?
INNOVATION 74	How can the turn-around time for microbial monitoring at rural water treatment works be simplified and reduced?
INNOVATION 75	What efficient, low-cost technologies can be developed for water purification in rural communities?
INNOVATION 76	What are the emerging microbiological threats to drinking water quality?
INNOVATION 77	How can more efficient urban drainage be developed to accommodate flood events?
INNOVATION 78	How should urban planning approach the potential of waste separation at source?
INNOVATION 79	How can excessive plant growth in waterways and estuaries be utilised?
INNOVATION 80	Which technologies provide innovative ways to decrease the waste in waste water treatment?
INNOVATION 81	How relevant is nano-waste in municipal waste water treatment plants?
INNOVATION 82	What is the most cost effective and hygienic technology for treating human faecal matter and wastewater disposal in urban slums?
INNOVATION 83	How viable are water-less sanitation technologies in a South African context?
RESOURCES 01	How can acid mine water become a resource?
RESOURCES 02	What is the overall effect of acid-mine drainage on the production of safe drinking water?
RESOURCES 03	What are the effects of acid-mine drainage on wetlands, water quality and on the living organisms within these systems?
RESOURCES 04	What is the cumulative ecological impact of the discharge of polluted water into freshwater systems that are used for drinking water or irrigation?
RESOURCES 05	Do alternative treatment options exist for polluted irrigation water?
RESOURCES 06	What are the effects of agricultural pesticides on water resources?
RESOURCES 07	How can crop productivity be increased with minimised water use?
RESOURCES 08	How can agricultural water demand be reduced?
RESOURCES 09	What are the agronomic and soil fertility management approaches that can increase water use efficiency in agriculture?

RESOURCES 10	What is the condition of aquifer vulnerability in agricultural areas?
RESOURCES 11	What is the maximum pollution level of irrigated crops such that they can still safely be consumed raw?
RESOURCES 12	What are the long-term implications of using grey-water for irrigation and horticulture?
RESOURCES 13	How can dryland salinity be managed?
RESOURCES 14	What is the water use productivity in food value chains?
RESOURCES 15	What measures are being implemented to prevent harmful algal blooms in water supply systems?
RESOURCES 16	How can the transmissivity and storativity determination in confined/semi-confined aquifer be improved?
RESOURCES 17	How can molecular typing of bacterial pathogens be improved?
RESOURCES 18	How can the removal of minerals from municipal borehole water supplies be implemented in a cost-effective way?
RESOURCES 19	At what stage can bottled water become unsafe to consume?
RESOURCES 20	What are the respective thresholds of urban agriculture and population density for effective nutrient recovery from sewage for food production?
RESOURCES 21	What alternative methods can be used to manage hydraulic overload in wastewater treatment plants?
RESOURCES 22	Can raw and local feedstock be used to prepare an appropriate absorbent for the removal of pollutants?
RESOURCES 23	How can water sensitive cities be created through urban development and design?
RESOURCES 24	What is the future of water augmentation in South Africa in the face of potential water shortages?
RESOURCES 25	What are the priority emerging contaminants in South African water systems and what mechanisms can be used to addressing them?
RESOURCES 26	What are the future trends and risks of endocrine disruptors on human and environmental health?
RESOURCES 27	What is the optimal utilisation of dam impoundments in South Africa?
RESOURCES 28	What resources are required for the sustainable management and rehabilitation of dams?
RESOURCES 29	What is the extent of demand estimation used in rural areas?
RESOURCES 30	How will it be possible to recover water that has been lost from the municipal water supply?
RESOURCES 31	How can present and future water demand be effectively met?
RESOURCES 32	To what degree does desalination provide a viable alternative supply?
RESOURCES 33	How can the gap in water access be reduced?
RESOURCES 34	What is the public perception of drinking water quality in South Africa?
RESOURCES 35	To what extent are current water pricing policies encouraging efficient resource utilisation?
RESOURCES 36	What are the effects of endocrine disruptors in freshwater resources?
RESOURCES 37	How can water conservation and demand management be improved in the electricity sector?
RESOURCES 38	What level of estrogenic activity will be acceptable in surface waters?
RESOURCES 39	What is the assimilative capacity of ground water and the potential for self-cleaning after source of pollution is removed?
RESOURCES 40	How can dam design be improved to cope with high sediment yield?
RESOURCES 41	What is the nanotoxicity impact assessment of freshwater systems and organisms?
RESOURCES 42	To what extent can nanotechnology provide solutions to the testing and treatment of water?
RESOURCES 43	What is the influence of groundwater inflow in estuaries?
RESOURCES 44	What are the sediment budgets for South Africa's estuaries based on catchment hydrology?
RESOURCES 45	What is the feasibility of combined coastal nuclear electricity generation and desalination?

RESOURCES 46	What impacts on water quality and quantity can be observed from flood attenuation practices in urban areas?
RESOURCES 47	What is the most appropriate water footprinting framework tool to use in irrigated agriculture?
RESOURCES 48	What are the impacts of forest harvesting on surface waters?
RESOURCES 49	What is the assimilative capacity of aquifers to further understand potential mine contamination?
RESOURCES 50	What correlations exist between South African water quality and human diseases?
RESOURCES 51	Is it possible to quantify the groundwater contamination caused by pit latrines?
RESOURCES 52	What is the effect of hydraulic fracturing in the Karoo on the future groundwater quality in South Africa?
RESOURCES 53	How can abstraction be better controlled in different areas?
RESOURCES 54	What role does groundwater play in sustaining near shore marine productivity along the South African coast?
RESOURCES 55	What are the pollution levels of groundwater in metropolitan areas?
RESOURCES 56	How can groundwater resources in be further developed and exploited?
RESOURCES 57	What is the effect of large scale wastewater discharge events on groundwater?
RESOURCES 58	Which diseases are most likely to be disseminated through polluted water in urban areas?
RESOURCES 59	What are the long term effects of drinking water fluoridation on humans and animals?
RESOURCES 60	What health risks can be associated with the inadequate treatment and management of wastewater and drinking water?
RESOURCES 61	What is the correlation of heavy metal pollution with organic matter content in water resources?
RESOURCES 62	What are the effects of poor water quality on individuals living with HIV/AIDS?
RESOURCES 63	What is the expected remaining life-span of the infrastructure charged with supplying bulk water?
RESOURCES 64	Can comparisons between different geological and climatic settings be used to estimate hydrological discharge?
RESOURCES 65	How can evaporation in reservoirs be reduced?
RESOURCES 66	What are the potential impacts of future land use on hydrological systems in South Africa?
RESOURCES 67	What is the impact of rainwater harvesting on urban stormwater?
RESOURCES 68	Can a more efficient sanitation design be created based on the needs of the South African people?
RESOURCES 69	How can society mimic the natural systems and processes of water capture, storage and distribution?
RESOURCES 70	How can water allocation be improved in water stressed regions?
RESOURCES 71	What is the influence of hospital effluent on the emergence of antibiotic resistant organisms?
RESOURCES 72	What are the impacts of metal pollution on inland waters?
RESOURCES 73	Do the presence of microbes in warm marine waters and beaches pose a threat to human health?
RESOURCES 74	What are the current microbiological base-line states of South African rivers?
RESOURCES 75	What is the potential for root uptake of pathogens by edible crops which have been irrigated with polluted water?
RESOURCES 76	How can brine treatment methods and technology research be increased in scale?
RESOURCES 77	How can water related health monitoring systems be developed?
RESOURCES 78	Is South Africa's monitoring capacity adequate to ensure protection and optimal utilisation of water resources?
RESOURCES 79	What are the long-term effects of consuming water from sources that contain high levels of potentially-harmful organic compounds?
RESOURCES 80	What unmonitored pathogens exist in surface waters that should be monitored?
RESOURCES 81	To what extent can phytoremediation be implemented to manage polluted water systems using native aquatic plants?

RESOURCES 82	What policies can ensure effective water demand management?
RESOURCES 83	What is the economic cost of water pollution?
RESOURCES 84	To what extent is South Africa effectively saving water?
RESOURCES 85	What competitive pricing models can be developed for treated wastewater?
RESOURCES 86	How can cost benefit analysis within a macroeconomic modelling system be used to evaluate water projects and programmes at a basic level?
RESOURCES 87	To what extent to national parks and protected areas contribute to water quality and flow?
RESOURCES 88	Is the current free basic water allowance of adequate to protect public health?
RESOURCES 89	How can molecular biology be used for water quality monitoring?
RESOURCES 90	What are the long-term trends in South Africa's water quality?
RESOURCES 91	What is the role of soil (as part of the vadose zone) in determining the quality and quantity of water in the natural environment?
RESOURCES 92	What are the most effective frequencies to measure key variables in water quality?
RESOURCES 93	How can remote sensing technology be used to optimise benefits for water resource planning and management?
RESOURCES 94	How can water availability risk be incorporated into development planning decisions?
RESOURCES 95	What is the current state of functional sanitation coverage in South Africa?
RESOURCES 96	What will water-use in the South African economy look like by the year 2050?
RESOURCES 97	What are the linkages between socio-economic factors and household water consumption?
RESOURCES 98	Are water service utilities (especially municipalities) financially viable?
RESOURCES 99	What are the most effective methods in handling illegal water connections?
RESOURCES 100	What is the impact of transboundary changes on the condition of the catchment?
RESOURCES 101	To what extent will the beneficiaries of a dual (greywater and potable water) system be impacted if a cross-connection were to occur?
RESOURCES 102	How can wastewater treatment plants be retrofitted to become energy neutral?
RESOURCES 103	What is the efficiency of wastewater treatment in the removal or reduction of microbial pathogens?

ANNEXURE M: SHORT-LIST PRIORITY RESEARCH QUESTIONS BY THEME (91)

Theme	*Question*
CHANGE 04	How can people, communities and society be helped to adapt to water scarcity?
CHANGE 09	What data and information is essential for monitoring hydrological responses to the change drivers for South Africa?
CHANGE 12	How does global change impact water availability, sustainable water services delivery and food security and how can this be addressed in SADC region?
CHANGE 28	In which ways can the efficiency of utilities and municipalities be improved in terms of water and wastewater services delivery?
CHANGE 31	What can be done to address challenges of equity and lack of access to resources and infrastructure and how does poor infrastructure contribute to inequity?
CHANGE 33	What early warning systems need to be put in place to detect emerging waterborne contaminants?
CHANGE 42	How do we ensure that South African water research agenda is relevant and the outcomes adopted and implemented appropriately at a faster rate?
CHANGE ADD	What is the strategic value of water and what changes need to be made in the South African economy to accommodate future water scarcity?
CHANGE ADD	How can the social perception of the value of water be changed?
CHANGE ADD	How can integrated planning and development be implemented in order to deal with rapid rates of urbanisation?
CHANGE ADD	How can future cities in Africa be best or sustainably designed?
DATA 31	How can the value of monitoring systems be optimised, maximised and explained to ensure sustainability?
DATA ADD	How and why could society at large contribute to and benefit from open access data related to water quality and availability?
DATA ADD	What is the state of data collection, use and data driven accountability in water services authorities?
DATA ADD	How can real time water be collected in real time from which timely, reliable and transparent information can be efficiently generated for decision support?
DATA ADD	How can rainfall, runoff and hydrological monitoring in South Africa be improved for better use in terms of decision making, planning, management and operations?
DATA ADD	How do we ensure monitoring that is fit for purpose while conforming to the appropriate quality control and quality assurance processes relating to data storage, standardisation, verification and processing?
DATA ADD	What broad systems of monitoring, measuring and reporting can best drive improvement in water services authorities, decision making and accountability related to service delivery and water resource management?
DATA ADD	Is a citizen database technically feasible and can it contribute to better information about water resources and service provision?
ECOSYSTEMS 07	How can we better understand the effects of global change on South African aquatic ecosystems?
ECOSYSTEMS 12	How can biological systems such as biofilters and wetlands be more effectively (re)used to treat all sources of pollution before it enters the freshwater and marine environments?
ECOSYSTEMS 15	How can the implementation of the reserve be accelerated and effectively monitored into the future?
ECOSYSTEMS 20	What is the full ecosystem service value of our water resources and how can it be mainstreamed into the formal economy?
ECOSYSTEMS 23	How can public education more effectively communicate the balance and trade-offs between ecological protection and use of water resources?
ECOSYSTEMS 28	What is the extent and quantitative impact of alien invasive vegetation on a river's variable hydrology and water quality?
ECOSYSTEMS 29	What are the real costs and benefits of different management methods of invasive plants in waterways and estuaries?
ECOSYSTEMS 30	What threats does economic development such as mining hydraulic fracturing pose to the water-related environment?
ECOSYSTEMS 36	What is the ecological impact on communities and the environment of not implementing the ecological reserve including over abstraction of water?
ECOSYSTEMS 44	How can the efficacy of wetland and riparian buffer zones be improved?
ECOSYSTEMS ADD	What are the trends and effects of deteriorating water quality on the ecological function and associated risk and vulnerability of aquatic ecosystems?
ECOSYSTEMS ADD	How do we ensure the economic and environmental sustainability of aquaculture in SA?
ECOSYSTEMS ADD	How can bio-monitoring be more effectively used in catchment management?
GOVERNANCE 06	How can water resources within catchments be allocated to maximise sustainable economic, social and environmental benefits?
GOVERNANCE 11	How can sustainable business models for catchment management organisations be developed?

GOVERNANCE 12	What has slowed the implementation of integrated water resource management in South Africa?
GOVERNANCE 15	How can South Africa's water information systems be improved in terms of collection, management and dissemination?
GOVERNANCE 23	What policy and practice mechanisms need to be put in place to successfully implement water demand management and conservation?
GOVERNANCE 27	How can the values of water be more effectively determined in South Africa?
GOVERNANCE 32	How can we create a more effective approach to implementing environmental water requirements and the associated impact on catchment yields?
GOVERNANCE 38	How can effective regulation be achieved is South Africa?
GOVERNANCE 63	How can the controls on municipal water treatment in South Africa be improved to reduce the risk to human health?
GOVERNANCE 72	How do our institutions become financially viable?
GOVERNANCE 74	What can be done to reduce river pollution in South Africa?
GOVERNANCE ADD	What are the benefits of, and how effective is, ring fencing of water sales and waste water treatments costs for use in South Africa?
GOVERNANCE ADD	What can be done to improve water resource quality monitoring, control, implementation, and enforcement?
GOVERNANCE ADD	How effective would the implementations of co-operative environmental and water authorisation be in South Africa?
GOVERNANCE ADD	How do we ensure effective implementation of co-operative governance and regulation specially inter departmental communication?
GOVERNANCE ADD	How do we identify, build and sustain effective human capacity priorities?
INNOVATION 01	How can industrial and domestic wastewater and solid waste treatment become a resource recovery system when applied towards treated acid mine drainage?
INNOVATION 03	How can water efficiency technology in food production be developed and applied?
INNOVATION 12	Which tools can be developed for mobilising the prevention and evacuation of sediment from bulk water storage facilities?
INNOVATION 13	What are the future skills gaps for stakeholders in the water sector and how can those be effectively addressed?
INNOVATION 20	To what extent can the use of membrane-based technologies be made more affordable and environmentally sustainable?
INNOVATION 25	To what extent can earth observation and related technologies be operationalised for evapotranspiration and run-off estimation as well as water quality monitoring in South Africa?
INNOVATION 31	What are the potential opportunities for energy savings in water and wastewater abstraction, treatment, distribution, collection, treatment and management without compromising quality?
INNOVATION 41	What is the most effective and efficient means of preventing, testing, and treating drinking water and wastewater for emerging micropollutants and pathogens?
INNOVATION 47	How can the role of electronic and information systems assist in the measurement and management of the water and wastewater delivery?
INNOVATION 53	How can innovative process technologies, including nanotechnology, be applied to benefit the water and wastewater treatment process?
INNOVATION 65	How would it be best to review and optimise current infrastructure, including technologies in the sanitation sector, and identify alternative methods of wastewater treatment (such urine diversion and waterless sanitation systems)?
INNOVATION 70	How do we urgently, effectively and efficiently reduce water and wastewater losses in South Africa?
INNOVATION 77	How can more efficient urban drainage be developed to accommodate flood events?
INNOVATION 78	How should urban planning approach the potential of solid and liquid waste separation at source?
INNOVATION 82	What is the most cost effective and hygienic technology for treating sanitary waste, solid waste, and greywater disposal in low-income settlements?
INNOVATION ADD	Which new microbiological processes should be discovered to develop new wastewater treatment technology?
INNOVATION ADD	How can the rural poor effectively access water for productive use?
INNOVATION ADD	What could the role of entomology in augmenting microbiology in wastewater treatment and sludge handling processes be?
INNOVATION ADD	How can urban planning and implementation be used to provide cities and towns with safe, efficient and secure water wastewater and stormwater distribution and collection systems?
INNOVATION ADD	What are the governance systems that need to be implemented in order to reduce and control eutrophication and how are they best implemented in the South African context?
INNOVATION ADD	How should urban planning and implementation be used to provide efficient water, greywater and wastewater cascading and reuse considering separation at source including separation of solid waste?
RESOURCES 02	What is the overall effect of acid-mine drainage on the production of safe drinking water?
RESOURCES 08	How best should we approach the pricing of treated effluent to incentivise the reuse and pollution reduction?
RESOURCES 09	What are the management approaches (agronomical, soil fertility management, water quality, nutrient reuse and greywater reuse) that can optimise water use efficiency in agriculture?

RESOURCES 23	How can urban South Africa transition towards water sensitive, resilient cities?
RESOURCES 25	What are the priority emerging contaminants in South African water systems and what mechanisms can be used to address them?
RESOURCES 35	To what extent are current water pricing policies encouraging efficient resource utilisation?
RESOURCES 50	What correlations exist between South African water quality and human diseases?
RESOURCES 52	What is the effect of hydraulic fracturing in the Karoo on the future groundwater quality in South Africa?
RESOURCES 56	How can groundwater resources in be further developed and exploited?
RESOURCES 75	What are the health implications of irrigating various crops with polluted water?
RESOURCES 76	How can brine treatment methods and technology research be increased in scale?
RESOURCES 77	How can water related health monitoring systems be developed?
RESOURCES 79	What are the long-term effects of consuming water from sources that contain high levels of potentially-harmful organic compounds?
RESOURCES 82	What policies can ensure effective water demand management?
RESOURCES 94	How can water availability risk be incorporated into development planning decisions?
RESOURCES 99	What are the most effective methods in handling illegal water connections?
RESOURCES 102	How can wastewater treatment plants be retrofitted to become energy neutral?
RESOURCES ADD	How best should we quantify the economic value of water to address competing demands to ensure equitable and sustainable growth and development in the contexts of growing water scarcity?
RESOURCES ADD	How can water footprinting tools and frameworks improve the knowledge and assessment of urban and rural water use and risk?
RESOURCES ADD	What are the life cycle and systematic impacts of acid mine water and how can these be managed, mitigated and remediated in process and end of pipe?
RESOURCES ADD	What treatment tech technologies are required for neutralisation, desalination, brine and sludge treatment and what institutional arrangements are needed for each site with aims to produce reusable industrial and drinking water and valuable by-products?

ANNEXURE N: WORKSHOP SWOT-WO

Strengths
Being given work to go over beforehand
Excellent facilitation lead to valuable sessions
Existing knowledge, training and literature already dealt with
Good for coordination of research
If this process is done well then we may have created a national asset here
Mechanistic therefore allowing for a process and measurable outputs
Structured way of process
Submitted questions are strong stimulus for thinking
Synthesis of previous work needed
The opportunity for free expression and opinion was refreshing and welcomed
This is a strong way of reporting on research and understanding the threats or needs but may not necessarily be for horizon scanning
This is not a UCT product but a collective one created by all that participated - from the large scale survey to the workshop
Very enjoyable for participants- brings experts and issues together to discuss, energise, synergise,
We were given a framework to work within

Weaknesses
Experts have struggled to make themselves useful because of constraints- should have been able to describe questions (on horizon)
Group nervous about how the results can be used - will this be a full Water Research Commission strategic process or will it just be for a question list publication
Many experts are not involved/represented in this process
Needed more guidance on criteria
No reasons given as to why the prioritised list was important
Not allowed to think out of the box, not the best use of the expertise that exists here- too regimented
Quality of research questions that went into the process leaves much to be desired
Question structure is very important- lands output to an input- process assumes wise questions
Questions are reflection of stress in system- (people want their problems fixed), this should have been foreseen prior to soliciting questions
Questions not of a horizon scanning nature but this shows what the thinking on the ground was
Questions were limiting/confining- inappropriate/weak, some incorrectly categorised
Questions were more problem solving rather than horizon scanning in nature
Snowball sampling system- participants recommended others within similar fields to complete questionnaire, many volunteers were students (not experts, low-horizon concentration), - Process didn't generate the appropriate spread of questions/focus topics
Spent too much time discussing how to prioritise
System isn't conceived as multi-dimensional system, (time/space- water lifecycle, system hierarchy, various disciplines, research types)- create/reveals holes - this process as is cannot account for this
The question-building/accumulating process generated/resulted in poor questions - may have also been a product of who/how they chose questions

Very constrained by time- should time be spent discussing or in paper-work exercise (question selection/rewording)
Vision is foresight based on insight from hindsight- didn't engage in that process
We have found global issues that the Brown paper did not - is this a fatal flaw of the method?
While this is not potentially horizon scanning it did express what the greater community is concerned with and feeling

Opportunities
An opportunity exists to examine why questions themselves were generally linear or badly worded
Benefit for participants is opportunity for learning, networking- need more time for this to enhance outcomes
Could insights here be used to produce a critical paper of Sutherland's methods?

Threats
If we wanted a Sutherland publication then these may be the wrong people as that method is reductionist and these are deductionists
No indication of what has been missed
No mechanism to ensure horizon scan has been done- likely haven't picked up everything that ought to have been - no check to see what's been missed
Process - survey could have identified challenges rather than questions- this changes the time span (current vs. future problems)
Sutherland approach isn't appropriate for South Africa because stresses are different- develops incorrect results
The tone of all the questions are generally negative as they speak of problems and threats, not necessarily opportunities - is this a signal of the wider audience
What about changing circumstances?

Way Forward
Certain of the elements can be taken to a much higher order and then adapted for a developing country context
Do we need to look at whether our research systems are appropriate or sufficiently established to meet challenges?
If purpose is to produce national framework for water research for next decade in South Africa then process isn't complete - have to engage with Water Research Commission to re-address the strategic objectives that WRC has already set for itself
If want to create Sutherland-type publication, then invited wrong people; if intent was to improve the Sutherland approach for SA/developing countries context, then right people but wrong process
It is one thing to identify research needs and another to put these into practise - how can the results be used for this
Need chance to caucus with like-minded people: in large group, people need a means of finding out who is like-minded
Opportunity to put the right people on project committee - review this committee to improve project
Prior work on the themes (interdisciplinary teams before hand)
Re-engage this group in the future (use the energy that has been created again), after reformulating project to make strong contribution
Understand that this is a positive process overall but that the methods followed may be inappropriate

Would it be possible to give feedback to the original participants to see if they agree with the prioritised list
Write up process each group followed

Outcomes vs. Outputs
Copies of the final list to all
Nervous about who will use the outcomes of this process - WRC priorities are already set - this task is far from over - incomplete
Place these results in the global context
Potential outcome if done right will be a national/world asset
Process must be repeated every few years
Put process that we followed into context - master plan

ANNEXURE O: WORKSHOP CLOSING PLENARY QUOTES

Summary points as captured by rapporteurs (some are direct quotes and others are summary remarks distilled from the closing plenary session)
Workshop users best placed to define goals
Product has to be appropriate for its use - a product of an academic nature is not necessarily useful to research in South Africa
This methodology is not as unique as we think
The process, method and questions will hopefully form part of the end product
I have not felt that I have come here for horizon scanning
Are we producing a national-asset or a multi-authored paper?
Have we captured all horizon questions?
We weren't given a blank space to say what problems are over the horizon
In order to see the horizon we must first have an idea of what lies beyond the horizon
The most valuable thing that has come out for me is the potential for a new methodology
I'm struck by the difference of looking at the horizon from a United Kingdom and from here. It is easier to see the horizon in a clear space. Transferring a method from one place to another will have these challenges.
We have a process were the mechanisms were not analysed
Some of us believe that methodology is not appropriate for a developing country
Questions certainly do represent the different stressors between the third and first world
The group is positive and excited to be re-engaged
Issues of scale of questions and their perspective
Risk of a perception that this process is owned by UCT
Need to distinguish between horizons
Need for a short term follow-up
These results and findings should feed the National Water Resource Strategy as soon as possible
A lot of questions were not well formulated or were already researched
Some research questions were not useable
It is concerning that these very poorly structured questions are from researchers and users on the ground
The calibre of questions tells us a lot about the current situation in South Africa
Are the researchers actually researching to answer these questions from researchers on the ground
We need a breakdown of who gave these questions
There is a 10-15 year gap between research and practise
More than just publication is needed from research
The difference in question scale is highly problematic
Most scientific outputs are thick and simply sit on shelves
Research must be relevant and therefore discovering what the issues on the ground are is important
Research is very poorly communicated and messages and results are not being noticed
How can research better get through to politicians
Outputs will state clearly that this is one method amongst many to plan and prioritise research
Are we are researchers confident that the process has been substantive to form a paper
We have done a lot of work that is not necessarily horizon scanning

It is felt that the outputs may not necessarily need a national asset (for further work) but possibly of a paper
We may have not looked far enough in the first instance to call this horizon scanning
This research is certainly interesting but may need to be adjusted or refined for the future
We operate more in chaos in South Africa as researchers and may need to recognise this
Maybe start with a bigger range of questions, a bigger picture, and see what are the water related issues that can come from here
Let’s look at the bright side, the questions that we received doesn’t reflect the calibre and quality of the participants but it is telling us something important in this country - telling us the preoccupation of minds in this country - even if we take current WRC stagey: is all that research appropriate / relevant in the face of the questions that are here on the ground
Needed to have spent a bit of time with the group getting them in the mind-set of the future, which will lend itself to the mind-set of horizon scanning
This was a rare opportunity for experts to be sitting around a table discussing broader challenges
We also can't prejudge the outcome when the process is only half way through
A great learning process to take forward: democratic and collegial

ANNEXURE P: WORKSHOP SUMMARY REPORT

WATER RESEARCH HORIZON SCANNING WORKSHOP

Hosted by Aqua d'UCT, University of Cape Town and the Water Research Commission

8-9 OCTOBER 2012|THE ALPHEN BOUTIQUE HOTEL|CONSTANTIA|CAPE TOWN

SUMMARY REPORT

26 October 2012

Dear Delegate

We are pleased to offer a brief summary report on the Horizon Scanning workshop along with some supporting material that includes feedback from the participates and the current status of the list of research questions that emerged from the workshop. This summary attempts to identify the most salient issues and concerns, and to consider these in terms of strengths, weaknesses, methods, and opportunities.

We hope that you will find the report of interest and will use the opportunity to offer further feedback (see Way Forward'). Please consider the information and evidence that we have gathered and be prepared to offer constructive criticism. We wish to emphasise that the quality of this product is the result of collaborative and we implore you to assist by taking a lead role in developing the process further.

The report comprises various attachments:

- Final delegate attendance list (please refrain from distributing this list without permission)
- Consolidated feedback: delegate feedback responses; closing plenary comments; and the reflections captured at the final session
- Final workshop results: questions, themes, meta-data, descriptors, and journey.

Method/process summary

The workshop was preceded by an extensive question gathering exercise in which over 600 stakeholders in the water sector were invited to contribute questions which they felt were important in addressing various water resources issues in South Africa. These questions were gathered uses online database survey methods conducted under the auspices of Aqua d'UCT. The intention was always to gather a wide range of questions from across the country. This approach differed from the Sutherland *et al* methodology in that it attempted to canvas a far wider range of responses that was representative of the many pressing and diverse concerns and issues in water resources in South Africa. A total of 1600 questions were collected.

In the pre-workshop phase, these questions were shifted and then sorted into six categories or themes: innovation; change; ecosystems; resources; governance; and data. These themes were identified from the feedback received from delegates one week prior to the workshop.

The model and methods used by Sutherland *et al*., largely informed the participation and structure of the workshop. Similarly, an invitation to participate in the workshop was extended to 40 well known individuals whose reputation and work was widely known in South Africa; delegates were also chosen to represent various sector interests in water resource management; these participants were asked to read two articles from the academic literature on horizon scanning methods and products, and to complete a pre-workshop survey; finally, during the workshop, participants were asked to consider, modify and add to a batch of research questions that had been categorised into the six themes. The intended outcome of the workshop was always to develop a 'list' of research questions that reflected and respected, as far as possible, the process of question gathering in the initial question gathering phase; and the collaborative discussion and consensus seeking activity held at the workshop in which questions were modified, prioritized and identified as potential horizon scanning questions.

Significant positive outcomes and lessons learned

The workshop was acknowledged by many as an energising, interesting collaborative exercise, and there was general agreement that the delegates represented a number of sector interests in the field of water. While there were obvious gaps in the representation, delegates were pleased to able to interact with key leaders in the field. The quality and high level of exchange and interaction was appreciated.

Positive comment was made about the organisation, facilitation and structure of the workshop and many felt that the structured approach to the workshop had made the best use of time in achieving the intended product.

Significant criticisms and challenges

The strongest criticism from delegates is that the workshop was not designed to identify horizon scanning research questions. Delegates felt that they were coerced into responded to the questions that were put on the table. Moreover, delegates felt that it was too difficult to develop horizon scanning questions for a number of reasons: the groups were too diverse; there was insufficient time to consider and develop meaningful questions; and because the process demanded by the facilitators was often mechanistic in order to reach the target of achieving a certain number of questions within a tight timeframe.

There was widespread criticism that the questions that were presented at the workshop were generally of a poor quality. These questions were often poorly constructed; were questions about immediate issues; did not identify new research opportunities; were incorrectly categorised; were often limited to disciplines and fields within the natural sciences; and did not show insight into what might lie on the 'horizon'. Delegates were therefore frustrated by the pressure to modify a large set of questions that appeared to have limited value.

Other section to include in summary report

Points for discussion

In the final plenary session, it became clear that it would not be possible to reach consensus in the selection and prioritization of research questions. It was agreed that the researchers would consider further how to continue with the collaborative process but in a different form (e.g. through a further round of email exchanges); to factor in the limitations of the process and the Sutherland *et al* method; and to consider how the pool of questions that emerged from the workshop could be refined and organised further.

Way forward

We welcome further feedback and would like to remind you that the exercise is sponsored by the Water Research Commission and there is an expectation that the product will be of national interest. Please examine the attachments and respond to particular questions we have identified below, but also to add further comment.

(a) In the spreadsheet tab, JOURNEYS, what do you consider are 'gaps' in the questions that relate to each of these themes? What question(s) could fill these gaps?

(b) What would be the best way forward?

Acknowledgements

Thank-you again for attending the workshop and we look forward to receiving a further response from you. The interdisciplinary expertise and passion for South African water made the event and process extremely productive and challenging. Our special thanks to the student assistants and Inga Jacobs, David Schaub-Jones and Mark Dent for their expertise in facilitating the group discussions.

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