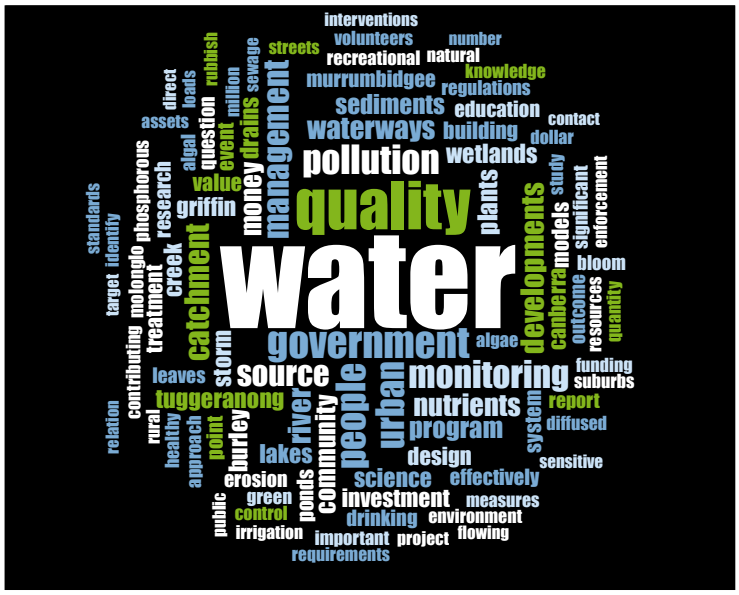

Water Quality Management Issues in the ACT Waterways: from the experts' perspective

A part of the Australian National Internship Program (ANIP A)

Prepared for Helen Oakey, The Executive Director, The Conservation Council, The Australian Capital Territory Region, Canberra

Thukten
U6450326
Environment Management and Development (Masters)
Crawford School of Public Policy
The Australian National University

Word count:5500 excluding titles, tables and figures

Acknowledgement

I would like to extend my heartfelt gratitude to Dr. Daniel Connell and Dr. Laurence Brown from the Australian National University for their valuable inputs and unwavering support throughout the research process. I would also like to thank Helen Oakey, Meg Walker and Eleanor Lawless from the Conservation Council, ACT region, for being a wonderful host. Last but not the least, to all the research participants for sparing their valuable time and providing their insightful inputs for the research.

Table of Contents

List of Figures

List of Tables

Executive Summary

The water quality is an important aspect of water resource as it largely dictates its value for potential uses. However, water quality in water bodies in the ACT continues to deteriorate as illustrated by the frequent closure of the urban lakes due to cyanobacterial bloom. To this date, there has been no, or negligible amount of studies carried out to understand the underlying drivers for the current water quality issues in the ACT. Therefore, this study seeks to provide nuanced understanding of the key underlying drivers for current water quality outcomes in the ACT waterways. The study uses qualitative analysis approach which involved interviewing water experts from a wide range of professional background and analysing the interview results with use of thematic analysis method. The use of inductive research approach provided an opportunity to understand the underlying factors that shapes current water quality issues through wisdom, world view and expertise of the research participants. The findings suggest that the water quality issue in the ACT waterways is predominantly an urban phenomenon. As hypothesized the urban issues are mostly related to cyanobacterial bloom in the urban lakes driven by high nutrient loads from the urban storm water channels. The key issue in dealing with the urban pollutants was found to be lack of adequate understanding on the type and source of pollutants and their behaviour during the storm events. This information gap has been a massive issue in taking proactive measures against the existing water quality issues by the water managers at various management levels. Further, the study indicates that soil erosion from the land developments and leaves and grass clipping could be the major source of the pollutants largely due to either poor compliance from the developers and urban dwellers or due to poor enforcement by the under resourced Environment Protection Agency. Furthermore, the findings suggest effective collaboration between the New South Wales, the Commonwealth and the ACT government is needed to address water quality issues in the long term.

Finally, to address these issues the paper suggests the following recommendations; I) Investment in robust monitoring system, ii) Improving compliance through better enforcement iii) Community engagement, iv) Setting up an official channel for open dialogue between the governments and v) Use of Water sensitive urban design (WSUD), building of wetlands and ponds.

1. Introduction

Human population grew rapidly in urban areas since 1950 at a rate 50% higher than the actual population growth of the world. As a result of this rapid urbanization, more than half of the world's population lives in urban areas and it is projected to grow more than 70% by 2050 (UN Department of Economic and Social Affairs, 2018). This urban population explosion has led to unprecedented challenges among which managing provision for water have been the most crucial one. The rising population not only increases the demand for the water consumption but also, increases the total waste produced. As a result, this will significantly put more pressure on water being a finite resource.

The highest level of societal risk over the next ten years will be from water crises (World Economic Forum, 2019). In addition to it, climate change is projected to significantly reduce the availability of water due to increased frequency of both meteorological and agricultural droughts. It will also have impact on raw water quality due to increased temperature, sediments, nutrient and pollutant loadings during heavy rainfall, reduced dilution of pollutants during droughts and through disruption of treatment facilities during floods (Intergovernmental Panel for Climate Change, Working Group II, 2014). United Nations World Water Assessment Programme (2015) warns of dire consequences in the future for both economic development and security due to poor water management. Therefore, water is increasingly becoming a priority policy area for many national governments and international organizations (Cosgrove and Loucks, 2015).

The Australian Capital Territory (ACT) is currently experiencing a residential population growth of 1.7% which is above the national residential growth rate of 1.6% per annum. In 50 years, the population of the ACT is expected to grow over 700,000 against the current population of 413,800 (the ACT Government, 2019). As a result, the current sustainable diversion limit agreed under Murray Darling Basin (MBD) Plan agreement won't be enough to meet its demand under the medium to high population growth scenarios (Water Service Association of Australia, 2010). Furthermore, CSIRO (2010) reported that south-eastern MDB (including Canberra) experienced a 19% reduction in total rainfall intensity and

significant reduction in run off into reservoir up to 44%; a similar pattern is anticipated in the future. Therefore, the pressure from rapid population growth coupled with the impacts of climate change will have dire implications for water resources management in the ACT.

In the light of these challenges, the *Water Act 2007* was legislated to drive policy reforms such as the National Water Initiative to ensure water resources in Australia is managed sustainably, efficiently and productively. Almost all water policies, strategies and plans, were devised initially to address issues of droughts, and as a result, attention to issues central to water quality have not received the same degree of importance. However, there are several legal frameworks (see Appendix 6.2) that have direct implications on water quality outcomes and under these acts several strategies are rolled out such as the *National Water Quality Management Strategy 2018* which is aimed at maintaining water quality essential for the health and wellbeing of all Australians.

Despite the presence of strong legal and regulatory frameworks for water quality management, water quality in Australia, including the ACT, continues to deteriorate. According to the Catchment Health Indicator Program (CHIP) (2018) by the Water Watch more than half of the sampled sites in the ACT were graded either fair or poor on salinity, oxygen content and biological value. Furthermore, there are several reports that claim the cyanobacteria (blue-green algal) is at extremely high concentrations across various recreational water bodies in the ACT (Raff, 2012; Faulkner et al, 2012); other media reports further corroborate this claim (Lievre, 2018; Morgan, 2019). This has led to the closure and restriction of the use of several waterways for recreation, especially during the summer months. It illustrates the issue of water quality and its impact particularly on recreational value of the various water bodies in the ACT. Therefore, it is important to understand the underlying causes that shape the current water quality outcomes in the ACT waterways to inform policy and practices. Having said that, there is no, or little research done to understand the underlying factors that drive current water quality outcomes in the ACT.

To address this gap, this study seeks to understand the underlying cause of water quality issues in the ACT waterways using the qualitative research methods. In doing so, the study aims to identify the existing challenges and opportunities to address water quality issues. Finally, the study aims to inform policy and decision choices for improved water quality outcomes in the ACT region.

2. Research Methodology

Qualitative research methods are widely acknowledged and used in the scientific community (Rosenthal, 2016). They seek to describe the phenomena of our interest based on the perspective of informants and discovers multiple realities which help to develop a holistic understanding of the phenomena within a given context (Glickman et al, 2007).

The qualitative data gathered from face to face interactions and field observations can help us gain deeper understandings of the problem than by simply analysing the data on a large scale (Malakolunthu, 2007). The qualitative research provides information about the issue from the "human" side. As a result, it is capable of understanding the skills, wisdoms and perspectives that underpin the phenomena under the investigation (Mac et al, 2005).

This study uses qualitative methods to probe deeper into current water quality outcomes in ACT by interviewing water experts from: the field of academia, community catchment groups, business groups and officials from government agencies. The interviews were based on open ended questions which involved asking participants about broad topics on: water quality issues, measures that are and can be adopted to address these issues and difficulties implementing these methods (see appendix 6.3). These questions were asked to encourage participants to engage in the discussion, not to guide the discussion.

2.1 Sampling Technique and Size

The interviewees were selected with the combination of purposive sampling and the snowball sampling technique. The purposive sampling is useful to gain a greater depth of information from a smaller number of carefully selected cases (Teddlie and Yu, 2007). It was selected based on its ability to provide an in-depth understanding of the research query in a short span of time. Additionally, snowball sampling is a useful technique when the informants are hard to reach (Barratt et al., 2015) and therefore, was chosen to improve the accessibility of the target population.

In total, nine informants were selected using the combination of the purposive and snowballing techniques. It should be noted that unlike probability sampling, which depends on number of samples for the representation, purposive sampling primarily relies on the technique of saturation i.e. collecting samples to a point where collecting new samples does not uncover new themes or provides new substantive information (van Rijnsoever, 2017).

After nine interview sessions neither new themes emerged, nor additional information was gained.

2.2 Participant Characteristics

The research informants were residents of the ACT and belonged to a diverse professional background. In terms of the sample composition, there were three female and seven males who participated in this study. Out of the nine interviewees, three interviewees have an academic background (i.e. The Australian National University and University of Canberra) with vast experience and expertise on water quality; two participants were from community catchment groups (i.e. Southern ACT and Northern ACT Community Catchment groups) and possess first-hand experience of the field problems, especially from the catchment management perspective; two participants were from a business entity; and finally, two experts were from government agencies (i.e. National Capital Authority (NCA) is responsible for managing the lake Burley Griffin and Environment Planning and Sustainable Development Directorate (EPSSDD) is responsible for managing all other ACT waterbodies.

2.3 Data collection and Ethics

Ethical clearance was obtained before the interviews via protocol number 2019/673 from the Human Ethics Staffs, Research Ethics & Integrity, Research Services Division, The Australian National University. The interviews were conducted from mid-September 2019 to mid-October 2019 by the researcher himself and therefore, maintaining the consistency throughout the sampling process. All interviewees have been kept anonymous and all audio data recordings had no access to any party other than the researcher himself. Each interview session lasted between 40 to 60 minutes at a venue and time chosen by the interviewees themselves. The interview process also included obtaining and managing informed consent from the interview participants. The responses from the interviews were audio-recorded and additional field notes were taken. Later, the responses from the interview data were transcribed manually using the verbatim transcription which involved transcribing everything the participants said exactly into the text format.

2.4 Data Analysis Methods

The study conducted thematic analysis to explore responses from the interview respondents. Thematic analyses identify, analyse, and report patterns or themes using the collected qualitative data (Braun and Clarke, 2006). There are several ways to conduct thematic

analysis (e.g. Boyatzis, 1998; Ibrahim, 2012), however this study specifically chose Braun and Clarke's (2006) framework for its clarity and reproducibility. They mentioned two levels of themes; first, semantic which refers to those themes identified with use of the surface meanings of words and second, latent which refers to themes identified using the underlying meanings, assumptions and concepts related to the words. This study identifies and analyses the first level semantic themes using the following six steps process outlined by the Braun and Clarke (2006); 1) familiarising with data, 2) generating initial codes, 3) searching for themes, 4) reviewing of themes, 5) defining and naming themes and 6) production of the themes (see Appendix 6.1. for the detailed procedure undertaken to analyse the themes)

3. Results and Discussion

This section reports on the results collected using the thematic and descriptive analyses. Using codes and reference counts (see Appendix 6.1) to enhance dependability and adequacy of the research approach, the findings are defined into two overarching themes: 1) the water quality issues as an urban phenomenon and 2) the drivers underpinning the water quality resources or urban and rural areas. Furthermore, under the overarching themes there are tiers of themes and subthemes which will be discussed in the following sub sections. It should be noted that quantifying references and the number of codes does not provide numerical generalization, but it is used to observe the patterns in the results.

3.1 The water quality issue is predominantly an urban issue

There was a general perception amongst the participants that water quality management in the ACT waterways was an important subject given its value for the human population for providing value for domestic uses and for its ecological, cultural and recreational services.

"*I think water quality is definitely an issue… I think the quality of water is important and the quality of water largely dictates its value and also, its potential use*" (A8, 00:01:17).

Thinking about the scale of the current issues in the ACT waterways, 100% of the respondents considered it as predominantly an urban problem while only 44% confirmed that there have been rural issues as well. There was a wide consensus across the respondents that the water quality issues in urban areas are largely associated with issue of cyanobacterial bloom in the urban lakes.

"I am biased, I have spent 40 years working in Cyanobacteria toxicity… my view is that recreational lakes should be fit to swim in… The actual situation we have is that every summer we have to close the lake for the recreation just when everybody wants to go to swimming and bathing, kayaking and they can't! because the lake is closed, and it is not safe" (A9,00:40:26).

3.2. The themes underpinning the rural and urban water quality outcomes

Seven major themes impacting water quality outcomes were identified (Table 1; Figure 1). The issues around storm water management in urban areas was the most critical issue where 89% of total respondents stated this over hundred times. We could observe a significant difference in the number of references made for this theme in relation to other themes; indicating that it is the key issue from the participants' perspective. The second most prominent theme was governance and collaboration where 63% of the total participants asserted as many as 25 times. This was followed by rural water management, drinking water management (water utility management), sewage management and cultural values of water. Each of these themes will be explored individually to provide a nuanced understanding of the water quality management issues in the ACT.

Table 1. Major themes underpinning water quality outcomes in the ACT waterways

Major themes	***Respondent size (n)***	***No. of references made***
Storm Water Management (see section 3.2.1)	8	110
Governance and Collaboration (see section 3.2.2)	5	25
Drinking Water Management (see section 3.2.3)	3	11
Rural water management (see section 3.2.4)	4	10
Sewage system (see section 3.2.5)	2	6
Cultural values of water (see section 3.2.6)	1	5

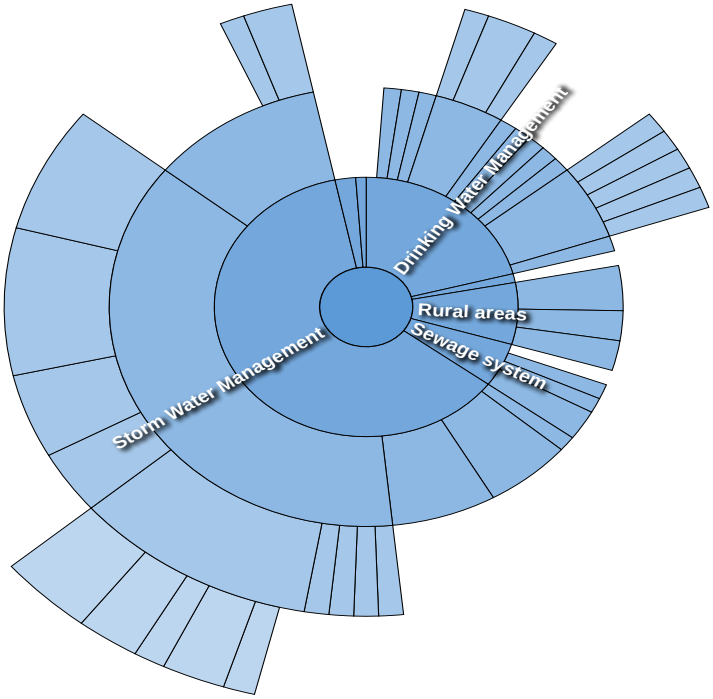

Figure 1 . *Sunbursts (NVivo 12 output, the drivers for the water quality and the size of pie represents the degree of assertion by the interviewees)*

3.2.1 Storm Water Management

Under the storm water management theme, many sub themes were found (Table 2). Pollution from the urban off was stressed most by almost 90% of the participants (see Table 2), which was closely followed by the issue of science and monitoring where 78% respondents made 30 references to the subject.

Furthermore, the issue of compliance and enforcement of the regulations had also notable references from at least 67% of the total interviewees. The other drivers identified were the impacts of climate change and population growth on the quality of the waterways. These subthemes are explored individually under the following subsection.

Table 2. *Themes and Sub themes associated with Storm Water Management Issues*

Themes and Sub themes	***Respondent size***	***No. of references made***
1. Urban pollution (see 3.2.1.1)	8	51
1.1 Recreational fishing	1	3
1.2 Detergents	3	4
1.3 Faeces	4	4
1.4 Hard Rubbish	1	5
1.5 High nutrient (Phosphorous and Nitrates)	7	8
1.6 Leaves and Grass clippings	6	9
1.7 Metal pollution	1	1
1.8. Soil erosion	4	15
1.8.1. Dirt tracks	1	2
1.8.2. Farmland	2	2
1.8.3 Private gardens	2	3
2. Science and monitoring (see 3.2.1.2)	7	30
2.1 issue with the current data	2	10
2.2 Issue with current paradigm	1	3
3. Compliance and enforcement (see 3.2.1.3)	6	21
4. Design (see 3.2.1.4)	5	6
5. Climate change and droughts (see 3.2.1.5)	1	2

3.2.1.1 POLLUTION FROM THE URBAN RUNOFF

The participants identified a number of urban pollutants such as soil sediments from the soil erosion, leaf litters and grass clippings, detergents, animal faeces, fertilizers from the lawns, yabby traps and fishhooks from the recreational fishing, hard rubbish and metal pollution (see Table 2). Most of the pollutants identified by the participants were diffuse source pollution (non-point source) (see Appendix for the definition) wherein the participants associated it directly with the cyanobacterial bloom in the lakes.

" *We are wrestling with the diffuse source in the ACT, we understand very well that the urban area produces a lot of diffuse source pollution, we definitely see the impacts that pollution on our Waterways, particularly urban areas where flow goes into large lakes, storm water runs*

into lakes, for us it is Lake Tuggeranong, Lake Ginninderra and Lake Burley Griffin, three major lakes in the ACT, they all suffer from time to time poor water quality, we know it is very much driven by the urban runoff to a large extent" (A8, 00:11:05).

"*I think the main problem, in my opinion is the storm water that it receives, the runoffs… the level of nitrates and phosphates, especially after rain it goes very high*" (A2, 00:05:37).

The sedimentation through soil erosion was stressed the most by the participants (see Table 2 and Figure 2). Participants claimed that soil erosion not only caused turbidity in the waterways but drove cyanobacterial bloom in the lakes to a large extent (blue green algae bloom) by releasing phosphorous which are bound to clay particles.

Participants identified several sources of erosion such as erosion from new real estate developments, private gardens, peri-urban farms, dirt tracks and land developments. Soil erosion from the real estate development was considered the most problematic by the research participants.

"*Some of the ponds in Giralang, they used to be bit deeper. I have also seen that in Yerrabi ponds, Gungahlin ponds and Giralang ponds, they used to be deeper but with the developments in Gungahlin and Crace, we have seen significant siltation in these ponds…the water levels are much lower now… The water gets warmer and not many creatures survive"* (A2, 00:10:21).

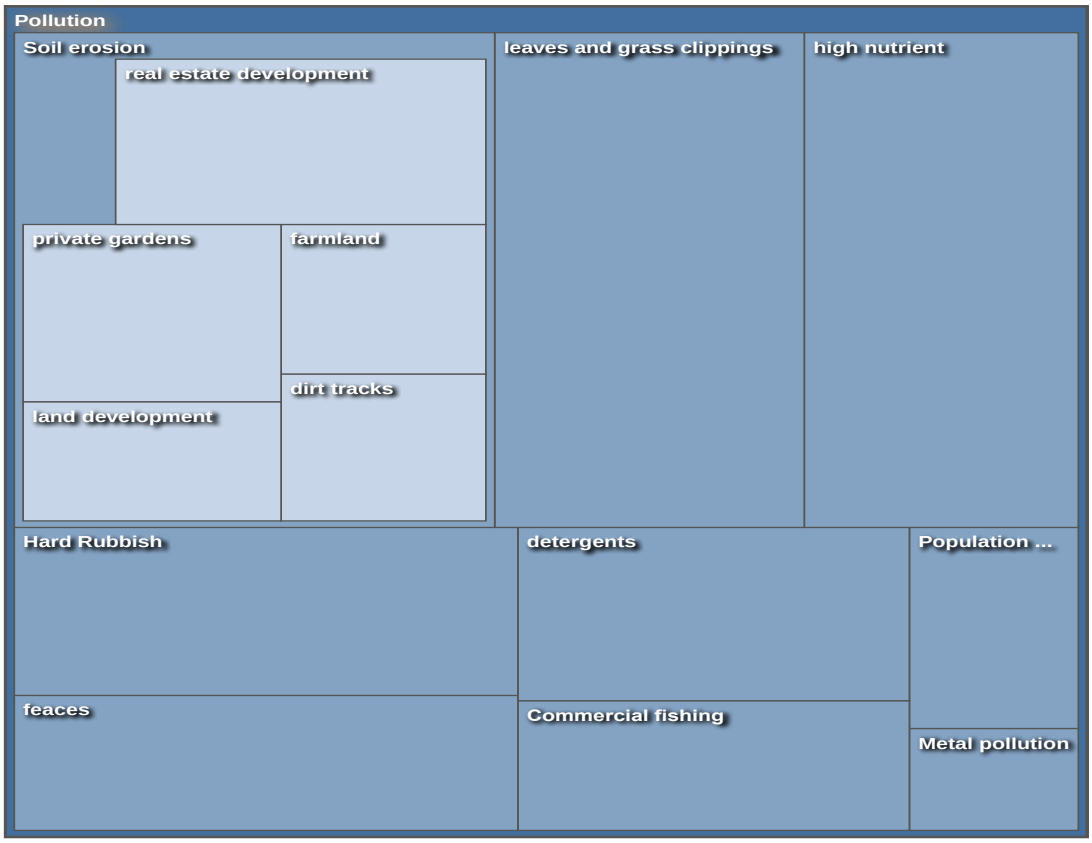

Figure 2 : *Tree map (NVivo 12 output, demonstrating various forms of urban runoff pollution arranged in hierarchy depending on the number coding received by each pollutant)*

Seventy-eight percent of the respondent highly suspected that organic wastes such leaf litters and grass clippings from the private gardens caused high nutrient loading in the runoffs. It is the second most cited being pollutants beside soil erosion loads (see Figure 2).

"*I have seen people putting leaves down the storm water drains deliberately [00:47:29]. We are actually using blower to blow the leaves down the storm water drains including Municipal workers*" (A9, 00:47:41).

This finding corroborates the findings from Schirmer and Mylek (2018) where they reported that the most common materials in storm water drains were soil/dirt, leaves, grass clippings, detergent, and fertilizer and oil or paints to a lesser degree.

However, 33% of the total participants claimed that there could be point sources in urban areas such as fertilizers from the playing fields and private gardens, detergent used in shopping centres that contributes to high amount of reactive dissolved phosphorous as observed in the lake Tuggeranong.

"*With work we have been doing in the Lake Tuggeranong, we have seen evidence associated with shopping centres, we are calling "Intermittent contamination events". It is when somebody has obviously dumped something into the storm water networks that has contributed a lot of nutrients*" (A1, 00:11:57).

The research participants also acknowledged that it is relatively cheaper and conceptually easier to monitor and control the point source pollution (see appendix for the definition) as opposed to diffuse source pollution.

"*If they are point sources, for me conceptually they are easy to deal with it, I would be absolutely delighted if they are point sources and we can identify them because they are easy to fix… you are dealing with few individuals but not with the whole community*" (A8, 00:32:10)

3.2.1.2 SCIENCE AND MONITORING

Seventy-eight percent of the total participants reported that there is significant knowledge gap in terms of understanding the sources for the different pollutants and levels of these pollutants entering into the urban waterways.

"*We have ideas but again if we don't have the data or what's coming in on the streets, we do not know where it's coming from. So, we can infer based on our understanding what the exports rate would be under different land uses, where the dominant source might be but there is uncertainty in that*" (A4, 00:08:34).

Whilst most of the participants acknowledged that the existing baseflow monitoring systems undertaken by the WaterWatch volunteers (see CHIP, 2019) provides some understanding to the situation, it is not clear as to what the sources and the variable level of pollutants are entering into the lakes, especially during the storm events.

"*We have been monitoring for a long time… the monitoring may be cost effective, but it does not necessarily tell us what we need to know. So, it is a lot of base flow monitoring, so, it is usually a "grab sampling" where somebody will go out there in a nice sunny day, grab a water sample and take it back to the lab and analyse it… but the problem with that is that the water quality you see during base flow conditions when it's not raining, it's usually quite*

good, pollutants move during storm events and so unless you are out there sampling the water… during the following event, you're not actually getting an understanding of what's happening in the waterway" (A8, 00:12:00).

According to some participants, the existing knowledge gap has been particularly problematic in targeting interventions to address the issue of water quality when there are many uncertainties around the effectiveness and efficiency of those interventions. For example, the participants had doubts regarding the effectiveness of wetlands and sedimentation ponds developed under the ACT healthy waterways project, particularly in addressing the underlying drivers for water quality issues.

"*Yes, while the issues do exist and public generally is accepting that there is an issue, that is not so much in our control without having a body of knowledge to treat the problem at the source*" (A6, 00:31:41).

"*Well, there was some analysis about whether it will the trap pollution but it will only ever trap a portion of the pollution and my concern is that it's about trapping pollution halfway along the creek system it's not about stopping the pollution, getting mobilised in the first place and I think that's the most important question the government is ignoring, it is how do you stop pollution being mobilised*" (A2, 00:04:37).

However, many participants claimed building wetlands and ponds is an effective measure to trap pollutants with additional ecological co-benefits.

"*When I was a kid here, we didn't see Currawongs, you only saw them in the winters, they only came through in winters in flocks, so and then go back up to the mountains, now they are all here… we find crakes that lives around these areas… if they are losing habitat in other parts of their wild, they will move into these wetlands and in a way provides a function*" (A5, 00:56:06)

Twenty-two percent of the participants revealed that the current paradigm in addressing most water quality issues is based on the thinking that urban water quality issues are driven by the diffused pollution. On the contrary, they reported that the point source pollutions in the urban areas is likely to be the major source too. It validates the issue of existing knowledge gaps

around understanding the sources and levels at which pollutants are entering into the waterways in storm events.

"*And there is something interesting about the data, we are seeing that the dissolved reactive component of phosphorus is very high, it's about 50% of the total phosphorus……it is quite unusual, and I think what it suggests to me is that there is a unique, possibly something of a point source of pollution within the Tuggeranong catchment that might be contributing a very large percentage of the pollution entering that lake*" (A8, 00:29:23)

3.2.1.3 COMPLIANCE AND ENFORCEMENT OF THE REGULATIONS

The issue of compliance and enforcement of the regulations (rules and legislation with implications on water quality outcomes in the ACT waterways (see Appendix 6.2)), is one of the most cited and stressed themes in the interviews. 67% of the total participants thought the issue is either due to poor compliances such as by urban dwellers, builders and business owners, or the poor enforcement by the Environment Protection Authority (EPA).

"*We brought in independent experts, we talk to others around the areas, we know that you can have the same builder building in the ACT and building across the border in New South Wales, in New South Wales he keeps his block really clean and he manages his sedimentation control, in the ACT he doesn't*" (A8, 00:55:17).

"*They have never prosecuted anyone ever, we have got legislation in the ACT that covers every eventuality, but the amount of actual compliance is not very good, and enforcement is negligible*" (A9, 00:52:23).

The poor enforcement of the regulations was attributed to the fact that the EPA was significantly under resourced.

"*I think we openly acknowledge that the EPA is under resourced and the question is why they are under resourced? That is a political question*" (A8, 00:58:20).

3.2.1.4 DESIGN

More than half of the participants pointed out that the water quality issues in the lakes is driven by the design of the storm water networks. These were initially designed to quickly drain the runoffs from the suburbs into the lakes to maintain a good water level.

"*The stream network is a concrete line channel designed to move runoffs through the system fast and get them to the lakes and ponds around the place*" (A1, 00:08:04)

"*The runoff goes into a large end of pipe system, into the lakes which now has both values for community, amenity and swimming as well as managing stormwater, with those two values are not compatible. Fundamentally, they are not compatible, so, we have got a real challenge there*" (A8, 00:34:35).

There was a wide acceptance that retrofitting the existing storm water drains with water sensitive urban design will be costly and disruptive.

"*Retrofitting water sensitive urban design infrastructure into the urban environment is a difficult thing to do, expensive thing to do… you look at the stormwater drain… carry large amounts of IT infrastructures, utilities, power and sewer… you are very quickly running into issue where you are only going to intercept the all flow of the utilities and moving utilities is incredibly expensive exercise, so, that becomes a major logistical constraint*"(A8, 00:22:19).

3.2.1.5 CLIMATE CHANGE

There were only few participants who were concerned about the impacts of climate change on the water quality outcomes, most of which were through indirect effect on water quality such as through prolonged droughts, increased risk of fire and higher intensity of rain.

"*The biggest thing is the drought condition. The sustained level of dryness will lose that ground cover…. then we get this intense rainfall periods that causes massive erosion*" (A5, 00:08:05).

3.2.1 GOVERNANCE AND COLLABORATION

Fifty percent of the participants pointed out that the water quality issues in the ACT waterways are associated with the governance and collaboration between NSW, the Commonwealth and the ACT government. It has been stressed over 25 times and is the most

critical issue after the issue related to storm water management. The participants claimed that high nutrient sewage discharge from the Queanbeyan Sewage Treatment Plant (NSW) and discharge from the urban suburbs in the ACT impacts the water quality of Lake Burley Griffin. Addressing the issue of water quality in the ACT, particularly in Lake Burley Griffin, would require effective coordination between three governments. There is a quasi-government body, ACT and Region Catchment Management Coordination Group, that serve as a coordination group to facilitate dialogue between the three governments, but it is not an open government channel.

"*The Queanbeyan sewage plant is an ancient treatment plant built originally around 1930s, it is absolutely on its last legs and it would fail anytime*" (A9, 00:13:25).

"*Queanbeyan Palerang council say that it is the ACT and National Capital Authority that benefits from the better quality of water in the Lake Burley Griffin. So, they should pay to the additional supplementary costs of the new better-quality sewage treatment plant, the ACT won't give any money, the NCA would not give any Money, it is a shocker*" (A9, 00:17:08).

"*There exists a certain communication path which is informal and very much reliant on people within the organisations being open and transparent with each other, there is nothing formal in place. Perhaps, a good measure is to have a group to work between different organisation to come to a centralised strategy*" (A6, 00:33:35)

3.2.2 DRINKING WATER MANAGEMENT

Drinking water quality is managed by ICON water in Canberra. The participants pointed out several minor issues around catchment management such as soil erosion, pollutants from the agricultural land uses and pathogenic contamination from the grazing area.

"*The water supply from the Murrumbidgee contains both bacterial pathogens and viral pathogens and protozoal farming due to upstream farming, bacterial pathogens such as E. coli forms and protozoal pathogens like Guardia and Cryptosporidium, and there are always viral pathogens*" (A9, 00:03:01).

However, most participants had strong confidence in the tap water quality. Perhaps, it is because the standards for drinking water is strictly monitored and regulated.

"*Canberra drinking water by law has to be of good quality… So, there is no issue with the quality of the tap water*" (A9, 00:19:49).

3.2.3 RURAL WATER MANAGEMENT

The participants identified soil erosion in the rural areas as a major issue. They reported that the soil erosion is caused by land uses such as agricultural stock grazing by the hard-hoofed animals and past land clearing practices which have made soil in the rural areas susceptible to splash erosion. Only few participants reported on the issue of pathogenic contamination from the animal faeces in the rural areas.

"*In rural areas, erosion from the land uses is the significant risk in the couple of our catchment here… causes of that are deforestation, meant that the clearing that has happened before and after the grazing*" (A5, 00:07:45).

3.2.5 SEWAGE ISSUE

There are two sewage treatment plants: 1) Queanbeyan Sewage Treatment Plant (QSTP) which drains into Molonglo rivers and 2) discharge from Lower Molonglo Water Quality Control Centre (LMWQCC) which drains into Lower Molonglo. These are two of the major point source that drain into the ACT waterways. Generally, the participants did not highlight the issue of sewage discharge from LMWQCC on the existing water quality outcomes. The participants admitted that it is relatively easy to monitor discharge from LMWQCC as compared to the diffused source. However, there were issues raised with regards to unregulated discharge of Endocrine Disrupting Chemicals from LMWQCC into lower Molonglo. The major issue was around QSTP which the participants claimed has historically contributed high amounts of nutrients. Addressing the issue would warrant collaboration between New South Wales government.

3.2.6 CULTURAL CONSIDERATION

Only one participant in the whole course of the interviews touched upon the importance of factoring cultural values in water quality management. It is an indication of a degree of consideration given to cultural values associated with the waterways while managing these waterways.

"*Every now and then something comes up that relates to Aboriginal cultures with respect to Murrumbidgee… along that bit of Murrumbidgee and the Ginninderra creek and they found men's' initiation sites and women's' sites, and number camp sites all of which are now mapped … There are whole lot of proposals… One was to build a hotel or convention centre*

right over the top of the Ginninderra fall, a magnificent site for a convention centre, ha! Of course! It will bloat out the whole lot of aboriginal heritage" (A9, 00:24:26).

4. Conclusion and Recommendation

The study suggests that the water quality issue in the ACT waterways is an urban phenomenon. Most urban water quality issues are related to Cyanobacterial blooms driven by the high nutrient inflows received through storm water drain networks. The key issue with managing urban runoff pollution is the inadequate understandings around the type and source of the pollutions, and levels at which different pollutions are entering into the lakes especially in terms of diffuse pollution.

The knowledge gap has been particularly problematic for making strategic interventions to address the issue of water quality; there are clear uncertainties around whether the measures taken to address the water quality issues is a reactive approach or proactive approach. This research further indicates that the issue of high nutrient urban runoff could be associated with soil erosion from the new suburb developments and private gardens, followed by leaves and grass clippings from the urban areas either due to poor compliance by the real estate developers and urban dwellers or due to poor enforcement by the under-resourced EPA.

Finally, the water quality management issue is not confined within the boundaries of the ACT. Therefore, managing water quality issues requires longer term collaboration and effective coordination between Queanbeyan Palerang Council (the NSW), NCA (the federal government) and the ACT government. Overall, urban water quality is a product of various themes that require further research, regulation, and collaboration between various stakeholders.

Considering the issues mentioned above, the paper suggests the following recommendation;

i) Investment in robust monitoring system; There is an urgent need to improve the current monitoring system. Current monitoring does not provide an in-depth understanding as to how pollutants behave in relation to the particular geography of the waterways, land uses and storm events. The report calls for a need for rigorous event-based monitoring systems if the government wants to take a proactive measure in addressing the water quality issue. However, the report does not dismiss the importance of the current longitudinal based flow monitoring system currently implemented by the Waterwatch.

ii) Improving compliance through better enforcement; Strengthening the capacity of the EPA would provide the resources to monitor the compliance of the regulations and requirements by the real estate developers and urban dwellers from being affluent.

iii) Community engagement; Most of the pollutions from the urban areas are due to affluent behaviour of the urban dwellers. Engaging with community through citizen science, engaging with kids in the schools and establishing targeted educational programs for the users of lakes and creeks would help address the issue of urban affluence in the long run.

iv) Setting up an official channel for open dialogue between the governments; water quality issues in the ACT and Lake Burley Griffin can be only addressed through effective collaboration between the ACT, the NSW and the NCA. This would require a formal channel, which would enable an open dialogue between the governments in order to identify a common goal and centralized strategy.

v) Water sensitive urban design (WSUD), wetlands and ponds; it is important to invest in wetlands and ponds as an adaptive approach to tackle the issue of the water quality at hand because the government cannot wait until the robust monitoring has an answer to the problem. WSUD should be made requirement in the new suburban developments and the compliance should be strictly monitored because it is expensive for the government to retrofit later.

5. References

Barratt, M.J., Ferris, J.A., Lenton, S., 2015. Hidden Populations, Online Purposive Sampling, and External Validity: Taking off the Blindfold. Field Methods 27, 3–21. https://doi.org/10.1177/1525822X14526838

Boyatzis, R.E., 1998. Transforming qualitative information: Thematic analysis and code development, Transforming qualitative information: Thematic analysis and code development. Sage Publications, Inc, Thousand Oaks, CA, US.

Braun, V., Clarke, V., 2006. Using thematic analysis in psychology. Qualitative Research in Psychology 3, 77–101. https://doi.org/10.1191/1478088706qp063oa'

Cosgrove, W.J., Loucks, D.P., 2015. Water management: Current and future challenges and research directions. Water Resources Research 51, 4823–4839. https://doi.org/10.1002/2014WR016869

CSIRO, 2010. Climate variability and change in south-eastern Australia: A synthesis of findings from Phase 1 of the South Eastern Australian Climate Initiative (SEACI). http://www.seaci.org/publications/documents/SEACI-1%20Reports/Phase1_SynthesisReport.pdf

Estimated Resident Population — March Quarter 2019 (No. ABS Cat. No. 3101.0), 2019. Chief Minister, Treasury and Economic Development, the ACT government

Faulkner, I., Farrant, A., Woollard, J., 2013. Lake Burley Griffin water quality: Health standards, protocols for lake closure and outcomes, in: Investigation into the State of the Water Courses and Catchments for Lake Burley Griffin. ACT Commissioner for Sustainability & Environment, pp. 1–14. https://www.envcomm.act.gov.au/__data/assets/pdf_file/0009/590859/Lake_Burley_Griffin_water_quality_Health_standards,_protocols_for_lake_closure.pdf

Glickman, C.D., Ross-Gordon, J., Gordon, S., 2001. Supervision and Instructional Leadership: A Developmental Approach. Sixth Edition. Allyn & Bacon/Longman Publishing, a Pearson Education Company, 1760 Gould Street, Needham Heights, MA 02494.

Ibrahim, M., 2012. Thematic analysis: a critical review of its process and evaluation 1, 9.

IPCC, 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University.Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp. https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-PartA_FINAL.pdf

Le Lievre, K., 2018. Farmers losing sheep to blue-green algae plead for healthy water. The Sydney Morning Herald. https://www.smh.com.au/national/farmers-losing-sheep-to-blue-green-algae-plead-for-healthy-water-20180725-p4ztiv.html

Mack, N., Woondsong, C., MacQueen, K.M., Guest, G., Namey, E., 2005. Qualitative research methods: a data collector's field guide. FLI USAID, North Carolina. https://www.fhi360.org/sites/default/files/media/documents/Qualitative%20Research%20Methods%20-%20A%20Data%20Collector's%20Field%20Guide.pdf

Malakolunthu, S.,2007. Teacher learning in Malaysia: problems and possibilities of reform. Kula Lumpur: University of Malaya Press.

Morgan, C., 2019. "Extreme" blue-green algae blooms dangerous for asthmatics: ecologist. The Canberra Times. https://www.canberratimes.com.au/story/5992930/extreme-blue-green-algae-blooms-dangerous-for-asthmatics-ecologist/

Raff, M., 2012. Lake Burley Griffin Governance Issues Relating to Water Quality and Integrated Catchment Management, in: Investigation into the State of the Water Courses and Catchments for Lake Burley Griffin. ACT Commissioner for Sustainability & Environment, p. 34. https://www.envcomm.act.gov.au/__data/assets/pdf_file/0008/590858/Lake_Burley_Griffin_governance_issues_relating_to_water_quality_and_integrated_catchment_management.pdf

Rosenthal, M., 2016. Qualitative research methods: Why, when, and how to conduct interviews and focus groups in pharmacy research. Currents in Pharmacy Teaching and Learning 8, 509–516. https://doi.org/10.1016/j.cptl.2016.03.021

Schirmer, J., Mylek, M., Dyer, F., 2018. Water quality and the community: views, values and actions of ACT residents, 2015. https://doi.org/10.26193/XMYIFQ

Teddlie, C., Yu, F., 2007. Mixed Methods Sampling: A Typology With Examples. Journal of Mixed Methods Research 1, 77–100. https://doi.org/10.1177/1558689806292430

The ACT Government, 2019. ACT Population Projection 2018 to 2058. Chief Minister, Treasury and Economic Development Directorate. https://apps.treasury.act.gov.au/__data/assets/pdf_file/0005/1305581/ACT-Population-Projections-Paper-FINAL.pdf

United Nations World Water Assessment Programme, 2015. The United Nations World Water Development Report 2015: Water for a Sustainable World. Paris, UNESCO. https://sustainabledevelopment.un.org/content/documents/1711Water%20for%20a%20Sustainable%20World.pdf

UN Department of Economic and Social Affairs, 2018. *The Revision of World Urbanization Prospects*, United Nation, New York.. https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf

Water Service Association of Australia, 2010. Implications of population growth in Australia on urban water resources. https://www.clearwatervic.com.au/user-data/resource-files/201007-WSAA-Occasional-Paper-25%5B1%5D.pdf

WaterWatch, Upper Murrumbidgee, 2018. *The Catchment Health Indicator Program (CHIP) Report Card,* ACT. http://www.act.waterwatch.org.au/Files/CHIP/CHIP%202018_FINAL_low%20res.pdf

World Economic Forum, 2019. The Global Risks Report 14th Edition; insight report. http://www3.weforum.org/docs/WEF_Global_Risks_Report_2019.pdf

van Rijnsoever, F.J., 2017. (I Can't Get No) Saturation: A simulation and guidelines for sample sizes in qualitative research. PLoS ONE 12, e0181689. https://doi.org/10.1371/journal.pone.0181689

6. Appendix

6.1. Thematic Analysis Method

6.1.1 FAMILIARISING WITH DATA: Both during the interview and transcription processes, significant familiarisation with the data was achieved. However, the interview transcripts were further reviewed and familiarised by reading the transcripts word by word to get a general idea of the data.

6.1.2 GENERATING INITIAL CODES: Codes refers to the labels that assign symbolic meaning to the descriptive or inferential information compiled during a study and coding refers to process identifying codes that succinctly summarises the raw data (Miles et al., 2014). Several methods of coding were used in the study; first, during the interview and transcription processes several themes emerged which were used as provisional themes. Second, line by line coding of transcripts were carried out and finally, NVIVO 12 qualitative analytical software were used to explore the data using "Word Frequency Search" and "Text Query Search" to identify additional themes. The software was also used to generate coding book which was further reviewed by the course advisor (see appendix).

6.1.3 SEARCHING FOR THEMES: Several codes were grouped together under one umbrella nodes using NVIVO 12 to generate themes. Furthermore, several umbrella nodes (sub-themes) were grouped into one major theme creating a systematic hierarchy of codes, nodes, umbrella nodes (sub themes) and major themes. The process of identifying themes were done inductively by familiarising with data, coding and searching for themes in an iterative process. This was done until no new codes and themes were generated.

6.1.4 REVIEWING OF THEMES: Themes identified in previous processes were reviewed again and those themes which had no substantial evidence were collated with the themes that overarched, and those themes that lacked evidences were deleted. These processes were all done using NVIVO 12.

6.1.5 DEFINING AND NAMING THEMES: The themes were further defined and refined ensuring that it succinctly captures the essence of the data or addresses the overall objective of the study and most importantly, ensuring the themes are accompanied with substantial amount of evidence and narratives.

6.1.6 PRODUCTION OF THE REPORT: The final stage involved culminating all the process into one technical report which was reviewed by several peers before the final reports was published

6.2 Legislations and Regulations with water quality implications *(adopted from various sources)*

Legislation	Key water-related responsibilities
Water Resources Act 2007 and related instruments	*The governing legislation for the sustainable management and uses of water resources within the ACT. Water access rights, water sharing, environmental flow provisions, water licensing requirements, resource management and monitoring responsibilities; and sets penalties for improper actions.*
Environment Protection Act 1997	*Regulates development, industry for water quality purposes*
Environmental Protection Regulations 2005	*Water quality standards (read in conjunction with the Territory Plan)*
Environmental Flow Guidelines 2013	*Outlines environmental flow requirements*
Utilities Act 2000	*Provides for the ICRC to issue licences and determine industry codes, and is the statutory basis for the imposition of temporary water restrictions and the permanent water conservation measures scheme*
Planning and Development Act 2007	*Includes water-related regulations e.g. water-sensitive urban design, environmental values, plans of management and land management agreements.*
Nature Conservation Act 1980* and Nature Conservation Act 2014	*Preserves, conserves and enhances the biodiversity of the ACT Provides action plans and research and monitoring programs for threatened species (flora and fauna) and ecosystems.*
Independent Competition and Regulatory Commission Act 1997	*Sets water and sewerage pricing, utility performance standards and investigates water industry matters*

6.3 Questionnaire

1.) Do you consider water quality of ACT waterways as an issue?
2.) What are general issues and problems central to water quality management in ACT?

- What is the major issue in your opinion and why?

3.) What are/could be some of the solutions to the stated issues and problems around water quality in ACT?
    - Which solution would best work in your opinion and why?
4.) What are/will be the difficulty in implementing those solution to address the issues of water quality in ACT?

5.) How often do you often engage with other stakeholders/community members/public?

6.4 Types of pollution (definition adopted from United States Environment Protection Agency)

"The term point source means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture"

"Non-Point Source pollution generally results from land runoff, precipitation, atmospheric deposition, drainage, seepage or hydrologic modification. NPS pollution, unlike pollution from industrial and sewage treatment plants, comes from many diffuse sources. NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters and ground waters".