

**Identifying Sustainable Water Supplies: A  
Preliminary Assessment of Sustainable Water from  
an Urban Metabolism Perspective**

Christopher John Eastwood

Bachelor of Information Technology  
Queensland University of Technology  
Queensland, Australia

Faculty of Environmental Science  
Master of Environmental Science  
Griffith University

Submitted in partial fulfilment of the requirements of the degree  
of Master of Environmental Science

June 2007

## **Abstract**

In late 2002, the water supply of the Gold Coast came close to failing. This thesis argues that the water crisis is not created by severe shortfalls in rainfall, but rather is a signal of unsustainable development. This issue is relevant also to other urban areas.

In this study the view is taken that to develop a sustainable water system the supply, use and disposal of water within society must be considered holistically. Accordingly the primary aim of the research is to identify and examine a sustainable water supply paradigm. The research first explores the environmental availability of water and the current nature of urban water provision to determine the carrying capacity of the existing strategy. It will be shown that the water demand of the Gold Coast is now at the limits of the ecological carrying capacity of the region. Secondly the research, using a perspective derived from ecological modernisation (EM) theory, identifies changes to the existing paradigm of water supply which will fit within the ecological carrying capacity of the region. Finally these findings are contrasted with the Gold Coast City Council's Waterfuture plan, which is the proposed strategy for sustainable water supplies until the year 2056. While dealing specifically with the Gold Coast region, the findings can be generalised into other urban areas within South East Queensland and throughout Australia.

The existing water supply paradigm is examined by comparing the material flows of water within the city to that of biological metabolism. The metaphor of urban metabolism has mainly been used in descriptive analysis rather than in the design and planning of systems. This study extends the metaphor by comparing other organisms and their successful adaptations to the urban metabolism. This is done to direct adaptation of the urban metabolism in order to increase its successfulness. The sustainability outcomes of the adaptations are contrasted to a proposal for sustainable water developed by the Gold Coast City Council which used Multi Criteria Analysis based on the "Triple Bottom Line" criteria.

EM theory suggests that by reorganising the character of consumption and production ecologically sound practices can be developed. The study identifies that, by

introducing on-site water reuse and rainwater tanks for supplemental supply, demands placed upon the existing reticulated water supply system would be reduced to bring consumption in line with ecological yields available to the present reservoir. By altering the basis for water supply and use, sufficient water exists in the environment to meet the needs of the Gold Coast population even as it doubles over the next 50 years.

The result of this research indicate that the restructuring of water use and supply would result in:

- sufficient water to meet the needs of the population;
- reduction of waste water and storm water discharges into the environment;
- savings in energy required by around 270GWh per year

by 2056. Further, local economic and social development would be stimulated, and environmental protection provided, resulting in a plan for the implementation of sustainable development that is consistent with the Johannesburg declaration.

<b>Abstract .....</b>	<b>ii</b>
<b>List of Figures .....</b>	<b>vi</b>
<b>List of Tables .....</b>	<b>vii</b>
<b>Glossary .....</b>	<b>viii</b>
<b>Acknowledgements .....</b>	<b>ix</b>
<b>Statement of Originality .....</b>	<b>x</b>
<b>1. Introduction .....</b>	<b>1</b>
1.1. Background to the problem .....	2
1.2. Aims .....	5
1.3. Structure of this thesis .....	7
<b>2. Research Design .....</b>	<b>9</b>
2.1. Research Method .....	9
<b>3. Building a framework for analysis .....</b>	<b>13</b>
3.1. Visualizing the problem - Urban Metabolism .....	13
3.1.1. The Ecological Modernization perspective .....	15
3.1.2. A new approach to water - sustainable practice.....	16
3.1.3. Carrying Capacity .....	17
3.2. Available water resources - rainfall .....	19
3.2.1. Seasonal trends in the regional meteorology .....	20
3.2.2. Estimating the current water carrying capacity for the Gold Coast.....	28
3.3. The Water Metabolism - consumption.....	33
3.3.1. Systems losses - UFW .....	34
3.3.2. How urban water is used .....	35
3.3.3. Water Cycles in the urban organism .....	39
3.3.4. Using the environment more effectively - supplementing and diversifying our reserves .....	50
3.4. Sustainable development - what is sustainability? .....	54
3.4.1. Markets as ongoing iterative community involvement .....	55
<b>4. Comparing results with the Gold Coast Waterfuture .....</b>	<b>57</b>
4.1. The Gold Coast Waterfuture – “we need 240ML/day” .....	57

4.2.	Demand management.....	60
4.2.1.	Water conservation, leakage and pressure management .....	60
4.3.	Supply .....	61
4.3.1.	Existing supply.....	61
4.3.2.	Anticipated water supplies.....	62
4.4.	Comparisons of results .....	67
4.4.1.	Triple bottom line vs the ‘Three Pillars’ .....	69
<b>5.</b>	<b>Conclusions .....</b>	<b>73</b>
<b>6.</b>	<b>References .....</b>	<b>76</b>

## List of Figures

Figure 1. Rainfall and Hinze dam percentage full (Gold Coast City Council, 2005e) .	3
Figure 2. Water consumption and property types .....	4
Figure 3. Mwd plotted with Ccw and Population .....	19
Figure 4. Springbrook Nerang and Southport monthly average rainfalls.....	21
Figure 5. Regional monthly averages (Bureau of Meteorology & Department of Primary Industries Queensland, 2004).....	21
Figure 6. Rainfall and Dam holding levels (Gold Coast City Council, 2005e) .....	22
Figure 7. Comparison of 2006 monthly rainfall at Springbrook and Hinze dam wall (Bureau of Meteorology & Department of Primary Industries Queensland, 2004) .....	24
Figure 8. Springbrook monthly rainfall 2001 - 2003 (including mean levels) (Bureau of Meteorology & Department of Primary Industries Queensland, 2004) .....	24
Figure 9. Springbrook catchment wet seasons 1915 – 2005 (Bureau of Meteorology & Department of Primary Industries Queensland, 2004) .....	26
Figure 10. Extrapolating no wet season on dam holdings (Gold Coast City Council, 2005e) .....	28
Figure 11. Population VS water availability.....	30
Figure 12. Annual water extraction Little Nerang and Hinze Dams (Australian Bureau of Statistics, 2006; Gold Coast Water, 2004a).....	31
Figure 13. Available water VS extracted water (per person) (Australian Bureau of Statistics, 2006; Gold Coast Water, 2004a) .....	32
Figure 14. urban water break down (cited in Department of the Environment and Heritage, 2004).....	36
Figure 15. Separate water and waste disposal .....	40
Figure 16. Gravity fed view of water and waste water.....	41
Figure 17. metaphor for the morphology of the urban organism.....	42
Figure 18. Water drawn into the metabolism and returned as waste .....	42
Figure 19. Recycling in the water use cycle .....	43
Figure 20. Separating property and community views of recycling and reuse.....	45
Figure 21. water demands BAU vs reducing Cellular losses .....	46
Figure 22. Indoor house hold waste water sources (Australian Bureau of Statistics, 2004b) .....	47
Figure 23. BAU vs evolved Mde for waste water (GWh).....	49
Figure 24. Southport vs Springbrook rainfall during 2001 – 02 drought (Bureau of Meteorology & Department of Primary Industries Queensland, 2004) .....	51
Figure 25. Water demands BAU vs rainwater harvesting evolved Cellular metabolism .....	52
Figure 26. Gold Coast Waterfutures water summary (Gold Coast City Council, 2006a) .....	59
Figure 27. Water consumption 2000 – 2004 (Gold Coast Water, 2004e) .....	60
Figure 28. Comparison of energy needs: desalination VS metabolic efficiency .....	64
Figure 30. Expenses VS revenue VS profit .....	71

## List of Tables

Table 1. Household water usages as percentage (Australian Bureau of Statistics, 2004b) .....	36
Table 2. Financial and metered water data 2002 – 2006 (Gold Coast City Council, 2002, 2004a, 2005b, 2006d, 2007) .....	70

## **Glossary**

BAU	business as usual
CC	carrying capacity
Ccw	Cellular consumption of water
EF	Ecological Footprint
EM	Ecological Modernisation
GCCC	Gold Coast City Council
GCW	Gold Coast Water
GWh	Gigawatt hour
KWh	Kilowatt hour
ML	Megalitre
Mwd	metabolic water demand
SD	Sustainable Development
UFW	unaccounted for water

## **Acknowledgements**

Firstly I would like to thank my mother, who sadly did not get to see this work completed. Her support has made this work possible I can only hope that it has done her justice. The support and encouragement of my partner in helping create an environment in which I could work and relax has been critical in supporting my spirit allowing me to recharge on what has been a long journey.

I would like to Professor Pat Dale for her support in making possible research and exploration in Korea. Credit must also go to my other course convenor Ms Jo-Anne Ferreira has provided support and guidance at a critical time for the completion of my work. I feel that I owe a lot to Dr Bill Metcalf, who provided excellent advice and steering over the development of my methodology.

### **Statement of Originality**

This work has not previously been submitted for a degree or diploma in any university. To the best of my knowledge and belief, the dissertation contains no material previously published or written by another person except where due reference is made in the dissertation itself.

Signed: \_\_\_\_\_

Christopher Eastwood

June 2007

# 1. Introduction

Water is the most essential substance for life. No one would doubt the statement “you can’t live without water”. Yet we seem to be using it in ways that fail to recognize its true value and scarcity. At the time this research commenced a “water crisis” was unfolding in the Gold Coast. This has subsequently expanded to cover the south east corner of the state of Queensland. Water is controlled under oligopoly conditions by the State government. Urban water supply in Australia has undergone significant evolution since the beginning of European settlement, with the supply component of the present model being bulk water storage (that is most typically dams) which take advantage of existing geographical river catchments. Water is then easily harvested and with some treatment supplied to the local area using pipes in a network called the ‘reticulated water system’.

Australia has a long history of drought which has, at intervals in our history drawn our focus onto the water supply, and brought about attempts to ‘drought-proof’ the cities. Successive iterations of this have resulted in the extension of the development of dams in an effort to supply more to the reticulated water system. To this point some 500 dams and large reservoirs have been constructed in Australia, with the peak construction of such projects being the later part of the 20<sup>th</sup> Century (Tisdell, Ward & Grudzinski, 2005). Yet the situation remains unchanged and water shortages continue to challenge the viability of our cities.

The cycle of flood and drought has been recognised as a part of the environment since early in Australia’s colonial history.

“I love a sunburnt country,  
A land of sweeping plains,  
Of ragged mountain ranges,  
Of droughts and flooding rains.”(Mackellar, 1904)

While this knowledge is reflected in the literature of the nation it has not been regarded as normal in infrastructure planning; rather as something to be “fought, cured or beaten” (Melbourne Water, 2005; South East Water Limited, 2002).

Australia has been following a supply oriented approach to solving problems of water shortage. Rather than learning how to adapt our living patterns and learning how to live within the ecological limits of the environment, technical solutions to adapt nature to yield more water have been employed as demands increase; with administration driven by the view that droughts need to be 'fought' (South East Water Limited, 2002). Yet it has been identified that dam capacities for the Australian environment would need to be six times that of Europe for us to achieve similar levels of water security using the present paradigm (Smith cited in Tisdell et al., 2005, p5).

Much of the recent writing on water problems in Australia has centred on the problems in agriculture, with the Murray Darling Basin being of greatest interest. However a different problem relating to mainly urban centres is also emerging. The crisis of water in the urban centres is the focus of this study.

### **1.1. Background to the problem**

The Gold Coast (GC) area in 2002 – 03 experienced low rainfall levels, causing significant drops in dam levels, and bringing into focus the possibility of the existing infrastructure being unable to continue to supply water (Gold Coast City Council, 2003). The Gold Coast is an urban area which supplies water to properties by a reticulated water system. This existing paradigm of water relies on a system of bulk water supply to source water, that is the Hinze and Little Nerang dams (Gold Coast City Council, 2005c). Had there not been sufficient rains in February 2003 then at that rate of consumption the dam would have become empty by September 2003. This situation was identified by local government as a "crisis" of the water supply system (Gold Coast City Council, 2003).

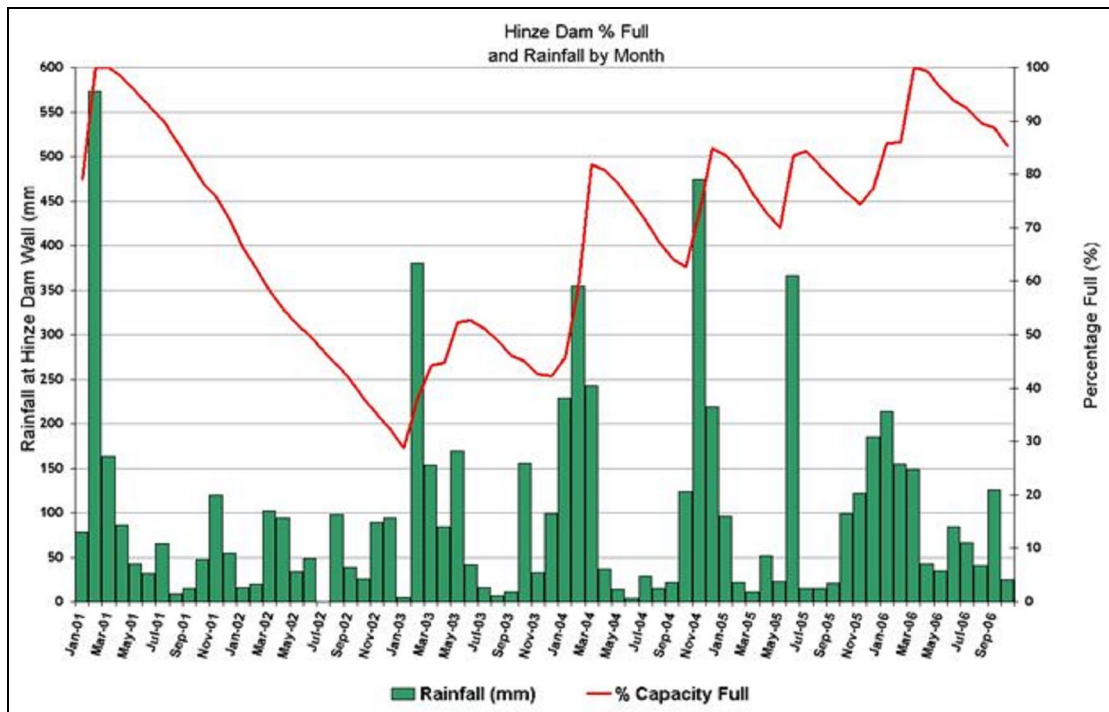


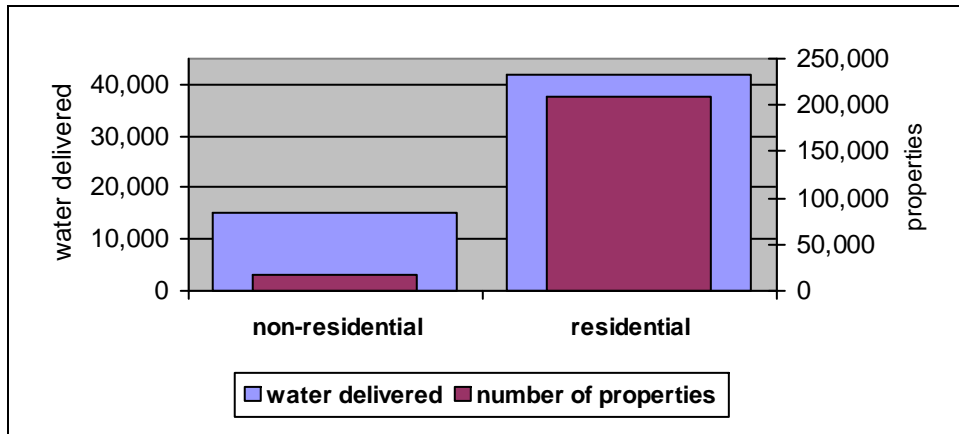
Figure 1. Rainfall and Hinze dam percentage full (Gold Coast City Council, 2005e)

Figure 1 shows rainfall levels in millimetres as bars, and the red line indicates Hinze dam level as a percentage

The official explanation of this crisis is that the region is in the grip of the worst drought on record. This thesis will examine an alternative explanation, that this situation is due to unsustainable development of the region, where the population and consumption demand has exceeded the water carrying capacity of the environment using the current paradigm of water use. This thesis proposes that the existing paradigm of water supply in urban centres is no longer sustainable, and that the deepest changes are needed “to develop a better understanding of the role of consumption and how to bring about more sustainable consumption patterns” (Cavalcanti, 1996).

The Gold Coast provides an excellent case study for urban water supply as the mix of residential and non-residential properties is strongly residential with 92% of the properties serviced by Gold Coast Water being residential, and these properties receiving 74% of the water (Gold Coast Water, 2007c). This simplifies the analysis of the paradigm of water use, as residential water is the largest component and can

become the primary focus of the study. The GC obtains the majority of its water from a reservoir system in the local hinterland, which makes examination of the water flows more straight forward.



**Figure 2. Water consumption and property types (Gold Coast Water, 2007c)**

The Gold Coast is one of the fastest growing regions in Australia, with population increasing by over ten times between 1961 and 2007. It is anticipated that this growth will continue with the population more than doubling, reaching over 1,000,000 by 2056 (Gold Coast Water, 2005a; Queensland Government Office of Urban Management, 2005). With such strong growth it is essential that water supply systems be developed accordingly or there be inadequate water to support the population. This thesis takes the view that development must encompass the way that water is sourced used and disposed of holistically and therefore a paradigm change is required.

The Gold Coast area obtains the overwhelming majority of its water from surface water, with water from dams providing the majority of the water. As has been shown, the levels of rainfall that fell in the 2001 – 2002 drought resulted in the dam levels dropping from nearly full (over 90% of capacity) to below 30% in less than 2 years (22 months). While this has been identified as the most severe drought on record (Gold Coast City Council, 2003), and used to explain the water crisis, it is not a claim that can be supported by examination of historical data for the region. This study will show that there have been periods of similar rainfall at various times in the recent past.

This indicates that low rainfall levels are not the only factor at work in the present water shortage. Rather than drought, this study will demonstrate that the water shortage is an indicator of unsustainable practice, and by undertaking modernisation of the water supply paradigm that regional socio-economic development can be facilitated, environmental protection afforded, and water supplied to meet the needs of growth.

## **1.2. Aims**

The study of water metabolism in Gold Coast area provides an opportunity to observe a system which is an example of the urban water paradigm of a dam providing water to a population through a reticulated water system, and waste water disposal by sewerage. The objectives of this research are:

1. To identify water supply strategies to allow sustainable development with respect to water that are cost effective and amenable to use in the urban areas of the Gold Coast.
2. To develop and extend the metabolic framework as a practical methodology for development of sustainable urban systems.
3. To contribute to the understanding of sustainable development and how to interpret and implement sustainable development.

The scope of existing research is too narrow, focusing on components of the issue, but not addressing the problem holistically. This work develops a strategy for a holistic vision of the system. To this point few studies have examined the sustainable development of the complete urban water cycle, from source to disposal. While there have been studies of urban water use and some on the sustainability practices of urban water suppliers, attempts to find any that consider the community use of water and waste water handling as part of the same system as the water supplier have been unsuccessful. Some studies in Australia have considered applying sustainability assessment criteria to organisations. For example the Ecological Footprint approach of Wackernagel and Rees (1995), has been adapted from the assessment of community to being used to assess the sustainability of supplier organizations such water supply

utilities. However Ecological Footprint (EF) analysis was developed to assess the amount of land and materials which are required by the activities of society (W. E. Rees, 2005). This would assume that it was the water utility, and not the population which was consuming the water.

Determination of the EF of a water utility neglects that the water utility exists to supply water to the community. Essentially the community and the water utility are part of one system. It is the water use practices and population levels which will effect the EF not only the practices of the water utility. Accordingly to identify sustainable water solutions a holistic view of the system as a single entity which sources water, uses water, and produces waste is required understand the process.

The concept of carrying capacity (CC) is central to the understanding of sustainable development (W. Rees, 2006), and while it has been explored in some research (Oha, Jeong, Lee, Lee, & Choi, 2005; Uhlmann, 2003) is often left as a general notion such as “Staying within critical ecological limits” (Uhlmann, 2004). Importantly remains absent or poorly defined in urban planning in the region. This thesis explores the existing water carrying capacity based on empirical observation of available water and within the context of the existing paradigm.

Researchers have identified the need of this holistic systems approach (Godau, 2000; Lundin, 1999; Uhlmann, 2003). This study extends the use of the metabolic frame of reference from providing simply descriptive language to becoming a base for analysis and comparison of material flow functionality. Used in this way the framework of urban metabolism can provide a context to the material flow of water in order to unify the examination of the sustainability of the population with respect to the supply and disposal of water. The model also allows the consideration of externalities such as energy consumption and waste disposal volumes.

Living organisms are complex whole entities with multiple aspects, and so their strategies at solving environmental challenges must not ignore their viability in other areas. Accordingly, while this study examines the flows of water and energy within the urban metabolism, it is premised on the sustainable development of the urban organism.

### 1.3. Structure of this thesis

This thesis will first demonstrate that the climatic conditions in this region are not as exceptionally extreme as has been offered as the reason for the water crisis. This then supports the hypothesis that the situation is actually an indicator that the present system of water supply is no longer able to sustain the population of the Gold Coast and therefore will not support further development without substantial paradigm changes.

The thesis then aims to identify water supply paradigms which are environmentally and economically robust and facilitate sustainable development (SD). The Johannesburg Declaration further defined sustainable development as that which supports the goals of economic and social development as well as environmental protection (United Nations, 2002). This declaration has clarified sustainable development to encompass *interdependent* and *mutually reinforcing* pillars of economic and social development as well as environmental protection. This concept is however often misunderstood, with reductionist analysis applied to its interpretation thus breaking apart the mutual interdependency. For example as recently as June 2003 the Australian Federal government guidelines such as “Triple Bottom Line Reporting in Australia” appears to be based on the three pillars, however separates them. Still further from the intention that document then focuses primarily on ecological reporting (Department of Environment and Heritage, 2003).

Understanding the importance of the mutual interdependency of the three pillars is essential. Reducing it to a consideration of separate environmental, social and economic factors loses the synergy of the interdependence and hence its importance (Pope, Annandale & Morrison-Saunders, 2004). Accordingly a framework for analysis which will address the three mutually reinforcing pillars of SD, while allowing for detailed holistic system analysis has been chosen for this study. Throughout this thesis the term ‘sustainable’ or ‘sustainable development’ is taken to mean one which conforms to this view.

This thesis is divided into 5 chapters. This first chapter provides a background to the problem, and then describes the aims of the thesis and its significance. Chapter 2 then explains the research design and methodologies. This makes clear the approach that has been undertaken in gathering data and synthesising results.

The third chapter develops and explores a model for water materials flow within the context of urban metabolism. A functional view of the metabolic mechanisms that exist within successful living systems is taken, as these are metabolisms which have been the successful result of the development of living organisms. The view is taken that by observing systems that are successful, that the development of the urban metabolism can be directed in similar ways and thus avoid uncertainty. During this process current literature is examined, and the theoretical framework is developed and compared empirically to the existing situation. From this, observations are made which form the basis of ideal sustainable outcomes. Using these outcomes as goals, some strategies are suggested which can direct the evolution of the urban metabolism to develop in sustainable ways. By the end of the chapter essential components for sustainable development of water systems are outlined.

The fourth chapter examines the GCCC Waterfuture strategy. The Waterfuture strategy is the current response to the water crisis by local government. From the view points developed in chapter 3 the inadequacies and omissions of the Waterfuture strategy becomes clear. The construction of the frame of reference in chapter 3 and its application in chapter 4 also serves to as an opportunity to examine the shortcomings observed in the current literature regarding triple bottom line (Pope et al., 2004; A. C. Taylor & Fletcher, 2005; Williams, 2004).

Finally the fifth chapter brings together the findings and highlights areas of future research. The findings suggest that the existing water infrastructure will become the core support structure for a new paradigm augmenting the results of a growing network of changes at the cells of the urban organism. In essence a fusion of self sufficiency of water supply and the interconnectedness of the reticulated water system.

## **2. Research Design**

This research follows a methodology called ‘Systematic review’, as described in more detail below. In attempting to undertake a holistic view to a problem, many apparently disparate issues must be brought together. To undertake this in the ‘classical’ approach of a literature review followed by an analysis would at least require the reader to recall so much as to be cumbersome. To ameliorate this difficulty some components of the model are developed later in the research. Specifically attention to sustainable development is given more specific attention just prior to chapter 4, at the end of the development of the metabolic framework.

Thus in summary the research strategies employed in this study are:

1. systematic review of related research to bring a more together details from studies undertaken in isolation into a holistic view for the analysis of the problems.
2. development of a framework of analysis based on review of existing material from which to provide a context for determining a sustainable strategy.

Just as the concept of sustainable development has eluded consistent definition, defining what is a sustainable water system is intuitively obvious yet practically complex (Parris & Kates, 2003). In answering the question on identifying sustainable water paradigms, it is essential to include an examination of the Waterfuture strategy put forward by the GCCC. This plan was developed and promulgated during the research of this thesis. The Waterfuture strategy is intended to provide a sustainable water solution to the Gold Coast area until the year 2056 (Gold Coast Water, 2006a).

### **2.1. Research Method**

For this research the ‘Systematic Review’ technique was chosen. Systematic review is a method for research in the medical area (Dixon-Woods et al., 2004) and is beginning to extend into Information Systems research (Clarke, 2000). Systematic Review is essentially combination of a literature review strategy and ‘secondary

analysis'. 'Secondary analysis' is a process where data gathered by other researchers is then re-analysed for a research purpose that was distinct from the original research intention (Heaton, 1998). A view taken by secondary analysis researchers is that there already exists an enormous amount of data that has been collected, and that this can form the basis of other works (Trochim, 2002), adding further value to the work that has been done. Given the large amount of existing research that is available undertaking the same components of data gathering and analysis for new work is replication and introduces the possibility of creating errors.

Systematic review differs from secondary analysis in that the analysis is not performed on the source data used in the works reviewed, but rather in the connection of common threads and the synthesis of new ideas from the findings of research papers themselves. There is some commonality with another method called "Disciplined Literature Reviews"; Seddon (cited in Clarke, 2000), suggests that this is "a combination of (1) grounded theory and (2) intuition based on a deep immersion in, and understanding of, the data". Using this technique will allow this study to take advantage of a bulk of research, both quantitative and qualitative, for the synthesis of new work.

In defining the scope of the review the inclusion criteria used to identify significant literature found in searching should be made clear to reader. In this research, the following searching areas have been employed:

- A search of GCCC publications
- Using computer based 'key words in text', a search of databases of academic publications
- Internet searching engines such as Google Scholar using similar key words
- direct personal communication with various key people to identify the key issues

Searching was initially performed using search key words "water policy urban sustainable management potable sustainable reticulated" in different arrangements Eg:

"water policy urban sustainable"

"water urban sustainable"

“water potable sustainable management”

“water potable policy urban sustainable”

Abstracts were then further reviewed on the basis of:

- relation to the problem of supply of water to Urban areas,
- policy on urban development with respect to relevance to alternative water supply, sustainable practices,
- methods of managing water demand

Subsequently documents were identified on the basis of reference material within works which were reviewed. Occasional material was identified by incidental reading or browsing of related journals.

In the review of these documents, the approach of initially assessing abstracts of the works, and determining if the work contributes to the understanding of:

- the technologies applicable to water recycling
- legislation and policy that pertains to water use in an urban environment
- the historical background of water consumption and use in Australia
- the ways that water is used in urban situation
- the ways that water provides economic benefits to both the individual and the community

Direct gathering of data was not undertaken in this research, this does not suggest however that quantitative data was not used. Primary data on rainfall levels, water consumption in the city of the Gold Coast, and financial data was obtained directly from a variety of sources. These sources include:

- Gold Coast City Council website and annual reports,
- The reporting tool ‘Rainman’ purchased from the Department of Natural Resources.

Issues of rigor in qualitative research are substantially different to those in quantitative research. The Systematic review method used in this study encompasses both to some degrees. Issues of rigor are addressed in this research by ensuring trustworthiness of the sources of data that is used for making decisions. By focusing

on refereed journal articles, proceedings submitted to refereed professional conferences, government legislation and publications, confidence in the openness and reliability of my sources is assured. The interpretive validity of my research is addressed by cross referencing with the findings of other sources.

### **3. Building a framework for analysis**

The existing paradigm of water supply in most urban regions in Australia, as well as that of the Gold Coast, is of a single water supplier provides water to properties through a network of pipes, where it is used on site, and then disposed of. This water is supplied in bulk, to a community who are detached from the provision of this water and often have no concept of how much water they use (Troy & Randolph, 2006). In many examinations of water systems the components of: water supply, waste water disposal and the use of water by the community, are seen as separate components. However in this thesis all are viewed as components of the one complete system.

To demonstrate that that the environmental limits of supplying water to the Gold Coast have been reached, the carrying capacity of the existing system will be examined with respect to rainfall. Available water is effectively rainfall, therefore understanding rainfall is central to understanding the carrying capacity of the region. Following this the way that water is used in the community will be examined to identify strategies for the developing sustainable water systems. This thesis will show that the structure of water supply, use and disposal requires subtle but distinct evolutionary changes to become sustainable.

#### **3.1. Visualizing the problem - Urban Metabolism**

Models are commonly employed to represent complex problems, partly to facilitate communication and partly to assist in the visualisation of a complex or intangible subject. The model of 'urban metabolism' has been used to describe the resource consumption of the cities for some time (see for example, Wolman, 1965). More recently the metabolism frame of reference has been used in the reporting of environmental information in Australia (State of the Environment Advisory Council, 1996) and it has been suggested the it can be used to define the sustainability of a city within the ecosystems capacity to support it (Newman, 1999). In the following sections a model of the urban metabolism of water will be developed to encapsulate the movement of water from the environment into the city and finally to be returned to

the environment after use. The construction and development of this model will make clear arguments relating to the sustainability of cycles of water in the Gold Coast.

In identifying a sustainable solution to water supply on the Gold Coast, an understanding of the water and energy flows in and out of the city is essential in order to improve them. By taking an overview of these as a metabolic processes, a metaphor for how the city uses water can be outlined and used to describe the current water supply paradigm. The flow of water in an organism such as a plant is quite comparable to the those within the city. Both have a network which extends into the environment for obtaining water and transferring energy.

Just as the metabolism of a plant would cease to function, the metabolism of the Gold Coast also would cease to function without adequate water. There are many plant species, with specific adaptations to make them suited to survive in their environment. Cities, unlike plants, are structures of people, and thus are able to modify their systems of water metabolism. If conditions alter in a way that becomes unfavourable to the city, the urban metabolism can be restructured in accordance with the ecological situation. The alteration of conditions could be either or both; changes in the metabolism, changes in the environment.

If the metabolism of a plant attempts to grow beyond the ability of the environment to support it its growth will be stunted; such as growing in a soil pocket atop of rock, where a plant can no longer expand its root structure. In the same way it is undesirable for the growth in the city's demands to exceed the environmental capacity to support it. If it can be shown that environmental conditions (and thus supply) have not changed substantially (such as drought) then resources (such as water) becoming scarce is a result of metabolic growth (that is population growth).

As has been suggested, the biophysical environment in which the Gold Coast is located has already shown signs of no longer being able to meet the city's metabolic demand for water. This has enormous implications for the economic and social development of the community. The city of Goulburn provides an example of what effect on economy and livelihood that the failure of the water supply has on a city (Australian Broadcasting Commission, 2005; Parliament of New South Wales, 2005).

If the nature of provision and use of water in the Gold Coast could be restructured such that it is possible to remain within the existing environmental limits this would be a significant outcome. Further, if this can be done in such a way as to stimulate the economy of the city, ensure social well being, and protect the environment then it would be a completely win - win outcome.

### **3.1.1. The Ecological Modernization perspective**

Ecological Modernisation is a theory on the normative direction of technology and society towards more environmentally sound practices . While the origins of EM may have been focused on the technical developments, other views of EM have encompassed the questions of social and policy modernisation with respect to the impacts of society on the environment (Freier, 2003). Whether technical or political, the focus of EM is on reorganising the character of production and consumption along ecologically sound criteria (Mol & Spaargaren, 2004). The question of “how would we need to re-organize the water supply paradigm to best support the population on the Gold Coast”, is essentially examining the re-organizing provision and consumption along the lines of what is environmentally available. Accordingly the research will be adopt the view that restructuring the flows of water within the Gold Coast are part of an ongoing process of restructure and the ecological modernisation of the water metabolism of the Gold Coast.

Answers to environmental problems such as the existing water crisis can be found in the examination the results of development, the social and mechanical processes which we have, and how they could be adapted to come in line with ecological realities. From this perspective, changes in the way we have used water are directed by desires to improve the health and well being of the population, and to secure a more reliable and safe supply of water for our society. Recently evidence has emerged that have identified environmental limitations in the move to this paradigm. The ecological modernization perspective would suggest that these issues are challenges to the structure of economic, technological and institutional systems to adapt (Freier,

2003). Markets and market forces are as significant components of the modernization process, as are technological devices (Freier, 2003; Mol, 2002).

In the following sections, it will be shown that to make significant alterations in our environmental water demands, that systemic changes are required, which will include technology, policy and social changes. These do not need to be undertaken in revolutionary ways, but evolutionary ways.

### **3.1.2. A new approach to water - sustainable practice**

Until recently the idea of sustainable development was not part of the thinking or planning for urban development. Since the publication of 'Our Common Future' in 1987 the idea has developed to become part of modern thinking. The Johannesburg Declaration on sustainable development further defined the idea of sustainable development as a multidimensional approach encompassing mutually reinforcing principles of sustainable development. This view of sustainable development is founded on the "interdependent and mutually reinforcing pillars" of economic development, social development and environmental protection (United Nations, 2002). This is a holistic view of sustainable development, and goes beyond ecologically sustainable development, and so accordingly a holistic approach to the analysis of the problem of identifying sustainable water solutions has been taken. A holistic appraisal in which the totality is not a mere heap, the whole is something besides the parts (Aristotle, 323 BC). Holistic examination of infra-structure has previously been identified as key to understanding the increasingly complex interrelationships that exist in the management infrastructure (Godau, 2000).

While it is true that every organism exploits the environment to make its living, from the earliest periods of settlement Australian society has engaged in extreme exploitation of the natural resources (Powell, 1976). As our population levels have grown, and our society and our urban structures have been evolving we have moved from a paradigm where many households were capable of at least supporting their water needs, to a paradigm where we are almost totally reliant on a centralized system

of provision (Troy, 2004). At the same time the design and effectiveness of these systems are further abstracting people from the effects of environmental variability. With months of no rainfall, people still have water at the tap and have no indicators in their homes of water levels at the dam

The evidence of the past 100 years of activity demonstrates that repeated attempts at 'drought proofing' the country has failed to achieve that objective. Successively complex engineering schemes to used to provide greater levels of water, can on longer be presented as credible solutions for solving the issue of sustainable water supply for Australia. Providing more water is not the only way to ensure that people have enough water.

The viability or sustainability of the urban metabolism depends on how closely the organism lives to the margins of the environmental capacity to provide resources, and on its adaptability to changes. Understanding the relationship between the amount available water and the population of the Gold Coast is effectively understanding the water carrying capacity of the region. The carrying capacity is the capacity of the earth to supply resources to the human economy (Daniels & Moore, 2001; Wackernagel & Rees, 1995). Water is not produced, so much as harvested, it is therefore supplied by the environment.

### **3.1.3. Carrying Capacity**

A good indicator for sustainability should be understandable, remain relevant in the long term and address carrying capacity (Lundin, 1999). Carrying Capacity is a measure of the population which can be supported by the environment in an area. This means that when the consumption of water by a population reaches the amount of available water, that population will have reached the environmental water carrying capacity for its usage. At this point environmental water resources will no longer be able to meet consumption. To explore this, we need to understand the capacity of the environment to supply water and the community consumption of water.

CC is dependent on:

- the usage practices of the population drawing upon the environment
- the available water

The usage practices of the population with respect to water consumption is the demand of the urban metabolism for water. This is determined by the water consumption of each residence and the of the population being supported. This is consistent with other findings which suggest that the behaviour of the community and the water utility effect the sustainability of the system (Lundin, 1999; Troy & Randolph, 2006). Therefore the metabolic water demand is directly related to the number of cells (or the population) and cellular consumption water. This can be expressed as:

$$Mwd = Pn \times Ccw$$

Where

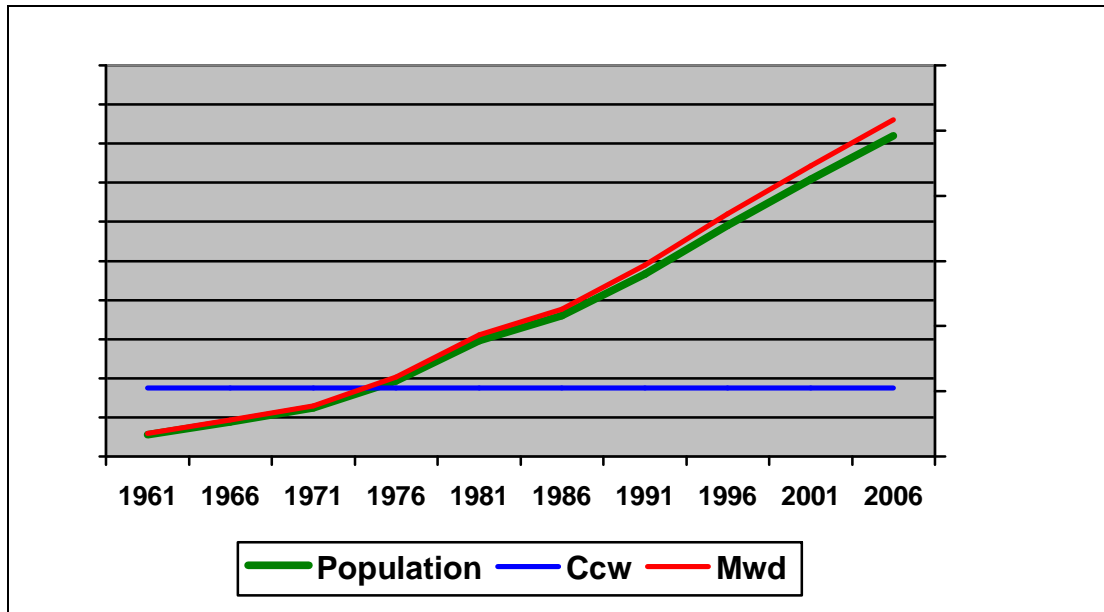
**Mwd** = Metabolic water demand

**Ccw** = Cellular consumption of water

**Pn** = Population.

Assuming (for example) a constant **Ccw**, then the **Mwd** will grow in a linear relationship with population (**Pn**).

So for a **Pn** increase a constant for **Ccw** the following overall growth for **Mwd** will reflect population changes.



**Figure 3. Mwd plotted with Ccw and Population**

As the CC is dependent on **Mwd** and the available resources, the CC is thus not fixed and can be changed by altering either available resources or **Mwd**.

### **3.2. Available water resources - rainfall**

The importance of rainfall to the nations water supply has been stated as “the primary indicator of water availability in Australia is rainfall” (Australian Bureau of Statistics, 1988). The Gold Coast currently obtains the vast majority of its water from surface waters gathered in catchments and held in dams (Gold Coast Water, 2007b), accordingly understanding the meteorology of the region is essential to understanding the amount of water that is reliably available. As stated the explanation of the current water crisis from State and local government is that the area is in the worst drought in a century (see for example, Department of Natural Resources Mines and Water (The State of Queensland), 2006; Gold Coast City Council, 2005d; Gold Coast Water, 2006b; Queensland Government: Department of Infrastructure, 2007). This view is not universally accepted, with other members of the community suggesting that it is actually not the worst drought, and that the current climatic conditions have simply highlighted the failure of planning.(Blainey, 2006; Colebatch, 2004).

Drought is variously defined as:

- a protracted period of deficient precipitation (National Drought Mitigation Center, 2006)
- acute water shortage (perhaps due to demands) (Bureau of Meteorology, 2006)
- rainfall periods of three months or more to that they lie below the 10th percentile (IE lowest 10% of records)(Beard, 2006)

Thus it is important to distinguish between meteorological drought (rainfall deficits) and hydrological drought (shortfalls in water supplies). The term hydrological drought is a relative one because water availability, which depends on supply and demand, is also affected by the activities of the water user (Australian Bureau of Statistics, 1988). In this thesis the view is taken that demands which exceed supply are not drought, but symptoms of unsustainable usage. In the following section it will be made clear that the case for a protracted period of deficient precipitation can not be made, which then means that unsustainable use is the other explanation.

### **3.2.1. Seasonal trends in the regional meteorology**

The greatest rainfalls occur around January February and March, however there is temporal movement of the peak rainfall, with occasional peak rain later in the year. Figure 4 below shows monthly averages since 1915 from Springbrook which is a measuring station in the dam catchment. Rainfall trends for the catchment show a clear pattern of seasonal rainfall, with stronger rainfalls starting in October, peaking in February and reducing in about April or May.

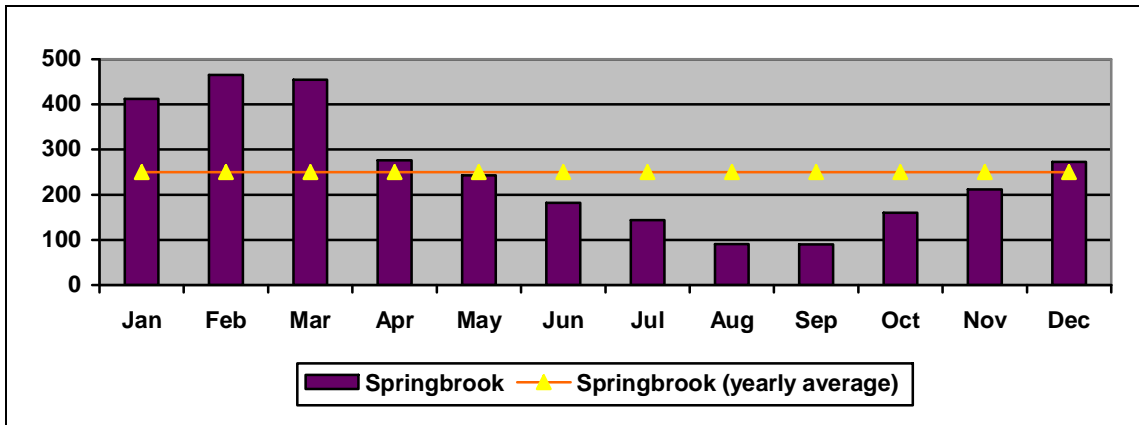


Figure 4. Springbrook Nerang and Southport monthly average rainfalls (Bureau of Meteorology & Department of Primary Industries Queensland, 2004)

The period from November through to March has much higher monthly rainfall levels than the yearly average. This shows that rainfall is strongly seasonal in the area. For the purposes of this analysis the period of November through to March has been chosen as the wet season, and June to September as the dry season. This pattern of seasonal rainfall is consistent throughout the entire GC region. Figure 5 below shows the monthly averages for two other locations within the GC region, Southport on the coast, and Nerang a slightly inland area. As can be seen, they follow exactly the same seasonal trends.

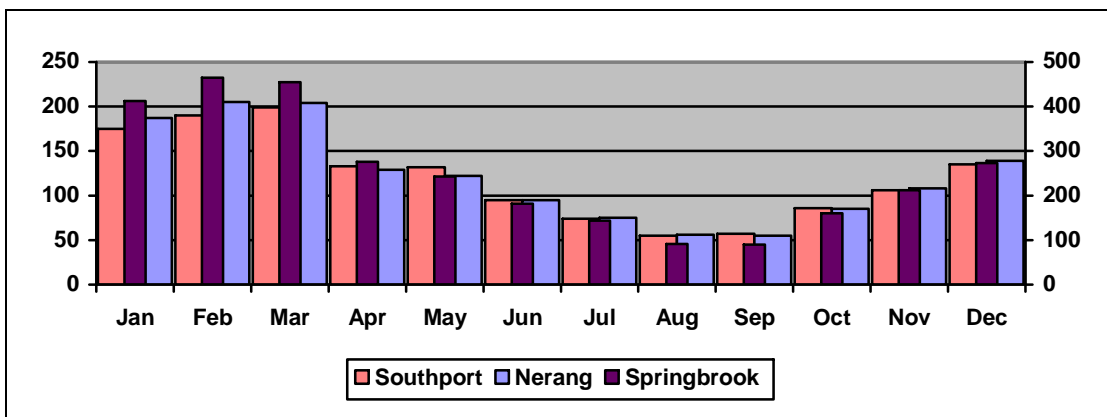


Figure 5. Regional monthly averages (Bureau of Meteorology & Department of Primary Industries Queensland, 2004)

### 3.2.1.1. The effects of seasonal rainfall on dam water levels

By examining the data in Figure 1 we can identify that clear relationships appear between rainfall and dam levels. Identifying these relationships has been done by marking them as appears in Figure 6 below. Comparing the rainfall and consumption levels for each month, one can determine empirically a range at which rainfall balances inflow and outflow. This simple method takes the two major parameters of water input and water output, and while all other effects such as evaporation and seepage effect the system they are not variables dependent on either usage or rainfall. It has been shown that when modelling dam and catchments that greater complexity does not necessarily equate to a more accurate model, and in fact require parameter tuning based on exactly these types of empirical observation (Kokkonen & Jakeman, 2001). Therefore a usable estimation range can be obtained and verified using this method.

The following categories of monthly rainfall have been identified from the chart:

1. less than 100 mm results in a decline in stored water levels,
2. around 150mm results in a more or less static situation,
3. 200mm and above results in an increase in stored water levels

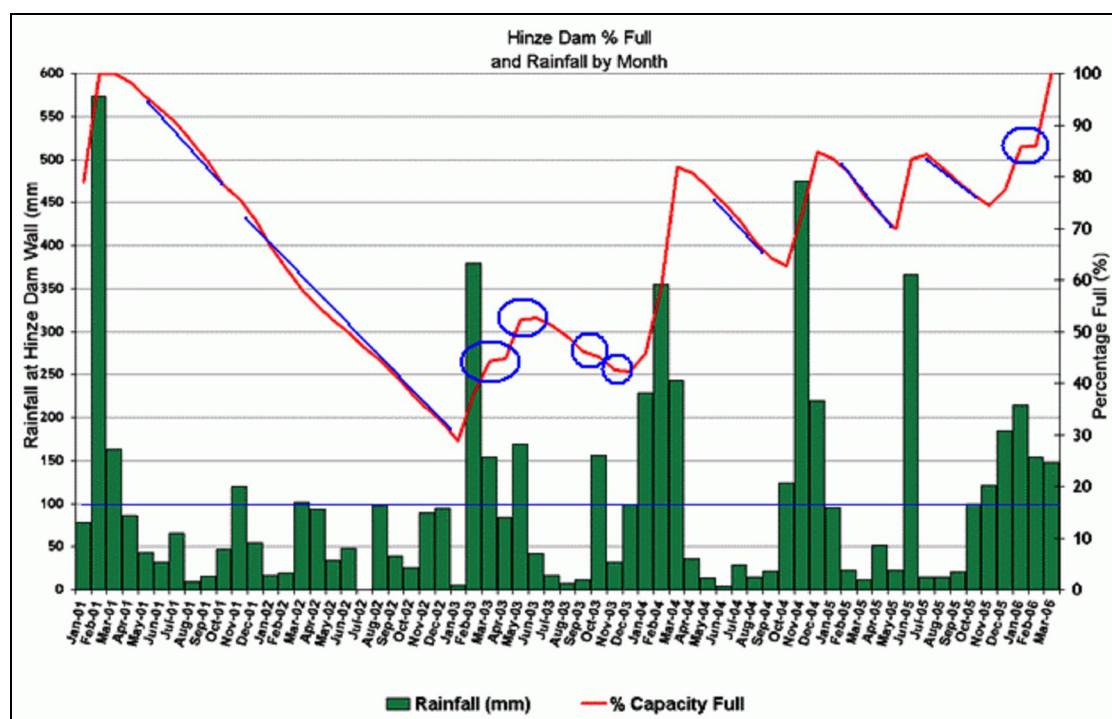


Figure 6. Rainfall and Dam holding levels (Gold Coast City Council, 2005e)

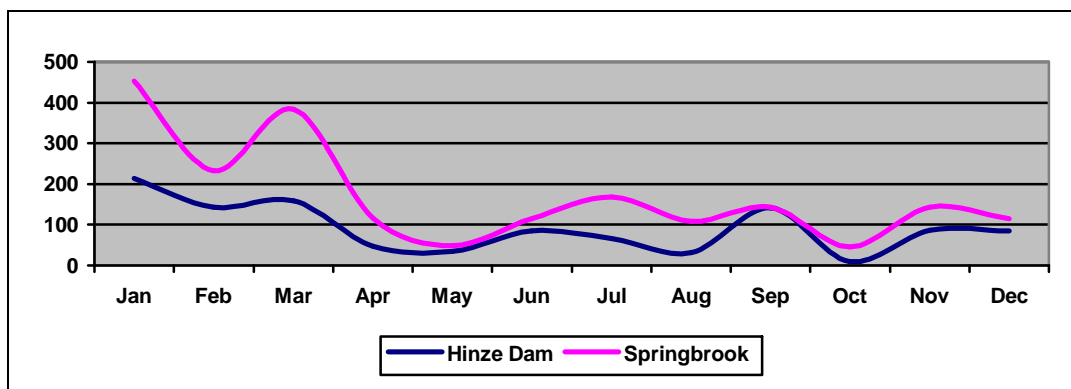
These have been marked on Figure 6 above by placing;

- a blue axis along the 100mm leading to decline level on the graph,
- a blue line beside the dam capacity gradient to indicate declines in capacity,
- a circle around the positions of static dam capacity.

These seem to be reliable indicators for this system, as wet season rains typically exceed 100mm per month and average rainfall levels for dry season rains (where dam storage is typically only in decline) where losses by consumption and evaporation are more significant than inflows.

It should be noted that the rainfall levels in Figure 6 are taken from the Hinze dam wall, where no metering records for exist prior to 1976. To make significant interpretations of weather patterns, data for longer periods is needed. Springbrook data (within the catchment area) is available from 1915 making it more useful for investigating longer term patterns. It is then important to establish if the previously identified relationship exists between readings from the Hinze dam and those which taken in the catchment at Springbrook, to allow those in Figure 6 above to become a reference for generalising rainfall level in the catchment and therefore the levels of water in the dam.

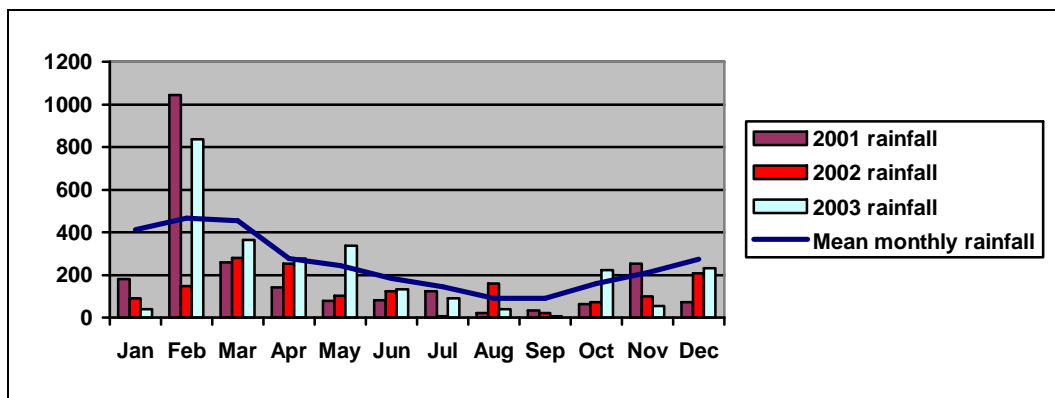
The monthly rainfall patterns in the immediate area show highly transferable trends. This is compared below in Figure 7 compares the data from both the dam wall, and data from Springbrook. A very high degree of transferability can be observed between the two areas, and so effective comparison can be made between relative rainfall levels in the two areas.



**Figure 7. Comparison of 2006 monthly rainfall at Springbrook and Hinze dam wall (Bureau of Meteorology & Department of Primary Industries Queensland, 2004)**

**3.2.1.2. Rainfall cycles – not drought**

As shown in Figure 6 above the dam holdings fell from full in March 2001 to less than 30% of its capacity by Jan 2003, that is in a period of about 22 months. This periods can not be considered as a significant, particularly when the seasonal nature of the region is considered. During 2001 – 2002 the wet season rains around January in other years were extremely low or absent, meaning that only a single years wet season was lost. This can be seen in Figure 8 below, where 2002 monthly rainfall is close to the monthly rainfall of other years.



**Figure 8. Springbrook monthly rainfall 2001 - 2003 (including mean levels) (Bureau of Meteorology & Department of Primary Industries Queensland, 2004)**

While it is true that the dry period rains were also slightly lower than historical averages, it has already been shown the average dry season rainfall levels are insignificant in contributions to water holdings in the system, and so the meaning of low or lower dry season rainfalls is irrelevant in determining the length of the dry period. The data presented so far supports that in areas which have a seasonal rainfall, it is not meaningful to label as drought lower than average dry season rainfall. Therefore it is the presence or absence of the wet seasons which is the significant indicator of reduced available water.

Another important observation can be made from Figure 6, that is in June 2005 rain gave a significant boost to the water holdings in the system mid year. This left them higher at the arrival of the 2006 wet season than they were than at the beginning of 2005. This was due to un-usually heavy rainfalls occurred in June 2005, with 450mm falling over just a 2 day period. June 2005 monthly rainfall was 511mm, which is almost 3 times the average rainfall for that month. This reveals another significant point, which is lost in some examinations of rainfalls, that un-seasonal single storm events can have can have significant influence on the system.

It has been shown to this point that the source of water to the metabolism of the Gold Coast is rainfall that is harvested in the Dam from the catchment, and that a single years loss of wet season resulted in the near failure of the water supply. To determine if this single wet season loss represents an unusual climate even greater data for greater lengths of time are needed. Figure 9 shows the wet season rainfall since 1915, with the critical levels of wet season rainfall which caused the water crisis in 2002. It shows clearly that while there have been significant peaks in the amount of rain over that period that there have also been many times where it has been lower.

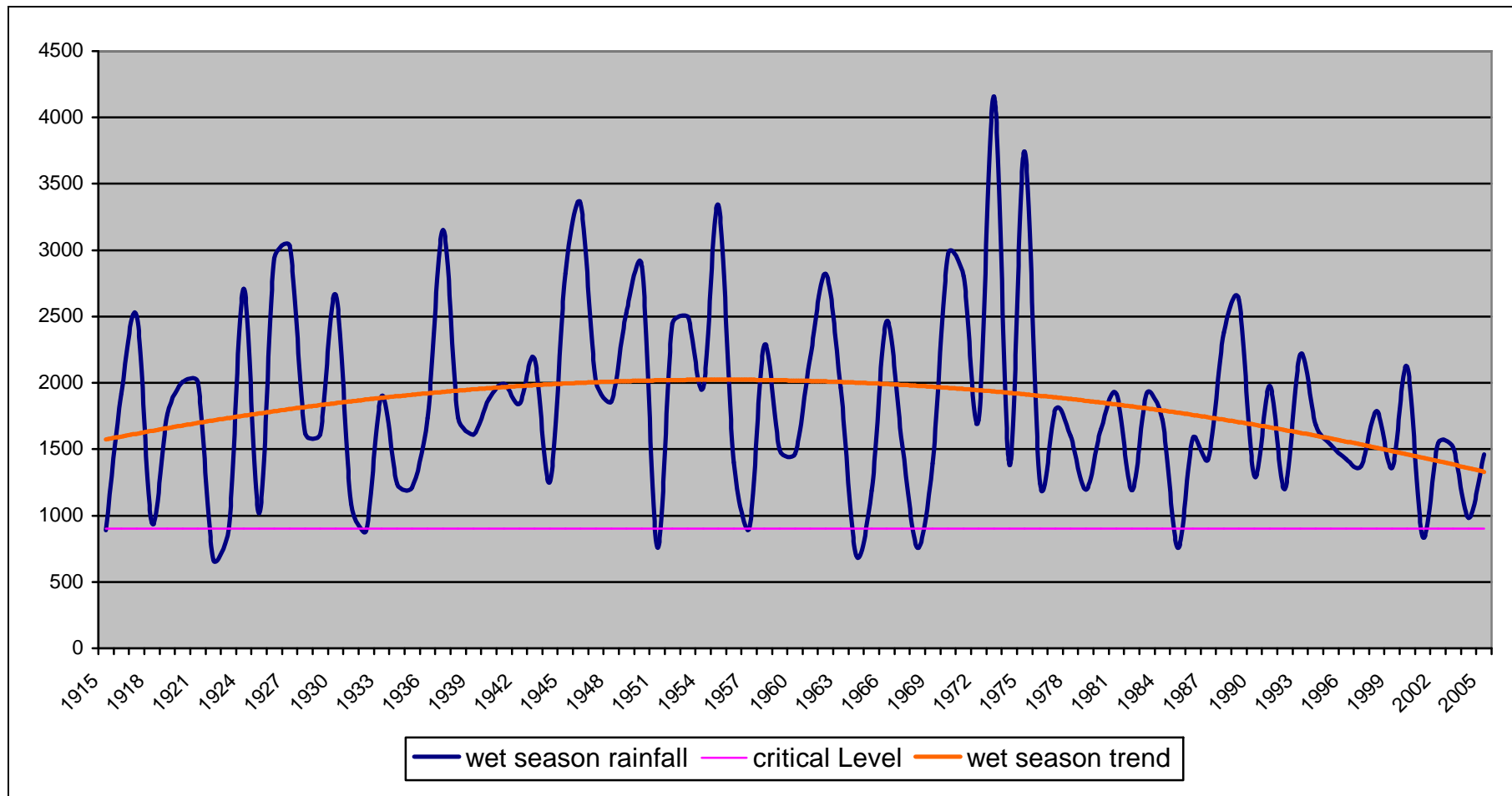
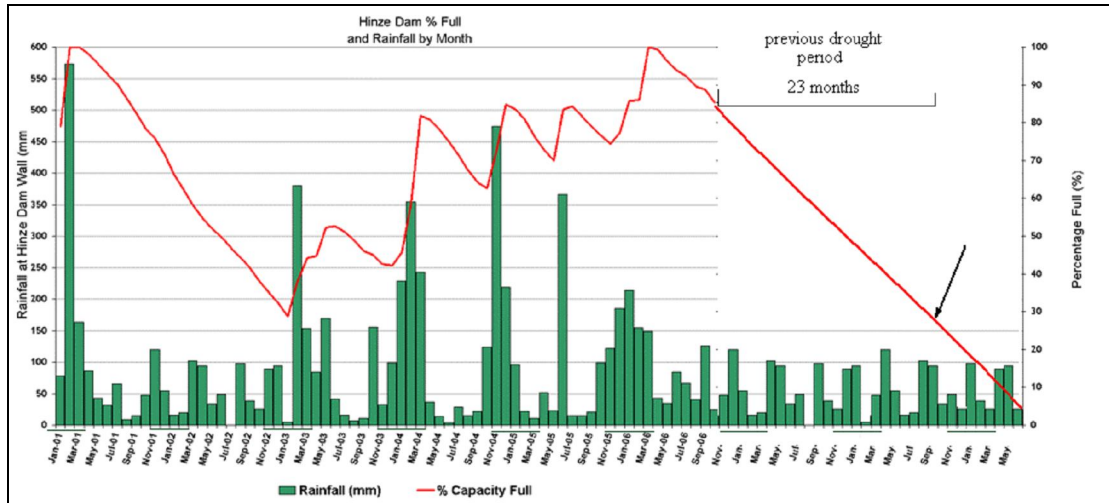


Figure 9. Springbrook catchment wet seasons 1915 – 2005 (Bureau of Meteorology & Department of Primary Industries Queensland, 2004)

The data represented in Figure 9 above shows that the wet season rainfall undergoes some intensity variation and that the possibility of having a low rainfall wet season of around 900mm is quite a common occurrence, with 6 such occurring in the period of data. There is also an apparent cyclical trend in the data, which trended up from the 50's to the 70's, further research is needed to understand this. This trend seems to be cycling down at present, but due to the relatively short span of available data and lack of knowledge in this area it is unknown what may occur in the future.

As can be seen from the rainfall data above, at around the time of construction of the Hinze dam (in 1976) the Gold Coast had quite bountiful wet seasons. This has contributed to the misunderstanding of sustainable yields from the system. The wet season in 1985 was however quite low (below the levels of the 2002 drought), but did not raise any attention at that time. It will be shown in the next section that this is likely to be due to the consumption being well within the ecological carrying capacity limits.

Since the Hinze dam was at a critical low point with a single year's low wet season, a 2 year low in wet seasons with current consumption levels would result in the Hinze dam failing to be able supply the regions consumption needs. This would have enormous implications for the social and economic sustainability in the Gold Coast. From analysis of the above rainfall data, it a 2 year low wet season has occurred in the periods 1964 – 65, 1931 – 32 and 1922 – 23. If then 2002 – 2003 wet season also happened to be a low season, then at the rate of metabolic consumption for water, the dam would have had no storage capacity remaining by about August of 2003.



**Figure 10. Extrapolating no wet season on dam holdings (Gold Coast City Council, 2005e)**

Extrapolating the rate at which storage for that period falls, indicates that the Gold Coast water supply only has capacity to withstand two low rainfall wet seasons in a row. This is now something that is perhaps recognised by the GCW as they subsequently identified a two year capacity for their dams in their sustainability reports for 2003/04 and 2004/05 (Gold Coast Water, 2003b, 2005b).

It has now been demonstrated that outstandingly low rainfalls can not be used to explain the water crisis of 2002 on the Gold Coast. Further, it has also been shown that based on the last 90 years of data the likelihood of experiencing a greater period of low wet seasons, such as 2 years, is significant. This supports that view that the current water supply paradigm is no longer sustainable for the existing water metabolism of the Gold Coast and clearly unable to cope with further expansion of the population.

### **3.2.2. Estimating the current water carrying capacity for the Gold Coast**

Incorporating carrying capacity into the development cycle, and understanding how it relates to sustainable water seems to be absent from current urban planning, despite broad recognition of it as being a significant factor in sustainable development (Gardner, 2002; Lenzen & Murray, 2003; Lundin, 1999; Oha et al., 2005; Parris & Kates, 2003; Troy, 2004; Uhlmann, 2004). While the exact limits of population that

can be supported in an area are subject to many variables, it is questionable that there would be no ecological limit on human activity (Haberl, Erb & Krausmann, 2001). A good working definition of carrying capacity is “the maximum population of a given species that can be supported indefinitely in a defined habit without permanently impairing the productivity of that habitat” (Wackernagel & Rees, 1995).

In attempting to determine the environmental water carrying capacity for the region the most basic parameters would be:

- amount of available water (assuming current water paradigm)
- water usage of the community (assuming current water paradigm)

As stated previously, the metabolic water usage of the GC is the relationship between the population of cells, and the cellular consumption (that is per person consumption) of water:

$$Mwd = Pn \times Ccw$$

Hence carrying capacity could be determined by the factors:

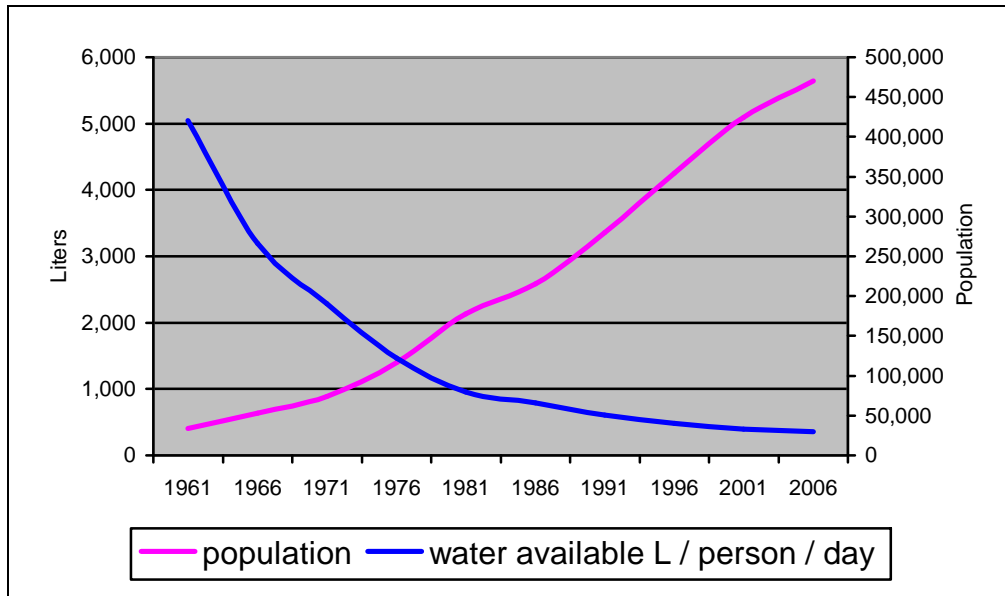
- amount of available water
- **Mwd**

Detailed data such per person water consumption for the GC is quite restricted, and perhaps not even available. For example no water consumption data prior to 1993 could be found for the Gold Coast. Three important sets of data have been identified that appear to reliable over a coincident period, these are:

- the amount of water extracted by GCW (Gold Coast Water, 2004a)
- the population (Australian Bureau of Statistics, 2006)
- water consumption data (Gold Coast Water, 2004a)

The GCCC in reviewing the impact of the 2002 water crisis determined that the sustainable yield of the dam system is some 170 ML/day (Gold Coast City Council, 2003). Accordingly for this study that figure has been used. Water is an exclusive resource, accordingly this amount was divided by the population at each of the sample years to get a water available per person.

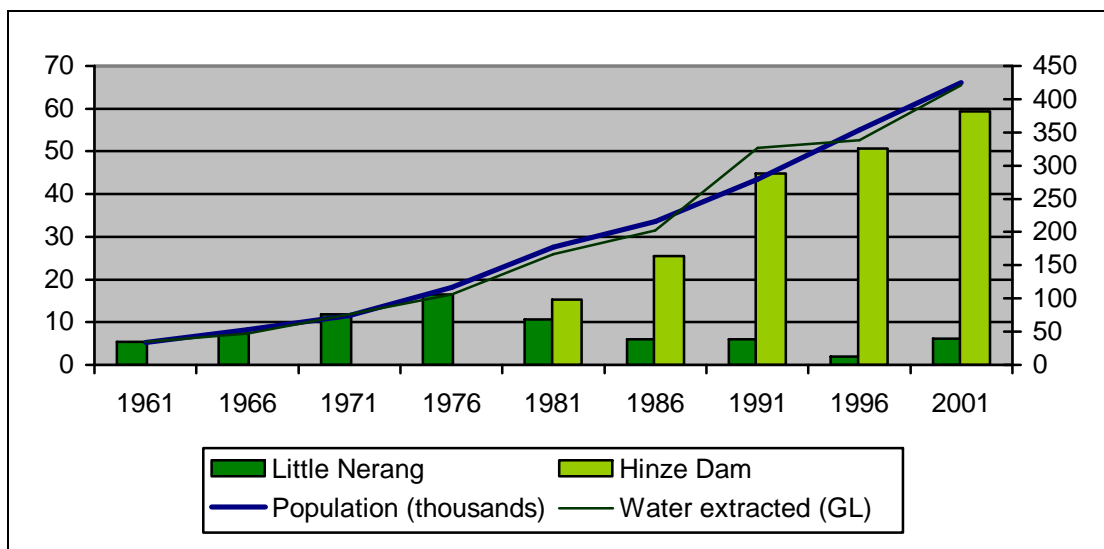
Using this and population data from ABS, over time the available water per person changes from over 5000L per person to under 400 L per person by 2006 (Australian Bureau of Statistics, 2006). The nature of this change is represented in Figure 11 below.



**Figure 11. Population VS water availability (Australian Bureau of Statistics, 2006; Gold Coast Water, 2004a)**

As the amounts of water are divided among successively greater populations the water available declines in a manner similar to  $(1/X)^n$ . If we calculate from a population of 440,482 in 2002 (Australian Bureau of Statistics, 2006) and average water consumption in Queensland of 376 L/person/day (Australian Bureau of Statistics, 2004b) we get an average consumption of 166 ML day. Including non-residential consumption into this, it is therefore not surprising that we see rates of well over 200ML per day in 2002. It is expectable that acute water shortages would be apparent.

To understand if the quantity of water extracted per person has also been effected by changes in water usage trends of the population, the water extraction rates were compared with the population. Figure 12 below shows the water extracted from both the Little Nerang and the Hinze dam from 1961 to 2001 along with population growth. Data on extracted water was derived from data presented to the GCCC Waterfuture committee (Gold Coast Water, 2004d). This shows that by 2001 about 65.5 GL was being extracted from the system per year, which equates to about 180 ML per day.

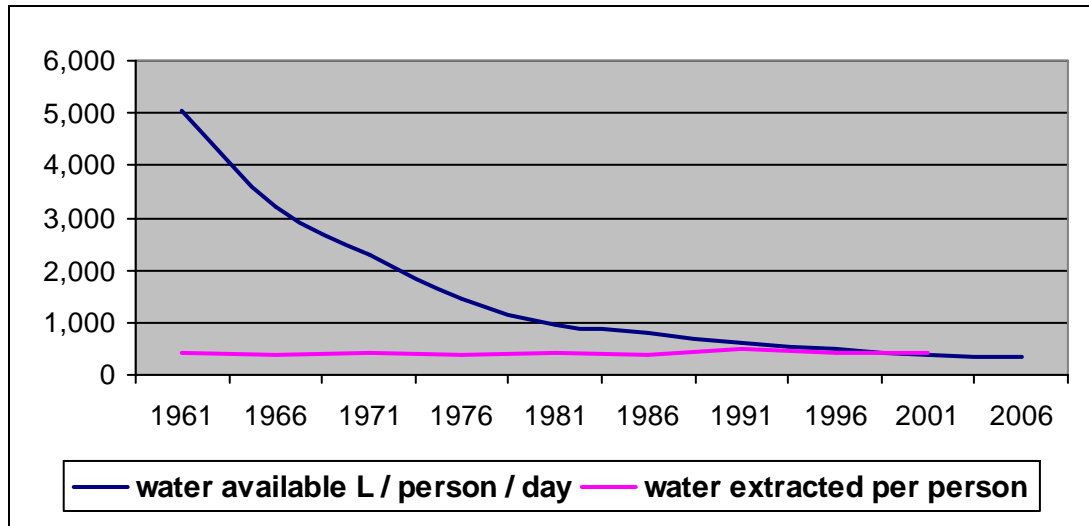


**Figure 12. Annual water extraction Little Nerang and Hinze Dams (Australian Bureau of Statistics, 2006; Gold Coast Water, 2004a)**

The population and water extracted show very similar growth rates, this follows the model that that was proposed in Figure 3 where cellular consumption of water remains constant, and the metabolic consumption of water increases due to population increase. This suggests that Ccw over the period has not changed significantly between 1961 and 2001. This is consistent with an ABS review of water which shows that household water use in Queensland has remained relatively constant between 1993 and 1997 (Australian Bureau of Statistics, 2004a).

By comparing the amount of water extracted per person with the amounts of water available, a point at which a limit is reached can be identified. As the population increases the available water is divided among more people, since water is used

exclusively (that is it is not a shared resource) the amount of water available per person must reduce as the population increases. Figure 13 below shows the amounts of water extracted per the population over time.



**Figure 13. Available water VS extracted water (per person) (Australian Bureau of Statistics, 2006; Gold Coast Water, 2004a)**

This indicates that in or around 2001 the Gold Coast reached the point where the available water has reached the amount of water being extracted per person. This makes it clearer that the environmental limits of carrying capacity using our existing water supply paradigm are at least close to being met. The amounts of available water previously exceeded metabolic consumption by significant margins, which explains why previous dry seasons had not brought about any crisis in water supply capacity.

As has been shown, exceptionally low rainfall conditions can not be identified in 2002, thus it is the assertion of this thesis that we are presently at the limit of environmental yields. Given no changes in water metabolism this means that the water carrying capacity is the existing population of the region.

As previously stated the population which can be supported by the environment in an area is dependent on

- the available resources and
- the practices of the population which needs to be supported

To further support that the current metabolic demand for has exceeded the sustainable carrying capacity of the area;

1. As established the existing water supply system is unable to withstand the loss of 2 consecutive wet seasons, which has a historical basis.
2. That the GCCC has been drawing an additional 35ML / day from Wivenhoe dam since January 2003 (Gold Coast City Council, 2004b) extending the reach of the metabolisms search for water ecologically available water.

This finding supports that for the available resources, and the existing practice of the population that the population has reached or exceeded the carrying capacity. This supports assertions in the literature that *“the population size of all major cities has reached the point where, at current levels of consumption, the limits of water supplies have been reached”* (Troy, 2004).

The developing population beyond the sustainable carrying capacity has been termed “overshoot”, and as can be seen from the curves in Figure 13 above the overshoot of the sustainable carrying capacity has been a gradual process. It has been suggested that communities can live in this situation for some time (W. Rees, 2006), and this is perhaps made more pronounced by our misunderstanding of the long term weather patterns. Clearly this needs to be redressed as soon as possible. From Ecological Modernisation perspective, this indicates that our existing metabolic consumption of water is no longer in balance with the ecological realities. Therefore our existing methods of production and consumption need to be altered, in accordance with environmentally realities of supply. Previously this research identified that CC is dependent on metabolic water demand and the available resources, thus the CC is not fixed and can be increased by altering either available resources or metabolic water demand. In the next section ways of altering metabolic water demand are explored.

### **3.3. The Water Metabolism - consumption**

As shown in Figure 2 the Gold Coast is a primarily residential area, with some levels of industrial and agricultural activity. Residential supply consumes around 74% of the

water supplied to the Gold Coast City, making it clearly at the greatest consumer of water (Gold Coast Water, 2005b). The nature of consumption in domestic situations is far more homogenous than that of the variety practices that form the non-residential properties serviced by GCW. Therefore making metabolic changes to the residential metabolism would at the very least represent the largest portion of consumption and potentially the greatest significance to sustainable water supply.

### **3.3.1. Systems losses - UFW**

Reducing water loss from the system is fundamental to an effective water metabolism, particularly in areas where water is less plentiful. In 2005 GCW extracted 65,650 ML (Gold Coast Water, 2007c) which is exactly the same amount that was reported as being extracted in 2001 (Gold Coast Water, 2004d). This is around 180ML/day, combining this with the 35ML/day supplemented from Logan, a supply of at least 215 ML/day has been available. However daily consumption is reported as averaging 180ML/day. In 2000 63,500ML (Gold Coast Water, 2004d) of water was extracted from the dams, yet 58,903ML was reported as being metered to residences (Gold Coast City Council, 2002, 2004a, 2005b). This suggests that between 12 - 35ML/day is either being lost or not reported.

Water losses within the water industry are unknown, and the concept is identified as Unaccounted For Water or UFW (Gold Coast Water, 2004b). The GCW is aware of these losses, and currently reports this as 13% (Gold Coast Water, 2004b). This is a high figure for losses within a domestic water distribution system, with national average figures being reported as between 8% and 11% (Australian Bureau of Statistics, 2004b). An alternative interpretation is that the figures returned in the ABS audit may be more conservative than the those in the findings here. Either interpretation shows that problems of losses exist within reticulated water systems, and potential exists for reducing needs to source water by reducing losses.

Water losses erode not only the water that is available to the organism, but also the effectiveness of increased water supply using the existing metabolism. Any additional water sources that input into the system will be reduced by at least 13%. The amounts

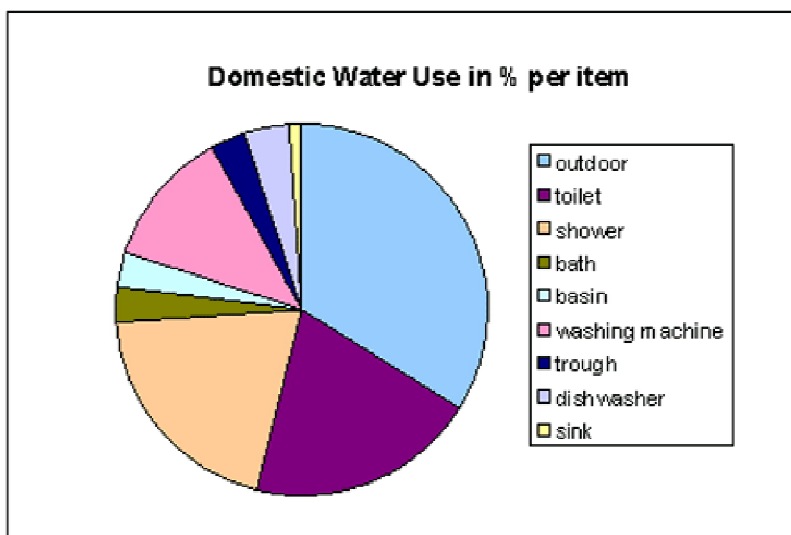
of water that could be saved by this are perhaps not metabolically sound to identify, as something like 50% of UFW is water lost through undetectable leaks (Gold Coast Water, 2004e). This supports suggestions in the literature that there is a diseconomy of scale for pipe network connections exceeding 1000 connections (Fane, Ashbolt & White, 2001). While the development of the reticulated water system for supplying all water needs may have been an appropriate paradigm in the past, communities have now grown to the point where the system is of questionable worth (Markcrow & Fox, 2005). The further expansion of the existing water systems may simply result in less efficient metabolism.

### **3.3.2. How urban water is used**

Understanding how water is used within the urban metabolism is as critical to sustainable use of water resources; perhaps more so than identifying additional sources. Since the times of colonial settlement, management of water in Australia has been characterized by cycles of increasing water supply to meet the growing demands of the urbanized society, and campaigns of ‘drought proofing’ the water supply (Melbourne Water, 2005; Powell, 1976; South East Water Limited, 2002; Tisdell et al., 2005). Successive governments in Australia have regarded providing water infrastructure as being a public good, and the necessity of constructing an infrastructure perceived as being essential to the development of the nation (Tisdell et al., 2005). Since settlement some 500 large dams have been constructed, and most of these since the 1970’s (Australian Bureau of Statistics, 2004b) indicating the pace to which this cycle has now increased.

Prior to 1993 there are no published data on how much water was being used per household, and how they might be using it, to allow water utilities or governments (who may wish to) to plan for water infrastructure. This makes understanding how the metabolism may have been evolving to this point a matter for conjecture. The use of water must have changed significantly since the 19<sup>th</sup> century, with the introduction of new metabolic ‘pathways’ such as: washing machines, flushing toilets and changed patterns of bathing, accordingly new pathways of conservation of that water could be developed.

High quality field data is essential to any methodology used in assessing the sustainability of urban water systems, and frequently a lack of validated data is used for interpretation (Betrand-Krajewski, Barraud & Chocat, 2000). Until about 2005 many government documents that discussed urban water usage were premised on data from a small number of sources such as the ABS and WSAA, one such example is Figure 14 below. The WSAA ceased publishing these figures due to the age of the original studies and recognition of their limited transferability in about 2001 (Foley, 2005). However, these studies continued to form the basis of decisions as recently as 2004, with government bodies making use of charts like the one below demonstrating the breakdown of domestic water use (Department of the Environment and Heritage, 2004).



**Figure 14. urban water break down (cited in Department of the Environment and Heritage, 2004)**

This suggests that outdoor water usage (watering lawns, washing cars) was as much as 40% of use, while ABS reports give a much larger range of outdoor usage, varying between 25 and 50%, as listed in the table below.

**Table 1. Household water usages as percentage (Australian Bureau of Statistics, 2004b)**

	NSW	Vic	Qld	SA	WA	ACT
bathroom	26	26	19	15	17	16
Toilet	23	19	12	13	11	14

Laundry	16	15	10	13	14	10
Kitchen	10	5	9	10	8	5
Outdoor	25	35	50	50	50	55

The significant variance in previous data suggests that either the data is of uncertain accuracy or that large regional variations are at work. Sources for this data are listed as a mixture of conference proceedings, personal communications and reports from a few major water suppliers ( NB ActewAGL 2003; Day, P. 2003, personal communication; Sydney Water 2001; Water Corporation 2001; WaterSmart 2001). Accordingly it is inappropriate to be using such data for an informed view of how urban water is used.

Water shortages have been identified by local governments for some time, with demand management and water conservation campaigns. Evaluations of these strategies at controlling the metabolic demand for water have been uncertain as to their long term viability (Kolokytha, Mylopoulos & Mentis, 2002; Syme, Nancarrow & Seligman, 2000; Troy, Holloway & Randolph, 2005). Understanding the water pathways in urban metabolism is becoming clearer, with a few recent studies undertaking exploration of ‘consumer use’. Significantly, in a country as large and climatically diverse as Australia only 3 studies into urban water use have been undertaken as at the date of writing. These are:

- Perth (Loh & Coghlan, 2003),
- Yarra Valley (P. Roberts, 2004, 2005),
- Sydney (Troy et al., 2005),

The key finding from these is that:

- that despite utility focus in this area, there is little or no benefit derived from demand management techniques such as restricting the capacity flow rate of taps in the residential setting.
- That demand management strategies are unlikely to bring any significant changes to water consumption
- The largest indoor use is shower followed by clothes washer and toilet
- That overall water use has been falling from 1991 to the present

- That restrictions targeting outdoor usage will be unlikely to continue to yield significant results

Considering that the focus of water restrictions has been on outdoor usages, this would support that outdoor usage has been significantly reduced by the existing water restriction regime, indeed the GCCC is already of this belief (Gold Coast City Council, 2003).

Demand reduction strategies, such as water restrictions and programs to refit homes with water efficient appliances, are not really a change in paradigm with no changes in sourcing water, supply strategy, community understanding of use or what is then done with the waste water. It therefore comes as no surprise that these have resulted in little significant reduction in water consumption (P. Roberts, 2005; Troy et al., 2005). While it is true that these strategies have yielded some reductions in the past, their ability to continue to provide reductions is doubtful (Syme et al., 2000; Troy et al., 2005). This brings into question the possibility that further water use reductions can be obtained from the community with demand management campaigns and suggests that a change at all levels is required; that is a holistic system or paradigm change.

Where to start is perhaps that the reticulated water system was intended for distributing drinking and cooking water (Peter H Gleick, 2000; Troy et al., 2005).

While evolutions which have taken place the cellular metabolism of the water (such as washing machines and flushing toilets), the water providers have not been concerned with directing that water usage, but just how to meet demands. Assuming a goal that reticulated water be provided as drinking water for drinking, two questions arise;

1. how much water should be the supply goal and
2. where to source the other water for existing metabolic activities.

The first question has already been the focus of attention for some years, with a basic amount of 80L/person/day has been put forward as being the a standard for drinking, food preparation and sanitation (P. H. Gleick, 1996). Others suggest that 20% of the existing supply be provided as the water supply obligation for a water;

“there is a basic need to supply only 10% of the water used in households at the highest quality. If we allow that some of the bathroom consumption should

also be of the highest standard, e.g. the bathroom hand basin and the shower/bath, we might settle on a need to supply potable water up to 20% of total consumption: say, 10% for kitchen use and 10% for bathroom use”(Troy et al., 2005).

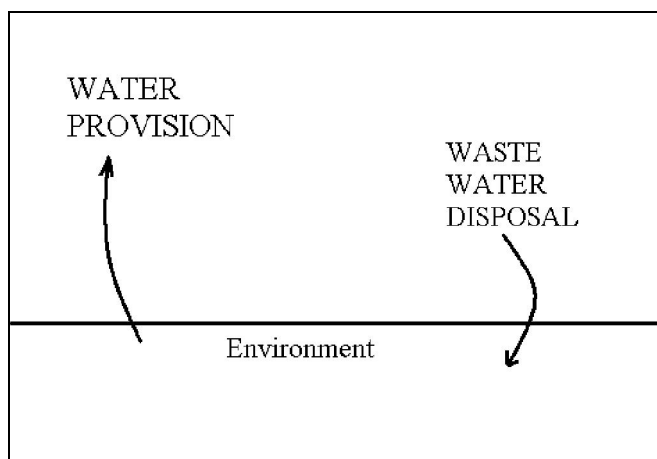
The present Queensland State government target for overall consumption is not far away from this figure at 140L/person/day (Queensland Water Commission, 2007) with data from ABS suggesting 189 L/person/day is already the amount used on drinking, showering, bathing and cooking(Australian Bureau of Statistics, 2004b).

Considering this from the perspective of ecological modernisation, we need to understand how we can reorganize our system in such a way as to find a balance between existing consumption and the ecological realities. Considering this from the framework of urban metabolism, we need to understand how can we reorganize the metabolism of the city to be within environmentally sustainable limits, without compromising our growth and viability as an organism. The next section explores restructuring the urban metabolism to enable this.

### **3.3.3. Water Cycles in the urban organism**

The urban metabolism organism could be thought of as being introduced into Australia with colonial settlement, at the same time other organisms were also introduced to Australia. As has been suggested plant ecology provides a number of useful examples. Among the introduced plants by settlement in Australia, the historically significant cactus *Opuntia stricta* was introduced sometime in the early 1900’s. This plant soon spread over the continent, including some of the driest parts of central NSW, with enormous vitality (Freeman, 1992). Clearly restricted environmental water is was not a limiting factor for the metabolism of *Opuntia stricta*. Organisms such as cacti are highly effective their ability to thrive in environments with low water availability. This is achieved by the reduction of water losses, and through the storage of water internally to the organism, providing models which could direct the adaptation of the urban metabolism towards sustainability.

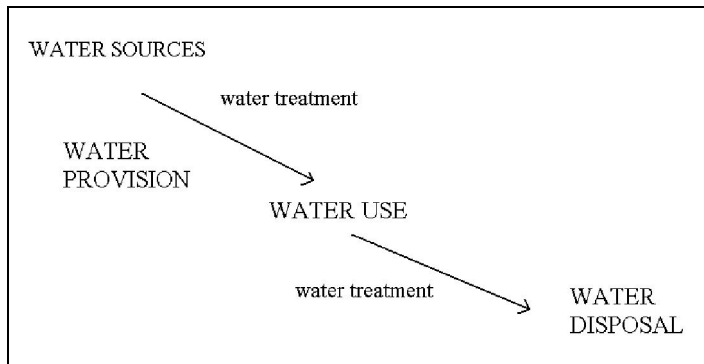
Water management in Australia has historically viewed water provision and waste water disposal as being separate. Provision of water supplies was gradually phased in from some times in the 1930's on the Gold Coast when Southport Water began operation (McRobbie, 2001). At this time there was no sewerage system, and so waste water was not collected and disposed of by the Council, most homes had their own 'grease traps' and disposed water into the environment, Figure 15 represents the separate nature of water services at that time.



**Figure 15. Separate water and waste disposal**

Initially the treatment of waste water was principally to satisfy health issues and reduction of nuisance, and only in the last 30 or so years consideration of the environment has been incorporated into waste water disposal. However both share a common base, that they depend upon environmental services.

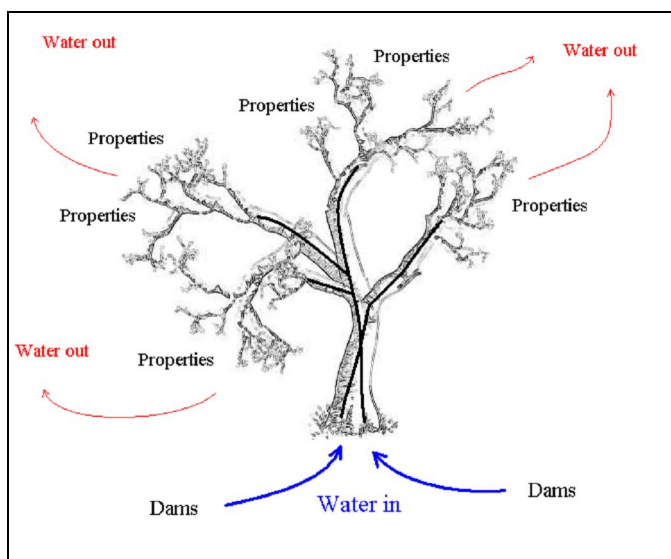
So far the predominate usage of water has been to extract, use, and then dispose of it in a linear system (Gardner, 2002). In this linear pathway of using water, water is obtained, treated, used, treated for disposal and then disposed of, which introduces a number of energy consumption steps as well.



**Figure 16. Gravity fed view of water and waste water**

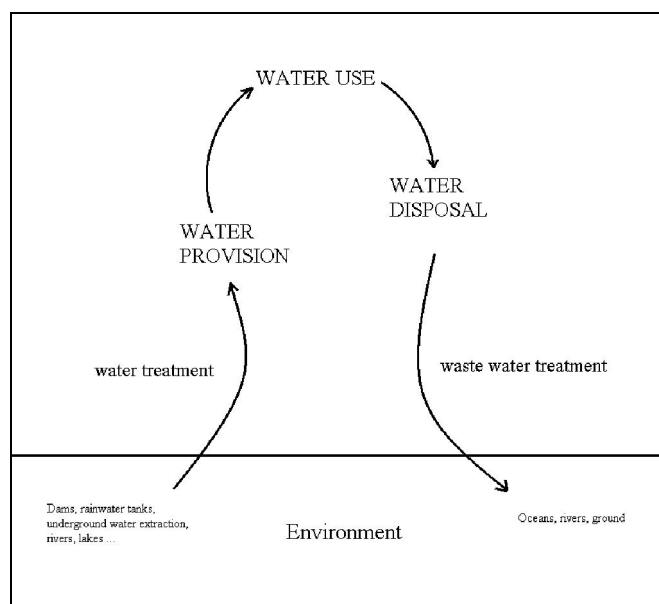
Typically this involves the water source being a dam in the hinterland, as it is in the Gold Coast , with gravity making the entire process more efficient. This in effect a ‘water production line’ with gravity contributing as free energy source, aiding the movement of water from the mountain reservoirs to the community and then to the ocean or rivers where water is most typically disposed.

The metabolic view unifies the community and the water supplier, to form parts of the whole system. The metabolism model can be developed further to encompass the morphology of the urban organism. As has been suggested, this organism can be modelled along the lines of plant. The water provider is thus the equivalent to the roots of the plant, the properties connected to the reticulated water system represents the leaves of the plant. This is essentially the cellular structure of the body of the organism.



**Figure 17. metaphor for the morphology of the urban organism**

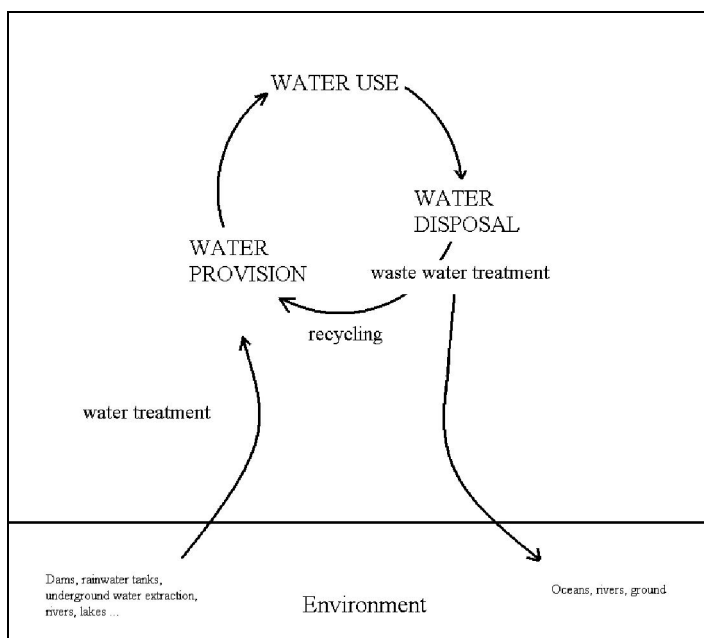
This expanded model for the metabolism of the city then gives scope to explore how other plants that are adapted to suite a dry environment can provide insights on strategies that would be appropriate to the organism of the Gold Coast. This is what occurs with GCW who supply water to the community, just like the roots of a plant, they do not actually keep the majority of the water that they source for the organism. The flows of water in this metabolism can therefore be represented as extracted from the environment, into the organism, and then back into the environment after use.



**Figure 18. Water drawn into the metabolism and returned as waste**

Figure 18 above shows the pathway of water across the boundary of the urban organism. This overlies well with existing views currently expressed within the literature, which concur that the community and the water utility both effect the entire water system (Lundin, 1999), and that it is the water use behaviour of the community which will make the greatest impact on the system overall (Troy et al., 2005; Troy & Randolph, 2006). As has been shown in the previous section water is, obtained and treated to drinking water standards, then used with little regard of its quality or “fit for purpose” and disposed of. Exactly following the “take, make & waste” cycle that Rees (1996) suggests is so typical of many water systems.

Many sources in the literature identify water recycling as a strategy for alternative sources of water (Gardner, 2002; Radcliffe, 2003). Some of the more progressive water authorities, such as the GCCC, are including some amount of recycling into their water strategy. This is done by essentially harvesting waste water from homes and business using the existing wastewater disposal system, and then at the waste water treatment plant further process it to become suitable for re-use. There are applications that do not re-distribute this as drinking water, but make the water available for other purposes, such as irrigation of park space within the city or distribution to non-residential users (Gold Coast City Council, 2006e).



**Figure 19. Recycling in the water use cycle**

This strategy is described above in Figure 19 and represents recycling currently providing reuse of around water amounting to around 14% of delivered water (Gold Coast Water, 2005c). This expands the amount of available water to the organism, but as will be shown is also at the cost of quite some amount of energy. Further, this in no way impacts on the amount of water which must be delivered to the properties, or in the costs of removal and disposal. As will be discussed later the costs of waste water disposal are 3 times higher than that of water supply. It does effectively reduce the water needs, however it comes at a significant energy cost. It has been identified that recycling projects created by waste water providers may be undertaken to achieve

targets set by other governmental authorities (MacDonald, 2004) rather than for water supply objectives.

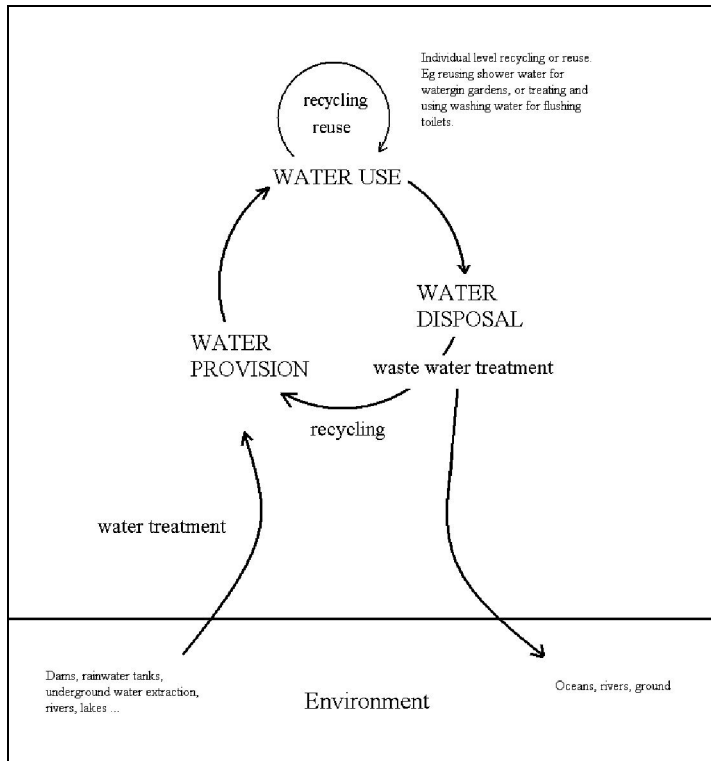
Water is conserved only if waste water is used on-site (Meade, 2007), and one of the major objectives for any water provider is to 'manage demand' which essentially means reduce consumption. These two objectives can be met if the properties are reusing or recycling water on site. Both the draw upon the reserves of water and the requirement to dispose of and treat waste water is reduced.

Terrestrial plants, like cities, are static in their location; meaning that unlike animals they are unable to move themselves to new locations in search of more favourable conditions. Many desert plants close their stomata during the day, the time when most water would be lost; this significantly reduces hence water loss to the plant. Water reuse at the *urban organisms cellular* level can effectively reduce the needs for water of the *urban metabolism*. Just as the plant effects significant water savings by each leaf cell closing its stomata the urban metabolism can benefit by reducing the water lost at each cell that undertakes some water reuse.

While there seems to have been an amount of reuse of water in the past (Jefferson, Laine, Parsons, Stephenson, & Judd, 2000), in current urban metabolism has become significantly reduced or absent. A useful input from the past is that my mother was raised on a remote rural property, with no access to 'town water'. Like so many other rural properties, their water was solely 'tank water' from roof catchment. Recalling how my mother had preferred using a more manual washing machine which allowed her to catch the water from different stages of washing and rinsing. She would wash the whites first, so as to be able to re-use the 'suds' water, then catch the rinse water to use for the next 'suds' load. In dry times, all water then finally re-used to water her plants around the yard.

Incorporating these concepts of water reuse at the urban organisms cellular metabolism means that water is conserved at the cellular level. This means that therefore the complete metabolic demand for water can be reduced, thus creating a more efficient water system. This is expressed in Figure 20 below, which makes clearer the relationships between the cellular (or per property) and organism level

water reuse. There is no reason why this cellular re-use need only be the residential component of the urban organism, as non-residential situations could also undertake re-use (as for example car wash businesses currently do).

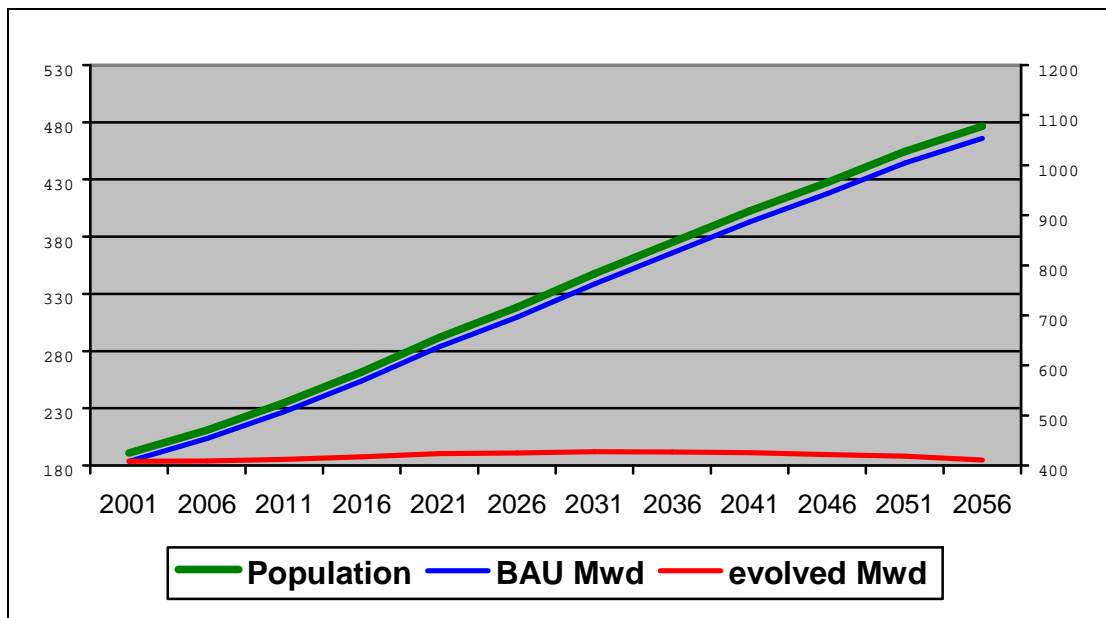


**Figure 20. Separating property and community views of recycling and reuse**

This water is being reapplied to metabolism within the cells this will alter the cellular demand of water, and therefore the metabolic demand of water. As previously shown the Metabolic demand of water (**Mwd**) is dependent on population (**Pn**) and cellular consumption of water (**Ccw**). During growth in **Pn**, if **Ccw** can be significantly reduced by recycling then **Mwd** could at least rise at a lower rate, and perhaps even reduce.

To demonstrate this a model was created as part of this research to contrast the metabolic water demand, incorporating recycling on site, with linear growth in water usages. The population of the Gold Coast is around 500,000 people (Australian Bureau of Statistics, 2006). Hence it may take time to distribute the required technology and practices through the population. Consumption has been chosen as

432 L / person / day<sup>1</sup> for existing population. The model is based on a modest evolution of cellular consumption of water, being a reduction of 5% every 5 years. New homes being built must comply with regulations on the water efficiency, which includes mandatory installation of rainwater tanks (Gold Coast City Council, 2006c). Therefore in the model new population growth will begin at using only 212 L / person / day. The same formula applied to these homes as on-site water recycling strategies are incorporated throughout the community. The graph below indicates the effect on **Mwd** over a period of 45 years, incorporating successive **Ccw** reductions. Population growth is simulated population growth over the period at rates that have occurred, and to give an end point population that is consistent with the data that was used by the GCCC in their calculations. The GCCC of 'business as usual' demand which appears as the BAU **Mwd**.



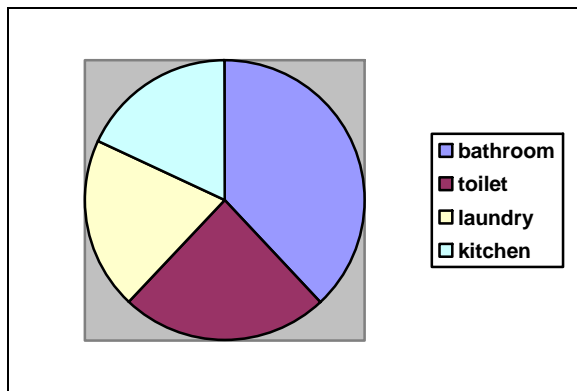
**Figure 21. water demands BAU vs reducing Cellular losses**

This model indicates that peak consumption of 192 ML/day is reached by 2031, while the BAU **Mwd** exceeds this by the first 5 year period. By 2056 the evolving metabolic reduction brings the Metabolic water demand to well under ½ of the GCCC BAU projections. The definition of **Water Carrying Capacity** included **Ccw** and **Pn**. Applying this finding to the calculation of **Wcc** as **Mwd** reduces water carrying

<sup>1</sup> which was determined to match the GCCC calculation of 935 L per residence per day. Using a population of 424829, and 196500 residences to determine the consumption per person at 2001.

capacity increases. This now brings **Mwd** nearly to levels which would more readily support a population of 1 million.

This level of water reduction is possible when one considers the nature of the ‘waste water’ produced by different home uses, such as showering, or the rinse component from doing the laundry. Not all of it becomes a dangerous health hazard which must be disposed of instantly. Residential water uses do not all make water unsuitable for use. Figure 22 below shows that the water levels used in the bathroom would provide enough to cover the volumes used for toilet flushing and a large amount of the laundry too if the water could be reused.



**Figure 22. Indoor house hold waste water sources (Australian Bureau of Statistics, 2004b)**

Making water reuse a part of the Cellular metabolism, would then reduce the level of water consumed to something in the order of half of the current metabolic water consumption. This form of reuse has been identified previously, however in many contexts a major technical impediment being the temporal difference in the generation of grey water, and the requirement for flushing necessitating the storage of grey water (Jefferson et al., 2000). However obstacles to the treatment and storage of this water are emerging, some of which can a process grey water to grade A level recycled water making it possible consider storing the water without harmful health effects (Australian Nuclear Science Technology Organisation, 2006). This would enable the evolution of metabolic water demand to reduce by 60%, potentially more as it may be possible to re-use laundry and shower more than once (A. Taylor, 2006). While not commercially available at this level yet, other cost effective and practical technology

for water reuse at different scales on-site already exists. It is expected that this type of reuse technology could be commercial within the next five to ten years (A. Taylor, 2006).

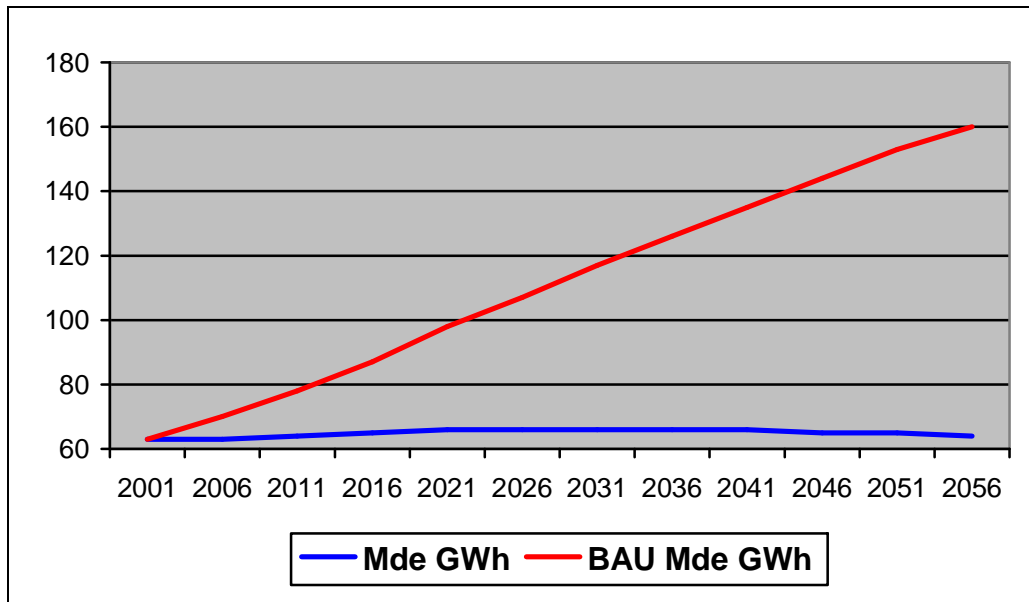
The inclusion of these technologies and strategies to within homes will require some social capacity building. This however will have beneficial effects as the community will again become more involved in the water which affects their lives. On-site reuse would also yield positive external benefits in reduced waste and reduced energy demands. The holistic view that has been adopted by this study by incorporating the disposal of water is now able to identify a significant component of the metabolism that is often not considered, energy needs.

### **Externalities to water metabolism – energy**

Providing water requires energy, but the disposal of it requires more. The energy costs of waste water disposal are typically 3 times that of the cost of water supply (Gold Coast Water, 2005d). In terms of energy usage, disposal of sewage accounted for 78% of the electricity usage of GCW while supply and treatment only required 22% (Gold Coast Water, 2003a). With 67KWh consumed per property in water supply, and 255KWh per property in waste water treatment. There is a significant difference in the contribution to externalities between water supply and water disposal, however these can not really be treated separately. To explore this further, another model for the energy of the metabolism water was created for this research, this is termed Metabolic demand for energy (**Mde**). Based on the same number of residential properties used in the previous model and the above stated energy consumptions per property for water and waste water treatment, energy uses were projected assuming the same growths in the urban water metabolism.

Figure 23 below shows the variation in metabolic energy needs between the two scenarios generated in the previous model. As expected the growth in metabolic water demand contributes significantly to the energy demand. By evolving the metabolic demands for water the future energy needs remain fairly constant, however the with increased water demand energy needs increase around 160 GWh, approximately a 100

GWh increase. Therefore the strategy to reduce water consumption has resulted in significantly reduced energy consumption by around 100 GWh of electricity required by 2056.



**Figure 23. BAU vs evolved Mde for waste water (GWh)**

To place these energy amounts in some sort of context, the energy component of waste water is about 10% of the total electricity that this researcher uses in domestic consumption for the same period.

While this reduction of energy demand does directly effect the amount of available water, it is a significant positive externality or cobenefit of this option, as it impacts significantly on the ecological and economic sustainability. Questions have been raised on the ability of the region to supply sufficient quantities of electricity due to among other factors, limitations of water supply needed by power generation (Marszalek, 2007; G. Roberts, 2007), so reducing **Med** will have further beneficial external effects.

The findings of this model support observations that integrating externalities into water management is essential in working towards understanding the full costs of water (MacDonald, 2004). As waste water is conserved only if reuse occurs onsite (White & Fane, 2001), by evolving the urban metabolism to incorporate on site reuse the demand for water and the requirement for waste water disposal is reduced, thus the complete water footprint of the society is reduced significantly.

### **3.3.4. Using the environment more effectively - supplementing and diversifying our reserves**

Aside from improving the water efficiency of the urban metabolism, making more effective use of existing environmental water is another way of extending the water carrying capacity of the environment. Looking again to nature for an example, some solutions are readily found. The family of bromeliads are remarkable plants, as they obtain their water not only from their roots, but from their leaves, in some cases, obtaining all of their water through their leaves (D. H. Benzing & Pridgeon, 1983). The leaves of the plant are covered in absorptive structures called foliar trichomes, which function to draw water that lands on their leaves into the interior by a combination of capillary action, and osmosis (David H. Benzing, Henderson, Kessel, & Sulak, 1976). In locations where there is insufficient water available to their roots, these plants do quite well by gathering water through their roots. Applying this concept to the organism of the Gold Coast would indicate that altering the cells (that is the property's) structure to be able to obtain water for themselves would reduce the demand on the root structure (that is the dam and existing reticulated water system) to provide water needed by the organism and allow for growth.

Rainwater tanks, once common to homes in the Gold Coast, had been legislated against for a number of reasons of health (O'Connell, 2007; Troy, 2004). These have recently been made available to the community again as a source of water to on the Gold Coast. As has been shown in earlier sections, rainfall is the greatest source of water for the Gold Coast, and rainwater tanks on site are a reliable method for obtaining water. Studies have shown that the use of on site harvested rainwater in urban environments can provide as much as 60% of the water requirements of each residence (Gardner, Coombes & Marks, 2001). This would reduce consumption from the reticulated water system by greater than 60%, and even 43% during low rainfall periods (P. J. Coombes, Spinks, Evans, & Dunstan, 2004).

Significantly due to the impermeability of the roof harvesting surface, rainwater harvested can effectively provide water even in times where there would be little or

no increase in dam holdings. Rainfall records from BoM show that residential areas, such as Southport, receive significant rainfall during periods dry seasons and lower rainfall periods. As is clear in Figure 24, while wet season rainfall levels in Southport and Springbrook are both below average levels, there are also periods when significant rainfall occurred, even during the 2002 water crisis period.

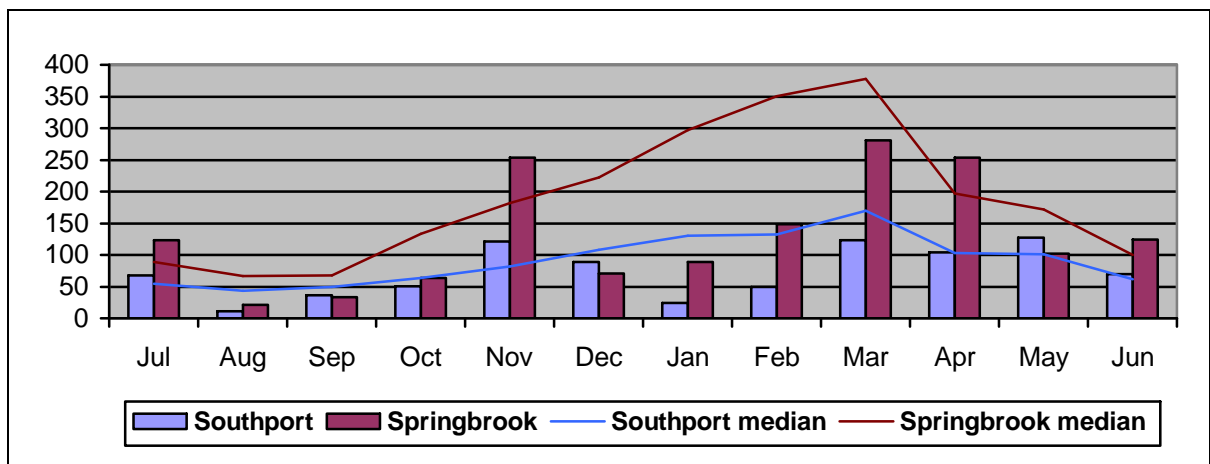
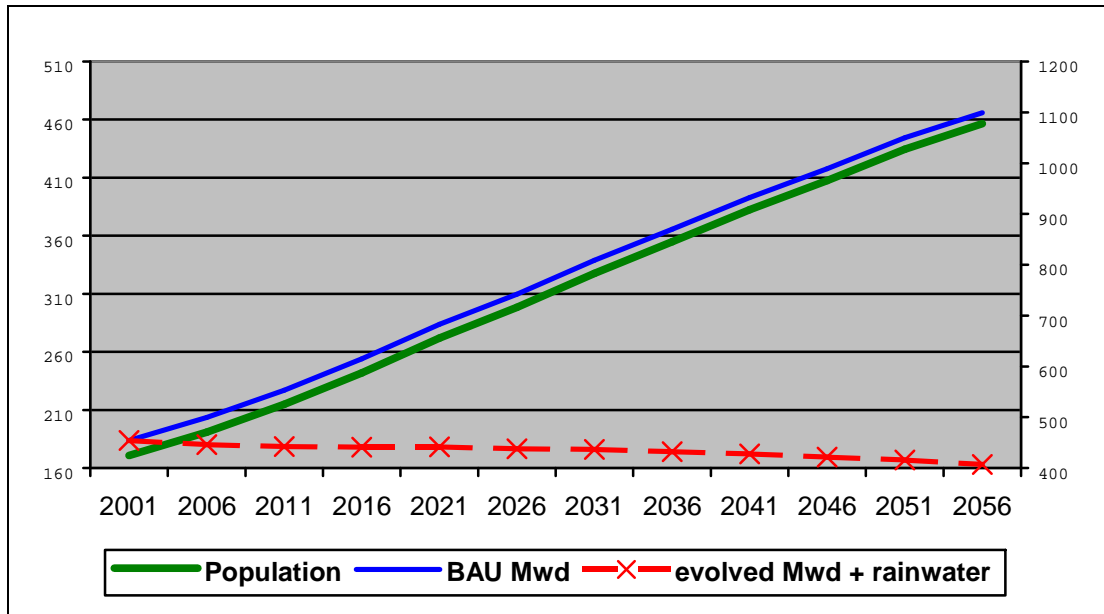


Figure 24. Southport vs Springbrook rainfall during 2001 – 02 drought (Bureau of Meteorology & Department of Primary Industries Queensland, 2004)

In months where Springbrook rainfall fell to levels that would yield no improvement in dam holdings, rainfall in residential areas such as Southport was sufficient to add to rainwater tank holdings.

To demonstrate the changes to the metabolic water demand the model which was constructed to demonstrate metabolic water demand in Figure 21 was altered to incorporate rainwater harvesting. A very conservative reduction in water demands of 3% every 5 years to the existing population was used, and previous assumptions about the conditions placed for the additional population created by growth. This is shown in Figure 25. The results indicate that **Mwd** would actually begin and continue to fall. This would significantly alter the metabolic water demand and further extend the ecological carrying capacity. The Gold Coast **Mwd** would then be able to sustain a population increase of over double with an actual decrease in demands for water from the existing reservoir.



**Figure 25. Water demands BAU vs rainwater harvesting evolved Cellular metabolism**

Additional to the increased water carrying capacity provided by rainwater tanks, there are significant external co-benefits to the society derived from more effective management of storm-water runoff and the potentials for energy reduction.

Infrastructure savings and minimisation of community losses are also significant, as tanks reduce the amounts of runoff from the impermeable urban surface. This is well recognized in the literature as a side effect benefits that can be obtained, resulting in the ability to forestall the requirement of upgrading stormwater management systems (P. Coombes & Kuczera, 2000; Dupont & Shackel, 2005; Gardner & Samara).

Rainwater can also be harvested in this way in many different properties not only detached homes. This is also significant because as much as 30% of the population growth in the region is expected to be from infill and redevelopment (Queensland Government Office of Urban Management, 2005). A study by Gardner et al shows that for high density housing developments rainwater gathered on site can supply as much as 60% for the whole water needs of the residential development. Studies have shown onsite rainwater harvesting in the New South Wales city of Newcastle provided savings of up to half of the mains water usage, additionally half of the storm water discharge could be saved, as well as a reduction of approximately 20% of the peak daily water demand when employed across the whole of the city (Gardner et al., 2001). This saving was estimated to be around 66 ML/ day, which is larger than any

single new component of the Waterfuture strategy (Gold Coast Water, 2006a). The population of Newcastle and the Gold Coast are approximately the same, so this result is comparable to the Gold Coast region.

Solutions which leverage off harvesting rainwater at the site contain a number of external benefits these are:

- The contribution to the water supply is not statically defined, but proportional to the community utilization and population, thus the amount of mains water savings increases with population and utilization
- Water security improves as the community is less reliant on mains water, if the mains water should become compromised properties would still have access to water, as occurred in Sydney (Stein, 1998),
- Energy and resources are saved in the reduction of treated water which needs to be supplied to the community
- Storm water hazards (such as flooding events) would be lessened, and existing infra structure would not need to be upgraded to handle greater volumes.
- High volume users can identify and cater for their own water needs without raising overall community consumption

To this point it has been shown that the water crisis on the Gold Coast has not been caused by meteorological drought, and that the water shortage is an indicator of unsustainable growth in the urban metabolism's metabolic demand for water. This growth is now at the limits of ecological carrying capacity. Further, some proposals for modification of how the urban organisms metabolism could evolve to fit within the ecological carrying capacity have been explored. It has also been shown that this has additional significant co-benefits in externalities to the water metabolism.

In the following section these findings are reflexively applied to the concept of sustainable development. It is because it is the goals of sustainable development that has driven this analysis. At this point reflection on the nature of sustainable development is required to carefully address the comparison of these findings to that undertaken by the GCCC in their Waterfuture strategy.

### **3.4. Sustainable development - what is sustainability?**

Perhaps the longest standing accepted definition of sustainable development is as defined in the Brundtland Report is:

“development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” (World Commission on Environment and Development, 1987)

Since this time hundreds of attempts have been made to define what is to be sustained, for how long, and how to link development to the environment, yet there appears to be no universally accepted definitions of sustainable development (Parris & Kates, 2003). With so much work being directed at this topic there must be some reason that 20 years after the findings of The World Commission that this seems such an elusive goal.

It has been suggested that the reason for this is lies in that sustainability is a dialectical concept (Peet, 2001). A component of dialectic reasoning is that it “attempts to characterize the nature of reality in its most abstract and general terms”, and can encompass contradictory statements (Sayers, 1990). Sayers offers an eminently comprehensible understanding of this in applying dialectic analysis to the logical paradox of describing motion. Motion can be described as an object being at a point in space for an instant of time, and that in another instant it is in a different location. This in essence a reductionist approach, and while succeeds in describing the effects of motion, and is not describing motion itself. Describing motion as an object being at one point at one instant of time, while accurate does not identify motion, as it may also describe a stationary object which is moved and then at rest again. In order to express motion the description must also include the concept that the object ceases to be at that location in that instant of time, and thus identifying it as being in motion (Sayers, 1990).

Viewing sustainable development as a dialectic we would need to include discussion on what it was, and what it was not. This goes some way to explaining the difficulties in conceptualising sustainable development that is reported researchers and theorists

who suggest that it is only in ongoing iterative processes involving all stake holders that sustainable systems will be developed (Cavalcanti, 1996; Elkington, 1999; Manners, 2002; A. C. Taylor & Fletcher, 2005; Uhlmann, 2004).

### **3.4.1. Markets as ongoing iterative community involvement**

The market is effectively an ongoing iterative process on the establishment of the relative value of commodities with respect to the prevailing environment. Price and worth are reflected in the scarcity of the goods and govern supply and demand. By allowing the market to operate freely the value of water and the worth of systems to conserve it is effectively understood and clarified by society. This has been a major impediment to the discourse on the sustainability of water, with the existing water oligopoly effectively undermining this with prices which prohibit the valuation of such systems. A recent study on the Gold Coast found that the effective payback time for water efficiency systems being between 74 years and never (Gardner, Millar & Hyde, 2003). It is observed that the financial calculations undertaken by the State in its decisions do not include the savings in infrastructure conferred by water efficiency systems when determining development plans (P. J. Coombes & Kuczera, 2003; Institute for Sustainable Futures, 2002).

As identified previously not all of the metabolic requirement for water must to be at the same level of quality as drinking water. It is systems in providing non-drinking water needs which could be addressed by the market. Until 2004 grey water reuse was not permitted in sewered areas in Queensland (Environmental Protection Agency (Queensland), 2004), however recently changes due to pressing community concerns and water supply issues has prompted the regulations to change (Green light for Grey water, 2004). Despite this legislative impediment there already exists a number of systems on the market, which have enabled the community to begin using and speeding uptake of these water saving systems.

Allowing market participation will extend this existing market, and provide the sort of evolutionary environment that will facilitate the innovation to provide technical solutions. It has been suggested that water restrictions are a symptom of failure to allow a properly functioning market to balance supply and demand (Business Council

of Australia, 2006). An effect of market participation is the successful development of technological solutions according to market fitness, and the speculation by State water providers on what will be the best sustainable outcome can be decided by the discourse and interactions of the market. This is consistent with the views of EM scholars that reorganisation of the systems can only be realised by moving into the modernisation process, involving mechanisms of free markets and democratic pluralism (Mol & Spaargaren, 2004).

By stimulating markets, economic development is also further stimulated, which has positive effects for the community. As identified above, markets are already moving in the directions of providing exactly the types of changes in the water metabolism that have been identified by this thesis. A further finding of this research then becomes that a sustainable water solution needs to involve market participation in the regulatory mechanism of the urban metabolism and the evolution of water efficient metabolic systems.

## **4. Comparing results with the Gold Coast Waterfuture**

As most readers would know, “there are more ways than one to skin a cat” (Twain, 1889). Therefore the outcome of this research is not the only solution to the problem. During the this study the GCCC developed a solution to address the water crisis on the Gold Coast, accordingly it should be examined. This section will examine the Gold Coast Waterfuture strategy, which has been put forward as the way to “secure the City’s water supply needs” and “ensuring the sustainable management of our water supply 50 years into the future” (Gold Coast Water, 2006a).

The Waterfuture strategy was created to “establish a sustainable water supply strategy for the City which accounts for its current and future growth requirements” (Gold Coast City Council, 2003). The strategy was developed over a period starting in April 2004 and concluding in November 2005, when it was “formally adopted by the Gold Coast City Council on 12 December 2005” (Gold Coast Water, 2006a). According to GCW, “the Gold Coast’s variable climate and growing population requires a paradigm shift in thinking” (2006b), and so it would appear that there is much in common with the premises of this thesis. However while the plan set out to create “an innovative, integrated water supply strategy that presents first-rate outcomes for the City in terms of long-term environmental, economic and social sustainability” (Gold Coast Water, 2006a) it will be shown that it represents more of the ‘business as usual’ that has been the approach of government that has brought us to where we are now.

### **4.1. The Gold Coast Waterfuture – “we need 240ML/day”**

The starting point for the creation of the Waterfuture plan declares the future of “the city’s ‘business as usual’ water demand” as 466ML/day (Gold Coast Water, 2005a). So the Waterfuture strategy begins by determining the water requirement for the end point of its time reference. Calculations for determining the future demand for water assumed that demand would grow linearly with population. The calculation following the formula:

$$\text{Water requirement} = \text{Water ET} \times \text{Unit Demand}$$

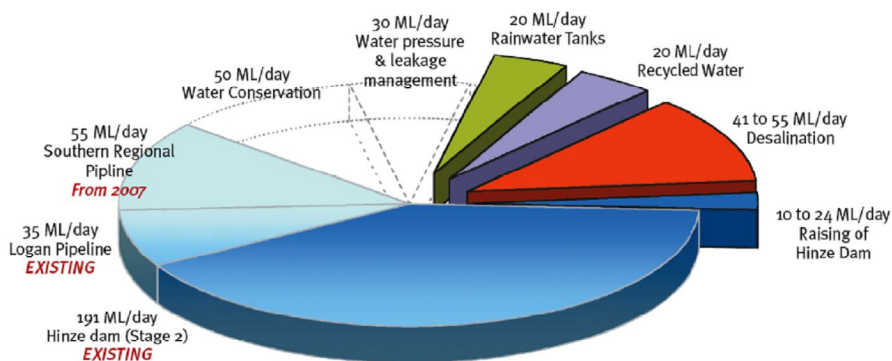
Where a ‘Water ET’ is a unit of measurement of water demand, comparable to the water demand for a single detached dwelling, having approximately 3 people and ‘Unit Demand’ is the number of properties that receive water (Gold Coast Water, 2004c).

Even though the calculations were undertaken in 2005, the ET derives a figure for calculation by taking into account daily consumption from 2001 meter readings and includes allowance for unaccounted for water (UFW), stolen water, discrepancies in meter readings and a climate correction factor of 2% (Gold Coast Water, 2004c). A figure of 935 L/ET/day was derived (Gold Coast Water, 2004c). Based on projected population growth from 196,500 to 497,952 properties by 2056, the city’s water needs were then projected. 2056 water needs = ‘Water ET’ x ‘Unit Demand’

$$= 935 \text{ L/ET/day} \times 497,952$$

$$= 466 \text{ ML/day (Gold Coast Water, 2004c)}^2.$$

It was assumed that existing water supply was 226ML/day, so subtracting this from the ‘business as usual’ needs it was determined that there is a need for 240 ML/day. To meet this 240ML/day shortfall a number of new sources were identified. Sources and demand reductions were treated as sources in an additive process to produce a total.



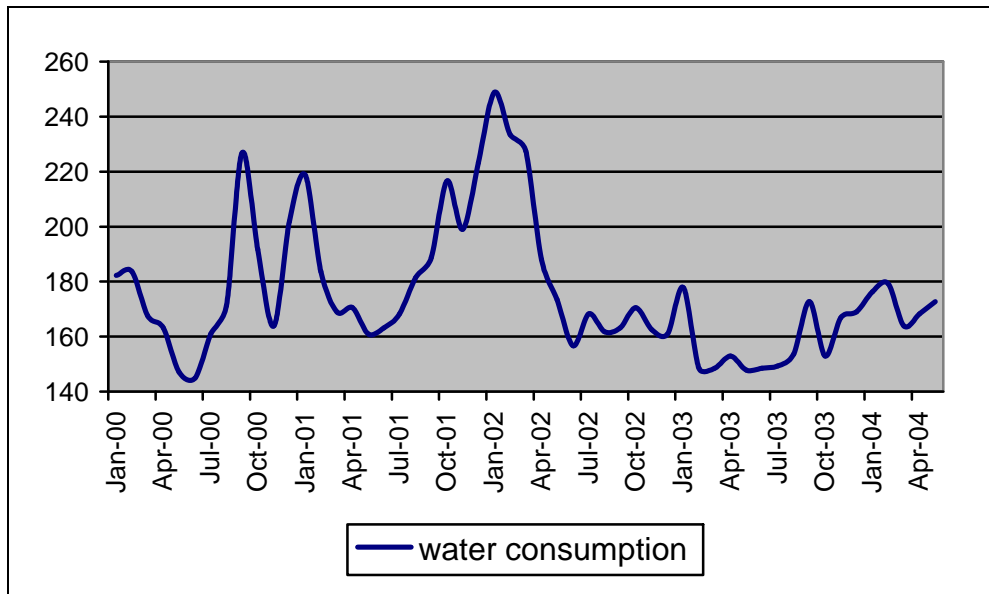
Note: Recent changes in dam safety requirements have meant final water supply contributions from Hinze Dam are undergoing investigation. This may alter both the raising of Hinze Dam yield and desalination capacity by approximately 14 ML/day.

<sup>2</sup> Where an ET is an Equivalent tenement which is approximately 3 people living in a house, total water ET comprises residential and non-residential ET

**Figure 26. Gold Coast Waterfuture water summary (Gold Coast City Council, 2006a)**

The empty components of Water Conservation and Water pressure and leakage management are in fact reductions in needs totalling 80 ML/day. Providing water by reducing needs and suggests that 160ML/day and not 240 ML/day is the real goal. The GCCC has followed the historical approach identified in the introduction for solving the problems of water shortages, that is by seeking to obtain more water. This is essentially the opposite of the approach that was used in the metabolic model. In contrast the metabolic model starts with understanding the limits of the existing paradigm and makes modifications to remain within the environmental resources.

Apart from seeking to identify more water, the values which appear to have driven the Waterfuture strategy are questionable for other reasons. For example premising the 'Water ET' calculation on 2001 data. The water requirement at that point was 184 ML/day (Gold Coast Water, 2004c), yet the strategy report states that water requirement in "2005 was 185 ML/day", during this time the population grew by over 57 thousand from 424829 to 482037 throwing some doubt onto the calculation (Australian Bureau of Statistics, 2006; Gold Coast Water, 2006a). With an occupancy of 2.43 (Gold Coast Water, 2007a) this would suggest that the consumption should have grown by 22 ML/day over this period. Additionally, given that the calculations were undertaken in 2004, what would be the reason for the use of 2001 consumption figures as the basis for the calculations, as detailed records were also available for 2004 data. The biasing of calculations due to the effects of water restrictions can not be the reason, as there were no water restrictions in force between March 2004 and October 2005 (Gold Coast Water, 2005b). Looking at the data of water consumption from 2000 to 2004 it is clear that already significant changes in consumption are emerging at that time. Figure 27 below shows monthly average water consumption data from January 2000 to April 2004. Despite population increases water consumption trends fell remarkably.



**Figure 27. Water consumption 2000 – 2004 (Gold Coast Water, 2004e)**

One possible explanation is that using figures from the 2001 period would make the task of bringing consumption down by 2056 easier as the average consumption for 2001 was 186ML/day while in 2003 it was 157ML/day. This is already a reduction in demand of almost 30ML/day even before the Waterfuture plan has begun.

## **4.2. Demand management**

As has already been discussed, demand management is increasingly understood to be of little significant value to the real reduction in water use, with studies showing that increased savings from demand management practices are unlikely to yield results in influencing water demand (Gold Coast City Council, 2003; P. Roberts, 2005; Troy et al., 2005). This notwithstanding all avenues of approach are worthy of consideration.

### **4.2.1. Water conservation, leakage and pressure management**

The Gold Coast Water Preferred Strategy suggests that 50ML/day of water will be ‘made available’ through water conservation. A further 30ML/day will be available through ‘water pressure and leakage management’. Leakage management addresses unaccounted for water (UFW), which has the potential to return some of the water lost to the system. As shown above in Figure 27 reductions of almost 30ML/day have already been achieved between 2001 and 2004, so it would appear that this target is

already met, however it is uncertain what may occur to the systems presently under construction when they become 40 years old.

Water conservation is listed in the 'Preferred Strategy' as contributing some 50ML/day. As identified earlier the 'business as usual' demand was premised on 2001 data, which is significantly higher consumption than has occurred subsequently. Comparing data from 2002 and 2003 water consumption has already dropped from 375KL/property to 293KL/property (Gold Coast City Council, 2007). It seems that the figure used in calculations (which were undertaken in 2004) were inflated to begin with. Accordingly, as long as these already existing reductions are maintained then the goal is already assured.

Contrasting this with the results of efficiency created by metabolic adaptations, which identifies a water demand which is falling not rising. The increase in water needs of the Gold Coast City Council is striking, and contains no treatment of the increases in waste water, and energy. The holistic approach used in the metabolic model has produced a result which demonstrates the difference between paradigm change and 'business as usual'.

### **4.3. Supply**

The Waterfuture supply side of the strategy is divided into existing and proposed, the existing components provide around half of the needs as projected. These are the existing reservoir and the Logan pipeline.

#### **4.3.1. Existing supply**

##### **4.3.1.1. Hinze dam (Gold Coasts' major reservoir) – 191ML/Day**

In the preferred strategy the Hinze dam is rated at being able to supply 191 ML per day, however as has been demonstrated this is essentially a best case figure; reviews by the GCCC has placed it as being between 170 to 210 ML/day (Gold Coast City Council, 2003). As has been shown, with water consumption being recorded at about 180ML/day the water supply reached critically low levels in Jan 2003, and would

have “failed” by September 2003 with the loss of a second wet season. To be sustainable this source therefore depends on being supplemented by other sources, such as the Logan pipeline.

#### **4.3.1.2. Logan Pipeline – 35ML/day**

The Logan Pipeline essentially takes water from Wivenhoe dam, a water system that is presently even more challenged to meet supply than the Gold Coast system. While this is increasing the available water to the Gold Coast region, that the Gold Coast requires this in its calculation is demonstrating that the Gold Coast can not live within the amount of water in the region, and needs to draw upon supply from other regions. Since these other regions are also populated, further research would be required to understand this, as the ecological region to which the carrying capacity is applied will be enlarged, and the metabolism of Brisbane would then need to be included.

However, it subsequently became clear that this figure is not fixed, the supply is also linked to water restrictions “if Level 2 restrictions are in place consumption is to be reduced by 15%, Level 3 by 20% and this is by how much the supply is reduced” (Gold Coast Water, 2005g). With this information at hand during the process, it raises questions about the process. Further research would be needed to understand why the findings still appear as they do in the final Waterfuture strategy.

Further this amount has subsequently by been reduced by 25ML/day and will be reduced by a further 10ML/day by 31 Oct 2007 in a decisions made by the Queensland government effectively bringing the value of this source to nil (Water Amendment Regulation (No. 6) 2006, 2006). Clearly this supply strategy is neither certain or a sustainable option. This analysis shows that at this time rather than 226ML/day, around 180ML/day is available with any certainty.

#### **4.3.2. Anticipated water supplies**

The following section deals with the anticipated components of the Waterfuture strategy, this accounts for around 150ML/day of the anticipated demand by 2056.

It is important to factor the losses that exist in the system, as while around 13% all water injected into the system is lost, additional water sources will be effectively eroded. While work is being done to address the issues of losses, it remains that diseconomy of scale that exists within urban water systems (Fane et al., 2001; Markcrow & Fox, 2005) may make the continued expansion of the network increasingly difficult to keep efficient.

#### **4.3.2.1. Regional Pipeline – 55ML/day**

The proposed regional pipeline is at the time is still not existent. Further it has been identified that the pipeline is intended to flow in both directions (Gold Coast Water, 2005f) meaning that it will also result in the reduction of available water given the water shortages being experienced in the remainder of South East Queensland. The project is expected to commence in the next 10 years (Queensland Government: Department of Infrastructure, 2006). This will effectively tie the metabolism of the GC to that of the rest of the region. Further research would be required to understand how the metabolism of Brisbane would effect the sustainability of the Gold Coast.

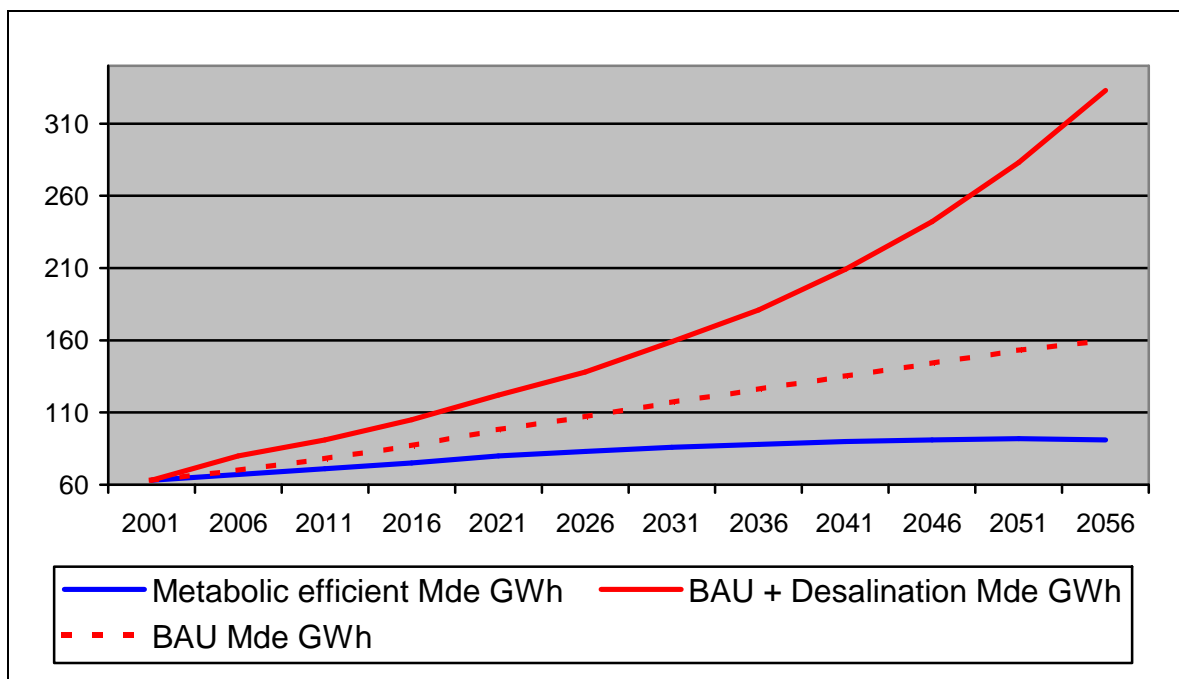
#### **4.3.2.2. Desalination – 55ML/day**

Desalination is a key component examined by the Waterfuture committee. While not popularly supported by the community as anything more than emergency supply (Gold Coast City Council, 2005a), it has gone from being a an optional emergency supply to becoming part of the Waterfuture strategy to being mandated by the Queensland State government (Water Amendment Regulation (No. 6) 2006, 2006). Despite the assurance given to the Waterfuture committee as late as October 2005 that a desalination plant would not be built if there were good rains (Gold Coast Water, 2005g), it turns out that with good rains and a dam capacity of 100% it will be built as a component on the Waterfuture Strategy.

Subsequently the matter is no longer a choice for the Gold Coast City Council as the State Government has mandated that a 125ML/day plant be built (Water Amendment Regulation (No. 6) 2006, 2006). This is significantly larger than the 55ML/day plant

which was being explored as an option by the Waterfuture Committee. It seems that there may be another agenda for the provision of the desalination plant in the region, and that is as a regional financial asset (Gold Coast Water, 2005g). Given that the construction of desalination has been identified as being a ‘cash cow’ for cities (Frew, 2005), and that it has been suggested that it could supply water to Tweed Heads in New South Wales it is reasonable to consider that this is being undertaken with a view to enhancing revenue rather than sustainability.

Desalination power requirements for a 55ML plant are around 79GWh/year, a 125ML plant then is likely to be in the order of 180 GWH/year of electricity (Gold Coast Water, 2005g). Applying the data for energy requirements of desalination to the same model as used for determining the metabolic demand for energy changes the energy requirement as can be seen in Figure 28 below. The energy needs of the urban metabolism increasing now from of 63GWh to well over 300GWh. This brings the difference to now over 270GWh, sharply different to the small increase in needs created by making adaptations to the Urban Metabolism found in Figure 23..



**Figure 28. Comparison of energy needs: desalination VS metabolic efficiency**

The capital and operational costs of the desalination plant are not yet completely clear, estimations undertaken by GCCC for a 55ML plant suggested capital costs of

around \$300 Million (Gold Coast Water, 2004f). The costs for a 125ML plant must be significantly higher. To give some perspective as to what alternative infrastructure this could provide, it has been shown that effective rainwater tanks could be installed in homes for around \$2,500 per home (P. J. Coombes et al., 2004; Marsend Jacob Associates, 2007), would mean that approximately half of the residential properties in the Gold Coast could be supplied and fitted with a rainwater tank<sup>3</sup>. Based on 193,953 residential properties with ½ fitted with 5KL water tanks would reduce reliance on reticulated on the Gold Coast from 48GL a year to 40GL/year. This would be with no additional increase in power consumption and the stimulation of local economy.

Additional to capital expenditure, desalination plant operational costs are expected to be around \$30 million per year, if these funds were applied to the provision of further water tank purchases, it could extend this throughout the community providing over 12,000 tanks per year, further reducing the urban water footprint.

Considering that desalination effectively links water availability with power availability and increases power demands in the treatment of greater volumes of waste water, this option does not meet with almost any criteria of sustainability.

#### **4.3.2.3. Rainwater tanks – 20ML/day**

As has been previously shown, the Gold Coast currently obtains effectively all of its water from rainwater, yet the Waterfuture strategy counts the contribution from rainwater tanks to be only 20ML day by 2056. This indicates that they have failed to understand the potentials of tanks, and perhaps this is related to the model of identifying supply that has been used. The benefit of rainwater tanks is that they reduce demands, rather than contribute to supply. When interpreting the data of rainwater tanks it is important to understand the difference between reduced demands over that of contribution to supply.

For example in the 2005 there were 193,953 households, had ½ of these been using a tank (affording 80,000L savings per year)<sup>4</sup> this would appear to contribute some 21ML/day to the water supply. This appears to be insignificant when viewed with the

---

<sup>3</sup> Given that not all residences are detached homes, and the number of residential properties is 193,953 (Gold Coast Water, 2005c)

<sup>4</sup> This is the average yield expectable from rainwater tanks on the Gold Coast (P. Coombes, 2007)

overall consumption. However, when viewed as a reduction, it means that demand falls from 131ML/day to 110ML/day. In June 2005, Council endorsed a policy requiring all new homes to fit rainwater tanks, this applies to “Detached dwellings” and “attached dwellings (eg. duplexes, townhouses etc up to a 3 storey walk up)” (Gold Coast City Council, 2006c). This effectively enforces the development of the urban metabolism in exactly the same directions as developed in the urban metabolism view.

So, with the installation of rainwater tanks on new homes enforced, this will further reduce growth in demand as population grows. Assuming that the population growth by 2056 increases the number of households to around 490,000, (with ½ of the original households also using rainwater tanks) gives a reduction in demand growth of around 80ML/day. As was demonstrated in Figure 25 above, by using a model based on reduced demands rather than one based on additional components, the same scenario yields entirely different outcomes.

Similar information to this has been presented to the Waterfuture Project (but it seems not to the Advisory Committee), (Gold Coast Water, 2005d) however still the same paradigm of attempting to obtain more water has remained as the solution. Further research is needed to understand why this continues in the administration of water resources.

#### **4.3.2.4. Hinze Dam Stage 3 – 10ML/day**

The extension of the Hinze dam is effectively an extension of the existing main bulk water supply. While the reasons for the upgrade are a combination of flood mitigation and water supply (Gold Coast City Council, 2006b; Gold Coast Water, 2005f) The upgrade will see the dam wall raised from 93.5 metres to 106 metres, and will provide:

- an additional 79,000 million litres of flood mitigation capacity
- up to 24 million litres of additional water supply per day
- an improved design to meet new dam design guidelines and standards

(Gold Coast City Council, 2006b). This option is not really about increasing water yield for the area, so much as protecting the area from the damage created by floods (Gold Coast City Council, 2005f, 2006b; Gold Coast Water, 2004d). While it will extend the water supply its contribution to the overall water situation is relatively minor.

#### **4.3.2.5. Use of recycled water – 20ML/day**

The Waterfuture plan suggests that by 2056 the city will be making use of 20ML/day of recycled water. The GCW Annual Report for 2004/05 already suggests that 6,468 ML is being used per year, which is around 18ML/day (Gold Coast Water, 2005b). It therefore seems that 20ML/day by 2056 is not a significant development. Given that the GCCC has a long history of using recycled water, and regards itself as a leader in this area (Gold Coast City Council, 2006e), this target would therefore seem specifically low by 2056.

#### **4.4. Comparisons of results**

The strategy benefit of “variety of water sources to provide a more secure water supply” used in this solution fails to address diversity of supply at the property. While rainwater tanks are mandated on new constructions, leaves the older properties obtaining their water primarily from the reticulated water system. As identified in the Sydney water crisis, residences supplied by reticulated water supply are vulnerable to anything which can infiltrate it (Stein, 1998), which can be bacterial infections and perhaps even terrorist threats.

The plan continues the existing system of providing water to the population through the reticulated water system, and does not provide any measure of water used. By involving people with their water systems such as rainwater tanks, and recycling systems develop awareness of water used. Identifying how the community values and contributes to the sustainability of the system are absent from the Waterfutures plan.

Results of GCCC community consultation during the Water future process has identified: there is a lack of confidence in Council's ability to plan for the long-term; less confidence in large scale initiatives such as Desalination; and population growth remains high as the main contributor to the regions water problems (Gold Coast Water, 2004f). Considering that the Waterfuture process did include any of exploration of carrying capacity and focuses on identifying more water to supply growth in demand it would be expectable that the community would remain sceptical on its ability to deliver.

Gold Coast Water has stated it's objectives for the management of water resources as having the hierarchy of:

1. Reduce (consumption)
2. Use/Recycle (water and recycled water)
3. Release (wastewater) (Gold Coast City Council, 2006e).

Yet in their proposal reductions contributed less than 18% of the planned water while recycling contributed under 5% and their plan called for the sourcing of an additional 240ML/day. Nowhere in the Waterfuture strategy is there mention of dealing with the release of wastewater. The latest approach is again attempting to solve our water crisis by finding more water.

The Gold Coast Waterfuture plan as well as not achieving most of its water supply objectives, does not address the amount of wastewater to be treated or make attempt to address the significant externalities its plan creates such as energy consumption. Since the major review of water supply in 2003, the GCCC has held the view that water needs will be assured until some time in the future, perhaps 2025 (Gold Coast City Council, 2003), perhaps 2030 (Gold Coast Water, 2005e). With the effective removal of supply from Logan and delays in the implementation of Regional Pipeline almost none of the 'certainties' that the GCCC have relied on have proven to be certain. Why despite a rigorous triple bottom line analysis have findings been as disparate as these two approaches presented in this analysis?

#### **4.4.1. Triple bottom line vs the ‘Three Pillars’**

In stating the ‘challenges we face’ it was made clear that changing unsustainable patterns of production and consumption and protecting and managing the natural resource base of economic and social development are overarching objectives of, and essential requirements for, sustainable development (United Nations, 2002).

Throughout that report reference is made to synergy and interoperations between groups, not the subdivision and reductionist analysis of the components. Synergy means that the interaction of the parts exceeds the sum of them, while reductionism seeks to subdivide and understand each of the parts, clearly these methodologies are disparate.

Triple bottom line analysis has become a popular and common method in attempting to come to grips with sustainable development (see for example Department of Environment and Heritage, 2003; Pope et al., 2004; A. C. Taylor & Fletcher, 2005; Uhlmann, 2004; Young, 2005). Triple bottom line is regarded variously as a methodology for reporting sustainability and an approach of design of systems which are expected to be sustainable (Department of Environment and Heritage, 2003; Pope et al., 2004). Despite the popularity of associating triple bottom line analysis with sustainability, it is not a panacea for achieving a sustainable outcome in itself and may only be able to select what is the most sustainable of a number of bad options (Pope et al., 2004; A. C. Taylor & Fletcher, 2005).

Recent work with the water authorities in developing sustainable practice has suggested that a lack of knowledge and inadequate institutional frameworks are impediments to the development of sustainable systems.

“not a great deal of understanding of sustainability at the water utility level in Queensland” ... “In addition to this lack of knowledge, the greatest obstacles to improved sustainability management for water utilities are an inability, at least presently, to manage the water cycle holistically and to address externalities within the catchment. These are in turn based on a lack of data, institutional frameworks and political drivers” (Uhlmann, 2004).

This is supported by other recent findings that sustainable outcomes are unlikely without

“an organisational culture that is prepared to invest in a structured, transparent and rigorous assessment process, involving stakeholders with varying skills and opinions”(A. C. Taylor & Fletcher, 2005)

It has been suggested that institutional inertia impedes or blocks inventive approaches, and it would seem on the surface of the outcome of the comparison of the Waterfuture strategy and the later Queensland State government changes that this might be occurring (Darbas, 2004; Fane et al., 2001). While the evaluation of the process may have been undertaken according to triple bottom line values, the process for selecting the strategies was not part of the mandate of the Waterfuture Advisory Committee, this was charged to the Waterfuture Project team, who remained opaque to the process (Gold Coast Water, 2005d).

Given the market readiness for changes to water infrastructure (as seen by the product availability of systems from rainwater tanks to grey water reuse), yet apparent resistance to this by institutional and regulatory bodies, further research is suggested to investigate what has been identified by Darbas as ‘widening gulf between state and society’ (2004).

#### 4.4.1.1. Financial bottom line

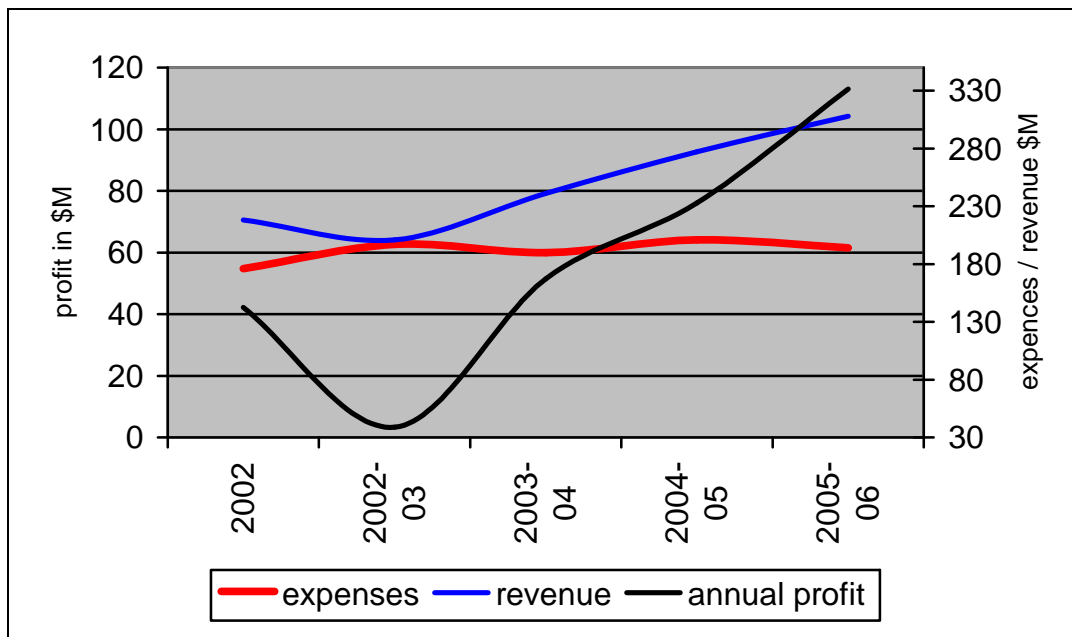
Harvesting treating and delivering water for the region is an important economic function and Gold Coast Water is effectively part of the community. Table 2 shows the comparison since 2002 of the amount of water treated (this is assumed to be the amount of water delivered to customers) compared to the financial bottom lines of GCW.

**Table 2. Financial and metered water data 2002 – 2006 (Gold Coast City Council, 2002, 2004a, 2005b, 2006d, 2007)**

year ended	total revenue \$M	Expenses \$M	net result \$M	Metered water (ML)
30-Jun-02	\$218	\$176	\$42	75,337
30-Jun-03	\$201	\$197	\$3	60,392
30-Jun-04	\$241	\$190	\$51	63,486
30-Jun-05	\$277	\$201	\$76	72,518

Analysis of this reveals the fragility of the relationship between the business of providing water, and the amounts of water provided. Relatively small changes in the amounts of water delivered by GCW made for very substantial changes in its financial bottom line.

The water crisis of 2002 brought about unplanned water restrictions and accordingly reductions to the amount of water delivered to the community. Revenue is gained from the provision of water, given the tight balancing of revenue and expenses changes in the amounts of water delivered result in this bottom line becoming very tight. This is demonstrated clearly in Figure 29 below.



**Figure 29. Expenses VS revenue VS profit (Gold Coast City Council, 2002, 2004a, 2005b, 2006d, 2007)**

This brief financial evaluation reveals just how tight the margins of operation are for GCW. The small reductions in delivery of water during the 2002 water crisis effected their revenue base relatively slightly, while at the same time resulting in a large loss in profit. This is an economically undesirable outcome for the community, as GCW operations are a part of local community. The ‘business as usual’ projections in water requirements will provide a very large expansion of business for GCW, and the GCCC. However this will also require enormous growth, and the associated exposure to risk. It is beyond the scope of this research to undertake such analysis.

Economic stimulation will be occur with the creation of the large public works schemes required by the GCCC Waterfuture strategy, however further research would be required to determine if this is the most beneficial economic to the community. Previous studies of rural water supply have identified that greater economic benefits to the community are obtained by following alternative approaches to water supply as proposed in this thesis (Institute for Sustainable Futures, 2002).

## 5. Conclusions

Ecological modernisation theory with respect to the question of consumption and production is not a question of how much is enough but rather seeks to consider ways of restructuring social practices of consumption along ecologically sustainable lines (Mol & Spaargaren, 2004). The findings of this analysis supports view that holistic analysis of the water supply system “can provide an insight into the significant relationships that need to be considered when developing management approaches for infrastructure” (Godau, 2000). The analysis of the climatic conditions has shown that environmentally available water is not significantly scarce, and that growth in the metabolic demands for water has reached the carrying capacity of the environment using the existing paradigm of water provision. This supports that the water crisis in the Gold Coast is an indicator that the current paradigm of urban water needs to undergo changes to fit within the ecological carrying capacity.

By contrasting the findings of the holistic frame of reference to that taken by GCCC in developing a sustainable water system this research show that quantities of energy, as much as 270GWh, can be saved annually and the city of the Gold Coast’s metabolic needs for water can be met by through existing ecologically available water, even with a population which more than doubles by 2056. This supports the assertion that paradigm change consistent with the principles of ecological modernisation theory rather than sourcing and supplying more water is required to facilitate sustainable development. The extension of the model of urban metabolism to facilitate exploration of metabolic pathways has proven useful in helping to guide analysis. In this way strategies that have been employed successfully by biological organisms has facilitated the visualisation of abstract systems (such as rainwater tanks) and their potential for application to the city.

A significant finding of this research is that the scope for sustainable adaptations of urban metabolism are not completely within the GCCC’s power, and that the Queensland State government also has a significant role to play in facilitating the legislation and policy changes to allow the evolution of the urban water metabolism. This has already begun with the reintroduction of rainwater tanks to areas previously

not allowed to access them, but further changes are required to facilitate markets providing on-site water recycling systems, and water re-use systems critical to the efficient metabolism of water. This suggests that institutional inertia is playing some role in subverting inventive processes (Darbas, 2004).

The evidence found identifies that while the Gold Coast is currently on the edge of the carrying capacity of the existing system, the existing water supply system will continue to be of great importance. The existing reservoir system is able to provide the Gold Coast with enough water, if the process of modernising our systems is begun promptly. Implementing water use changes such as on-site water reuse and rain water tanks, will begin reducing demand on the existing water supply structure, which will afford the community time to make the shift into the next paradigm with minimal difficulty.

Due to the size of the population these systems must be phased in gradually, to minimize the problems associated with the change in paradigm, such as identifying the best systems. This means that GCW needs to continue to supply water at the volumes that they are currently supplying them and that their assets (owned by the community effectively) will continue to operate profitably. Their business does not need to undergo radical restructure or growth, which is risky in itself. In this way the delicate financial bottom line of GCW will be protected, and at the same time the economy and social development of the community can be stimulated in adapting to the new paradigm.

As has been shown, with the legislation being passed to enforce the creation of solutions such as desalination, State and local government are making determinations in the directions that the development of water supply should go. Ecological modernisation theory would suggest that by moving further into modern institutions, such as markets, that better solutions will be found. The Australian Business Council has objected to the interference by government, suggesting that it is a costly exercise to be “picking winners” rather than allowing markets to determine the most effective solutions (2006).

As identified, the State government is also currently involved in similar issues to this in a rural / agricultural water supply (the Paradise dam in the Burnett region), which independent studies found that water efficiency and reuse systems rather than the construction of the dam would yield the best outcomes for the region (Institute for Sustainable Futures, 2002). This study suggests that the same is true of the approach to the development of water supplies in urban areas and supports assertions that these institutions may have self referential and self perpetuating agendas (Darbas, 2004). Further research needs to be undertaken to develop and understanding the difference between State Government position and the position of the community, as already some doubt exists as to the ability of the proposed directions to provide the best outcomes to environmental economic and social sustainability of the region.

Lack of knowledge has been suggested as a reason that water utilities do not engage in sustainable practice, leading to sustainable solutions. However immediately prior to engaging in the process to identify the Waterfuture strategy, GCW had been integrally involved in a study designed to build capacity and understanding in what is a sustainable water utility (Uhlmann, 2004). Therefore it would be expected that this would provide an opportunity to directly implement this new knowledge. Further research is required to understand the reasons why this issue may be persisting in water utility management.

## 6. References

- Aristotle. (323 BC). *Metaphysica*.
- Australian Broadcasting Commission. (2005). *Goulburn's water crisis*, from <http://www.abc.net.au/canberra/stories/s1381787.htm>
- Australian Bureau of Statistics. (1988). *Year Book Australia - 1988*: AusStats.
- Australian Bureau of Statistics. (2004a, 19 May 2004). *Water Account for Australia, 1993-94 to 1996-97*. Retrieved 2 March, 2006
- Australian Bureau of Statistics. (2004b). *Water Account, Australia 2000 - 2001*: AusStats.
- Australian Bureau of Statistics. (2006). Australian Historical Population Statistics. In 3105065001\_table17.xls (Ed.): AusStats.
- Australian Nuclear Science Technology Organisation. (2006). *Nano-Particulate Membrane Bioreactor Eats Waste Matter and Breathes Air*, from <http://www.azonano.com/news.asp?newsID=2418>
- Beard, G. (2006). question about the definition of drought. In C. Eastwood (Ed.).
- Benzing, D. H., Henderson, K., Kessel, B., & Sulak, J. (1976). The Absorptive Capacities of Bromeliad Trichomes. *American Journal of Botany*, 63(7), 1009-1014.
- Benzing, D. H., & Pridgeon, A. M. (1983). Foliar Trichomes of Pleurothallidinae (Orchidaceae): Functional Significance. *American Journal of Botany*, 173-180.
- Betrand-Krajewski, J.-L., Barraud, S., & Chocat, B. (2000). Need for improved methodologies and measurements for sustainable management of urban water systems. *Environmental Impact Assessment Review*, 20, 323-331.
- Blainey, G. (2006, 30 Dec 2006). Dry and drier. *The Australian*.
- Bureau of Meteorology. (2006). *Climate Glossary*, from <http://www.bom.gov.au/climate/glossary/drought.shtml>
- Bureau of Meteorology, & Department of Primary Industries Queensland. (2004). *Rainman*.
- Business Council of Australia. (2006). *Water under pressure: Australia's man-made water scarcity and how to fix it*.
- Cavalcanti, H. B. (1996). The Deepest of Changes are Needed. *Our Planet*, 7, 4-6.
- Clarke, R. (2000). *Disciplined Literature Reviews*. Retrieved 13 May 2005, 2005, from <http://www.anu.edu.au/people/Roger.Clarke/SOS/DLR.html>
- Colebatch, T. (2004, 24th June). The water crisis is a huge issue we must get right. *The Age*.
- Coombes, P. (2007). question about modeling performance of rainwater tanks in gold coast. In C. Eastwood (Ed.).
- Coombes, P., & Kuczera, G. (2000, November 2000). *Economic benefits arising from use of water sensitive urban development source control measures*. Paper presented at the 3rd International Hydrological and Water Resources Symposium, Perth.
- Coombes, P. J., & Kuczera, G. (2003, 10 -14 November). *A Sensitivity Analysis of an Investment Model Used to Determine the Economic Benefits of Rainwater Tanks*. Paper presented at the 28th International Hydrology and Water resources Symposium, Wollongong, NSW.

- Coombes, P. J., Spinks, A., Evans, C., & Dunstan, H. (2004). Performance of Rainwater Tanks at an Inner City House in Carrington NSW During a Drought.
- Daniels, P. L., & Moore, S. (2001). Approaches for Quantifying the Metabolism of Physical Economies. *Journal of Industrial Ecology*, 5(4), 69-93.
- Darbas, T. (2004). *Reflexive Governance of Urban Catchments: A Case of Deliberative Truncation*.
- Department of Environment and Heritage. (2003). *Triple Bottom Line Reporting in Australia*.
- Department of Natural Resources Mines and Water (The State of Queensland). (2006). *Gold Coast draft water resource plan*.
- Department of the Environment and Heritage. (2004). *National Urban Water Efficiency Program (NUWEP) - Urban water use statistics in Australia*. Retrieved 7 April 2005, 2005, from <http://www.deh.gov.au/water/urban/statistics.html>
- Dixon-Woods, M., Booth, A., Jones, D., Miller, T., Shaw, R., Smith, J. A., et al. (2004). *How can systematic reviews incorporate qualitative research?* Retrieved 13 May 2005, 2005, from <http://www.ccsr.ac.uk/methods/publications/documents/dixonwoods.pdf>
- Dupont, P., & Shackel, S. (2005). *Rainwater*. Retrieved 10 May 2005, 2005, from <http://www.greenhouse.gov.au/yourhome/technical/pdf/fs22.pdf>
- Elkington. (1999). Triple bottom-line reporting: looking for balance. *Australian CPA, March*.
- Environmental Protection Agency (Queensland). (2004, 17 June 2004). *Queensland Guidelines for the Safe Use of Recycled Water*. Retrieved 10 May 2005, 2005, from [http://www.epa.qld.gov.au/environmental\\_management/water/safe\\_use\\_of\\_recycled\\_water/](http://www.epa.qld.gov.au/environmental_management/water/safe_use_of_recycled_water/)
- Fane, S. A., Ashbolt, N. J., & White, S. B. (2001). Decentralised urban water reuse: the implications of system scale for cost and pathogen risk. *Water Science and Technology*, 46(6-7).
- Foley, A. (2005). RE: questions about data from The Australian Urban Water Industry WSAAFacts 2001. In C. Eastwood (Ed.) (pp. email query about water).
- Freeman, D. B. (1992). Prickly Pear Menace In Eastern Australia 1880-1940. *Geographical Review*, 82(4), 413-429.
- Freier, I. (2003). *Environmental management from an ecological modernisation and innovation perspective*. Paper presented at the Danish Research Unit for Industrial Dynamics winter conference 2003, Aalborg, Denmark.
- Frew, W. (2005, 4 June 2005). Desalination to fill state coffers, not dams. *Sydney Morning Herald*.
- Gardner, T. (2002). *Some examples of water recycling in Australian Urban Environments - a step towards environmental sustainability*. Paper presented at the In IWA Mediterranean Regional Symposium on Water Recycling and Reuse, Crete.
- Gardner, T., Coombes, P., & Marks, R. (2001, September 2001). *Use of Rainwater at a Range of Scales in Australian Urban Environments*. Paper presented at the 10th International Conference, Germany.
- Gardner, T., Millar, G., & Hyde, R. (2003, September 2003). *The Healthy Home - A Step Towards Sustainable Suburbs*. Paper presented at the 2nd National Water Recycling Conference, Brisbane.

- Gardner, T., & Samara, A. Water Resources for a Transit Oriented Sustainable Urban Development in Australia.
- Gleick, P. H. (1996). Basic Water Requirements for Human Activities: Meeting Basic Needs. *Water International*, 21(2), 83-92.
- Gleick, P. H. (2000). The Changing Water Paradigm A Look at Twenty-first Century Water Resources Devel. *Water International*, 25(1), 127-138.
- Godau, R. I. (2000). The changing face of infrastructure management. *Systems Engineering*, 2(4), 226-236.
- Gold Coast City Council. (2002). *Gold Coast City Council Annual report 2001-2002*. Gold Coast City: Gold Coast City Council.
- Gold Coast City Council. (2003). *Reviewing The Impact of the 2002/2003 Drought upon Council's Water Supply Strategy*. Gold Coast: Gold Coast City Council.
- Gold Coast City Council. (2004a). *Gold Coast City Council Annual report 2002-2003*. Gold Coast City: Gold Coast City Council.
- Gold Coast City Council. (2004b). *Previous Planning*. Retrieved 12 April 2005, 2005, from [http://www.goldcoast.qld.gov.au/t\\_gcw.asp?PID=3122](http://www.goldcoast.qld.gov.au/t_gcw.asp?PID=3122)
- Gold Coast City Council. (2005a). *Emergency Bulk Water Supply Planning - desalination: Community Consultation Report Phase 1 December 2005*.
- Gold Coast City Council. (2005b). *Gold Coast City Council Annual Report 2003-2004*. Gold Coast City: Gold Coast City Council.
- Gold Coast City Council. (2005c). *Hinze Dam*. Retrieved 2 April 2005, 2005, from [http://www.goldcoast.qld.gov.au/t\\_gcw.asp?PID=139](http://www.goldcoast.qld.gov.au/t_gcw.asp?PID=139)
- Gold Coast City Council. (2005d). *Pimpama Coomera Water Futures Project*. Retrieved 12 April 2005, 2005, from [http://www.goldcoast.qld.gov.au/t\\_gcw.asp?PID=2969](http://www.goldcoast.qld.gov.au/t_gcw.asp?PID=2969)
- Gold Coast City Council. (2005e). *Statistics*. Retrieved 26 May 2005, 2005, from [http://www.goldcoastcity.com.au/t\\_gcw.asp?PID=2895](http://www.goldcoastcity.com.au/t_gcw.asp?PID=2895)
- Gold Coast City Council. (2005f). *Water Supply Plans*. Retrieved 15 April 2005, 2005, from [http://www.goldcoast.qld.gov.au/t\\_std.asp?PID=3574](http://www.goldcoast.qld.gov.au/t_std.asp?PID=3574)
- Gold Coast City Council. (2006a, 31 Oct 2006). *GCWF - strategy components*. Retrieved 16 Sept 2006, 2006, from [http://www.goldcoast.qld.gov.au/t\\_gcw.asp?PID=5142](http://www.goldcoast.qld.gov.au/t_gcw.asp?PID=5142)
- Gold Coast City Council. (2006b, 13 Nov 2006). *Hinze Dam Stage 3*. Retrieved 16 Nov 2006, 2006, from [http://www.goldcoast.qld.gov.au/t\\_gcw.asp?PID=5953](http://www.goldcoast.qld.gov.au/t_gcw.asp?PID=5953)
- Gold Coast City Council. (2006c, 6 June 2006). *Mandatory rainwater tank policy*. Retrieved 6 Nov 2006, 2006, from [http://www.goldcoast.qld.gov.au/t\\_gcw.asp?PID=4913](http://www.goldcoast.qld.gov.au/t_gcw.asp?PID=4913)
- Gold Coast City Council. (2006d). *Our Annual Report 2004-2005*. Gold Coast City: Gold Coast City Council.
- Gold Coast City Council. (2006e, 25 Oct 2006). *Recycled Water*. Retrieved 14 Sept 2006, 2006, from [http://www.goldcoast.qld.gov.au/t\\_gcw.asp?PID=3111](http://www.goldcoast.qld.gov.au/t_gcw.asp?PID=3111)
- Gold Coast City Council. (2007). *Gold Coast City Council Annual Report 2005-2006*. Gold Coast City: Gold Coast City Council.
- Gold Coast Water. (2003a). *Sustainability Report 2002/2003*. Gold Coast: Gold Coast City Council.
- Gold Coast Water. (2003b). *Sustainability Report 2003/2004*. Gold Coast: Gold Coast City Council.
- Gold Coast Water. (2004a). *Hinze Dam – Little Nerang Dam Water Supply System Water Yield Re-assessment*. Gold Coast: Gold Coast City Council.

- Gold Coast Water. (2004b). *Population and Water Supply Requirements*. Gold Coast: Gold Coast City Council.
- Gold Coast Water. (2004c). *Waterfuture: Meeting 2 minutes*. Gold Coast: Gold Coast City Council.
- Gold Coast Water. (2004d). *Waterfuture: Meeting 4 minutes*. Gold Coast: Gold Coast City Council.
- Gold Coast Water. (2004e). *Waterfuture: Meeting 5 minutes*. Gold Coast: Gold Coast City Council.
- Gold Coast Water. (2004f). *Waterfuture: Meeting 8 minutes*. Gold Coast: Gold Coast City Council.
- Gold Coast Water. (2005a). *Ensuring our future is on tap*.
- Gold Coast Water. (2005b). *Sustainability Report 2004/2005*. Gold Coast: Gold Coast City Council.
- Gold Coast Water. (2005c). *Sustainability Report 2005/2006*. Gold Coast: Gold Coast City Council.
- Gold Coast Water. (2005d). *Waterfuture: Meeting 9 minutes*. Gold Coast: Gold Coast City Council.
- Gold Coast Water. (2005e). *Waterfuture: Meeting 11 minutes*. Gold Coast: Gold Coast City Council.
- Gold Coast Water. (2005f). *Waterfuture: Meeting 14 minutes*. Gold Coast: Gold Coast City Council.
- Gold Coast Water. (2005g). *Waterfuture: meeting 16 minutes*. Gold Coast: Gold Coast City Council.
- Gold Coast Water. (2006a). *Gold Coast Waterfuture Strategy 2006 – 2056*.
- Gold Coast Water. (2006b). *Securing Our Waterfuture for the Gold Coast*. Paper presented at the IWA World Water Congress, Beijing.
- Gold Coast Water. (2007a). high rise residential population. In C. Eastwood (Ed.).
- Gold Coast Water. (2007b). *Key facts & Figures*. Retrieved 1 Feb, 2007, from [http://www.goldcoast.qld.gov.au/t\\_gcw.asp?PID=304](http://www.goldcoast.qld.gov.au/t_gcw.asp?PID=304)
- Gold Coast Water. (2007c). question about consumption graphs. In C. Eastwood (Ed.).
- Green light for Grey water. (2004, 4 June). *Courier Mail*.
- Haberl, H., Erb, K.-H., & Krausmann, F. (2001). How to calculate and interpret ecological footprints for long periods of time: the case of Austria 1926–1995. *Ecological Economics*, 38, 22-45.
- Heaton, J. (1998). *Secondary analysis of qualitative data*. Retrieved 10 May 2005, 2005, from <http://www.soc.surrey.ac.uk/sru/SRU1.html>
- Institute for Sustainable Futures. (2002). *Burnett region least cost planning study - final draft report*: Institute for Sustainable Futures,.
- Jefferson, B., Laine, A., Parsons, S., Stephenson, T., & Judd, S. (2000). Technologies for domestic wastewater recycling. *Urban Water*, 1(4).
- Kokkonen, T. S., & Jakeman, A. J. (2001). A comparison of metric and conceptual approaches in rainfall-runoff modeling and its implications. *WATER RESOURCES RESEARCH*, 37(9), 2345–2352.
- Kolokytha, E. G., Mylopoulos, Y. A., & Mentis, A. K. (2002). Evaluating demand management aspects of urban water policy a field survey in the city of Thessaloniki, Greece. *Urban Water*, 4, 391 - 400.
- Lenzen, M., & Murray, S. A. (2003). Assessing the Ecological Footprint of a Large Metropolitan Water Supplier: Lessons for Water Management and Planning

- towards Sustainability. *Journal of Environmental Planning and Management*, 46(1), 113–141.
- Loh, M., & Coghlan, P. (2003). *Domestic water use study*. Perth.
- Lundin, M. (1999). *Assessment of the Environmental Sustainability of Urban Water Systems*. Göteborg,: CHALMERS UNIVERSITY OF TECHNOLOGY, Department of Technical Environmental Planning.
- MacDonald, D. H. (2004). *The Economics of Water: Taking Full Account of First Use, Reuse and Return to the Environment*: CSIRO.
- Mackellar, D. (Artist). (1904). *My Country*
- Manners, E. (2002). *The Role of Participatory Democracy in Achieving Environmental Sustainability: A Review of Community Engagement in Regional Transport Planning in South East Queensland*. Unpublished Masters, Griffith University.
- Markcrow, E., & Fox, J. (2005). Planned Communities No Longer Need Large-scale Water System. *SUSTAINABILITY NETWORK UPDATE*, 48E.
- Marsend Jacob Associates. (2007). *The cost-effectiveness of rainwater tanks in urban Australia*: National Water Commission.
- Marszalek, J. (2007). Water flow cut to power stations. *The Australian*.
- McRobbie, A. (2001). *Timeline – Gold Coast*. Retrieved 23 Oct, 2005
- Meade, K. (2007, 10 Jan). Where the suburbs overflow with water tanks [ 10jan07 ]. *The Australian*.
- Melbourne Water. (2005). *History of Drought*, from [http://drought.melbournwater.com.au/content/history\\_of\\_drought.asp](http://drought.melbournwater.com.au/content/history_of_drought.asp)
- Mol, A. P. J. (2002). Ecological Modernization and the Global Economy. *Global Environmental Politics*, 2(2), 92-115.
- Mol, A. P. J., & Spaargaren, G. (2004). Ecological Modernization and Consumption: A Reply. *Society & Natural Resources*, 17(3), 261-265.
- National Drought Mitigation Center. (2006). *What is Drought?* Retrieved Oct 2006, 2006, from <http://drought.unl.edu/whatis/concept.htm>
- Newman, P. W. G. (1999). Sustainability and cities: extending the metabolism model. *Landscape and Urban Planning*, 44, 219-226.
- O'Connell, D. (2007). Water history on the Gold Coast. In C. Eastwood (Ed.).
- Oha, K., Jeong, Y., Lee, D., Lee, W., & Choi, J. (2005). Determining development density using the Urban Carrying Capacity Assessment System. *Landscape and Urban Planning*.
- Parliament of New South Wales. (2005). *GOULBURN WATER SUPPLY*. Retrieved 23 November, 2006, from <http://www.parliament.nsw.gov.au/prod/PARLMENT/hansArt.nsf/V3Key/LA20050527008>
- Parris, T. M., & Kates, R. W. (2003). Characterizing and Measuring Sustainable Development. *Annual Review of Environment and Resources*, 28, 559-586.
- Peet, J. (2001, 18 September). *If indicators are the answer, what was the question*. Paper presented at the Sustainable Auckland, Auckland.
- Pope, J., Annandale, D., & Morrison-Saunders, A. (2004). Conceptualising sustainability assessment. *Environmental Impact Assessment Review*(24), 595-616.
- Powell, J. M. (1976). *Environmental Management in Australia, 1788-1914: guardians, improvers and profit : an introductory survey*.

- Queensland Government Office of Urban Management. (2005). *Draft South East Queensland Regional Plan*. Brisbane: Office of Urban Management.
- Queensland Government: Department of Infrastructure. (2006). *Environmental Impact Statement for the proposed Southern Regional Water Pipeline*.
- Queensland Government: Department of Infrastructure. (2007). *Western Corridor Recycled Water Project business case*.
- Queensland Water Commission. (2007). *Target 140*. Retrieved 27 May, 2007, from <http://www.target140.com.au/>
- Radcliffe, J. (2003). *Water - Second-Third Time Around*. Paper presented at the WATER - The Australian Dilema.
- Rees, W. (1996). Revisiting carrying capacity: Area based indicators of sustainability. *Population and Environment*, 17, 195-215.
- Rees, W. (2006). Ecological Footprints and Bio-Capacity: Essential Elements in Sustainability Assessment. In J. Dewulf & H. V. Langenhove (Eds.), *Renewables-Based Technology: Sustainability Assessment*. Chichester: John Wiley and Sons.
- Rees, W. E. (2005). Question on ecological footprinting and its implied components. In C. Eastwood (Ed.).
- Roberts, G. (2007). Big bills to pump water for power. *The Australian*.
- Roberts, P. (2004). *Yarra Valley Water 2003 Appliance Stock and usage patterns survey*: Yarra Valley Water.
- Roberts, P. (2005). *Yarra Valley Water 2004 Residential End Use Measurement Study*.
- Sayers, S. (1990). *Contradiction and Dialectic*. Unpublished manuscript.
- South East Water Limited. (2002). *History of our water supply*. Retrieved 24 August 2006, 2005, from [http://www.southeastwater.com.au/sewl/index.asp?link\\_id=30.1533](http://www.southeastwater.com.au/sewl/index.asp?link_id=30.1533)
- State of the Environment Advisory Council. (1996). *State of the Environment Report 1996*: CSIRO.
- Stein, P. L. (1998). The Great Sydney Water Crisis of 1998. *Water, Air, & Soil Pollution*, 123(1-4), 419-436.
- Syme, G. J., Nancarrow, B. E., & Seligman, C. (2000). The Evaluation Of Information Campaigns To Promote Voluntary Household Water Conservation. *Evaluation Review*, 24(6), 539-578.
- Taylor, A. (2006). questions about NMB wastewater treatment. In C. Eastwood (Ed.).
- Taylor, A. C., & Fletcher, T. D. (2005, 21-26 August). *Triple-bottom-line assessment of urban stormwater projects*. Paper presented at the 10th International Conference on Urban Drainage, Copenhagen/Denmark.
- Tisdell, J., Ward, J., & Grudzinski, T. (2005). *The Development of Water Reform in Australia*: CRC Catchment Hydrology.
- Trochim, W. M. K. (2002, 01/16/2005). *Unobtrusive Measures*. Retrieved 12 May 2005, 2005, from <http://www.socialresearchmethods.net/kb/unobtrus.htm>
- Troy, P. (2004). The Structure and Form of the Australian City: Prospects for improved urban planning. *Griffith University*.
- Troy, P., Holloway, D., & Randolph, B. (2005). *Water Use and the Built Environment: Patterns of Water Consumption in Sydney*.
- Troy, P., & Randolph, B. (2006). *Water Consumption and the Built Environment: A Social and Behavioural Analysis*: City Futures Research Centre.
- Twain, M. (1889). *A Connecticut Yankee in King Arthur's Court*. London: Chatto & Windus.

- Uhlmann, V. (2003). What is a sustainable water utility? *AWA Water*, 30(5).
- Uhlmann, V. (2004). *Sustainability Management for Water Utilities*. University of Queensland.
- United Nations. (2002). *Report of the World Summit on Sustainable Development*. New York: United Nations.
- Wackernagel, M., & Rees, W. (1995). *Our Ecological Footprint: Reducing Human Impact on the Earth.*: New Society Publishers.
- Water Amendment Regulation (No. 6) 2006, (2006).
- White, S. B., & Fane, S. A. (2001). Designing Cost Effective Water Demand Management Programs in Australia. *Water Science and Technology*, 46(6-7).
- Williams, R. (2004, 20 Feb). *Beyond the Strategic Scorecard and the Triple Bottom Line is the Need for Ethics*. Paper presented at the One-Day Symposium on Accountability, Governance and Performance in Transition, Brisbane, Australia.
- Wolman, A. (1965). The metabolism of cities. *Scientific American*, 179-190.
- World Commission on Environment and Development. (1987). *Our common future - World Commission on Environment and Development*. Oxford: Oxford University Press.
- Young, R. (2005). *National Trends in Urban Water Resource Management*. Gold Coast: WSAA.