Resilience and water security in two outback cities

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Preface

The National Climate Change Research Facility (NCCARF) is undertaking a program of Synthesis and Integrative Research to synthesise existing and emerging national and international research on climate change impacts and adaptation. The purpose of this program is to provide decision-makers with information they need to manage the risks of climate change.

This report on Drought and water security: Kalgoorlie and Broken Hill forms part of a series of studies/reports commissioned by NCCARF that look at historical extreme weather events, their impacts and subsequent adaptations. These studies examine particular events – primarily extremes – and seek to explore prior vulnerabilities and resilience, the character and management of the event, subsequent adaptation, and the effects on present-day vulnerability. The reports should inform thinking about adapting to climate change, i.e. capacity to adapt, barriers to adaptation, and translating capacity into action. While it is recognised that the comparison is not and never can be exact, the overarching goal is to better understand the requirements of successful adaptation to future climate change.

This report compares water security issues in two Australian mining communities. Kalgoorlie in Western Australia and Broken Hill in New South Wales are towns with populations of around 30,000 and 20,000 respectively in semi-arid environments with limited local water supplies. Each has a rich history based on mineral resources and, more recently, a developing tourism industry. The catalyst for development has been the exploitation of mineral resources (silver, zinc and lead in Broken Hill and gold in Kalgoorlie); this development has been constrained and tested by water limitations. Throughout the history of each town, the reaction to extreme dry periods and economic booms has been to develop new infrastructure and strategies to deliver more water and increase efficiencies. The challenges of balancing water supply and growth are ongoing and likely to become more severe with climate change.

Other reports in the series are:
- Cyclone Tracy
- East Coast Lows and the Newcastle-Central Coast Pasha Bulker storm
- The 2008 Floods in Queensland: Charleville and Mackay
- Storm tides along east-coast Australia
- Heatwaves: The southern Australian experience of 2009
- Drought and the Future of Rural Communities: Drought impacts and adaptation in regional Victoria, Australia

To highlight common learnings from all the case studies, a Synthesis Report has been produced which is a summary of responses and lessons learned.

All reports are available from the website at [www.nccarf.edu.au](http://www.nccarf.edu.au).
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1. Background to the study

This project explores the adaptive capacity of two relatively large inland regional cities facing different challenges relating to climate change and water supply on two sides of the continent. Kalgoorlie in WA and Broken Hill in NSW are towns with populations of around 30,000 and 20,000 respectively in semi-arid environments with limited local water supplies. Each has a rich history based on mineral resources and a developing tourism industry. However, they face different resilience problems in the face of climate change and variable water supply.

Kalgoorlie is reliant on transported surface water through the Golden Pipeline from Mundaring Dam about 560 km away in the Darling Range catchment near Perth. Kalgoorlie has no alternative water source other than a possible desalination plant and another pipeline from coastal Esperance over 350 km south. Kalgoorlie will experience little direct climate change impact but a strong climate change impact on the source of its water supply. The Perth catchment is under intense pressure with desalination and aquifer extraction already supplementing declining rainfall. Despite the likelihood of increasing costs for potable water, Kalgoorlie has a strong economic resource and population base that will continue to be supported by Government.

On the other hand, Broken Hill has a much diminished mining industry but strong social base and an emergent economy as an ‘outback’ tourism destination. With substantial industrial and domestic requirements for water, Broken Hill remains totally reliant on limited local ground water catchment and irregular inflows to Menindee from the Murray Darling Basin. The Australian Government is currently supporting further investigation into regional groundwater resources and the potential for managed aquifer recharge. There has also been speculation about the possibility of a connection to a proposed BHP coastal desalinization plant 350 km away at the head of Spencers Gulf in SA.

Without a full understanding of the likely impacts of climate change, extreme variability and the increased technical difficulties and economic costs of providing potable water in remote communities, the future resilience of Kalgoorlie and Broken Hill is not secure. This project will assess stakeholders’ current understanding of climate variability and extremes. In the light of that understanding, Murdoch University will also assess community views on water security in the form of Water Expos. The Water Expos will provide information and future scenarios on the implications of community demand for water and water resource availability in the context of a hotter and dryer climate.
2. Project Objectives

The project objectives were:

1. To outline the challenge of water security and sustainability for the inland cities of Kalgoorlie and Broken Hill;
2. To identify the historical and current processes which interact to create this challenge, and which also provide the basis for a systematic understanding of water resource use;
3. To provide a range of water security future scenarios that will assist in planning for and adapting to climate change and other pressures; and
4. To consider the infrastructure, cultural and organisational change needed to meet the water security and sustainability challenge for each city.

3. Outcomes

The research team:

- Produced baseline research data on past and contemporary water issues for each city/region;
- Identified current stakeholder understanding of the complex issue of water security;
- Evaluated institutional and organisational capacity to manage change;
- Evaluated community willingness to live with the change;
- Refined a research method that can be used and replicated in other contexts in Australia; and
- Has developed an innovative research methodology/approach to water resilience and a comprehensive analysis the issues facing leaders and communities in inland water constrained cities.

As indicated above, Key Informant Interviews and the Community Water Expos were the main mechanisms for community engagement and to help inform the community of the implications of a drying climate, the community’s capacity to adapt and the factors that confer resilience.

The objectives of the community engagement were to:

1. Identify a broad range of key informants that were comprehensive and inclusive; and
2. Gather information from a wider representation of community interests via a community water expo.
4. Methods

A Resilient Regions Assessment Process (RRAP) has been developed to enable delivery of project objectives. It has been developed by the research team to produce a complex adaptive systems framework to evaluate water issues in the two cities. It consists of:

1. Literature Reviews;
2. Resilience Histories;
3. Key Informant Interviews; and
4. Community Water Expos - Understanding the Issues and incorporating resilience futures, which will include different scenarios based on differing degrees of water scarcity, as defined within climate science, technological options and water price modelling.

4.1 Literature reviews

The literature reviews:
(a) Briefly reviewed the principal methodological literature underpinning the project in order to establish authenticity; and
(b) Assembled the relevant technical and cultural data on the two cities and their immediate regions in the context of domestic, commercial, agricultural and industrial demands for water.

Resilience histories have been documented for each city in order to describe the biophysical foundations for water security and to account for the ways the challenges of water needs have been met in the past.

Key informant interviews and two Community Water Expos (one in each city) have been used as two-way conduits for information gathering and sharing. The community water expos facilitated both stakeholder and community involvement.

Participation statistics: 20-50 key informant interviews in each city/region.

4.2 Community Engagement

4.2.1 Community Water Expos

The two community Water Expos were professionally organised and managed events where ‘water’ stakeholders were invited to display their policies and practices and where community members could gain information. As two-way conduits, they were the prime mechanism for the researchers to characterise community understanding of water supply issues past, present and future. The Water Expos were conducted in Kalgoorlie and Broken Hill on 16 and 24 June 2010 respectively in which we presented four possible futures for each city.
4.2.2 Scenarios

The scenarios were created in the context of different climate change outcomes, a range of water technologies and cost models that included e.g., supply from coastal desalination, water recycling to potable standards and groundwater options. The scenarios were created from photographs of the town centre of each city and then digitally changed to create a picture for each scenario of the city in 2070. They were printed at AO size, large enough for the viewer to feel immersed in the scene. We were seeking a considered response from both the poster images and the support data. Data was also provided on A4 sheets with the image on the reverse side (see Appendix 1 and 2).

Scenario 1 ‘She'll be right mate!’

This scenario is business as usual. It represents a future with no important change to the climate of the region or the water catchment region. Water is still in plentiful supply. Projections of future mining activity are positive with new mineral discoveries. Life will go on much as it has in the past producing a vibrant economy and community.

Scenario 2 ‘Chill out man! It’s all sorted!’

This scenario represents changes in climate under a model of low emissions. A future with increased temperature reduced rainfall and increased evaporation. The adaptive response is increased investment in technology on a large scale with much greater cost to consumers. There is a diversified economy with new employment opportunities.

Scenario 3 ‘Mmmmmm........it’s not looking good’

This scenario represents change in climate under a model of high emissions. The sky portrays storm activity representing an increase in extreme weather events. Mining is no longer part of the economy. Government provides less support of infrastructure. Water and power are supplied by distributed systems on a small scale. There is a reduced and aging population.

Scenario 4 ‘Up shit creek (Kalgoorlie), We’ll all be rooned’ said Hanrahan (Broken Hill)

This scenario represents the cities with a change in climate at the extreme end of high emissions models. Mining is exhausted and there has been no diversification in the economy to support a population. One hotel remains open to provide for a small tourism industry with off-road vehicles the only passing traffic.

The scenarios were presented as poster displays in the community water expos with the opportunity for citizens to provide immediate responses to the research team by placing a vote in the form of a sticker on the future vision they saw as most realistic and likely. The attendees at each expo event showed great dedication to the task of selecting the future vision which most clearly matched their own. They clearly thought hard about their choice and as such, the Water Expos represented a successful environmental education and research outcome. The future scenarios were also presented in conceptual form to stakeholders in interviews as prompts for establishing the range of potential adaptive responses to water security in a drying climate.
5. Regional Resilience Histories and Water

5.1 Broken Hill

5.1.1 Summary

With the major remaining large-scale Broken Hill mine set to close in ten years, the future economic security of Broken Hill is not secure. The mines still heavily subsidise water prices in Broken Hill and they remain the main users of water. However, when they leave, the costs upkeep for old and provision of new infrastructure will have to be fully met by consumers and the taxpayers of NSW. In a more severe climate regime where the whole of the Murray Darling Basin is under intense pressure, Broken Hill might not have a strong case to defend its continued ‘subsidised’ existence in the face of a continent-wide retreat to the coast to be close to secure supplies of potable water.

The people of Broken Hill, historically, have shown great resilience in the face of a highly variable climate. The past engineering strategies used to build such resilience into the natural variability have been impressive and the professionals who have run this system have themselves shown great creativity and resilience in the light of multiple water security crises. It can be reasonably concluded that the people of Broken Hill, above all others in Australia, are capable of higher degrees of resilience in the reality of even greater variability and extremes under climate change and global warming. However, while the water engineers might be able to continue to guarantee water security with large corporate and government subsidies, they might not be able to do so in a harsh cost recovery economic climate. If the mining corporations go and a hotter climate enters, Broken Hill might not have a secure future.

The increasing cost of building greater resilience into the water catchment and supply system has already generated public concern in the city of Broken Hill. In 2009, a well attended community forum on water pricing expressed heated opposition to current prices and projected cost increases of 10% per annum over the next three years. Water is a hot topic in Broken Hill, as a major crisis in water availability and quality was recently averted only by drought-breaking rains in the regional catchment followed by a 1-in-100 year flood event in the Murray Darling Basin. A ten year period of extreme dryness in both the region and the wider catchment was relieved by natural rain events at a critical moment. In 2002-2003 the city of Broken Hill almost ran out of water and the resumption of bulk water imports by train was being seriously considered. Again, chance rainfall alleviated a crisis situation.

The need for water security for the city of Broken Hill has seen the two major agencies, Country Water and State Water, invest in new plant and infrastructure to maintain a reliable water delivery system. There is much discussion within these agencies and by community
leaders about the various options for Broken Hill to maintain a reliable and resilient water supply. However, all options entail extreme engineering considerations and significantly increased costs. Moreover, a lack of serious consideration of the possible failure of both regional and catchment-wide water supply options suggests that more future planning is necessary.

A hotter and dryer climate and the implications of this for water catchment and retention will likely generate new system-wide considerations of water security and resilience. The water supply issues in Broken Hill provide an illustration of the benefits of a systems perspective on water. The case study of Broken Hill displays classic complex systems’ characteristics where the biophysical component covers a large geographical extent, the climate is naturally highly variable, major human activities in the catchment such as irrigated crops and mining are water intensive, the climate system itself is changing and technological innovation is providing new opportunities for adaptive management. As such it is possible to see the totality as a social-ecological complex adaptive system with water resilience a possible, but never guaranteed, emergent property (Walker and Salt, 2006).

5.1.2 Climate Change, Water and Indigenous History

Climate change is not a new phenomenon to those Aboriginal people living in central and inland New South Wales who possess traditional knowledge. The Aboriginal history in this region has been shaped by powerful climatic changes which have seen the landscape transform over tens of thousands of years from fertile wetlands, to barren saline wastelands, to the conditions we see today (White, 1994).

Evidence of Aboriginal occupation in this region dates back 45,000 years with the discovery of Aboriginal archaeological remains at Lake Mungo. During that period the lakes of the Murray basin and Willandra Lake region were full. Lake Mungo would have been some 20 km long, 10 km wide and 15 m deep (Flood, 1983). On its shores lies evidence of the biological productivity within the lake, with masses of shellfish remains or middens piled next to ancient fireplaces, a scene replicated at the Menindee Lakes. Here also lie the remains of ancient stone tools, hearths, ochre and evidence of ritual cremation, the oldest in the world (Flood, 1983). Evidently these communities were dependent upon the freshwater of the lakes.

About 21,000 years ago the lakes began to dry, coinciding with the peak of the Glacial Maximum (ice age). As the temperature dropped the land became hyper-arid and saline (Mulvaney and Kamminga, 1999). Eventually the Willandra and Menindee lakes dried altogether, the Murray basin becoming a saline wasteland (White, 1994). In meeting the demands of the changing climate the Aboriginal people depopulated the drying lake regions for the waters of the Darling and Murray rivers. In addition, local economies were
transformed with the development of grinding tools and mortars from freshwater to grass seed based economies. As the Glacial Maximum receded, temperature and rainfall began a steady change to modern day levels. The Willandra lakes were left permanently dry apart from the occasional flood run-off, however, the Menindee lakes still held water and its shores became more heavily populated than ever before with the development of more permanent base-camps (Mulvaney and Kamminga, 1999).

It is evident that climate change and the resultant changes in natural water systems dramatically affected Aboriginal history in inland New South Wales. The Aboriginal peoples responded to the changing climate by altering their settlement patterns, local economies and by developing new technologies (Flood, 1983). However, local Aboriginal populations did not just respond to crisis, they also planned ahead and provide evidence of adaptive management in the face of major change.

### 5.1.3 Aboriginal Water Management

Across Australia Aboriginal peoples engaged in water management activities for either the storage of water itself or for the production of food (Laudine, 2009). According to Langton (2006), Aboriginal societies construed water sources beyond their physical domain to inform cultural and spiritual histories, social obligations and personal identities. Thus Aboriginal water management practices resulted from Aboriginal worldviews which entwined physical water systems with spiritual and cultural significance. This made Aboriginal societies sensitive to the fluctuations in Australia’s water systems and allowed for the creation of water engineering that took into account seasonal variations. For instance, in several sites in the Western District of Victoria, an area characterised by drought and flood, fish weirs were constructed to store water in the summer and regulate the system during times of flood. Some of these structures were immense; a weir constructed at the foot of Mt William covered at least 15 acres. These systems were built to optimize water and food supplies during seasonal variations.

Equally impressive structures were found along the Darling at Brewarrina in western New South Wales. Here, the Ngemba people built the largest series of fish traps in Australia, extending some five hundred metres down the river. This system was called Ngunnhu and was used to capture fish as they migrated up stream (Cathcart, 2009). It was believed that the ancient dreamtime ancestor Baiame spoke of Ngunnhu and taught the Ngemba people how to use it. The fish were chased into smaller and smaller ponds and either immediately speared or kept live in storage. The great abundance afforded by the Ngunnhu allowed for great gatherings on its shore. These were times for feasting, religious ceremony, games and tests of ability (Dargin, 1976). Other fish traps have been reported 40 km north of Brewarrina near...
Collewarry, on the present site of the Bogan River weir, and along the upper Lachlan and Murrumbidgee rivers (Laudine, 2009).

The intersection of Aboriginal cosmology and water management allowed Aboriginal peoples to exist in one of the driest places on Earth for thousands of generations. Sensitive to the fluctuations of the seasons, Aboriginal peoples engineered resilience into local water systems which allowed the development of sustainable cultures with relatively simple technologies. These were people finely attuned to the characteristics of the Australian climate, able to adapt themselves and the environment to the demands of a highly variable climate.

The adaptations made by Indigenous people in the Murray Darling basin in general, and in specific locations such as the Broken Hill region in particular, provide strong evidence that humans are capable of extensive adaptive responses to changing climates/environments. It remains to be seen if contemporary humans operating within a very different economy and lifestyle have similar adaptive capacity in the face of an even hotter and dryer climate than that experienced long-term by Indigenous people.

5.1.4 Colonial Settlement and its Relationship to Water.

Broken Hill incurred massive social and ecological change from its meteoric rise as a mining town in the 1880s to the development of the Menindee Lakes pipeline in the 1950s. In the space of a few decades Broken Hill rose out of a semi-arid landscape to become a world-significant mining community of 30,000 citizens. The influence of mining in Broken Hill reached beyond its locality, spurring industrial growth along Australia’s eastern and southern seabords and beyond to the industrial complexes of Europe. The rise of multinational mining companies such as the Broken Hill Proprietary Ltd. owe their beginnings to the rich boomerang shaped load of silver, zinc and lead which, as it was mined and processed, saw billions of pounds/dollars flow through the financial centres of Australia and its stock exchanges, buffering the Australian economy against several worldwide economic downturns. Yet, despite its influence, Broken Hill was a town often defined by deplorable social conditions resultant from the impacts of mining (e.g. lead dust), disease and the lack of water.

This analysis further examines two key drivers, climate variability and mining, in relation to their impact on the social-ecological context of Broken Hill’s water supply from its beginnings to the development of the Menindee Lakes pipeline.
5.1.5 Natural Climate Variability: Drought and Flood

The reoccurring cycles of drought and flood have significantly impacted upon the development of Broken Hill and its water supply. The aridity of the Barrier Range, upon which Broken Hill is situated, was noted by the first explorers to pass through the region. On an expedition to Lake Torrens, Surveyor-General of South Australia Captain Frome noted “a succession of apparently barren ranges running north and south” but he made no attempt to investigate the ranges (Hardy, 1968). It was not until late 1844, after a year of pushing inland, that Charles Sturt and his team first penetrated the ranges. By this stage in their expedition Sturt and his men had already endured severe hardships, tortured by the unforgiving molten desert and the ravages of thirst. Sturt camped on what was to become the shores of the Stephens Creek reservoir before pushing further onward, ultimately into the heart of the Simpson Desert (Hardy, 1968).

The aridity of the region meant the settlement of the Barrier Range region was not forthcoming. By 1866 a few sheep stations occupied the plains around Broken Hill and the Mount Gipps station was only nine miles from Broken Hill. A few soaks and wells were noted at this time, however, the lack of water meant small scale agriculture was not viable, giving rise to massive sheep stations. As Blainey (1968) put it, this was a land in which “acres were measured to the sheep, rather than sheep to the acre”.

Silver was discovered on the Broken Hill site by Charles Rasp in September 1883. By mid 1885, Rasp had floated his company, the aptly named Broken Hill Proprietary (BHP), and mining began in earnest. The township swelled from 30 tents, 23 houses, 15 huts, 3 hotels, 2 blacksmith shops, 1 general store and a few sheds and humpies in 1885, to a population of 17,000 in 1888 and onto 31,000 by 1907 (Hardy, 1968). Mineral exports grew at a staggering rate, from 600,000 tons in 1887 to 3.5 million tons in the year ending 1891 (Hardy, 1968). All the while local water resources dwindled with each new resident and mining development. Heroic efforts to secure water supply included camel trains from river ports to Broken Hill and Wilcannia.

5.1.6 Water Security

It has been estimated that, over the long term, the Broken Hill region has received an average rainfall of 9.75 inches per year (Evans 2001). However, averages can be deceiving as they do not depict seasonal and yearly variation. For instance, during the boom of 1888, Broken Hill received just 3.5 inches for the year, 2.0 inches of which fell in early February leaving 1.5 inches for the remainder of the year (Hardy, 1968). From 1888 to 1952, Broken Hill experienced no less than five drought events, spanning two to five years each. Even this statistic can be misleading as such analysis does not take into account slow moving climate
variations across decades or centuries (see Davis, 2007 for recent climate research on stalactites in NSW).

During each drought event, engineering schemes were promoted to deliver Broken Hill from its water shortage. For instance, the combined drought and boom conditions of 1888 produced the Stephens Creek Reservoir. As demand out-stripped supply during the 1902-1903 drought, railways were completed so that water could be delivered via rail-cart from neighbouring Silverton and across the border from South Australia (Hardy 1968). The use of rail-carts to supply the dwindling water supply of Broken Hill was utilized in each subsequent drought (1925-1926, 1941-1946, 1948-1951) up to and even during the building of the pipeline. Drought conditions also spurred the construction of the Government-built Umberumberka dam in 1914 and ultimately the Menindee pipeline itself.

In each instance the belief that the newly constructed engineering feat would save Broken Hill from episodic water shortages was confirmed with good rains and contradicted with each subsequent severe drought.

5.1.7 The Socio-Political Context of Change 1888-1940

Climate conditions coupled with mining developments, shifts in government policy, civic attitudes and world economic conditions interacted to produce shifting socio-political contexts under which each water engineering feat was developed and implemented. In 1888, with a mass of people arriving at the newly established mining fields, the residents of Broken Hill pleaded with the NSW government for the provision of a water supply. Locals had begun to dig their own small storages to collect the meagre rainwater. Although well intentioned, when the rain finally came, the drinking water often overflowed and mixed with households’ cesspits, bringing devastating typhoid epidemics. These epidemics persisted well into the 1920s. In addition, blast furnaces, used for the extraction of silver, were inundating the town with lead dust. Lead poisoning was cited as one of the main sources of illness in Broken Hill. The problem was so bad that residents complained that they could not rear stock or domestic animals. The lack of water meant the cost of running a bath was beyond what an average resident could afford. Miners, filthy from an underground shift, were constantly covered in the toxic dust and were accumulating heavy metals in their bodies. The children of the town were also affected by lead poisoning readily apparent in unfortunate cases.

The Barrier country was geographically and economically isolated from the distant “Sydney Government” and, furthermore, much of the wealth produced from the mines was directed into the Melbourne and Adelaide stock exchanges. In addition, prior to Broken Hill, Sydney-based government had already invested in costly water projects in a few ephemeral mining towns near the Barrier, only to see the capital expenditure end in nothing but dust during the
droughts. Indifference towards the plight of Broken Hill by the distant Sydney Government, in conjunction with the severe drought conditions gave rise to competition among several newly established local water companies, resulting in the birth of the privately owned Broken Hill Water Supply Company and its reservoir at Stephens Creek. However, fearful of a private monopoly, the NSW Government ensured that the Water Supply Company could not control the price it would charge for its water to both domestic customers and the mines. In addition, Government proclaimed the company was to hand over all operations to the Government without compensation in 28 years (Hardy, 1968).

Ironically the clauses in the Broken Hill Water Supply Contract that were meant to safeguard the government from costly capital expenditure on Broken Hill’s water supply led to greater Governmental involvement. In the drought of 1902-1903, resenting its limited tenure and lack of control over water charges, the Water Supply Company was reluctant to expend capital. At the time, the future of the mines was uncertain and they were also reluctant to help. With the Government footing the cost, the Broken Hill municipal council organized water rail lifts from South Australia to supply domestic and industrial water needs. Also, in desperation, construction of the Umberumberka reservoir began without Parliamentary authorization. As the drought progressed the mines slowed operations, the two breweries closed and unemployment soared. Relief rains came in late August 1903. For the first time since its construction in 1892 the Stephens Creek Reservoir filled to the brim and overflowed. Works at Umberumberka were discontinued by the NSW Parliament in favour of a scheme at Yancowinna Glen. The Water Supply Company did not share the Government’s vision and renounced involvement in the project. The cycle of worry and apathy had begun.

As mines began to develop floatation processes for the extraction of silver, lead and zinc, they required additional amounts of industrial water. It quickly became evident that, if the mines were to continue to reap the revenue of the Broken Hill lode, much more water would be required. With the costs of the water rail lifts still escalating, the NSW Government passed the Broken Hill and Umberumberka Water Supply Act in December 1906 for the provision of a Water Trust. The Trust consisted of representatives from the government, the Broken Hill Council and each of the major mining companies. The mining companies were to lend 200,000 pounds to the construction of the Umberumberka reservoir. This was the first real coming together of the mines and government. Despite good intentions, by May 1908 the mining companies had only raised 100,000 pounds.

With growing community pressure and the rise of the Labor party’s influence in NSW, the Government took control of the Trust’s operations by the end of 1908. The Broken Hill water supply had finally been accepted into the fold of the Sydney Government (Hardy, 1968). By 1915, works at Umberumberka were nearing an end and the town was transformed. Seventy seven miles of reticulation pipes had been laid down in Broken Hill town along with another six miles supplying the mines. Over two thousand homes were now connected to a water
supply at a cost of 425,000 pounds. The mines accepted a higher charge for water so that the scheme could be paid off as soon as possible. By 1916, the Stephens Creek reservoir came under control of the Government. Fifty thousand pounds were spent removing silt and making additions to the ageing reservoir. It appeared at this time that Broken Hill’s water problems had been resolved.

Conditions in Broken Hill remained relatively stable for the next three years. The new-found water security allowed some civic greenery to appear and gardens to grow. Although water use was still restricted compared to other towns, there was finally enough to go round. However, by January 1925, Stephens Creek was once again practically dry and Umberumberka was struggling to meet the peak summer demand. According to Hardy (1968), “a supply which had seemed a permanent solution to the water problem in 1915 was no longer satisfactory”. Typhoid once again ravaged the townspeople and living conditions became intolerable.

According to Blainey (1968), rail lifts were once again sought from South Australia. However, the neighbouring state was also suffering a severe drought. The nearest viable water source available was Adelaide, a haulage of over 300 miles with a change of gauge midway. These difficulties made the cost of water transport prohibitive. To make matters worse Broken Hill was connected by rail to Menindee but the connecting link with the rest of the NSW system from Condobolin had not been completed. Blainey (1968) observed that:

“... a rail lift of water could not be organized without the necessary standard gauge rolling stock, and there was no way of sending this direct. The Public Works Department enlisted the aid of the railway Commissioners and the incredibly cumbersome business began of dispatching the necessary locomotives and tank wagons by sea from Sydney to Port Pirie. Here, each item had to be dismantled for haulage to Broken Hill by the narrow gauge South Australian and Silverton Tramway systems. In the event, only one of the four trains sent from Sydney was ever commissioned.”

The drought broke on 17th March 1926 after only one train had commenced running from the Darling to Broken Hill. Had the drought continued, the Sydney Government would have railed four million gallons per week to enable the mines to work part time and to ensure some sort of domestic supply (Hardy, 1968). Throughout the entire crisis the mines were forced to reduce their operations by half for a fortnight, and altogether for only a week. Complete economic and social disaster had been narrowly averted.

Reeling from the costly intervention in 1926, the NSW Government was more willing to listen to other proposals for a permanent solution to Broken Hill’s water supply problems. The Parliamentary Standing Committee on Public Works was commissioned to investigate the feasibility of schemes at Yancowinna Glen and of tapping the Darling River. The committee found that any augmentation would add to the cost of water, a cost not willingly
accepted by townspeople or the mining companies. As chief engineer for the Water Supply Company put it, from the point of view of the mines, the issue was a matter of “*What is the amount of security you are prepared to buy?*” (Hardy, 1968). Departmental policy over the next decade was one of gradual improvement of the existing systems but again apathy set in.

Throughout the 1930s, Broken Hill enjoyed a decade of stability and increased wealth. The silver city had become one of the largest producers of lead and zinc in the world. This up-turn assured the longevity of Broken Hill’s mining industry. This new conception of the city saw new standards of civic pride emerge. Further parks and sporting fields were constructed; its streets were lined with trees and its barren southern and western sides were subjected to a native plant regeneration effort within designated regeneration areas. By 1938, a confident NSW Government approved plans at Yancowinna Glen and the construction of a sewerage system. By the end of the 1930s, Broken Hill and the NSW Government had been lulled into a false sense of security. Increasing demands for water from the mining industry coupled with the more liberal attitude to water from local residents placed greater pressure on existing water supplies. The lessons from the last decade had been forgotten.

**5.1.8 Crisis and the Pipeline**

By the end of 1941, Broken Hill was dry yet again. Stephens Creek had run out and the Umberumberka dam could not meet peak summer demand. Coupled with drought, fuel shortages and an increased price of coal, the cost of water rose. By 1944, the water situation was dire; Stephens Creek had been dry for the fourth year in succession (Hardy, 1968). By August rail lifts had commenced again from the Darling River, with two trains a day delivering water to the drying town. By November that year the deliveries had increased to eight per day.

In the same year the mining companies jointly hired J. R. Dridan, an expert water supply engineer from South Australia, to report on augmentation of Broken Hill’s water supply. Dridan reported that the capacity of both Stephens Creek and Umberumberka had been severely reduced due to siltation, a condition that would ultimately render Umberumberka useless within thirty years. In addition to dismissing the augmentation of local supplies, Dridan also reported that the Yancowinna scheme would not be able to meet Broken Hill’s increasing water demands. After consideration of several proposals to draw supplies from different locations along the Darling and Murray Rivers, Dridan concluded that the original plan to tap the Darling at Menindee was to be preferred. Dridan argued that the Menindee-Broken Hill pipeline would provide the most cost effective solution to Broken Hill’s water needs, that augmentation of the Menindee Lakes would not impinge upon riparian rights downstream, that it would provide storage of water for 16 months even when the Darling was not flowing, and that the unit price of water would be between $36 and 43 per 1,000 gallons depending upon its use as a primary or supplementary water supply. Spurred by the
increasing costs of railing water, the Broken Hill Water Board adopted the Darling River Proposal.

The drought broke in mid 1946. The price of water now stood at $45.42 per 1,000 gallons. Between August 1944 and January 1946 water trains had operated continuously. A total of 172,433,000 gallons of water was transported via rail from the Darling River at Menindee to Broken Hill. One hundred and thirty six million gallons were consumed by the mines, 36 million by the town. In total the water trains travelled just over 280,460 miles. Despite the prolonged drought Hardy (1968) suggests improved rail and road communications plus the addition of air services made the drought more tolerable for Broken Hill residents.

By January 1947, the Water Board had to rethink its Darling pipeline. Broken Hill was enjoying a post-war boom; zinc and lead prices had sky-rocketed and mining had accelerated. Again there was another influx of people looking to earn quick money in the booming resource sector. Within the next decade the Zinc Corporation sponsored the construction of 1,200 new homes, particularly in Broken Hill South. At the same time the old frugality in the use of water was abandoned as residents demanded an improved standard of living to complement their new found prosperity. The Water Board increased the pipe size from 20 to 24 inches with a capacity to deliver an additional 0.5 to 1 million gallons per day.

By the end of 1950, only 10 miles of the required 62 miles of the Menindee pipeline had been built. Hardy (1968) suggested this was due to labour shortages attributable to the mining boom. However, Broken Hill was soon in drought again. By November 1951 rail lifts had commenced, and continued into February 1952. During this time construction along the pipeline was intensified. On June 11th 1952 the pipeline was finally completed. The pipeline, which was first dreamt of by Harry Stockdale in 1888, was now a reality, at a cost of over 2 million pounds. The final piece of the works was finished in 1958 with the completion of Weir 32, a 15.5 foot high weir that was built to ensure water security at the Darling River as part of the Lakes Storage Project. The feeling of the time is captured by Hardy’s (1968) summation of the finishing of the pipeline and Weir 32:

“Because of the Lakes Storage and the pipeline, life on the arid Barrier has been transformed. Although as the demand for water in Broken Hill continues to rise....the Board’s worries with regard to adequate storage are virtually at an end, and the city should never again know the anxieties of water famine.”
5.1.9 The Current Situation

Needless to say, the water crises of the 1940s and 1950s were not the last. In 2002-2003, the situation again reached a critical point, so much so that a contingency plan to train water was put back on the agenda despite the potential multi-million dollar cost and a portable desalination plant was installed (but not used) in 2004 for emergency water production. In addition, because the water residue in the Menindee Lakes was so high in organic matter and salt, water quality suffered, so much so that many citizens still, in 2010, will not drink the scheme water, despite the recent commissioning of a new water treatment plant. In addition to the public health risks, the highly saline water damaged hot water systems and other water-based technologies such as evaporative air conditioners.

The water crisis of this period also prompted a voluntary water conservation strategy for the city which has been successful; however, there have been unforeseen consequences as a result of its success. One is that the sewage system requires constant flushing to remain viable and too much water conservation in the home leads to system failure. A second is that the mining legacy of Broken Hill includes lead dust, and water is needed to minimise dust levels in public places. In the face of concern about blood lead levels in children, Broken Hill had previously embarked on a ‘greening’ strategy that countered dust with lawns, gardens and well vegetated public places and parks. However, this was reversed from 2004 onwards and the public health consequences of minimisation of greenery in the city, particularly lead poisoning in children, have yet to be fully quantified. A third consequence is that, with an elderly population, dependence on high water use evaporative air conditioning systems for household cooling, water restrictions and increasing costs will see a rise in heat related health impacts. Hence, although water conservation is necessary, in a hot climate mining city such as Broken Hill, the consequences of conserving and reducing water use have yet to be fully considered.

With an official drought declared from 2005 onwards, the breaking of the regional drought in March of 2010 has seen the city once again avoid a major water crisis. While the Murdoch research team was present in May 2010 to conduct key informant interviews, the Menindee Lakes were filling from the record Queensland floods and, with Umberumberka and Stephens Creek at capacity, it was estimated that Broken Hill had at least 2 years of water left in the pipeline.

5.1.10 Key Informant Interviews

The key informant interviews undertaken in May of 2010 by Murdoch University revealed that, while individuals were highly aware of their own role and responsibilities with respect to the provision of water, there was little evidence of awareness of system-wide issues. However, there is an emerging awareness that changes in one part of the complex system that
is Broken Hill’s water supply generate changes in other parts of the social-ecological system. Water conservation leads to sewer flushing problems, greater toxic dust issues and potentially, greater heat stress in an elderly and vulnerable population. In a toxic landscape and a hot, dry climate, water conservation has its limitations.

A more serious systemic problem emerged as civic leaders, water management officials and community representatives all had differing views as to what might finally secure a reliable water supply for Broken Hill.

The following options to deliver more water to Broken Hill have been compiled from notes taken from the key informant interviews:

- Lachlan River pipeline;
- Diverting the Clarence River (Coastal NSW) into the M-D Basin;
- Lake Argyle (WA) Pipeline;
- Managed Aquifer Recharge (MAR) at Menindee;
- Bore fields at Menindee;
- Pipeline from the Murray (Mildura);
- Pipeline from Great Artesian Basin (GAB) bore field and pipeline;
- Rail lifts in emergency;
- Portable Reverse Osmosis plant to put on line when needed; and
- Tighter control of irrigation in the Murray-Darling system.

It was clear that no future scenario being contemplated for Broken Hill by key informants included consideration that the Murray Darling Basin might itself be a victim of a drying and hotter climate. The Darling River was seen by community group interviewees to be under intense pressure upstream from irrigators but not from climate change. Moreover, options to tap the Lachlan and the Murray did not consider that these catchments may also be in water crisis at the same time as the city of Broken Hill and its local catchment. Finally, different officials differed significantly on the technical feasibility and cost of other options such as MAR and bore fields at Menindee and the GAB. Even though the research team mentioned the Spencers Gulf desalination scheme to the key informants in the Broken Hill region, nobody thought it was a viable option for the future of the city.

Beyond the engineering issues, adequate environmental flows through the system remain a hotly contested issue. The rain in both Broken Hill and the Murray Darling Basin in early 2010 seemed yet again to provide a timely solution to the perennial problem of water security. However, as one senior water official suggested, there just might be a degree of complacency even in the minds of people who manage the water system because of the fortuitous rainfall of 2010 and ‘lucky’ rain in the past.
The Broken Hill water situation can best be described within the language of complexity theory. There is a basin of attraction with many attractors or factors present that drive system evolution. Historically, the basin of attraction and the attractors (mines, domestic users, irrigators, pastoralists, the environment, government), have been unable to deliver long-term water security for Broken Hill because of the failure of all players and stakeholders to have system-wide knowledge. It could be argued that although there is a complex horizontal network of components within the catchment, the weak connectivity between the key players means that there is incomplete knowledge of the system as a whole.

### 5.1.11 The Future: A Hotter and Dryer Climate

Based on international climate change models as summarised by the IPCC 4th Assessment Report (2007), CSIRO has predicted that by 2030 there will be an 11-15% reduction in surface water availability across the entire Murray Darling Basin. Winter rainfall is likely to be reduced and evaporation rates are likely to increase significantly with rising temperatures. Since the publication of the IPCC 4th Assessment Report, it seems that the high end predictions for temperature are the most likely to occur.

Now that the water system has a new and potentially powerful vertical attractor, global warming, that exists outside the natural variability of the basin of attraction, it is even less likely than ever for there to be full knowledge of the system dynamics and its emergent properties. The system now acts as a panarchy (Gunderson and Holling, 2002) where interactions occur at different levels and scales in the complex adaptive system. Without knowledge of panarchical system dynamics, it is unlikely that key stakeholders will have sufficient knowledge to plan for resilience in a future that will amplify the natural variability into non-manageable and non-adaptable domains.

### 5.1.12 The Future Scenarios

In order to test the awareness of possible future scenarios, the research team presented four future visions of Broken Hill in 2070 at the Water Expo (see Appendix 1). As per the Kalgoorlie Expo, Scenario 1 assumed no important change to the underlying climatic variability of the region and its water supply. Scenario 2 suggested that there will be increased temperature, reduced rainfall and increased evaporation that will be countered by more investment and technology but at a much greater cost to consumers. Scenario 3 assumed large change to all underlying climatic variables and that the mining viability of the city has passed. Only small scale, self-reliant water supply systems remain viable in a city with much reduced population and a small economy. Scenario 4 presented a worst case future vision with almost total depopulation as the climate and landscape become hostile to life.
Over 50 people attended the Broken Hill Water Expo and as was the case in Kalgoorlie, the 47 people who actually participated in the exercise took seriously their choice of a future for their city and engaged in deep and prolonged conversation with Murdoch researchers during the event. While the results of the Broken Hill Expo are still being evaluated, there was a clear trend towards Scenario 3 with approximately 50% of participants opting for mild or strong locations on the matrix. There was another clear cluster (12 choices) of weakly held choices for Scenario 2. Two out the 47 opted for Scenario 4 while 4 voted for strongly held visions of Scenario 1. The significant differences between the results of the two Water Expos will be discussed below (Figure 1).

Figure 1. Results from the Broken Hill Water Expo
5.2 Kalgoorlie

5.2.1 Summary

It has often been stated that in Western Australia, water is the State’s most valuable resource. This statement is as true today as it was when the State Government of just over 100 years ago launched forth on the Goldfields Pipeline, an engineering undertaking which was the single most important contributing factor to the explosive development of Western Australia in a period leading to the First World War (Jones, 1996).

The city of Kalgoorlie-Boulder, with a population of around 30,000, has the largest population of any regional city in Western Australia and is also the largest city in the Australian outback. Kalgoorlie is a city of 6,761 homes. In 2008 the median house price in Kalgoorlie was $350,000 and the median weekly family income was in excess of $1700. Kalgoorlie is Australia’s ‘gold capital’. Annual regional gold production is valued at more than $2.7 billion. Nickel is also an extensive and prosperous mining operation in the region. Approximately 5,800 people are employed in the Goldfields mining industry.

The South West of Western Australia (SW WA) has already experienced long-term decline in rainfall and the catchments and dams that supply water to Perth and the Goldfields are now rarely above 50% of capacity. Climate change models suggest that for SW WA, the situation is likely to get much worse than the 20% reduction in rainfall that has already occurred over the last 30 years. In addition to reduced rainfall, reduced runoff by a factor of 66% into the dams that supply Perth and hence, the Integrated Water Supply Scheme that supplies the Kalgoorlie-Boulder area, will create chronic water supply problems.

With increased temperatures, declining rainfall and run-off and increasing evaporation, the water catchments of the Perth region are predicted to come under extreme stress. Based on CSIRO and BOM research, it has been estimated that by 2060, an additional 365 gigalitres of water will be needed to supply Perth and places such as Kalgoorlie that are connected to the reticulated water supply system. The users of water in the greater Perth and Goldfields regions will ultimately have to pay much more than they do at present for such expensive water. Kalgoorlie water increases in value fivefold as it moves from the catchment in Mundaring to a tap in a private house in the Goldfields and this gap is subsidised by the State Government.

In order to bridge the gap between supply and current and projected demand, natural, free surface water produced by rainfall has had to be augmented with supplies extracted from coastal aquifers and now, desalination plants. However, building resilience into the water supply system with energy intensive technologies such as desalination plants comes at a cost. Despite the likelihood of increasing costs for potable water, Kalgoorlie currently has a strong economic resource and population base that will continue to be supported and subsidised by the government and tax payers of Western Australia. However, such support may not be guaranteed in the longer term as mining wealth and employment decline over time, and the
price of supplying water continues to rise. Such a scenario is distinctly possible given that the working life of the gold super pit is considered to be approximately 10 years from now (2020). When increased climate pressure on the Perth catchment is factored into the equation, the outlook for Kalgoorlie becomes more uncertain and future planning will have to take into account the possibility of regime shifts in rainfall and hence water supply systems. Long-term planning, rather than the three year political cycle planning, will be needed to confront this increasingly uncertain future.

5.2.2 Climate Change, Water and Indigenous history

The name Kalgoorlie is derived from the local Indigenous word Karlkurla, meaning ‘place of the silky pears’. The Karlkurla vine or native silky pear (*Marsdenia australis*) produced fruit and was also known as the bush banana and was a valuable regional food source. The Maduwonnga or Wongi people were the original inhabitants of the Kalgoorlie region. But they were quickly displaced by the immigration of both the colonial gold rush population and the arrival of different tribes and clans from other parts of remote Western Australia as missions and other services were built in Kalgoorlie.

Humans were able to live in the arid environment largely because of the existence of waterholes in granite formations known by the Indigenous people as Gnammas (Bindon, 1997). The Indigenous people exercised stewardship over these water supply sites and maintained their purity with active management such as ensuring that animals could escape the depression via carefully placed sticks in the water reservoir. Such stewardship was vital not only for water purity, but also to maintain these sites as places where hunting could take place as animals came to the water to drink.

5.2.3 Early Colonial History

The Kalgoorlie-Boulder area was first explored in 1863 by H. M. Lefroy. He was followed by C. C. Hunt in 1864 - 1868. Neither party was looking for gold but for pastoral areas, and therefore missed the geological clues. In 1887, gold was discovered at Southern Cross, then at Coolgardie, 38 km west of Kalgoorlie-Boulder in 1892. Patrick (Paddy) Hannan first discovered gold east of Kalgoorlie on 15 June 1893.

As indicated above, the location of water holes was the key determinant of exploration and subsequent gold prospecting. It was the Aboriginal people who showed the Europeans how to find the water connected to Gnammas and because of the aridity of the region and the very real prospect of dying of thirst, prospectors were often told to look for granite before they looked for gold. Despite these warnings, many prospectors did die either of thirst or of diseases such as typhoid as water holes became poisoned through lack of sanitation and maintenance.
5.2.4 Early Colonial Water Resilience History

The landscape of the Kalgoorlie region was unable to provide adequate food or water for the increasing number of people who came seeking gold. All food had to be imported from Perth, some 300 miles away on the coast. In the summer months in particular, there was little or no potable surface water available in the Goldfields. With the need to use water to find and expose gold and the demand from people, the need for more water became an overriding concern. Blainey (1993) wrote of it that during the first summer of settlement:

“Water to quench the thirst – it was warm and brown – was absurdly expensive. In drought a gold miner needed perhaps a quarter ounce of gold just to pay for the week’s drinking water. A few miles away from Hannan’s find was a lake of salt water, and on the shores a few primitive condensing machines used wood stoves to boil the water and remove most of the salt, making the brackish water more fit for human consumption. As Kalgoorlie’s first summer set in, water became scarcer and dearer. The surface gold was also becoming scarcer. Many prospectors decided to go to the coast. Even riding a horse in Coolgardie, merely the first stage of the journey could be risky; and on the long stretches of parched track towards Southern Cross long queues of horse teams stood at the few waterholes.”

With seasonal summer drought the norm and longer periods of low rainfall, Kalgoorlie identified its first colonially declared drought in 1894 and the township was officially declared a crisis area. The serving warden in charge of the Eastern Goldfields, John Finnerty, sent an urgent telegram from Southern Cross to Perth that read, “The scarcity of water is becoming alarming” (Blainey 1993).

A supply of water close to Kalgoorlie was a salt lake, known as Hannan’s Lake. It was about seven and a half miles from Kalgoorlie, where salt water by the aid of steam condensers was converted into potable water. This was perhaps one of Australia’s first desalination plants and the distilled water was carried by camel trains to Kalgoorlie. Brackish groundwater was also found as mineshafts reached new depths and the condensing method was also used to purify this source of water (Blainey, 1993). In some circumstances, useful sources of potable water were found underground. Blainey (1993) notes:

“On most mines the men received not only a daily wage but a daily allowance of water. Two gallons was the ration at the start of the shift and two gallons to take home at the end of the shift. The water was usually condensed from salt water at high cost, the salt water coming from lakes nearby or from shafts sunk on the mining lease in order to tap the water found in some abundance at a depth of about 200 feet. Many of the mines sank a special shaft solely to reach this rainwater which had been percolating down from the surface in past centuries. Many companies owned shafts in which the water was 20 to 25 feet deep. The shaft in Hannan’s Golden Pebbles found no gold but something equally as valuable: 25 000 gallons of water were sold each day.”
In addition to the drought, the early miners cut down trees for condenser firewood, pit props and housing. Prior to the Goldfields Pipeline, the town of Coolgardie about 30 km from Kalgoorlie was said to have the largest condenser in the world. Run by the Government it had 30 wood-fired boilers flanked on either side by banks of condensers. The water was used to supply the locomotive boilers. Condensed water was about the only reliable source of high quality water for drinking and for boilers at the time (Webb and Webb, 1993).

The lack of trees exacerbated the heat and many could not stay in the Goldfields during the height of the summer drought. Those who did stay had to pay huge prices for drinking water but so prohibitively expensive was water that washing clothes and other non-essential uses for water were rare. It was reported at the time that “successful prospectors would sometimes shout their friends a bath rather than a beer”.

Due to local concerns about the drought and lack of water, the then premier of WA, John Forrest, visited the region in 1895 and considered the plight of a great wealth-producing region for the state of WA that had no water security. By 1897, Kalgoorlie had a private water factory that delivered water to an exclusive list of private clients in a limited number of streets. Water recycling was the norm for all who had access to it and no water was wasted. By 1899, the town’s population reached 25,000 and the need for a systematic approach to the supply of water had become overwhelming.

5.2.5 Engineering Water Resilience: The Golden Pipeline

The early pioneers of the Goldfields had shown a high degree of resilience in the face of their adopted hostile climate. Despite the technical difficulties and expense, small water supply companies existed, people were able to install iron tanks to roof capture and store their own water and the camel trains continued to deliver water from sources distant from the major towns of Kalgoorlie, Boulder and Coolgardie. However, there were huge health burdens placed on the residents of goldfields towns as a result of unhygienic water provision. Scurvy, typhoid and dysentery all caused major morbidity and mortality with, for example, a typhoid epidemic that killed hundreds of people in Coolgardie caused by diggers drinking from the stagnant Coolgardie Gorge during a drought.

As a result of his direct experience in Kalgoorlie, Sir John Forrest asked the Director of Public Works to produce a practical plan for pumping water to the Goldfields. In 1896 the state parliament gave approval to raise $5 million to finance the scheme, with a high degree of confidence in the future of Kalgoorlie-Boulder and the surrounding Goldfields being able to repay the State for its investment with further economic growth and revenue.
5.2.6 C.Y. O’Connor

The engineer chosen to lead the construction of the Goldfields water supply scheme was Charles Yelverton O’Connor. O’Connor was born on 11 January 1843 in County Meath, Ireland. He migrated to New Zealand in 1865 and married Susan Laetitia Ness in 1874. They had seven children. In April 1891 O’Connor moved to Western Australia as Engineer-in-Chief of Public Works and Manager of Railways for Western Australia.

The new water supply scheme consisted of the building of a reservoir at Mundaring in the Perth Hills and the construction of what at the time was the world’s longest pipeline to pump uphill (over 800 m) five million gallons of water daily, through 330 miles of cast iron pipes to a reservoir to be constructed at Mt Burgess near Coolgardie. The scheme was later extended to Kalgoorlie with gravity feed to Coolgardie from the Mt Charlotte Reservoir.

In 1900, O’Connor authorised the start of the concrete pour for the dam wall. By early 1902 work on the weir was nearing completion. On opening the pipeline on 24 January 2003, Sir John Forrest (Casey and Mayman, 1964) announced that:

“Future generations, I am quite certain, will think of us and bless us for our far-seeing patriotism, and it will be said of us as Isaiah said of old, ‘They made a way in the wilderness and rivers in the desert’.”

Pumping began from Mundaring Weir in 1902, however, O’Connor was not to see the results of his plan as he took his own life at a Fremantle beach three weeks before the pumping all the way to Coolgardie began. The water reached Southern Cross on October 30 1902, Coolgardie on December 22 1902, and finally Kalgoorlie on January 16 1903. A statue marking the place where C.Y. O’Connor took his life was erected at South Beach where the tragic event took place.

5.2.7 The Perth Catchment and the Future of Water for Kalgoorlie

Although Mundaring Weir was built in 1902 to supply water to the Goldfields, in 1951 its height was increased so that it could also serve the water needs the agricultural areas of the Wheatbelt and changed its name to the Goldfields and Agricultural Water Supply Scheme (G&AWS). The Mundaring Weir also supplies water to some residents in the Perth Hills area.

In its current configuration, the Integrated Water Supply System (IWSS) delivers water to 1.6 million people across Perth, the South West, Kalgoorlie-Boulder and the Wheatbelt, Goldfields and Agricultural regions.
According to Water Corporation documents, the water for the IWSS comes from three sources:

1. Surface water is obtained from dams (storage reservoirs) in the Darling Range. Surface water sources supply approximately 25-45% of the water. The dams supplying water are Canning, Serpentine, Serpentine Pipehead, Conjurunup Pipehead, Victoria, Mundaring Weir, South Dandalup, North Dandalup, Wungong, Stirling and Churchman's Brook. Note that Mundaring Weir normally only supplies water to the Perth Hills, Goldfields and Agricultural Region;

2. Groundwater, supplying 35-50% through the integrated system, is obtained from huge natural reservoirs in the deep sands of the coastal plain. It is treated at groundwater treatment plants at Jandakot, Mirrabooka, Wanneroo, Neerabup, Lexia and Gwelup before being added to the distribution system; and

3. The Perth Seawater Desalination Plant in Kwinana supplies 15-20% of water needs. The largest desalination plant in the southern and eastern hemispheres, it produces on average 130 million litres of water a day.

Since 1980, large expansions in gold mining activity have exceeded the capacity available from the G&AWS scheme and required development of local saline groundwater resources. The saline groundwater is drawn almost entirely from aquifers within infilled paleodrainage channels (paleochannels) which have extremely low rates of recharge relative to abstraction rates. High rates of water abstraction are mining the aquifers and potential exists for depletion of the groundwater resource (Turner et al., 1994 1996).

Two additional sources for Kalgoorlie’s water supply have been seriously considered. One is ground water sources via bores in the Officer and Eucla Basins while the other is piped water from a desalination plant at Esperance. Both options have so far been rejected on risk and economic grounds.

The water provided to the goldfields is subsidised by the state government as the community service obligation ensures that the cost is an average of water prices across the scheme as a whole. This cost is rising as the life cycle costs of desalination are added to the bottom line and new infrastructure to improve water security is completed.

The Water Corporation and Department of Water, in their future planning scenarios for 2060, estimate that there will be a significant increase in demand for water due to population growth and a reduction in supply due to a warming and drying climate. In a worst case scenario, based on high emissions of greenhouse gases, CSIRO has projected a possible 60% decline in annual rainfall by 2070 (Water Corporation, 2009). In addition to the need for potable water, there is also the need to expand the wastewater system to cope with the increased population.
The shortfall in supply will possibly be met, according to Water Corporation by:

- Groundwater replenishment;
- Southern seawater desalination plant expansion;
- Wellington Dam desalination;
- Esperance-Kalgoorlie desalination;
- New desalination sites;
- NW metro coastal groundwater;
- Gingin-Jurien Bay groundwater;
- Jandakot groundwater expansion;
- Wellington dewatering;
- Catchment management;
- Gnangara water trading;
- Water efficiencies and recycling; and
- Demand management.

However, groundwater extraction remains at best controversial as past use has been implicated in the loss and degradation of coastal wetlands and lakes. In addition, it is claimed that groundwater replenishment can be highly rainfall independent, but this is a claim that requires careful scrutiny. The bulk of the shortfall will most likely have to come from new desalination sites. While desalination is rainfall independent, it is not climate change immune as sea level rise combined with increased intensity of coastal storm surge may cause damage to plants and hence the security of the system. In the absence of other water options, such a situation carries with it high levels of risk.

The community, looking at ground water generally, see it from two perspectives. First, a resource that should be well managed and second, a resource that has the potential to be polluted and spoiled. There is general community support for the idea that good aquifer management should only extract the through-flow of water. However, the ground water situation that many companies are faced with in the Goldfields is little flow through and therefore they are forced to mine ground water as a non-renewable resource (Jones, 1996). This creates a potential future problem as ground water that has been extracted from many of the paleochannels cannot be replaced naturally at anything like the rate it is being extracted. Therefore, this resource would not be available to support any further mining developments or for potential extraction for desalination for potable purposes. It is important that the total water supply from ground water and from the Goldfields Pipeline be managed as an integrated system.

The pollution of ground water is also of extreme concern as any degradation of the resource diminishes potential for future use. Concern has been raised about the potential contamination from seepage into ground water systems from tailings disposal altering the pH
potentially mobilising many heavy metals. In addition, there is concern about contamination from mining treatment reagents including cyanide (Jones, 1996).

The recent report, The Sustainable Cities Index (ACF, 2010) judged Perth to be the least sustainable city in Australia. In large part, this rating was achieved because of high water consumption and poor comparative performance on other environmental factors.

Such a conclusion suggests that despite the rhetoric of seeking to achieve a resilient and diverse water supply system for Perth and the pipeline, there is much more work to be done, particularly on the demand side of the water equation.

5.2.8 Kalgoorlie Conclusions

The research team completed key informant interviews of people in both the Perth and Kalgoorlie contexts and their views on the future of water supply and security in the face of a changing climate will be discussed below and further incorporated in the book chapter which will issue from the research. In all 48 interviews were conducted, 15 in Perth and 23 in Kalgoorlie.

In addition, via the Water Expo for Kalgoorlie, the preparedness of citizens for change has been evaluated. We are very grateful for the support of Kalgoorlie-Boulder Urbane Landcare Group, Water Corporation and KCGM, who provided information on their water management activities in Kalgoorlie-Boulder. Three other organisations presented information in relation to water management in Kalgoorlie. The Expo attracted a strong crowd for an event of this kind, with 65 people attending. What became clear from the Water Expo was that people, when given the opportunity, take seriously the task of making evaluations about the future. The four scenarios were challenging and many people took considerable time examining the images and the interpretative material supplied for each scenario. The results of the choices made by participants at the Kalgoorlie Water Expo are given in Figures 2 and 3. Their choices revealed that very few saw an apocalyptic future for Kalgoorlie. Most participants, about 40%, saw a future with problems solved by technology but many saw a future with climate-induced difficulties that would entail major change. This finding suggests that there is a significant proportion of the people in Kalgoorlie for whom adaptation to changing circumstances will not be a major issue but that many are also fearful of a negative future unfolding.
Figure 2. Results from the Kalgoorlie Water Expo

Figure 3. Percentage of responses for the four scenarios
6. Consideration of the infrastructure, cultural and organisational change needed to meet the water security and sustainability challenge for Broken Hill and Kalgoorlie

On the basis of information gleaned from the literature reviews, water histories and that received from the key informant interviews and the water expos, a number of issues can be identified that will determine water security and sustainability in Kalgoorlie and Broken Hill.

6.1 Infrastructure Needs

A key finding is that despite the similarities between the two cities, a vital difference is that for over 100 years Kalgoorlie has had reliable provision of potable water while Broken Hill has not. The Golden Pipeline infrastructure has produced a mentality of security about water quite independent of the reality of climate change in the SW of WA and the serious decline in rainfall over the last 50-100 years. Broken Hill, on the other hand, has experienced water crises on a regular basis and has attempted, over time, via larger and more sophisticated technologies, to gain water security. It is testimony to the challenge facing Broken Hill that 120 years after its establishment, The Darling River Water Saving Project (DRWSP, 2009), an initiative of the State Government of NSW and the Commonwealth of Australia, has as one of its objectives to secure the water supply for Broken Hill. A budget of up to $400 million was committed to address problems such as evaporation and water storage in the Menindee Lakes to achieve that end.

The different situation of the two cities is reflected in the Community Expo results with people in Broken Hill far less optimistic about their future than people in Kalgoorlie. Broken Hill people have a lived experience of water shortage during severe drought while the people of Kalgoorlie have been insulated from ecological and climate realities by the pipeline. Hence, Kalgoorlie remains optimistic that technology will continue to provide water security and a solid economic foundation while the popular choice of option three by Broken Hill participants in the Expo, one that reflects more self-reliance and a small role for government and big technology, suggests that people are skeptical or pessimistic about the ability of government and technology to ultimately solve the water security problem. Such a conclusion is also consistent with the history of Broken Hill with an editorial comment in The Conveyor of June 1952 where it is stated “old records reveal a sad state of apathy to the most vital necessity of the industry and community – an assured water supply”. 

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The historically informed pessimism in Broken Hill even extended to discussion about the current DRWSP project, with community based key informants critical, for example, that in their opinion little money has been spent so far, that it has been wasted on consultants reports, that the Menindee ground water aquifer recharge option is hugely costly, untested and risky, and that the issue of evaporation rates for water in Menindee Lakes has been overplayed. A number of interviewees even suggested that the money could have been better spent removing silt from the Menindee Lakes while they were empty over the last 5 years and that the real problem of upstream irrigation and excessive water extraction from the Darling was not being addressed. Such a conclusion prevailed despite the existence of the Commonwealth Government water entitlement buy-back scheme, Restoring the Balance in the Basin Program. Community informants pointed out that evaporation cannot be a critical water security issue as the Menindee lakes have been often empty in the last decade and that evaporation rates are the same for all areas of exposed water, including large dams used for irrigation. Needless to say, there were a great many views aired on what should be done to fix Broken Hill’s water supply. Furthermore, the current scheme on the table is not seen by many locals as any more likely to succeed as others in the past.

The future water infrastructure needs of Kalgoorlie have been addressed as part of the State Governments’ attempt to respond to the well documented decline in rainfall and runoff in the Perth catchments. The Water Corporation have a Water Forever policy and shows evidence of systematic water resilience planning in the context of increased population and declining water availability. Infrastructure investment into desalination plants has been a key strategy to overcome the decline in rainfall and runoff within a 50 year plan to meet water supply needs for the whole of the reticulation system. As indicated above, the Water Corporation has planned to build resilience into its water supply options by using a diversity of water conservation and supply options, including groundwater replenishment using recycled water.

With respect to Kalgoorlie, the Water Corporation has committed to the Mundaring Weir Water Supply Improvement Project (2010-2014), which involves construction of a water treatment plant, a new pump station and pipelines and weir improvements. However, the majority of water that enters the Mundaring system is from the major coastal aquifers and is then pumped into the Mundaring Weir system. With groundwater levels falling under a large part of the Perth region and visible signs of the drying-out of coastal lakes such as Lake Gnangara, the precautionary principle requires that a balance be reached between water extraction and infiltration. Currently, about 60% of Perth’s drinking water supply is sourced from groundwater aquifers on the Swan Coastal Plain and significant diminution of the aquifer source would be a major blow to the future resilience of both Perth’s and Kalgoorlie’s water supply. At the time of writing this report the Perth catchment had its second lowest June rainfall on record and June is usually the month of highest rainfall. With declining
groundwater availability and a dryer climate, the water engineers are finding it increasingly hard to meaningfully deliver water forever and resilience.

Without its first desalination plant, Perth’s water security would already be in crisis. With a second desalination plant coming on-stream in late 2011, about 30% of SW WA’s water will come from the ocean. If groundwater supply is reduced because of over extraction and/or environmental considerations, then more desalination plants will be required. The water agencies are currently assessing other coastal locations for additional desalination plants, although Water Corporation has already dismissed, on economic grounds, a possible private desalination plant at Esperance to service the needs of Kalgoorlie (Water Corp, 2005). Also, as indicated above, coastal locations have a measure of risk associated with them because of potential sea level rise and damage due to increased intensity and frequency of storms.

Finally, the high cost of technologically sophisticated and energy intensive ‘solutions’ to both Perth’s and Kalgoorlie’s drinking water security will inevitably mean an increased cost of water to consumers (both domestic and commercial). We have seen that if critical cost thresholds are passed in places like Broken Hill, the public backlash is something that the political and policy sectors will have to take into account. In this respect, Broken Hill provides a snapshot of the likely future of Kalgoorlie as it sees mining wind down and population decrease while at the same time experiencing a dramatic rise in the price of water.

6.2 Cultural Issues

The cultural issues relevant to both Broken Hill and Kalgoorlie are centered on the fact that both are mining towns in arid environments. In the case of mining, there is a culture of optimism that drives investment and ongoing extraction of mineral wealth. Even in Broken Hill, for some, there is a belief that the next big mineral discovery will see a resurgence of the city into something resembling its heyday. Similar considerations apply to Kalgoorlie in that despite knowledge that the Big Pit will likely close in less than a decade, another huge load of gold ore is just waiting to be discovered.

The culture of optimism still prevails in Kalgoorlie and was expressed in the Water Expo findings, however, Broken Hill’s optimism has been severely tested as more of the larger mines in the region close. Perelya, the largest remaining mine and the largest water user (subsidises the water cost for the whole city) is set to close in 2020. The optimism and the belief in the inevitability of ‘progress’ means that there is a high likelihood of climate change skepticism and denialism associated with mining communities.

With government locked into short term election cycles (3 years) and the problem of water security locked in the context of longer term anthropogenic climate change (decades and centuries), the role of political leadership in leading adaptation to change and anticipating
future change becomes a critical issue. If political ideology is out of step with climate science, then the future of issues such as water security for Perth and Kalgoorlie sit in the short-term with the political whim of individual ministers. Such an outcome is not conducive to sustainability and resilience of water supply to Perth and Kalgoorlie.

One element of the cultural history of both Broken Hill and Kalgoorlie is their long-term commitment to collective action on issues of mutual interest. The history of unionism in both towns might be a foundation for a collective adaptive response to climate and water challenges. However, there is also a history of libertarianism in both towns with people wanting to be self-reliant and not dependent on big government to organise their lives for them. Broken Hill, in particular, a city with a historically strong union presence, demonstrated that despite heavy dependence on both corporate and government investment and subsidy of water, they could see a future where they would have to be more self-reliant and supply their own water. Kalgoorlie, despite being a politically conservative federal seat with many prominent free market and small government leaders, opted for continued investment by government and industry to deliver water security. Further research is needed to tease out these apparent contradictions and paradoxes.

6.3 Organisational Change

As outlined above, the research undertaken for this project has revealed that while civic leaders and water system individuals were highly aware of their own role and responsibilities with respect to the provision of water, there was little evidence of high level awareness of system-wide issues. In both contexts, the Murray-Darling Basin and Perth’s water catchments, there is an emerging awareness that change in one part of the complex system generates change in other parts of the social-ecological system. For example, in Broken Hill, water conservation leads to sewer flushing problems, greater toxic dust issues and potentially, greater heat stress in an elderly and vulnerable population. In the context of Kalgoorlie, the Perth catchment is under extreme pressure with the connectivity between aquifer extraction, coastal ecosystem distress, acid sulphate soil creation, SW river health all tied to population pressure, development pressures and dramatic evidence of a drying climate.

For both catchments, in the language of complexity theory, there is a basin of attraction with many ‘attractors’ or factors present that drive system evolution (Higginbotham et al., 2001). Historically, the basin of attraction and the attractors (mines, domestic users, irrigators, pastoralists, the environment, government), have been unable to deliver long-term water security for Broken Hill because of the failure of players and stakeholders to have system-wide knowledge. A similar situation is emerging for Kalgoorlie as the security delivered by the Golden Pipeline is undermined by reduced rainfall in the Perth catchment.
It could be argued that although there is a complex horizontal network of components/people within the catchment, the weak connectivity between the key players and their organisations means that there is incomplete knowledge of the system as a whole and a tendency toward silo mentalities. In both contexts, such a situation can be alleviated if water organisations commit to trans-disciplinary and trans-specialist perspectives on water. The strengthening of the horizontal links in the complex adaptive system would see much greater communication and information sharing between social, ecological, geological and technological experts. In addition, political and policy leaders will need to receive such cross-system information in ways that enhance understanding of the connections between the social and biophysical elements of the complex adaptive system (Allison and Hobbs, 2006).

In addition to the horizontal complexity, it was argued above that a new vertical attractor was now an additional factor that organisations need to consider. Climate change and attendant global warming impacts on all elements of the system and does so in ways that produces surprise and emergent properties. The climate change scenarios produced by CSIRO, BOM and the IPCC all point to a major challenge for the two inland cities studied in this research. Since the publication of the IPCC 4th Assessment Report, the scientific consensus is that it is more likely that the high-end predictions for temperature rise due to anthropogenic climate change will occur. Planning for such change will not be easy.

Reduced rainfall, reduced run-off, increased evaporation and more severe flood and drought events all point to the need to understand system-wide properties at scales and within timeframes that exist outside the former comfort zone of regional and remote organisations and even State and National ones. As argued in this report, the total system context within which we must consider Broken Hill and Kalgoorlie as inland cities is now global. The system now acts as a global panarchy (Gunderson and Holling, 2002) where interactions occur at different levels and scales in the complex adaptive system. Without knowledge of panarchical system dynamics, it is unlikely that key stakeholders and policy makers will have sufficient knowledge to plan for or achieve resilience.
7. Bibliography

ACF (2010) *Sustainable Cities Index*  


Resilience and Water Security in Two Outback Cities


**Other Electronic sources**


8. Appendix 1. Broken Hill Scenarios

Broken Hill Scenario 1.

“She’ll be right mate!”

Rainfall and streamflows

Temperature

Small rise in the cost of water

Economy

No change

Population: 15,000

Slight increase in the cost of water

“Shall I be your mate?” is a quote by one of Australia's famous comedians of the 1960s.
Resilience and Water Security in Two Outback Cities

Broken Hill Scenario 2

“Chill out man! It’s all sorted!”

Temperature

Rainfall and water rights

Rainfall run-off into the northern Murray-Darling Basin

Population: 12,000

Economy

*Chill out man! It’s all sorted!* is part of the possible scenarios of Broken Hill in 2014.
Resilience and Water Security in Two Outback Cities

Broken Hill Scenario 3

“Mmmm... it’s not looking good.”

Rainfall and warm nights

Temperature

Cost of water at users expense

Rainfall run-off into the northern Murray-Darling Basin

Population: 5,000

Economy

“Mmmm... it’s not looking good” to just one of four possible outcomes of reducing in the 2024...
Broken Hill Scenario 4

“We’ll all be rooned” said Hanrahan.

[Graphs showing temperature changes and rainfall run-off into the Murray-Darling Basin]

No water

Population, under 100

Economy

Tourism

Services

“We’ll all be rooned” and Hanrahan is right, one of their possible scenarios is expected to occur in 2050.
9. Appendix 2. Kalgoorlie Scenarios

Kalgoorlie Scenario 1

“She’ll be right mate!”

Temperature

Population: 29,000

Economy

Mining: No change

Tourism: Up

Services: Stable

Small rise in the cost of water

Rainfall and warm nights

Average number of warm nights (deciles)

Average number of warm nights (deciles)

2008-2014

2006-2010
Kalgoorlie Scenario 2

“Chill out man! It’s all sorted!”

Temperature

<table>
<thead>
<tr>
<th>Temperature change (°C)</th>
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<tbody>
<tr>
<td>0</td>
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Steep increase in the cost of water

Population: 25,000

Economy

- Mining: Up
- Tourism: Stable
- Services: Up

Rainfall and warm nights

Monetary average rainfall (decade) 2000-2010

Average number of warm nights (decade) 2000-2010

Nightly temperatures above 30° percentile average 1846-1990
“Mmmm… it’s not looking good.”

Kalgoorlie scenario 3

“Mmmm… it’s not looking good” is just one of four possible scenarios of Kalgoorlie in 2050.
Kalgoorlie scenario 4

“Up shit creek.”

Rainfall and warm nights

Population: under 100

Economy

“Up shit creek” is just one of four possible scenarios of Kalgoorlie in 2015.