THE POTENTIAL IMPACTS OF CLIMATE CHANGE ON WATER SUPPLY IN JOHANNESBURG

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A research report submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the Degree of Master of Science in Development Planning.

Johannesburg, 2009
DECLARATION

I declare that this research report is my own, unaided work. It is being submitted for the Degree of Master of Science in Development Planning in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other university.

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(Signature of candidate)

__________ day of _________________ (year) _____
ABSTRACT

Climate change is a global issue that is not yet entirely understood and acknowledged by all individuals. Climate change has a variety of impacts that affect every corner of the world and every aspect of life. Water supply is one of the aspects that is currently (and will be, in the future) altered by climate change.

The purpose of this research report is to examine, utilise and select the existing information on climate change worldwide, and consequently to use this information to predict the potential impacts of climate change on water supply in the city of Johannesburg.

This report utilises predominantly secondary, existing and accessible information on existing and projected future climate changes. The method employed, firstly included selecting and providing information on worldwide climate change, and secondly, focusing to narrow down and apply the research to the case study.

The research report concludes that water supply in Johannesburg will be influenced by a variety of factors, which in turn, will be affected by climate change. Climate change is therefore a global issue that needs to be incorporated in the design and planning of any future human settlements.
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1 INTRODUCTION

“Climate change is the defining issue of our era . . . For climate change is upon us, and the problem is here to stay” (Kirby, 2008, 12).

1.1 BACKGROUND TO REPORT

Climate change, due to human-induced global warming, is an existing problem that occurs world-wide. Over the past couple of decades – and especially the past few years – it has become one of the most important and recognised global issues. Climate change affects everyone and everything on earth. There have been worldwide environmental changes and incidences that may be attributed to climate change, for instance an increase in temperatures, and severe and unpredictable disruptions in weather patterns. Consequently, while many climate change-driven impacts are expected to continue occurring in the future, the topic will continue to be debated, with a variety of views and perceptions surfacing on the severity of its potential impacts.

Water is one of the most important resources on earth, for all species. No humans, animals or vegetation can survive without water (Bates et al., 2008). Water supply is controlled by an array of factors that include the earth’s temperature, climate, weather and rainfall. South Africa and consequently Johannesburg are currently experiencing water problems, which means water supply is under stress (DEAT, date unknown; Hirji et al., 2002). As South Africa’s population continues to grow, and industries in the country expand and develop, our water supply will be placed under increasing pressure. Climate change currently affects and will continue to affect water supply, in terms of availability.

While several studies have been conducted, numerous aspects of the phenomenon of climate change have either not been thoroughly studied and examined, or have been completely overlooked. The impacts of climate change on water supply have not been examined in depth either (Bates et al., 2008). In addition, where the impact of climate change on water supply has been studied
globally, such studies have focused more on the northern hemisphere (Joubert, 2006).

In reference to Johannesburg and the existing climate change research, the City of Johannesburg has produced the Climate Change Strategy and Action Plan and the vulnerability assessment study (City of Johannesburg, 2008a; City of Johannesburg, 2008c). The Climate Change Strategy and Action Plan identifies processes in limiting and dealing with climate change, while the vulnerability assessment study pinpoints susceptible areas and their impacts and possible overall solutions to climate change (City of Johannesburg, 2008c; Golder Associates Africa, 2008). This report aims to investigate the possible future impacts of climate change on water supply in South Africa and Johannesburg, by examining and studying the topic extensively.

1.2 AIM

The research sets out to provide a compilation of existing research and information on the current and potential impacts of climate change on water supply. Subsequently, this knowledge will be applied to South Africa and to Johannesburg in particular. The research seeks out to present the necessary general background, contextual and related information on the issue of climate change. Hence, this information will be used in order to narrow down and relate the focus to Johannesburg.

The research aims to offer a more focused and appropriate inquiry into the possible impacts on water supply or the consequences of climate change that might occur in Johannesburg, South Africa. The intention of this report is to examine climate change and water supply from a planning perspective, by investigating the link between these two aspects and urban planning.
1.3 RATIONALE AND PROBLEM STATEMENT

International research has focused on the current and possible future impacts of climate change. However, this research has been limited in relation to South Africa, and it has not been focused, narrowed down and related to Johannesburg. The rationale for collating this information is to provide a relevant report that inquires and offers insight into the impacts of climate change on planning in respect of sustaining Johannesburg’s water supply.

Hence the contribution of this research is to offer a report that conveys and establishes understandable information on climate change, its link with planning and water and consequently relevant and appropriate data for Johannesburg.

The problem that this study addresses, and therefore the problem statement is the question of whether climate change will exacerbate the existing (as identified in the background to report section) water supply problem in Johannesburg.

This report is based on the precautionary principle found in the sustainable literature, that “prevention is better than cure”. Planners prepare for the future, and because climate change does and will continue to affect human settlement, expansion and sustainability in the future, planners need knowledge on how cities may develop, and the possible physical limitations of sustaining life in those cities. Therefore this research is necessary because future cities will be shaped by climate change.
1.4 RESEARCH QUESTION AND HYPOTHESIS

Research question:

➢ What potential impacts will climate change have on water supply in Johannesburg?

Sub-questions:

1. Will the impacts be temporary or permanent?
2. Which aspect (e.g., demand; source; quality) of water supply will primarily be affected or compromised?
3. Will the predicted impacts be positive or negative?

Hypothesis:

➢ Climate change will exacerbate the existing water supply problem in Johannesburg.

1.5 APPROACH OF RESEARCH REPORT

The approach to climate change that has been utilised in this research report is based on the point of view that climate change has been occurring due to accelerated global warming. Secondly, it is held that human action adds to the severity of climatic changes worldwide. Lastly, as stated in the background to report, water is an important and precious resource, and for this reason Johannesburg’s water supply has been selected as theme of this research. This approach has been used as the foundation for gathering, exploring and selecting research and data on climate change, for incorporation and analysis in this report.
1.6 RESEARCH METHOD

The following types of research are included in this report:

- Quantitative in terms of using empirical data;
- Qualitative research;
- Descriptive / exploratory research;
- Fact collection and the examination of existing knowledge and information;
- Instrumental case study and review research.

The exploratory research firstly incorporates studying, evaluating, exploring and examining existing information, knowledge and research on the topic. Secondly, the accumulated information has been assessed, selected and combined to provide a potential future outcome on the topic. Johannesburg has been selected as a case study, in order to focus and narrow down the research to a particular area, with the aid of the vast quantity of international information available on the topic of climate change. Johannesburg has also been selected in order to show a physical example of the potential implications climate change can have for any city. Johannesburg is an unusually located city, in that it is not positioned on any major river, and consequently experiences water supply difficulties. In addition, Johannesburg is a city that is expanding and growing in size and population, and furthermore, this will contribute to future water problems.

The information that was needed for this report includes local and international data on:

1. Climate change (existing debates, views and theories, as well as existing and potential impacts from around the world);
2. Water (since this is an important resource, and South Africa and Johannesburg already face water supply problems, the impact that climate change has or will have on water supply needed to be investigated);
3. Johannesburg (climate change and water supply: the related human development, and our understanding of the impacts different phenomena will have on this city);
4. Planning aspects (the effect of climate change on water supply, and consequently on planning).

This report has been approached from a planning perspective, therefore the entire report relates, links and emphasises the notions of climate change and water, to planning. In addition, the information, research and international examples used are related to planning, and to the city of Johannesburg. Therefore, only selective, relevant and necessary information on climate change and water are utilised in this report, and are justified accordingly.

Furthermore, when needed or required, primary data have been utilised in order to obtain unpublished data, research and information from particular personnel who are well versed on the relevant topic. However, only personal correspondence was employed with one key departmental individual (Lisa McNamara from the City of Johannesburg) and an environmental consultant (Herman Wiechers from Dube Ngeleza Wiechers Environmental Consultancy) in this report – in order to acquire documents and information, and therefore no interviews were conducted.

This research has not necessarily referred to or drawn on specific case studies: the information has focused on countries’ across the globe, but also on the continent of Africa. This research has primarily utilised existing findings on climate change, garnered from documents, books, the Internet and journals. The research has been based on and obtained from various sources, including the Intergovernmental Panel On Climate Change (IPCC), South African Department of Environmental Affairs and Tourism (DEAT), South African Department of Water Affairs and Forestry (DWAF), South African Cities Network (SACN), City of Johannesburg and the Water Research Commission (WRC), and various organisations active in the field of climate change.
1.7 CONSTRAINTS

The limitations of the research of this report have been the following:

1. The lack of data and information on the relationship between climate change and planning, and consequently the effect on water;
2. The fact that the impact of climate change on water supply has not been a highly researched topic to date;
3. A lack of information on the way in which climate change impacts on the city of Johannesburg;
4. The lack of access to or difficulty in retrieving locally published documents on water and climate change, and difficulty in accessing local personnel associated with water and climate change, for example employees of the DWAF; DEAT and City of Johannesburg;
5. The limitation of the accumulated information possibly being of a speculative nature; and
6. Lastly, the time and length constraints of this research report, therefore limiting the quantity and depth of analysis and presented information.

1.8 ETHICAL CONSIDERATIONS

Personal correspondence with relevant personnel has been utilised in this report in order to attain existing documentation and research, and to acquire information on the availability of documents and their publishing dates. This communication has been conducted by telephone and e-mail, due to problems related to distance, time and accessibility.

This research report has utilised an objective approach in presenting both positive and negative views and debates on the topic of climate change. However, the data utilised in this report has been based on the notion that climate change has resulted from global warming, as has been presented in the approach of research report section. Additionally, it should be taken into consideration, that the authors of all the data and research assembled have
presented their own personal views on climate change. Moreover, the information used in this research report may reflect the approaches of a variety of individuals, institutions or organisations - who may not all be in agreement on various issues.

1.9 OUTLINE OF REPORT

This chapter comprises the introduction and outline of the report, including the background, aim, problem statement and rationale; the research question; the approach of the research; the research method and the structure of the final report.

Chapter two presents and examines the literature review on the planning notions of uncertainty and scenarios, and consequently highlights the relationship between planning and climate change. Definitions have also been included in this chapter. The chapter emphasises the fact that the entire report, with its respective chapters, has been based on and linked to planning.

The third chapter is a literature review that looks at the fundamentals of climate change and water supply, by presenting the relevant debates, views and theories on the topics. This chapter also reflects international and local views on these subjects, as well as the existing problem of water supply in South Africa.

Chapter four puts forward a general overview of existing worldwide climatic changes relating to the aspect of water supply. In addition, the chapter gives an overview of the potential international and predominantly African climate change impacts, before focusing on and relating those impacts to the issue of water supply. This chapter also provides some justification for using the selected research and information on climate change and water supply.

Chapter five provides a broad outline and highlights the context of the situation in South Africa in general, and Johannesburg in particular. It focuses on the general context and planning; the water supply aspect; the available experience and future outlook regarding climate change in South Africa and Johannesburg, and
already existing changes which can be laid at the door of climate change. Furthermore, this chapter offers an explanation as to why the specific international research, summarised in Chapter four, is applicable to Johannesburg.

Chapter six draws on the information from Chapters two to four, and applies this information in predicting the potential climate change impacts on Johannesburg. In addition, Chapter six presents the stated potential climate change scenarios for South Africa and Johannesburg, before outlining and analysing the potential future implications of climate change in Johannesburg from a planning perspective and from other water-related aspects.

Chapter seven, which provides a conclusion to the report, tries to determine whether the main aim of the report has been achieved. In addition, this chapter provides recommendations on essential future research on the topic, and likely planning and other related actions that ought to be taken in order to prevent or limit climatic change in South Africa in general, and Johannesburg in particular. In each chapter, emphasis is placed on linking the research to planning, climate change and water supply.
2 PLANNING AND CLIMATE CHANGE

“Problems created by man can be solved by man.”
– John F. Kennedy (Hall and Pfeiffer, 2000, 103).

Planning, in the design of urban and rural areas, is used to schedule both existing and future projects. Therefore, planning uses existing information to plan in the present and to plan for the unknown future. Climate change, which is an irrefutable phenomenon that occurs on a continuous basis, will keep impacting cities in a variety of ways in the future. Thus, climate change will have an effect on the scope and limitations of planning. This chapter presents and examines the concept of planning, and its relationship to climate change. This section provides the basis for this report, as it shows the importance of planning for climate change. Firstly, planning in a context of uncertainty and different planning scenarios are examined. Secondly, the link between climate change and planning is shown. Thirdly, definitions are provided before a conclusion to this chapter is presented. In view of the fact that this report focuses on the city of Johannesburg, the factors used in this report are based on or related to urban planning. The thought process followed in this chapter is based on selecting information that is appropriate and relevant for the link between planning and climate change.

2.1 PLANNING DESPITE UNCERTAINTY AND SCENARIO PLANNING

Planning is a profession that plans and designs the existing and future use of land in urban areas. Many factors and physical features such as topography, the availability of water, the population, services, the environment and climate influence the intended function and subsequent development of land. These factors and features are significant issues in planning, since they shape and determine the way in which plans are designed for present and future cities.
Planning is a discipline that envisions and plans for the future; therefore it is based on our unknown or limited knowledge of the future.

Planning, as argued by Lein (2003), will never be ideal or fixed, as it is founded on the notion of taking into account various possible options and results. Lein (2003) suggests that planning is used to avoid potential problems by concentrating on supposed problems. He adds that planning is meant to identify possible risks and look at the future, when trying to predict what will happen. Accordingly Abbott (2005, 237) demonstrates this essential point by stating that, “planning is about changing the future, or at least the expected future”.

An important every day function in planning is to establish, evaluate and tackle uncertainty, and ultimately decrease uncertainty (Christensen, 1985; Donaghy, 2007). That’s why a big component in planning is the element of uncertainty, possibly in the present, but most definitely in the future (Abbott, 2005). For this reason, prediction as revealed by Lein (2003), is one of the main features of planning. Planning and hence planners need to rely on existing knowledge and experience, whether it be primary or secondary, to formulate successful plans for both present and future scenarios (Kartez and Lindell, 1987). Therefore, Marris (in Abbott, 2005) emphasises that planning is about organising present or future activities, in an attempt to control uncertainty. In that case it would be feasible to say that planning incorporates and is based (to some extent) on uncertainty.

Furthermore Abbott (2005, 241) emphasises that “if planning is about changing the expected future, then it is about understanding and changing these links between the present and the future”. Thus, planning has to utilise and take into account past and present information in order to predict and speculate about the future (Abbott, 2005). So for this reason, Flinn and Grant (1992, 111) emphasise that, “when planners peer into an uncertain future they have to base their mathematical predictions on certain assumptions over which they have little or no control. . . . Planners have to accept this constraint on their work as a fact of life”.

As planning integrates the component of uncertainty, while relying on the constant use of existing knowledge and experience to plan for the unknown future, the planning concept of scenarios or alternatives develops. A scenario as
Lein (2003, 145) demonstrates, presents possible flexible futures, and they are based on the belief that the future is unclear and almost impossible to predict. Scenarios come about by using known information to develop feasible outcomes. What is more, they indicate possibilities, not certainties (Bridgman, 1998). Since scenarios are derived from trends and likely future events (Lein, 2003), planning develops and predicts scenarios that might occur at some time in the future. It is about considering the unthinkable and preparing for any possible event (Ilbury and Sunter, 2001).

Planning practices tend to differ from situation to situation (Christensen, 1985). For this reason, planning scenarios will be different for each city, due to the variety of factors and physical features that influence the development of land in that city. So therefore in closing it can be settled that “the planner creates a scenario to describe the interaction of trends and events and to explore the possible course of alternative decisions on the future state of the planning area” (Lein, 2003, 146).

2.2 THE LINK BETWEEN CLIMATE CHANGE AND PLANNING

As presented above, the design, creation, development and sustainability of a city depends on its position and surroundings, its function, accessibility and size. Planning (and by implication city plans) are shaped and guided by these factors. The above points emphasise that planning is based on uncertainty in predicting the future, while relying on scenarios derived from past and existing knowledge. Therefore, the ability of planners and hence the capacity of planning are founded on knowing and understanding aspects related to an array of professions, including, amongst others, engineering and geography. This range of knowledge gives planners a wider view and understanding of aspects that affect planning.

In order to ascertain the link between climate change and planning, it is necessary to investigate the concept of environmental planning. Environmental
planning incorporates the notions of environment and earth science with planning (Lein, 2003). Our environment is important and necessary because we, as human beings, rely on that environment for food, water, land, oxygen, shelter and resources. The environment provides us with all the necessary requisites to survive in the present and in the future. Climate change falls within the boundaries of environmental planning, because it has to do not only with changes in the environment, but also the influence those changes have on urban areas. Climate is part of our environment, and therefore climate change can be categorised as an environmental problem – it brings about changes in our environment and hence changes in our lives.

Environmental planners, by investigating alternative scenarios, aim to maximise the benefits for humans and the environment, while concurrently aiming to minimise the impact of human development (Lein, 2003). Therefore, environmental planning ensures and protects our future and our children’s future, because the environment is an important and limited resource. If environmental degradation continues at the present rate (due, for example, to climate change) it will have dire consequences for all life on earth.

Planners, by planning, as revealed previously, design our future cities. “All cities cause climate change, emitting toxic chemicals” (Hall and Pfeiffer, 2000, 106). Hall and Pfeiffer (2000) emphasise that climate change, as an environmental problem, is a dilemma that is being faced worldwide, and it is therefore everybody’s shared responsibility. Consequently, any urban planning is and will inevitably be linked to climate change, as climate being part of the environment influences the design of future cities, and future plans are based and guided by the environment. Planners’ play an important role in the future design, functioning and structuring of cities, and consequently their contribution to negating the effects of climate change, is vital.

“Climate change is fundamentally about degrees of uncertainty” (Jarman, 2007, 82), and in addition climate change is a challenging, uncertain issue with increasing ambiguity about its speed, influence and scope, and the possible scenarios that might develop. It is, therefore, necessary to investigate and research alternative scenarios, in order to envisage possible outcomes and
formulate meaningful interventions (Houghton, 2004; Donaghy, 2007; Du Plessis and Van Wageningen, 2007).

For the above reasons, climate change and planning are inevitably linked in that they both comprise a significant degree of uncertainty despite requiring calculated action. Harris (1978, 266) asserts, “The effects of many current decisions will have major long-term impacts”. Therefore, as long as climate change continues to have a worldwide impact on cities, urban planners will have to prepare for and anticipate the unknown future impacts of this phenomenon. They will also have to incorporate the envisaged impact of climate change in their present and future plans. Hence there is a link between (environmental) planning and climate change, given that planners design the future, and climate change as an environmental problem must, of necessity, form part of that design. In addition, human beings have to “learn to work with nature and to accept the basic ecological trade-offs between protection and production” (Boyan and Ophuls, 1992, 40).

Donaghy (2007) points out that due to events related to climate change, a number of impacts are foreseen, such as increased stress on emergency services and public utilities, and damage to infrastructure and housing. The stated impacts are all, in one way or another, linked to planning, since planning considers, incorporates or relates to these aspects in the design of cities. Subsequently, the envisaged impacts show a significant link between the actual impacts of climate change and their potential effect on planning.

The point emphasised in the previous section, namely of planners using their experience and knowledge to plan for the future, is an essential factor when it comes to climate change and environmental planning. In planning, environmental planners require the necessary knowledge on the land they are working with. They need to know how the land works to sustain life, what the purpose of the land is, and also how it changes from season to season (Lein, 2003). Climate change will, without question, unavoidably bring about changes to the land, which, in turn, will impact planning.
Inadequate or inappropriate planning may result in increased environmental risks to humans. One of these environmental risks may be a natural hazard, where hazard is the danger related to a potential problem, and risk is the possibility of being harmed by a hazard. Weather-related natural hazards include floods and droughts (Randolph, 2004). Natural hazards pose a constant threat to humans, and in one way or another most societies will be forced to deal with them at some stage (Lein, 2003). Climate change may bring about or increase such natural hazards.

Kartez and Lindell (1987) aver that planning (as described previously) has to utilise existing experience or available knowledge about disaster planning in order to plan for future disaster management. Therefore, skilful planning may reduce the risks posed by natural hazards (Randolph, 2004). Planning needs to work with nature in order to ensure sustainable hazard management and decrease human and environmental vulnerability (Lein, 2003). Having the knowledge and understanding of possible hazards will not only help planners plan, but will also help them evaluate current levels of vulnerability and concomitant future risk (Lein, 2003).

The United Nations Framework Convention on Climate Change (UNFCCC) (2000) and Alcamo et al. (2009) have identified a significant issue related to the link between climate change and planning. They reveal that any present development of infrastructure, has to be constructed with the knowledge that present infrastructure will function under altered climatic conditions in the future. This is owing to the fact that infrastructure takes years to be build, and has a duration in excess of 75 years, therefore during the construction period and its existence, the climate may possibly change and result in a variety of impacts on the infrastructure. Consequently, adapting to climate change is a necessary factor in planning and designing the built environment (UNFCCC, 2000; Alcamo et al., 2009).

“The natural tendency to tinker encourages us to seek greater powers of prediction and to incorporate the implications of forecasted climate impacts earlier in the planning process” (Jarman, 2007, 82). Therefore, planning in the
present and in the future needs to be “prepared in anticipation rather than after a natural disaster” (Randolph, 2004, 243).

In the past, planning as a profession “often proved too slow, too reluctant to intervene, or [was] based on unrealistically high standards which were ignored” (Hall and Pfeiffer, 2000, 108). In most instances, planning did not make provision for the need to incorporate climatic impacts, even thought the knowledge of such factors was considered when planning. Nowadays, planning has developed into a profession that requires the informed integration of all aspects of various related professions (geography, engineering, architecture). Most recently, planners have begun to accept the fact that worldwide environmental challenges and problems are occurring, and to accept the consequences of those impacts on planning.

Climate change is a relatively new issue worldwide, which has an affect on everyone and everything in some way or another. It has also developed into a global challenge that influences any proposed development in respect of urban planning. Therefore, climate change ought to be integrated and recognised in planning, as it will affect the way in which plans are developed, and also determine the manner in which cities will expand in future.

Hallegatte (2009) stresses that due to growing worldwide awareness of climate change, planners are increasingly worrying about its effect on their activities, in the face of heightened uncertainty about the actual impact of climate change.

2.3 DEFINITIONS

WEATHER

Weather is “the fluctuating state of the atmosphere around us, characterised by temperature, wind, precipitation, clouds and other weather elements” – IPCC (Leroux, 2005, 41). Weather occurs “at a given place and time” (Miller, 1996, 129).
CLIMATE
Climate is the average weather that includes wind, precipitation and temperature over a specific period of time (normally about 30 years) (Bates et al., 2008; Joubert, 2008). Climate consists of normal weather patterns, weather extremes (long-term rain or drought and storms) and seasonal deviations (Miller, 1996). Climate varies from one area to another, thanks to specific factors such as topography, latitude, vegetation and distance from the sea. The climate may also change annually, seasonally or over decades (Leroux, 2005).

CLIMATE CHANGE
The IPCC defines climate change as a change in the state of the climate over decades, or longer, due to external unnatural forces or natural systems (Bates et al., 2008). The UNFCCC classifies climate change as “a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is, in addition to natural climate variability, observed over comparable time periods” (IPCC, 2007, 30).

GREENHOUSE GASES
Greenhouse gases are the gases in the atmosphere that include water vapour, methane, carbon dioxide, nitrous oxide and ozone. These atmospheric gases (natural and produced by human intervention) absorb infrared radiation (Bates et al., 2008; Alcamo et al., 2009). The level of gases in the troposphere (inner layer of the atmosphere), according to Miller (1996), determines the level of sunlight entering the troposphere and the absorption of the heat in the troposphere, given off by the earth’s surface (greenhouse effect), which consequently determines the temperature and climate on earth.

GREENHOUSE EFFECT
The greenhouse effect is the process whereby greenhouse gases trap heat in the troposphere. As explained above, the absorbed infrared radiation is produced by the earth’s surface, and is absorbed by clouds and by the atmosphere itself (Bates et al., 2008). Due to the greenhouse effect, the earth’s atmosphere and consequently its temperature remain warm enough for the survival of humans, animals and plant species (Spence, 2005).
GLOBAL WARMING

Global warming is the observed or projected steady increase in mean surface temperature globally. An increase in temperature is one of the side effects of a change in carbon dioxide levels – a product of human intervention (Bates et al., 2008). In the normal course of things, the earth absorbs heat rays from the sun and consequently gives off infrared radiation, some of which is trapped within the earth’s atmosphere. The process of global warming occurs when, due to an increase in the level of carbon dioxide in the atmosphere, the atmosphere thickens. Subsequently, the atmosphere traps more infrared radiation, which causes the warming of the planet, and leads to increased temperatures (Houghton, 2004; Gore, 2006).

CARBON SINKS

Carbon sinks are natural terrestrial or aquatic systems that absorb atmospheric carbon dioxide. The two natural carbon sinks are the ocean and the land: they reduce by more than half the carbon dioxide produced by land use and fossil fuel emissions, by eliminating these from the atmosphere. Therefore, a huge part of the entire human-induced atmospheric carbon dioxide load does not merely stay in the atmosphere. Carbon sinks are very susceptible to land use and climate change (Alcamo et al., 2009).

In summary, planning is a profession that is based on uncertainty and uses past scenarios or possible alternatives to foresee likely changes in the future. In order to limit and minimise uncertainty in future plans, planning needs to use existing knowledge and experience drawn from a vast array of disciplines, in order to formulate alternatives or scenarios.

Climate change is a phenomenon that affects every country on earth. It can be categorised as an environmental problem, given that it can manifest or aggravate natural hazards. As natural hazards occur worldwide, the impact of climate change will, therefore, be experienced globally. Planning and climate change have, without a doubt, gradually become interconnected because both are based on uncertainty. Climate change influences the development and expansion of
cities, and therefore planning needs to understand and incorporate climate change-related aspects in all future urban planning.

This chapter forms the springboard for the remainder of the report, since it presents the link between planning and climate change, and shows the importance and need for conducting this and further research. The report utilises the planning aspects of uncertainty and possible scenarios, by outlining the possible future climate change impacts on water supply. Aspects of planning and climate change, as highlighted in this chapter, have been utilised, referred to and linked to in the rest of the report.
3 CLIMATE CHANGE AND WATER SUPPLY

"We’re the modern weather-makers and we’re threatening the future of life as we know it” (Joubert, 2008, 76).

Climate change has become a worldwide phenomenon that has resulted in diverse changes in weather and climate. These events are capable of having global repercussions; therefore every country will be affected. Water is a valuable commodity, and its supply is influenced by a wide range of factors closely related to climate and weather. This chapter describes the fundamentals of climate change and water supply. The section forms a vital component of the report in that it introduces, examines and provides a broad overview of two principal elements. Firstly, climate change and its depiction, theories, views and debates are presented. Secondly, accepted notions surrounding water supply are stated – from both a local and an international point of view. Thirdly, water supply problems in Africa and South Africa in particular, are put forward. These problems include existing barriers pertaining to water supply. Lastly, a conclusion to this chapter is presented. The rationale for this section is based on providing background and overall knowledge on the two main elements that provide the foundation of the rest of the report.

3.1 A DESCRIPTION OF CLIMATE CHANGE

Climate change is the result of an intensification of the greenhouse effect. As the level of atmospheric greenhouse gases increases, more heat is trapped in the atmosphere, that increases energy, which in turn drives the global climate and consequently intensifies climate systems worldwide, thereby altering the earth’s temperature (Joubert, 2008).
“We know that climate change is happening, and we know that carbon dioxide (CO₂) and other greenhouse gases that we emit are the cause” – Ban Ki-moon (Kirby, 2008, 6). “Global climate change is possibly the greatest environmental challenge facing the world this century” (DEAT, 2004, 3).

Climate change is sometimes labelled ‘global warming’, but global climate change refers to the disarray in the world’s climate and weather patterns (DEAT, 2004). Therefore, a more accurate explanation would be to say that climate change arises out of global warming, or as Keeney and McDaniels (2001) declare, global warming brings about climate change. Global warming occurs due to an increase in the level of greenhouse gases in the atmosphere that trap heat and consequently warm the earth in an unnatural way. This unnatural warming leads to a worldwide change in the earth, climate and weather worldwide, which explains why climate change is a global phenomenon.

Rowlands (1998) emphasises that three key environmental outcomes can be related to climate change:

1. Rising sea levels;
2. A shift of climatic zones; and
3. An increase in the number of severe events occurring.

Another aspect that is influenced by climate change and will affect climate change is the notion of carbon sinks. Given that carbon sinks have a tendency to be affected by climate change, there is a high probability that they will deteriorate in the future, due to terrestrial (land) and oceanic (ocean) changes, which are caused by climatic changes. This, in turn, will result in more carbon dioxide remaining in the atmosphere, which will bring about further changes in the earth’s climate (Alcamo et al., 2009).

It is important to emphasise that climate change, as a consequence of global warming, is a continuous process with present as well as future impacts. The present impact, namely a rise in global temperatures, is a consequence of past fossil fuel emissions, dating back millennia (Johansen, 2006). Future impacts on earth will be as a direct outcome of present changes that humans are making to the climate (Alcamo et al., 2009). In truth, sea levels globally will keep rising for
centuries to come, even if the concentrations of greenhouse gases are somehow stabilised (Bates et al., 2008). It is predicted that the “global average surface temperature will hardly drop in the first thousand years after greenhouse gas emissions are cut to zero” (Alcamo et al., 2009, 10).

Chapter two has demonstrated that climate change and planning are linked, thus the impact that climate change will have on planning is that any future urban plans and designs will be changed by and will have to make allowances for the phenomenon – as a city expands and develops, any proposed future developments will have to make provision for climate change. The location, size and function of any new human settlement will be based on and driven by climate change considerations. Firstly, each new human settlement will have to take into consideration physical variability in both climate and weather. Secondly, the function of any human settlement determines how much carbon dioxide will be produced. Thirdly, in relation to location, the distance to work for employees will establish any additional carbon dioxide produced. Hence, the greater the number of employees, and the distance travelled, the greater the levels of carbon dioxide. Lastly, the size of the development will have to be taken into account. Planning mediates and verifies the factors of location, size and function of urban developments, and accordingly the consequences of climate change. Planning will have to incorporate and allow for engineering and geographical factors in any future plans and designs. All professionals will have to think outside the box, and take into account possible scenarios and likely alternatives.

By the 1960s scientists had begun warning that global warming, due to human activity, was emerging as a real threat (Leroux, 2005). In the 1970s environmental awareness really began taking a hold. Since then, scientists have been questioning, evaluating and analysing not only the possible effect of climate change on the world, but also the role that we humans play in contributing to or exacerbating the problem (Leroux, 2005; Spence, 2005; Joubert, 2006).

In 1995, scientists were in agreement that humankind was responsible for warming the earth (Rowlands, 1998; Johansen, 2006). Spence (2005) focuses on the reality that, after decades of research, scientists and experts have collectively agreed on the existence of the phenomenon of global warming, on the fact that
climate change is still occurring, and on the possibility that the warming of the past 50 years may have been caused by human activity (through the burning of fossil fuels; petrol, oil and coal). According to Joubert (2008), climate change became a highly publicised topic in 2006/2007, leading to greater public awareness and an acceptance of climate change globally. This gave rise to research documents, films on the topic and documentaries, and saw conferences being held on the subject. Houghton (2004), Godrej (2006), McCaffrey (2006), Jarman (2007), Joubert (2008) and Alcamo et al. (2009) confirm that worldwide, the notion of climate change has been accepted, and collectively they established that humans are accountable for global climate change and for – in effect – affecting the future of the entire world.

The concept of climate change (and its consequences) has, in the past been questioned (and is still being questioned to a certain extent). In this respect, Godrej (2006) emphasises that ‘denial’ is one of the main responses to climate change problems and the essential changes that the phenomenon requires. This aspect may also be connected to the theory that will be presented below, namely of certain individuals writing off climate change as essentially being a phase (hot or cold) that the earth is going through.

Jarman (2007) and Alcamo et al. (2009) stress that one of the existing problems related to climate change is a lack of public knowledge and awareness on the topic. Jarman (2007) argues that the concept of climate change is not publicised sufficiently or presented clearly enough to the average person. In addition, climate change has long-term consequences, and therefore the man in the street tends not to be concerned with ‘possible’ future scenarios, because he is more concerned with everyday, present problems (Jarman, 2007).

In addition to the above, other professions (in addition to planning) also find themselves at a disadvantage when it comes to knowledge on climate change. Scientists, politicians, climatologists, geographers and others in the field acquire the necessary, first-hand information on climate change. Therefore, planners are not usually the initial primary researchers on the subject, but are the secondary recipients of information. Consequently, the data, knowledge and research available to planners on the topic will be limited in both quantity and quality.
Parks and Roberts (2007) highlight the dilemma of developing countries’, with limited knowledge of climate change and fewer scientists. As a result, Third World nations are less geared to execute their responsibilities regarding climate change; they produce fewer reports on the topic and participate less frequently in global functions due to a lack of money and resources. Joubert (2006) reiterates that the southern hemisphere lacks information, research and data on the impacts of climate change and lags behind research being done in the northern hemisphere. “The developing world faces greater challenges than the developed world, both in terms of the impacts of climate change and the capacity to respond to it” (DEAT, 2004, 3).

Another significant problem with regards to climate change is the issue of disproportion and inequality between the developed and developing countries’. The developed countries’ are demanding a decrease in emissions on the part of developing countries, yet the problem is that developing countries are reluctant to curb their economic development, and hence cut back on their output of carbon dioxide. Developing countries’ want to be allowed to develop and grow economically in the same way that the developed countries’ have, in the past. Consequently, this causes friction in attempts to resolve the problem of climate change (Parks and Roberts, 2007).

The dilemma is that it is impossible for a country to develop economically while trying to limit its carbon dioxide outputs. The reality is that developing countries’ are at a disadvantage in trying to develop economically while the world bears the burden of the effects of climate change.

The Intergovernmental Panel on Climate Change (IPCC) states that one of the main reasons for worldwide scepticism on climate change is the fact that the definition of ‘climate’ is often confused with that of ‘weather’ (Joubert, 2008). The IPCC states that another aspect, which confuses people, is related to the warming and the cooling of the earth. The earth goes through phases of hot and cold periods, but climate change will affect and exacerbate these phases (Rowlands, 1998; Joubert, 2008). “Due to natural climate variability, it is entirely possible to have a period as long as a decade or two of ‘cooling’ superimposed on the longer-term warming trend due to anthropogenic greenhouse gas forcing”
(Easterling and Wehner, 2009, 1). However, it is important to differentiate between the foreseen potential outcome of climate change and the regular periods of climatic unevenness that produce severe weather patterns (Lawson, 2008).

In recent years, according to Joubert (2008), the existing problem has not been the acknowledgment (or denial) of climate change, but the quality of research that has been published and presented globally on the subject. Jarman (2007) and Joubert (2008) state that politicians influenced the most recent IPCC predictions report of 2007. “The scientists received so much pressure from politicians that they were forced to tone down the severity of their findings” (Joubert, 2008, 151). Lawson (2008, 12) suggests that the IPCC “has mutated in the minds of most of those who head it, into something more like a politically correct alarmist pressure group”.

Nonetheless, the IPCC continues to be a highly prominent and respected group that puts forward reports presenting worldwide accepted knowledge on the most predominant global warming issues (Lawson, 2008).

Lawson (2008) insists that the science of global warming has yet to be finalised. While he argues that certain scientific facts have been settled, a number still remain unresolved. In addition Lawson (2008) draws attention to the reality that the science of global warming is a fairly new field, it is complicated and based on many uncertainties.

The empirical facts that have been confirmed, include:

1. The levels of carbon dioxide in the atmosphere have increased due to man-made emissions;

2. The increase in carbon dioxide in the atmosphere has primarily played a role in warming the earth and increasing temperatures (Lawson, 2008).
The following empirical facts (recognised by Lawson 2008), ought to be carefully examined and resolved:

1. Because plants require carbon dioxide to stay alive, will increased carbon dioxide levels result in improved plant growth? (Derr, 2004; Lawson, 2008);
2. How great has the increase of carbon dioxide been?
   a. Lawson questions future predictions of temperature variations;
   b. What price will present generations pay, and how effective will preventative methods be in reducing global warming; and
   c. The danger of forced action (Derr, 2004; Lawson, 2008);
3. The media tend to attribute every unusual weather event to global warming (Derr, 2004; Lawson, 2008) – even events which may have been caused locally, or which are unrelated to global warming.

To conclude this section of the chapter, the approach used (as pointed out in the introduction) is that this report is based on the reality that humans have contributed to global warming and consequently to climate change. The consequences of human contributions have resulted in an increase in the level of carbon dioxide in the atmosphere and a concurrent increase in global temperatures.

Climate change is a significant current issue. It is important to understand the origin, effect and future consequences of the phenomenon. While it has been stated that climate and weather change over time because of regular terrestrial hot and cold phases, not every weather and climate variation can be attributed to climate change. Nonetheless, it is necessary to be aware of climate change, of its consequences and of how we, as humans, contribute to it. Climate change and global warming can disrupt the regular cycles of the earth, causing increasingly brutal and unpredictable weather patterns.

Climate change influences and affects the supply of water, because changes in the earth’s climate and weather alter the availability of usable water. The following sections will introduce the importance of and current problems associated with water supply.
3.2 AN ANALYSIS OF WATER SUPPLY

Water, as emphasised by Bates et al. (2008, 7), is “indispensable for all forms of life and is needed, in large quantities, in almost all human activities.” It is an irreplaceable commodity that is essential for the development of any human habitation, and as a vital necessity it determines the continued existence of man (Flinn and Grant, 1992). “In fact, without water, life as we know it could not exist” (Miller, 1996, 453).

“Water is never finally consumed: it changes its location, its form and its degree of purity but it does not leave the global system” (Barclays Bank, 1971, 11). Water repeatedly converts from one form to another, because it is a renewable resource: from evaporation to rainfall, to runoff and storage, to evaporation, before the cycle begins again (Hirji et al., 2002). There will never be global water scarcity; the problem lies with the adequate preservation and allocation of water (Barclays Bank, 1971).

“Global supply is fresh water lying on the surface of the earth stored in rivers, lakes and streams or temporarily frozen as ice and snow” (Barclays Bank, 1971, 11). The supply of water is affected by a wide range of factors:

1. Regular rainfall brings a fixed supply of water, which in turn seeps into the ground;
2. Increased water supply due to heavy rainfall or flooding will only occur if there is adequate storage capacity;
3. Heavy rainfall that occurs in short surges may not necessarily be a positive aspect, because due to the vast amounts of rainfall a great deal of water may be wasted, and there may be a scarcity of water between storms (Jarman, 2007).

Water shortages might produce a range of outcomes, including undesirable health-related implications (e.g. diseases from water contamination and parasites); affected food supply and agriculture; and a change in biodiversity and ecosystems (Bates et al., 2008). Increases in population and urbanisation may
possibly cause additional stress and competition for this limited resource (Hirji et al., 2002).

In reference to climate change, the effect that climate change has or is going to have on water supply will be guided by changes in temperature and precipitation, and consequently its effect on drought, floods and water availability. However, Bates et al. (2008, 7) believe that “so far, water resource issues have not been adequately addressed in climate change analyses and climate policy formulations”. This point demonstrates that exact and specific changes from climate change are difficult to state, but nevertheless Houghton (2004) and Bates et al. (2008) concluded that that freshwater resources have a high probability of being influenced by climate change. Bates et al. (2008) state that this will have extensive consequences for both ecosystems and humans. Additionally, Bates et al. (2008) stress that due to climate change the environment and humanity will experience the greatest stress in water availability and quality.

Climate change causes unpredictable climate and weather changes that lead to severe natural hazards and unpredictable rainfall patterns. Therefore climate change is going to influence water supply by conditional changes in precipitation, temperature, drought and floods. Changes and increases in variability of these factors are going to lead to changes in the availability of water, the demand for water and may cause water stress. “Climate change because of global warming will result in large changes in water supplies in many places” (Houghton, 2004, 164). Houghton (2004) demonstrates that due to increased and unpredictable rainfall and higher temperatures, this will bring about more powerful and larger number of floods and droughts. Hence, this will lead to changes in the supply of water and the demand for water.

Consequently, this links back to the points in chapter two, of demonstrating the link between planning and climate change; planning performs a significant role, as it shapes the development and growth of a city and contemplates the quantity of water that needs to be supplied. The actual existing and potential impacts from climate change on the supply of water are presented and expanded in chapter four.
Lawson (2008) identifies an interesting theory in relation to the predicted shortage of water supply in the future. He states that the envisaged water shortages may not necessarily be attributed to climate change, but believes our dilemma is related to the massive increase in the earth’s population. Lawson argues that this will greatly increase the demand for water, whereas the supply of water will remain constant (Lawson, 2008). This point indicates and reiterates that the future of water supply is going to be affected by a variety of aspects that will include climate change.

3.3 WATER SUPPLY PROBLEMS IN SOUTH AFRICA

In Africa, water is an important existing and potential issue (Bates et al., 2008). Africa suffers the following water-related problems: inconsistency of rivers; fast runoff on arid land after intense rainfall; excessive transpiration and evaporation; greater water needs owing to extreme heat; and unpredictable seasonal rainfalls (Barclays Bank, 1971). “Of the 19 countries in the world that are classified as water-stressed, more are in Africa than any other continent” (Brunner et al., 2005, 176).

In southern Africa, water is a threatened resource, because the sub-Saharan region has been prone to droughts since the 1960s (Bates et al., 2008). This is mainly exacerbated by the following:

1. Transboundary waters create uncertainty in water supply due to complicated water rights;
2. Severe climatic unpredictability and rising temperatures;
3. Overuse of water, the loss of wetlands, water pollution and degradation of the watershed result in the increased deterioration of the water supply (Hirji et al., 2002).

Climate change may place extra stresses on water accessibility and availability (Bates et al., 2008). Hirji et al. (2002, 41) emphasise that “climate variability has
always been a fact of life in southern Africa, and the emerging challenge is the expected increase in variability due to global climate change.

Murewi and Sithole (2009) emphasise that Africa, as a developing continent, has been categorised as the most susceptible to climate change and variability. Ironically, for a continent that is so hard hit, Africa “produces the smallest amount of the greenhouse gases blamed for climate change” (Baldauf, 2006, 1).

Since South Africa lies within a semi-arid region, its water resources are limited and sparse. The availability of water nationwide is unequal on account of irregular spatial coverage, seasonality and the unpredictability of rainfall. Furthermore, evaporation outweighs rainfall. Generally, urban areas are located far away from big rivers, but South Africa is susceptible to both droughts and flooding (DWAF, 2004).

Surface water is the predominant means of accessing water in South Africa. In places where surface water is inadequate, for example in arid and rural areas, groundwater is used. Notably, 66% of the normal river flow remains in the rivers, therefore this water can be used further down the river and in neighbouring countries’ (DEAT, 2007b).

According to DWAF (2004), the use of water in South Africa is divided into:

1. Irrigation – 62%;
2. Urban and domestic use – 27%;
3. Power generation, mining and industries – 8%; and
4. Forest plantations – less than 3%.

The South African Department of Environmental Affairs and Tourism (DEAT) (DEAT, 2007a) identified a number of factors that have an effect on the availability of water in South Africa. These include:

1. Human activities and urbanisation influence the level and speed of water, and limit the quantity of water that filters into the groundwater;
2. Unwise agricultural practices cause land erosion, leading to valuable topsoil being washed away into rivers;
3. Climate change;
4. Foreign vegetation uses more water; and
5. Human migration patterns place undue stresses on urban water supply.

While looking at the water supply problem in South Africa, Barclays Bank (1971, 47) noted that “few countries in the world have so formidable a basic problem in respect of water supplies as South Africa”. The warning that there would be water supply problems in South Africa by the year 2000 was already presented in 1971 (Barclays Bank, 1971).

In the most recent studies and projected demographics on water supply in the Southern African Development Community (SADC) region, South Africa is at present in the ‘water stress’ stage and will probably move into the ‘water shortage’ stage by 2025 (Hirji et al., 2002). Hirji et al. (2002, 5) point out that “in southern Africa, water is not only an essential resource, but also a limited and fragile resource”, because local water supply is under great stress.

According to Hirji et al. (2002), South Africa withdraws the most water in the whole SADC region. The researchers also noted that the South African population makes up 25% of the total population in the region, but its withdrawal of annual freshwater represents 63% of that of the entire SADC region. Consequently, “the spectre of water scarcity in the region is now a reality and it is likely to seriously undermine food production, environmental conservation and economic development” (Hirji et al., 2002, 33).

South Africa, as has been revealed, is a water-stressed nation, but Du Plessis et al. (2003) draw attention to the fact that as the country grows and develops in order to offer a sufficient quality of life for all its people, the demand for water may exceed the supply. “Based on a population growth rate of 0.5%, domestic demand for water is expected to grow at 219% between 1996 and 2030” (Du Plessis et al., 2003, 241).

In summary, climate change arises out of global warming that has been induced by human activity. Climate change produces three main outcomes that will affect the design and function of future cities. It is a continuous process that will have future impacts caused by present carbon dioxide levels. The notion of climate
change arose in the 1960s, and since the 1970s the phenomenon has continued to be investigated on the one hand, and questioned on the other. In 1995 it was established that climate change came about as a result of human-induced carbon dioxide production. Problems relating to perceptions about climate change include issues such as denial, a lack of knowledge, discrimination between the countries’ of the north and the south, general misunderstanding, and the notion that it is a fairly recent development in science. This report supports the notion that climate change is a result of man-made carbon dioxide emissions, and agrees that the future impacts and consequences of climate change need to be examined.

Water is an important product that is required by all species. Water supply is a renewable, cyclical process that is altered by rainfall and severe natural events. Climate change, which causes unpredictable climate and weather changes, affects the levels of water supply available for use and for general consumption. Planning controls the way in which urban areas develop, and could help to determine whether the necessary water will be available to us, in the future.

Problems relating to water supply in Africa and southern Africa include: the unpredictability of rainfall; the seasonality of rain; drought; high evaporation and the misuse of water. In addition, climate change will severely impact on Africa, even though the continent makes the smallest contribution to carbon dioxide emissions. As South Africa is a semi-arid country, which also has problems with the unpredictability and seasonality of rainfall, water shortages are expected to occur here by the year 2025.

The importance of this chapter in relation to the rest of the report is that it presents and examines two main, fundamental issues. The rest of the report refers to and is based on these two main issues. The exact impacts of climate change on water supply are presented and described in Chapter four. Chapter five provides a more detailed explanation of the context and climate of South Africa and Johannesburg in particular, the availability of water, and the effect which climate change has on water resources. Without the necessary knowledge contained in this chapter, the information presented in the rest of the report would be useless.
4 EXISTING CLIMATE CHANGES AND POTENTIAL CLIMATE CHANGE IMPACTS

“If we continue as we are, we might push the system into overdrive, bringing on irreversible and catastrophic climate change” (Joubert, 2008, 147).

Climate change has a variety of impacts, because it is a consequence of global warming and the concomitant increase in global temperature. The impacts of climate change are experienced across the planet: the sea, water levels, the land, people and animals are all affected. The impacts will vary from country to country, depending on their environment and location. This chapter provides a general overview of worldwide existing and potential water supply problems, which can be attributed to climate change. Chapter four offers a summary of the climate change that has already occurred, and this may accordingly be used in predicting its effect on the city of Johannesburg. Firstly, existing international and African climate change impacts on water supply are presented. Secondly, the potential climate change impacts on water supply internationally and on Africa are put forward. Lastly, the concluding points of this chapter are revealed. This chapter also provides justification for using the selected research and information on water supply. The reason underlying this chapter is to put together a framework of the essential, universally experienced climate change impacts on water supply.

4.1 EXISTING CLIMATE CHANGES

Climate change has led to numerous unusual changes in weather and climate worldwide – such changes include irregular rain and snowfall; global temperatures; ocean acidification; rising sea levels; a worldwide rise in ocean temperatures; changes in the extent of the Arctic sea ice, and intense climatic events (Spence, 2005; Alcamo et al., 2009). In the past 50 years there has been
a decrease in the ability of carbon sinks to eliminate human-induced carbon
dioxide emissions (Alcamo et al., 2009).

The single occurrence of natural disasters, for example floods, droughts, heat
waves and extreme storms (that occur in Africa and around the world), cannot be
classified as climate change. However, the fact that these disasters are occurring
more frequently, and on a global scale, is a good warning that change in usual
climate trends is brewing (Joubert, 2008). Therefore this reiterates the reality that
climate change is occurring worldwide and in South Africa.

Since climate change adds to existing problems in a country, it is important to
note that existing stresses and vulnerabilities, such as poor infrastructure, poverty
and excessive population density are the facts that climate change will “play out
against”, as Depledge and Yamin (2004, 21) suggest.

Johansen (2006), Parks and Roberts (2007) and Alcamo et al. (2009) stress that
Latin America, Africa and Asia (mainly developing countries’) are subjected to
more severe and experience many additional floods, droughts and storms than
developed countries’. These continents also boast fast-expanding populations
and have lost more livelihood and encountered higher fatality rates. Furthermore
Fields (2005, 106) adds, “Africa can easily be said to contribute the least of any
continent to global warming”. The continent of Africa is made up of developing
countries’ that have fewer numbers of human produced emissions from
industries, factories and other aspects.

4.1.1 INTERNATIONAL EXPERIENCES

PRECIPITATION AND TEMPERATURE

“The two most important factors determining the climate of an area are
temperature and precipitation” (Miller, 1996, 129).

The observed outcomes of climate change include: changes in precipitation
patterns; an increase in evapotranspiration (surface water evaporation, together
with the evaporation of water vapour from leaves); an increase in the inconsistency of interannual precipitation; more powerful and more frequent severe events; and an accelerated water cycle (Bates et al., 2008).

Spence (2005) points to the fact that over the past century the average temperature has risen by about 0.6°C – a trend that became particularly noticeable in the 1970s. “The temperature increase is widespread over the globe and is greater at higher northern latitudes” (IPCC, 2007, 30).

As indicated in Chapters two and three, Joubert (2008) declares that the strength and rate of repetition of normal weather patterns or behaviour have grown, due to rising temperatures. Furthermore “we’ve seen fewer cold snaps (days and nights) and frost events, but more hot spells and heat waves, with an increasing tendency towards temperature extremes” (Joubert, 2008, 150).

Globally, an escalation in the occurrence of severe precipitation in the late twentieth century has predominantly been attributed to human interventions (Bates et al., 2008). Since the 1980s, the level of water vapour in the atmosphere has escalated due to an increase in atmospheric temperature. Heightened evaporation occurs due to those warmer temperatures, and consequently more water vapour signifies more precipitation (Joubert, 2008). Therefore, an increase in precipitation has been the result of a rise in atmospheric water vapour and global warming (Godrej, 2006; Bates et al., 2008).

In the Mediterranean, parts of southern Asia, the Sahel and southern Africa precipitation has declined, causing these areas to become increasingly dry. By contrast, extensively increased precipitation has occurred in the eastern parts of North and South America, Northern Europe, and central and northern Asia (IPCC, 2007; Joubert, 2008).

**FLOODS**

“The observed increase in precipitation intensity and other observed climate changes . . . indicate that climate might already have had an impact on floods” (Kundzewicz et al., 2007, 177). Throughout the twentieth century there has been
an increase in the occurrence of severe flooding, and this trend will probably keep repeating itself (Johansen, 2006). In the course of ten years, between 1996 and 2005, the number of inland flood disasters was double that of the period between 1950 and 1980. On average, 140 million people annually are hampered by the natural disaster of flooding, since globally it has been the most reported natural disaster (Bates et al., 2008).

From a planning perspective, the increased damage due to natural disasters (e.g. floods) linked to climate change can be attributed to changes in land use, population explosion, economic development and the infiltration of human settlements into flood plains (Bates et al., 2008). All these factors are somehow either controlled by planning or will affect planning. Therefore, as these factors increase or change, they will contribute to the effect of climate change and therefore planning will, in some way, influence or be influenced by climate change.

**DROUGHTS**

For the most part, droughts can be attributed to global warming due to human-induced carbon emissions (Bates et al., 2008). Since the 1970s, droughts – particularly in the sub-tropics and tropics – have become more frequent and have occurred in more areas globally (IPCC, 2007; Bates et al., 2008; Joubert, 2008). Globally, “droughts were also estimated to be slightly more frequent and of much longer duration by the second half of the 21st century relative to the present day” (Boko et al., 2007, 444).

Contributing to the escalation of areas experiencing drought, are an increase in temperatures and a decrease in land precipitation. These features reduce soil moisture and intensify evapotranspiration, thus resulting in droughts. Globally, areas that have experienced more frequent droughts include Eurasia, Canada and Alaska, Europe, Australia and northern Africa (Bates et al., 2008; Joubert, 2008).
WATER AVAILABILITY

Bates et al. (2008, 38) declare that “the most dominant climate drivers for water availability are precipitation, temperature and evaporative demand”. Globally “there is evidence of a broadly coherent pattern of change in annual runoff” (Bates et al., 2008, 35). In higher latitudes, areas in Finland, China and the USA have encountered an increase in annual runoff. By contrast, a decrease in annual runoff has occurred in southern Europe, parts of West Africa and southern Latin America (Bates et al., 2008).

In lakes and rivers the temperature of the surface water in North America, Europe and Asia has warmed by 0.2–2.0°C since the 1960s. In east African lakes, in addition to the surface water warming, the deep-water temperatures have warmed by 0.2–0.7°C since the 1900s (Bates et al., 2008).

“Groundwater flow in shallow aquifers is part of the hydrological cycle and is affected by climate variability and change through recharge processes, as well as by human interventions in many locations” (Bates et al., 2008, 36). In south-western Australia, due to a decrease in surface water recharge supplies on account of climate change and due to an increase in the demand for water, groundwater withdrawals have increased (Bates et al., 2008).

Globally, impacts on water systems from climate change are visible in many countries’. In addition, water supply strains around the world have intensified – this can be attributed to changes, brought about by climate change, in respect of water availability, changes in rainfall patterns and by the migration of people into cities from water-stressed neighbouring areas (Alcamo et al., 2009).

In reference to Chapter three, the above-mentioned factors will affect the quantity of water available for consumption, be it for human, agricultural or other needs. However, as has been established, these factors ought to be considered in conjunction with the existing storage infrastructure and means of preserving water.
PLANNING
Internationally, planning (to a certain degree) has been controlled by climate change, seeing as the location and size of settlements are influenced by this phenomenon. The IPCC (2007, 48) states that settlements in river flood plains and those in coastal plains are most susceptible to climate change, and are “in areas prone to extreme weather events, especially where rapid urbanisation is occurring”. As revealed earlier, disadvantaged communities are more susceptible to such changes, and to make matters worse, they do not have the ability to adjust to climate change (IPCC, 2007; Alcamo et al., 2009).

It is primarily the disadvantaged and developing countries’ that suffer most from climate change. For starters, these countries’ already have limited infrastructure, response measures and finance than rich, developed countries’. In addition, developing countries’ are home to more informal settlements located on the outskirts of cities and in derelict and unsafe urban areas. Hence, the number of people suffering or at risk is increased, due to the impacts of floods and forced migration (caused by climate change). Developing countries’ also experience more severe weather events, which merely add to their existing problems. Therefore, while more people suffer the effects of climate change in developing countries’, these countries’ do not have the necessary response measures, the ability, money or the experience needed to adapt and change rapidly.

4.1.2 AFRICAN EXPERIENCES

PRECIPITATION AND TEMPERATURE
“The continent of Africa is warmer than it was 100 years ago” (Doherty et al., 2005, 30). Since the 1960s, temperatures in Africa have generally become warmer, but inconsistencies and varying patterns emerge when one investigates these transformations. In western and southern Africa, between 1961 and 2000, the number of particularly cold days decreased, while the number of warm days increased (Boko et al., 2007). Inconsistency in the west of Africa is a result of a change in the temperature patterns of the tropical sea surfaces and changes in atmospheric circulation (Bates et al., 2008).
“In South Africa and Ethiopia, minimum temperatures have increased slightly faster than maximum or mean temperatures” (Boko et al., 2007, 436), while in eastern Africa, area temperatures near internal lakes or the coast have decreased (Boko et al., 2007).

In Africa there are immense inconsistencies in the inter-annual rainfall (Doherty et al., 2005; Boko et al., 2007). Furthermore, unpredictability in multi-decadal rainfall is characteristic of western Africa’s Sahel region (Doherty et al., 2005; Boko et al., 2007; Bates et al., 2008). In the 1950s and 1960s the West of the continent experienced a wet phase, but from the 1970s until the 1990s it suffered an extremely dry phase. Since the end of the 1960s, the annual rainfall has been decreasing. Between 1968 and 1990 a decrease of 20–40% in annual rainfall was noted, compared to the period 1931 to 1960. The deficit in rainfall, mainly during the dry spells, was associated with a decrease in the normal rainfall during the monsoon seasons (Boko et al., 2007; Bates et al., 2008).

“In the tropical rain-forest zone, declines in mean annual precipitation of around 4% in West Africa, 3% in North Congo and 2% in South Congo for the period 1960 to 1998 have been noted” (Boko et al., 2007, 436). Since the 1970s southern Africa’s inter-annual inconsistency has increased, resulting in more extensive and severe droughts and higher precipitation irregularity. In Malawi, Namibia, Angola, Mozambique and Zambia, changes in seasonality, a rise in intense rainfall and extremes in weather have been recorded (Boko et al., 2007).

**FLOODS**

In the past two decades, southern Africa has been subjected to severe flooding, which has resulted in extensive and extremely costly damage to livestock and produce as well as physical infrastructure. It has also caused fatalities and waterborne diseases, as well as a number of health risks (Hirji et al., 2002).

**DROUGHTS**

Over the past couple of years, droughts have hit Africa harder than other parts of the world. Countries that have suffered as a result are: South Africa, Botswana,
the Sudan, Mozambique, Ethiopia, Zimbabwe and Eritrea (Spence, 2005). “The recurrent droughts experienced in southern Africa highlight the sensitivity of the region’s water resources to climate variability” (Hirji et al., 2002, 40).

Since the end of the 1960s, droughts have primarily occurred in southern Africa, in the Sahel and the Horn of Africa (Boko et al., 2007; Bates et al., 2008). The droughts or drying trends prevalent in the southern hemisphere from 1974 to 1998 can be attributed to global warming and the decrease in land precipitation. Sadly, such droughts result in a lack of food security and the spread of famine (Bates et al., 2008).

As shown in the precipitation and temperature section, the inconsistency and decrease in monsoon rainfall in the Sahel region ultimately resulted in a drought: “The decreasing rainfall and devastating droughts in the Sahel region during the last three decades of the 20th century are among the largest climate changes anywhere” (Bates et al., 2008, 80).

WATER AVAILABILITY

Rivers, rainfall and lakes are very important suppliers of water; the quantity of water that they supply is directly linked to unsustainable water use, and on the irregular physical distribution and accessibility of water. Climate change places additional stresses on water accessibility and availability (Bates et al., 2008).

Presently, in Africa, “water resources are becoming increasingly scarce” (Spence, 2005, 82) and it is clear that many water sources are already reacting to and being transformed by shifts in rainfall. This may be a sign of the likely future climate change-induced stress that may impact on water sources (Spence, 2005). Countries’ that have been altered by changes in hydrology and runoff include Kenya, Tanzania, South Africa, Ethiopia and other states on the continent (Boko et al., 2007). (See Figure A1 in Appendix A).

“In some parts of Africa access to water has become highly unreliable, with floods and droughts occurring within months of each other” (Jarman, 2007, 36). In the east of Africa, many lakes have recorded unstable annual water levels. On top of
this, as a result of warmer conditions, the temperature of the water in the lakes has increased (Bates et al., 2008).

**PLANNING**

Earlier in this chapter, it was stated that developing countries’ – and Africa in particular – make only a limited contribution to global warming, but are set to bear the brunt of extreme events. Brunner et al. (2005) argue that it is useless for Africa to try to halt climate change, and state the only thing left to do is to take action.

Many countries in Africa and sub-Saharan Africa are “ill prepared to deal effectively with the adverse impacts of climate change” (Brunner et al., 2005, 176), since Africa has only a limited capacity to adjust to change (Spence, 2005). Also, many Africans live in areas that are susceptible to flooding and drought (Brunner et al., 2005). “Preexisting environmental vulnerabilities often exacerbate already bad situations and lead to higher than usual levels of climate-related risk . . . Preexisting environmental vulnerabilities can therefore transform an extreme weather event into a human disaster” (Parks and Roberts, 2007, 118). Climate change makes weather harder to forecast, in addition to making weather patterns more severe (Depledge and Yamin, 2004; Brunner et al., 2005).

The people of Africa are already exposed to weather events, therefore climate change will only serve to exacerbate their existing problems and worsen the impacts of this phenomenon. If Africa lacks the necessary and proper response measures to cope with climate change, planning is vital: planning formulates and anticipates for the future and consequently provides different possible scenarios. Since climate change is a global phenomenon that seems set to stay, planning needs to work towards limiting the risks and vulnerabilities to humans, animals and nature. Planning can be used to plan cities and towns so as to reduce the effects of severe weather, and to reduce the number of fatalities associated with climate change.


4.2 POTENTIAL CLIMATE CHANGE IMPACTS

“While the experts know climate change is happening, it is not always easy to predict precisely how fast it will happen, and how bad the problem will become” (Spence, 2005, 18).

"It is changing, but predicting by how much is tricky” (Joubert, 2008, 152), and therefore “reliable prediction is impossible”, according to Lawson (2008, 91).

Provided that emissions continue to be produced, countless changes in climate around the world that include droughts, floods, storms and heat waves are expected to increase, and hence may give rise to unpredictable and permanent climatic changes (Joubert, 2008; Alcamo et al., 2009).

The majority of future predictions tend to be negative, and as research has developed and become increasingly accurate, so the predictions have tended to become gloomier (Godrej, 2006). Spence (2005) stresses that predicting climate change globally is much easier than predicting climate change for a specific country or town, due to a lack of accurate weather records. The IPCC states that predicting future climate change is an extremely risky process. The IPCC further asserts that it does not provide predictions but projections of future climate scenarios, based on the notion: “what if” (Lawson, 2008, 26). This point reiterates the links that were made (see Chapter two) between climate change and planning – both planning and climate change are based on uncertainty, and use the concept of scenarios for forecasting the future.

In the climate change section, it was stated that climate change exacerbates existing problems in a country, and that developing countries’ experience more severe weather extremes. On top of this, informal settlements (predominantly in developing countries’) experience the impact of climate change more intensely owing to their poor location, lack of services and facilities, and their lack of knowledge of climate change.
4.2.1 POTENTIAL INTERNATIONAL IMPACTS

PRECIPITATION AND TEMPERATURE

Warming per decade of about 0.2°C is anticipated for the next two decades. Temperatures are expected to keep rising, but the actual figure depends on the level of carbon emissions we humans generate. If the emissions remain constant at year 2000 levels, an additional increase of about 0.1°C would occur (IPCC, 2007; Joubert, 2008). By the last two decades of this century, the projections for temperature increase range from the smallest increment of 1.1°C to the greatest of 6.4°C (Joubert, 2008). As temperatures increase, so evaporation levels from sea and land will also rise (Godrej, 2006). “Warming is expected to be greatest over land and at most high northern latitudes, and least over the Southern Ocean (near Antarctica) and northern North Atlantic, continuing recent observed trends” (IPCC, 2007, 46).

Spence (2005) draws our attention to the projection that several parts of the world, including South Asia, Australia, North America, southern Africa and the South Pacific will be affected by more powerful storms and lower rainfall. By 2100 there may possibly be a decrease in precipitation in subtropical, mid-latitude and semi-arid regions, hence these areas are projected to become drier and to experience increased stress on their water reserves, while some equatorial regions and places situated at high latitudes might experience an increase in precipitation, and so become wetter (Fields, 2005; Joubert, 2006; Joubert, 2008).

“Precipitation variability is very likely to increase, and more frequent floods and droughts are anticipated” (Bates et al., 2008, 44). But the negative outcome of a rise in precipitation may cause nutrients to rise to the surface water, and heralding a growth in periods of turbidity (Bates et al., 2008).

A decrease in the efficiency of and absorption by carbon sinks (of high carbon dioxide emissions) are very likely to occur, and will subsequently produce additional human-induced carbon dioxide in the atmosphere, with a concomitant increase in changes in global climate (Alcamo et al., 2009). Therefore the failing of carbon sinks, may result in increased global temperatures and unpredictable
precipitation, which may be in addition to the above projected increases in temperature and precipitation.

**FLOODS**

As a result of global warming, an increase in the discharge of a river may cause increased rainfall-associated events, flooding and, in major river basins, an increase in the risk of rivers flooding (Meehl, 2007). “More frequent heavy rainfall events could threaten regions already prone to flooding” (Depledge and Yamin, 2004, 22). During the 21st century, extreme rainfall events are anticipated to become more common worldwide, which will increase the possibility of urban and flash flooding (Bates et al., 2008). Irregular weather events, including freak floods, are expected to increase and may be longer in duration (Godrej, 2006).

Research has shown that an escalation in heavy precipitation is linked to an escalation in flooding. In Asia, in the monsoon region in summer, and in the high, northern latitude areas in winter, it is projected that due to heavier rainfall increased flooding might occur. In Europe there is also a projection of increased flooding in summer and/or winter, due to increased precipitation (Meehl, 2007).

**DROUGHTS**

Future projections estimate that globally there will be an increase in the number of areas affected by droughts (Bates et al., 2008). High latitudes will experience a reduced number of summer droughts (Hardy, 2003). In the mid-continental areas, there is a trend for these regions to become dry during summer, which may possibly herald the onset of a period of drought (Hardy, 2003; Depledge and Yamin, 2004; Godrej, 2006; Bates et al., 2008).

Bates et al. (2008) put forward a projection of the global occurrence of droughts, until the year 2090:

1. Severe drought events will increase two-fold;
2. The average length of a drought will increase six-fold; and
3. The percentage of land encountering harsh drought at the same time will increase ten- to thirty-fold.
WATER AVAILABILITY

Hardy (2003) predicts that the combination of evaporation, increased temperature and a decrease in rainfall will cause water shortages. "Water supplies are expected to decrease as weather patterns become more extreme" (Jarman, 2007, 36). This scenario may be prevalent in the mid-latitude, sub-tropical and semi-arid areas of the world.

Bates et al. (2008) indicate that water availability may be reduced by a decline in the levels of groundwater; a reduction in summer rainfall leading to a decrease in stored reservoir water; seasonal changes in streamflow and unpredictability of interannual rainfall, as well as high temperatures and an increase in evaporation (surface water and water from leaves).

According to Bates et al. (2008), climate change alters the depth of groundwater tables and the resources feeding that groundwater. Changes in surface water flows (e.g. due to precipitation, flood and drought) will impact the levels of groundwater: "Increased precipitation variability may decrease groundwater recharge in humid areas because more frequent heavy precipitation events may result in the infiltration capacity of the soil being exceeded more often" (Bates et al., 2008, 38).

Annual river runoff is projected to escalate in the northern hemisphere (Hardy, 2003). This escalation needs to be taken advantage of by having sufficient capacity and infrastructure to secure and accumulate the surplus water. Future changes in water supply may produce both negative and positive outcomes. The positive outcome of an increase in annual runoff may be just that – an increase in the quantity of water available to consumers. The negative outcomes may be an escalation in flooding and greater destruction in areas with low water tables (Bates et al., 2008). "In addition, an increase in annual runoff may not lead to a beneficial increase in readily available water resources, if that additional runoff is concentrated during the high-flow season" (Bates et al., 2008, 44).
WATER DEMAND

The demands for water are predicted to modify due to changes in:
1. Wealth;
2. Population;
3. Industrial activity;
4. Settlement patterns; and
5. Technology. (Kundzewicz et al., 2007)

Urbanisation, according to Kundzewicz et al. (2007) may bring about an escalation in the demand for water – a demand that will peak in arid areas. “Climate change will probably alter the desired uses of water (demands) as well as actual uses (demands in each sector that are actually met)” (Kundzewicz et al., 2007, 191). The demand for irrigation water is expected to increase because of greater inconsistency in precipitation levels, and temperature increases (Bates et al., 2008).

WATER STRESS

As indicated by Kundzewicz et al. (2007), until the 2050s the projected percentage of global land area influenced by water stress will be as follows:
1. On 62–76% of global land area, water stress is projected to escalate;
2. On 20–29% of global land area, water stress is expected to decline.

This 2050 projection indicates that the number of individuals living in the floodplains of water-stressed rivers is likely to increase, and climate change would be one of the reasons for this stress (Bates et al., 2008). This estimate shows that on account of climate change, river floodplains will probably become more vulnerable, heightening the risk to settlements and communities located in floodplains.

“The principal cause of decreasing water stress is the greater availability of water due to increased precipitation, while the principal cause of increasing water stress is growing water withdrawals” (Kundzewicz et al., 2007, 194).
"Human settlements have been, and continue to be, linked closely to the availability of freshwater" (Hardy, 2003, 77). Climate change will influence not only the infrastructure that supports nations, but also the design of human settlements (Hardy, 2003). The outcomes of climate change that are assumed to impact future infrastructure and human settlements include the possibility and severity of flooding, and changes in water quality, precipitation patterns and water availability (Bates et al., 2008).

Globally, countless human settlements do not have access to secure and ample water supplies. In view of the fact that water supply quality and the availability of water will be impacted by climate change, this phenomenon will, in all probability, intensify the challenges, which need to be overcome, and increase the focus on water provision. The areas that are expected to experience the greatest disruption will be places with growing populations and reduced runoff, i.e. water stress (Bates et al., 2008).

Hardy (2003), in discussing the design of human settlements, refers in particular to the potential relocation of people and extensive human migrations on account of climate change. Therefore, urbanisation may also speed up thanks to climate change, as the impacts of droughts and floods on the outskirts of a city and in rural areas could be the push factors causing individuals to migrate to the city to seek additional water or protection against climate change. In addition to climate change-induced urbanisation, increased rainfall and flooding may possibly produce landslides and slope instability (Hardy, 2003).

Planners need to know and understand the consequences of climate change in respect of its impacts on water supply, infrastructure and human settlements. Given that climate change will add to our existing problems and will most certainly create additional difficulties, knowing the potential future scenarios will limit those possible impacts and prepare us for a number of likely scenarios. Planning for water supply, planning when designing cities and preparing for the envisaged population growth may at best prevent and at worst limit certain risks.
4.2.2 POTENTIAL IMPACTS ON AFRICA

PRECIPITATION AND TEMPERATURE

The future projections of precipitation and temperature for sub-Saharan Africa are uncertain and differ widely, as some researchers and weather forecasters envision decreases while others project increases (Kulindwa et al., 2006; Bates et al., 2008).

Southern Africa, as a result of climate change, will face consistent warming. Thus, future water availability will decrease and evapotranspiration rates will increase, thanks to a rise in temperatures (Hirji et al., 2002). The entire African continent is projected to become 1.5 times warmer than the rest of the world. Temperatures across the continent are set to escalate between 3 and 4°C by the end of the century, with the arid subtropics (e.g. central southern Africa and the Sahara) warming more than the wet tropical areas (Doherty et al., 2005; Joubert, 2006; Kulindwa et al., 2006; Boko et al., 2007; Joubert, 2008).

In the northern Sahara, North Africa and along the west coast, yearly rainfall is projected to decrease, and in southern Africa winter rainfall will most likely decrease. In east and tropical Africa, the average annual rainfall will presumably rise (Kulindwa et al., 2006; Boko et al., 2007).

In semi-arid and arid sections of Africa (Sahel and Southern Sahara) it is extremely difficult to predict future runoff (Kulindwa et al., 2006; Boko et al., 2007) seeing that runoff can be altered by the smallest change in precipitation (Boko et al., 2007). “However, increased precipitation variability may increase groundwater recharge, because only high-intensity rainfalls are able to infiltrate fast enough before evaporating, and alluvial aquifers are recharged mainly by inundations due to floods” (Bates et al., 2008, 40). (See Figure A2 in Appendix A).

FLOODS

“A warmer climate, with its increased climate variability, will increase the risk of both floods and droughts” (Kundzewicz et al., 2007, 186). Unfortunately “there
has been relatively little work published on future climate change scenarios for Africa” (Doherty et al., 2005, 32).

Rural and urban settlements that are located in floodplains and wetlands on account of their fertile soil and their proximity to fish resources may encounter flooding. Consequently, due to the flooding of rivers, the settlements will suffer physical damage to buildings, structures and infrastructure such as roads (Magadza, 2000). “Human encroachment into flood plains and lack of flood response plans increase the damage potential” (Kundzewicz et al., 2007, 186). “Floods invariably lead to disease, destruction of food reserves, and habitations” (Magadza, 2000, 194).

DROUGHTS

Hardy (2003) states that summer droughts will be more frequent in low latitudes. As argued above, there is also a lack of data on African drought predictions. However, for the 21st century, drought projections indicate that central Africa could experience increased rainfall, while northern Africa may suffer under drier conditions (Boko et al., 2007).

WATER AVAILABILITY

Climate change will have an affect on water assets, the flow of rivers, irrigation and the use of water (Hirji et al., 2002). Boko et al. (2007, 446) offer projections, stating that in southern Africa “almost all countries except South Africa will probably experience a significant reduction in streamflow”. Although future projections for Africa, in respect of river-runoff differ considerably, a common forecast includes an increase in eastern Africa and a decrease in northern Africa’s river-runoff (Bates et al., 2008).

By 2025, the availability of water in many countries’ in southern Africa is assumed to decrease. Several SADC countries’ (according to Hirji et al., 2002) will either experience water stress (Lesotho, Mauritius, Tanzania and Zimbabwe), water scarcity (Malawi and South Africa) or water fluctuations during the dry season (Angola, Botswana, DRC, Mozambique, Swaziland and Zambia). By 2055,
western and eastern Africa could see a decline in water stress, whereas southern and northern African areas may well be subjected to increased water stress (Boko et al., 2007). (See Figure A1 in Appendix A).

In Africa, “by 2020, between 75 and 250 million people are projected to be exposed to increased water stress due to climate change” (IPCC, 2007, 50). However, excluding climate change impacts, up to 460 million people, primarily in the west of Africa, are expected to be at risk of water stress (Bates et al., 2008). What's more, there is a possibility of “the proportion of the African population at risk of water stress and scarcity increasing from 47% in 2000 to 65% in 2025” (Bates et al., 2008, 79).

WATER DEMAND
In view of the fact that runoff and rainfall will decrease in the southern hemisphere, the demand for water will also increase (Hardy, 2003). In Africa, factors like climate change, increased desertification and drought, and fast-growing populations may cause “increased competition for the scarce resources and heightened resource scarcity “ (Kulindwa et al., 2006, 36).

WATER STRESS
“The impact of climate change on water resources across the continent is not uniform” (Bates et al., 2008, 81). In Africa, by the year 2025, increased water demand is projected to aggravate water stress for numerous population groups. This situation will be worsened by climate change (Bates et al., 2008). Arnell, in Bates et al. (2008), projects the number of people to be faced with water stress as:

1. 2020s: 75–250 million;
2. 2050s: 350–600 million.

The main source of drinking water in Africa is groundwater, but as precipitation and runoff decrease this will reduce the levels of groundwater. Likewise, it will
place additional stresses on water for domestic and agricultural use (Bates et al., 2008).

PLANNING

“Human settlements will be affected by climate change through several processes, among them water resources, sea level changes and changes in frequency of extreme factors such as droughts, hurricanes and extreme temperatures causing heat waves” (Magadza, 2000, 194). In developing countries’ in semi-arid areas, fast-growing mainly impoverished settlements of people are particularly susceptible to the reduced availability of water, because they have restricted adaptive capabilities. In addition, this problem will increase the costs associated with acquiring water supplies (Bates et al., 2008).

Hirji et al. (2002) reveal that in order to safeguard the security of its citizens and the economy, water-resources planning in any region needs to allow for climatic inconsistency and incorporate the capability to observe and predict climatic changes. “Management for sustainable water supplies will require new policy approaches that plan ahead to accommodate climate change” (Hardy, 2003, 93). In addition, Hardy (2003, 93) emphasises that future plans and designs need to incorporate “a wider range of climatic conditions than traditionally used“. These aspects highlight the requirement that planning for both the present and the future have to take cognisance of climate change.

The above point and the ones stated previously in the section on existing changes and that of potential impacts re-emphasise the facts presented in Chapters two and three, of the link between planning and climate change. Climate change will result in numerous changes, which will have dire consequences for people, animals and the environment. Climate change will affect water supply in the future, as well as the location of human settlements. Planning – and more specifically environmental planning – endeavours to envision the future and, accordingly, through the use of scenarios, tries to minimise the effect of development, while optimally benefiting humans and protecting the environment. Planning relies on existing knowledge to reduce future environmental risks and hazards. In review, climate change will have a
number of future impacts on human settlements and infrastructure. Therefore, planners need to be aware of these impacts and must be able to design and plan future developments and cities accordingly.

Bridgman (1998) illustrates an important point in support of the above, namely that any kind of prediction of future climate will always be based on some degree of uncertainty or assumption. He emphasises that future decision making needs to incorporate climate change for the reason that it is an important factor, and there are enough accurate and dependable scenarios to warrant the issue. In addition, there is the fact that the impact of current human carbon dioxide emissions may possibly be recorded for the next 50–100 years. Therefore he stresses “this makes the inclusion of climatic change impacts in planning processes all the more critical” (Bridgman, 1998, 265).

In short, existing global climate changes include an overall rise in the global temperature. In certain parts of the world, rainfall has increased due to increased evaporation, which has brought about more frequent flooding and resulted in greater runoff. In other areas, precipitation has decreased, which has led to more instances of drought and less runoff (caused by a reduction in rainfall and a rise in temperatures). Globally, the speed of the hydrological cycle has increased, making predicting the weather even more difficult. Furthermore, the increases in the supply of water have to be considered in conjunction with the aspects of storage.

The climate changes, which Africa is currently experiencing, include warmer temperatures, inconsistent rainfall and extreme weather events. In Africa there has been an overall decrease in rainfall, which has resulted in longer dry spells, and has intensified droughts. Hence the availability of water has decreased, and many countries’ on the continent are experiencing water scarcity. The rise in temperatures has also made rainfall unpredictable in certain areas in southern Africa, which has resulted in flooding.

Existing climate change planning problems are that settlements worldwide have already been affected by climate change. While many informal settlements in
developing countries’ and in floodplains or low-lying areas in particular are already at risk of extreme weather, they have also become more vulnerable to the effects of climate change. Africa’s increased vulnerability is already burdened by climatic inconsistencies, and the continent may not be capable of dealing with further problems.

The international potential impacts of climate change are similar to existing climate changes in Africa. Internationally, temperatures are expected to increase, with greater inconsistency in rainfall, and a greater prevalence of droughts and floods. In the mid-latitude, semi-arid and subtropical areas, rainfall is expected to decrease; hence conditions will become drier, with more frequent droughts and greater stress and demand on water resources. Less water will be available. In the equatorial and high-latitude regions, rainfall will increase and the areas will become wetter, have more runoff and may experience stronger, unpredictable flooding. In addition, surplus water from such instances of increased rainfall will only add to the availability of water – if it is stored.

In relation to the potential African impacts, some inconsistencies remain. Also, there is a lack of data on expected future impacts in Africa, but what is certain is that there will be a general rise in temperature. As with the above-mentioned forecast international impacts, in the eastern and tropical areas of Africa, precipitation will increase. In the north, west and south, which are mainly arid areas, there will be a decrease in rainfall. This will lead to the decreased availability of water, an increase in the demand for water, and increased water stress.

The potential planning impacts will be that all the stated aspects of temperature, precipitation, floods, droughts and water availability will affect planning when it comes to the location and size of future settlements. Hence, planning needs to take cognisance of potential climate changes in order to plan effectively.

The information used in this chapter is appropriate for this report, seeing that the aforementioned factors of rainfall, temperature, drought and floods are all relevant to issues of water supply. The predicted water supply and planning impacts are both relevant to this report, since they are the two main areas of
focus. All the stated existing and potential impacts of climate change provide a good general explanation of the various factors related to water supply, and the limitations hampering the supply of water. Planning has been the driving force behind this report, therefore the impacts of planning need to be highlighted and examined.

Chapter four has provided an overall summary of existing changes and the potential impacts of climate change in the world and in Africa, in particular, with a focus on water supply and planning perspectives. This chapter is important because it shows the actual physical changes which climate change can and do bring about, and therefore these impacts are used in the following chapters to ultimately investigate the potential impacts of climate change on water supply in Johannesburg.
5 BACKGROUND ON SOUTH AFRICA AND JOHANNESBURG

“Climate change is an issue of the utmost seriousness, and its effects will be felt by everyone all over the world”
– Minister of Water Affairs and Forestry (Sonjica, 2005, 1).

South Africa – and particularly Johannesburg – will not escape the impacts of climate change. In fact, South Africa has already begun experiencing the consequences of a change in climate due to global warming. As revealed in Chapter three, this developing country has had to deal with the reality and burden of balancing development, with the environmental problem of climate change. Chapter five provides an outline and context of South Africa and the city of Johannesburg, in terms of the physical and climate change factors impacting on this region. This chapter provides background knowledge to the following chapter, in projecting the potential impacts that Johannesburg will be facing. Firstly, overall concise context, description and planning features of South Africa and Johannesburg are introduced. Secondly, a picture is painted of South African and Johannesburg’s water supply. Thirdly, the history, understanding and acknowledgement of climate change in South Africa – and predominantly in Johannesburg – is presented. Fourthly, the existing climate change impacts encountered in South Africa are highlighted. Lastly, a conclusion to this chapter is provided, in addition to clarifying why the specific international and African research in Chapter four is relevant to the city of Johannesburg. The basis for this chapter is to offer information, which applies, to the entire South Africa, and then subsequently narrowing that down to the province of Gauteng and to Johannesburg in particular.
5.1 CONTEXT AND PLANNING

South Africa is mostly a semi-arid country, with a desert and semi-desert climate in the west and a sub-humid climate along the east coast (see Figure A3 in Appendix A). The South African mean rainfall of 450 mm per year is beneath the world standard of 860 mm per year, and evaporation is relatively high, therefore, compared to other countries’ in the world, South Africa’s water resources are exceptionally restricted and limited. This is also partly due to the fact that the country is not home to many large rivers – in fact, its total river flow is small, compared to other rivers in Africa. Groundwater is significant in that it is the main source of water in the rural areas. However, only approximately 20% of groundwater can be utilised (DWAF, 2004).

In South Africa, several densely populated rural settlements and numerous industrial and urban developments originated in isolated areas that were located a long way from constant and sufficient sources of water (DEAT, date unknown; Mukheibir and Sparks, 2003).

The province of Gauteng (See Figure A4, A6, A7 & A8 in Appendix A) has a population of 10.5 million people (2008 estimates). There is constant migration into and out of the province. In Gauteng, greenhouse gas emissions are made up of industry and motor vehicle emissions, and emissions from burning coal. The greenhouse gases appear to be worse in winter, because the pollution is trapped by the steep inversion in temperature. Countless natural water systems in Gauteng have been permanently degraded through mining and construction. The bulk of the water intended for Gauteng is extracted from half the capacity of the Vaal River (See Figure A5, A6 & A9 in Appendix A). Guaranteeing Gauteng’s water supply for the future is a significant concern to the province (UN-Habitat, 2008).

The city of Johannesburg (See Figure A7 in Appendix A) has a population of 3.2 million people (2001), residing in both formal and informal residential patterns. Informal settlements are mainly located on the periphery and in marginalised areas. Rapid urbanisation and migration into Johannesburg has occurred due to
various factors, but over the past couple of years commercial and residential development has been the dominant factor. This rapid human settlement has curtailed conservation efforts, and placed the city’s natural ridges and open spaces under stress from development. Nowadays, the majority of open spaces are found on the periphery of the city (City of Johannesburg, 2008b).

Environmental concerns and the lack of open spaces are caused by urban sprawl, population growth, urbanisation, the unsustainable misuse of resources and a lack of enforcement when it comes to anti-pollution guidelines. These factors place increased pressure on, exhaust and abuse existing resources and lead to poor water quality. Due to massive human development, water-related infrastructure, sewerage, Stormwater facilities and power supplies have come under increasing strain (City of Johannesburg, 2008b).

“Johannesburg straddles the main watershed divide for the subcontinent and is one of the few cities of its size and kind in the world, which is not situated on a major watercourse” (DWAF, 1999, 1). (See Figure A5 & A8 in Appendix A).

5.2 A DESCRIPTION OF WATER SUPPLY IN SOUTH AFRICA

South Africa is a water-scarce country, with water sources being in limited supply. Across the country, the availability of water is restricted and its distribution unequal because evaporation levels are higher than rainfall, there is inconsistent surface runoff, irregular spatial coverage of rainfall, which is unpredictable and unseasonal (Bridgman, 1998; DWAF, 2004). “Summer, across the majority of southern Africa, is the dominant rainfall season” (Bridgman, 1998, 274). South Africa is also known to be susceptible to droughts and flooding (DWAF, 2004).

South Africa has four major river basins: the Orange River, Maputo River, Limpopo River and the Incomati River. These are international river basins, which means they are shared with neighbouring countries’. These aforementioned
rivers supply about 40% of the entire surface runoff (Hirji et al., 2002; DWAF, 2004).

The local irrigation sector is the main consumer of water, but water is also required for domestic and urban use, power generation, mining, industries and forest plantations (DWAF, 2004). Surface water is the main source of water in South Africa; being mainly used for industrial, urban and irrigation needs (DWAF, 2004; DEAT, 2007b). Groundwater is primarily used in rural areas (DEAT, 2007b). As South Africa develops and grows, the demand for water may soon exceed the supply (Du Plessis et al., 2003).

Numerous industrial developments and settlements in South Africa are “not in line with water availability” and Gauteng province is one such region, which is located in an area with restricted water availability (Du Plessis et al., 2003, 242). Gauteng province receives the bulk of its water from the Vaal River System, which ought to be able to provide the province with the necessary water until about 2025 (see Figure A6 & A9 in Appendix A). As expansion and development continue in Johannesburg, additional water transfers may be required into the Vaal area towards the end of 2025, or if the Vaal River System experiences a shortage before about 2025 (DWAF, 2004).

Johannesburg pipes water from the Vaal River System, which supplies the entire Gauteng province. In addition, Johannesburg has two principal catchment areas: the Jukskei River catchment and the Upper Klip River catchment. The Jukskei River catchment is situated to the north of Johannesburg, and its water supply is mainly used for industrial and agricultural purposes. The Upper Klip River catchment is located to the south, and its water is intended for industrial, domestic, agricultural, recreational and natural environmental uses. In the greater Johannesburg area, water is an important yet limited resource. Although the quality of drinking water in the city is very high, the main problems related to its water are the impacts of pollution, and increased demands being made on water resources (DEAT, date unknown). (See Figure A5, A6 & A8 in Appendix A).
5.3 CLIMATE CHANGE IN SOUTH AFRICA

SOUTH AFRICA

In August 1997, the government of South Africa approved and accepted the United Nations Framework Convention on Climate Change (UNFCCC). The goal of the UNFCCC was to stabilise the atmospheric levels of greenhouse gases. The Kyoto Protocol was formulated in 1997 – since the obligations of the UNFCCC were insufficient to stabilise the levels, Kyoto was established in an attempt to meet the main goal. South Africa became a signatory to this protocol in July 2002 (DEAT, 2004).

“Climate change is a relatively new issue in South Africa due to the prior isolation of this country from international events” (DEAT, 2004, 5). The government departments that are directly engaged with the issue of climate change and its possible impacts have proven to be the most informed. Other departments have a somewhat limited understanding on this issue, and therefore many unconcerned departmental officials (in all fields of government) do not view climate change as an imperative and compulsory issue, but often perceive it as a hindrance to development. Furthermore, in South Africa the mandatory standards of training, education and public awareness on the issue of climate change lag behind (DEAT, 2004).

“By and large, the implications of climate change have not yet been fully and explicitly considered in current water policy and decision-making frameworks” (Schulze, 2005b, 4). However, in 2008, the Minister of Environmental Affairs and Tourism, Marthinus van Schalkwyk, stated that “a progressive policy on climate change had been agreed upon by Cabinet that would help ensure that the country was helping prevent global temperatures from rising a further two percent” (Benton, 2008, 1).

In southern Africa, South Africa is the foremost contributor of carbon emissions, as identified by Rowlands (1998). South Africa contributes 41.9% of the entire emissions produced in Africa, and South Africa is “one of the top 20 greenhouse gas-emitting countries” (Du Plessis et al., 2003, 244). In 2002, the total global
greenhouse gas emissions that South Africa pumped into the atmosphere amounted to about 2% of the world’s total output (Du Plessis et al., 2003; Brunner et al., 2005).

JOHANNESBURG

Johannesburg has taken the initiative in acknowledging and curbing the impacts of climate change. The city has entered into a partnership with the International Organisation of ICLEI - Local Governments for Sustainability (also known as ICLEI, originally named - International Council for Local Environmental Initiatives). This organisation has been helping local governments since 1992 with sustainability issues. One of the ICLEI campaigns conducted in South Africa was the Cities for Climate Protection (CCP). The donor-funded CCP operation was implemented in Johannesburg, to help reduce the city’s global warming and air pollution emissions by helping it to set up phased quantifiable reduction objectives (SACN, 2007a).

“Johannesburg prides itself in being a world-class city that will unashamedly look at best practices elsewhere and adapting them to local Johannesburg conditions“ – Johannesburg Mayor, Amos Masondo (SACN, 2007a, 44).

The City of Johannesburg has also been chosen by the former US President Bill Clinton’s Foundation (known as the Clinton Climate Initiative [CCI]) to ‘go green’. Johannesburg is one of 40 cities globally to be chosen, and the only one in South Africa, in an initiative to cut greenhouse gas emissions. The foundation provides low-interest loans to establish devices that are energy saving (SACN, 2007a).

The CCI was established in 2006. Its first major venture is operating with the C40 Large Cities Climate Leadership Group. Johannesburg is one of the 15 biggest global cities of this group, which is endeavouring to embark on climate change. Amongst others, these cities allow their municipal buildings to be fitted with energy retrofits in a pilot project aimed at reducing energy use (SACN, 2007a; SACN, 2007b).
The City of Johannesburg, in order to adjust to the impacts of climate change and reduce greenhouse gas emissions, has developed the Johannesburg Climate Change Strategy and Action Plan (City of Johannesburg, 2008a; City of Johannesburg, 2008c). This plan provides mitigation and strategy processes to counteract climate change (City of Johannesburg, 2008c). This strategy and action plan, which was produced in 2008, is currently being updated (McNamara, 2009).

The city of Johannesburg has carried out a vulnerability assessment study, the draft of which, produced in 2008, is currently being updated (McNamara, 2009). Johannesburg embarked on this study in order to improve its capacity to resist and make adjustments for any possible impacts related to climate change (City of Johannesburg, 2008a). The study concentrates on evidence of climate change in Johannesburg, identifies vulnerable areas and their possible impacts and mitigations, and provides overall possible future alternatives for the city, in dealing with climate change (Golder Associates Africa, 2008).

The findings of this vulnerability assessment study will be used to inform Johannesburg’s adaptation plans in respect of climate change (City of Johannesburg, 2008a). The plan, which is aimed at adapting to climate change impacts (City of Johannesburg, date unknown a) is scheduled for completion by the end of the year (2009) (McNamara, 2009).

Johannesburg has also established a department (Environmental Management Department) to handle environmental issues and tackle projects to reduce the impact of climate change and enhance the environment (SACN, 2007a). The Johannesburg mitigation programmes include:

1. Solar water heaters in Cosmo City;
2. Solar street lights in Zandspruit;
3. A Bus Rapid Transit system;
4. In the Environmental Management Department, a climate change programme;
5. Electricity-saving measures in five city-owned buildings;
6. A possible landfill gas project;
7. Water-related projects include:
   a. Infrastructure upgrading;
   b. Storm-water maintenance and management plans;
   c. The improvement of and management plans for catchment areas;
   d. Education and public awareness campaigns;
   e. Focus on flood-prone areas and revision of flood lines
   (City Of Johannesburg, date unknown b; SACN, 2007a).

One of the projects that has been implemented in Johannesburg, as regards water supply, is Operation Gcin’amanzi in Soweto. This water-saving project, an initiative of Johannesburg Water, came into being in 2001 (pilot project in 2003) and was set to continue for five years (in 2008 – has been halted due to legal action). The goal is to upgrade Soweto’s water reticulation network and provide inexpensive and dependable services to every home. In addition, this project will reduce water loss by slowing water wastage by 15% by the year 2011. Water loss in Johannesburg has mainly occurred due to old underground infrastructure, with bursting and leaking pipes (SACN, 2007a; SACN, 2007b).

5.4 EXISTING CLIMATE CHANGES IN SOUTH AFRICA

Specific existing changes in climate are mainly attributed to existing phenomena, since not many studies have been done on the existing climate change impacts on South Africa, or especially on the city of Johannesburg.

“South Africa is already warming up” (Joubert, 2008, 153). Between 1960 and 2003, both minimum and maximum temperatures in the country have shown a slight increase (Boko et al., 2007; Benhin, 2008; Joubert, 2008). Although the maximum temperatures have increased at a slower rate than minimum temperatures (Boko et al., 2007), “decadal warming rates of 0.1 to 0.3 °C in South
In South Africa, recent decades have seen increases in the occurrence of the strongest daily rainfall. On the other hand, the total annual precipitation has shown minor long-term trends (Doherty et al., 2005). The primary precipitation changes occur in winter, although in the eastern areas of South Africa an increase in late summer rainfall has occurred, accompanied by a decrease in early summer rainfall (Boko et al., 2007). In Johannesburg the “water consumption has more than doubled over the past thirty years” (Warburton and Schulze, 2005, 258).

In review, South Africa is a semi-arid country with below-average rainfall, high evaporation rates, and limited water resources. Evaporation levels are higher than rainfall, there is unpredictability and seasonal rainfall, and inconsistent runoff. The country is also prone to droughts and flooding. Surface water is the greatest supplier of water for urban and industrial areas and for irrigation, with the irrigation sector being the main consumer of water in South Africa. Groundwater is mainly used in rural areas. Many urban and rural settlements as well as industrial areas are located far from any water sources.

Johannesburg is a growing city, with large numbers of people migrating to it and high rates of urbanisation – all of which has placed great strain on water resources. The increased demand for water in Johannesburg is one of the city’s greatest problems. The city lacks sufficient open spaces. Also, Johannesburg is not situated on a main watercourse. Gauteng, and hence the city of
Johannesburg, receive its water from the Vaal dam, but the water supply should only be sufficient until about 2025.

Since 1997, government has accepted the reality of climate change in South Africa, but given that this is a relatively new concept. Many government departments and a great segment of the public do not understand or support the issue. Climate change is also slowly being considered in future plans and policies. The existing climate change impacts in South Africa include an increase in warming in both minimum and maximum temperatures, and an increase in the level of daily rainfall.

Johannesburg has taken the initiative in accepting and trying to limit the effect of climate change. The city is working with many international climate change groups to curb and minimise the affect of greenhouse gases. It has also implemented a climate change strategy and action plan, it is undertaking a vulnerability assessment study, and it is in the process of developing adaptation plans. The Environmental Management Department, which has been set up to deal with the issue of climate change, has already initiated several projects and programmes in Johannesburg that include water schemes – especially since water consumption in Johannesburg has doubled in the past thirty years.

The reason why the particular information in Chapter four is used and focused on, is that it relates directly to planning. All the highlighted factors, in one way or another, affect planning. The existing changes and the potential impacts that are presented in Chapter four are appropriate for Johannesburg, as they will be used in the next chapter to formulate envisaged future impacts for the city. The international information provides a clear foundation to and background on worldwide trends and experiences in the area of climate change. Information related particularly to Africa, narrows down and focuses the data to areas similar to those found in South Africa. In the next chapter, the potential international and African impacts are used in formulating potential future climate change impacts on water supply in Johannesburg.

This chapter has shown and introduced the case study for this report, that being the city of Johannesburg. Therefore, as the report focuses on this city, it is
necessary to introduce, explain and explore the facts on South Africa, as they relate specifically to Johannesburg. As this report is based on water supply and climate change, it is therefore essential to highlight these pertinent aspects. This chapter provides the outline and basis for the next chapter, as the fundamental, specific information provided in this chapter gives a better understanding of the situation in South Africa and in Johannesburg in particular. The information from Chapter four is applied to the subsequent chapter, in an attempt to predict the potential impacts that climate change will have on water supply in Johannesburg.
6 POTENTIAL CLIMATE CHANGE IMPACTS FOR JOHANNESBURG

“No-one can predict the consequences of climate change with complete certainty; but we now know enough to understand the risks”

(Stern, 2006, i).

Johannesburg is a growing and developing urban city that is presently experiencing climate change and will, without a doubt, continue to do so in the future. Johannesburg has, to a certain extent, taken the necessary steps in acknowledging and responding to the challenges of climate change. This chapter reveals the potential climate change impacts projected for Johannesburg. Chapter six also represents the point of convergence of the entire report, as it combines all the information, knowledge and impacts referred to previously, before applying these findings to the city of Johannesburg, as the case study. Firstly, the potential water supply impacts, which Johannesburg will face due to climate change, are presented. These impacts are drawn from envisaged international and African impacts outlined in Chapter four, while additionally putting forward potential South African and Johannesburg impacts. Secondly, the impacts of climate change on planning in Johannesburg are examined; in addition this section assesses the overall planning consequences of climate change. Thirdly, the need for climate change and water supply planning is outlined. This part of the chapter emphasises and recaps the importance of climate change in planning. Lastly, a conclusion to this chapter is formulated; the identified information from previous chapters is used to help project the possible impacts on water supply that might occur in Johannesburg, in the future. The importance and contribution of this chapter to the whole report is essential, since it draws together and summarises the impacts that Johannesburg might experience and evaluates those impacts from a planning perspective.
6.1 WATER SUPPLY IMPACTS

6.1.1 PRECIPITATION AND TEMPERATURE

In summary, internationally the projected impacts of climate change will result in a rise in temperature and greater irregularity in rainfall. In addition, this trend may be further exacerbated by the deterioration of carbon sinks due to climate change. In semi-arid, subtropical and mid-latitude areas of the world, precipitation is projected to decrease. In Africa, temperatures are expected to increase, and southern Africa is anticipated to receive lower levels of rainfall. As South Africa is situated in one of the world’s mid-latitude and semi-arid regions, a rise in temperature and decreased and more irregular rainfall can be projected for the country.

The following projections for South Africa – and Johannesburg in particular – have been recorded. In southern Africa, the standard temperature, by the end of the century, will increase by about 2 – 4°C (Hewitson, date unknown; Du Plessis et al., 2003; DEAT, 2004; Joubert, 2006; Joubert, 2008). Night-time temperatures will escalate more than day-time temperatures, which means the difference in temperatures will decrease. Furthermore, minimum winter temperatures will increase more than the maximum temperatures in summer (Du Plessis et al., 2003). The central region of South Africa will be warmer than the coast, as the sea will mediate temperatures in those regions. Escalating temperatures will bring about stronger floods as well as a rise in the prevalence of floods, droughts and heat-waves (DEAT, 2004; DWAF, 2004; Joubert, 2006; Joubert, 2008).

Precipitation in South Africa is expected to decrease by about 5–10% during the 21st century, because South Africa is situated in a subtropical region (Hewitson, date unknown; Du Plessis et al., 2003; DEAT, 2004; DWAF, 2004). DEAT (2004) emphasises that lengthy dry periods will be followed by periods of severe storms. “A marginal increase in early winter rainfall is predicted for the winter rainfall region of the country” (DEAT, 2004). Due to increased water vapour in the atmosphere, during summer the eastern parts of South Africa are expected to
become wetter. What is more, the storms will bring added rain, will be more powerful and will occur more regularly (Joubert, 2006; Joubert, 2008).

In Johannesburg, the predicted daily minimum and maximum temperatures for the period 2046–2065 are expected to increase. The minimum temperatures for January to March are projected to increase by about 2–2.7°C, and from April to December by about 3.5°C. During the period 2070–2100, the minimum summer temperatures will increase between 1 and 3°C, and in winter between 1 and 2°C. The maximum summer temperatures could potentially increase by as much as 3–4°C, and between 2 and 4°C in winter (City of Johannesburg, 2008a; City of Johannesburg, 2008c; Golder Associates Africa, 2008).

The predicted rainfall for Johannesburg, between the periods 2070 and 2100, for the months December to February, may possibly show an increase of about 20%. Between March and May, rainfall could decrease by 20–30%, and rainfall between June and August could increase by 5–10 mm. During September, rainfall may decrease by 40–80%, but increase by 40% in November (City of Johannesburg, 2008a; City of Johannesburg, 2008c; Golder Associates Africa, 2008).

The temperature in Johannesburg is set to increase, with overall decreases in rainfall and possible precipitation variability in the distant future. Therefore, temperature and precipitation are set to influence water supply in Johannesburg, because due to higher temperatures and decreased rainfall, the demand for water may increase. This stress will add to the already existing large numbers of migrants flowing into the city, and rapid urbanisation which is occurring in areas, and already stressing water reserves. Furthermore, as Johannesburg receives most of its water from the Vaal dam area, and because South Africa is a semi-arid country with rainfall variability, the future supply of water in Johannesburg may be under stress.
6.1.2 DROUGHT

In review, the potential impacts of climate change on global drought would be a predicted rise in the occurrence of droughts. The semi-arid, mid-latitude and subtropical regions of the world will become drier and will experience more frequent droughts. As a result of higher temperatures, decreased levels of precipitation and arid climatic conditions, droughts in southern Africa are expected to occur more frequently.

In South Africa it has been projected that “the west of the country will become hotter and drier, the east will become hotter and possibly wetter, but this will not spare it from the impact of increasing drought stress” (Joubert, 2008, 81). The rise in temperatures will lead to lengthier periods between precipitations, an increase in the incidence of droughts, and stronger drought events, which will inevitably result in drought stress (DWAF, 2004; Joubert, 2006; Joubert, 2008). “Desertification, which is already a problem in South Africa, could be exacerbated by climate change” (DEAT, 2004, 15).

The possible impacts which drought will have on water supply in Johannesburg will be that the frequency of droughts might rise due to a rise in temperatures. Surface water is important in many urban areas, and because of increased incidences of drought, such water levels will most likely decrease. Johannesburg, which is not situated on a watercourse, relies on water from other sources. Therefore, the quantity of water supplied to the city from the Vaal River might be affected by water shortages due to more frequent droughts. As disclosed earlier in the report, South Africa and Johannesburg may experience water shortages within the next sixteen years (until 2025).

6.1.3 FLOODS

To summarise, the international consequences of climate change and global warming will result in greater unpredictability when it comes to weather events, as well as increased flooding. In Africa, due to the predicted higher temperatures,
the variability of rainfall will increase. Therefore, for South Africa there is the prediction that rainfall variability will occur, with possible increases in flooding.

In South Africa, as stated under the temperature and precipitation section, periods of drought will be followed by periods of rainfall, and during certain times of the year rainfall will increase. The eastern side of South Africa may receive more rain. Water is a very important commodity: a warmer atmosphere and higher water vapour levels will result in heavier rainfall. Therefore, due to increased precipitation, South Africa will be especially susceptible to a reduced quantity of water infiltrating the soil, added runoff and increased flooding (Joubert, 2008). Incidences of flooding, which are attributable to rising temperatures, will not only bring more flooding, but will also bring stronger floods (DWAF, 2004; Joubert, 2006; Joubert, 2008). Climate change may influence the location, size and period of the storms, creating flood events (DEAT, 2004).

Johannesburg may experience more inconsistent rainfall, as well as heavier and more frequent flooding. Flooding will affect Johannesburg in that due to increased rainfall, the water supply in the Vaal River may increase, but this will only occur if adequate storage facilities exist. Floods may bring about other related problems, for instance causing damage to settlements and infrastructure. In Johannesburg, owing to the intensification of migration and urbanisation, there is a lack of green spaces, but a prevalence of informal settlements, thus exacerbating the risk of damage, because man-made surfaces influence the speed and directionality of floods. Flooding may affect and damage settlements, and consequently water supply to these areas may be contaminated with sewerage, for example.

### 6.1.4 THE SUPPLY OF WATER

Water supply worldwide in semi-arid, subtropical and mid-latitude regions, due to decreased rainfall and increased periods of drought, may be affected in that there will be less available water, an increased demand for water, and greater water stress. Furthermore, globally the increase in temperature may bring more frequent periods of droughts and floods, and rainfall will become more
inconsistent. Southern Africa is also expected to experience greater water stress and increased demand for lower reserves of water. South Africa may experience water shortages, as one of a variety of impacts which climate change will have on the region.

Water is the one of the most vulnerable resources in South Africa, because the country’s rainfall is so unpredictable, and because its climate is so arid. “Runoff was found to be highly sensitive to changes in precipitation” (DWAF, 2004, 51). As revealed previously, precipitation will decrease, and therefore the runoff may potentially decrease by up to 10% in certain areas – the western parts of South Africa are expected to begin experiencing such decreases by the year 2015. The reduction in runoff will advance from the west coast of the country to the east; potentially the east coast will experience a decrease in rainfall of up to 10% by the year 2060 (DWAF, 2004; Schulze, 2005b).

Joubert (2006) mentions that as the level of runoff decreases, so the quantity of water flowing into rivers, streams and groundwater will be altered. In addition, on account of a possible 2°C rise in temperature, certain susceptible areas in southern Africa are likely to experience a 20–30% decrease in water availability (Jarman, 2007). “The balance between water coming into the system and water going out of the system will be shifted towards an overall drying trend, as heat stress and changed rainfall will probably result in greater runoff, evaporation and drying out of soils” (Joubert, 2008, 154).

Other factors associated with water stress or water shortage will have overall economic and social impacts. The cost of water might increase per unit, and the quality of that water might be affected, due to limitations on availability of water (DWAF, 2004). Climate change additionally, may bring about socio-economic impacts because as the price of water may increase, this may result in social impacts due to changes in the economy. Subsequently, the quality of life for individuals will be affected given that more money will have to be spent on water, less water will have to be consumed, water will become a valuable resource that will have to be protected and other aspects of life (e.g. food, shelter and clothing) will have to be restricted in order to have the basic shrinking resource that is water (Birdsall and Giddens, 2001).
Water supply in Johannesburg will be affected by climate change because, as
droughts occur more frequently, rainfall will decrease and water availability will be
compromised, so the demand for and use of groundwater will increase. The
effect which climate change has on water supply, will sooner or later have far-
reaching effects, including the following: the potential price of water may
increase; water shortages and lower-quality water may result in water-related
diseases and problems in the disposal of wastewater; informal settlements will
bear the brunt of the impact, with leaking pipes and blockages in sanitation
services potentially polluting the surface water (City of Johannesburg, 2008a; City

In summary, the potential impacts of climate change on water supply in
Johannesburg have been outlined above, along with other impacts that are
attributable to changes in temperature, precipitation, drought and floods.
Therefore, the impacts for Johannesburg could include:

1. An increase in the demand for water supply;
2. Greater stress on the future supply of water;
3. A decrease in surface water;
4. Water shortages;
5. A possible water supply increase in the Vaal River due to high rainfall;
6. The contamination of water supply through sewerage;
7. A decrease in runoff;
8. An increase in water tariffs; and

6.1.5 OTHER WATER SUPPLY-RELATED IMPACTS

Climate change produces countless primary, secondary and tertiary
consequences related to water supply. The factors highlighted above are all
primary physical impacts on water supply, which are attributable to climate
change. In addition to these presented physical impacts, there are other possible
water supply-related impacts, which will not only affect the city of Johannesburg,
but also South Africa in general. The impacts may include social, economic,
environmental and political factors. These impacts are going to be the secondary and tertiary consequences of climate change on both society and the environment. This is as a result of change in the supply of water to Johannesburg and South Africa. The section below presents and examines certain basic secondary and tertiary consequences from changes in water supply. However numerous other simultaneous and unrelated consequences do exist but due to time and length constraints, could not be examined in detail. Hence, below are a couple of other human-related secondary and tertiary consequences due to changes in the supply of water:

1. Water supply changes may bring about changes in quantity, quality and size of food. This may in turn lead to malnutrition – which may affect mental and bodily development in children and lead to low efficiency in adults. Hence this might cause undernourishment and increase the vulnerability to disease (Bates et al., 2008; Joubert 2008);

2. Diseases are related to human health (food availability) and hygiene. Inadequate infrastructure leads to poor removal of sanitation and water contamination causes diarrhoea. Therefore this increases morbidity and mortality of people (Spence, 2005; Bates et al., 2008);

3. Ecosystems may perhaps be affected by encroachment of alien species, loss or extinction of biodiversity and loss of fauna and flora (Jarman, 2007; Bates et al., 2008);

4. Agriculture could experience lower production of crops that might cause increases in prices. In farming, loss of land may lead to poor performance of cattle or death, hence this might result in less production of food and milk and also lead to price increases (Bates et al., 2008);

5. Lastly, there may be loss of livelihood and displacement for individuals and depletion of open grasslands (Spence, 2005; Godrej 2006; Joubert, 2006; McCaffrey, 2006; Joubert, 2008).

The impacts stated below of social, economic, environmental and political factors relating to a change in the supply of water, will examine both possibilities of increases and decreases in the supply of water. This is based on the reality that in South Africa and in Johannesburg, the unpredictability of climate change and
seasonality may bring about increases or decreases of water supply and demand. The increase in water supply may be due to heavier precipitation and consequently flooding and therefore greater quantity of water available. The decrease in the supply of water may be as a result of higher temperatures, higher evaporation rates and droughts and hence less water being available.

SOCIAL IMPACTS

The social impacts from increases in temperature and drought might bring about an increase in the demand for water and less water supply due to higher evaporation levels. Hence related to this aspect is the point that due to higher water demand and less water supply, this will give rise to stricter management of water. Consequently municipalities will have to impose laws, raise prices and severe penalties in reference to water use, and hence citizens will have to limit and control their use of water. The social impacts, which refer to negative factors such as increased water tariffs, and a lack of and higher demand for water, could result in residents and communities experiencing difficulty in accessing water, not being able to afford water and hence the potential risk of conflict over the commodity. In addition, a lack of water may lead to more migrants coming to Johannesburg from rural areas in search of water, which will lead to further stresses on water.

A further negative impact from a lack of water and heat waves due to higher temperatures, could lead to dehydration of individuals and a possible increase in deaths. Additionally, higher temperatures could result in the spread of diseases. This may arise as a consequence of the fact that in higher temperatures, many insects that may include malaria-carrying mosquitoes in South Africa, flourish and spread in warmer environments (Houghton, 2004).

The rise in precipitation and flooding and consequently more water supply may produce physical damage to housing and buildings. This successively will result in increased costs of fixing damages, and in addition, paying for and replacing damaged furniture, appliances and cars. In certain areas, possible relocation of settlements may be required because of the danger in location; hence the owner will have to buy a new house. These aspects may cause additional financial
stresses for flood victims. Flooding may also cause overflowing of the sewer water that will produce health risks and diseases, and therefore the negative impact of water contamination and water scarcity may result in more people becoming ill, and in the worst-case scenario, a rise in the death toll. In addition, the increased availability of water may result in an influx of illegal aliens and immigrants from African countries' who are experiencing water shortages, this too will cause additional stresses on water.

ECONOMIC IMPACTS

The availability of increased water supplies may have an economic impact, in the form of increased tourism due to better environmental care. This will encourage the influx of finance into Johannesburg in particular, and the rest of South Africa in general. Increased water supply can also bring about higher costs for government and individual municipalities, having to spend more funding on flood protection, prevention measures, response and water management. Lastly, the increased availability of water can highlight other uses of this precious commodity, such as hydropower, resulting in more opportunities for the country.

The negative impact of a decrease in water supplies is that it may give rise to an economic crisis, because less water will be available to all sectors (domestic, agricultural, industrial, recreational and environmental). This will curb production in especially the industrial and agricultural sectors. Many sectors will be subject to prioritisation, which means certain sectors may suffer, as socio-economic development may take priority over environmental protection and the provision of water to water-stricken communities. Related to this impact is the possible introduction of penalties for the overuse of water in the various sectors that will inevitably cause social impacts.

In addition more of the country's municipal budgets will be spent on water management and water supply. This will cause shortage and reductions in funding in other sectors of the economy, as water supply will take priority over other aspects that may include providing housing, education, infrastructure upgrade or other sectors. More money will have to be spent on adapting and managing the problem and consequences of climate change. Another impact
flowing from water shortages (from rivers) caused by drought and temperature rise, may be the introduction of other water supply sources, for example, desalination plants to desalinate seawater (however this is not directly relevant to Johannesburg, but predominantly to coastal areas in South Africa).

ENVIRONMENTAL IMPACTS

Environmentally, a change in the country’s water supply may impact negatively on biodiversity, ecosystems and animals, and may simultaneously lead to the spread and development of desertification in South Africa, and even in Johannesburg. Water shortages may result in environmental degradation by changing the shapes of rivers, and leading to water shortages for those animals which use river water as their primary water source. The environment will become secondary to human needs, as water will be needed for industrial, domestic and agricultural use. Related to this aspect is the point mentioned in the economic impacts section, namely the fact that the economy uses, is affected by and depends on the environment (for example the use of water in agricultural purposes). The economy draws on environmental resources for production. Therefore, if the environment becomes degraded, the economy will also suffer due to losses in production. Hence these sectors are all inter-related, in that they are reliant on one another. Consequently, a loss in production can cause a loss in finance and a decrease and instability of the economy. A decrease in production may also bring about less food production and therefore, food shortages and cause a crisis in the food market.

The positive side to an increase in water supply as a consequence of more rain and floods, is that it may lead to (as presented earlier) a greater focus on the environment, due to more water being used for the environment and not only for human use. This may result in improved protection and conservation efforts, which may, in turn, boost tourism and consequently bring about more money to the country. However, having access to a greater supply of water may give rise to bigger rivers with greater carrying capacity, thereby creating new river meanders that may lead to loss of fauna and flora in floodplains. In addition, more precipitation and flooding could cause overflow of rivers and seepage of the ground; this will instigate erosion of topsoil, washing away of nutrients and
damage to food sources. Hence, this will cause repercussions for animals and people relying on these food sources.

**POLITICAL IMPACTS**

The negative political impacts are related to possible water shortages (from higher temperatures and drought) – something that will lead to disarray in South Africa, with water becoming a scarce and very expensive commodity. The government will be forced to heighten its involvement, and will need to prioritise aspects like water supply and climate change, over other planned goals that might include providing housing and employment. Climate change impacts may bring about changes in government’s goals and agendas. Another impact of water shortages could be that South Africa may require help from other countries’ to access water. This will create additional stress seeing that the country’s growth and development will be guided by the amount of imported water, and on its relations with other countries’. On the other hand, increased water supplies may lead to positive impacts as our ability to export water could result in improved relations with our neighbouring countries’.

Consequently related to the above aspect of acquiring assistance from other countries’, is the problem of ‘water wars’. This notion may arise in the future as a result of the increasing problem with water shortages across the globe. Countries’ that possess water will have power and control over the limited resource; hence countries’ with a lack of water will have to conform to these countries’ regulations. In the worst case, conflicts and fighting may arise over the limited resource. South Africa may be one of those countries’ with a water shortage in the future, and subsequently this may lead to a need in acquiring water from other water prosperous countries’. This inevitably will lead to more changes and influences on social and economic impacts, as water will be more expensive for the average person and more of South Africa’s finance will be spent on water.
6.2 CLIMATE CHANGE IMPACTS ON PLANNING IN JOHANNESBURG

Increased rainfall and flooding due to climate change can have the worst possible outcomes on planning, which might bring about the most visible changes as far as cities are concerned. The overall impacts influencing planning in Johannesburg may include a strain on Johannesburg's service delivery and, in particular, on its infrastructure. When rainfall and flooding occur, the increased water levels will lead to Stormwater drainage overflow, which will seriously damage infrastructure, such as roads, and this will result in the spread of pollution, while erosion due to flooding may also make some terrains unstable.

A rise in rainfall and flooding may also cause damage to housing, not only residential buildings but also offices, industrial warehouses, and formal and informal settlements in Johannesburg. All of these structures will suffer physical damages to their foundations and walls, windows and electric cables; sewerage blockages may lead to pipes overflowing, which will bring additional repair costs for the owners. The effect of all of these factors on planning will be that the location, altitude, use and size of any new development, settlement or service will have to be considered and planned with the possible effects of climate change in mind.

In addition to the abovementioned impacts, the reality is that due to factors like urbanisation, population growth, changes in land use and the development of settlements in areas at risk of flooding (or in floodplains) will add to the effect of climate change and worsen the potential damages. These urban development and expansion factors will amplify the risk associated with vast man-made surfaces, because of an increase in the number of settlements, roads and developments. In turn, these surfaces will guide and speed up flooding waters, since they act as man-made channels for flooding water. In addition, due to the increased number of people and developments in a city, there will be fewer open or green spaces available to absorb rainfall and excess water. Consequently, in Johannesburg all of these factors will increase the damage to buildings, roads
and houses, there will be a rise in the number of casualties related to floods, and an increase in the number of low-lying settlements which are at risk of flooding. Therefore, planning will have to integrate these additional features and their possible consequences into any future planning.

In Johannesburg, planning will be impacted by climate change in a number of ways. The planning-related impacts projected for the city are that, due to the increasing impacts of climate change and the required focus on the issue, more money will be spent on preventing and adapting to climate change, which will lower people’s standard of living, while the cost of living will sky-rocket (City of Johannesburg, 2008c; Golder Associates Africa, 2008). Planning might be forced to adjust its contemporary thinking and priorities from planning for future basic services, settlements and any type of human development, to having to adjust, improve and inspect existing developments. In addition, due to climate change-induced water stress, the number of new developments may be reduced due to an increase in water tariffs, and the limited availability of this commodity.

Due to migration into Johannesburg, the increase in population numbers will bring about an increase in water consumption and air pollution, the number of informal settlements will rise, there will be an increased demand for sanitation and water – all of which may place additional stresses on infrastructure and could lead to health problems (City of Johannesburg, 2008a; City of Johannesburg, 2008c; Golder Associates Africa, 2008). The future of planning will have to incorporate various related aspects in future developments, such as raised pollution levels due to traffic congestion, construction, factories and industries, water use and sewage from informal and formal settlements, and any other kind of human development.

Informal settlements in Johannesburg will be more susceptible to climate change and may become breeding grounds for diseases (City of Johannesburg, 2008a; City of Johannesburg, 2008c; Golder Associates Africa, 2008). As revealed earlier in this chapter, due to urbanisation and migration, the number of people in Johannesburg will increase, meaning informal settlements will mushroom. The impacts these settlements will have on planning include the need to provide
proper housing, with services, in appropriate locations, which are free from the danger of flooding.

The environment is one aspect of planning that has in the past due to a lack of information on the environment and global warming taken a back seat to new development. However, in recent years (in Johannesburg and worldwide) the focus on the environment and the possible future implications of any human developments have started to become priority issues. In addition, global warming and climate change have led to greater public awareness of the importance of any new and existing developments in cities, and their effect on our surroundings. Climate change will change our environment, as human expansion, urbanisation and migration to the city continue to take place. Therefore, any local planning must incorporate environmental aspects, but the aspects that should receive priority include the number of open or green spaces, the planting of trees and, where necessary, the protection of plant and animal species.

Schulze (2005b, 14) identifies an important point, namely that “in water resources one needs to evaluate both: impacts of water availability on land use . . . and impacts of land use on water availability”. This statement reiterates the aforementioned point, namely that planning should not only focus on the physical location and size of any existing or future developments, but should also integrate other related aspects, such as costs, health implications, social aspects, economic and political aspects and the impact on the environment.

All the presented sections in this chapter will have an affect on planning, as they will all be affected by climate change, and will therefore alter the composition of the city. Therefore planning in the face of climate change will affect the city of Johannesburg by having an influence on services, the location and spread of any existing or new developments, the priorities and goals of planning and on the population numbers in the city. Planners will be needed not only to predict the possible future impacts, but also to plan for those impacts becoming a reality.
6.3 PLANNING IN THE FACE OF CLIMATE CHANGE

While climate change is an existing issue, it is also essential to be aware of possible future consequences, and of our contributions to climate change, since climate change and global warming have the ability to alter and intensify existing weather patterns. Climate change influences the quantity and availability of a region’s water supply, which is what makes planning such a significant aspect. Planning considers the quantity of water that will be required for any development, it shapes the development and growth of a city, and makes provision for the storage of surplus water.

Climate change will not only add to a country’s existing problems, but will also create additional problems. Therefore, in order to limit and prevent possible environmental risks, planners need to be familiar with and comprehend the consequences of climate change as it impacts on water supply, infrastructure and human settlements. Planning formulates ideas and anticipates the future by providing workable scenarios to counteract the impact of climate change.

Changes and the subsequent future consequences for people, animals and the environment will occur as a result of climate change, and for that reason planners need to be able to design and plan future developments and cities accordingly. Planning has to be used to try to predict, prepare and limit the future consequences of climate change; to plan and design future settlements; to envisage current and future developments by taking into account possible altered climatic conditions; to mitigate and adapt to climate change; to adapt to the existing limitations of countries’; to prepare for possible increases in urban populations and to ensure the availability of adequate supplies of water. Therefore, planning for climate change and making allowances for climate change in planning are not only necessary, but also vital.

To conclude, the location and topography of Johannesburg and the aridity, variability of rainfall and weather events, along with the rise in temperature will
influence water supply in the city. A rise in temperature, lower precipitation, and increased drought and floods across South Africa and Johannesburg will shape the supply of water to the city. The features of water supply that may be affected by climate change include the demand, stress on and supply of water, the quantity and quality of surface water, water shortages, run-off, higher water tariffs and water-related health problems. The other water supply-related impacts on Johannesburg and the rest of South Africa will relate to secondary and tertiary social, economic, environmental and political factors, which may have positive as well as negative spin-offs. Overall, humans and animals will have to adjust to the changes from climate change, as the changes may be an increase or decrease in water supply.

In Johannesburg, planning as a consequence of climate change will be altered and subjected to a number of influencing factors. The overall aspects of planning that might be influenced include damage to existing informal settlements, developments, formal settlements, infrastructure and services. Furthermore, any future developments, informal settlements and changes in land use will place additional stresses on water supply services and heighten the risk of damage to any development. The other impacts that might affect Johannesburg include increased water use and air pollution, finance being spent on prevention and adapting to climate change, health-related problems in informal settlements and the effect on the environment. Hence the above impacts of climate change will emphasise the need to consider and include aspects of climate change and their possible effect in any type of urban planning.

Climate change and global warming have a variety of impacts on humans, animals and the environment. Climate change shapes water supply, in addition to worsening existing problems in countries’ and altering weather events. Planning shapes the future design of cities and relies on scenarios to limit future risks, while planning for adequate and effective water supply to cities. Climate change factors will need to be incorporated into any planning, so as to limit the future impacts on people, animals and the environment. To limit the effect of climate change, all possible consequences have to be considered and provided for in future plans.
7 CONCLUSIONS AND RECOMMENDATIONS

“We have the choice how to act, but the change we need to make ourselves. We can make a difference by supporting the transition to a climate-neutral world.”
(Kirby, 2008, 12).

This chapter reviews, summarises and concludes the entire report. Chapter seven brings together all the information and impacts presented throughout this report on climate change. Firstly, this chapter provides a conclusion to the entire document and reveals how the main aim of the report has been achieved. It also investigates whether the research question has been answered. Secondly, recommendations on possible future actions for South Africa and Johannesburg, in their attempts to counteract climate change, are put forward. Chapter seven emphasises the main or fundamental aspects of this report, which focuses on planning, climate change and water supply.

7.1 CONCLUSIONS

Climate change and global warming are important issues worldwide, as they influence every country and nation on this earth. Climate change arises out of global warming, which is induced through human activity. Natural hazards occur in all countries’, which means the effect of climate change is felt globally. Climate change has an assortment of impacts on humans, animals and the environment. The deterioration of carbon sinks may lead to additional changes in climate. The notion of climate change, which first caught our attention in the 1960s, continued to be questioned until the 1970s. In 1995 it was established that climate change was as a result of human-induced carbon dioxide emissions, and from about 2005 the existence of this phenomenon has been acknowledged and accepted, making it a well-publicised concept worldwide.
Climate change needs to be considered by people in every profession, as every aspect of our lives has already been or will be altered by global warming and climate change, be it in the distance that we drive, the food we eat, the water we drink or the place where we live – everything is related to global warming in that it either adds to the problem, limits it, or helps to curtail it. We all live on the same earth, and we can contribute something to it or take away something from it. If we continue to harm our planet in some way or the other, but were in a position to do something about it, would it not be foolish to sit back and do nothing, to deny the evidence or pretend not to care, or use the excuse that since we are not directly affected, we do not have to act. One person can do great things. One person can make a difference. As the famous Gandhi said: “Be the change you want to see in the world”.

Climate change is not only a factor for scientists or environmentalists to consider – it is something that transforms the lives of each and every one of us: terrestrial and aquatic animals, human beings and the environment. All aspects of life on earth are inter-connected; we are dependent on one another for our survival. We, as human beings, have the responsibility to change the way we live, in order to conserve and prolong the life of our planet for future generations. Planning is a big part of that future, as planning envisions the future.

Planning is a profession that is based on uncertainty. It is concerned with planning in advance, and considering various options that might occur. Planning is about using existing knowledge and experience to look into the future and see the possibilities that might arise. Planners, to a certain extent, can be categorised as foretellers, given that they have to consider and envisage alternatives and scenarios others might not think of. Planning views things from a different perspective, it incorporates and extends to various aspects (human, environmental and animal) and the way these living organisms might be influenced by a variety of factors.

Planning and climate change are inevitably linked, since they are both based on uncertainty. Urban planners need to understand and incorporate all possible aspects of climate change in their future plans, as existing and future infrastructure, buildings and settlements will function under changed climate
conditions. Even though, at present, planners may not necessarily always consider the notions of climate change, in the future it will become one of the main driving and guiding forces behind planning.

Water, being a renewable resource, is affected by rainfall and severe weather events. Water supply is influenced by the unpredictable weather events brought on by climate change. Problems related to water supply in Africa and southern Africa include: the unpredictability of rainfall; the seasonality of rain; drought; high evaporation and the misuse of water. Water shortages are expected to occur in South Africa by the year 2025. Climate change shapes water supply, in addition to worsening existing problems. Planning shapes the future design of cities and uses scenarios to limit future risks from climate change. It also plans for the supply of water to cities. Climate change influences water supply in that it affects regional temperature, precipitation, drought and floods; all of which, individually, alter the supply, demand and quantity of water both locally and internationally.

Internationally, existing changes attributable to climate change include an increase in temperature and, in certain regions of the world, increased rainfall, which has resulted in greater runoff and more frequent flooding. In some parts of the world rainfall has decreased, leading to decreased runoff and the increased prevalence of droughts. The potential impacts of climate change around the world could cause further increases in temperature and greater inconsistency in precipitation and weather patterns (which include droughts and floods).

In Africa, climate change has resulted in temperature increases, unpredictable rainfall, and extreme weather events. The availability of water has decreased, due to an overall decrease in rainfall, which has resulted in lengthier dry phases and an increase in the occurrence and intensity of droughts. In the future, climate change may bring about a further rise in temperature, and in some areas of Africa an increase in rainfall, which means increased runoff and flooding, while other areas may experience reduced precipitation and runoff, and consequently more frequent incidents of drought. This will reduce the availability of water, increase the demand for water, and aggravate water stresses.
Climate change has influenced planning by the fact that some settlements and human habitations are already troubled by climate change, mainly owing to weather extremes and their location in low-lying areas and river floodplains. The African continent is very vulnerable to the impacts of climate change, as it has always been burdened by inconsistencies in the weather – climate change only worsens the problem. Therefore, planning needs to take into account any potential climate change, before planning for the future.

South Africa, which is a semi-arid country with below-average rainfall, high evaporation rates and limited water resources, is very vulnerable to droughts and floods, despite the fact that numerous urban and rural settlements and industrial areas are located in regions far removed from water sources. Since 1997, the government has accepted the notion of climate change, and has slowly been implementing policies and plans to counteract this phenomenon. Presently, South Africa has experienced a rise in the quantity of strongest daily rainfall and increases in both minimum and maximum temperatures.

Johannesburg is a developing city that experiences urbanisation and migration – factors that have resulted in increased demands for water. As Johannesburg receives its water from the Vaal River, the city ought to have sufficient water reserves until 2025. Johannesburg has partnered with many international climate change groups in an attempt to limit the effect of climate change. In addition, the environmental department has initiated many projects and programmes aimed at counteracting climate change. The City of Johannesburg has initiated many mitigation programmes, and is in the process of developing an adaptation plan for climate change.

Precipitation, temperature, droughts and floods all determine the potential impacts of climate change on Johannesburg’s water supply. Therefore, the aspects that will be changed include the demand for, stresses on and the actual supply of water, the quantity and quality of surface water, water shortages, runoff, increased water tariffs and water-related health problems. Other water supply-related impacts of social, economic, environmental and political factors (secondary and tertiary impacts) will be affected by the changes in water supply due to climate change impacts on Johannesburg and the greater South Africa.
These impacts may result in difficulty in accessing water, higher water prices, environmental problems, changes in food source and size, loss in production (problems in agriculture and farming), physical damages, diseases, greater focus on water supply and climate change, lack of water, migration and possible ‘water wars’. Furthermore, any future developments will place greater stresses on water supplies. In addition, the planning aspects (in Johannesburg) that will be influenced by climate change include damage to existing informal settlements, new urban developments, formal settlements, infrastructure and services, an increase in water consumption and air pollution, health-related problems in informal settlements, and funding being spent on prevention and adaptation to meet the challenges of climate change.

As a final point, climate change and global warming are imperative issues that need to be incorporated into planning, in order to limit the future impacts on humans, animals and the environment. The impact of climate change will be limited if all possible consequences have been considered, contemplated and included in future plans. Therefore, as has been stated and examined in this report, the link between climate change and planning is very strong, and is a necessary concept that has to be explored and used in the future planning of any developments and in the protection of existing developments. Presently, no profession can escape the implications and ramifications of climate change, and consequently everyone will have to take the necessary steps to counteract the effects of climate change and global warming.

In conclusion, the aim of this research report has been achieved, seeing that it provides a comprehensive view of existing and well as potential climate change impacts. This report also presents various factors relating to water supply, both internationally and on the African continent. Consequently, this information is applied to South Africa and in particular Johannesburg’s water supply, in envisioning the possible future impacts of climate change. This report offers information that is specifically focused on, appropriate to and relevant for the city of Johannesburg. In addition, the intention of examining climate change from a planning perspective has been achieved.
This existing problem of climate change and its potential impacts on water supply in Johannesburg to this day has not been a thoroughly examined and studied issue in South Africa. Therefore the process utilised in this research report has been based on providing an overall background to this large worldwide issue and consequently focusing and narrowing it down to Johannesburg. This report has presented a small fragment of each significant and crucial aspect related to the issue of climate change, each of these aspects have provided an essential and beneficial understanding and context of this issue. Hence this process has limited the quantity, quality, detail and analysis of information presented on Johannesburg. This report has been an amalgamation of all contextual, related and important backdrop information that has been used as a prelude in order to present the unexamined issue of climate change and its potential impacts on water supply in Johannesburg.

The conclusion of this research report is that the research question has been answered. In the future, Johannesburg is likely to experience a variety of impacts on water supply as a result of climate change. The effect on Johannesburg’s water supply will most probably be determined by the following factors: temperature; precipitation; drought and flooding – all factors which control and affect the quantity of water supplied to the city itself. In addition, these climate change-influenced factors will guide a number of planning impacts in respect of safeguarding our water supply.

The sub-questions of this research report have also been answered. Firstly, some impacts of climate change on Johannesburg are expected to be temporary, while others will be permanent. Permanent impacts will include the fact that global climate change has brought about permanent changes in temperature, leading to global warming. Climate change and global warming do not seem set to decrease or disappear – on the contrary, the phenomena are likely to become even more prevalent. In future, the earth’s temperature will continue to rise due to human-induced carbon dioxide emissions spewed into the air over the past decades, and the degree by which temperature increases will be determined by our current emissions. Therefore, the continued rise in the earth’s temperature will have a permanent impact – also on Johannesburg. As regards temporary impacts, factors like precipitation, drought and flooding are expected to be
affected. In addition, these factors are influenced by climate change. Precipitation, drought and flooding do not have constant impacts, but vary from season to season, and are more variable due to climate change. For that reason, Johannesburg will experience mainly temporary impacts in this respect.

Secondly, the aspects of demand, source and quality of water supply will all be impacted by climate change. All three of these aspects are influenced by temperature, precipitation, drought and floods. These factors are all susceptible to and influenced by climate change, and hence will impact on the demand, source and quality of Johannesburg’s water supply. In addition, these aspects will also be affected by factors such as urbanisation, migration, population growth and human development, which may result from climate change as well as other factors. Factors like the demand for, source of and quality of water supply will be affected by climate change in one way or another, which makes it impossible to predict which aspect will be worst off.

Thirdly, the impact of climate change on water supply in Johannesburg has both a negative and a positive spin-off. Negative impacts include increased temperatures and greater variability in drought, flooding and precipitation, and consequently changes in water supply. These same impacts may be turned into positives, if the city of Johannesburg’s programmes, policies, documents and assessments help the city to timeously mitigate and adapt to the challenge of climate change.

The hypothesis of this report was supported, because climate change will exacerbate the existing water supply problem in Johannesburg. This problem will be aggravated by climate change, as the availability of water will be determined by direct water supply-related factors such as temperature, precipitation, droughts and flooding. In addition, other indirect climate change-driven impacts of migration, changes in land use and development will also add to the stated direct water supply-related issues. Therefore, water supply problems in Johannesburg will be made worse by the climate change impacts of higher temperatures, increased evaporation and drought which will lead to greater demand and less availability of water in Johannesburg. While, increased rainfall and flooding will result in less usable water and consequently greater demand for clean water.
Therefore climate change in some way will impact and exacerbate the existing water supply problem in Johannesburg.

### 7.2 RECOMMENDATIONS

In reference to climate change, the

“Only action that is inexcusable is to take no action at all”

(Lynch in Alcamo et al., 2009, 36).

The recommendations identified below are wide-ranging critical suggestions for South Africa and Johannesburg in dealing with, managing and limiting climate change. These recommendations are not necessarily related to the impacts stated in this report; they are general propositions for various government and non-governmental sectors in South Africa. The following suggestions are presented with an understanding that certain basic aspects (stated here) need to be in place first in order for planning impacts and aspects to be considered and dealt with.

The most important aspect of climate change is that each and every country in the world needs to acknowledge and take responsibility for its contribution to the problem, and for its inevitable response to the issue (DEAT, 2004). Therefore, the most common phrase in responding to climate change is that “business-as-usual is dead” (Alcamo et al., 2009, 32). Responsibility needs to be taken from the very top, right down to local government and individual level. The crisis posed by climate change can only be resolved through a joint global response and the dedication of all individuals; businesses; national, regional and local governments; industries; scientific research organisations and environmental NGOs (DEAT, 2004; Alcamo et al., 2009). Hallegatte (2009) emphasises that those responsible for rubber-stamping decisions need to change their thought process to make allowances for climatic uncertainty in their decisions.

Related to the above point of individual change and personal responsibility is the important notion of improved knowledge and understanding of the topic. As
argued in Chapter three, the general public have a limited understanding and knowledge of climate change, which leads to a lack of interest in the subject, and, consequently, a lack of action. Alcamo et al. (2009) emphasise that worldwide there is a need to reassess our beliefs, behaviours, core values and worldviews on climate change, in order to ensure a sustainable future for all humankind. Malala (date unknown) draws attention in the need to heighten awareness, increase the available information, and improve media and public education on climate change.

One of the most important factors in limiting the future impacts of climate change is research. Continuous research is needed to limit and narrow down uncertainties (Schulze et al., 2005a; Lawson, 2008), but also to focus on the scale of climate change in individual countries’ and regions, such as sub-Saharan Africa, or east Africa (Boko et al., 2007). Research has to concentrate on our vulnerability to climate change and should focus on assessing its impacts (Boko et al., 2007; Bates et al., 2008). Bates et al. (2008) recommend conducting monthly and ongoing studies to show how water stress is brought about by climate change. Additional research is also required into individual experiences and views on climate change (Alcamo et al., 2009), which will improve public knowledge and understanding.

Investment is another feature that is vital in helping to find answers to the problem of climate change. Each country needs to invest in climate change response measures. Developing countries’ are likely to suffer most from climate change, while actually contributing least to the problem. Therefore, developed countries’ may possibly invest in developing countries’, in order to help them limit the expected impact. Worldwide, the notion of wealthier countries’ contributing to poorer nations has been initiated and subscribed to by the UNFCCC and the Kyoto Protocol. Alcamo et al. (2009) state that this notion ought to be followed through, defined and carefully monitored. Each wealthy country selected should be based on capability (those that have the means and finance, can contribute) and responsibility (each country is part of this world, and hence has a responsibility to the environment in which we all live in). In addition, a successful and equitable distribution of this investment has to be maintained (Alcamo et al., 2009).
The two main themes that are normally associated with responding to climate change are adaptation and mitigation. The inclusion of both mitigating actions and adaptive processes in climate policies will give rise to more effective legislation (Alcamo et al., 2009). Hence, urban planners are responsible for creating and designing future plans and policies that incorporate mitigation and adaptation factors. Planners have to plan for the uncertain future, where only one thing is certain – we will definitely see further changes in climate!

Adaptation is the process whereby a society minimises its potential impacts from climate change and increases its capability to deal with such change (Adger et al., 2007; Alcamo et al., 2009). Adaptation and advance preparation could be more economical than having to respond to or act only once disaster has struck (Downing et al., 1997; Lawson, 2008). Most researchers are confident that our ability to adapt will improve as technology develops (Lawson, 2008).

In 2001, the IPCC identified six reasons for adapting to climate change (Schulze, 2005a):

1. Climate change cannot be evaded;
2. Climate change may result in both difficulties and benefits;
3. Benefits may result from improved adaptation;
4. Additionally, benefits can result when limiting practices and policies are eliminated;
5. Preventative adaptation is cheaper than crisis adaptation;
6. Climate change may be worse than anticipated.

One of the responses to climate change is mitigation, which needs to be considered in order to limit future impacts. Mitigation is altering existing processes and human activities that cause climate change by decreasing or adjusting certain practices, so that the outcomes and impacts also change (Alcamo et al., 2009). Global fair and equal mitigation actions are required on the part of every country, if we want to limit or decrease climate change impacts worldwide (Alcamo et al., 2009). Schulze et al. (2005a, 426) identify an important factor in respect of the water strategies of various countries; they state that “establishing balances between consumptive use, environmental needs, subsidiary functions . . . . It requires difficult decisions involving the interests of
various sectors of the economy, the community and the environment”. This implies that there have to be realistic and reasonable responses on the part of different water consumers and users. Schulze et al. (2005a) also mention that in southern Africa, water resource adaptation schemes need to be made more prominent.

As stated earlier, learning from our mistakes is one of the best responses to limiting and understanding climate change. Certain cities worldwide have adopted the concept of disaster-risk reduction in their development plans, which include limiting disaster and having a suitable plan of action ready when disaster strikes. The process incorporates improving existing developments in order to limit their risk to disasters, and adapting disaster-risk reduction in plans for future developments (Huq et al., 2007). Natural hazard mitigation planning is also very important, as it helps limit the impacts stemming from hazards (Randolph, 2004). The above recommendations are good examples that can be used to reduce climate change impacts when undertaking urban planning. However, any type of planning needs to be adjustable and adapted to each respective country, right down to local scales – this, in order to work with each country’s and municipality’s strengths, weaknesses and wealth of expertise (Hall and Pfeiffer, 2000; Alcamo et al., 2009).

To summarise, the issue of climate change and global warming is no longer an unknown topic that still needs to be questioned and verified. Climate change due to global warming is occurring and will continue to have consequences long into the future. Therefore, this issue is more about existing responses, research and the future plans and responsibilities each country has in respect of this phenomenon. The imperative aspects for each country consist of acknowledging and accepting that we humans are adding to the problem, and then making every effort to limit our greenhouse gas emissions. The need for additional research and investment – and especially investment in developing countries’ (in order to help them curb and alleviate the impacts) – is vitally important. Adaptation, mitigation and realistic responses and plans for each country, according to their strengths and limitations, are crucial.
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**APPENDIX A  FIGURES**

**Figure A1:** Graph showing water scarcity in Southern African countries.

(After Ohlsson in Weakley, 2009)

**Figure A2:** Map of Africa: showing the predicted changes in precipitation in Africa by the end of the 20th century.

(De Wit and Stankiewicz in Weakley, 2009)
Figure A3: Satellite map of South Africa: showing the topographical conditions of South Africa.
(SouthAfrica.info, www.southafrica.info - cited 04/10/2009)
Figure A4: Map of South Africa, featuring the location of Gauteng, and the city of Johannesburg.

Figure A5: Map of southern Africa, showing the city of Johannesburg and its location in relation to the Vaal River.

Figure A6: Map of South Africa, featuring Gauteng, the city of Johannesburg, and its water source - Vaal River.

Figure A7: Map of Gauteng, showing the location of the city of Johannesburg.

Figure A8: Map of Gauteng, featuring the city of Johannesburg and its location to its main water source - Vaal Dam.

(Google, http://images.google.co.za - cited 09/12/2009)
Figure A9: Map showing inter basin transfer schemes into the Vaal River Basin.

(DWAF[a] in Weakley, 2009)