Integrated Catchment Management: From Source to Receptor

Report to the
Water Research Commission

by

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EXECUTIVE SUMMARY

Introduction

South Africa's climate and water resource availability patterns are characterised by dry conditions over most of the country with the accompanying high spatial and temporal variability in rainfall patterns where temporal variability ranges between 20% and 50%. The natural water availability patterns have little relationship with water demand patterns such that closing the gaps in natural availability had to be achieved through a network of water infrastructure. The developed water provision systems that were meant to extend water availability and improve access have a historical link to national policies that discriminated against a largely black population. This resulted in infrastructure that tends to worsen the levels of water access inequalities. In addition to the natural and social challenges afflicting the water sector, water quality has been deteriorating rapidly, all of which extend the complexity of water management. The resultant complex water challenges call for best practices in integrated catchment management (ICM) if the country is to meet its water provision goals.

The proposed ICM approach is based on several variables that include natural water resource availability patterns, natural environmental conditions, the built environment, societal systems, institutional arrangements, strategic policies, national and local economics, legislation, water management methods, water resources, land uses and the strategic direction of the nation. The study recognised that the country is grappling with transforming the water sector in an environment where the necessary pillars for good water management and governance are still to be established. The structure of the solution targets the weaknesses inherent in compartmentalised water management approaches where there are numerous institutions involved in the water sector. Usually these institutions do not have a platform on which to share resources and manage water in an integrated way.

Background

The ruins and historical remnants of ancient water structures and irrigation schemes in North Africa, show that water management started as far back as the beginning of irrigated agriculture in about 5000 BC. These water management practices, which were widely used after 2000 BC, have involved from simple planned flooding techniques to the use of water infrastructure that could store, distribute and drain water. Over the following thousands of years' water management involved to account for multiple objectives in management methods that could be described as early ICM. In the recent past, global developments began to include multiple water management objectives that were more aligned to building socio-economic values, and advancing environmental and ecological sustainability, while seeking to address global challenges, especially climate change. In all these developments, water management became even more multi-sectoral, creating challenges of increasing complexity to governments and citizens. The quest for development has also meant that the natural environment, including aquatic ecosystems, suffered through degradation and excessive water utilisation as various forms of development took place on the land. Land use development in the past was mostly driven by food and economic needs with little regard for the environment, resulting in wide scale destruction of both land and water resources. Legislation is now being used to direct water access and land use to possible sustainable patterns. In South Africa, a new water legislation, the National Water Act (Act No. 36 of 1998), was promulgated, with among its aims the idea of advancing sustainability in water use and management. The National Water Act directed the National Water Resource Strategy to seek integration in how the various objectives of the water sector were going to be managed. It also provided for the formation of a water management system that was based on catchments, where the local stakeholders had a better say. These stakeholders participated in water management in deciding on a path that would be most suitable in addressing the multiple objectives. The new government thus sought to bring water management to higher levels in various aspects according to the projection of global patterns as well as the unique South African conditions.

The Department of Water and Sanitation’s policies and strategies have tended to focus on specific water sector issues, resulting in less being implemented in other areas, such as in the upkeep of the environment, infrastructure maintenance and modernising the water sector to become more efficient. The use of integrated approaches is set to see water management changing from the focus on only a few objectives to include water quality, socio-economics and groundwater as part of holistic water management. The policies and strategies applied at national level do not presently mention ICM but rather Integrated Water Resource Management (IWRM), Integrated Water Quality Management (IWQM) and Integrated Water Resources Planning (IWRP). These programmes are usually considered under separate national units in the Government Departments and other institutions such as Water Boards, municipalities and private service providers. The resultant fragmented water management practices have been blamed for being inefficient and requiring more resources than are available. These approaches are rooted in the country’s historical values and governance where water management has been about control and purely dominated by technical considerations with little consideration for people and the environment.

The nature of water management practices are partly shaped by the legislation. In the case of the NWA, the emphasis is on surface water. The understanding of a catchment, which is based on surface water hydrology, as defined in the NWA has driven local water resources planning and management over the years. The resultant water management approaches have not adequately accounted for other components of water that have direct implications on ICM, such as water quality, groundwater systems and administrative boundaries. Integrated catchment management is set to assume a holistic way of managing water bodies in which all relevant variables are considered. This calls for the concept of a catchment being a virtual unit that is beyond the physical boundary.

Study Objectives

The study arises from the realisation that water management approaches, usually thought to be holistic, have failed to integrate all the variables important to how water is managed. The study aimed at bringing understanding to what has to be included in this holistic management approach, including water resources, land use, nature, culture, legislation, institutions, economics, environment, methods, practices, infrastructure and communities. The study aimed at doing away with the piecemeal approaches that were identified to be artificially separating land management from water management, and as isolating the roles played by various stakeholders.

The study also sought to establish a method for ICM that will achieve a sustainable balance between resource protection and resource utilisation while strengthening governance and other institutional provisions in the water sector. Specifically, the study aimed for the following:

1 To develop a model catchment that will enable the formulation of a living integrated Catchment Management Strategy
2 To develop an approach that incorporates both land management and water management to ensure resource protection and sustainable utilisation
3 To develop a model catchment, using a priority catchment in South Africa, to develop appropriate tools and strategies to effectively manage catchments on a variety of scales.

Study Approach

Inception, literature review and workshop

The study commenced with investigations into how ICM developed over the years as well as how it was understood in different regions and at different times. The study's inception phase involved identifying everything that should be understood as components of ICM rather than limiting the focus to what is usually addressed under IWRM. Land and water were identified as the main elements of holistic ICM. Early investigations showed that in addition to land and water there was need to include nature and the human element as part of four basic units of integrated catchment management. The human element was represented through the use of the term 'infrastructure'. The 'infrastructure' element captured the built environment, the institutional set up and other roles played by humans in the management of water that do not fall directly under the other three elements (land, water and nature).

A review of literature was carried out to gather and appreciate the information on available developments on the subject. In addition to literature and desktop investigations, a workshop was held to engage on the subject of the role of stakeholders in ICM. The participants workshopped ICM approaches and had the opportunity to define management preferences, given past developments, and their knowledge as well as experiences. The understanding of the role of land and water in ICM was also shared. The idea of a government system that is supposed to lead water and land management, even though it owned or had access to a very small fraction of both, also came under scrutiny as part of unique qualities that require attention in ICM. The workshop provided a platform to share and interrogate solutions for building holistic ICM, dealing with associated perceptions, as well as accounting for observations and goals as articulated in the current discourse. The participants projected a vision for future ICM where both water and land are central. Several of the participants also gave formal presentations based on selected subject areas that were important to the ICM project development.

The first phase of the research work involved consultations with various stakeholders in addition to the literature and desktop investigations. Consultations and discussions with both randomly and purposively selected communities in the catchment were aimed at extending the understanding of broader grassroots expectations. These included their expectations regarding integrated catchment management. Researchers also sought to ensure that the project development was informed by how the stakeholders are dealing with day-to-day issues as well as other activities involving water and land in their respective areas. Two sets of questionnaires, one for the general community and non-commercial water users and another one for commercial farmers and other commercial water users were used in the case study areas.

Development of the model catchment approach

ICM development in this study was based on the concept of a model catchment. The model catchment was conceptualised as a virtual catchment built on the characteristics exhibited by two selected case study catchments, Olifants-Doring and Olifants-Steelpoort Catchments. To cover all the regions in the country, the selected catchments' characteristics were supplemented with additional variables derived from commonly encountered attributes of other local catchments. The purpose of the model catchment approach was to build a generic ICM framework most representative of nationally found catchments. The motivation in the model catchment approach was that it would be directly linked to real case study arrangements, while processing the ability to be disaggregated and strategically recoupled in ways that allowed the user to account for activities and other dimensions within specific catchments being managed.

To develop this framework, possible case study catchments were identified and a selection criterion applied. The catchment assessments started with a comparison of all Water Management Areas (WMAs). This comparison entailed a screening phase. The intention in the screening stage was to come out with the most relevant choices based on how they can be considered to be generally representative of other areas in the country. The screening entailed evaluating the different physical characteristics of the WMAs and determining similarities as well as those unique characteristics that make the WMA suitable for selection as a catchment for use as one of the case study areas. The variable screening and analysis produced two top performing WMAs out of the nine. These were the Olifants and the Berg-Olifants WMAs. Further considerations of qualitative variables in all the WMAs were done to confirm the initial selections.

The next selection phase involved river catchments from the two best performing WMAs as revealed in the screening stage. In assessing catchments from the identified WMAs, similar variables to those used in the screening of WMAs were applied to the catchments. Catchments being much smaller than WMAs meant that the variables used were usually the actual records rather than averages as was the case at WMA level. The variable performance was calculated on the basis of observed quality of data, homogenous nature of variable, relevance to the objective, and possibility for easy comparison of the variables between different areas. Variables exhibiting higher levels of similarities in different catchments were considered to be better performing. The objective in the selection criteria was to select the catchments with the overall high scores for variable performance when compared to all other variables from other catchments considered.

In the multivariable analysis of catchments, the Olifants-Steelpoort (in Mpumalanga and Limpopo), which is located in the Olifants WMA, had the highest aggregate score when all inputs were considered. This was followed closely by Olifants-Doring (Western Cape and Northern Cape) in the Berg-Olifants WMA. These catchments gave the best representativeness of the South African catchments with respect to land use and water use activities. It was observed that the two catchments also covered large areas where more diversified land uses are taking place when compared with the other catchments. The decision to select either one or two catchments for use as case studies was analysed. An important output of this assessment was that there would be more value in using two case studies that seem to cover the widest variation in catchment characteristics.

Developing a catchment inventory based on a model catchment approach

The development of the integrated catchment management approach was guided by a future vision of holistic integrated water management with inspiration from ideal water management needs as envisaged in past and present studies as well as the NWA. The project terms of reference suggested the need to move away from the past fragmented water management approach that artificially separated land and water management. This approach was also blamed for failing to take advantage of common objectives in dealing with water and land that could be shared by various institutions mandated to address similar or supplementary needs. The ICM approach pursued relied on the understanding of the trending international benchmarks, knowledge sustainability, state of land use, water affairs and water management practices. The intended water management approach was set to establish viability, build sustainability and establish practicality while balancing the synergies and conflicts that are part of how water, which is everyone's natural resource, should be managed for the benefit of all.

The ICM framework development therefore relied on the following:

- *Local knowledge*
- *Characteristics of the catchment*
- *International direction, guidance and examples*
- *Model catchment structure*

The above considerations were used to develop the components of the ICM framework that would constitute accessible nodes of the ICM repository. Through these nodes the ICM framework links users to associated data, information, tools and other methods that are shared across different parts of the water sector, where stakeholders and institutions that are spatially dispersed can connect, and use and share resources. In the ICM model catchment approach, attributes that are not relevant to the other catchments can be excluded as necessary.

ICM Inventory/Repository

The development of the ICM inventory, also referred to as the repository, enhanced the various dimensions in which water management can take place. These included the location, scale, purpose and resource considerations. To achieve this, the ICM framework attempted to account for most variables in a catchment management setting. The framework included the development of an open source approach, where the variables covered can be extended and updated by various users. The

ICM repository was developed to bring together the various elements of ICM under one umbrella that is set to be available to a wide spectrum of users. It was envisaged that the ICM would ultimately allow for enhancement of resonance in management units rather than fragmentation. The data in the framework could be used to address both common and specific catchment management questions.

Investigations of the old ICM concepts revealed the limitations of hydrological-based boundaries in water management. A layered approach was used to allow virtual extension of physical boundaries to include, inter alia, the appreciation of groundwater boundaries, municipal boundaries, hydro-climatic zones, political boundaries and ecosystem boundaries that do not correspond to surface water hydrological systems and yet are linked to these systems in other ways.

The early developments of the ICM repository structure were based on the original motivation of seeking holistic integration of land and water management. However, observations from literature and consultations showed that in addition to land and water, there was a need to include nature and the human contribution or anthropogenic factors as part of four basic units of integration in integrated catchment management (Figure i). The anthropogenic factors were captured as ‘infrastructure’ even though it was envisaged to be a variety of contributions beyond ‘infrastructure’, such as legislation, institutional strategies and human practices. Human practices considered under ‘infrastructure’ include practices that alter the nature of the resources, such as activities that are responsible for changing the quality and quantity of water (Figure i).

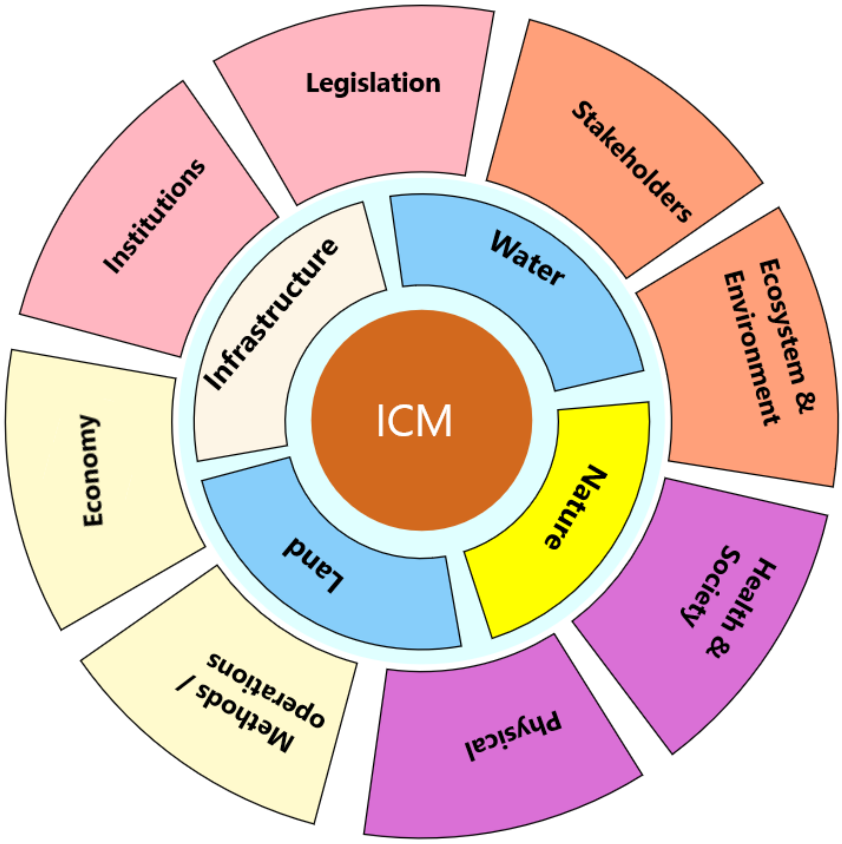

Figure (i): The catchment elements used as the front-end of the Integrated Catchment Management Repository

ICM Inventory components/elements

The development of the ICM framework prioritised the need to seek new solutions using new techniques rather than placing emphasis on historical methods and practices. Historical methods are mostly outdated, having missed the opportunities for update over the years, while legislation, available technology and even knowledge have been changing at a fast pace. The Integrated Catchment Management-Repository (ICM-R) presented a new platform that calls for stakeholders and users to test the many variables and account for as many aspects of the catchment as applicable in each case. The framework provides for users from other disciplines to become part of ICM in their catchments and populate the variables that are related to their focus areas. In so doing, existing water management templates are expanded thereby giving a picture that realistically represents all components that should be integrated in managing their catchment.

The ICM elements were organised into eight divisions (Figure (ii)) where ecosystem and environment, health and society, as well as methods and operations were represented in single segments as shown. Individually, all the ICM elements are considered against each of the four inner components. This is illustrated in how there is legislation for land, water, nature and infrastructure to provide a more realistic perspective of how the actual processes take place in a catchment setting.

Figure (ii): Sub-elements of the ICM-R that are developed for user interaction and update

The holistic ICM approach, as developed in this study, uses eight elements to define all activities, characteristics and other provisions required to manage a catchment. These elements are broken down into sub-elements that are linked to various modules, datasets, records and other files. The breakdown of the elements into sub-elements is presented in Figure (ii).

The approach pursued in using the ICM-R can be illustrated as applying a rolling ICM Wheel (Figure (ii)) along the water cycle within each catchment and using the data and other tools associated with each element at each point.

Many institutions perform ICM functions without even recognising the roles which their activities are playing in broader water management within their catchment. In addition to the integration of points of interest, especially water uses that are dispersed within catchments, the ICM-R also presents an integration of institutional roles with a stake in water management. The ICM-R was developed to allow the different institutions to use the tool and populate it with data and information related to their functions and roles.

Study findings

Integrated Catchment Management (ICM) has meant different concepts of integration in different areas, at different times and for different stakeholders. The involvement of a plethora of institutions dealing with water management on the basis of isolated interests and mandates has also meant that several water management processes are disjointed and lacking in synergy. The study also revealed a number of insights, which are listed below:

- *There are too many institutions dealing with water and land management*

Multiple institutions with roles in the water sector tend to generate the fragmented approaches that characterise the management of water and land within a catchment. These centres of management are not only disjointed in the legislation and policies driving their roles but also in terms of the different temporal and spatial distinctions in which their functions are implemented.

- *There is poor implementation of legislative clauses that are set to build ICM approaches*

While local water management as envisaged in the NWA was centred on a physical unit that is described as a 'catchment', the idea of a catchment has not been static over the years. The NWA provides for ICM that should take place on a parcel of land that has surface water hydrological boundaries in a geographical context. The idea of holistic ICM has evolved to include other variables that are not directly aligned to these physical boundaries. Examples include groundwater, land use, resource degradation, water administration, and application of legislated mandates through institutions whose location could be geographically unaligned to the physical boundaries of the catchment as defined in the NWA.

- *There are complications associated with spatial integration at different scales*

In terms of scale, catchment areas in South Africa are often managed across different geographical boundaries including the borders defining countries, regions, provinces, municipalities, cities, farms and how others define land uses. Most of these boundaries are defined according to legislation, politics, administration mandates and uses, while they rarely reflect the environment's natural ecological patterns such as ecological zones. The non-coherent boundaries add an extra layer of complexity to the water and land management process.

- *Radiation rather than rainfall should be the start of water management approaches*

The commonly applied management practices in catchments tend to focus on indicators of the role that the sun plays rather than include some characteristics of the sun and radiation into what happens at catchment level. Climate and weather are directly driven by the sun. At local level, a catchment's weather patterns are solar-powered, while runoff and seepage are driven by the terrain, gravitational forces and harnessed power through pumping mechanisms. Global warming studies are based on how long-term climate change occurs as a result of changes in intensity and distribution of solar radiation reaching the earth's surface. The variations in radiation for each catchment determine the weather patterns and indeed the rainfall characteristics. Rainfall, which is a result of the sun's radiation, is used as the starting point in water management practices rather than starting with radiation and airflow patterns. This approach over-simplifies the natural water cycle and in so doing, makes it difficult to have a good grip of all the tools that could be used to manage water.

- *Convergence and integration in an environment that is characterised by inequalities*

The state of water management is complicated by inequalities in access to resources and diversity in needs, as well as values of communities in the same catchments. This has usually been blamed on a history fraught with segregation and the continued lack of tangible reforms. In the water sector, participation in water issues has always been influenced by the historical background of access and use of land, as well as water resources. The balance of access to resource allocation has always tipped in favour of the minority white population. While commercial water users consume more than 70% of the water resources, approximately 98% of individual commercial water users are white, of which 88% are white males. Participation in water and land management is thus limited to a few stakeholders and does not involve all those affected by the catchment resources and activities.

- *Settlement patterns restrict the potential for integration in managing water at catchment level*

The study revealed that most large dams in the Olifants (Mpumalanga) catchment were not being operated to full capacity due to reasons that include the nature of settlement patterns. The majority of possible users, who are black, can hardly benefit from these dams even when initiatives are made to improve water allocation and management. This is due to their communities being located in dense rural settlements further away from established water sources including on inaccessible areas such as mountainous terrain, which requires excessively high investment expenditure to deliver water for any use.

- *Slow transformation of irrigation boards derails prospects for holistic ICM*

According to the NWA, irrigation boards should have started the process for transformation into WUAs within six months of the commencement of the NWA. This translates to 19 February 1999.

The transformation of all irrigation boards was expected to be complete within an estimated three months, based on the outlined procedures. The study observed that there is a continued conflict between the operations of the irrigation boards, which are based on the 1956 Water Act, and the intentions of the NWA. This was most evident when consulting the farming community. It was noted that the black farming community remains outside the irrigation boards and, since there are no WUAs, they are also outside any formal structures for managing water at local levels.

- *Water management at catchment level has erroneously excluded land*

Under ICM, land is central and equally significant to water in how it should be addressed as part of management programmes. The failure of many catchment-based water management practices, including the limited progress that characterises water provision in the country, is partly a result of the omissions made in recognising land as the underlying resource on which water access is experienced. This shortcoming has been exacerbated by the fact that the NWA omitted the link between land and water. Land in the NWA is only discussed under pollution instead of being considered in many other important roles, including how land is used in commercial activities. This is especially the case for commercial farming, which requires most of the land as well as the largest fraction of the available water.

- *Land ownership is not being considered in water resource management*

The water sector legislation, policies and strategies do not acknowledge the problem associated with high levels of inequality in land ownership and the resultant disparities in access to resources that is skewed in favour of white people. A number of other important national documents, such as the National Water Resources Strategy and the NDP Vision 2030, do not account for provisions on how water and land intersect. These omissions are detrimental to the management of water, especially when it comes to transforming commercial use of both land and water as required by the Constitution and provided for in the preamble of the NWA.

In addition, it was also observed that prevailing water management approaches assume that the government owns or has control over the land and water. This assumption remains in the realm of theoretical consideration and an academic perspective, given that in practice there is little that government can do to control water on private land. The challenges are evident in how the government has to regularly go to the courts seeking to exercise control over water on private land and losing in most of these legal battles to private land owners. Recent audits show that most of the land (>70%) and water (>90%) are privately owned and accessed.

Conclusions and Recommendations

- *Integration of ICM resources (data, information and tools)*

ICM seeks to address the lack of integration in how water is managed by a variety of institutions on the basis of various pieces of legislation. The ICM-R provides a consolidated platform for advancing an integrated effort while recognising the positive impacts of sharing between stakeholders. For integrated catchment management to be achieved, a number of role players at all spheres of government are expected to perform their roles in ways that compliment other role players.

- *Water management entails energy management*

The elements as defined in the ICM wheel (Figure (ii)) have a strong alignment with how the sciences have evolved. The idea of catchment management as a way of balancing the forms of energy in a catchment seems to be the long-term goal. However, this goal is not yet receiving attention within the water sector except in the discussion of climate change. The water balance is driven by energy and this energy is continuously changing with implications for all elements of ICM. Water management has to be based on the radiation energy balance as the starting point rather than starting with the rainfall patterns, which are a result of radiation patterns.

- *ICM rather than IWRM*

IWRM is a narrow approach that dissociates water management from many other important variables. These variables are also reactive to development and sustainable management of resources at catchment levels. The tendency in IWRM is to restrict management to a few targeted objectives such as water quantity and quality without appreciating the economics of water, financial positions, environmental issues, social aspects, water infrastructure, legal implications, institutional limitations, and a number of other variables.

- *Virtual integration that is not restricted by physical boundaries*

The investigations in this study showed that the term ‘Integrated Catchment Management’ tends to restrict the management approach envisaged to a less holistic method that is bound by physical catchment boundaries. This ICM-R approach is an attempt to seek a holistic integration that is not restricted by the physical boundaries associated with surface water hydrology, groundwater zones, administration zones and political boundaries. A virtual catchment model that allows for coupling and decoupling of various resources and water management variables as required for each management exercise was attempted in this study and it is recommended for holistic water management in the future.

- *Limitations in knowledge due to missing linkages of water and land*

Current water legislation and institutional structures, associated policies, regulations, as well as water sector strategies do not adequately provide for water and land linkages, especially for commercial activities. By omitting the integration of water and land in addressing economic uses, these provisions do not address many other dimensions of water existence that could be applied in holistic resource management. This omission limits the knowledge development in subjects that are important to addressing the quantification of available land and water resources, in building accurate water balances, and in accounting for realistic long-term water use patterns. Legislation and practices that deal with accessing water and land should be converged and applied simultaneously. Databases and other information resources dealing with water, land and land uses should be commonly shared.

- *ICM-R use in advancing the NDP*

At national level, the NDP calls for consolidation of initiatives and integration across sectors including water, mining, agriculture, energy and environment. It also makes provision for the establishment of several water sector programmes that are important for supporting a strong economy and a healthy environment to support the national 2030 vision. Several of these programmes could be enabled across sectors through the use of integration tools such as the ICM-R developed in this study for addressing multi-sectoral challenges in a catchment setting.

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Agri-SA:	Agriculture South Africa
AMD:	Acid Mine Drainage
ANC:	African National Congress
ARC:	Agricultural Research Council
AWS:	Alliance for Water Stewardship
BUSA:	Business Union of South Africa
CAPE:	Cape Action for People and the Environment
CARA:	Conservation of Agricultural Resources Act
CMA:	Catchment Management Agency
CMAs:	Catchment Management Agencies
CMIP:	Coupled Model Inter-comparison Project
CMIP5:	Coupled Model Inter-comparison Project Phase 5
CMS:	Catchment Management Strategies
CO_2:	Carbon Dioxide
COD:	Chemical Oxygen Demand
CSIR:	Council for Scientific and Industrial Research
CSIRO:	Commonwealth Scientific and Industrial Research Organisation
DA:	Democratic Alliance
DAFF:	Department of Agriculture, Fisheries and Forestry
DBSA:	Development Bank of Southern Africa
DEAT:	Department of Environmental Affairs and Tourism
DED:	Department of Development
DMR:	Department of Mineral Resources
DWA:	Department of Water Affairs
DWAF:	Department of Water Affairs and Forestry
DWS:	Department of Water and Sanitation
EFR:	Ecological Flow Requirements
ELU:	Existing Lawful Use
ELUs:	Existing Lawful Users
EPA:	Environmental Protection Agency
FAO:	Food and Agriculture Organization
GB:	Gigabyte
GCMs:	Global Circulation Models
GIP:	Groundwater Information Portal

GIS:	Geographic Information System
GSSA:	Geological Society for South Africa
GW:	Groundwater
HRC:	Human Rights Commission
IB:	Irrigation Boards
ICM:	Integrated Catchment Management
ICM-R:	Integrated Catchment Management Repository
IHP:	International Hydrological Programme
IPCC:	Intergovernmental Panel on Climate Change
IWM:	Integrated Watershed Management
IWRM:	Integrated Water Resources Management
LCLU:	Land Cover and Land Use
MAP:	Mean Annual Precipitation
MAR:	Mean Annual Rainfall
MCDA:	Multi Criteria Decision Analysis
MS:	Microsoft
NDP:	National Development Plan
NEMA:	National Environmental Management Act
NEMAQA:	National Environmental Management: Air Quality Act
NEMWA:	National Environmental Management: Waste Act
NGIS:	National Groundwater Information System
NGO:	Non-Governmental Organisation
NGOs:	Non-Governmental Organisations
NGS:	National Groundwater Strategy
NHRA:	National Heritage Resources Act
NLC:	National Land Cover
NOAA:	National Oceanic and Atmospheric Administration
NPC:	National Planning Commission
NT:	National Treasury
NWA:	National Water Act
NWPR:	National Water Policy Review
NWRS2:	National Water Resource Strategy 2
NWSMP:	National Water & Sanitation Master Plan
OECD:	Organisation for Economic Cooperation and Development
ORASECOM:	Orange-Senqu River Basin Commission
PC:	Personal Computer
PCA:	Principal Components Analysis
PCM:	Participatory Catchment Management

PES:	Present Ecological State
PMG:	Parliamentary Monitoring Group
PPP:	Public Private Partnership
RCP:	Representative Concentration Pathways
RQOs:	Resource Quality Objectives
RSA:	Republic of South Africa
SA:	South Africa
SADC:	Southern African Development Community
SADC-GMI:	Southern African Development Community Groundwater Management Institute
SAICE:	South African Institution of Civil Engineering
SANBI:	South African National Biodiversity Institute
SARVA:	South African Risk and Vulnerability Atlas
SAWS:	South African Weather Services
SDGs:	Sustainable Development Goals
SDM:	Sekhukhune District Municipality
SPLUMA:	Spatial Planning and Land Use Management Act
SW:	Surface Water
SWAT:	Soil and Water Assessment Tool
UK:	United Kingdom
UN:	United Nations
UNDP:	United Nations Development Programme
UNESCO:	United Nations Educational Scientific and Cultural Organization
UN-Water:	United Nations Water
WAR:	Water Allocation Reform
WMA:	Water Management Area
WMAs:	Water Management Areas
WRC:	Water Research Commission
WRSM:	Water Resources Simulation Model
WRYPM:	Water Resources Yield and Planning Models
WSA:	Water Service Act
WUA:	Water User Association
WWF:	World Wide Fund
WWTW:	Wastewater Treatment Works

1 Introduction and background

1.1 Introduction

1.1.1 General background: ICM studies

Historically, the management of land and water has been highly fragmented, resulting in a piecemeal approach that fails to successfully integrate the issues that affect both systems. Lerner, Kumar, Holzkämper, Surridge and Harris (2009) explained that the management of water and land as a single system is a challenging ideology; however, the need for an integrated approach can no longer be ignored if there is to be an equilibrium between resource demand, usage and resource conservation. Similar observations have been reiterated by Acheampong, Swilling and Urama (2016).

The development and implementation of Integrated Catchment Management (ICM) has been lauded as one of the major steps towards excellence in sustainable development and use of water resources. ICM concepts differ markedly across the world and even within the same regions. Prior to the integration of land and water management, the focus rested mostly on the management of water resources as a separate system from land (Montgomery & Elimelech, 2007).

Segregated approaches in managing water were practical in the past when the footprint of human activities was minimal. Over the years, large scale developments have created a very delicate balance between the various aspects of anthropogenic and natural systems. Land and water developments have now reached or exceeded sustainable environmental limits in most catchments, especially for water systems that pass through urban and other developed areas. Humanity is now competing with nature for the limited resources. Any new imbalances are generating long-lasting negative impacts at an escalating pace. A famous quote by Dr Jonas Salk emphasises the importance of maintaining a healthy balance in nature for the sake of our own being (Dhiman, 2018). He is attributed to have said that ‘‘if all the insects were to disappear from the Earth, within fifty years all life on Earth would end. If all human beings disappeared from the Earth, within fifty years all forms of life would flourish’’ To avoid such a cataclysmic eventuality, holistic approaches in ecosystem management are called for. Our ICM approach has to ensure that, apart from the focus on managing land and water, the sustainable ecosystem is equally important and has to be part of the integrated approach.

Past efforts in South Africa have also focused mainly on Integrated Water Resource Management (IWRM). This approach has been driven by global actors such as the United Nations and the World Bank where integration was usually discussed in terms of water resources rather than both land and water. However, recent trends highlight the need to take into consideration the management of land in the course of managing water resources and other associated systems (Kragt, Newham, Bennett & Jakeman, 2011). At the heart of the need for integrated catchment management are the constituent elements that affect resource planning, resource allocation and efficient resource distribution (UN-Water, 2008). Some of these elements include water demand and usage, population demographics, efficiency of water infrastructure and land uses.

In response to water management challenges, the United Nations has ongoing initiatives where governments are called upon to monitor and address the adverse effects of anthropogenic activities on water availability, distribution and use (UN-Water, 2008). Some of the factors that complicate water and land management are socio-economic in nature, such as population growth and the accompanying escalation in unplanned settlements, especially in urban areas. As the population changes, the provision of services including planned land uses and water services become challenging. In addition to the population changes are the changes in settlements and the climate, which add to the complexity of catchment management. Rouillard and Spray (2016) characterised the changes in land use, population and climate as the ‘‘wicked problems’’. These additional problems add unanticipated uncertainties in catchment decision-making processes.

Other definitions of ICM contemplate the improvement of water availability and its quality to a state where pristine conditions are attained. The improvement of biodiversity, as well as reducing the impacts of flood damage and erosion, are also considered important components of ICM. Dealing with land and water use-based sources of degradation have also become part of the ICM approach.

Water management in the past was dictated by the historical paradigms where the focus was very narrow and driven by isolated programmes and projects without a holistic approach to the catchment management. In the past, land uses in South Africa were usually developed and implemented with little regard for the environment, resulting in wide scale destruction of both land and water resources. The most prominent destructive forces came from human settlements, mining and agriculture where the nature of natural resource degradation has been so widespread that addressing the legacy of the destruction in both surface and groundwater is now dominating the resources allocated to certain government departments. While the focus on rehabilitation of the damaged resources is currently focused on water, the damaged soil and associated land that continue to degrade water resources is not yet being addressed. This calls for a relooking at the catchment management approaches being applied to ensure that all variables in a catchment are accounted for.

1.1.2 Introduction to holistic ICM land and water approach

Integrated catchment management, or several versions of it, have been described using different terms depending on the region, country, language in use as well as the emphasis of the author. Campbell (2016) describes several terms that are used sometimes interchangeably as equal in meaning and sometimes to define a generally similar concept to ICM with a certain emphasis around the management of land and water within a watershed or catchment. Some of the descriptive terms used include: Integrated River Management (IRM), Integrated River Basin Management (IRBM), Integrated Water Resources Management (IWRM), Integrated Watershed Management (IWM), Integrated River Basin Governance and Integrated Natural Resource Management. Campbell (2016) explained that, while the terminology differs, the issues under consideration are usually similar and deal with land and water management in a defined area with a broad set of cross-linked issues. Other authors contend that the term "integrated" has been used to define the complexity of river basins as hydrological, ecological, economic, political and social systems (Stosch, Quilliam, Bunnefeld & Oliver, 2017; Hooper, 2003; Watson, 2004).

A sustainable ICM involves an in-depth understanding of all the processes involved in the catchment, especially those associated with the land and water interactions. Apart from the negative effects of land uses polluting water, FAO (2000) also takes into consideration effects on the hydrophysical nature of the associated land. FAO (2000) further explained that the land and water interactions are complex and differ significantly between small land plots. The land and water interactions are complicated by the little-known processes that have to do with different soil types and soil depth, location, topography, land cover, nature of rainfall, as well as upstream conditions. In addition, there is no adequate information regarding the full implications of programmes such as different agricultural activities, afforestation, forest clearing and other land uses in the area under consideration as well as upstream of it. FAO (2000) recommends the use of models developed for site-specific conditions to address the complexities associated with the land and water interactions to ensure that ICM is based on well-informed ideas.

ICM approaches are based on the understanding that land and water are inextricably linked and have to be managed holistically without separating the points of focus as these affect both. However, more recently other researchers have come to an understanding that it is not just land and water that have to be managed in an integrated approach, but rather all nature and even the infrastructure that has been developed to become part of the catchment. The ICM should also embrace the different points in time as well as the different points of the water cycle including the geographical references.

Figure 1.1 below summarises the variables that are embraced in ICM in a catchment when considered along the path of water from the water source to the receptor. Figure 1.1 also captures time-related events that may not be easily evident, such as a flood in a town, cattle grazing, abstraction, purification and pollution.

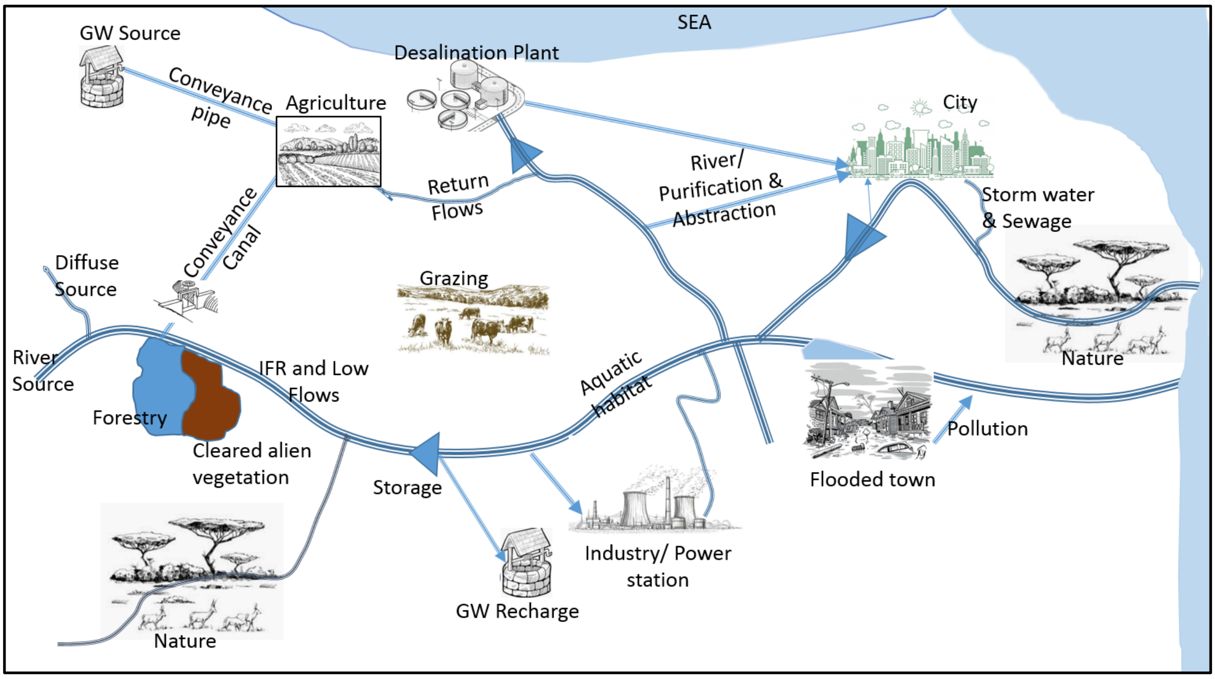


Figure 1.1: Illustration of the points for consideration in ICM along the path of water from the sources to receptor (Drawn by the Hydrosoft research team)

Development of ICM is guided by legislation. In 1996, the National Water Act (NWA) of South Africa defined a catchment as "the area from which any rainfall will drain into the watercourse or watercourses or part of a watercourse, through surface flow to a common point or common points" (RSA, 1998a). The second National Water Resource Strategy (NWRS2) (DWA, 2013a) repeats this definition. However, international organisations have been updating the understanding of catchments. The United States' Environmental Protection Agency (EPA) (2017) provides a simplified but clearer interpretation: a catchment is defined as "an area contributing water to a river and its tributaries, with all the water ultimately running off to a single outlet". In South Africa, the NWA makes provision for ICM. In its preamble, the Act recognises "the need for the integrated management of all aspects of water resources and, where appropriate, the delegation of management functions to a regional or catchment level so as to enable everyone to participate" (RSA, 1998a). Part 2 of Chapter 2 of the NWA is dedicated to the establishment of catchment management strategies, while Chapter 7 deals with the catchment management agencies, which are tasked with the mandate for managing water at catchment level. In response to the National Planning Commission's Vision 2030 and alignment with NWRS2, the NWRS2 has "Integrated catchment management and resource protection" (DWA, 2013a) as one of its programmes that are targeted at job creation through water functional management.

While the NWA makes provision for ICM, it falls short when it comes to addressing the state of degradation, an increasingly important factor in how water provision is planned, managed and provided for all forms of uses. Even though the NWA was established in 1998, at a time when water resources were already in a state of degradation, only a small part of the Act, in Section 65, deals with rehabilitation of water resources. The limited focus on water and land degradation in the NWA is replicated in the national water organisational structures. The Department of Water and Sanitation (DWS) does not have a directorate dealing with rehabilitation of water resources as an everyday concern (DWS, 2017a).

The rehabilitation programmes are now being addressed as costly emergency programmes such as the Acid Mine Drainage Programme in Gauteng being implemented at a cost of R12 billion and the isolated dam rehabilitation programmes for a few eutrophic dams. PWC (2012:14) reported that as early as 1987, the US Environmental Protection Agency recognised that "…problems related to mining waste may be rated as second only to global warming and stratospheric ozone depletion in terms of ecological risk". Given the state of past and ongoing water resource degradation, it follows that any ICM programme has to have resource rehabilitation as one of the main objectives. It has to be noted that the label "water quality" in water institutions is usually limited to monitoring pollutants. Their mandate does not extend to addressing the damage caused to the ecosystem by past practices.

The conceptualisation of the ICM is limited to the consideration that this will be implemented and led by formal structures of government with well set out legal provisions. Brinkerhoff and Goldsmith (2002) explained that the philosophy of ICM is structured on a formal governance system and tends to be unconnected to the informal governance that plays a major role in all societies. No human society is so advanced that it relies exclusively on formal *de jure* institutions to run its common affairs. When the decision makers dealing with land and water management fail to accommodate informal governance systems, they also fail to integrate the ICM system into the way of life that prevails in the targeted communities. Brinkerhoff and Goldsmith (2002) explained that all nations have both formal and informal governance systems — that is, systems within which citizens and government officials interact. While the formal government in South Africa is based on the Constitution and structured legislation that are supported by formal institutions, the informal system is based on undocumented implicit understandings that rely on socio-cultural norms, ethnicity, culture and other well accepted practices, which sometimes conflict with formal governance structures.

The development and implementation of the ICM in local catchments is usually impeded by the lack of buy-in as well as lack of ownership by the community of targeted beneficiaries. In many cases, those in authority do not see the value of selling the ICM programme to communities and yet they expect stakeholder participation. Auerbach (1997) explained that there is no way that community stakeholders will be convinced by someone coming from Pretoria (Capital City) to “teach” them ICM. He recommended that the ICM stakeholders in communities need to understand the programme and its objectives. He explained that it works much better when this is implemented as part of the community’s own initiative.

1.2 Project background

1.2.1 Objectives of the study

The study was guided by the following three objectives:

1. To develop a model catchment that will enable the formulation of a living integrated Catchment Management Strategy

2. To develop an approach that incorporates both land management and water management to ensure resource protection and sustainable utilisation

3. To develop a model catchment, using a priority catchment in South Africa, to develop appropriate tools and strategies to effectively manage catchments at a variety of scales.

The idea of a model catchment in the objectives aimed to identify a catchment system that could be considered to be more representative of most catchments and use it in defining a solution that could be as generic as possible while avoiding the clutter and complexity involved when all catchments are used. Instead of the single model catchment, the project ended up using two catchments that covered the range of variables associated with most catchments in the whole country. While the study was originally envisaged without an example of an ICM software approach, one was later developed to address the aspect of development that is consistent with all the objectives.

1.2.2 Study rationale

The South African Constitution calls for the government to pass legislation and other measures to achieve land, water and related reform, in order to redress the results of past racial discrimination (RSA, 1996). The Constitution also declares that everyone has the right to have access to water. These provisions are carried into the NWA (RSA, 1998a), which makes several provisions to guide holistic integrated catchment management. According to the NWA (RSA, 1998a), a catchment management strategy should take into account the geology, demography, land use, climate, vegetation and waterworks within its water management area. The NWA also calls for certain land uses to be regulated if they affect the quantity and quality of water resources. The NWA also makes provision for the establishment of dedicated catchment management agencies. ICM is expected to be holistic and sustainable, covering all aspects of the catchments rather than being a piecemeal approach where land management is separated from water management by artificial boundaries. This has not been the case in the past with the result that there is a lack of balance between resource protection and resource utilisation. The use of land and water has been directed in such a way that it has caused degradation of natural ecosystems. Water provision is now constrained by the poor resource quality and limited quantities, which are increasing the costs of securing water for all citizens. The bill for rehabilitating degraded natural resources has escalated to levels that are beyond the country’s resources.

Governance and cross-sector policy coordination have been identified as being weak and increasingly coming short in providing for the demands exerted on the natural resources by people and nature. As a result, the environment is poorly protected and the use of land and water resources is no longer sustainable. The responses to the challenges are fragmented, due to the many disconnected mandates coming out of disjointed administrative jurisdictions. Far too many institutions are currently involved in land and water management, thus making accountability difficult to achieve. The bureaucratic process involved inside these many institutions and between them impedes progress in achieving holistic oversight on overall institutional performance. The translation of the legislation into implementation has been blamed for many of the shortcomings in ICM. This is observed in the strategies and programmes that fall short of catchment requirements. Strategies such as the NWRS2 are more aligned to IWRM rather than ICM. In addition water quantity and quality monitoring is taking place intermittently in a poorly coordinated process. In many instances, at various stages of water management in the catchment, there is no oversight even though the legal provisions require such oversight. Typical cases include the monitoring of water quality downstream of WWTW that are managed by the municipalities and metros. This collected data is hardly available to the DWS. Also, even if it is made available to the DWS, there are no enforceable measures to enforce compliance, except when there are cases of extreme levels of pollution that are evident to the media.

Responses to cases of major water quality degradation are primarily localised rather than using holistic catchment-wide approaches. This study sought to provide the direction for holistic catchment management where catchment management accounts for all variables at play within the catchment and connected areas, such as the case in transboundary water. In catchment management, solutions are usually complex and tend to cross the boundaries of responsibility for the various institutions and role players involved. These interventions are complex and are composed of many dimensions: they have to be ecologically sound, comply with legislation, meet accepted technical standards, address the socio-economic objectives, fall within the financial provisions and meet political objectives, as well as comply with time and location constraints.

Past ICM programmes have largely been unadaptable to ongoing organisational initiatives in such a way as to be imbedded in the structure of how water is managed in the country. These previous interventions tended to deal with single issues and also failed to include the multi-stakeholder interests. In addition, ICM initiatives have had their roots in European studies as well as other developed nations in the Northern hemisphere. FAO (2000) expressed concern at how the better-studied catchments in the temperate zones have influenced catchment management methods in the arid and semi-arid countries where the dominant bio-physical processes are very different. Catchment-based approaches in South Africa have to be distinguished from developments made in countries that do not share similar characteristics.

Past ICM developments have also been blamed for being mostly theoretical with little potential to inform the water business processes. Knowledge and documentation on past ICM efforts are available through recorded literature and desktop material. This historical content is expected to inform the new ICM initiative. To ensure success of the approach, existing constraints in institutions, in legislation and at cultural level were mapped and changes instituted to effectively achieve a transition into an adaptive management approach. The catchment management model was expected to be able to handle decision making on various scales and for different environments through dimensional changes as well as changes to the constituent algorithms. The nature of issues within catchments calls for a multidisciplinary approach that will involve wide stakeholder participation and engagement.

1.3 Scope of the study

1.3.1 Introduction to the scope of the ICM study

The scope of the investigations was set to appreciate the starting point in ICM for most if not all our catchments. This is due to the fact that the catchments are already degraded, such that any solution has to start by addressing this state of degradation for sustainable results to be achieved. In this study, the scope of work was set to place rehabilitation of the catchments as a permanent consideration in the decision-making process as well as in the development of ICM solutions.

The study was carried out in six main phases as follows:

- Study development
- Literature, data and information collation
- Consultations and stakeholder engagements
- Development of ICM components
- Integrated ICM solution development
- Development of outputs.

These phases have been presented in more detail in the deliverable section. In summary, the distinctions of these deliverables were as illustrated in Table 1.1 below:

Table 1.1: Study phases covered in the report

Phase	Name of Phase	Associated Deliverables
1	Study development	Project Inception report
2	Literature, data and information collation	Desktop and literature investigation
2	Further literature, data and information collation Case Study identification	Report on the selection of priority case study catchments and criteria applied
3	Consultations	Stakeholder workshop and consultations

Phase	Name of Phase	Associated Deliverables
4	Development of ICM components	Catchment inventory report covering the hydrological and environmental considerations – (Groundwater/Surface water interactions, socio-economic and political aspects of ICM included)
4	Development of ICM components	Catchment inventory report for land use and water use
4	Development of ICM components	Report on the water legislation, policy and institutional module
5	Integrated ICM solution development	Integrated assessment, Tools and ICM Strategies report (Sources and pathways as well as solution modules)
6	Development of outputs	Edited print ready final report

1.3.2 Scope of the ICM study: Study phases

Phase 1

This phase of the study involved the investigations leading to the inception report as well as the development of the initial study concepts, including the conceptualisation of solutions. It was envisaged that the study would look at the water cycle and associated activities, methods, tools, legislation, policies and other approaches. The investigations dealt with the various constituencies of the ICM land and water approach. These included the hydrologic component, water quality, air pollution, water degradation, land uses, biodiversity, ecosystem health, flood and erosion management, stakeholder participation, as well as ownership.

It was envisaged that a good ICM was set to build a catchment with enhanced qualities of social, economic and environmental character as well as dealing with complex decision making to satisfy multiple stakeholders with diverse interests. Such a system would come out with the best catchment management options to satisfy multiple objectives (see Figure 1.2).

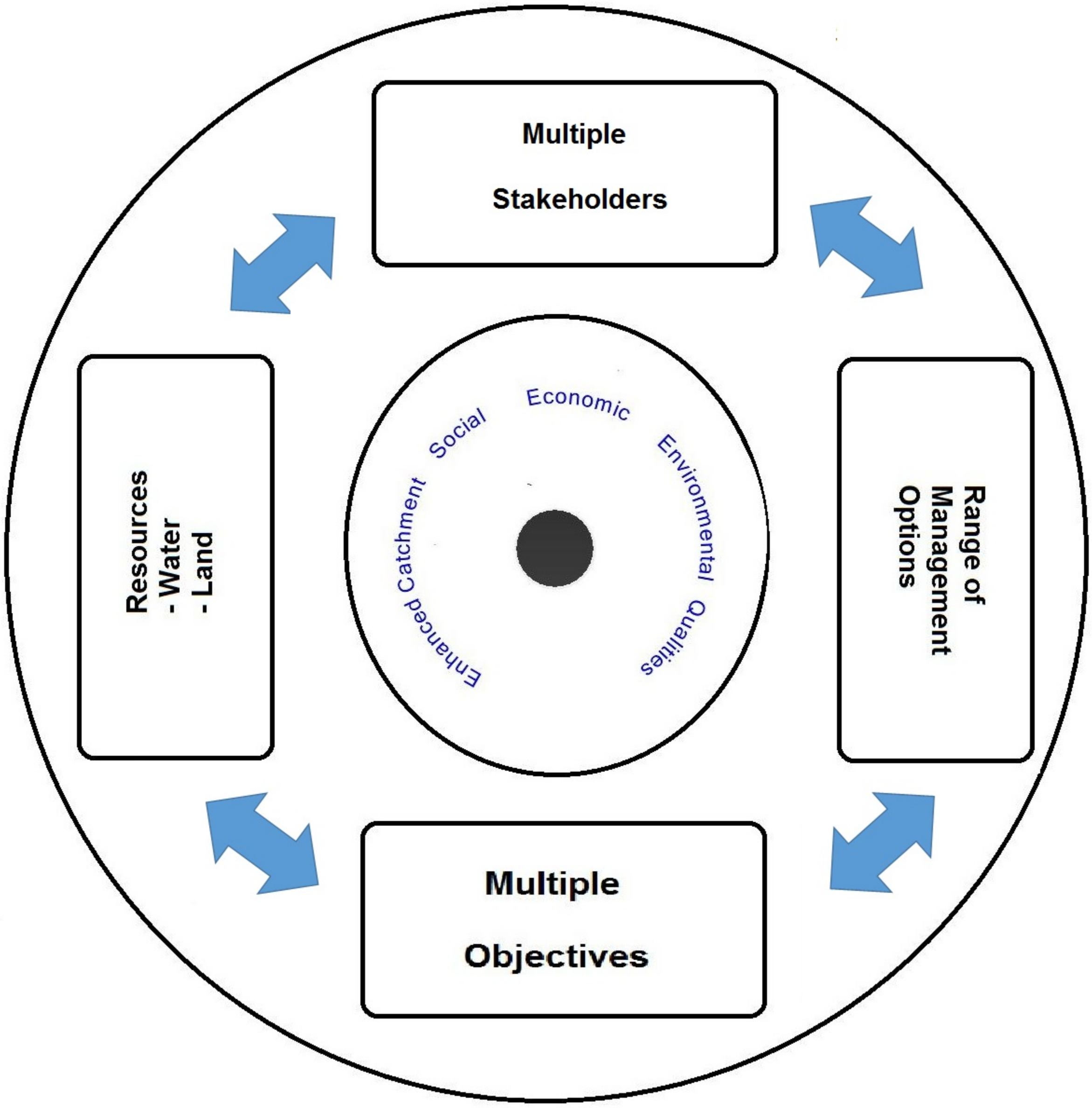


Figure 1.2: ICM involving complex decision making for multiple stakeholders

Phase 2: Literature, data and information collation

(i) Literature

This stage, entailed developing an improved understanding of the study area, thus improving the study team's understanding of available literature on integrated catchment management, as well as specific literature regarding the associated areas of interest in the study. Literature and data collation was enhanced as the research progressed. The section on literature is further discussed in Chapter 2 of this document.

(ii) Data and information

Data and information collation were carried out first to understand available content, and then to use the data in the development of suitable solution concepts. In the later stages of the study the data collated as part of the ICM and associated component tools and methods was applied for the case studies. The data collated was more targeted to the model catchment as determined for the study.

As part of this phase, the research team investigated what constituted a sustainable ICM Land Water Approach for a typical catchment in South Africa. The investigations included an assessment of existing documented material as well as content residing in models and tools used in catchment management. The ICM approach planned for the study was set out to look at two important dimensions as follows:

(i) ICM from source to receptor (Figure 1.3)

(ii) ICM the water and land approach

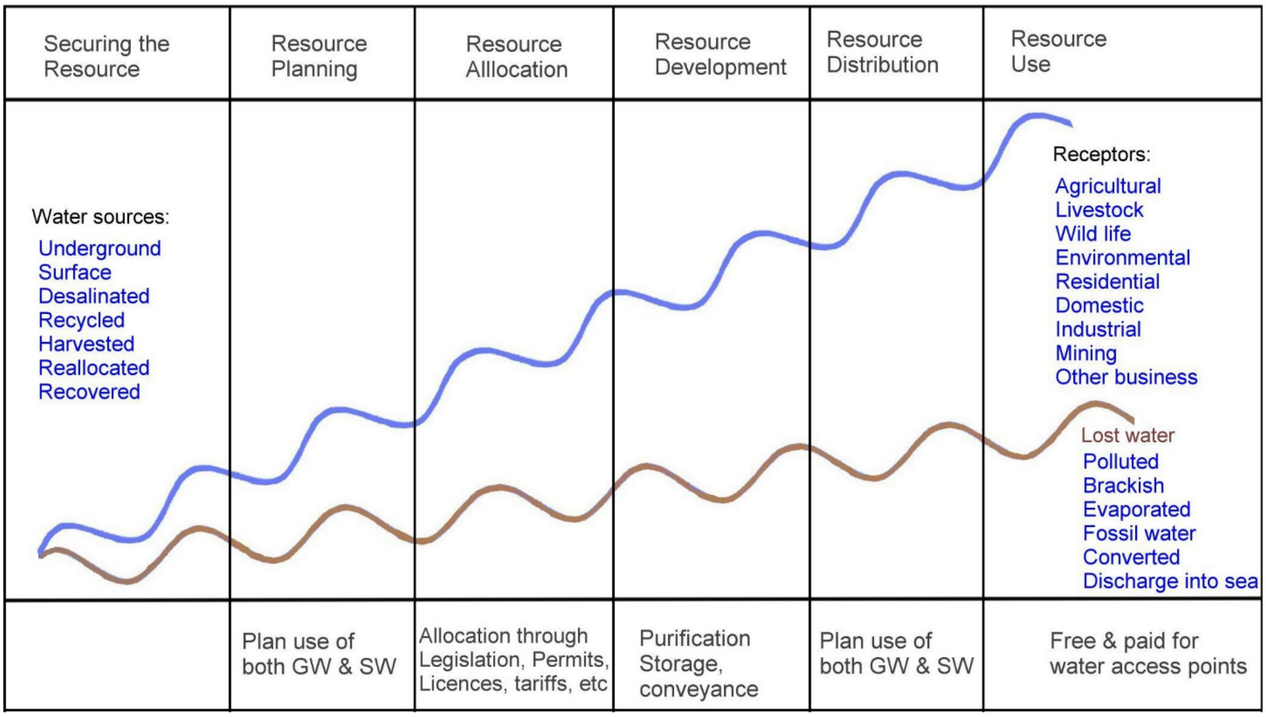


Figure 1.3: The hydrologic component in ICM, a source to receptor perspective

The ICM components were set out to be integrated for the benefit of all stakeholders and the ecosystem.

The various components of ICM were considered in developing an adaptive integrated catchment management approach that addresses all the shortcomings associated with managing water and land resources through disaggregated piecemeal methods. ICM was considered as involving steering or managing the Integrated Catchment Plan to produce defined outputs.

The envisaged solution was set to generate a sustainable balance between use and protection of land and water resources. This perceived solution was drafted in a way so as to incorporate methods and tools for addressing existing and ongoing resource degradation as part of catchment management.

Phase 3: Consultations

Apart from developing improved understanding of ICM within the setting of a model catchment, the study investigated and defined the ICM philosophical concepts and how they can be applied to derive the best benefits for all stakeholders in a catchment. The envisaged benefits are set to be measured against established best practices as well as the interests and objectives of the stakeholders. The ICM approach as understood in the study involved a process where the stakeholders were expected to be on board from the very start of concept development and ultimately take ownership of the final tools and decisions coming out of their implementation. As such, project consultations did not only seek to obtain insights from stakeholders but also to develop a common path that would satisfy technical objectives based on catchment knowledge, and the perceptions that constitute the stakeholder's visions and objectives. Through the consultations, some stakeholder perceptions were altered as the values of the integration were unpacked for sharing and interrogation by other role players. As an example, the perception of participation being solely through employment in the catchment as held by mostly black stakeholders was questioned and discussed during the one-on-one discussions. The aim was to share and develop a common appreciation of the range of possibilities in which black stakeholders could be involved in ICM especially in economic activities that are part of what takes place in a catchment. Further aims of the consultations and stakeholder engagements entailed the following:

- Sharing project ideas, project plans
- Understanding stakeholder positions, their perceptions and expectations in the project
- Understanding what has worked in the past and what will not work based on the knowledge of stakeholders
- Providing a platform to obtain feedback from stakeholders and develop synergy
- Testing the ICM decision support platform to improve its ability to meet objectives
- Developing common goals that will constitute the project decisions for the model catchment
- Understanding stakeholder objectives and setting up a commonly agreed study basis to capture varied interests

- Facilitating trade-offs between multiple objectives and possible decisions associated with stakeholders from varied interest groups
- Identifying stakeholders who were to run with and own the ICM approach, once it is completed.

In dealing with stakeholders, the researchers were cognisant of how reality as perceived by stakeholders is not always aligned to actual realities. Kokx and van Kempen (2010) concede that "Facts are facts, but perceptions are reality", and the process of consultation was seeking to bring the stakeholder perceptions closer to the facts, to ensure that the ICM approach addressed established real problems while gaining from the available synergies.

Phase 4: Development of ICM components

This stage of the study dealt with Data, Information and Tools covering considerations of the ICM components including hydrology, climate, environment, socio-economics, culture, politics, governance, land uses, legislation, policy and institutions. It was envisaged that the study would take advantage of existing tools and methods established to address the separate components of ICM. These tools have been developed to answer unique separate questions with little or no integration to other associated solution development platforms. Typical cases involved hydrology models that only deal with water quantity but have no connection with water quality despite the fact that water quality reduces availability. Another important area of interest in the study was seeking to integrate the knowledge and methods used in land use with water resource considerations.

Further discussions on the development of the ICM components are discussed in Chapter 7 of this report.

Phase 5: Integrated ICM solution development

The integration process integrated the ICM components as developed for the different associated areas to constitute a common platform that would generate the required inputs for decision making at catchment level. The first level of integration involved the scientific and philosophical nature of ICM as generated from the components considered in Phase 5 of the study as well as the stakeholder knowledge and perceptions. The integration entailed the development and application of linkages between the tools and methods.

Integration boundaries were set up as the model catchment boundaries. The study appreciated the limitations in the use of boundaries in cases where the established methods already cross these boundaries. It was noted that the process of untangling methods that cross catchment boundaries in how they are conceived or implemented had the potential to bring a mixed bag of fortunes and required much consideration to unpack the implications before being applied. Examples include cases where one would aim to see that a groundwater model is limited to a catchment as defined along surface hydrology. It was clear that such a pursuit could only waste resources as the benefits are limited to very specific issues that are not commonly encountered in most other scenarios and as such not expected to be part of a representative model catchment approach.

The integration in the ICM tool used inputs based on local scales or small portions of the model catchment, while on the other hand disaggregating broadly captured inputs to isolate the applicable routines for the target area. The process involved cases where the researchers and stakeholders would come up with preferred tools or methods in cases where there were several addressing the same subject matter.

Most existing water management solutions were noted to be based on narrowly defined objectives without consideration for integration of the vast number of interconnected variables. As such the tools that could give a more complete catchment-wide assessment were expected to be identified as part of the ICM solution mix. It was also envisaged that the project would identify areas within the various ICM components where the continued use of past methods would limit the potential benefits of holistic ICM. Further discussion on this phase is presented in Chapter 7 of this report.

Phase 6: Development of Outputs

The development of the final output involved a consolidated electronic platform and a publishable report. The report accounts for all project stages including providing detailed insights into the ICM platform developed as part of the research process.

1.4 Report structure

The report is based on a research that was developed out of the needs identified in the South African water sector. As such, the report starts with an assessment of available literature to establish the background as well as to understand the local requirements that were set out along the guiding study objectives. In Chapter 2, the report draws from local and international literature on ICM especially to appreciate the dimensions of ICM that could be of interest to the local setting while addressing the water management gaps as identified in the background and study groundwork developed in Chapter 1. The concept of a model catchment as well as the selection of the case studies that could be used to represent other catchments across the nation are contained in Chapter 3. Chapter 3 also captures the consultation process as well as the questionnaires applied in the case study areas to share and obtain relevant insights from stakeholders and other role players in the identified case study areas. Chapters 4, 5 and 6 looks at different components that were set to be integrated in an ICM system. The focus was set on hydrological and environmental considerations in Chapter 4, land and water considerations in Chapter 5, as well as a focus on legislation, policy, socio-economics, institutions and stakeholders in Chapter 6. The reporting on the ICM components took place in alignment with the development of an ICM inventory which is also referred to as the ICM Repository (ICM-R) in this report. The ICM-R was developed as a generic platform that was set to compliment the ICM investigations and appreciate the applicability of the ICM proposals as developed in the ICM study. This ICM-R tool was consolidated to account for all components and is documented in Chapter 7. Following the development and limited application of the ICM-R tool, the report focused on ICM strategies emanating from the research process that are captured in Chapter 8. Conclusions and recommendations are presented in Chapter 9. The report includes Annexures 1 and 2, which are dedicated to the ICM-R software, with descriptions associated with the software and tools covered in the first section and the more detailed user manual covered in Annexure 2.

2 Investigating ICM literature

2.1 Integration in water and the development of ICM

Investigations of the state and future of water resource management in the country can only be holistic if they are based on a solid understanding of the historical circumstances through which the country came to be. Of much significance to water management are the ways in which historical legislative framework and legal tools were implemented, as well as how past and current developments continue to shape the water sector. Tewari (2009) pointed out that the water legislation in South Africa over the past 350 years should be understood within the context of conquest and colonisation. Water legislation and its management was influenced by the colonial powers starting with the Dutch from 1652 to 1810 followed by a period under the rule of the British and the Afrikaner nationalists, which ended in 1990 at the dawn of the democratic rule in modern South Africa. The historical management of water has been focused on securing supply for various uses, particularly for economic benefit. The roles of land uses in water availability and its degradation received limited attention within the legislation and practice of the time.

The provisions for water management are currently set out in the South African Constitution and supported by various legislations, especially the two Water Acts, the NWA and the Water Services Act (WSA). The Constitution is severely criticised by a growing community of concerned stakeholders who argue that it has failed to adequately remove historical inequalities or resolve present-day challenges in accessing resources (The South African, 2017). Many community members who feel that they were not adequately represented in the formulation of the Constitution are starting to air their reservations regarding the persistent inequalities in accessing water and land, and the levelling of the playing field in the use of these resources. These grievances are fuelled by the slow progress in improving water and land access in the past 23 years (DWA, 2014).

In terms of water management, the main legal tools applied are the NWA (RSA, 1998a) and the Water Services Act (RSA, 1997). These key legislations were based on a purely European system with much influence from the Dutch and English legislators who were active when the two legislations were formulated. The National Water Act calls for an integrated approach to the management of water that is less catchment-based but more of IWRM in nature. In 1998, the NWA also set out the provision for the establishment of Catchment Management Agencies, which were meant to develop Catchment Management Strategies (CMS) for managing water within each of the catchment management areas (RSA, 1998a). The development of these agencies was to be initiated and driven by the DWS, with the Minister of DWS approving the key milestones. These provisions were viewed as the necessary basis for possible ICM; however, since 1998, only two Catchment Management Agencies (CMAs) have been formed and implemented out of the original 19 possible CMAs. There has been much reluctance by stakeholders to develop the CMAs and ensure that they become functional (DWA, 2014).

The DWS is focused on developing IWRM rather than ICM. This is evident in the NWRS2, which only discusses other forms of integration, especially IWRM and not ICM (DWA, 2013a). The distinction of IWRM from ICM as practised in the country is best described by Ashton (2000) and illustrated in Figure 2.1.

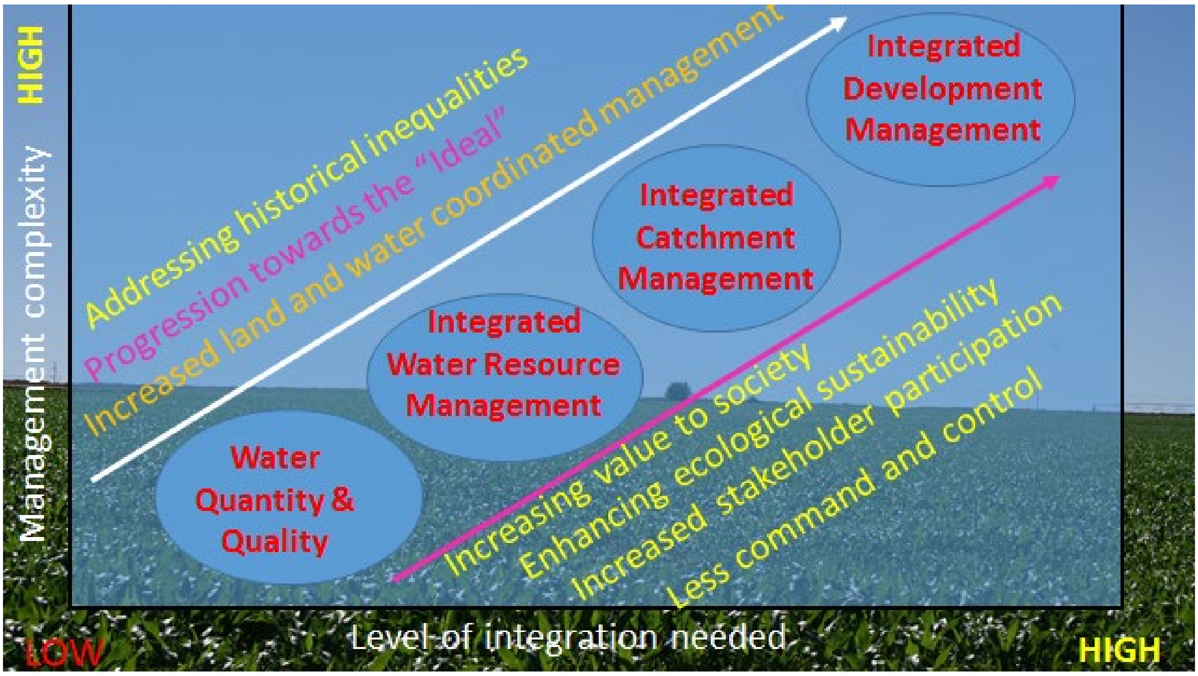


Figure 2.1: Diagrammatic representation of the relationship between IWRM and ICM (Adapted from Ashton, 2000)

Ashton (2000) explained that ICM recognises the need to integrate all environmental, economic and social issues within a river basin (or related to a river basin) into an overall management philosophy, process and strategy or plan. In the definition is the aspect of resource management based on a strategy where all resources in a catchment are sustainably used and protected – using a people-centred approach. Ashton (2000) explained that at the lower level of water management is water quality and quantity management, while the higher level of ICM focuses on societal values and environmental sustainability. IWRM is explained as a subset of ICM but it involves much more than merely focusing on water quantity and quality. What is absent or receives relatively little attention in IWRM when compared with ICM are socio-economic and political factors. The emphasis in IWRM is on bio-physical factors. When compared to ICM, IWRM also lacks the direct consideration of land and other resources within the catchment or associated with that catchment. While IWRM is considered to be a subset of ICM, the physical boundaries of IWRM tend to come short in the consideration of other sources of water such as groundwater, which exists outside of the boundaries dictated by ICM.

Jewitt and Görgens (2000) explained a different hierarchy where river management is at the bottom, followed by the management of catchments. In this hierarchy, IWRM and ICM follow the same sequence as suggested by Ashton (2000) (see Figure 2.1). However, there is a difference in the ultimate goal of the management process, which in this case is the Integrated Resource Management (IRM). The advantage of considering the IRM as a final goal is that one can align development with other value systems such as those that seek to enhance the natural state in which water exists. The decision to have integrated resources management as the ultimate goal is also influenced by the dominant issues and factors in the affected catchment. In the case of the Kruger National Park water management study, Jewitt and Görgens (2000) looked at Integrated Resource Management as the highest goal. The focus here is on ensuring that the natural state of affairs flourishes, whereas the focus on integrated development management is usually influenced by experiences where water is being managed in an area where environmental sustainability is always being weighed against developments that are planned in the catchment. In the nature park, the objectives cover the success of water access and availability to all animals and other forms of nature.

2.2 Influences of regional characteristics on ICM practices

2.2.1 ICM in international water management

ICM, natural differences in different regions

The issues that are considered or emphasised under ICM differ significantly between regions. These differences are magnified when the regions are in different hydro-climatic zones, economic zones or political boundaries. Schulze (2007) reported that more developed countries (countries of the north) are more concerned with physical and chemical degradation in water management, while in lesser developed countries (countries of the south) water poverty and biological degradation, especially due to pollution from human and animal waste, are additional issues of major concern.

The differences in the hydro climatic regimes in the North when compared to the South also affect how water management solutions, which are usually developed in the North, are applied in countries in the South such as South Africa. The Northern countries have a winter season characterised by snow as well as humid conditions with very low levels of evaporation. On the other hand, countries in the South rarely experience snow and the potential for evaporation is relatively much higher throughout the year. Figure 2.2 below illustrates the dry and wet season rainfall for Cape Town and Pretoria compared with selected European cities. In South Africa, the dry and wet seasons are distinctly different, while countries in the North exhibit less variation in precipitation throughout the year. The effect of this is that many tools that are developed in the North for water management are not representative of South African conditions. This is one of the factors that reduces the confidence levels associated with the applicability and efficiency of water management tools developed in the North.

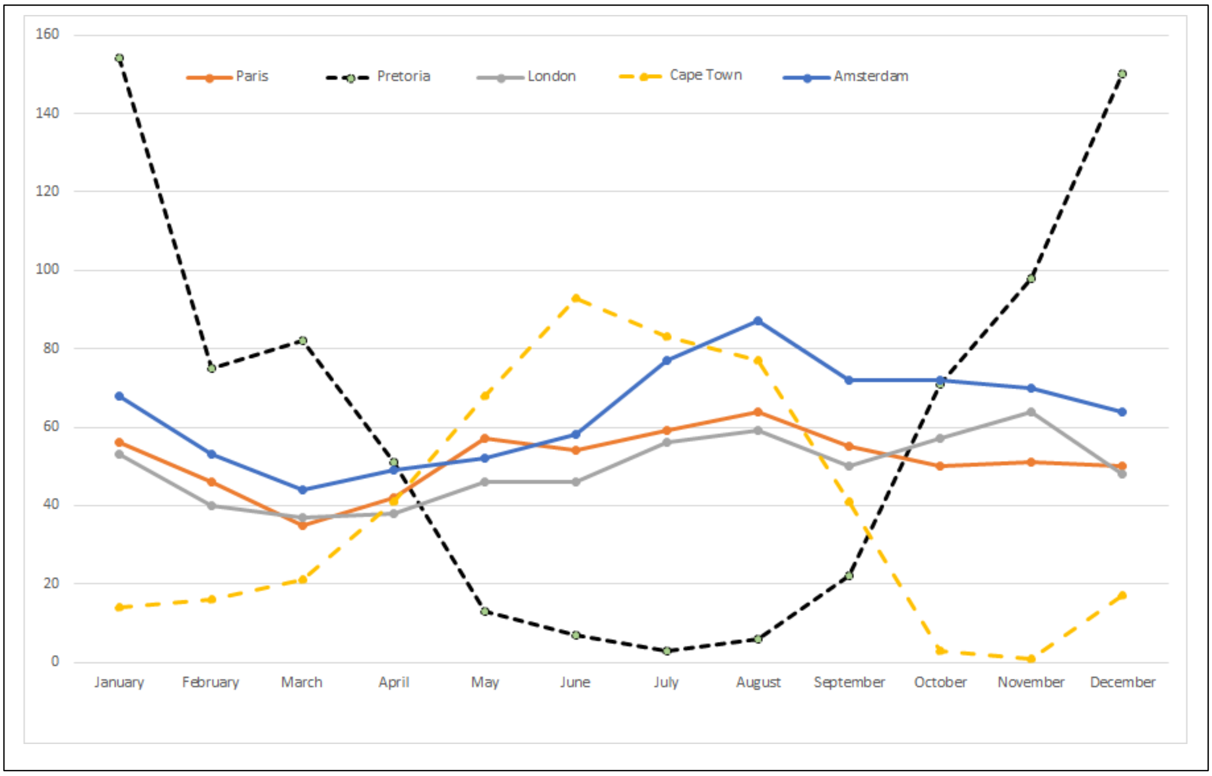


Figure 2.2: Monthly rainfall distribution in mm for selected areas in South Africa compared to selected European locations

In addition to the differences in rainfall regimes, the terrain, climate and geology of an area, the composition of the water balance also influences the processes that dominate water and how it can be managed. Nigussie et al. (2012) explained these differences as watershed characteristics that also define the nature of catchment response to natural events such as rainfall. Another important difference between countries in the North and South lies in the role of evaporation and evapotranspiration in the hydrology and geo-hydrology. The countries that lie further north of the equator (Northern Countries) such as United Kingdom have very low average annual potential evaporation, and temperatures that are less variable (Figure 2.3). Figures 2.4, 2.5 and 2.6 show the amount of evaporation for South Africa when compared to the United Kingdom. The very low average evaporation potential in the North is due to the generally lower temperatures, wet and humid weather that limit actual evaporation (Figure 2.3). In South Africa, actual evaporation is greatly limited by available water. The low rainfall, which is highly variable, means that there is little water available to be evaporated. Potential annual evaporation is therefore much higher than the actual annual rainfall in millimetres. The potential evaporation for summer rainfall areas is well above 2000 mm while rainfall is below 1000 mm, which means most of the water is lost to evaporation.

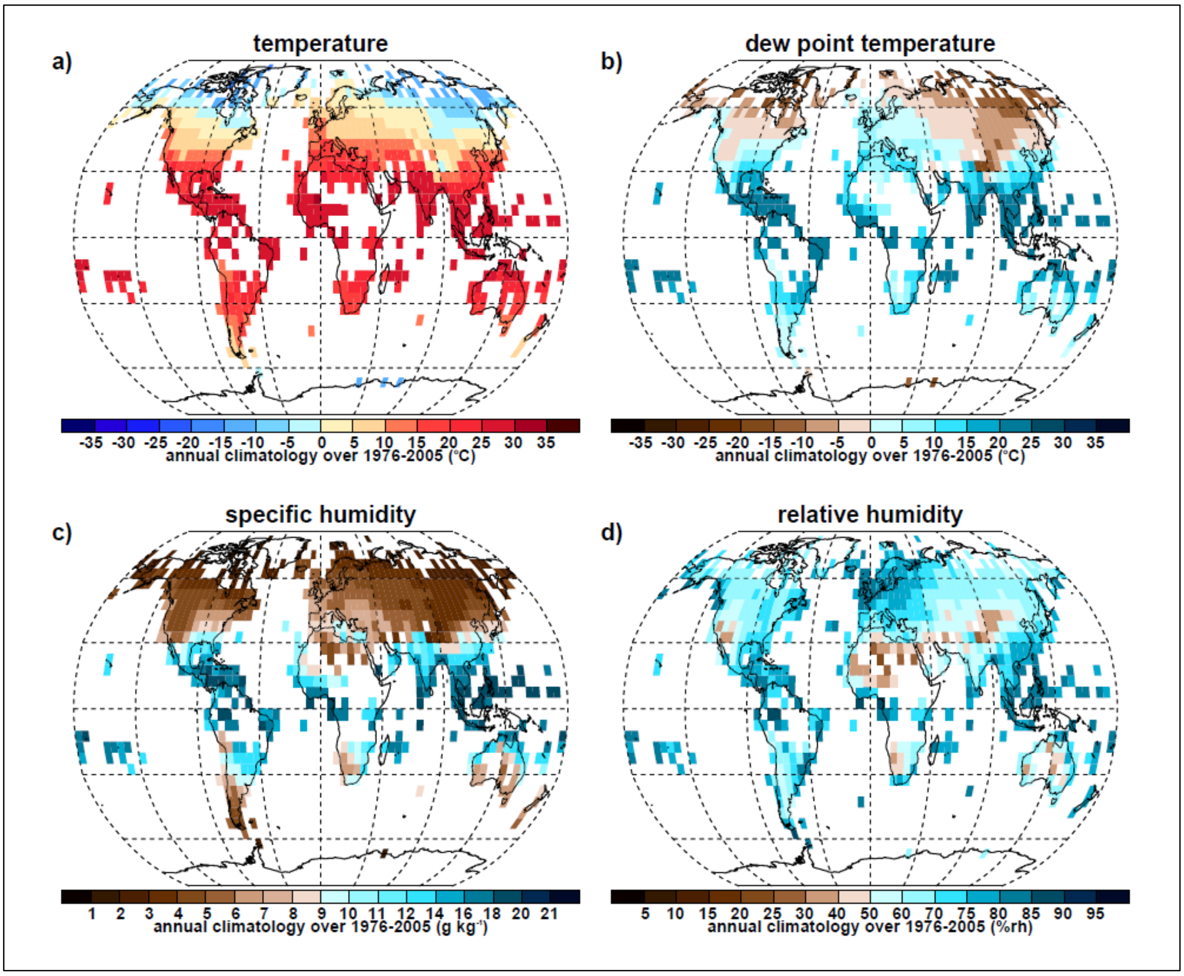


Figure 2.3: Annual climatologies (1976-2005) for (a) temperature, (b) dew point temperature, (c) specific humidity and (d) relative humidity (Willett et al., 2014)

In his work towards correcting the calculations of evapotranspiration, Hess (2010) pointed out that the water retained from the winter season is available in the summer when evapotranspiration is very high (Figure 2.7). This helps mitigate net loss of water through evapotranspiration. In light of this, Hess (2010) indicated that those methods that only consider precipitation and current weather as the source of evapotranspiration had to be updated. Hess (2010) presented that large quantities of water that were kept in the soil became readily available to plants during seasons with high temperatures and dry conditions. His findings also illustrated the need to develop methods for water management that are built on the unique character of the specific area under consideration. Given these findings, methods for water management developed for England will not be suitable for conditions in Pretoria and other catchments in warmer climates (Figures 2.4 to 2.7).

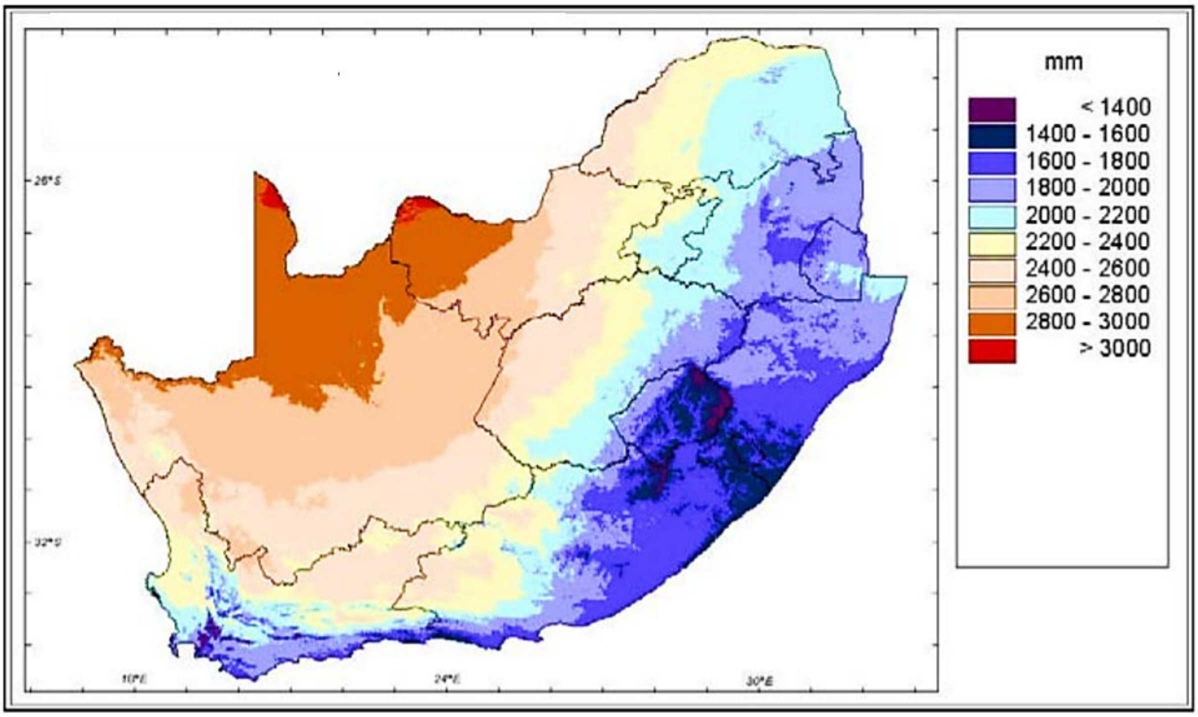


Figure 2.4: Annual E-pan Evaporation figures for South Africa (Schulze& Maharaj, 1991)

Australia's climate shares some similarities with the South Africa's such that there is a relatively better potential for successfully using or adopting water management methods and approaches that emanate from this region. Australia has areas where the climate and weather are relatively more similar when compared with those from the Northern regions. As an example, the average E-pan evaporation statistics for Australia are similar to South African areas in some cases (Figures 2.4 and 2.5). The map in Figure 2.5 also shows that the interior areas of Australia have E-pan evaporation that is as high as 4000 mm, which is more than twice the maximum values found in South Africa. In such cases, the hydrological as well as the geo-hydrological water balances will be too different for similar methods to be applied to models and manage water provision to plants and even to carry out water storage management in dams.

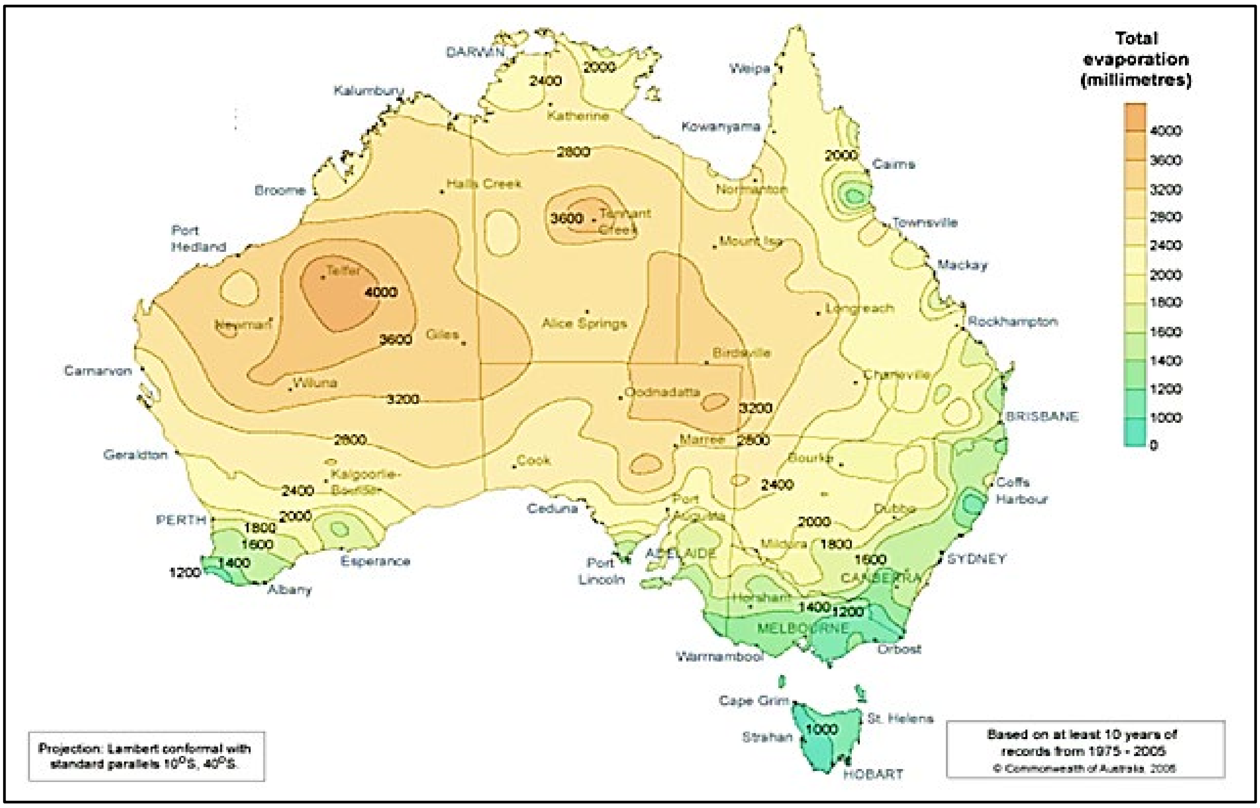


Figure 2.5: Australian average annual pan evaporation (Australia Government Bureau of Meteorology, 2006)

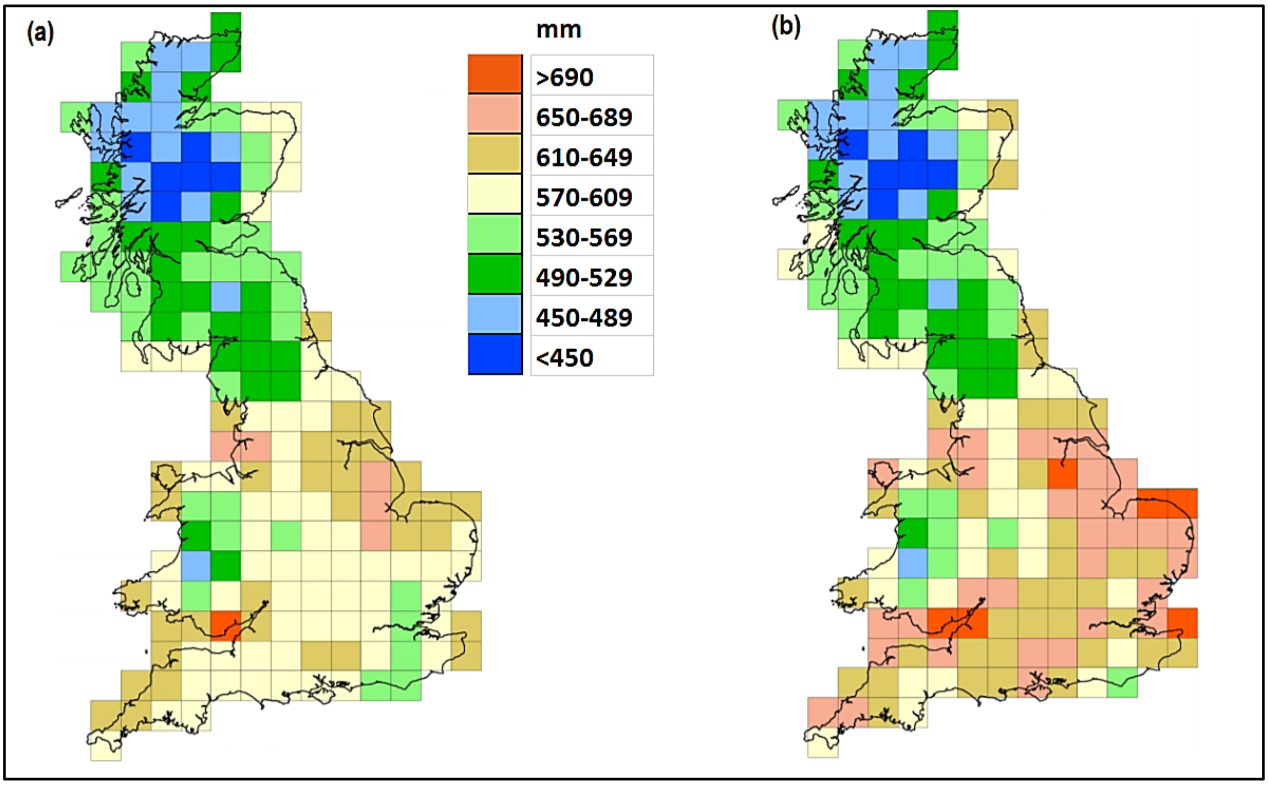


Figure 2.6: United Kingdom (a) annual evaporation statistics for 2004, (b) potential evaporation for 2004 (Marsh & Sanderson, 2004).

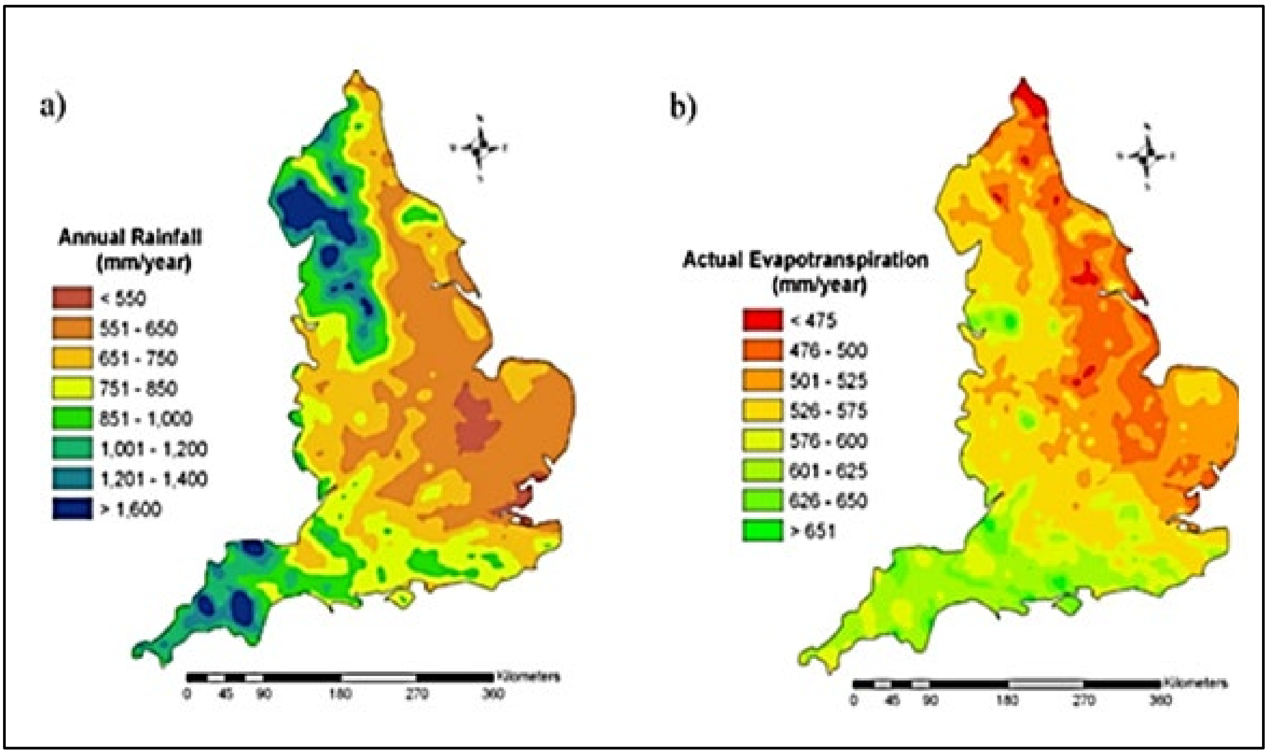


Figure 2.7: Map of England showing average (a) annual rainfall and (b) evapotranspiration for grasslands (Hess, 2010)

Cost-benefit in ICM: The issue of maximising benefits

ICM tends to be so broad that in most instances not all the relevant variables are accounted for in the plans for the development and implementation of catchment strategies. The result of these limitations is that poorly conceptualised strategies are developed and advanced for implementation. Campbell (2016) explained that the whole range of components required for integration are usually not fully covered in the initial stages since the focus is usually on the immediate challenges identified in the initial phases. He explained that the inclusion of various other role players from other disciplines brings with it a more comprehensive picture and potential for more holistic integration. Ostrom (2009) explained how the increased integration calls for more resources to cover the needs that come with the integration of components that emanate from different disciplines. This issue is worsened by the uneven distribution of resources that are available to address the ICM objectives. Ashton (2000) pointed out that in the case of South Africa, ICM implementation calls for significant investments in new institutions, suitable statutory provisions, as well as better coordination so that water and associated land-based resources are managed in harmony.

Ashton (2000) suggested that the DWS was deliberately opting for IWRM rather than ICM after having noted that the available institutions and other resources are inadequate to implement ICM.

Recent changes in 2012, where the number of CMAs were reduced from 19 to 9, demonstrated the capacity constraints for establishing new water institutions. By 2012, only two CMAs had been established and they still were not fully responsible for their catchments. Meissner, Funke, and Nortje (2016) also point out that 19 CMAs were not going to promote integration. As originally envisaged, the ICM will have to be planned based on fewer institutions rather than one in every water management area. In the comparison of the challenges faced in Southern Africa to those faced in the Northern countries, Schulze (2005) explained that it was common that government water projects were failing frequently because there were inadequate funds for both new projects and to maintain existing infrastructure. The poor availability of resources to implement various policies and water management programmes also mean that even though South Africa is praised for having some of the most advanced and adequate legislation, implementation of these has remained elusive.

In many cases, the objectives for water authorities and municipalities to minimise costs and be economically sustainable while providing adequate services tend to reduce the ability to maintain and manage the catchments sustainably. This conflict is most evidenced by how new developments are being implemented with such cost cutting measures that exclude options to improve or stop the environmental and catchment degradation. New wastewater purification plants are being developed based on design codes that still allow additional discharges of pollutants in catchments that are already clogged with excessively high pollutant concentrations. Sikosana, Randall and Blottnitz (2017) argued that the infrastructure development initiatives in South Africa are failing the environment and also losing out on the potential long-term benefits of the recovery of phosphates at sewage treatment facilities. The targeted discharge of 1 mg/L results in large volumes of phosphates that are still discharged into the rivers and dams even in cases where these water bodies are already eutrophic. In the 1990s, many wastewater purification plants in the UK were upgraded to purify effluents to the tertiary stage. Penn, Chagas, Klimeski and Lyngsie (2017) explained the improved WWTW designs, which include phosphate stripping techniques using vertical sand filters. In the UK, this has resulted in the lowering of the total phosphorus content of the waterways by 90%.

The development of large water infrastructure such as dams and major canals is usually evaluated based on cost-benefit analysis where the net difference in monetary benefits and costs is used to determine the preferred actions, methods and resultant developments. Prato and Herath (2007) explained how the use of monetary benefits to determine ICM decisions was very limiting and inappropriate due to the many other variables that are important and need to be evaluated as part of decision making in ICM.

These large water infrastructure assets tend to define the nature of activities that can be performed using the water. Water uses that are considered unprofitable or a social service such as provision of free water access for domestic uses require additional inputs from the government to secure this right of access (RSA, 1998a). However, the nature of land rights and the location of large-scale infrastructure have meant that the majority of South Africans will never have reasonable access to water resources without the associated changes in settlement patterns or extremely high costs of extending the infrastructure to new areas (Smith & Hanson, 2003).

Degradation and rehabilitation as drivers of ICM

Erosion and physical damage are drivers of ICM in some areas, especially areas that experience flooding or are defined by wet and dry seasons resulting in erosive water flow regimes, or areas affected by wind erosion as well as vegetation clearing. In most dry climates with seasonal rainfall, soil erosion is a major problem that tends to define the character of ICM. Several African countries fall into this category due to the large areas that are exposed to direct natural runoff as opposed to the usually-controlled runoff in most developed countries. Haregeweyn et al. (2012) explained that ICM in Ethiopia's northern regions was being developed to address soil erosion, which is the country’s greatest threat to the land in the Northern Region of the continent.

In Asia, Nepal is one of the countries that are affected by physical land degradation from flooding. According to Acharya, Poudel and Dangi (2003), the country has a large range of altitudes, from 80 m in the Terai flatlands to 8484 m on Mount Everest. Coupled with the large potential for fast water flows on the steep areas, the annual average rainfall is 1600 mm, most of which (80%) falls in the Monsoon summer rainfall season (June to September). After a long dry spell, sustained heavy rainfall follows, and the implications are that land is eroded significantly during the rainy season. With 86% of the total area of Nepal being mountainous and hilly, and 87% of the people dependent on agriculture, agricultural activities are practised on these steep slopes. Water and land management practices in these areas thus focus on rehabilitation of degraded land to address pollution from fertilisers, pesticides, invasive alien plants and erosion issues (Acharya, Poudel & Dangi, 2003).

In India, the Ministry of Environment, Forest and Climate Change reported that out of the geographical area of 328.73 million hectares (mha), about 120.40 mha (more than a third) were already affected by various levels of land degradation and in total even more land was threatened by desertification as a result of climatic and anthropogenic factors (Space Applications Centre, 2013). At the top of agents causing the degradation are water erosion, which is causing just above 10% of all degradation, vegetation degradation at 9% and wind erosion at 6% in the period ending 2011 (Space Applications Centre, 2013). The management of land and water in areas in India is therefore focused on achieving a land degradation neutral status by 2030.

In Scotland, Werritty, Spray, Ball, Bonell, Rouillard, MacDonald et al. (2015) observed how ICM was theoretically associated with holistic, efficient and cost-effective catchment management while in reality there were many differences. One of the main objectives in the catchments was restoration of degraded water systems to enhance water quality, improve biodiversity, improve amenities and reduce the impacts of flooding. The focus on river health in water resources management is also seen as a result of ICM in this Scottish perspective. In the ICM approach promoted, recommendations are also made where ICM is developed in such a way that it works “with” rather than “against” nature. The use of physical barriers for floods and other infrastructure to control hydrology is observed to offer limited solutions that are not sustainable and cost effective (Werritty et al., 2015). In Auckland, the Ministry of the Environment (2010) also highlighted the idea of working harmoniously with nature in ICM as part of environmental restoration and hence increase quality of life and improve the environment while building jobs as well as a sense of wellbeing.

Climates’ influence on ICM approaches

Tiffen and Gichuki (2000) looked at how the different climates influenced ICM. They observed that ICM in dry climates is centred around maximising the utility of rainfall, while in wet climates the emphasis is on limiting water damage. For some areas where there is a distinct wet and dry season, the people tend to aim to balance both issues. They have a lot of rain in some periods and would rather store as much as possible to use during the dry periods. South Africa is largely characterised by these two extremes of dry and wet seasons, making it necessary for the development of water storage in the form of dams. To respond to the specific climatic character, the past water development has seen South Africa acquiring the title of the country with the largest number of dams on the African continent. Out of the 1 300 large and medium-size dams in Africa, 40% are located in South Africa (FAO Aquastat 2007) (Figure 2.8). As such, water management and ICM in South Africa has to do with complex management of dam inflows, storage, releases as well as water transfers between catchments. Groundwater (GW) management is also an important component of ICM in some regions and there is even greater scope for more GW use and management as part of the water resource mix. Schulze (2007) also pointed out that water poverty in lesser developed countries was an important issue for consideration in water management. In these countries, communities affected by water poverty also suffer other associated problems such as poor health due to poorer quality water and poor levels of hygiene due to the difficulty associated with securing adequate water. Reliance on livelihoods that require water as an input is risky and not sustainable for them.

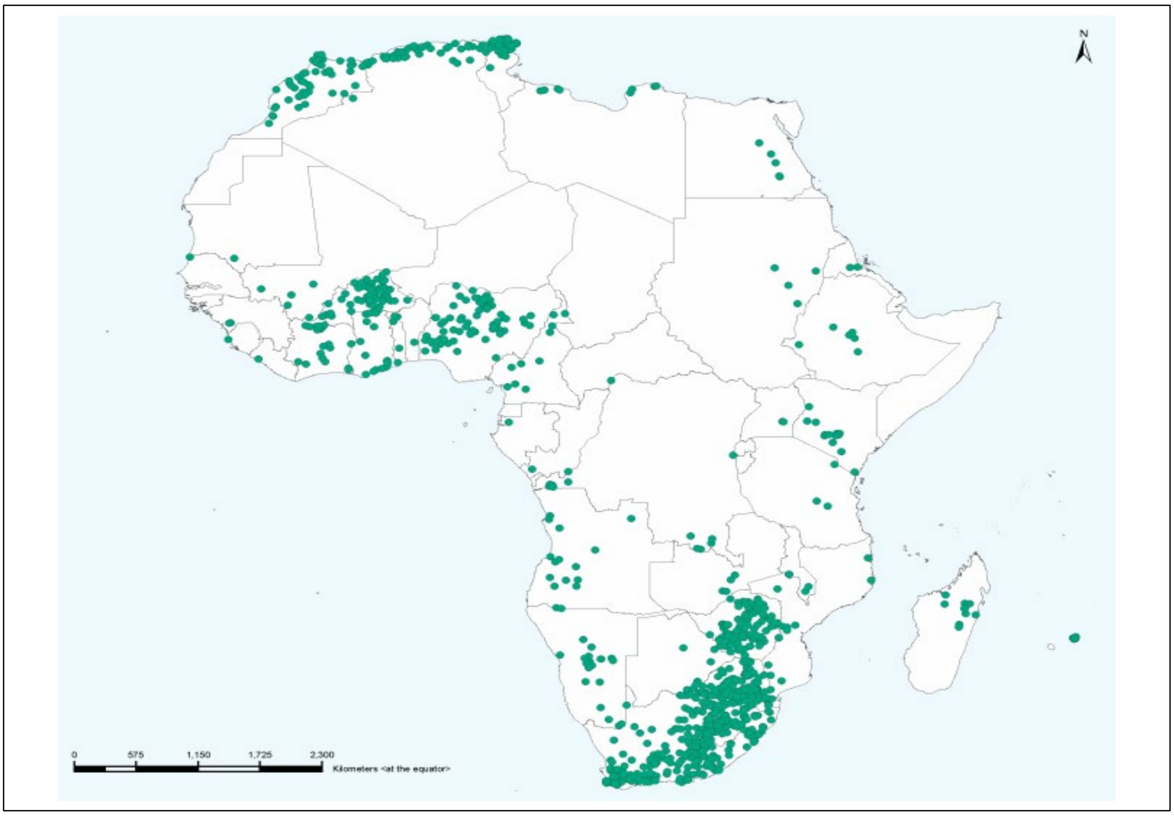


Figure 2.8: Distribution of dams in Africa (FAO Aquastat, 2007)

Role of cultural and social dynamics in sustainability of ICM

Observations made in several ICM programmes where communities are involved showed the need to align ICM projects to the culture and societal norms of the targeted communities. Tiffen and Gichuki (2000) observed that in Kenya, ICM programmes are likely to be acceptable and sustainable if they are structured along the cultural and social dynamics of the community. In ICM work that was targeted at the restoration of eroded land in Ethiopia, Haregeweyn et al. (2012) observed that for land management strategies to be effective and successful, they had to be compatible with the social environment and not just the physical environment in which they are applied. The nature of units or unique dimensions of the spatial scales to be applied in ICM were also observed to be critical in influencing successful ICM (Tiffen & Gichuki, 2000 It is noted that people do not live in catchments but rather in social units. If the catchment is large, it will most likely be dealing with very diverse interests and several social units of stakeholders. The likelihood of disputes and divergent objectives is greatest in large catchments that are managed as one unit. Many researchers propose the use of smaller units. Maherry, Horan, Smith-Adao, van Deventer, Nel et al. (2013) made such a proposal and divided South Africa into quaternary and even smaller units, called quinary catchments. The quinary catchments are based on specific characteristic of an area such as altitude, river networks or divisions along areas that are agro-hydrologically homogenous.

2.2.2 ICM and IWRM influences in South Africa and local regions

The water management process in the country is based on two pieces of legislation, the National Water Act of 1998 (RSA, 1998a) and the Water Services Act of 1997 (RSA, 1997). The original intention was to have one legislation covering all water management matters/concerns, but the need to urgently provide water services to at least 14 million people who were not included in water service provision by the apartheid regime drove the legislators to fast track a separate water services act (DWA, 2014). At this stage, the process to revise the two legislations is ongoing and there is even consideration to have one piece of legislation that covers all the provisions in the two Acts. The implication of the separate legislation is that it entrenches a system where water resources are considered separately from water services. ICM looks at water management with water services, water resources and governance in one framework – a framework that also includes the integration of water and land uses. In practice, there are no holistic policies and associated legislation that clearly direct this integrated approach. Land uses and land cover, which are important to water management in a catchment, are legally provided for under several other pieces of legislation that are administered from other departments and institutions.

The national institutions that have a role in water and land management include the following departments:

- Water and Sanitation
- Agriculture Forestry and Fisheries
- Economic Development
- Environmental Affairs
- Human Settlements
- Mineral Resources
- Rural Development and Land Reform
- Tourism
- Trade and Industry (DTI)
- Cooperative Governance and Traditional Affairs (CoGTA).

The roles of the many departments in ICM generate the disjointed approaches that characterise the management of water and land within a catchment. These centres of management are not only disjointed in the legislation and policies driving their roles but also in terms of the different temporal and spatial distinctions in which their functions are implemented. Auerbach (1997) noticed how ICM functions were being run from different national departments while the issue of collaboration on the ground remained outside the strategies of these various departments. He observed that the local role players who operated on behalf of the national institutions in communities had no mandate to seek integration with other field operators and possibly improve the processes, better serve the communities or even save the resources through integrated approaches. The structure in the management of water and other natural resources has not changed over the years; it is the same columnar structure of government, where a number of national departments are running their services through regional directorates located in large cities, while their technicians work on the ground with the people.

Apart from the numerous national departments, South Africa's ICM initiatives are also influenced by transboundary treaties and other commitments particularly to do with water. There are several catchment systems that South Africa shares with neighbouring countries. South Africa's transboundary catchments are listed in Table 2.1 below. Apart from national drivers in catchment management, in each case additional dimensions are added to satisfy issues affecting other countries. Muller, Chikozho and Hollingworth (2015) explained these drivers as mitigation and management of negative impacts in transboundary countries, avoiding conflict and resource development for use.

Table 2.1: South Africa's Transboundary River Basins (adapted from ORASECOM, 2017)

River	Basin Area (km^2)	River Length (km)	MAR (Mm^3)	Riparian States
Inkomati	49 965	480	3.5	South Africa, Swaziland, Mozambique
Limpopo	408 000	1 750	5.5	Botswana, South Africa, Zimbabwe, Mozambique
Maputo-Usutu-Pongola	32 000	380	2.5	South Africa, Swaziland, Mozambique
Orange-Senqu	721 000	2 300	11.5	Lesotho, South Africa, Botswana, Namibia

The use of hydrological boundaries in ICM is criticised by some authors. Most of the criticism has to do with the fact that hydrological boundaries are limiting when it comes to dealing with all the issues that have to be captured in a holistic water management framework. Muller, Chikozho and Hollingworth (2015) explained that the catchment unit is good for hydrological and ecological analysis. However, the water users are usually organised at scales that reflect political boundaries. In addition, the water uses are usually considered within economic rather than hydrological boundaries. Van Koppen and Schreiner (2014) explained that given that in seven of South Africa's current nine provinces more than 50% of water is provided by inter-basin transfers, water management is more inclined to be successful if it ignores administrative and even country boundaries. There are several angles that different authors use to encourage and discourage the use of national boundaries in managing water. These can be captured by indicating recommendations on what the ideal ICM should address, which include:

- Both groundwater (GW) and surface water (SW) where GW boundaries are not along hydrological boundaries
- Dealing with the whole area that is covered by an administrative boundary. Separating some sections could create more administrative work, increased costs and discrepancies in service delivery. An example is the management of water provision in Gauteng where the water from the Vaal River system is planned to be supplied to all Gauteng citizens even though they are located in several catchment systems.
- Provide one water management service for targeted communities. This has to be done cognisant of the fact that community areas are not aligned to catchment boundaries and sometimes they occupy a small section of the whole catchment. The Limpopo catchment covers areas in four countries. While at international level there are treaties regarding its water management, each country follows its own detailed system of managing and using the water while making provisions for defined variables such as amount of water to flow past the country at any one point in time and location.
- Integration could be motivated to deal with a problem, an issue or a policy that is not along a catchment (Muller et al., 2015). These issues may not follow the catchment boundaries. In Malamulele in Limpopo Province, one of the major challenges for the community was poor water service delivery. The Malamulele community was administered under the Thulamela Local Municipality which was being blamed for providing better services to areas around Thohoyandou (Venda-speaking areas) and poor services to areas around Malamulele (Tsonga-speaking areas). In the past, these two areas had separate municipalities before they were combined under Thulamela. The service delivery problems were evident in the investigations on water access to these areas (Dube et al., 2014). It was noticed that there was a disproportionately large area of communities that had no access to water in the Malamulele area. Their water service system was dysfunctional and the local water purification plant lacked basic water purification chemicals. These chemicals were widely available at water purification points in Thohoyandou. The national government also observed that the areas were not being served fairly by the single municipal office located in Thohoyandou and agreed to form the separate Malamulele Local Municipality. In this case, the historical circumstances make it much easier for water management to be handled by each municipality for the areas they cover rather than as one combined system even though they are located in one catchment system.

Resource ownership and its influence on ICM

The nature of ICM or the components of ICM that can be applied in a catchment depend on how water and land are owned. ICM would be easy to implement if indeed the provision that the custodian of water in South Africa is the Minister of the DWS was practically valid. However, there are major limitations in government ownership of water and land, among other resources. Out of the 5122 dams (small, medium and large dams) that are registered with the DWS, only 320 dams are either owned or operated by the Department, and the rest are in private ownership (DWS, 2015a). Several thousands of mostly small dams are not even registered in the DWS, which adds to water storage in private ownership. That means most of the catchment runoff, land and stored water is owned by private persons as well as private companies and farms. Including the water and catchment area components that are in private hands in an ICM programme may require a greater role being played by the private sector rather than the government. However, while the private ownership is in control of most of the land and water, the population dynamics are such that the greater percentage of the population does not have ownership of these resources that they need.

A typical example is Letsemeng Local Municipality in the Northern Cape. The Letsemeng Local Municipal area is 10 180.71 km^2, with a population of 38 700 people, where 800 farmers own 99% of the water and approximately 96% of the land area (Letsemeng Local Municipality, 2016). Turton, Meissner, Mampane and Seremo (2004) discussed how these vast land areas were previously occupied by the black community members who were driven into homelands in the 1950s to make way for irrigation farms. The farms were allocated to a few members of the white community, especially members of the National Party. In the current state, ICM to the broader population in the area has no meaning, given the skewed allocation of resources and the fact that any management of the water and land benefits the few farmers who own these resources. Water infrastructure assets in the area consist of several dams, very large capacity pumping systems (23 m^3/s), canals, balancing dams and other major water conveyance structures that are worth several billion rand (DWAF, 2011a). The infrastructure belongs to the government and is managed and maintained by the DWS for the benefit of the farmers (DWAF, 2011a). In 2016, the government, through the DWS, completed a R276 million balancing dam to extend the operational capacity of the water conveyance system. There is no record of wider stakeholder consultation and participation with the exception of the regular contact with a few irrigation farmers who are also direct beneficiaries (DWS, 2017a).

The ICM concept is less prioritised in the country and what has been important of late are large scale projects that tend to make more political impact. The motivation for large scale infrastructure has less to do with advancing ICM as is evidenced in a number of these large-scale capital projects. One of the major points of motivation for new infrastructure development is based on the number of jobs to be created and where these jobs are going to be created. The same argument is also used in political campaigns where candidates talk of the jobs they will create if they are selected. The point of improved management of available resources including better catchment management is not a preferred point for motivation. In the NWRS2 (DWA, 2013a), water infrastructure development projects are planned to contribute significantly to job creation as articulated in the National Planning Commission's vision 2030. While job creation is one of the three main objectives in the NWRS2, this strategy fails to prioritise holistic catchment management, giving the impression that job creation is more important than integrated catchment management (DWA, 2013a).

Auerbach (1997) observed that many of the local government technocrats were obsessed with planning and applied most of the available resources to the plans without much being done to implement the plans. The overemphasis on planning rather than implementation has persisted in the water sector where new strategic directions are frequently suggested and developed while little is done to implement the new plans. Ideally, ICM should be backed by a long-term vision where departmental strategies are developed around established ICM objectives. It is in this way that the ICM programme can withstand major possible interruptions such as changes in the water governance role players. Changes in ministerial positions and other changes at top management have derailed several plans and strategic developments that had to be shelved as the new top management started new initiatives. The House of Commons (2014) compiled an analysis of findings and observations regarding the implications of changes in a minister's position or other changes in top management for various departments. They concluded that frequent ministerial reshuffles are bad for continuity of government policy and programmes in the ministries affected. They also observed that long-term solutions are set aside by new ministers while those shorter programmes that tend to show the new minister in good standing in the shortest possible time are preferred. The report also observed that the new appointments require time for learning and building a fitting team, which results in further changes in the top management structures. New members will waste time trying to understand the new responsibilities and appreciate the requirements of the new brief before they start working.

2.2.3 A different perspective (ICM in Asia and Latin America)

In Asia, just as in some parts of the Americas, ICM is referred to as Integrated Watershed Management (IWM) or just Watershed Management. In a similar manner to which an ICM is used, the term IWM also comes with unique interpretations depending on the issues at hand. In Asia, the focus on ICM started in the early 1980s following the programmes that led to the publication of "Our Common Future" by the United Nations (Reddy, Saharawat & George, 2017).

For the developing countries such as India, Nepal, Pakistan and Bangladesh, the proponents of ICM have mostly targeted its use as a technology for poverty alleviation suitable for communities involved in agriculture. Areas of interest in ICM programmes in Asia have included:

- addressing land degradation including countering the effects of many years of land use with little control, which caused extensive degradation of agricultural land. Reddy, Saharawat and George (2017) pointed out that up to 43% of agricultural land was in a state of degradation in most Asian countries
- enhancing soil fertility, which is deteriorating at an alarming rate with agricultural intensification as more people join the agriculture sector where use of land is being intensified
- Participatory catchment management approaches. Auerbach (1997) observed that some Asian countries were very strong on participatory catchment management (PCM). However, he cautioned that the participatory programmes were over-reliant on one leader, which could be avoided if these programmes were developed around communication networks with less emphasis on an individual leader
- rehabilitation of degraded water bodies. Asian countries are grappling with many cases where they are using integrated watershed management methods in water basins to restore degraded water bodies. Most Asian countries, from the most developed such as Japan to the least developed such as Yemen, have reservoirs and other water bodies that have been negatively affected by many years of continued degradation. In Japan, Lake Inba-numa is considered one of the most severely polluted lakes in Japan (Hayashi et al., 2010). While pollution inflows have been reduced through complex nature-based and other structural techniques, the reduction in pollution in the water body has been relatively slow but consistent. An IWRM programme is expected to address the problem by applying mitigation and pollution exclusion measures throughout the catchment area. In 2005, the COD load was about 7.1 ton/day. It had been reduced to the 1970's level. The Chiba Prefectural Government, which is responsible for the lake is set to meet the water quality targets for the lake by 2030.The indicators as interpreted by Hayashi et al. (2010) are as shown in Figure 2.9 below:

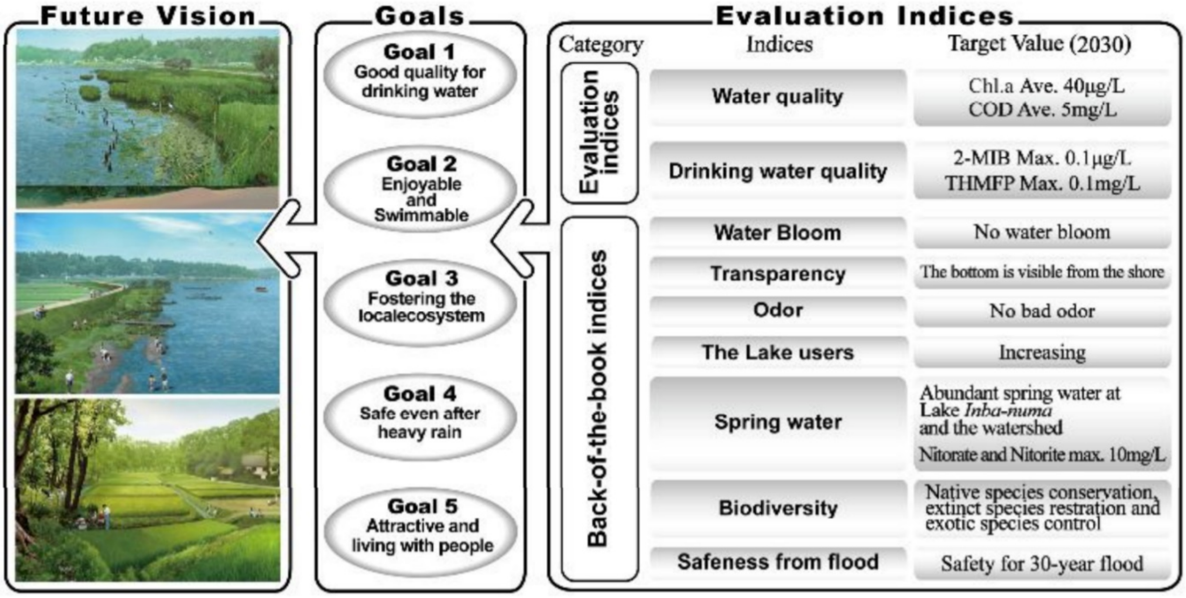


Figure 2.9: Future vision, goals and evaluation indices for Lake Inba-numa – Target date: 2030
Source: Hayashi et al., 2010

The ICM programmes are also defined by other local conditions in Asia. Reddy et al. (2017) identified the implications of differential benefits from ICM. These include:

- Those with more land and water resources tend to gain more from ICM than those who hardly have these resources
- Technical aspects in terms of integrating hydrogeology and biophysical aspects into catchment design are still behind in Asia when compared to Europe and North America. However, their importance to ICM is appreciated.

South America and Caribbean countries generally have higher-than-world-average rainfall. Their water challenges are also unique but a few are similar for the countries in this region. Ringler, Rosegrant and Paisner (2000) observed that ICM could be the solution to water management challenges in South America and the Caribbean countries. In an assessment of water management for these areas, Ringler et al. (2000) pointed out that the challenges in this region are around a situation where water demand is rapidly escalating while water management is fragmented without suitable institutions and supportive policies. The improvement of water policy and management reform to better the efficiency and equity of irrigation and water supply systems was also observed to be important for countries in South America and the Caribbean. The more developed countries in Latin America such as Mexico have well established institutions and legislative frameworks for Integrated Catchment Management. For example, Mexico has devolved many water resources administration functions to local bodies that are focused on river basins, with 13 hydrological-administrative regions defined by the river basin boundaries. There are 13 corresponding river basin organisations that govern the administrative regions (Comisión Nacional del Agua, 2010).

Latin American countries are also actively pursuing the development of early warning systems and associated institutions in collaboration with UNESCO and the International Hydrological Programme (IHP). The development of early warning systems and other water management tools is taking place in the whole Latin American region and also at individual country level. Some of these initiatives include the Latin American Flood and Drought Monitor and the Latin American Drought Atlas, all of which were completed and released in October of 2018 (UNESCO, 2018).

Water quality is a major water management problem for most Latin American countries, especially from agricultural activities and wastewater purification plants. Much irrigation is also done using wastewater resulting in increased diffuse pollution. Ringler et al. (2000) reported that only 41% of the urban population is linked to sewerage systems, and over 90% of wastewater is discharged untreated into the environment.

2.3 ICM in local knowledge and practice

Historical water management in South Africa was driven by several elements that were not aligned to holistic catchment management. Initially, societal issues to do with access and pollution were the motivation for localised management of water for targeted communities. Tewari (2009) discussed how water management in the country was shaped by historical changes, especially in social dynamics, politics and the environment, in the past three hundred years. He explains that South African water legislation and control has changed from the influences of the African customary law, then the Dutch, followed by the British, then the Afrikaner and more recently the democratic South Africa. Of significance in the South African history of water is how water management was used to support both positive and negative causes through the maintenance of livelihoods, economic development, environmental support and degradation, discrimination and even segregation before, during and after apartheid.

The different government policies that were instituted over several hundred years resulted in unbalanced water management practices that benefited a few at the expense of the majority of stakeholders. For many decades water management was one of the main tools used in maintaining unequal development practices, economic segregation and biased participatory practices that alienated the majority of the stakeholders while allocating resources to a few white people. Of particular interest to the current dispensation is the 1956 Water Act (RSA, 1956) where water rights were aligned to land rights and in which environmental sustainability was not prioritised. The legislation ensured that, rather than extending the management of water resources to the whole catchment and all stakeholders, water management was focused on riparian land uses and the associated users. This legislation also extended the potential for widespread environmental degradation, which would lead to long-term degradation of many water bodies. Several years of land and water degradation effects have been carried over to the present day where many water bodies have become eutrophic. The legacy of Acid Mine Drainage (AMD) is also a result of the poor management of water and land degradation in the past (Hilson, 2002). The alienation of the majority of the population from land and water resources has also played a part in defining these stakeholders' relationship with these resources.

The legislation suggests that water is owned by the state and makes provision for a system where water management is a competence of state institutions (RSA, 1998a). At local level, Water User Associations (WUAs) are expected to act in the interests of the different stakeholders (Figure 2.10). The WUAs are developed as building blocks of the Catchment Management Agencies (CMAs), where the CMAs manage water within a defined water management area using a catchment management strategy that is approved by the Minister of the DWS (DWAF, 2000).

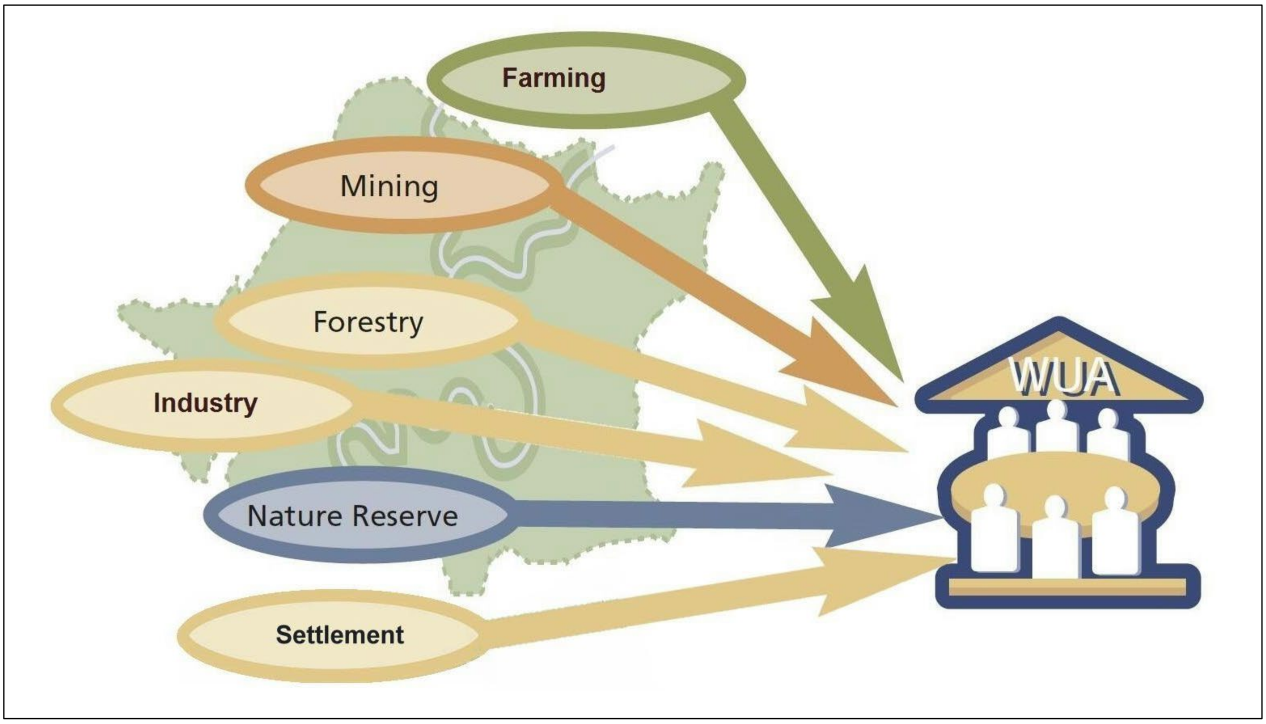


Figure 2.10: Multi-sector WUA (Adapted from DWAF, 2000)

The nature of resource ownership, especially land and water, in the country is such that most of the resources are in the private sector. In the case of water resources, the greater percentage of the catchment areas is in privately owned land, most of which have private dams and water conveyance systems that are not registered or accounted for in the national water resources data base (DWS, 2015a). To add to the management problem is the fact that the privately owned and managed sections of the catchment area were expected to fall under CMAs in the current Water Act and yet these institutions have hardly been established. With only two out of the original total of 19 CMAs having been established in the past eighteen years, in real terms very little has changed in the practice of water management (Meissner et al., 2016).

The NWA makes it clear that the development of ICM is set to take place on the basis of strong institutions, especially CMAs that can implement the roles as provided for in the NWA. Section 19 of the NWA covers the role of the CMAs in addressing the relationship between land uses and water (RSA, 1998a). While the integration in the management of polluting land uses and water is also handled in this section of the act, the provisions do not adequately address a situation where the CMAs are not in place, such as has been the case since 1999 (Meissner et al., 2016). In addition, the degradation of land and soils, which will ultimately cause water degradation in the future, are also not covered. While it can be argued that the DWS could carry out the functions of the CMAs, it is evident that this is not practical given that the Department is also responsible for monitoring and enforcing the legislation. As a result, past government practices have contributed to the widespread pollution and degradation.

The wastewater purification plants have been the major sources of pollutants in rivers that pass through urban areas (Correll, 1998). These sources of degradation have gone unrestricted because the water quality policing agents are the Blue Scorpions, which themselves are a directorate in the DWS. The SAICE (2017) national infrastructure report pointed out that at least 30% of large Wastewater Treatment Works are in a critical condition, implying that millions of litres of untreated or inadequately treated sewage are illegally discharged into rivers and streams each day. An assessment of available water quality data from DWS, water quality in rivers downstream of WWTW showed that there are many cases when wastewater purification is not taking place. Data analysed for the Jukskei River, Kuils and Pienaars Rivers showed high and frequent incidences when E-Coli and faecal coliform counts exceeded a million. The high counts showed that there was raw sewage that was being discharged into the rivers (DWS, 2015b). In two instances, direct sewage water flows into the river were observed on the Jukskei and on the Pienaars Rivers (Dube et al., 2016). The nature of pollution observed from the data obtained from the Roodeplaat Water Quality Centre is graphically illustrated in Figures 2.11 and 2.12 below. Several incidences of very high pollution levels can be observed, including many cases when the coliform counts exceeded one million (Dube et al., 2016).

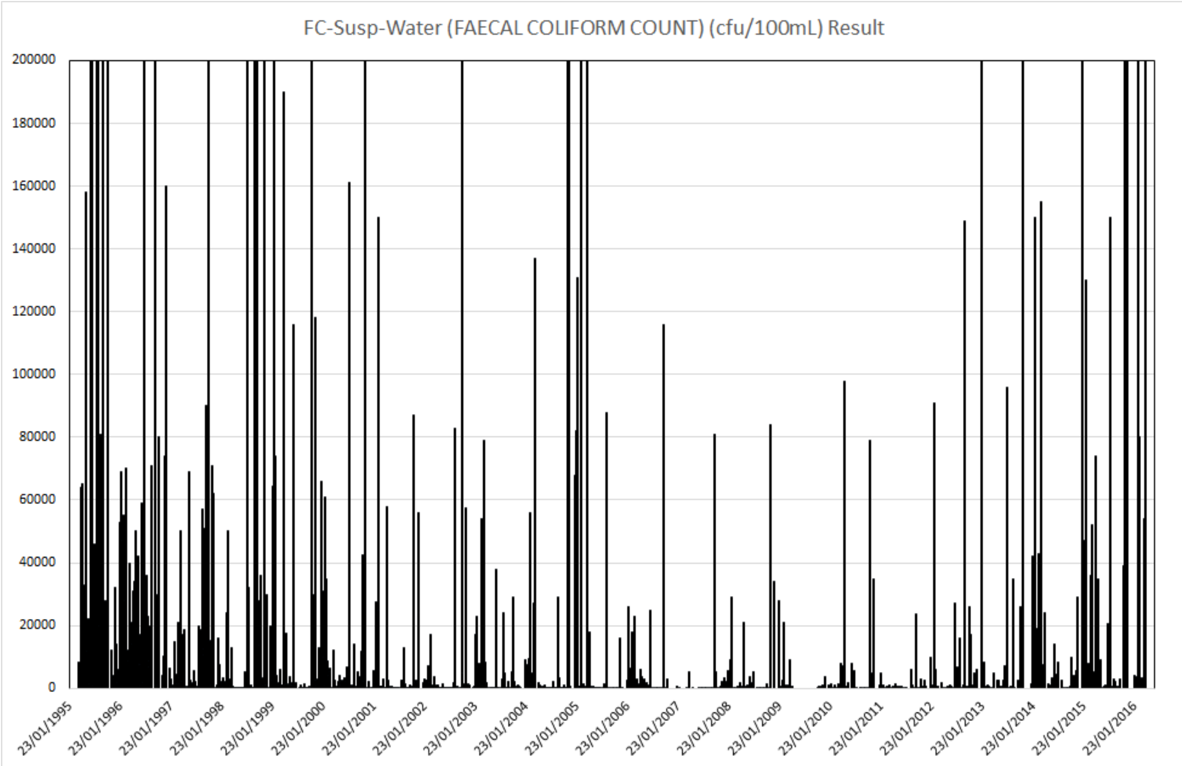


Figure 2.11: Faecal coliform count for Pienaars River at the Bavianspoort sewage plant for the period from January 1995 to February 2016 (Dube et al., 2016)

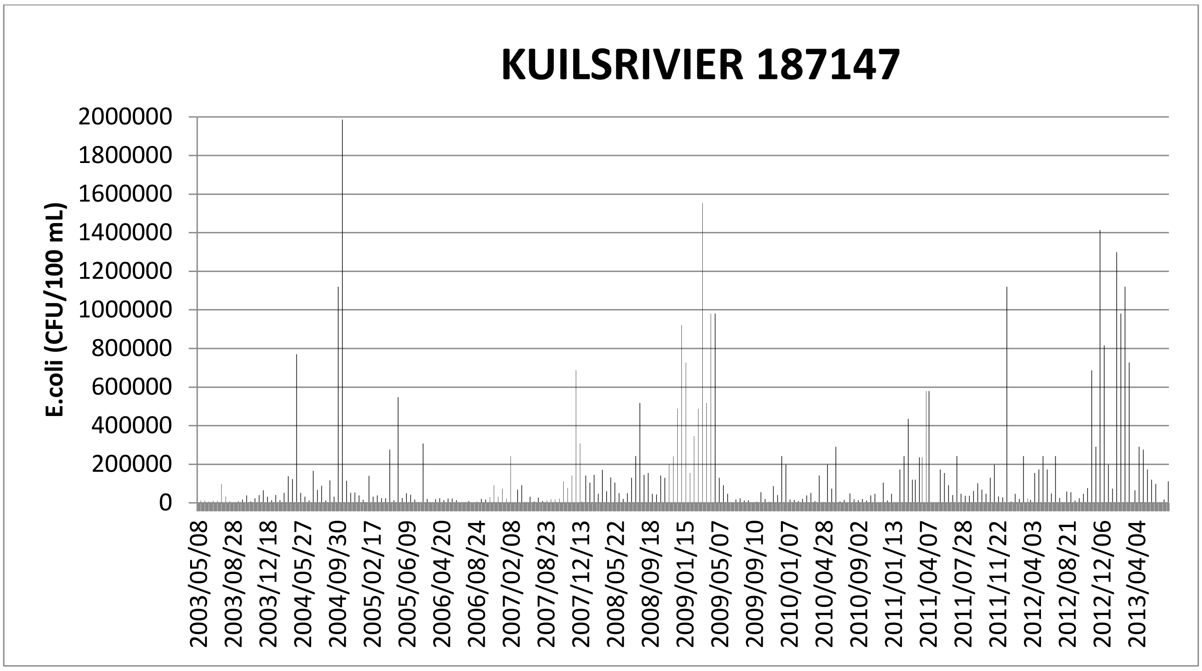


Figure 2.12: E.coli counts in Kuils River 100 m downstream of the Bellville WWTW discharge point from May 2003 to June 2013 (Dube et al., 2016)

Investigations on direct sewage pollution from wastewater purification facilities revealed that in cases where the operations or management of a government-managed water infrastructure caused pollution to a river or dam, the cases only ended up in court when an NGO laid charges (Mail &

Guardian, 2015). Such charges could only be laid after the pollution has caused serious and easily verifiable damage such as fish death or in worst cases human death such as the case when babies died in Bloemhof, North West, in June 2014 after consuming polluted water. When there is no loss of life to support the charges there is usually no interest in attempting to lay pollution charges against the government units (Mail & Guardian, 2015). The SAICE report on infrastructure for 2017 showed that one of the worst performing infrastructures was the Wastewater Purification facilities under the DWS (SAICE, 2017). These were given a score of “E”, the worst possible score out of the five levels used in the infrastructure assessment.

3 Developing the model catchment approach

3.1 The model catchment concept and structure

The model for integrated catchment management in this project was a product of various influences. In this study, these influences are set to be guided by a future vision of integrated water management that appreciates the holistic mix of present influential realities. The project terms of reference suggest the need to move away from the past piecemeal water management approach, which artificially separated land management from water management and failed to contextualise ICM as part of environmental management. The approach, which is set to use a future vision of ideal water management as the underlying basis for present water management, will rely more on the understanding of the trending international benchmarks, knowledge sustainability as an important goal, current state of land use and water management as the constraining elements. The intended water management approach seeks to establish viability and build sustainability as well as establishing practicality in how the project outputs can be successfully accomplished.

The ICM Model in this study therefore relied on the following:

Local knowledge:

- Baseline or historical state including understating of catchment pristine conditions
- Past influences which define the present state of water/land and its management
- Present state of land and water, current local knowledge and practices.

Characteristics of the catchment:

- Physical state (climate, topography, rivers, groundwater availability, soils)
- State of land use
- Policies, legislation
- Vegetation and life on the land (plant and animal life).

International direction, guidance and examples:

- UN SDGs
- Other UN programmes, Treatie
- SADC leadership and strategy for the region
- State of the art in ICM as set by international countries for different areas of ICM.

Model catchment structure

Decision making, using ICM in a catchment, inherently involves the consideration of numerous complex variables. Given the hundreds of catchments in the country, the use of various ICM models will mean that other methods have to be developed to bring the deferent ICM approaches to be considered under a common scale. In this study, this common scale is set first and applied to the single catchment model. The catchment model therefore, made to be generic and extensible, can be modified, extended and populated with data to represent different catchments as required by the different users and at different timelines.

The model catchment is composed of depictions of variables that characterise a real catchment in such a way that when the data and other attributes associated with these depictions are altered to capture another catchment, this model is used to make decisions in the target catchment. In Figure 3.1 below, the model catchment is illustrated as a development that is made on a case study catchment. The model catchment could then be applied to other catchments by adding relevant attributes and values to define these management areas. Within this model, attributes that are not relevant to the other catchments are excluded when necessary.

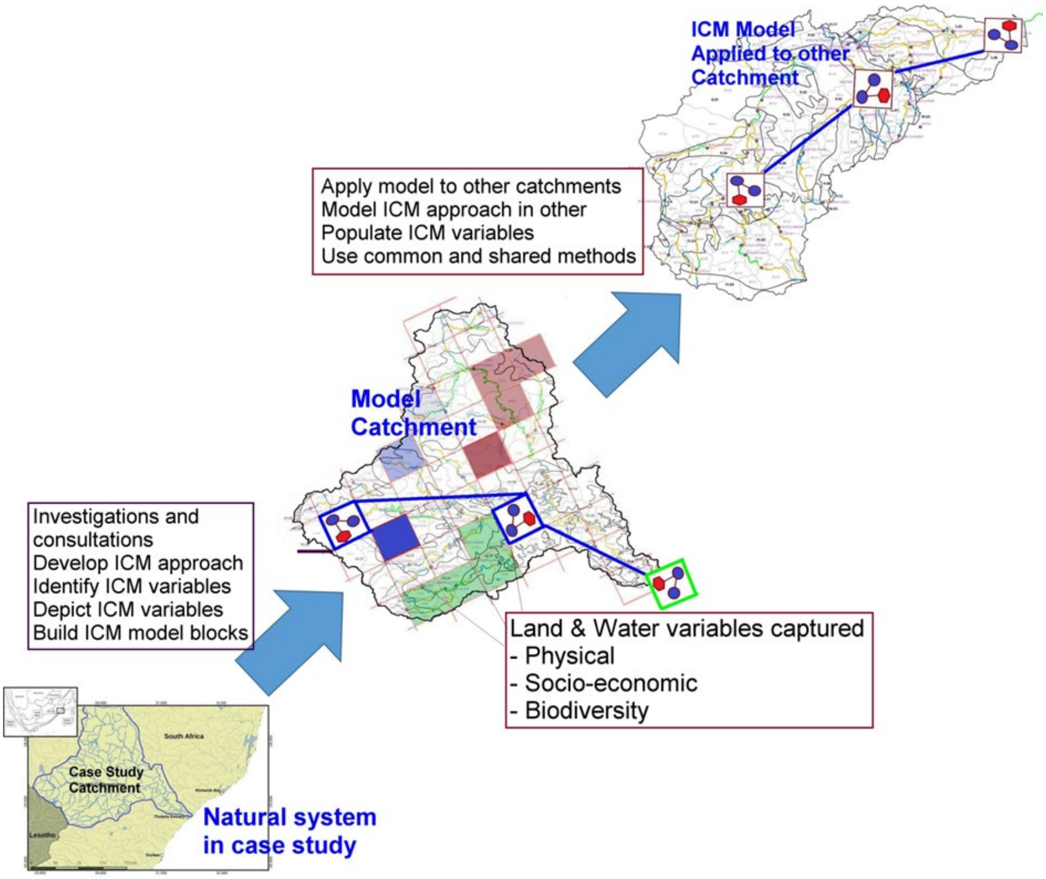


Figure 3.1: Illustration of the model catchment, development and use

Ideally, the catchment model consists of an intricate maze of variables that are connected to represent how the catchment exists and functions. The variables in the model catchment are strategically disaggregated and recoupled to create a representation of the catchment processes, while also applying alternative scenarios of the environment in which these processes function, such as the legislation, policies, politics, institutions, culture, etc.

3.2 Case study selection criteria

3.2.1 Multi-criteria decision analysis

Multi-criteria decision analysis (MCDA) is a tool that can be used to methodically evaluate complex data in order to facilitate decision making (Dodgson et al., 2009, Angelis & Kanavos, 2017). MCDA has been used successfully to evaluate various options with the purpose of coming up with one or more acceptable option by ranking them according to their weighted performance in the evaluation criteria (Angelis & Kanavos, 2017). There are numerous techniques that fall under multi-criteria analysis and a number of software-based models have been developed for the purpose of MCDA (Dodgson et al., 2009; Marttunen, 2010). MCDA can be adapted to suit varying problems and situations such as in selection of a case study area. While there may exist varying MCDA methods, the key underlying factor is the dependence on the discernment of the decision-making team for criteria development (Dodgson et al., 2009).

MCDA allows for a methodical and clear procedure that is open to analysis and adjustments. In the case of selecting the case study catchment for developing an ICM approach, the multi-variables of interest in ICM constitute the multi-criteria to be evaluated. This approach was also used to define variables that are important in the model catchment to be used to develop a generic ICM approach that can be applied to other catchments.

According to Dodgson et al. (2009), the development of MCDA can follow a series of steps, which are outlined in Table 3.1.

Table 3.1: Steps in multi-criteria analysis (adapted from Dodgson et al., 2009)

	Establish the decision context
1.1	Establish aim/s of the MCDA
1.2	Design the socio-technical system for conducting the MCDA
1.3	Take into account the context
1.	Identify options to be evaluated
3.	Identify objectives and criteria
3.1	Identify criteria for identifying consequences of each option
3.2	Classify the criteria as high or low level

	Establish the decision context
4	Scoring – assess each case against the criteria and assign a score
4.1	Weighting – assign weights to the criteria according to relative importance
4.2	Combine or aggregate weights and scores to derive an overall value
5	Examine the results
6	Sensitivity analysis
7	Do other preferences or weights affect the overall ordering of the options?
9	Assess advantages and disadvantages of selected options
10	Eliminate options that do not add value to the overall objectives of the MCDA
11	Add more options that may be better than those considered
12	Select best performing options based on the consolidated scores

Three stage method of analysing potential case study areas

Ideally, the methodology should involve a comparison of catchments. However, there are so many catchments that such an approach will need to be structured in such a way that direct comparison of all catchments in the country is avoided. In this study, the methods applied involve using a three-stage process in dealing with the scale at which the analysis of the case study catchments is done. The first two stages involve determining the most representative two WMAs. These are the WMAs that achieve the highest aggregated scores for all the variables considered in stage 1. In stage 3, the catchments in the two WMAs are compared using identified representative variables with the greatest correlation as observed from the analysis in stage 1 and 2.

These three stages are captured as:

Stage 1: WMA Screening

Screening stage involves physical characteristics of WMA.

Stage 2: Analysis to select two WMAs from which case studies are selected

The analysis involves the use of principle component analysis to determine outliers.

Stage 3: Selection from individual catchments in the two WMAs.

3.2.2 Use of WMAs in screening and selection

In this stage, the selection involved evaluating all the WMAs to come up with a few WMAs from which actual catchments were considered. The screening stage was carried out according to the spatial locations or boundaries defined in the nine WMAs, taking into account the spatial position and orientation of hydrological zones and the administrative/governance boundaries. This was intended to show the most relevant choices based on how they can be considered generally representative of other areas in the country.

The method selected in the screening process was tested against the ongoing changes in the development of local water management in the country. During this stage of the project, the DWS announced that there would only be one CMA for the country. This strategic approach where a single CMA will ultimately be established for the whole country as articulated in the DWS business case for the establishment of a single catchment management agency (DWS, 2017b) was used as the guiding framework in understanding the proposed ICM approach and how it will be formulated for the country, as well as the WMAs as part of this structure. The single CMA approach is based on the nine WMAs with the main difference being that the WMAs will no longer have a board and a CEO such that in terms of administration they will be branches of the proposed single CMA (Figure 3.2). In this study, the structures proposed for the single CMA were also interrogated along the proposal objectives. The objective was to have a fresh look at ICM, which is not necessarily aligned to the motivation and ideas behind the formation of the single CMA or other past practices. The project terms of reference assumed that the failure of integrated water management in the country has to do with shortcomings in how it was formulated in the past as well as other weaknesses in the institutions, legislation, policies, etc. It will, therefore, add value if the project does not seek to understand these weaknesses before building an approach on top of the inherent weaknesses.

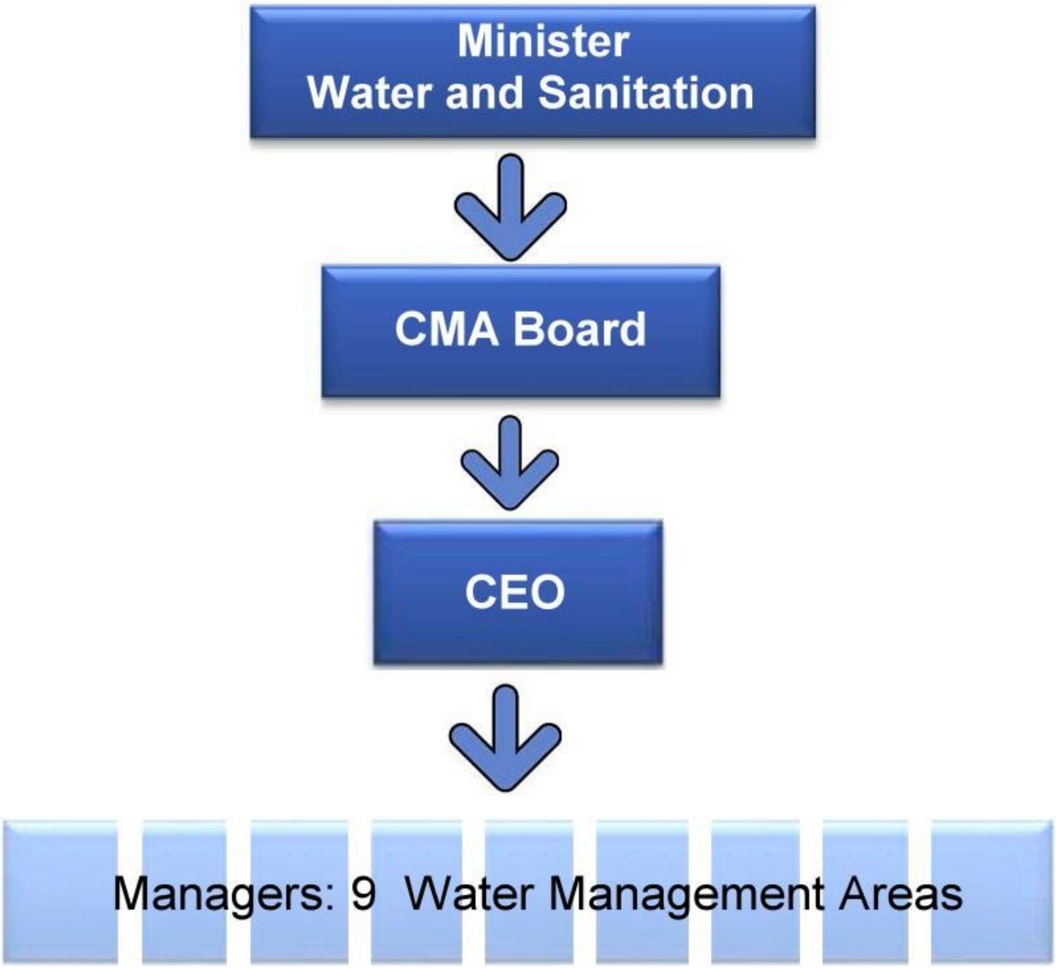


Figure 3.2: Illustration of the structure of the governance under the proposed single CMA (adapted from DWS, 2017b)

The National Water Act (RSA, 1998) provided for the establishment of a water management system that was based on the catchment as the main unit of management. In the National Water Act, it was advised that the water resources strategy would give the delineation of these WMAs. In the period leading to December 2013, the National Water Resource Strategy II was finalised with a revision of the WMAs where the original 19 were re-organised to combine some previous WMAs and change boundaries in others to come up with nine WMAs (Figure 3.3). The reduction to nine WMA was motivated as the best way forward to address the slow pace of progress in establishing the WMAs. It was also concluded that there were inadequate resources to develop and establish 19 WMAs (DWA, 2013b).

In this study, the nine WMAs as currently defined and based on the latest divisions as presented in the National Water Resources Strategy 2 (DWA, 2013a) were used in the methodology designed to select priority case study areas.

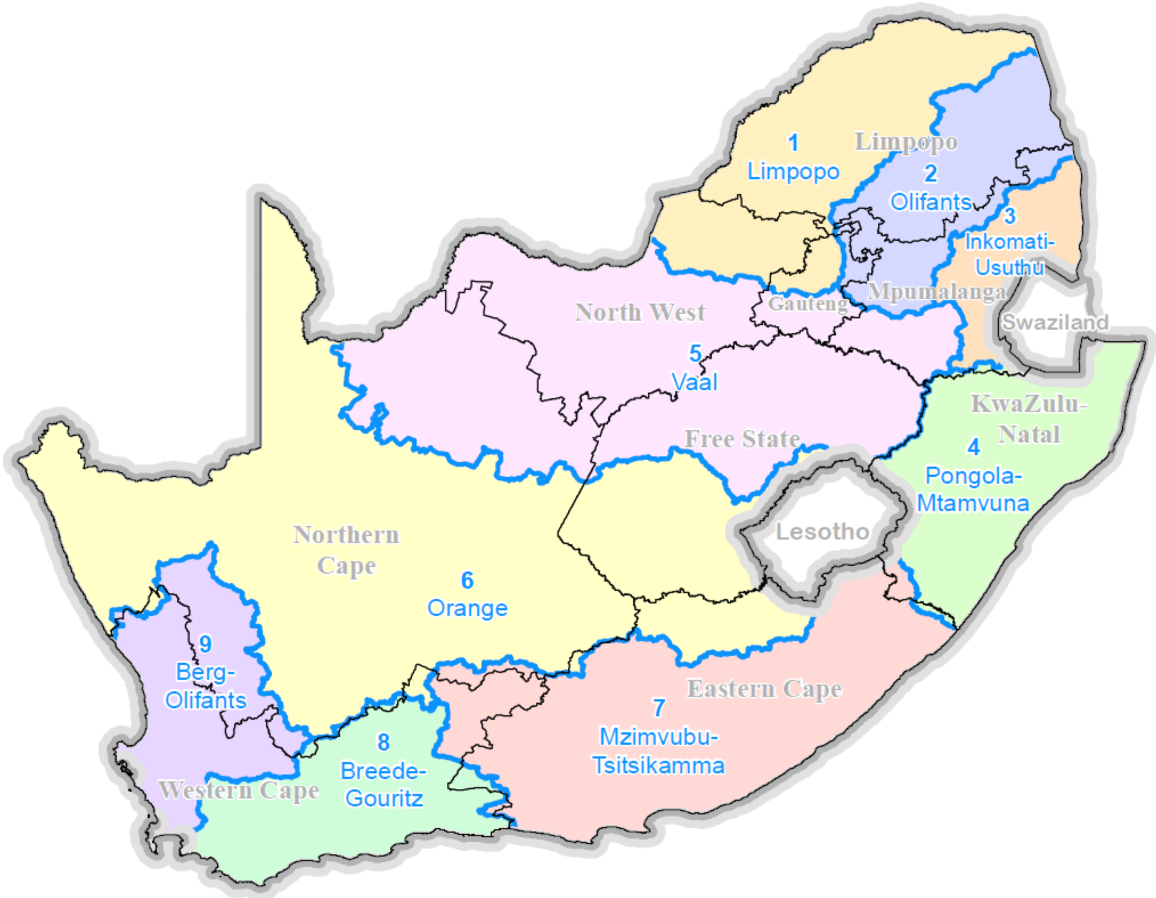


Figure 3.3: The nine WMAs as revised in 2012 and the provincial regions (DWA, 2012b)

Stage 1 screening involved the use of physical characteristics of the water management areas to investigate how each one performs towards the objective of being the most applicable case study for the development of an ICM approach. This entails evaluating the different physical characteristics of the WMAs and determining similarities and unique characters that make the WMA suitable for selecting a catchment within as a case study catchment. The physical characteristics evaluated include the following:

- location
- number of administrative provinces occupied by WMA
- total WMA area in km^2
- transboundary borders with WMA
- elevation minimum and maximum
- water transfer in/out
- general ecological condition of WMA rivers
- rivers (surface water yield) also called available water
- wetlands (major wetlands – such as declared UNESCO sites)

- groundwater resources (volume of groundwater used)
- Mean Annual Precipitation (MAP)
- dams (FSC of dams in the area)
- total water requirements m^3/yr (estimate for all uses)
- total surface and groundwater yield m^3/yr (total available water in WMA).

In the screening stage, it was observed that river catchments are mostly contained within one WMA, but there are rare instances when the river passes through more than one WMA as illustrated in Figure 3.4 below for the Vaal River. The catchment-based management approach will tend to be different in the cases where a major river is part of two or more WMAs. Since this is a unique feature when considering all the WMAs, this physical characteristic reduced the chances of the affected WMAs to represent the rest of the WMAs.

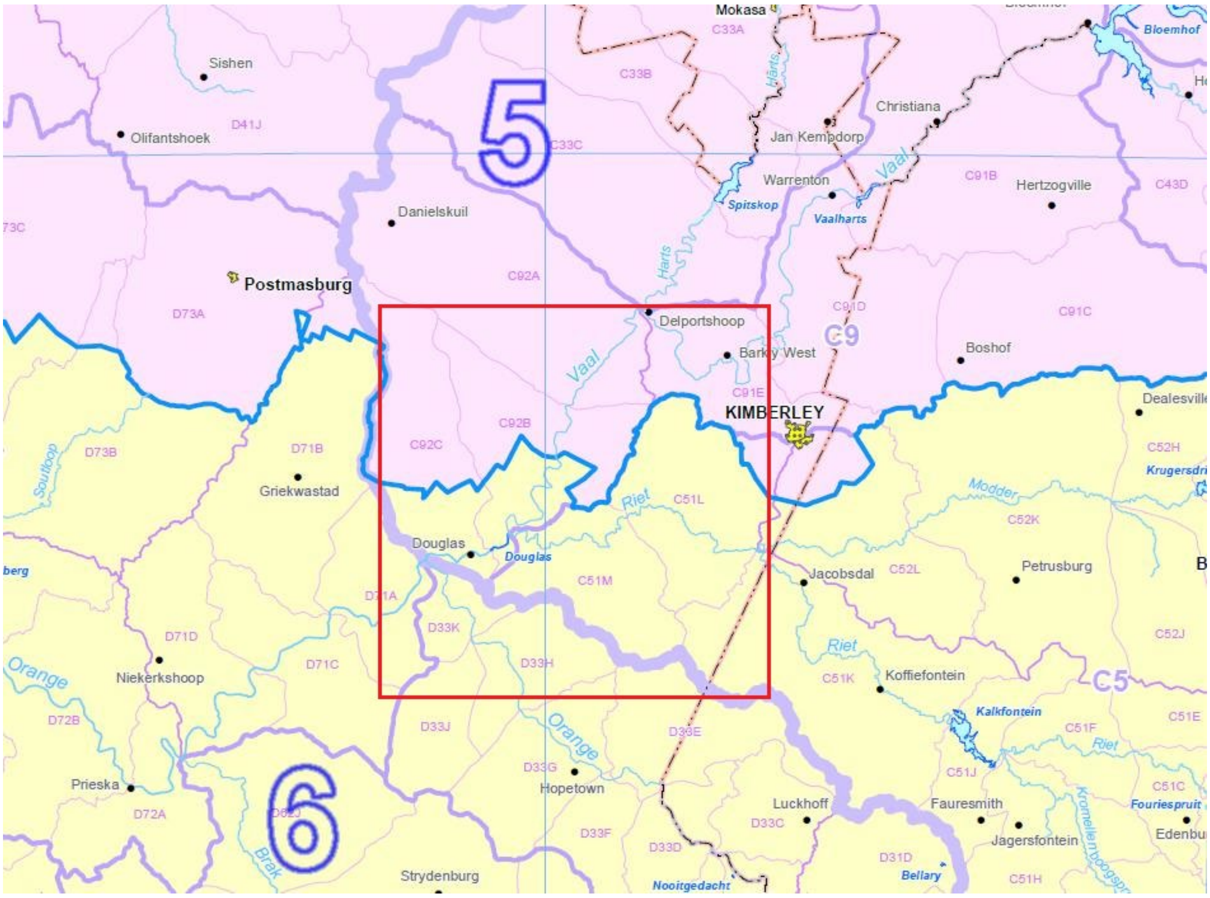


Figure 3.4: Map showing the Vaal River crossing from WMA 5 to WMA 6

Stage 2: Secondary Screening using WMAs

After considering the physical characteristics in the initial screening, the WMAs where analysed to determine the distribution of variable values using principal components analysis (PCA). In this stage, the outliers were identified. These were those WMAs that were consistently different from the majority of the WMAs when several variables were analysed. The idea behind the exclusion of outliers was that, if the WMA variables are generally very different from the rest of the other WMAs, then the affected WMA is not a good candidate for the case study. The case study catchment was set to be the model for the development of the ICM approach that will be applicable in other catchments.

3.2.3 Analysis of MCDA variables

Decision making in water resources management is characterised by many variables that have to be considered, a scenario that is also referred to as multi-criteria analysis. In the case of identifying a suitable case study catchment out of hundreds of catchments, intuition can never yield the best results. In this case, the best approach involves structuring the problem of identifying a suitable catchment into a structured approach where the several criteria are analysed explicitly. The complexity of deciding on the catchment emanates from the presence of more than one criterion that has to be satisfied, especially given that these variables present different levels of competition when weighed against management objectives, including the different values offered to stakeholders. As an example, the catchment to be selected should be very similar to the other catchments. In reality, however, these catchments come with so many other differences as well as similarities affecting different variables. These differences are randomly distributed with some cases of ordering especially where anthropogenic characteristics factors are concerned.

Identifying the variables

To select the case study, multi-criteria analysis was undertaken. The method selection was based on its ability to evaluate the many variables that are pertinent to the holistic interpretation of all important issues as well as what is required for the ICM land-water approach. The MCDA method applied in selecting a case study catchment used the socio-economic, legislation and institutions, ICM resources and physical characteristics variables.

Scoring or rating the variables

This entails rating the variables according to the objective (the objective was for the WMA to be the most representative case study that has more characteristics that are similar to the other WMAs). The assumption was that if the WMA is similar to all other eight WMA in that variable, the score is eight, which is one for each WMA that it is similar to. It should be noted that a variable in which the WMA is similar to all the other WMAs is not worthy of including in this analysis, since it does not add value to the determination of the objective.

Normalisation of variable scores

The variables describing the catchment areas are both quantitative and qualitative. To obtain common indices, all indicators were converted to a common scale. The approach used in the study involves assigning a value to the indicator. The indicator values were checked against expert inputs to reach a consensus using averages as well as revising some estimates based on consensus in suggestions. Each value is based on a number of factors including frequency, intensity and actual average values. In the method developed for the study, the indicator values can be changed in future to capture improved knowledge and data changes. Assignment of values to the variables requires standardisation and a set of rules to ensure that the final ratings are comparable and have the same meaning. The United Nations Development Programme (UNDP)'s Human Development Index (UNDP, 2002) method was used to normalise all of the variables in the vulnerability indices to a range of 0 to 1. The values of each variable were normalised to the range of values in the data set for all case study areas by applying the following general formula:

$$z_{j,i} = \frac{Z_{ji} - Z_{min,i}}{Z_{max,i} - Z_{min,i}} \qquad \text{Equation 1}$$

$z_{j,i}$ $is\ j^{th}\ normalised\ value\ for\ indicator\ i;$

Z_{ji} $is\ j^{th}\ actual\ value\ for\ indicator\ i;$

$Z_{min,i}$ $is\ minimum\ value\ for\ all\ i^{th}\ indicator\ values;$

$Z_{max,i}$ $is\ maximum\ value\ for\ all\ i^{th}\ indicator\ values$

Applying weights to the variables

There variables have different relevance to the objective of the MCDA. This means that different weights have to be applied to the different variables. The weights are expected to capture relevance when compared with other variables in relation to (i) the objectives of the ICM, (ii) the objectives of the case study selection. As an example, in deciding if a catchment is most representative of others (selection objective), one of the variables is identified as Mean Annual Precipitation (MAP) while another variable could be average duration of rainfall event. The MAP is more representative of what is commonly known and used to define a catchment, while the average duration of rainfall event is not commonly identified as being of similar importance in defining catchment characteristics and in ICM. The weighting process thus allocated a higher weight for MAP and a lower weight for "average duration of a rainfall event". For the purposes of this evaluation, an expert judgment approach was used to generate the initial weights. Data and information from consultations were also applied to confirm, update and change the weighting inputs based on responses from experts and stakeholders in the field.

Eliminating variables that are not reliable given the available data

Data from some WMAs was not available or is unreliable in several variables. The methodology selected is efficient if applied where there is reliable data to identify the effect of the variable towards the MCDA objective. As such, the variables with unreliable or missing data are eliminated in the final case study selection considerations. Table 3.2 below shows a selection of variables that could be used to characterise a catchment area. There was no readily available data for all catchments for the following:

- Settlements on wetlands
- Surface area of water bodies in catchment
- Population of youth in catchment area.

In the absence of suitable data covering all areas to be considered, these variables were excluded from the selection criteria.

Table 3.2: Sample of variables to demonstrate basis for eliminating variable

	1	2	3	4	5	6	7	8	9	10	11
VARIABLE	**Total Surface Water and Ground water yield**	**Level of physical pollution and degradation in rivers**	**Consists of many separate catchments going into sea**	**Portions of quaternaries are in two WMAs**	**Settlements on wetlands**	**Has closed River mouth**	**Area of natural forests in catchment**	**Surface Area of Water Bodies in Catchment**	**Evaporation in catchment**	**Preciptation in Catchment**	**Population of youth in catchment area**
Readily Available Data	Surface Water=Yes Groundwater = No	Yes	Yes	Yes	No	Yes	Yes/No	No	Yes/No	Yes	No
Rellevance to objective of MCDA objectives	Yes	Yes	Yes/No	No (only small potions affected)	Yes	No	Yes	Yes	Yes	Yes	No

Eliminating the variables that do not add much value to a decision variable irrelevant to the overall decisions of the ICM. This also applies to the variable identified as Number 5, which deals with catchments with estuaries. The estuaries are only in the coastal catchments and a few are closed in the dry season. This is a unique characteristic that can lead to the catchment being excluded from the MCDA technique, especially if the unique variable is a dominant aspect of the catchment. However, in the case of unique variables, it is important to note whether the unique variable will affect the catchment's ability to represent other catchments. The principal components analysis (PCA) was then used to determine the cut-off point for the number of variables to be included in the MDSA. In PCA, a subset of variables is selected from a larger set, which is based on the original variables that have the highest correlations with the principal component. PCA is described as a dimension-reduction tool that can be used to reduce a large set of variables to a small set that still contains most of the information in the large set.

Weighted scores (Weighted ratings)

The use of weights places value to the extent to which the common information derived from the variables is most aligned to pushing the ICM study objective in a positive direction, that is, to create an increase in the extent to which the WMA or catchment can represent other WMAs or catchments in being a model catchment for developing an ICM approach. The value of each weight was derived from a scale of 1 to 10 based on the opinion of the study team and selected experts. The values were such that 1 was applied for those instances where the variable is least aligned to pushing the ICM study objective in a positive direction and 10 is when the variable has more significance to the objectives of the study.

The weighted score value (after weighting) was then given by:

$$x_{ji} = z_i \text{ x } b_i$$

Where:

x_{ji} is the weighted variable value

z_i is the normalised variable value or score

b_i is the weight assigned to variable *i* for the WMA

Aggregate score

The comparison of how each WMA or catchment fairs as a case study or most representative catchment for the ICM approach was performed using the aggregate scores achieved in each case. This approach determines the extent to which the common information derived from the variables is most aligned to pushing the objectives of appropriate ICM approach in a positive direction.

The aggregate score for each area was given as follows:

Equation 2: $s_{ij} = \sum_{ij=0}^{n} z_i \text{ x } b_i$

Where *n* is the number of the variables considered
z_i is the normalised variable value or score
b_i is the weight assigned to variable *i* for the WMA45
s_{ij} is the aggregate score

3.3 Analysis and assessment of variables in the selected case studies

3.3.1 Stakeholders and Institutions

At this stage, the assessment of stakeholders and institutions was done to determine the status of the following variables within the WMAs:

- Responsible water board or has no water board
- Type of water service provider
- Irrigation boards and change to WUA (progress made so far)
- Volume of illegal water abstraction
- State of water licensing
- Is water in WMA fully committed/allocated?
- Ownership and sales of water
- Land under control of Chiefs and local leaders
- Land in private commercial ownership
- Proportion of land owned by government
- How established is the CMA?

3.3.2 Physical variables

The first stage in the selection process involved the use of physical variables to determine the general area where the conditions were generally representative of most other areas at the level of the WMA. The objective in this selection stage was to determine the WMA with the best performing catchment variables where the goal was "closest fit" or "most similar" when compared to similar variables in the other eight WMAs. Out of the identified physical variables, some variables could not be used in the assessment because they had unreliable data, data gaps or incomplete information.

Out of the list of variables given in section 3.2.2, the following variables were not considered in the analysis due to the reasons as provided:

- Wetlands (major wetlands – such as the declared UNESCO sites) (were left out due to poor data for some WMAs)
- groundwater resources (volume of groundwater used) (were left out due to poor data in some WMAs
- types of most common rainfall (left out because information was not adequately representative of all areas).

The assessment of the WMA variables revealed that the best areas to select a catchment from were the Olifants and the Berg-Olifants WMAs. These catchments were chosen based on their representativeness of the South African catchments with respect to land use and water use activities. The two catchments, both named the Olifants, cover large areas where more land uses are taking place when compared with the other catchments. The two catchments are, however, located in very different areas. Based on this assessment, the two are the most representative of the conditions in the other WMAs. With the highest weighted score of 351 and 336 respectively (Table 3.3), these two Olifants WMAs were further evaluated to select the most representative case study catchment.

Table 3.3: Summary of score from comparison of WMA variables

WMA	Limpopo	Olifants	Pongola-Umzimkulu	Vaal	Orange	Inkomati-Usuthu	Breede Gouritz	Berg Olifants	Mzimvubu-Tsitsikamma
Ratings	46	49	37	30	31	46	46	47	42
Weighted score	324	351	259	195	204	330	332	336	285

3.4 Selected case studies

3.4.1 Results of selection criteria

From shortlisted WMAs mentioned above, the selection of the study catchment was applied. The catchments in the shortlisted WMAs were evaluated on the basis of four variable groups as follows:

- Physical variables
- Socio-economic variables
- Variables on governance and institutions
- Variables on ICM resources.

The catchment areas that were evaluated to finalise the selection of case studies are illustrated in Figure 3.5 and 3.6 below. The extended names Olifants-Steelpoort, Letaba and Berg-Sout and Olifants-Doring have been used in this study to distinguish the catchment areas by including key tributaries in the catchment name. The data and information collected, and the investigations undertaken, resulted in the selection of two catchments as case studies. The case studies selected are described in Table 3.4 below.

Table 3.4: Selected case study catchments

WMA	Catchment name used in the study	Location in provinces	Length of longest river reach (km)	Area (km^2)
Berg-Olifants	Olifants/Doring	50% in Western Cape 50% in Northern Cape	285	46 220
Olifants	Olifants/Steelpoort	47% in Mpumalanga 50% in Limpopo 3% in Gauteng	560	54 388

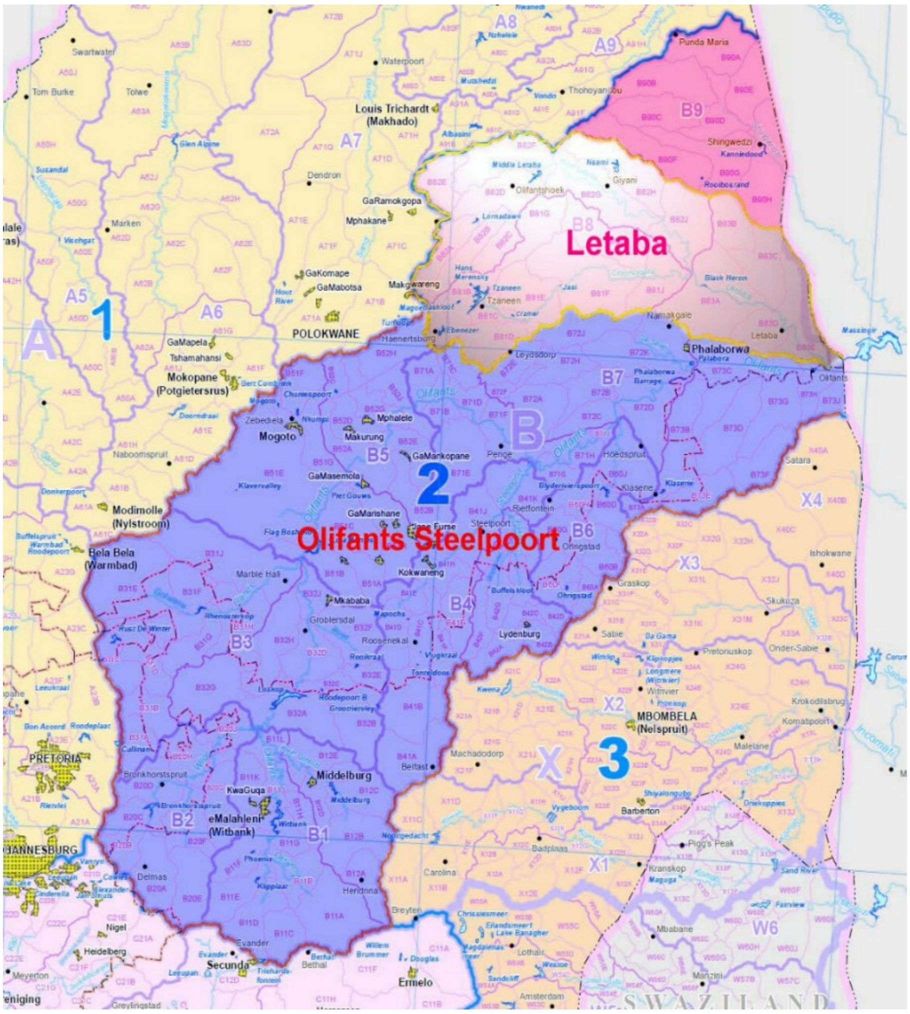


Figure 3.5: Catchment areas in the Olifants WMA (adapted from DWA, 2012b)

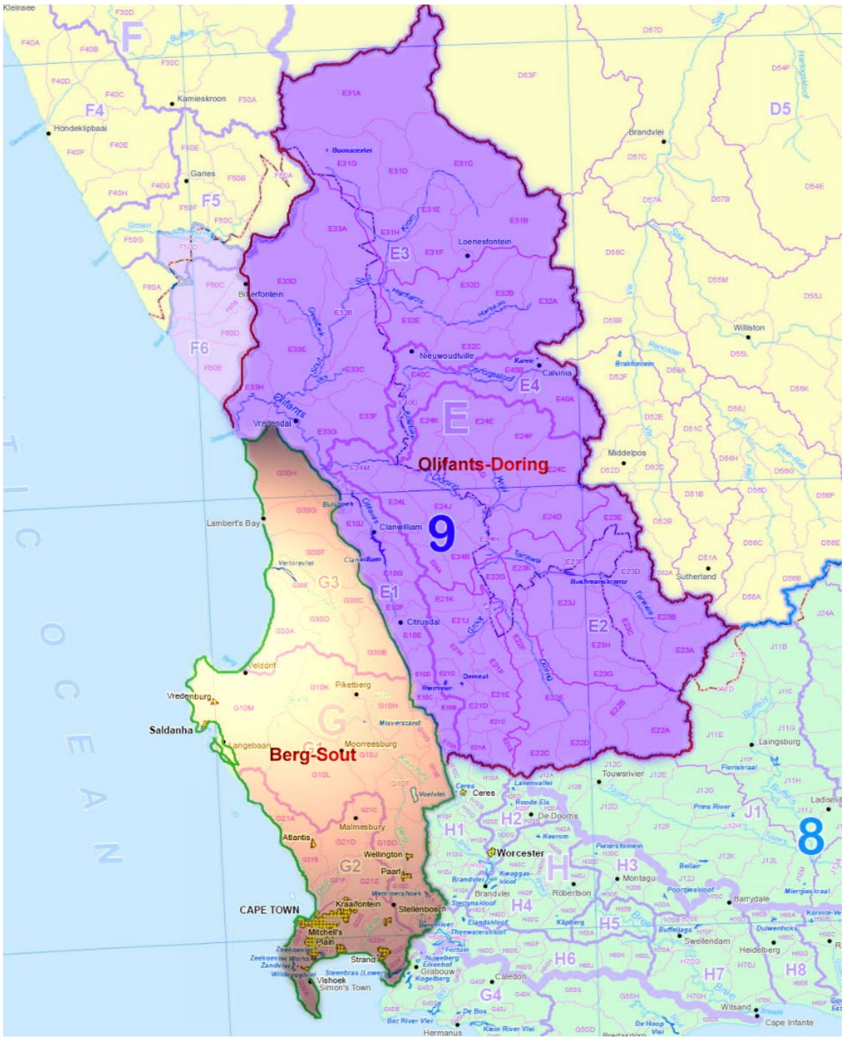


Figure 3.6: Catchment areas in the Berg-Olifants WMA (adapted from DWA, 2012b)

The decision to select either one or two catchments for use as case studies was analysed. An important output of this assessment was that there would be more value in using two case studies that seem to cover the widest variation in catchment characteristics. This decision was made after several observations were investigated. These observations included the following:

Implications of land and water ownership to the success of an ICM: It was observed that there is no doubt that success of ICM is affected by availability and access to the resources to be managed. In this case, it is land and water. An assessment of land ownership showed that most of the land is privately owned, with very little land under government ownership. This is particularly the case in the Olifants-Doring catchment where 91% of the land is privately owned and less so in the Olifants-Steelpoort catchment with 67% land that is privately owned.

The ICM approach should appreciate the roles of different stakeholders in both theory and practice when land and water ownership are different. The ICM has to be built within the realms of what is on the ground rather than the wishes of one stakeholder such as the state. In dealing with selecting a case study catchment, an area where the water users and land owners have interest in full participation provides a better chance of developing something that is practically useful. Catchments with high levels of land and water use are also much better in this regard. The two catchments, Olifants-Doring and Olifants-Steelpoort, represent the greatest variations in terms of land and water ownership as well as the most diverse land use practices.

Presence and absence of former homelands in a catchment: The spatial locations indicating the state of service delivery in water provision, sanitation and municipal vulnerability closely correspond with the boundaries of former homelands. The areas of WMAs that are located on former homelands are still in a very poor state when several ICM variables are compared to those for the rest of the country. In addition, the population densities in rural areas also follow these former homeland boundaries, making water management challenges more intense in the Olifants-Steelpoort when compared to the Olifants-Doring. It is with this background that two rather than one catchment are preferred for use as case studies. The one in the Berg-Olifants WMA presents a large, intensively used area with the lowest population density in the country and the Olifants-Steelpoort catchment, which represents an area where several former homelands were located and also an area where the population density is generally high and yet water services are fair to poor. The set of two catchments will represent many other dimensions that are characteristic of most catchments in the country.

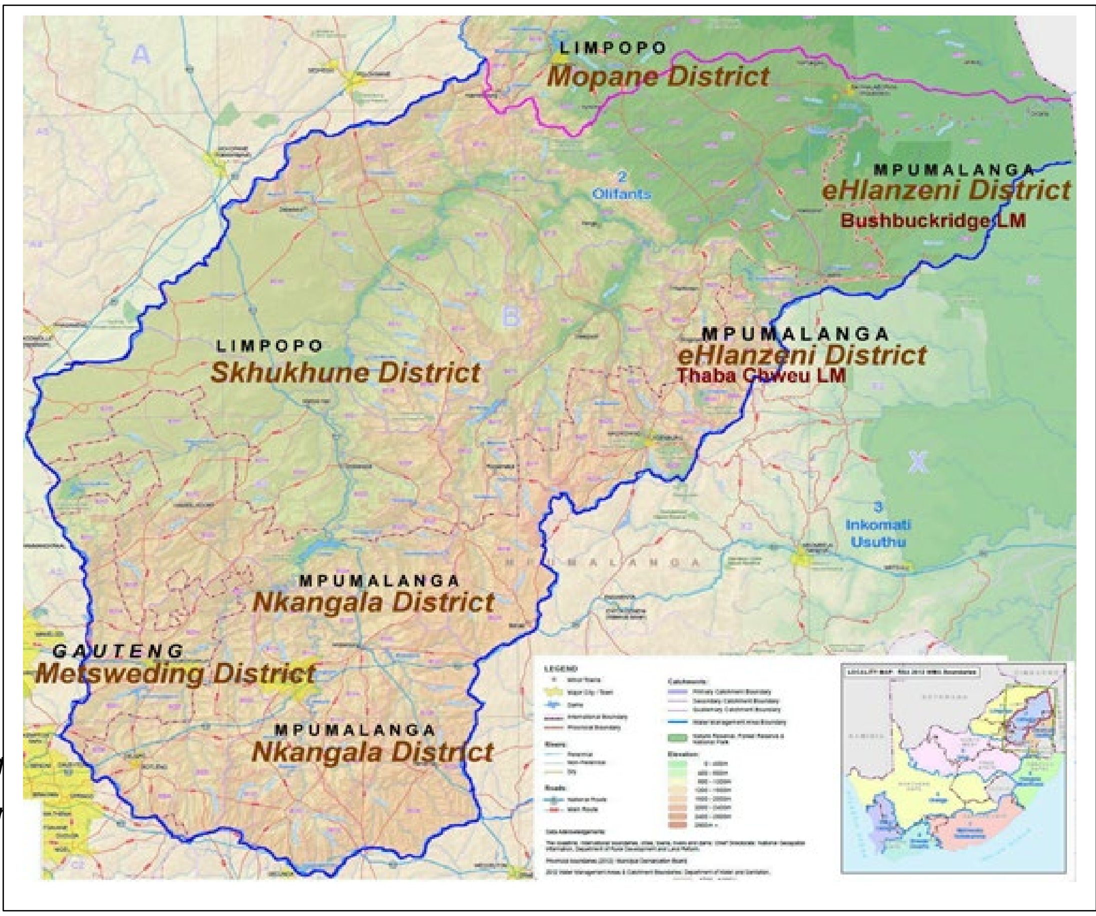
3.5 Olifants-Steelpoort catchment area

The Olifants-Steelpoort catchment includes the Olifants and the Steelpoort River sub catchment. This catchment excludes the Letaba and Mphongolo Rivers, which are considered as part of the Olifants Water Management Area (WMA). The two tributaries, Letaba and Mphongolo respectively, connect to the Olifants River at the border and after the border with Mozambique. The Letaba River is a tributary of the Olifants River with a confluence very close to the border with Mozambique such that it has no direct influence on the Olifants River before it drains into Mozambique. The Mphongolo River is also a tributary of the Olifants catchment but its confluence is inside Mozambique. The Olifants-Steelpoort catchment area as considered in this study is 4794 km^2 in area and has a population of 2.6 million people (RSA, 2017). The catchment area statistics are shown in Table 3.5 below.

Table 3.5: Olifants-Steelpoort catchment area statistics

Catchment	Location	Inland or coastal	River length of longest reach (km)	Available Surface Water milliom m^3/annum	Available Ground (GW) water in million m^3/annum	Total available yield per annum (Million m^3/ annum) Figures Include Return flows	Groundwater usage /developed Groundwater resources	Annual rainfall/mm
Olifants-Steelpoort	limpopo, Mpumalanga, Gauteng	Inland	560	in	468.9	609	100.5	400-1000

The Olifants-Steelpoort catchment is in three provinces where about 7% of the land area is in Gauteng while 27% is in Mpumalanga and approximately 66% in Limpopo (DWS, 2015c; RSA, 2017). It was observed from the consultation process that most of the water related maps that are currently available in most reports and from the DWS show the municipal boundaries from 1997, which are no longer accurate. Consideration of the boundaries used is important in this study as it can easily become a major source of error in the catchment area data and statistics. The map in Figure 3.7 shows the Olifants-Steelpoort catchment boundaries as well as the provincial areas in this catchment. Of importance to the discussion of the Olifants-Steelpoort catchment area are the municipal boundary changes made in 2011, which increased Limpopo while reducing Mpumalanga in the Olifants-Steelpoort catchment. In light of these changes some available literature, data and information about the Olifants-Steelpoort area becomes inaccurate. The data and other content that are based on old municipal demarcations or were obtained from old municipal records will no longer be applicable.



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3.6 Olifants-Doring catchment area

The Olifants-Doring catchment area is the area drained by the Olifants River in the Berg-Olifants Water Management Area (WMA9). The Doring River is the main tributary of the Olifants River, hence the name used for this case study area. This catchment area is located partly in the Western Cape and partly in the Northern Cape Province. Most of the rainfall in the catchment area falls in the south west sections of the Olifants River where the MAP is above 900 mm. Rainfall drops sharply from the high values in the south west to an MAP of 200 mm in most of the catchment area to the north and east. The furthest northern sections of the catchment have an MAP below 100 mm (DWAF, 2002). Most of the available water resources known to exist are surface water, where the yield is up to 335 million m^3 per year as illustrated in Table 3.6 below.

The Olifants-Doring Catchment area has a winter rainfall season which starts in May and ends in September. Much surface water is lost in summer where maximum temperature figures range from 39 to 44°C while the mean annual evaporation exceeds 2000 mm per annum. A large section of the Olifants-Doring Catchment area, especially the drier sections, are in a state that is described as moderately modified to largely natural. There are sections of the catchment that are described as pristine where there have not been any human modifications. These sections are protected as areas of high ecological value, especially given that they are also the habitats supporting some species of fish and plants that are not found elsewhere in the country (DWAF, 2002).

Table 3.6: Olifants-Doring catchment statistics

Catchment	Location	Inland or coastal	River length of longest reach (km)	Total Area of catchment in km^2	Available surface water milliom m^3/annum	Available groundwater in million m^3/annum	Total available yield per annum (Million m^3/ annum) Figures Include Return flows	Groundwater usage /developed Groundwater resources	Water resource quality monitoring stations (Active stations/All stations)
Olifants-Doring	Northern Cape, Western Cape	Coastal , flows into the atlantic	285	46220	257	45	335	45	184/233

3.7 Consultations in study areas

3.7.1 Questionnaires and direct engagement of stakeholders

Consultations and discussions with communities in the catchment were aimed at extending the understanding of expectations regarding integrated catchment management as well as ensuring that the project development was informed by how the stakeholders are dealing with day-to-day issues, as well as other activities involving water and land in their areas. Two sets of questionnaires were used in the case study areas. The first questionnaire were aimed at getting insight from community and non-commercial use, while the second questionnaire probed the insights from the farming and commercial water users.

In addition to the questionnaires the stakeholders were consulted through open discussions, which were more elaborate in providing details useful for this and future sections of the study. Several community members were also contacted by telephone, and in some instances, they also agreed to complete the questionnaires even after giving a telephonic interview. The Olifants-Steelpoort catchment area covers a large area. To improve the nature of inputs, the areas visited were randomly selected in the different districts and then accessibility was used to finalise on the specific routes and areas to be visited. The observations and conclusions are a general representation based on the consultations made.

3.7.2 ICM Workshop

The workshop platform was used to engage with the key role players such as government officials, researchers and policy experts in the water sector. The workshop objectives, were as follows:

- To share and contribute to ICM project development
- To build understanding of stakeholder expectations
- To be more informed of developments related to ICM
- To build an environment for synergy in water management
- To understand the ICM land and water linkages
- To build institutional networks for collaboration.

Several experts, academics and other role players were requested to participate. Those who could were also requested to develop a presentation that could add to the discussions. The workshop was also an opportunity to generate a common understanding of the research topic with the stakeholders while determining the boundaries to what should be in the study.

Further stakeholder input

After the presentations and the discussions around the presentations, participants were each given an A4 card and coloured board marker. They were requested to write down in short phrases an area or subject that they wish to see being covered in more detail in the study. This was supposed to be something they felt had to be prioritised in ICM and required further discussion. The following phrases were recorded from these inputs and the discussion that pursued:

Participants view on a holistic ICM

- Stakeholder integration
- Integration of institutional strategies
- Embracing stakeholder empowerment
- Intergovernmental partnership
- Complete catchment coverage.

Role of government in ICM

- Overseer/Facilitator/Regulator
- Monitoring and evaluation
- Compliance support

- Development support
- Financial support
- Auditing the outputs
- Leading accountability.

Role of municipality in water management at catchment level

- Local knowledge
- Lead local policies and strategies
- Implementation of policies and strategies
- Support CMA roles at local level
- House-to-house implementation
- Water quality compliance at local level
- First level of interaction with community.

Improvements to the Constitution and water legislation

- No improvements before attempting to fully implement available provisions
- Making government accountable for failed programmes such as formation of WUA
- Ensure the legislative tools are aligned
- Deal with local water access conflicts
- Expand to include land issues in water management

Main limitations of ICM in the South African context

- Inadequate resources for implementation
- Lack of will in the stakeholder community
- Complexity of ICM not adequately understood
- The multidisciplinary nature not fully comprehended
- Failed transformation of institutions in the water sector
- Failure to integrate connected/related departmental mandates
- Poor or lack of government coordination
- Limitations in human resources
- Lack of champions
- Weakness in sharing the vision for the catchment
- Shared vision
- Changing environment especially due to politics
- Tendency to avoid changes and protect the status quo.

Factors affecting attainment of common ICM goals

- Lack of political will
- Different catchment needs or resource access levels
- Bad leadership in government institutions
- Poor capacity to implement at all levels
- Formation of too many forums and platforms
- Diverse departmental mandates and sectors working in silos
- Legislation and community mentality and attitudes.

4 Hydrological and environmental considerations in ICM inventory

4.1 Introduction to the catchment inventory

Water management is an age old practice that has evolved over time as knowledge expanded, especially the improvements in understanding the interactions between humanity and the water cycle and its processes. The focus on water management has also transformed over the years from practices that were focused on single objectives to the current approaches where multiple objectives of multiple stakeholders are pursued using different concepts of integration (Ashton, 2000). In the integrated water management approach, components of the management platform are represented through processes, modules and resources. The study of processes and management systems requires a reliable and exhaustive data source that aids in the understanding of the system. In integrated water management, the catchment has been the unit of choice in organising the methods in ways that users and beneficiaries understand, particularly in cases where surface water was considered to be the main source. In a catchment, a number of processes are at play that include but are not limited to, hydrological, geo-hydrological, ecological, socio-economics, and politics.

In each catchment, the level of interaction of these processes is dynamic and sensitive to catchment activities (Yu & Duffy, 2018; Smith, Porter, Hiscock, Porter & Benson, 2015). However, the catchment approach in its strict definition is poor in accounting for important water management areas that are not aligned to the hydrological boundaries, especially groundwater systems, and the political or administration boundaries. Fraser, Dougill, Mabee and Reed (2006) pointed out the frequent mismatch between environmental and political boundaries and the implications that this has for decision making and monitoring in a catchment. Approaches that use both surface and subsurface considerations in an integrated fashion allow for reliable and better accounting of water resources in the present and in the future (Ala-aho, Soulsby, Wang & Tetzlaff, 2017).

In ICM, where consideration of the local water cycle is important, the nature of tools and data required has to be motivated by the nature of the specific problems holistically. ICM involves integrating tools and methods that were previously used to address targeted problems that include tools for groundwater assessments, pollution management, population projections, community vulnerability assessments, climate change projections and ecosystem sustainability needs assessments. In this project, developing an inventory of tools that brings together the available information and resources that are being used for water management by local catchment managers were crucial. This inventory could allow for the selection of the different tools according to their application success in the local environment as well as an appreciation of the problem to be addressed in different areas. The inventory that is being developed in this project also links the user to data and other resources required by the user or rather according to the description of the problem to be solved.

4.2 Consideration of climate, hydrology and geo-hydrology in ICM

4.2.1 Understanding the natural and manmade water cycle in ICM

The water cycle drives catchment hydrological and geo-hydrological processes. There are two clear distinctions in hydrology with uniquely different characteristics at different stages of the water cycle. The urban hydrological systems exist in an environment that has been disturbed by land uses, while the rural hydrological systems remain to a greater extent undisturbed. Rural hydrology may include other forms of hydrology, especially those that are more aligned to natural processes such as mountain hydrology and forest hydrology, therefore a basin or catchment system has its own unique hydrology but based on the same basic principles of hydrology. This is what is usually important in an ICM system.

Several processes are involved in the water cycle that are assessed separately or within a more global water system such as is done using water systems modelling. These processes include evaporation, transpiration, condensation and precipitation, which together determine catchment water availability. It therefore follows that each of these processes requires in-depth appreciation and understanding of individual catchments in order to detect the impact of changes to the cycle. The fundamental need behind the study of the water cycle is to ensure water security and thus food security for the global population. The continued increase in population also puts an increasing pressure on the availability of water for man and nature. Securing water and food for man has led to some of the major alterations to the hydrological cycle, such as damming for irrigation or for hydroelectricity, wetland drainage, deforestation and groundwater abstraction (Vorosmarty & Sahagian, 2000). These alterations have an impact on the hydrological processes of the water cycle, for example, over-abstraction of groundwater at a rate faster than it can be recharged increases the water available in the atmosphere through evaporation but the groundwater reserves would have been depleted thereby distorting the water balance (Table 4.1 below) (Vorosmarty & Sahagian, 2000).

Table 4.1: Water balance

The water balance	$P - E - ET - Q \pm \Delta S \pm L = 0$
P	Precipitation
E	Evaporation
ET	Evapotranspiration
Q	Water yield (streamflow + groundwater recharge)
S	Storage (Δ signifies “change”)
L	Leakage, in or out of the watershed

The catchments chosen for this study are the Olifants-Steelpoort (in Mpumalanga and Limpopo) and the Olifants-Doring (Western Cape and Northern Cape) catchments. These catchments were chosen based on their representativeness of the South African catchments with respect to land use and water use activities. The selection process is covered in section 3 of this research project. The Olifants-Steelpoort catchment (Figure 3.7) is characterised by several infrastructure modifications to the river system and the whole catchment area. The Olifants River and its tributaries have several dams scattered all over the catchment area.

The Steelpoort catchment comprises the Steelpoort River and its tributaries (Dwars and Spekboom Rivers) and has three major dams, seven irrigation schemes, 118 km of canal systems and 5.9 km of pipelines (DWS, 2017c). There is significant commercial agricultural activity in the catchment as well as platinum and chrome mining. These activities draw on the available water in the Steelpoort River catchment system (DWS, 2017c). In addition, municipal responsibilities such as sewage treatment and discharge and waste management pose a threat to the water quality in the catchment due to poor maintenance of infrastructure, which leads to the discharge of polluted wastewater, unavailability of resources, poor storm water management and lack of awareness on the impacts of illegal waste dumping and disposal (DWS, 2017c). Studies have shown that damming increases the standing time of water thereby reducing turbulence and affecting the biogeochemical cycling of nutrients, which consequently impacts on the ecosystem services of downstream ecosystems such as wetlands and estuaries (Friedl & Wuest, 2001).

On the other hand, the Olifants Doring catchment lies in the Northern and Western Cape Province. The Doring is a major tributary of the Olifants River, which rises in the Agter Witzenberg Mountains. Flow into the Doring River is restricted by the Clanwilliam and Bulshoek Dams built on the upper catchment of the Olifants River. The area has several dams that benefit from the higher rainfall in the upper catchment reaches. Figure 4.1 shows the dams and their relative positions in the GIS platform of the ICM repository software that is being developed as part of the project. The main activity in the catchment is agriculture (citrus farming) and the communities in the area are sparsely distributed. The Doring Catchment contains some rare species of aquatic life and its catchment remains largely undeveloped and unaffected by human activities, providing a tourist destination. Olifants-Doring Catchment is part of the Olifants-Doorn Water Management area. The communities in the catchment have over the years increased their environmental awareness aided by policies put in place that have impacted positively on the maintenance of the ecological integrity in the catchment. Challenges facing the catchment are land clearing for agriculture and over-allocation of water resources (Knuppe & Meissner, 2016). A number of participatory programmes have occurred in the catchment during the drafting of the business case for the establishment of the Olifants-Doorn Catchment Management Agency. Other programmes, such as the CAPE (Cape Action for People and the Environment) and the Biodiversity Stewardship programme have helped raise awareness for sustainable land and water use practices in the catchment. However, the cross sectoral coherence in natural resource management still remains a challenge that needs to be addressed (Knuppe & Meissner, 2016).

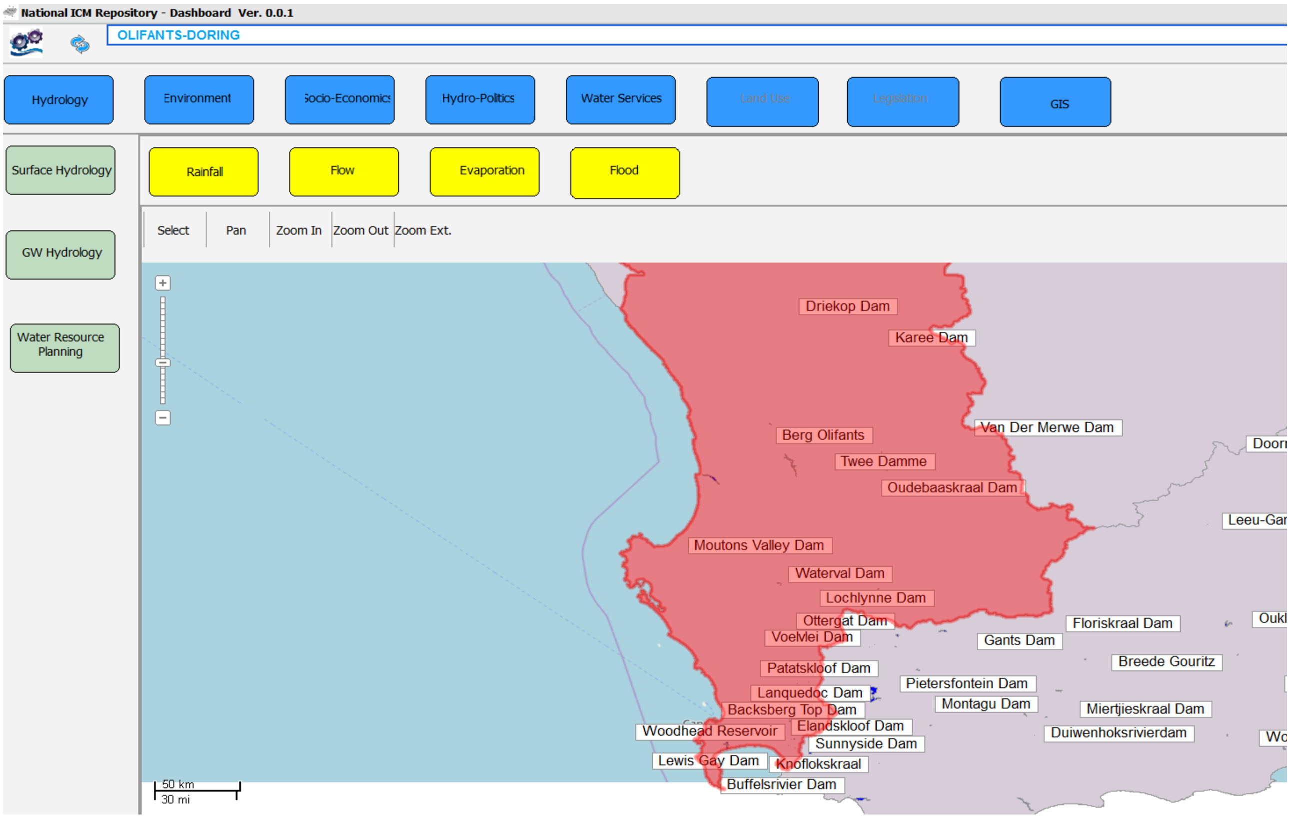

Figure 4.1: Olifants-Doring catchment area with information on dams as illustrated in the ICM platform

4.2.2 Hydrology and Geohydrology Tools for the ICM

This section focused on few models in light of their contribution to the overall objective of ICM from source to receptor, as well their limitations in achieving the goal of a model catchment. Currently the most commonly used hydrological models include the Soil and Water Assessment Tool (SWAT), the

Water Resources Yield and Planning models (WRPM/WRYM) and the WRSM2000/Pitman model. The planning models are mostly applied at the national level by the DWS.

Soil and Water Assessment Tool

Changes in the land cover and land use impact on the infiltration, evapotranspiration and groundwater recharge thereby affecting the hydrological system. The extent of such impacts can be studied through models such as the SWAT. This tool has been particularly useful in determining the extent to which land use and land cover changes have affected the hydrological functions within the Olifants catchment, based on the Hydrological Response Unit as the model's operational unit (Gyamfi, Ndambuki & Salim, 2016). To run the model, the following input variables are required:

- Digital Elevation Model (DEM)
- Digital soil data
- Digital land use
- Land cover maps (Gyamfi et al., 2016).

The ability of the model to combine data from different spatial sources makes it a useful and preferred tool in catchment management. The study found that a reduction in grazing land and increase in agricultural land led to the subsequent increase in surface runoff. Such results can then be used in catchment management strategies to counter the impacts of the increased surface runoff and implement intervention measures. This function is a useful characteristic in the proposed ICM approach in that it allows for the analysis of the land use and water resource interaction, which will then be augmented with other tools.

Water Resources Simulation Model 2000

Developed to simulate hydrological processes, the Water Resources Simulation Model (WRSM) 2000 has found widespread use in the modelling of a number of catchments in Southern Africa, including the Olifants catchment. It consists of five core modules that are independently programmed (runoff, channel, irrigation, reservoir and mining). Within each module, one or more hydrological aspects can be simulated and the tool has been upgraded to also include the surface/groundwater interaction. Over time, the model has been enhanced and improved to result in three versions, with the latest being the WRSM/Pitman version 2.9. The different modes or scenarios of the WRSM 2000 can be linked to simulate an entire basin's hydrological state. Some of its more common uses are determining reservoir yields, water resources assessments and as an input to other models (Middleton & Bailey, 2008; Bailey & Pitman, 2012). In the consideration of the proposed ICM source to receptor solution, WRSM 2000 provides a good launching pad for a holistic platform. This is due to the fact that one of the key objectives of this study is to integrate other processes outside of hydrological processes such as social, political and economic processes that have substantial bearing on a catchment's hydrological functions.

MIKE- SHE

The MIKE-SHE model (Figure 4.2) simulates groundwater and surface water flow. It is an integrated hydrological system that takes into account and integrates groundwater, surface water, evapotranspiration and recharge. This model was designed to fill the gap left by traditional models. Graham & Butts (2005) observed that traditional groundwater and surface water models were not designed to answer questions related to conjunctive use of groundwater and surface water, water quality impacts of surface water on groundwater, impact of land-use changes and urban development on water resources, and floodplain and wetland management. Instead, fully integrated hydrologic models of the watershed behaviour are required.

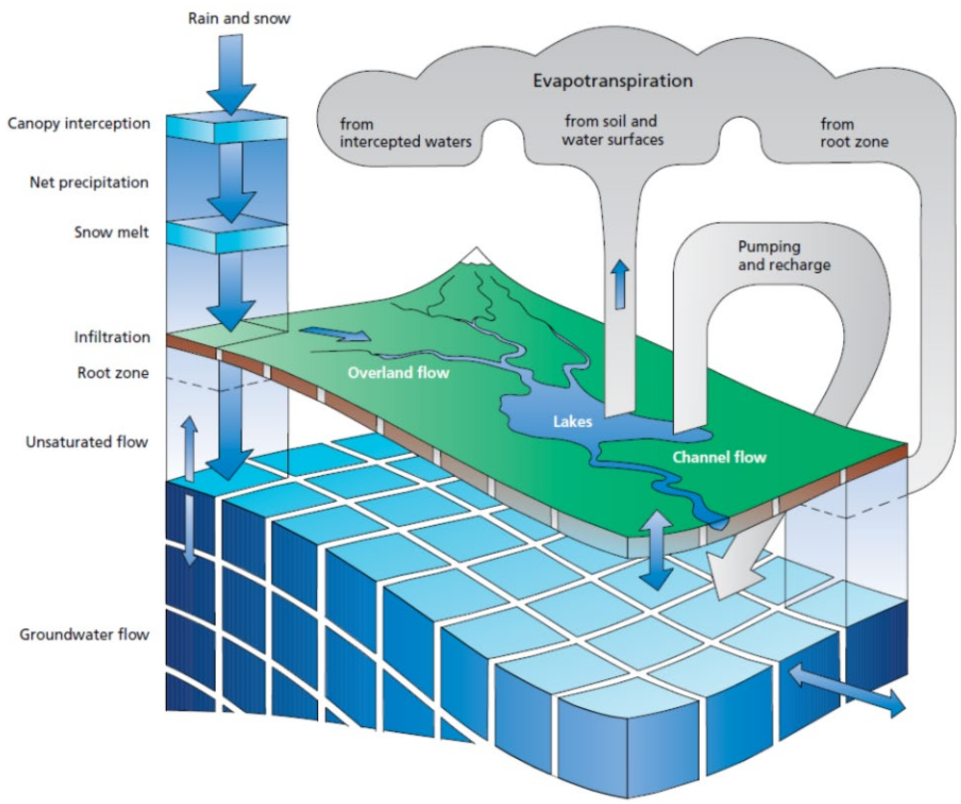

Figure 4.2: The MIKE-SHE hydrological model conceptual framework (Graham & Butts, 2005)

The MIKE-SHE was successfully applied for the Makolo River Catchment, a tributary of the Limpopo. However, the model is reliant on characterisation of available data to effectively conceptualise the system. The input data required includes climate data, groundwater pumping (irrigation and dewatering) data, artificial recharge, river operations, subsurface flow data (geology, stratigraphy, surface soils, topography, hydraulic properties, subsurface utilities), surface water flow system data (land use, vegetation, drainage diversions, etc.), subsurface flow data (groundwater recharge, soil moisture, etc.), and surface water data (evapotranspiration, infiltration rates, base flows, overland flow, etc.). The study was limited by a data gap in the catchment, particularly for groundwater flows, which affected the characterisation of the catchment (Prucha, Graham, Watson, Avenant, Esterhuyse, Joubert et al., 2016). The MIKE-SHE, to a large extent, addresses the interaction of physical processes in the hydrological system and allows for decision making based on these simulations, however, as with hydrological models, the critical areas of social, political and economic characterisation of a catchment are not included in the model, but are deemed important in the overall execution and implementation of ICM.

4.2.3 Hydrology and geohydrology tools and methods

While the connection and intimate interaction between surface and groundwater may be obvious, there is a tendency to separate the two systems, both strategically and operationally. The dependency of groundwater on surface water recharge and of surface water on groundwater is a vital relationship. As a result, most water resource assessment models are taking into account this interaction, e.g. in the WRSM2000/Pitman. However, there are other systems, particularly for groundwater monitoring, and these are briefly described here with respect to their overall contribution to the ICM objective.

National Groundwater Information System (NGIS) – DWS

The NGIS is composed of a suite of tools that are integrated to present information on groundwater availability and abstraction level across the country (DWS, 2018). The suite is composed of the National Groundwater Archive: Repository for geosites (boreholes, springs, wells, etc.). The NGIS is readily available on the DWS website and can be accessed by interested parties. One of the aims of achieving a successful ICM implementation is to have access to information, and such systems support this aim.

Geological Society for South Africa (GSSA)

This society promotes the study of earth science and publishes a journal on the groundwater studies (*South Africa Journal of Geology*).

SADC Groundwater Management Institute (SADC-GMI)

The SADC-GMI is an organ of the Southern Africa Development Community and its main aim is to ensure sustainable management of groundwater resources in the SADC region. Part of its main activities includes maintaining a database of hydrogeological activities in the region through the Groundwater Information Portal (GIP). Information contained in the GIP includes maps, boreholes data and other supporting information on climate droughts. The institute is currently overseeing a project to capacitate SADC member states in groundwater and data collection and management. The Institute is also focused on conjunctive use of ground and surface water where both sources are harmoniously used in a catchment setting to optimally manage supply and demand.

4.3 Environmental management and climate change in ICM

4.3.1 Environmental management

Integrated catchment management takes place within an environment that consists of land, water and the atmosphere as the media. Ashton (2010) observes that managing water on catchment level should acknowledge that any action in one part of the system, whether the land, water or atmospheric aspects, will have implications for the others. However, most scholars tend to separate the atmosphere from being an active component of water management and part of the environment in which ICM takes place. Fenemor, Young, Bowden, Phillips and Allen (2011) observe that land use and land cover are intractably linked to water resources and integration in water resources seeks to manage water along a catchment as an ecologically appropriate spatial unit. A catchment is indeed a piece of land but there's a tendency to separate land units depending on uses when in fact land uses are uses on the catchment. Ashton (2010) observes that the narrow segmentation of functions and responsibilities between different government departments, and the lack of effective inter-departmental collaboration, resulted in restricting the Water Department in water resources. In that domain, the DWS cannot account for the land-based activities that affect the water environment through effects on quality as well as other water resources characteristics. However, water cuts across many sectors and legislation pertaining to its use and governance also cross sectoral boundaries. As such, various role players in different sectors have different aspects of water that they have to deal with, especially where water and other parts of the water environment are concerned.

Where integrated catchment management is considered, it is important to ensure that the concept is understood in its completeness. Very often a two-dimensional plane that focuses on aspects of the atmosphere together with water and land aspects is given, an approach that neglects the third dimension, that of groundwater beneath the land. The definition of ICM by Fenemor et al. (2011) provides the dimensions sought in this comprehension. Fenemor et al. (2011:307) define ICM as a "process that recognises the catchment as the appropriate organising unit for understanding and managing ecosystem processes in a context that includes social, economic and political considerations, and guides communities towards an agreed vision of sustainable natural resource management in their catchment". It is important to note that ICM is an ecosystem issue dealing with management of natural resources in a spatial unit defined by catchment boundaries rather than being just a water issue. Ashton (2000) blames the Department of Water for the lack of shared understanding of exactly what ICM really is, or could be, which has resulted in a rather ad-hoc approach that focuses on specific hydrological issues. Therefore, it is important to consider that ICM is not just about water but includes the management of other resources within the catchment (Fenemor et al., 2011). These main elements are defined by several other characteristics, which include the following:

- Air, land and water degradation (pollution, eutrophication, erosion, soil leaching, sedimentation)
- Ecosystem balance (natural balance, sustainable balance, a balance influenced by land uses)
- Human influences to the environment (land uses, urban, rural, Environmental Impact Assessments (EIAs), environmental rehabilitation, air pollution, soil and groundwater pollution)
- Ability of the environment to purify or renew itself following degradation
- Climatic influences to the environment

The ICM repository approach proposed in the study thus seeks to build the holistic ICM approach that recognises the environment in which ICM takes place as being constituted by the atmosphere, land and water, both surface water and groundwater. In the methods, the gaps in legislation, institutional arrangements, organisational mandates, as well as the restrictive systems that separate the roles of institutions, will be explored and accounted for.

4.3.2 Climate change

Temperature change as a main driver of global climate change

The earth's climate has always changed but because of human activities it is now changing faster than it has for thousands of years (United Nations Educational, Scientific and Cultural Organization, 2013). This observation, which is repeated in many other forums, sums up the threat of climate change, which is the faster pace of changes that are now threatening the natural ecosystem as well as livelihoods of many communities in the world. Africa has been identified as being very vulnerable. Niang, Ruppel, Abdrabo, Essel, Lennard, Padgham and Urquhart, (2014) observed that Africa as a whole is one of the most vulnerable continents due to its high exposure and low adaptive capacity. In addition, Africa's richness in natural resources tends to increase its sensitivity to climate and other global exposures. Adding to that, the confidence levels associated with the data from most African regions is very low due to absence of data monitoring and collection programmes. Poor data and information increase the costs involved in developing solutions for adaptation and building resilience against climate change.

The most recent climate change projections have shown that temperatures will continue to increase until 2100. Four types of projection simulations have been done using multiple global models, carried out by several different teams from Europe, the USA and Japan. The resultant sets of simulation outputs are the four Representative Concentration Pathways (RCP) (Intergovernmental Panel on Climate Change, 2013). The RCP 8.5 is the worst case scenario where the lowest effort is made to curb emissions and where consumption is relatively unchanged while polluting fossil fuel is used to power energy systems, just as is the case now. The RCP 2.6 describes the scenario in the future when the highest levels of emission reduction are developed and maintained, with emission capture being actively pursued while use of fossil fuel is eradicated. Figure 4.3 below shows that global surface temperature change will continue to increase, reaching at least 1.5°C by the end of the 21st century relative to 1850 to 1900 temperatures for all RCP scenarios presented except RCP 2.6. For most of the region in Southern Africa, which includes the Olifants-Steelpoort catchment area, the IPCC projected that the temperature will increase by 1.5°C by 2100 when compared to temperatures for the period ending in 2005. Lower temperature increases were projected for coastal areas including the Olifants-Doring catchment. These projections used averaged values from several CMIP5 models.

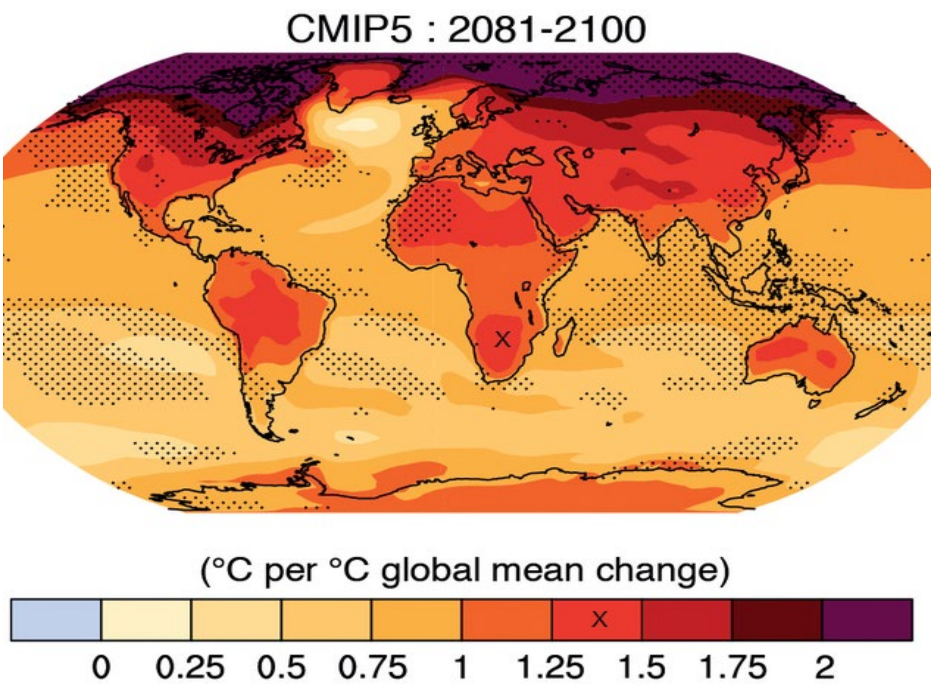

Figure 4.3: Average temperature from the period 2081-2100 is compared with the period 1986-2005 using averaged values from several CMIP5 models. (Intergovernmental Panel on Climate Change, 2013)

The RCP 8.5 global climate projections show that the mean annual global temperature is projected to increase by up to 3.4°C by the 2060s and up to 5.5°C by the 2090s. This is the worst-case scenario should the world continue with gas emissions at the same rate without slowing down. The global temperature changes for the different RCPs are shown in Figure 4.4 below.

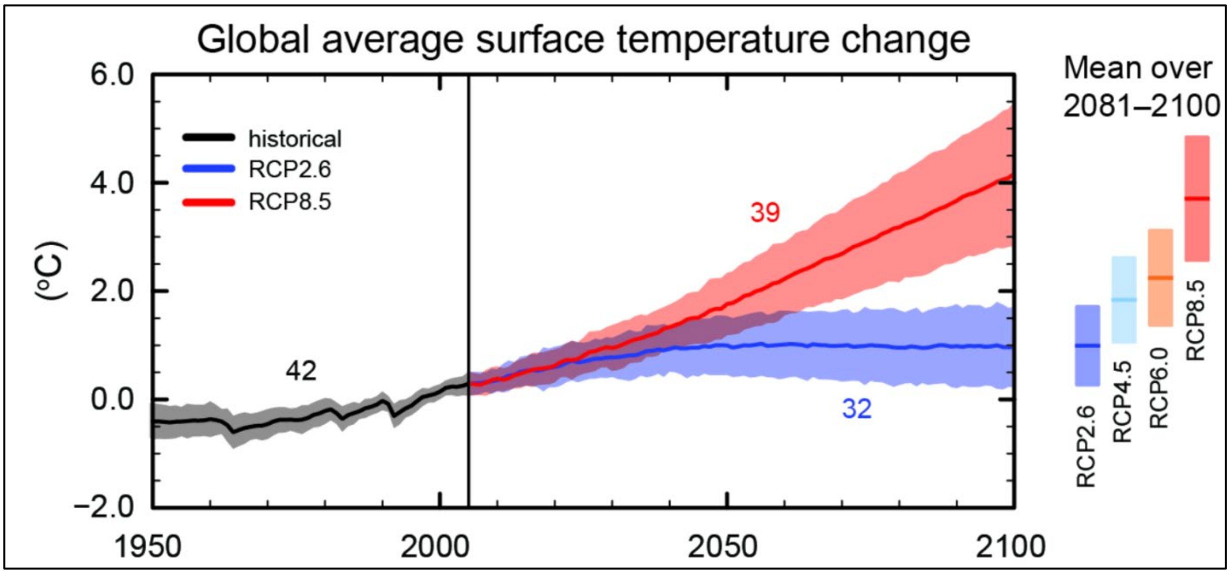

Figure 4.4: CMIP5 multi-model simulated time series from 1950-2100 for change in global annual mean surface temperature relative to 1986-2005

Source: Intergovernmental Panel on Climate Change (2013)

Primary, secondary and tertiary impacts of climate change

The effects of climate change on the water sector can be split into primary, secondary and tertiary effects. Primary effects of climate change are an increase in temperature and changes in rainfall patterns. Rainfall changes are sometimes classified under secondary impacts, since most of the changes in the rainfall characteristics are driven by global temperature change (Dube et al., 2014). However, other scholars classify rainfall changes as a primary impact of climate change (Douglas, Maghenda, Mcdonnell, McLean & Campbell, 2008). The primary impacts generate the secondary effects, such as an increase in surface water temperatures, reduced water quality due to higher dissolution of pollutant compounds, and reduction in available water due to longer dry periods in some areas (Douglas et al., 2008). The secondary effects of climate change will lead to inevitable tertiary effects, as shown in Figure 4.5.

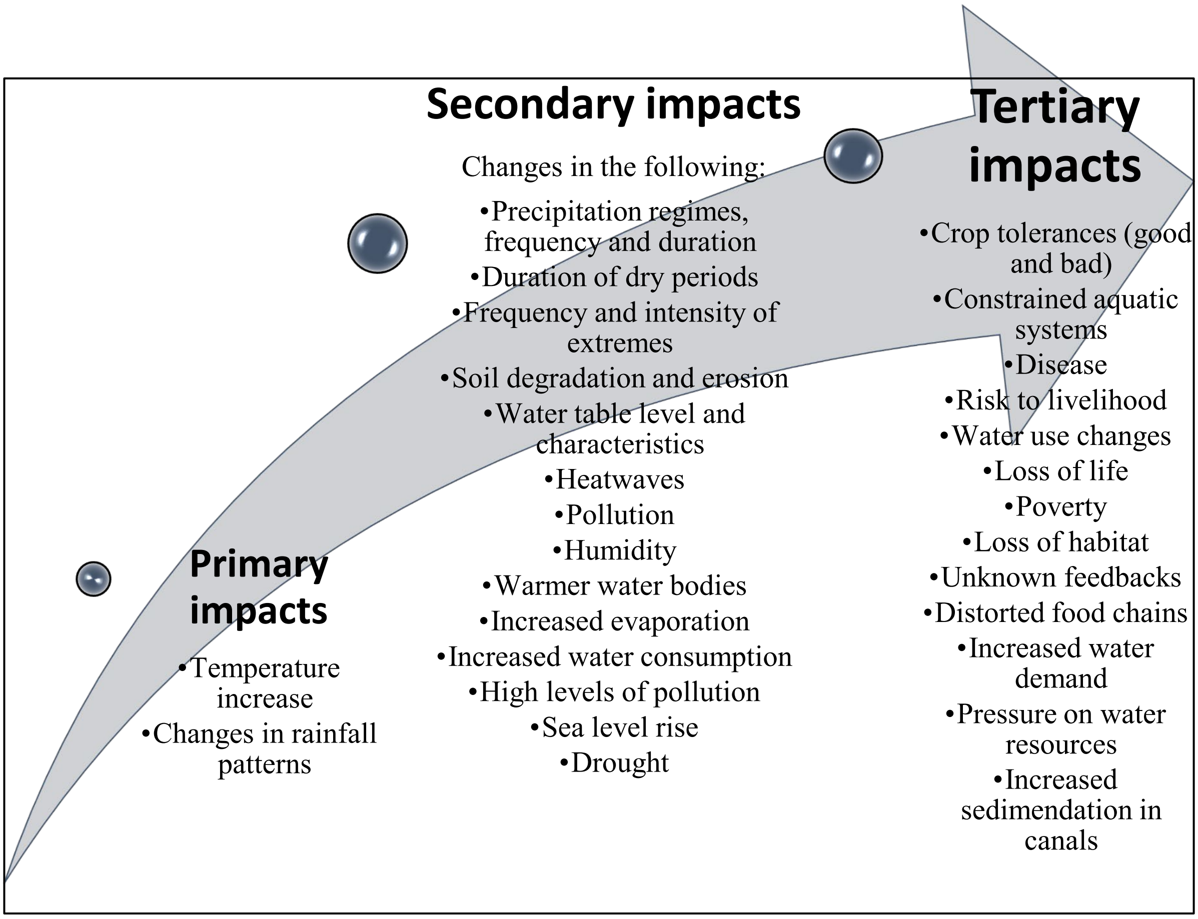

Figure 4.5: Schematic illustration of climate change impacts in the water sector, split into primary, secondary and tertiary impacts (Adapted from Dube et al., 2016).

Global Circulation Models (GCMs)

Various types of Global Circulation Models (GCMS) are used by international institutions to predict future climate patterns. While the models have been critiqued for their global scales, they are still the best in determining climate process holistically while accounting for all global influences in time. Downscaling processes in the country have resulted in products such as the South African Risk and Vulnerability Atlas (SARVA). This atlas shows SA regions and their likely response to climatic change on the basis of IPCC Assessment Report 4 (AR4) projections. In the ICM repository, tools for climate and downscaled climate modelling will be captured to serve as an information source for determining implications of climate change to various processes. Weather information will be linked to the repository by providing pointers to where it is located. The main source that the ICM will rely on is weather data from the South African Weather Services. The South African Weather Services (SAWS) has the mandate to monitor the country’s weather and climatic systems. Data obtained through SAWS is then processed to the interest of different stakeholders.

4.4 International and SA environmental goals in ICM

South Africa is signatory to the global Sustainable Development Agenda and it has set itself to the attainment of the Sustainable Development Goals (SDGs). Of relevance to ICM, South Africa is actively pursuing programmes and projects to ensure that the country achieves its targets under Goal 6 on Clean Water and Sanitation, Goal 13 on Climate Change, and Goal 14 on Life below Water. There are some characteristics that have been identified in South Africa's pursuit of SDGs that can be correlated with the situation when it comes to ICM objectives. The shortcomings of ICM identified in the past had to do with lack of coordination and integration both horizontally and vertically. In the United Nations Development Programme (2016), which came out of the OR Tambo Debate Series at the Wits University of Governance, the following observations were also made:

- There was an absence of multi-sectoral planning, which is horizontal coordination between, say, similar institutions
- It was also noted that the vertical coordination was weak such that priorities identified and addressed at the local (provincial) or sectoral level have little resonance with national priorities and policies.
- A lack of mechanisms for citizens' engagement and partnerships with the private sector was also noted as one of the historical fault lines in which the most vulnerable remained at greater risk of exclusion. In a catchment, it is still challenging to provide a meeting point, an acceptable balance between the historically advanced and the disadvantaged
- It was also observed that while there were capable institutions, the State's capacity for implementation was generally weak. The available resources could not meet most of the priorities set out in the National Development Plan.

South Africa is seen as having been instrumental in the signing of the Paris Agreement to Combat Climate Change in 2015. In recognition of this achievement, the Government of France recently bestowed on the Minister of Environmental Affairs (Edna Molewa) the honour of Officer de l'Ordre National de la Légion d'Honneur in recognition of her role in the negotiations that led to the signing of the Paris Agreement in 2015 (Department of Environmental Affairs and Tourism, 2018). The agreement tied South Africa to increased contributions to climate change mitigation with less emphasis on adaptation. Under the agreement, there is one flagship programme for the water sector response, which deals with water conservation and demand management where the DWS provides leadership (Department of Environmental Affairs and Tourism, 2016). The climate change response contributions in the water sector include rainwater harvesting and water recycling. Adaptation to climate change will also be achieved through expansion of water provision infrastructure, especially to take advantage of the increased rainfall rates that are projected in the central parts of South Africa. Expansion of infrastructure will also deal with societal inequalities by providing better access to those who are located in areas where there is no infrastructure or through accommodating more active economic contributors.

5 Land and water in the ICM inventory

5.1 Land and water use in the ICM-Inventory

5.1.1 Introduction to catchment land and water use inventory

Land Cover and Land Use (LCLU) are usually discussed together because of the common understanding they generate and their interrelatedness in use. According to Ngcofe and Thompson (2015), land cover is the physical material on the surface of the earth, while land use is the description of the manner in which humans utilise a particular piece of land cover. In explaining the most recent Food and Agricultural Organization (FAO) standards of LCLU mapping, Cumani and Latham (2015) also explained that land use is characterised by the arrangements and activities undertaken in a certain land cover type to produce change or maintain it. According to Cumani and Latham (2015), land use establishes a direct link between land cover and the actions of people in their environment (socio-economic functions). The nature of land cover and land use is determined by a variety of factors of which the most influential are climate, topography, geology, development and habitation by people and other organisms.

While land cover has a historical basis as natural, human habitation and use change the landscape over time, modifying the land cover or completely altering it to a new state. Development of reliable land cover data covering the whole country has been proved to be a great resource for spatial development, settlement and land use planning. The range of support that can be achieved from this data includes analysis of water availability and distribution networks, settlement and land use patterns, and natural phenomena such as climate change. It also provides a means to assess carbon stock accountability, helps monitor agriculture development, and also provides supporting resources for disaster management, land planning, defence of biodiversity, etc. (Figure 5.1). The data on land use changes, which is part of this inventory, is known to have attracted a wide group of users, significantly increasing the user base and generated returns on investment. A survey of data users in the European CLC2000 data inventory has shown that the use of this data has already generated €250 million of benefits from the initial investment of €13 million (Kleeschulte & Büttner, 2006). In this study the European Commission used Landsat 7 Enhanced Thematic Mapper (ETM) satellite images of the European territory to generate land cover maps covering 27 countries (Kleeschulte & Büttner, 2006). The CLC2000 was validated using the re-interpretation of the field photographs using codes from an existing European Land Use/Cover Area frame statistical Survey, LUCAS project, which covers the whole of Europe.

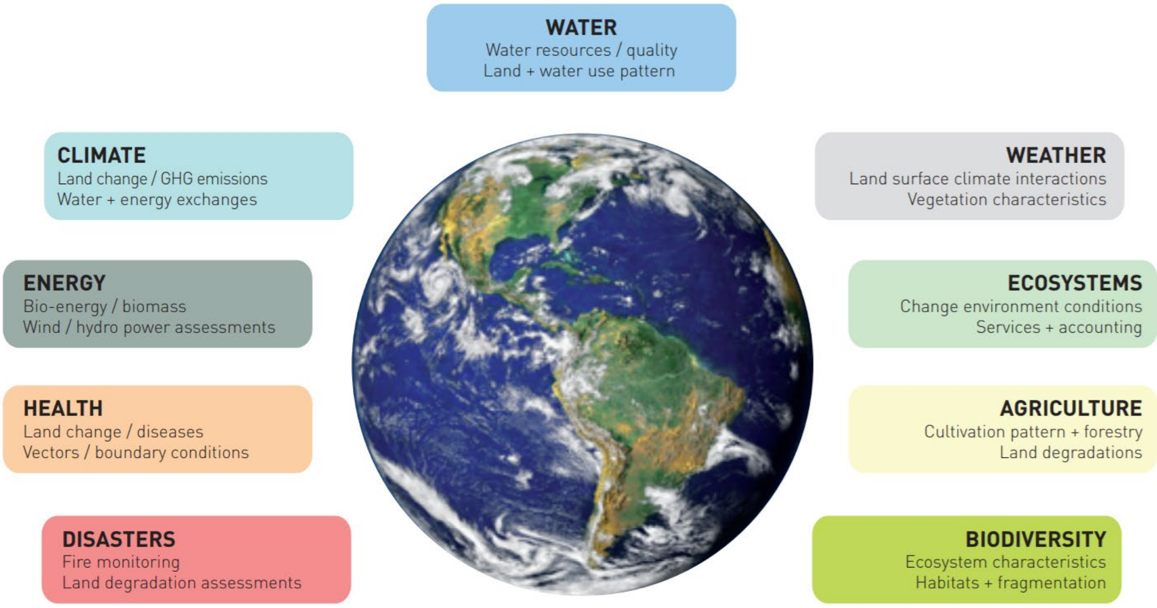

Figure 5.1: Geographical-societal benefits and land cover/vegetation observations (FAO, 2016)

The development of LCLU datasets in South Africa has been aligned to the developments that have been taking place in Europe, but the use of satellite and digital imagery has been at least ten years behind. The participation of the United Nations' Food and Agricultural Organization (UN-FAO), in the LCLU mapping in South Africa has, however, assisted in closing that technological gap, making the mapping process approach similar standards to those applied in Europe and the Unites States where Landsat imagery is also used. The first national Spatial LCLU patterns were published in 1996 and were based on the imagery obtained using Landsat, an American earth observation satellite that had been produced earlier. In this dataset, land cover data was manually interpreted off 1:250 000 scale paper image-maps, and then recaptured as a digital vector dataset comprising 31 land cover classes. This 1994 land cover was developed from images obtained from Landsat 5's missions in 1994 to 1995, thus giving the name National Land Cover 94 (NLC 94).

Ngcofe and Thompson (2015) explained that the history of land cover mapping that was based on the use of earth observations can be traced back to the 1990s; however, digital interpretations of the data only started in South Africa with the LCLU data of 2000. Later versions were produced and called NLC 2000, NLC 2005 and NLC 2013, respectively. More alignment of the South African mapping standards was achieved through NLC 2005, which was produced through the funding by FAO and would later be updated to NLC 2009. The continuity and comparability of the different LCLU mapping projects have been characterised by the use of classes that were usually different in some aspects such that some of the older data sets have continued to be useful in covering certain aspects of LCLU.

5.1.2 ICM inventory and state of land use practices in the study catchment areas

The Olifants-Steelpoort catchment

This study area is named after the key tributary in the area, the Steelpoort, also known as the Thubatse River, and falls within the Olifants Water Management Area. Other tributaries in the study catchment include the Dwars, Waterval, Spekboom, Eland and Klip Rivers. Administratively, the study catchment falls partly in the Limpopo and Mpumalanga provinces and includes the Sekhukhune settlement of the Pedi lying between the Steelpoort and the Olifants Rivers. The hydrological delineation covers the B1-B7 quaternary catchments. Considered as one of the more polluted rivers in South Africa, the Olifants River has been the centre of studies due to the impacts it has suffered from industry, farming and mining activities, which have left the river with compromised water quality and reduced water quantity. Developments that involve land clearing and invasive alien species in the catchment area have also negatively impacted on water quantity in the Olifants catchment (Morokong, Blignaut, Nkambule et al., 2016). The Present Ecological State (PES) of the Steelpoort is largely modified from its natural state stemming from the mining, agriculture and human settlements. However, the Klip and Dwars Rivers are considered to be in a better ecological state despite the impact of mining activities on the Dwars. The Verloren Vallei nature reserve in the Dwars and Klip catchments gives the two rivers high ecological importance (DWA, 2011b), calling for a greater effort to stop and reverse degradation.

The spatial area naming concept used in the study is the same as what the DWS Hydrological sections name hydrological areas. This is illustrated as follows: In Figure 5.2 below, B3 will be the Secondary drainage region number 3 of the Primary drainage region B. Tertiary drainage region number 2 will be B32, while B32E refers to Quaternary catchment E in tertiary region number 2. The region B3 is home to two large dams, Rust de Winter Dam (B3R001) and Loskop Dam (B3R002). The information on these dams is also provided in the inventory from the national dams' data files that are accessed through the dams' information access button. An illustration of the updated dams in the tertiary catchment B32 has already been covered in section 4.2.1.

Figure 5.2: Olifants-Steelpoort area illustrated according to its drainage region

In terms of legislative boundary, the Olifants-Steelpoort catchment comprises an area that is mostly the Sekhukhune District Municipality of Mpumalanga province with small portions of the catchment falling in Gauteng and Limpopo provinces. The densely settled areas in the catchment are the former homeland areas where the population dynamics have mostly remained the same over decades. These areas are characterised by unemployment, poverty, poor service delivery, as well as lack of access to other social goods such as health and education. Local municipalities in these areas are understandably overly preoccupied with the emancipation of former homelands, notwithstanding the higher than national average corruption and misuse of funds that occur within the same municipalities.

The main tributary of the Olifants in this study, the Steelpoort River catchment, is described as follows (adapted from DWA, 2011b; DWS, 2016a):

- The Steelpoort River is in a fair to unacceptable ecological state
- Overgrazing and dryland cultivation throughout the area surrounding the Spekboom, Steelpoort, Beetgekraal, and Waterval Rivers including within the riparian zone, leads to erosion, which causes high silt levels in the rivers
- High silt levels in the aforementioned rivers increases the risk of flooding and leads to the smothering of in-stream habitats and fish gills resulting in loss of invertebrates and fish species
- Runoff from mines and other activities lowers the water quality in the Steelpoort River

- The nutrients in the Steelpoort catchment are not of a major concern with orthophosphate mostly <0.05 mg/L. Nitrates are elevated on the Dwars River (9 mg/L) downstream of the Two Rivers mine, although no Resource Quality Objectives (RQOs) have been set for nitrates in this sub-catchment.
- The electrical conductivity in the Steelpoort sub-catchment ranges from 18.37 to 124.5 mS/m and total dissolved solids concentrations range from 92 mg/L to 980 mg/L (Steelpoort River at Alverton), indicating the impacts from mining. pH values are >8 in most cases tending to a slight alkaline state.
- Steelpoort mining and community water supply aquifer areas (B41J and B41K), where groundwater quantity and quality are affected, should be prioritised for action.
- Priority wetlands have been identified in the Steelpoort catchment (B41A and B41B-headwaters of Steelpoort and B41 Klip River, tributary to Steelpoort, which includes a Ramsar Site.

Olifants-Doring catchment

The Olifants River of the Olifants-Doring catchment area rises in the Agter Witzenberg on the Western Coast of South Africa. The Doring and Sout Rivers are two of the major tributaries of the Olifants. Intensive irrigation in the Olifants catchment has resulted in the river being over-abstracted, thus making the Doring an important resource for maintaining the ecological integrity of the catchment, specifically the Olifants estuary, which has high ecological value. To this end it has been suggested that no further development occur on the Doring River so as not to disturb the flows (DWS, 2015c). The Doring River supports a thriving tourism industry and its largely good ecological conditions have been responsible for the continued sustenance of this catchment. Flowing for over 200 km undisturbed, the Doring is one of the longest free flowing rivers in South Africa (Nel, Reyers, Roux, Dean-Impson and Cowling, 2011).

The Olifants-Doring catchment has a total of 88 quaternary catchments and straddles two provinces, namely, the Western and Northern Cape. The main river is the Olifants with the Doring River as its major tributary. The Olifants River rises in the mountains in the south-west and is joined by the Doring River as it approaches the river mouth in the Atlantic Ocean. The Doring River catchment is much larger but has lower rainfall averaging 200 mm and a higher annual evaporation that averages 2200 mm when compared to the Olifants River upper tributary where rainfall averages 800 mm and evaporation is 1800 mm per annum. The Olifants River generates in excess of 46% of the surface water runoff before its confluence with the Doring River. Approximately half of catchment runoff (48%) comes from the Doring River. Other characteristics of the Olifants-Doring catchment are presented as follows:

- The Doring is in a still acceptable ecological condition and contains endemic fish (e.g. sandfish) species unique to this region
- White water rafting is an important activity on the Doring River boosting local tourism
- Population growth in the area is low, and negative in some areas
- In-migration to the area is low
- Agriculture is the dominant economic sector. Growth in the agricultural sector has, however, been slow and employment is seasonal
- The needs of emerging farmers, both in terms of land and water, need to be addressed
- Education, income and skills levels in the region are low. This is exacerbated by the dominance of the agricultural sector
- Tourism represents a key growth sector
- The mining sector may grow in the future and place additional pressure on water resources.

5.1.3 Representation of water use and land cover and land use in the inventory

Water use and land use in Olifants-Steelpoort catchment

The Olifants-Steelpoort catchment has a wide range of water uses that include mining operations, irrigated and dryland agriculture, feedlots, forestry, nature reserves, tanneries, fisheries, food processing, factories, especially steel, power generation in wet and dry coal-fired thermal facilities, domestic use and recreational activities. Figure 5.3 shows the main uses recorded in the catchment. The Olifants-Steelpoort catchment is a major mining area in the country. This area has most of the coal deposits that are mined in the country, with at least 84 collieries that are currently actively mined and several other deposits that are still to be mined. There are also several coal-fired power stations in the area, which makes the Olifants one of the most important area for power production in the country. (Mining operations also play a major role in the state of water quality in the area.) Other water and land uses in the area include:

- Factories: Steel factories around Middleburg and eMalahleni
- Agriculture: Irrigation, especially in the vicinity of Loskop Dam, Steelpoort valley and upper Selati sub-catchment, as well as along the riparian areas of the Olifants River
- Settlements: Central and North western areas have several semi-urban and rural villages with dense population but relying on employment from other areas especially Gauteng and to a lesser extent eMalahleni, Middelburg and Phalaborwa
- Nature reserves: The Kruger National Park is located at the downstream extremity of the Olifants catchment area.

Several of the tributaries supplying water to many locations are perennial or at least unable to provide adequate water throughout the year. Storages are used to smoothen the water provision gaps, which are otherwise a major characteristic of the very variable hydrology. There are at least ten major dams in the catchment and numerous other medium and small dams. The data on all the dams in the area, together with the GIS representation of these, is provided in the accompanying ICM Repository software in this project.

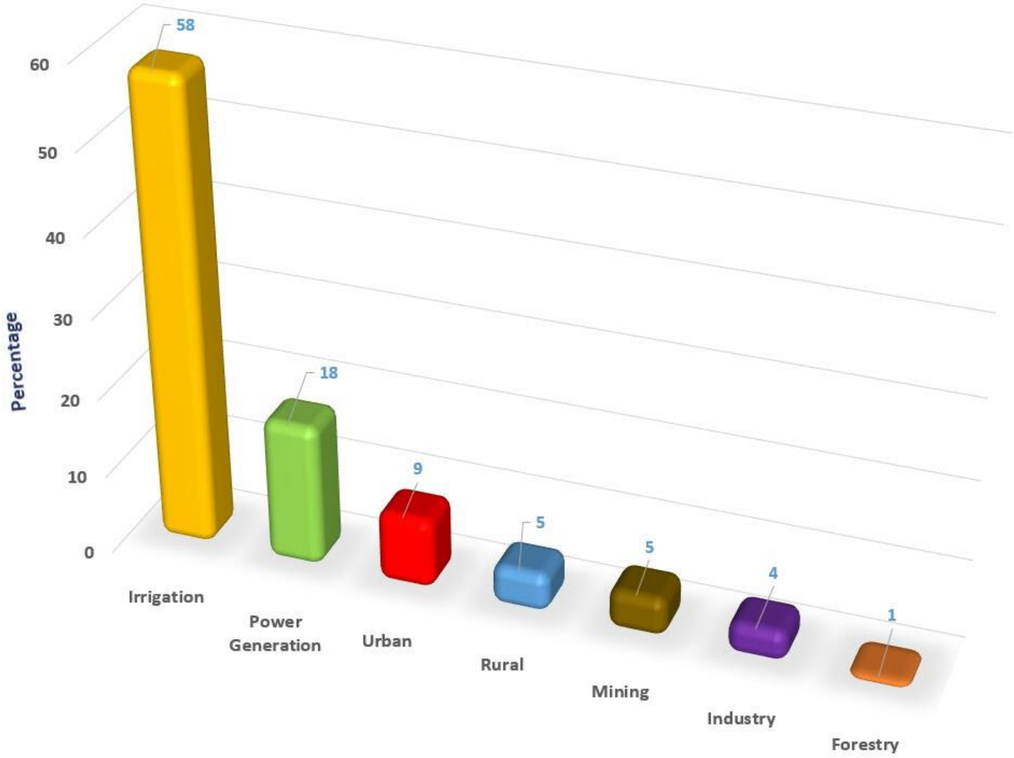

Figure 5.3: Water use statistics in the Olifants catchment area (Source: Republic of South Africa, 2017)

Water use and land use in Olifants-Doring catchment

The nature of uses is mostly influenced by the available resources and the history of the catchment. The location of the Olifants-Doring catchment in relation to the Cape Town area, which was the first point of entry of the European settlers, placed it in the areas that would be settled by the early colonial farmers. Indeed, the water use is dominated by farming, which uses at least 98% of water used in the catchment area (Figure 5.4). This catchment area is known for intensive private commercial farming with a special focus on high value crops such as the table grape varieties that require much irrigation. However, there are other uses such as hydro power, industry and mining where a smaller percentage of the water is used. Rainfall in the area is very variable such that commercial farmers have to rely on irrigation using stored water to ensure stable levels of production. Their main source of water is the Clanwilliam Dam, which is currently being raised to increase its capacity and water yield in the area.

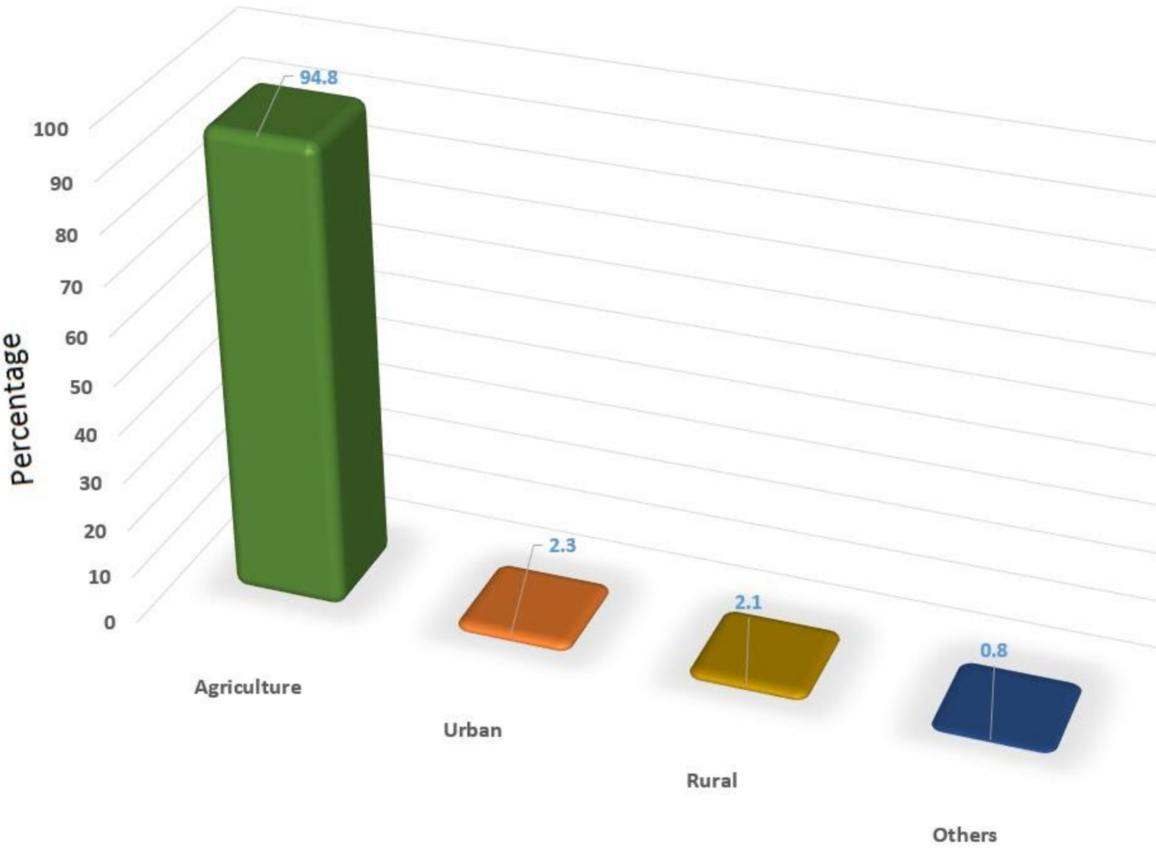

Figure 5.4: Water use in the Olifants-Doring
(Source: Calculated and drawn from data in Republic of South Africa (RSA), 2017)

The catchment area is described as over-allocated with water needs exceeding available water. The Olifants-Doring water requirement is estimated to be 373 million M^3 annually when water yield in the catchment is only 335 million M^3. The shortfall is supplied from water transfer especially from the Orange River. Groundwater is also included in the calculations. Due to many years of abstraction, groundwater volumes are now generally lower than they were in the past for some quaternaries and there is sea water intrusion in coastal areas close to the Atlantic Ocean. This reduces water availability. The sea water intrusion has decreased the volumes of potable water in areas around Sandveld and Matzikama Municipality. The cost of water has escalated in cases where costly distillation and reverse osmosis water purification plants have to be used, such as in small towns around the Matzikama Municipality. In the Hantam Municipality, which lies further upstream in the Olifants catchment, water access is also a challenge due to very low average rainfall and a persistent drought that has left the groundwater resources diminished. The Hantam municipal water provision is dominated by both surface and groundwater resources. Surface water resources have been less reliable due to high variability in the recent past, and have thus affected water use and restricted potential for development (Hantam Municipality, 2018).

While the area also has a high potential for groundwater use at present the available resources are mostly surface water that contributes at least 266 Mm^3 out of the 335 Mm^3 that is available as yield in the catchment. The yield of 335 Mm^3 was derived after accounting for the ecological reserve and river loses (DWA, 2012a).

5.2 Water quality degradation and loss in the economics of ICM

Ideally, an ICM approach that accounts for sustainability in land and water has to address resource degradation of which vegetation, soil and water are three biophysical components (Mambo & Archer, 2006). Codjoe (2007) explains some methods that take advantage of satellite and remote sensing in understanding land cover and land use changes such that the progression of degradation in catchments can be accounted for, quantified and analysed. He explains that the improved precision in GPS and remote sensing data can assist researchers in unravelling the processes that drive the cycle of land use change and resource degradation. Apart from mapping the degradation in the catchments using remote sensing and other satellite tools, the same tools can be used to track the changes in population. Studies of population density using remotely assessed concentration of housing units have been observed to be aligned to the extent of degradation experienced in resources. Codjoe (2007) points out that as the population increases, there is a correlation with the increases in settlements, cleared land for farming and settlement, increased wood cutting as part of land clearing, fire wood and other logging practices.

Land cover changes have been noted to have an impact on spatial and temporal distribution of environmental resources. The ecosystem composition is also altered and productivity of land is lost (Mancino, Mole, Ripullone & Ferrara, 2014: 75). Different methods can be used to detect these changes as well as potential land degradation. Mambo and Archer (2006) discuss Change Vector Analysis as one technique that can be used to detect any changes on land use. They discuss two types of change detection methods; one a comparative analysis of independently produced classifications or simultaneous analysis of multi-temporal data (Mambo & Archer, 2006:382). Mancino et al. (2014) discussed Normalized Difference Vegetation Index (NDVI) (or change vector differencing), a method that uses Landsat Thematic Mapping images. This method can detect the differences between human-induced and natural forest cover, as well as the changes due to season, and in that way, patterns can be drawn on vegetation cover changes.

5.3 Role of politics in land and water components of the ICM inventory

Politics concerns itself with an array of issues and is “at the heart of all collective social activity, formal and informal, public and private, in all human groups, institutions and societies” (Leftwich, 2004, in Heywood, 2013:9). South Africa’s history of colonisation and apartheid has left a legacy in which water management today is not only a social, economic and environmental issue but is highly political. The earliest political developments by the European settlers were around water. It is reported that the early settlers of 1652 stopped over in Cape Town to collect water and wood for their ships as they sailed to India from Europe. They would later settle to increase the amount of supplies through farming close to the coast. As such, some of the early legislation in the country dealt with how water was to be used, shared and protected. Fontein (2008) explained how water engineering was used by the European colonial settlers and postcolonial white Africans as “a mechanism for inscribing legitimacy, even white autochthony into the landscape”. Water is indeed a political issue (Jankielsohn, 2012) and its management therefore needs to be understood in that context.

Tewari (2009) explained that the development of water law in South Africa should be understood within the context of conquest and colonisation. South African water laws evolved in a period that was mired by inequalities, segregation, as well as a mentality to extract resources without regard for the need to protect the ecosystem. Like other legislation in the country, the pursuit of segregation in the colonial and apartheid administration of the country dictated who would benefit from the legislation (Turton & Meissner, 2002), rather than defining legislation that was good for all citizens. It is within this context that the political development in the country evolved over hundreds of years to end up with the basis for present water legislation, as well as the water management practices that are experienced today.

While water management practices in the country view ICM as the ideal way of managing water, Ashton (2000) explained that South Africa has opted for a version of IWRM, which is more practical, given the available institutions, the legal framework, as well as the governance systems. He pointed out that the background of South Africa as a country where the political environment was such that communities were hardly consulted meant that “in many cases, the public were informed of impending management actions on an ad hoc basis, rather than participating in a management system based on shared responsibility and joint decision-making”. He found this lack of participation of stakeholders in decisions about their own water issues as one of the impediments to the full realisation of ICM. Reports from Water User Forums, for instance, indicate that the political environment still operates on binary terms whereby the previously advantaged individuals continue to enjoy privileges in terms of water access rights and decision making, and civil society is not necessarily united under the same goals. This thus refutes the Lockean philosophy as discussed by Turton and Meissner (2002) where civil society participates equally in a democracy for the achievement of equitable redistribution or environmentalism.

The NWA provides a basis for the participation of all stakeholders through the intention to devolve water management practices from a mostly top down system to a system where there is more water management at catchment level. However, developments or lack thereof have resulted in a situation where the proposed catchment management system has mostly failed to take off over the period of approximately twenty years, starting in 1998, when all CMAs should have been established. Other areas that have been identified as shortcomings before ICMs are to be fully realised also have a background in the politics of the country. These are the institutional and legal frameworks. Of importance in the legal framework is that, while water management is to a large extent taking place on land, legislation on land is completely outside the provisions administered by the water sector institutions, including the government DWS (Ashton, 2000).

The structures defined for water management in catchments contemplate a level playing field where the rights of all citizens are respected, where they can all participate in the management of the common resources including water. Given the current inequalities in access to water and land, this is not practical. The past provisions of water access have focused on basic water services and excluded addressing inequalities in access to water for economic activities. The settlement patterns also continued to ensure that the past patterns are maintained such that those who were in locations where it was difficult or where there was no value in obtaining water are still experiencing the same constraints. For these patterns to change, there should a political will to address the gaps and constraints in the current legislation framework. Although legislation plays a vital role in a nation’s water management, the country’s current water legislation and water management practices are dominated by statutory law (Kapfudzaruwa & Sowman, 2009). This has a direct impact on how different societies within a catchment appreciate their water management system as part of their cultural system (Newson, 1992:2), or as foreign principles enforced on them. More details on the legislation, and how it influences the practice of ICM in the country are covered in section 6 of this project report.

6 Legislation, policy, socio-economics, institutions, and stakeholders in holistic ICM

6.1 Legislation in the ICM inventory

6.1.1 Legislation as the basis of ICM

Legislation is often associated with developing and enabling the environment, however, from another angle it is also an approach that legalised and formalised practices that were detrimental to the environment, including water. In South Africa, some of the first records of disruptions to the naturally sustainable ecosystem come from the recordings of the establishment of the Dutch East India Company in Cape Town. The single issue that started water legislation was a response to a case of pollution. Magoba and Brown (2009) reported that the first environmental legislation was passed in South Africa in 1655, following the outbreak of an illness that affected ship crew members who had taken water supplied from the Varsche River. The river water was being used to replenish the Dutch East India Company ships. This first environmental legislation within South Africa was in the form of a *placcaet* issued on 10 April 1655 (Tewari, 2009) (*Placcaet* is a decree or declaration of a regulation in early Dutch law). This first *placcaet* prohibited upstream water pollution especially bathing and washing personal belongings in the river. While protecting the water in what was defined as upstream, it formalised pollution in areas that were regarded as "downstream". This was only downstream in terms of the location of where the early settlers obtained their water from the river. Several other *placcaets* were subsequently issued to manage the ownership and the sharing of water between farmers. Again, these *placcaets* formalised a certain way in which certain people could own land and water access at the expense of several other water users that included nature and indigenous people. The interpretation of the role of legislation in any field including the water sector is dominated by those who establish the laws and benefit from these laws. In water management, the law has historically benefited white people and indeed, systems developed on the basis of these laws are aligned to continue with this legacy unless decisive steps are taken to abandon the established path and actively seek redress. Indeed, the ICM approach discussed in this study is an attempt at wrestling an established way of water management using concepts that are predominantly part of this is establishment. As a result, the prospects of integration in the proposed water management approach that involve both water and land focuses remain challenged.

6.1.2 Water legislation framework

The UN Dublin principles guided water legislation in the later part of the twentieth century. The recommendations from the International Conference on Water and the Environment in 1992 (Dublin principles) encouraged the development of IWRM (Global Water Partnership, 1996). Three principles underpin IWRM:

- Social equity: ensuring equal access for all users and focus on women and other marginalised groups
- Economic efficiency where water was recognised to have economic value
- Ecological sustainability – where management and use of water recognises nature as another important user.

In South Africa, the UN Dublin Principles generally set the basis for the practice of water management. Ferrier, Jenkins and Blackstock (2009) discussed the transition from a global focus on IWRM to ICM and pointed out that in the recent past, growing economies were placing increasing demands on regional resources such that the management of water alone without considering the land dynamics was no longer addressing the pertinent issues or yielding sustainable solutions. The South African water legislation was developed in 1997 and 1998, which explains the clarity in which IWRM is addressed, and it was during this period when ICM was developing that is noted from the provisions that address the water management at catchment level.

6.1.3 Shortcomings in the legal framework for equitable access, allocation and sustainable use of water

Following the promulgation of the NWA in 1998 (RSA, 1998), South Africa initiated programmes that were targeted towards aligning the water sector to the provisions of this new legislation. These programmes were guided by the intention to address the following:

- Water is a natural resource that belongs to all people
- The racially discriminatory past of the country was supposed to be dismantled in the water sector
- Government was to be responsible for water reallocation, its use and management
- Beneficial use by all users, while recognising nature and pollution as a use among many other previously recognised uses
- Embracing IWRM and where applicable, delegating management functions to the catchment level.

Furthermore, the Water Services Act (WSA) provides a regulatory framework for the provision of water supply and sanitation services to which people are entitled. It specifically provides for the rights of access to basic water supply and basic sanitation and because municipalities must fulfil their duty to provide water and sanitation services to their communities.

While the guiding principles in water management, as provided for through the legislation, received much positive feedback from the international stage and even locally, there has been intense debate in recent times regarding questions around whether it was achieving or enabling what it set out to do (Movik, 2009). The WWF described the NWA Act as very progressive with provisions to address the needs of nature and provide basic water for all. It also points to the difficulty that was being experienced in providing water to rural communities and informal settlements in the urban areas (World Wide Fund [WWF], 2016). The WWF also raises questions regarding the potential of the country to provide water to the growing population. Schreiner (2013) also observed that the NWA was hailed by the international water community as one of the world's most progressive pieces of water legislation, and a major step forward in the translation of the concept of integrated water resources management (IWRM) into legislation. However, its implementation has been weak and, in some cases, unsuccessful. There is growing evidence to suggest that there are some aspects of the NWA that are to be blamed for the failure to ensure proper management of water resources in the broader sense, especially related to the failure to implement transformation of the water sector as well as to establish the various institutions that are required to apply the water legislation. As such, this section intends to examine and unpack some of the shortcomings in the NWA, which are a hindrance to the equitable access of water by all racial groups.

Some of the shortcomings of the NWA, which have been advanced, include the following:

- The water legislation was developed on a foreign legal system that was developed in a European eco-system. This system does not exist in South Africa. The country is dry and suffers from water scarcity which is exacerbated by very high rainfall variability. In addition, the country's history is dominated by racial discrimination in provision of all resources including water.
- Important institutions which were supposed to be developed to apply the Act were never fully developed
- There is much confusion regarding the establishment of CMAs, many options that were initiated were never implemented and there are even new suggestions for a single CMA
- Irrigation boards were to be transformed to WUAs that would embrace all water users in a catchment, but this has mostly failed to be implemented

- Decisions on managing water resources infrastructure have not been finalised in the last 26 years. An infrastructure agency that was planned in the 1990s is still in the planning stages more than two decades after the ideas were included in water sector planning.
- While the NWA and the WSA are all for transforming water access and bringing about equality through redress programmes, these legal tools enable a situation where water access is still distributed along racial lines without penalising the failure to transform
- Licensing of water use is progressing at a snail's pace with some licences taking more than ten years to be issued
- Registration of existing water use is also incomplete and riddled with errors, making water use charges difficult to implement
- Water provision is divided into basic water, which is mostly being provided to black people, and water for productive use, which is benefiting white people
- Protection of aquatic ecosystems has been impossible resulting in continued degradation of water systems and distraction of aquatic life in some waterways
- There is no incentive to get water users registered and licensed which would improve water allocation and management. The NWA makes provisions for financial compensation if water rights which fall under ELUs are lost but the same Act does not make similar provisions for loss of rights in licensed water. In addition, ELUs have no limiting time frames while new licenses are restricted by timeframes.

The equitable allocation of water for economic use, since it is fundamental to all aspects of integrated catchment management (ICM), is not implemented in practice. Equitable allocation was central to the formulation of the NWA given historic injustices in the way in which water and land resources were allocated. It would seem that the main thrust of the South African National Water Act (RSA, 1998) therefore, was to redress water allocation inequities in a way that enables all racial groupings to access and use water for productive purposes (Goldin, 2010). However, two decades since adoption of the NWA, the allocation and water rights of water for economic use has not substantially changed in South Africa. The pattern of water rights across racial groups shows that more than 90% of water by volume is available to white people in the pattern similar to that which existed during the apartheid era. This suggests that there are issues in the water reform policy that were not dealt with properly.

In the case of Inkomati Water Management Area, Movik (2009) argues that the entrenchment of existing users in the interests of "sustainability", the increasing technocratic approach to redistribution, and the social dynamics and discourses at the regional and local levels narrowed down the room for manoeuvre, resulting in the water allocation reform ending in a temporary impasse. Reflecting from this scenario, it was clear from the beginning that the desired outcome of the water reform could not be achieved, as the Constitution did not allow much flexibility for redistribution. The mechanism to which land and water resources were dispossessed in South Africa was very radical, shifting everything to the ownership of white people and consequently leaving black people owning nothing.

The provisions for redressing water access equality are also restricted by provisions in other legislation, especially around land and expropriation rights. There are several legal instruments on land, which are at the core of the problems encountered in transforming the water sector. At the fore is the attachment of land to water access rights. This provision, also known as the riparian water right, was formally established in the 1956 Water Act even though it had existed since early colonisation 350 years before. The NWA took with it all the rights for water access as allocated or provided for in the 1912 Irrigation Act as well as in the 1956 Water Act. These water access rights were defined as ELUs in the NWA and they were protected, requiring that they be converted to water use licences. In this way, all the riparian rights became part of the Act and with their nature as being associated with land, they brought with them the architecture of colonial land legislation.

One of the instruments used to try to redress water allocation inequality was the redistribution of formal water use rights, primarily through the process of compulsory licensing (Anderson, Eiman & Stefano, 2008; Movik, 2014). Essentially, this required all current and future water users for productive purposes to apply for a water licence. However, the legislation did not deal specifically with how exactly the water rights should be re-allocated in practice (Perret, 2002). At the same time, both water and land reform were initiated and implemented as two separate processes, without coordinated effort to ensure that the two processes complement each other. The NWA separates ownership of land from ownership of water (riparian rights) therefore making it difficult to integrate the two separate but connected processes for transforming access to resources. The transformation of water for productive use is directly encountered every day in the provision of water for agricultural users including smallholder farmers, which is the type of farming that is associated with black farmers. The new entrants into farming usually find themselves with the land but without the water for farming.

The licensing process involves allocation of water along volumetric quantities. While this licensing process is set to enable the state to set aside water for basic needs and ecological purposes, there are usually challenges associated with it because most catchments are fully committed; their water is fully registered to existing users through ELUs and the allocation for basic uses. As a result, the emerging farmers do not necessarily get automatic access to water even when they now have occupied the farm.

In addition, Movik (2009) argued that vesting the state with the discretionary power of determining use rights led to the emergence of “allocation discourses” that were also deeply influenced by the particular political context in post-apartheid South Africa. The system has been long manipulated to adversely affect redistribution. The mistake was also that the overriding notion of achieving equity was subsumed by framings of socio-ecological-technological dynamics that represented redistribution as a potential environmental risk, and presented the continued use of already privileged users as vital to sustain South Africa's economy (Movik, 2009; Denby, Movik, Mehta & van Koppen, 2016). With such framework in place, nothing much can be done to advance reform, but it rather sustains the past system of white privilege in owning most of the water. Although the Water Act specified that its purpose is underpinned by principles of equity, efficiency, sustainability, and stakeholder representation, the increasing technocratisation of the policy process, the failure to deal with local dynamics, and the inability to determine the extent of existing users contributed to leading the reform efforts into an impasse (Chikozho, 2005; Movik, 2009). Arrangements to enforce a compulsory licensing mechanism, whereby all the users in a specific area were to be cancelled, and a new reallocation process to be started according to the criteria of equity and efficiency set out in the Act (section 27.1b) has not materialised. This situation essentially serves the interests of large-scale white commercial farmers whose families obtained water permits during apartheid rather than those of emerging black farmers.

Policy makers and practitioners have to revisit the water reform programme model and ensure that the existing gap is closed. Many studies acknowledge that efforts to implement the NWA and sustainable water resources management in South Africa have been fraught with challenges. As the current policies are formed based on the negotiated nature of the settlement guided by the Constitution, it would be difficult to make progress towards equitable access and management of water resources for all citizens. It can be argued that at no stage was the legislation intended to enable the reallocation of water access rights to black communities. This is worse so because, unlike land, a beneficiary of water access rights cannot sell this right if he does not need it. The question that then arises is when can a potential new stakeholder in water for productive use become a beneficiary of water access rights if he cannot buy the water access right and if he cannot rely on the contemplated water access reform which has not been taking place? The process was rather meant to maintain the previous economic system, including upholding private property "rights" through section 25 of the Constitution (Movik, 2009). Noting the fundamental right to access adequate water of a quality fit for human consumption and productive use, the Human Rights Commission (HRC) finds that the water user licences, as provided in current water legislation, must be reviewed to allow for rights assertion where terms and conditions of such water user licences can reasonably be anticipated to adversely impact the rights of affected communities to access water (SAHRC, 2018).

6.1.4 Shortcomings and opportunities in the water sector policy

South African water policy has developed in an environment that is characterised by the challenges encountered as well as the interpretation of these challenges as observed by decision makers. South Africa is a water-stressed country and is facing several water challenges and concerns, including security of supply, environmental degradation and resource pollution. Thus, national water resource strategies are being developed to enable the provision of basic water services to every citizen, while meeting the needs of economic growth without threatening the environmental integrity of water resources. While water management principles are being applied based on universally developed approaches, the South African case is unique in a variety of ways. On the fore is the need to redress inequalities of water allocation, which were formalised through the apartheid government ideology of the past and followed by the changes in the political environment that saw government interests, extending to cover the rights of all citizens. The country's water management must appreciate the character of prevailing socio-economics in which high levels of poverty prevail and where resource deprivation among the majority of its citizens is the order of the day. The nature of rainfall, which is generally lower than world averages, highly variable patterns of geography, a wide range of land use patterns as well as unique community interest are also other factors that are important in accounting for holistic water management in South Africa. As directed by the National Water Act, any strategy that seeks to manage water resources should do so based on ensuring equity, efficiency and sustainable management (RSA, 1998). Although South Africa is known to be a water scarce country, water challenges that the country is facing are not entirely about physical availability, but involve social, political and distribution issues on top of wide-scale water quality challenges.

The water policy strategies are also influenced by the fact that the NWA does not explicitly mention ICM but recognises the need for the integrated management of all aspects of water resources, which has been the basis for IWRM. It, however, dwells on the management of water at catchment level, which, together with the other provisions around ICM, constitute a comprehensive set of guidance for ICM. Although the water management approach presented in the NWA recognised the delegation of management functions to regional or catchment level to enable all stakeholders to participate, it failed to recognise the need to integrate the land management along with water resources. In addition to integrating land and water, the IWRM framework also had problems integrating natural territorial river basins with administrative organisations, and more importantly, political participation and behavioural considerations in the planning process (Wescoat Jr, 1984).

Chapter 2 of the National Water Act deals with the development of strategies to facilitate the proper management of water resources. The first part gives the Minister provision for the establishment of national water resource strategies to provide the framework for the protection, use, development, conservation, management and control of water resources for the country (RSA, 1998). According to Biswas (2004), the IWRM strategy promotes the devolution of decision-making powers to the lowest possible level (the principle of subsidiarity) and argues the case for market-oriented solutions to allocating water resources, while simultaneously advocating for a holistic and integrated management that necessitates greater bureaucracy and centralisation. They may also be controversies involving contestation of the rational techno-centric approach by various stakeholders, mainly in the instance where competition for water resources allocation is high.

The NWA further provides the framework within which water is managed at regional or catchment level, in defined water management areas. The second part then requires every catchment management agency (CMA) to progressively develop a catchment management strategy for the water resources within its water management area. The catchment management strategies should be in line with the national water resource strategy. In accordance with the principles of ICM, catchment management agencies should essentially seek cooperation and agreement on water-related matters from all stakeholders and institutions. However, the ICM had been struggling to successfully establish CMAs for all catchment areas as required by the Water Act, with only two CMAs currently operational. As a result, this limits the functions of current policy strategy to promote ICM, since CMAs are central to the water resource management at the catchment level.

Policy strategies that seek to advance from IWRM to ICM are well justified, but NWRS2 has placed emphasis on IWRM rather than ICM approach. As discussed in section 2 above, interconnectedness of both water and land is crucial to redressing inequalities in the South African context, and improving the integrated approach in the management of water resources.

Another area that is important to the water sector policy strategy in South Africa is the management of groundwater. The technical, legal, institutional and operational governance provisions of groundwater were found to be reasonable at the national level but weak with regard to cross-sector policy coordination (Pietersen, Beekman, Holland & Adams, 2012). Similar patterns do exist at the local level, where the basic technical provisions such as hydrogeological maps and aquifer delineation with classified typology are in place, but other governance provisions such as institutional capacity, provisions to control groundwater abstraction and pollution, cross-sector policy coordination and the implementation of a groundwater management action plan are weak or non-existent (Pietersen et al., 2012). There has been also a delay in the implementation of the National Groundwater Strategy (NGS) since its inception in the early 2000s. One of the contributing factors is that the NGS was not widely aligned to the National Water Resource Strategy 2. The DWS has also acknowledged this existing gap and promised that the groundwater strategy will be an integral part and sub-strategy of the next National Water Resource Strategy (DWS, 2016b).

Lastly, Ashton (2000) pointed out that there was a lack of an overarching national policy for ICM that will bridge the line functions of different government departments. This policy is already overdue given the criticisms made against the continued poor state of integration in water sector institutions.

6.1.5 Institutional arrangements in the ICM Inventory

The NWA initiated a large-scale reform of South Africa's institutional water structure to align it with the country's new constitutional values. This move was set to steer the country away from a centralised water governance structure that had been established by the apartheid Water Act of 1956, NWA (RSA, 1956). The NWA enabled a legislative shift, which directed the establishment of water institutions aimed at decentralising water resource governance. These institutions, when properly constituted and fully functional, would promote the ICM approach for water resource management. The role of each institution needed to be well understood to ensure that their functions are coordinated and integrated to provide a balance between state control in the national interest and local participation towards equitable benefits. As provided for by the NWA, the balance of responsibilities was to be maintained from the Minister and Director General at national level in DWS, to Catchment Management Agencies (CMAs) at the basin level and Water User Associations (WUAs) at a sub-basin level (Claassen, 2013). Table 6.1 below summarises details regarding sectors and institutions involved in the water management. Further details that focus on government departments are provided in Table 7.2.

Table 6.1: Institutions and structures that are playing a role in the water sector

Institutions	**Role related to ICM**
Department of Water and Sanitation	Through the Minister, the Department is the custodian of water and the organ of the state that executes which water management mandates. The Department is responsible for overall policy setting, development and implementation of legislation, national water resources planning, development and management of national water resources infrastructure (large dams, transfer schemes, etc.), regulation of water use and regulatory oversight over various water sector institutions (water boards, Catchment Management Agencies, Water User Associations). The Department manages water on behalf of all citizens.
Other National government departments (Agriculture and Forestry, Mineral Resources,	Mandated to implement functions that affect or are affected by water, as well any other issues around water related to their core business

Institutions	Role related to ICM
Energy, Environmental Affairs, Human Settlement, Rural Development and Land Reform, etc.)	
Public/quasi-government institutions (e.g. ESKOM)	Responsible for business activities that affect and require water resources
Water sector institutions (water boards, Catchment Management Agencies, international water management bodies, Water User Associations)	Implement activities that affect water use. Carry out specific functions around water according to legal obligations and delegations from national government
Provincial government departments (Agriculture, Health, Environment, etc.)	Engage in functions that affect water use, water protection and aquatic environments
Local Government (water service authorities)	Responsible for providing potable water and sanitation services to domestic consumers, and also for providing water for sanitation
Institutions of Higher Learning and Research Universities, Water Research Commission, ARC, CSIR, MINTEK, etc.	Conduct learning and research on water resources. They also carry out capacity development and dissemination of information in the water sector
Water Sector Professional Bodies Water Institute of South Africa	Actively promote peer learning and knowledge management for water professionals
Civil Society and Organised Sector Structures Association of WUAs AgriSA, National African Farmers Association and various NGOs	Play a role in advocacy, lobbying and implementation of water sector programmes

6.1.6 Shortcomings in water sector institutional arrangements

The above-mentioned institutions and structures cover aspects of ICM through the interaction and other activities of various institutions. There are several challenges that have been identified regarding institutions and the water sector.

One important challenge that has always been identified is the lack of integration between these institutions (DWA, 2009). The alignment of institutional programmes, how they are planned as well as how they interact to serve common objectives at catchment level are key determinants of the effectiveness of water resource management under the ICM principles (Denby, 2013). The importance of integration and cooperation between all relevant departments and sectors are recognised by the NWRS 2 (DWA, 2013a), as drivers that satisfy the objectives of NWA and ICM principles.

The ICM requires an integrated approach to water resources management, where water use sectors and other stakeholders plan and manage water resources together rather than in compartmentalised silos. The resulting common strategies and plans would help the DWS to better coordinate the responsibilities of different institutions, as well as the contributions of civil society and other stakeholders (DWA, 2009). At the centre of ICM is a principled acknowledgement that water is managed to achieve societal needs, i.e. economic, social and environmental, and as such, the institutional partnerships must be established to ensure a balance between allocation and conservation, development and maintenance. The DWA (2009) acknowledged that the development of strong partnerships within government, underlined by a strong sense of one government, and strong partnerships between government and non-government stakeholders forms the basis for improving water resource management, thereby promoting ICM principles.

Institutional arrangements are still a challenge in catchment management, and there is a lack of an integrated inter-governmental approach, leading to some conflicts or overlaps in powers and functions, specifically between the DWS, DMR and local government. For example, the DWS raised the concern that local authorities often grant permits for sand mining in rivers, which the DWS regulates (PMG, 2016). As pointed out by sections 5 to 7 of the National Water Act, the inter-relationship between institutions involved in water resource management should be determined, and coordinated properly.

The introduction of the National Planning Commission (NPC, 2010) was thought to enforce the coherence and cohesion of government programmes at different levels. However, disparities and misaligned effort persist at many developmental programmes including in the water and land reform programmes. Institutional integration is the complex process that would require the commitment of each player, and very progressive policy strategies to promote such a process. Inter-government departmental coordination between DWS, Land Reform, DAFF, and DAE is crucial to achieve the integration that is envisaged in holistic ICM where water and associated resources are integrated.

From a water resource management perspective, the uncertainties related to the Catchment Management Agencies and Water User Associations have had impact upon strategic issues (i.e. the development of a Catchment Management Strategy) as well as the day-to-day operational matters (i.e. implementation activities, monitoring, regulation, etc.). This has affected the DWS Provincial Offices and the maintenance, and ongoing development of staff capacity has been difficult within this context. Not having CMAs in seven catchment areas, including the Olifants and Berg-Olifants, has limited the enforcement of important regulations to sustainably manage the water – particularly with regulating the abstraction of unallocated water and prevention of pollution activities.

The lack of strategic knowledge is also an important factor contributing to the weakness of water institutions in South Africa. This is more prevalent in the Department of Water and Sanitation head office as well as regional offices and in local government. After the reorganisation of the Department of Water and Sanitation, many experts in the field of water and environment left or were substituted by administrative staff (Knüppe & Meissner, 2016). Some of the white employees opted to voluntarily vacate the Department, but without transferring the skills to the emerging black water experts (Muller, 2012). As a result, institutional knowledge and experience were lost due to this process. Moreover, important management positions remain unfilled, as there are simply not enough trained and experienced people to fulfil the requirements of the National Water Act. The responsible employees are also changing on a regular base, which makes it difficult to reach a certain degree of consistency and routine.

The shortage of adequate catchment specific data, both hydrological and socio-economic, limits the upscaling of ICM practices in South Africa. This can be related to the narrow scale of the water management research in the past. As a holistic approach that embraces socio-economic, political and environment concerns, ICM also requires a shift in the research and academic focus on water resource management. The science community has been driven by climate change and attributes complexities such as seasonal availability of water to climate variations (Ziervogel, New, Archer van Garderen, Midgley et al., 2014), while having less focus on the water politics and governance (Knüppe & Meissner, 2016).

6.1.7 Challenges and opportunities in the institutional arrangement and governance for achieving holistic ICM

The state of water management needs are such that integration – both vertical (within the sector) and horizontal (across different established sectors) is seen as fundamental to balanced governance and policy making (Varis et al., 2014). These management needs are guided through rigorous organisational goals and visionary strategies. The historical legacy of apartheid in South Africa and the resulting discriminatory policies and power imbalances are critical to understanding how water is managed and allocated, and how people participate in designated water governance structures. This translation of ICM into the South African context and, in particular, the integration of institutions related to land and water has faced many challenges due to the political nature of water and land reforms, and the tendency of governmental departments to work in silos (Denby et al., 2016). There are many cases that come out as evidence of poor governance in the water sector. The World Water Assessment Programme (United Nation, 2006) cited by Molle (2008), reported that water problems in the world can be explained beyond the traditional scarce water supply, but rather by poor governance of water.

6.1.8 Shortcomings and opportunities in governance of water to achieving ICM

The failure in the governance system in South Africa to provide for successful ICM could be directly or indirectly linked to the following factors:

(i) Legislation that was not adequately customised for South African conditions

The legislation used in the country is based on Roman Dutch Law. This law is European and does not take adequate consideration of the complex nature of the South African water sector as well as the unique local environment. One prominent characteristic of the legislation is that it was developed out of a historical background where a large proportion of the population consisting mostly of all the black people were not considered legal citizens of the country. In essence, the very legislation that came before the NWA of 1998 ignored the presence of black people and yet the current legislation adopted several clause from it including upholding a large number of provisions which were put in place to build a segregated society. Typical examples include that the NWA of 1998 has clauses 32 to 35 which enforce the provisions made under the riparian rights system as provided for in the 1956 Water Act and the 1912 Irrigation Act. So far, the white commercial farmers have kept their entitlements to the water and the water allocations to the black smallholder farmers have not increased from the meagre provisions made under the colonial state (Kemerink, Ahlers & Van der Zaag, 2011).

Although the motives for water reform are perceived as ensuring equitable, efficient and sustainable use of water resources, they are difficult to achieve within the current legislation framework especially because of the provisions in this legislation. The development of the water sector legal framework was driven by the interests and ideologies adopted from Western (European) states and civil societies rather than seeking to emphasise the local context.

(ii) Lack of resources

The NWA made provisions for the establishment of 19 WMAs and yet it was very clear that there were no human resources available or to become available in the future who could fill the positions in these new institutions. This was later changed to nine WMAs and yet again, this proved to be a demand that was too ambitious to be fulfilled. There has been later talk of one Water Management Agency, which is presently being conceptually developed. The one Water Management Agency idea, however, lacks the ability to fulfil the provisions in the NWA, which was set to bring Water Management closer to the people and to the specific catchments. Business Unity South Africa (BUSA) also shared the same sentiment on its submission to Parliament to comment on the proposed establishment of a single national CMA. BUSA believes that not only is there currently no legal basis to establish a national catchment agency, but the proposal is in fact in conflict with the National Water Act and the current National Water Resource Strategy, which is binding on all entities exercising powers in terms of the National Water Act and which currently contemplates the establishment of nine CMAs (BUSA, 2018). The National Water Act includes an obligation on the Minister to promote the management of water resources at the catchment management level, and therefore a Bill would be required to change such obligation. In accordance with Chapter 7 of the National Water Act, one of the key objectives of establishing a CMA at catchment level is therefore to ensure involvement of communities, and other stakeholders, thereby promoting the principles of ICM.

(iii) Lack of accountability to manage and protect water resources

Water is the most important resource, requiring a responsive, accountable, effective and efficient government system for efficient management. Reflecting on recent incidences in some parts of the country, particularly the water shortage in the City of Cape Town, South Africa has no choice but to urgently move towards sustainable water resource management. In line with the National Water Act, this could be achieved within the context of ICM, which encourages land and water management as one aspect. In the near future, a countrywide water shortage is expected unless urgent action is taken to rehabilitate and preserve our rivers and catchment areas, fix and maintain crumbling infrastructure and implement water re-use (Kretzmann, 2019).

Another critical area of government accountability for water governance is to occasionally provide a wastewater audit. This was introduced in 2009 as a “Green Drop Report” that provided an annual audit of the country’s 824 sewage works. The functionality of these wastewater audits is very important as an indicator of the health of our groundwater, rivers, and entire associated catchment areas. Regardless of its importance in providing precaution for sustainable water resource management, wastewater audits have not been published since 2013 (Kretzmann, 2019). This is a serious concern given that the last Green Drop Report indicated that over four million litres of untreated or inadequately treated sewage was daily flowing into our rivers, according to Leonard Basson – a member of the Parliamentary Portfolio Committee on Water and Sanitation (GroundUp, 2019). Even the 2013 audit report is only available as an executive summary that shows provincial, and not municipal performance (DWA, 2013c). The last full Green Drop Report that drills down into the waste treatment plants managed by every municipality dates back to 2011 (DWA, 2011c).

(iv) Lack of political will to address the policy issues

Both the NWA and WSA defined the responsibilities of all government structures to govern water resources in the country. Most functions in the NWA fall within the authority of national government, while the WSA is more appealing to local government. However, the integrated approach for catchment management requires that these two water policy frameworks complement each other, and are not implemented in silos. As set out by the Water Service Act, local governments are not only entitled to provide water and sanitation services to the communities, but also required to promote effective water resource management and conservation. Although local government or municipalities are not directly involved in the management of water resources at the catchment areas, there are some functions within the control of municipalities that may directly or indirectly affect the practice of catchment management. Hence, there is a need to fully operationalise ICM approaches in South Africa. However, it seems as if there is a lack of integrative approach to ensure that the national and local government responsibilities, as provided by NWA and WSA, complement each other. Some of the past incidents may suggest the notion in which NWA and WSA each separately belong to one sphere of the government, rather than being implemented in the integrated manner. Having two separate Acts that deals with water issues seems to be blamed for making it difficult for the country to achieve ICM, and the call to introduce a Water and Sanitation Bill, which will merge the NWA and WSA into one piece of policy framework, has already been made. According to the DWS presentation to the Parliamentary Portfolio committee on Water and Sanitation, having a single Act will enable stakeholders within the water sector to better understand the legislative framework relating to water management across the water value chain (PMG, 2017).

(v) Mismanagement of financial resources

The NWRS2 makes provision for the investment in water infrastructure to support economic development through a strategy for infrastructure development and management and the National Water Sector Investment Framework. Great investment is required in the water sector to improve its management and to promote ICM. The NWRS2 adopts the principle of “source to tap and back to source” and the maximisation of local water resources to improve access to adequate water for domestic and productive use, particularly in rural communities. This will require great support of the infrastructure to strengthen the ability of current water treatment systems, and to improve technical skills of those working at water management structures.

The National Water Act provides the Minister with the power to give financial assistance to the governance of water resources in accordance with the current legislation or adopted strategies. However, it became evident in the past decade that those in government authorities have not properly managed public funds. The PMG (2018) revealed that the DWS is experiencing severe financial constraints because of mismanagement. As a result, the Department is failing to sustain some of its mandated programmes. War on Leaks (WoL) is one of the programmes that is currently struggling due to a financial crisis. The programme was initiated by the DWS in partnership with Rand Water as a means of addressing countrywide water losses, which result from failing and ageing infrastructure. The objective of the project was to train and develop 15 000 unemployed youth citizens to be water agents, artisans and plumbers, to embed a water conservation culture and advocacy across all municipalities, communities and households through stakeholder and communication campaigns. The municipalities are also struggling to pay their water bills, which had increased to R13.1bn in 2018.

(vi) Lack of capacity in the cooperative governance

To achieve the vision of NWA, DWS has been pursuing a programme to devolve powers CMAs that are close to stakeholders in each catchment while being more targeted to local issues. The NWA also provided for transformation of irrigation boards into more inclusive Water User Associations (WUAs), as well as creating new local associations (Colvin, Ballim, Chimbuya, Everard, Goss et al., 2008). The principle of cooperative governance was thought to be key to enabling CMAs and WUAs to implement their core functions, which include coordinating the activities of water users and water management institutions within their water management area (Colvin et al., 2008). For WUAs, the central function within the principles of cooperative governance was to build engagement between white commercial farmers and emerging black farmers, where the water resources can be equally shared and sustainably managed in a particular catchment. As guided by the principle of ICM, these engagements (in some cases) would also include a wider set of stakeholder interests including local government and environmental interests. However, a cooperative governance approach faced some challenges in achieving its objectives due to the lack of individual and institutional capacity for facilitating cooperative development processes within the South African water sector.

Following the Strategic Framework for Water Services (DWAF, 2003) and the National Water Resource Strategy (DWAF, 2004), there has been an effort at the development of training programmes to capacitate those responsible for management of water resources. While this had some impact, the mistake has been that the emphasis was put more on the traditional mould approach, rather than on a progressive mould approach. Capacity-building programmes under the traditional mould tend to assume an approach to learning that can be characterised as one-way and expert-driven. Colvin et al*.* (2008) referred to the approach as more “traditional” in the sense that they assume a relatively passive and a contextual model of learning in which those responsible for implementation, whose capacity needs to be built, are seen as “empty vessels” waiting to be informed by a one way flow of procedural knowledge from the source of expertise that resides in the heads of policy makers (via their guidance documents). In a more progressive mould approach, the capacity building can be characterised as more “progressive” in the sense that they assume a model of learning that is both active and interactive, and in which effective implementation results from those close to the action being supported to “make sense” of what is needed by working out how to apply national policy thinking in the context of local realities (Colvin et al., 2008).

6.2 Stakeholders in the ICM approach

6.2.1 Water sector stakeholders and ICM

Central to the successful implementation of ICM is a well-planned and coordinated stakeholder engagement programme. Given the numerous land use and water use activities that occur within catchment boundaries, it is apparent that there would emerge a mix of stakeholders from various backgrounds with different and often divergent interests. At the core of stakeholder involvement is an understanding of the concept of participation. The World Bank (1996:xi) defined participation as a process “through which stakeholders influence and share control over development initiatives and the decision and resources which affect them”. This chapter seeks to find out about stakeholder engagement and participation in ICM, both in theory and in practice.

Stakeholder participation in ICM is approached from various angles using multiple tools that depend on the particular area of interest, e.g. water quality or water allocation. While the main discussion of ICM lies within the realm of water resources, this research study realises the link between land use and water that is vital for a more holistic approach. This is because a catchment-based approach to managing water resources takes into consideration activities and issues in the catchment as a whole (social, cultural, political, economic, environmental), rather than considering different aspects separately (Ayre & Nettle, 2014; Everard, 2009).

The mix of stakeholders is driven by the current state of the environment and the role of human influence in its degradation (Campbell, 2016). As catchments are not independent in themselves due to the interconnectedness of resources and transfer of the same, it is vital that the planning and management of water and land resources be considered in a system where catchment boundaries are flexible. It is interesting to note the overlap of hydrological catchment boundaries, groundwater zones and administrative boundaries that widen the scope for participation in ICM. There has, however, been criticism of the use of the catchment as the ultimate natural unit for water management (Warner, Wester & Bolding, 2008). The arguments bring forward the shortcoming of using a catchment as an unchallenged water and land management tool, in view of the recent popularity by water managers. The suggestion has been to add the catchment as just another management tool that can be selected among others and not necessarily an end in itself (Cohen & Davidson, 2011; Warner et al., 2008). Stakeholder participation has become an inseparable aspect of ICM; however, it is argued that participation can occur at any management scale, and the same management challenges that exist at municipal level can also exist at the catchment scale (Cohen & Davidson, 2011; Molle, 2008; Warner et al., 2008).

Local ICM participation should seek to address an understanding of ICM in which the key objective as explained by Werritty et al. (2015:1), is the restoration of “degraded river corridors and catchments to a more natural state, enhancing water quality, improving biodiversity, improving amenities and reducing the impacts of flooding”. The questions to be addressed as part of the participation process should seek to understand the nature of both water and land resources, ownership of these resources and what is impeding the implementation to address the inequalities in access to the resources. Given their conflicting backgrounds due to historical inequalities and dispossession, it is worth assessing the most effective manner in which the various stakeholders can meaningfully participate. Hage, Leroy and Petersen (2010) also raised the question of the conflict between guaranteeing scientific validity of participation while at the same time ensuring social robustness of the participatory process. Other questions will relate to the role of government policies, programmes as well as the local administration’s strategies for resource access, resource upkeep and sustainability of the ecological system.

Franzén, Hammer and Balfors (2015) categorised participation into two; normative-enhanced democracy (basic human rights) and functional (effective implementation of policies and capacity building and learning). Considering these categories, South Africa’s water sector needs to level the playing field for the normative category and has only recently started to embrace the functional aspects of stakeholder participation.

6.2.2 Local stakeholder participation

In South Africa, participation is always going to be influenced by the historical background of access and use of land and water resources (Agrawal & Gupta, 2005). The country has a history of segregation and discriminative practices in the access and allocation of resources. The balance of access to resource allocation has always tipped in favour of the minority white population who dominated the political and economic landscape controlling water and land rights over a period of more than 300 years (Tewari, 2009). Participation in water and land management was thus limited to a few stakeholders and decision making was not inclusive of all those affected by the catchment resources and activities. Decades after attaining democratic rule, the relics of the apartheid system are still prevalent and notable during stakeholder engagement processes, leading to the marginalisation of some groups from critical decision-making processes (Kemerink et al., 2011). The DWA (2013d) expresses frustration at the lack of transformation after more than two decades and contemplates the development of new legislated instruments to speed up this process.

The issues of participation by the majority of stakeholders has continued to be well behind government targets, as explained in the motivation for the National Water Policy Review (NWPR) (DWA, 2013d) where the then Minister of Water Affairs stated that old irrigation boards had failed to meaningfully transform to WUAs and participate in or achieve the transformation goals of the NWA. She also said that Irrigation Boards had failed in achieving the adequate participation of municipalities, among others. The NWPR also points to the very slow pace of transformation to ensure inclusion of other stakeholders when it points to the existence of 129 untransformed Irrigation Boards in the country that are supposed to be disestablished to make way for more inclusive WUAs. It should be noted that the nature of irrigation boards is such that they are only composed of those involved in irrigation who also manage key government irrigation infrastructure and other resources that should belong to all those who reside in the catchment (DWA, 2013a).

6.2.3 Identifying the stakeholders

Identifying stakeholders is a process that requires critical assessment and cross-sectoral involvement. Rouillard and Spray (2016) suggested that the selection processes have to start by applying less formal techniques to encourage wider participation and then change to formalised cohesive methods to develop formal participation platforms. Ideally, the stakeholder formation should involve interlinkages between state institutions, community members, the private sector and civil organisations. Warner (2005) explained that involving all stakeholders would include individuals, groups or institutions that are concerned with, or have an interest in water resources and their management. Luyet, Schalaepfer, Parlange and Buttler (2012) discussed a collection of stakeholder identification techniques, which do have their advantages and risks. Box 1 below lists the techniques and the scholars who suggested them.

Box 1: Stakeholder identification techniques, (Luyet et al., 2012)

1. Proximity, economy, use and social values (Creighton, 1986)
2. Distinguishing between stakeholders with economic interest and those motivated by principles or values (Selman 2004)
3. Taking into account stakeholders' legitimacy, urgency and proximity (Mitchell et al., 1997)
4. Snowball technique where a list is obtained through brainstorming (King et al*.,* 1998, Stanghellini and Collentine, 2008)
5. Use of a set of questions whereby the answers generate a list of stakeholders (Mason & Mitroff 1981; Luyet, 2005; Banville et al., 1998).

Stakeholder participation has its advantages and risks that have to be taken into consideration in the identification process. For instance, the more the stakeholders, the bigger the budget required to meaningfully engage them. The structures available for participation and the capacity and availability of stakeholders all determine the extent and intensity of the stakeholder involvement (Du Toit et al., 2006). Needless to say, there are those stakeholders who by virtue of the magnitude of their "stake" should be included – the primary stakeholders, those who are directly affected, either positively or negatively by an initiative (Warner, 2005). At the same time, the value that stakeholders bring to the table also has to be considered, an issue that Hage et al. (2010) see as impacting on environmental knowledge production, as decisions have to be made at these stakeholder meetings.

6.2.4 Community participation in ICM

It has been argued that the success of natural resource management strategies lies in the willingness of communities to own and implement management solutions (Curtis & Lockwood, 2000). At the centre of any community socio-economic development is the environment and its goods and services. Thus, the involvement of community members in the ICM process requires attention.
Community participation brings with it indigenous knowledge that can enable the effective functioning of policies. It also improves trust between the policy initiators and the community that will enable better uptake and ownership of proposed solutions (Dungumaro & Madulu, 2003).

In South Africa, the displacement of communities from their original ancestral origins, migration patterns and urbanisation have all had an impact on the way natural resources are perceived, conserved and protected by communities. Ownership and participation in South African catchments are marred by the lack of a sense of ownership in many of the displaced community members. In the investigation of catchment degradation Dube, Maphosa, Malan, Fayemiwo, Ramulondi and Zuma (2017) observed that most of the urban and semi-urban communities were not keen to support the upkeep of the surrounding rivers because they did not feel that they were part of this environment or have any rights in its ownership. These sentiments were due to several circumstances that included that they were displaced to these areas and were considered squatters or informal settlers and lacked rights to title deeds, all of which seem to make them unsuitable for a claim to the surrounding resources. In rural and agricultural catchments, where there are clear distinctions between those with power and influence as opposed to the majority of the people who are still marginalised, the issues of power dynamics and again ownership of resources are central to how participation continues to take place. Dealing with power dynamics and trying to level the playing field of participation are issues that have been recognised and are being addressed through the implementation of provisions in the National Water Act of 1998.

6.2.5 Private sector and institutions as stakeholders

The involvement of the private sector in the ICM provides a platform whereby information on operations may be disclosed to remove feelings of being the hunter and the hunted (regulator vs the regulated). Such a platform serves to demystify business operations and exposes them to various avenues of socially, environmentally and economically sustainable operations. The Alliance for Water Stewardship (AWS) initiative, a local platform for business participation, takes its members through ways of managing their water footprint and giving back to the resources that ensure future profits (AWS, 2017). The alliance has regional partners who assist in the certification of businesses according to the AWS standards. This bridges the gap between regulation and practice and moves towards the integration and collaboration that the ICM envisages. These same channels can be effective means to propagate land use management within ICM.

In South Africa, private sector water stakeholder platforms have been established in some areas. These include Strategic Water Partners Network (SWPN), which was formed in 2011 as a public-private partnership (PPP) aimed at proactively solving the South African water quantity and quality crisis (DWS, 2013c). The thematic focal points in this partnership are water efficiency and leakage reduction, effluent and wastewater management, as well as agriculture and supply chain (DWA, 2013c). Such PPPs are a direct shift from the authoritarian way of governance to a collaborative position that allows stakeholders to be directly involved in decision making (Ansell & Gash 2008).

6.2.6 Challenges and opportunities involving stakeholders in the ICM inventory

The ICM principles are based on decentralising power from the state to the stakeholders at the catchment level. However, if all stakeholder groups seek to influence the way in which water resources are managed, having them integrated and equally represented in the decision-making process remains a challenge in South Africa. The stakeholder integration in ICM is faced with multiple challenges that need to be addressed accordingly. Against the mandate of legislation, the state is still attempting to hold onto the absolute power to drive the practices of water resource management. In the case studies of the Sabie catchment and the Lesotho Highlands Water Project, Mirumachi and Van Wyk, (2010) found a number of challenges related to power disparity and interdependence of actors, and risk perceptions of inclusive decision making. The conclusion from the study, was that the state, which is a “traditional” actor, still played an influential role in decision making, and sometimes denied to extend responsibilities to the new actors such as businesses, civil society, and regional institutions to influence the decision-making process. According to the National Water Act, the DWS is the custodian of South African water. However, the department is not allowed in principle to undertake integrated catchment management, because that would entail conflicting the roles as well as failing to build the stakeholder and local catchment institutions as provided for in the Water Act.

Although the legal framework is in place that broadly provides for ICM to be implemented, Funke, Oelofse, Hattingh, Ashton and Turton (2007) suggested that good governance, supported by management and institutional capacity, is needed to give effect to such implementation. A lesson learnt from a case study on the Mhlatuze Catchment in South Africa was that the practice of ICM is difficult to achieve due to the following factors (Funke et al., 2007):

- Internal institutional problems that delay acceptance of integration by water managers
- Insufficient cooperation between sectors and policies
- Difficulties in the involvement of stakeholders in decision making.

The biggest problem is the mismatch of the legal instruments that seek to promote interactive participation of rural people in the management of natural resources, with the real practice on the ground. In the first instance, the lack of capacity, experience and innovation underlying the absence of institutional culture for effective integration of rural people’s needs into the management of protected natural resources were not taken into consideration (Holmes-Watts & Watts, 2008).

At the Steelpoort Basin, a major tributary basin to the Olifants catchments, Lévite, Faysse and Ardorino (2003) found that rural communities were unaware of the provisions of the new water law and of the CMA process, despite efforts to inform people and offer them opportunities for expressing their views (Lévite et al., 2003). While the commercial farmers and mining companies are well organised and informed, millions of rural poor in the former homelands are not well organised to participate effectively in the stakeholder consultation process. At the Middle Olifants Sub-Basin, the smallholder sector is still struggling to organise itself (Kloos, Tsegai & Walter, 2011), and its interests could not be well represented in the catchment management.

ICM requires that the stakeholder engagement be progressive to drive the new practice and programmes for water management in a holistic approach. The effectiveness of dialogues and engagements on the value and governance of water is directly affected by the nature of conversations that take place between different water use stakeholders. It is important to find ways of stimulating these conversations as a means of finding effective collaborative ways of managing water. These conversations are often missing because of the absence of key stakeholders from discussion platforms, and underrepresentation of some stakeholders, particularly marginalised groups.

In order to achieve stakeholder integration in the water sector, engagement should never be once-off or an occasional process, but rather an on-going initiative aimed at allowing the constructive participation of stakeholders with rights, and therefore responsibilities and/or interests, through a systematic process that provides an opportunity for people to share their experiences, knowledge, needs and goals in water conservation and water demand management, and play a role in decision making and the consequent activities that affect them. These arrangements are, however, not easy to achieve at present, and they will require equal commitment from all relevant stakeholders. The role of the authorities in the participation process is crucial to facilitate and enable a conducive environment for all stakeholder participation in the integrated catchment management. It is therefore important to build the necessary capacity and skills among catchment management personnel.

In a broader perspective, OECD (2015) found that policy and legislation reform is the primary driver for stakeholder engagement (Figure 6.1). This suggests that most stakeholders are more likely to take part in discussions when they concern new policies which they will have to uphold, while decision makers look to consult and involve stakeholders that are likely to be impacted to ensure acceptability and sustainability of the policies to be implemented (Meissner, Stuart-Hill & Nakhooda, 2017). In the South African context, there is still some uncertainty and shifts taking place around national policy and this is likely to continue for some time. Therefore, stakeholders may be discouraged to participate in the catchment management engagements since they are not sure where their interest is placed in the policy strategy.

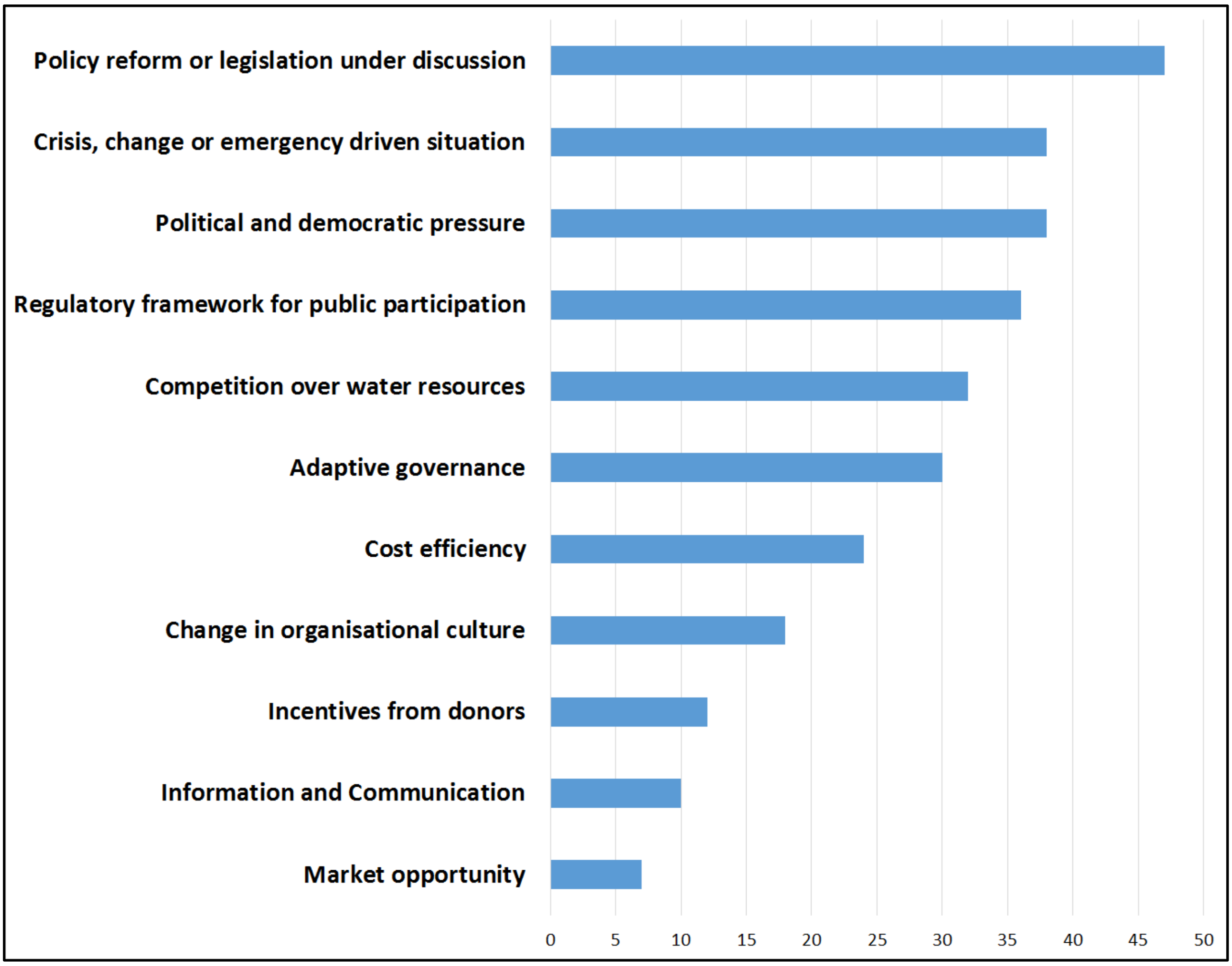

Figure 6.1: Primary drivers for stakeholder engagement (OECD, 2015)

7 A methodology for holistic ICM: The ICM Software repository

7.1 Introduction to ICM-Repository consolidation

7.1.1 ICM-R structure

7.1.1.1 Introduction to the ICM-R structure

Water management takes place at various levels, in different settings and for a variety of purposes but ultimately, the implications of its mismanagement take their toll without restrictions or limitation of damages to a few stakeholders. The ICM Repository seeks to bring together the various elements of Integrated Catchment Management under one platform that is set to be available to a wide spectrum of users and which would ultimately allow for enhancement of resonance in management units. The development in the research is set to demonstrate an approach rather than develop the datasets, models and other tools that should be accessible using this platform. These tools are the domain of the different stakeholders while the platform provides the potential for access across all interested parties irrespective of their dispersed geographical locations or diversity in core interests.

The development of the ICM Repository focused on different aspects of water management, especially those of importance to the case study areas being investigated, which are referred to in this study as the Olifants-Steelpoort and the Olifants-Doring Catchments. The investigations revealed the limitations of hydrological-based boundaries in water management but appreciated the need to have basic areas to use as reference points while extending the delineation to accommodate other boundaries that are important to water management from different points of interest. Examples include, inter alia, the appreciation of groundwater boundaries, municipal boundaries and ecosystem boundaries that do not correspond to surface water hydrological systems and yet are linked to these systems in other ways. The ICM repository framework also relied on available datasets, models and other developments, which also tend to define the boundaries that become important to the reader or user of the repository as they direct the user to a specific perspective. Examples include some land use maps developed by organisations with an interest in nature that may not show mines and settlements and, as such, direct the user to see a specific dimension of water use without accounting for all water users.

7.1.1.2 The holistic source to receptor approach in the ICM-R structure

The ICM repository structure was initially motivated by the need to seek holistic integrations that emphasise land and water integration. Early investigations showed that in addition to land and water, there was a need to include nature and the human element as part of four basic units of integration in integrated catchment management (Figure 7.1). The human element was represented in the ICM repository as "Infrastructure". The Infrastructure element captures the built environment, the institutional set up and other roles of the human element in the management of water that do not fall directly under the other three elements.

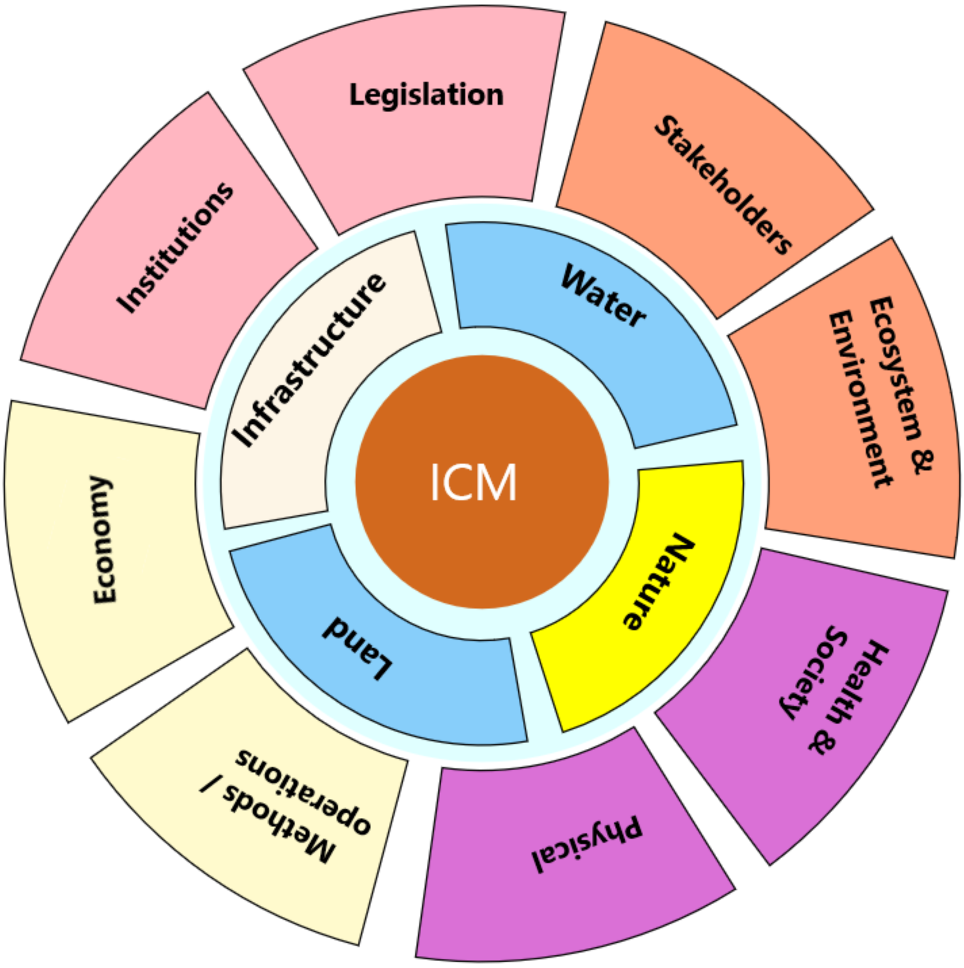

Figure 7.1: The wheel of catchment elements that is used as the front-end of the Integrated Catchment Management platform

7.1.1.3 Consolidation at different levels of ICM-R elements

The understanding of an area such as a catchment has evolved over time in alignment to the present knowledge and teachings. Historical records show that as early as the eighteenth to the sixteenth century BC, various cultures believed all matter was composed of just a few elements/things (Carpi, 2004). These elements were usually identified as earth, water, air, fire and aether (spirit or void), with the Chinese adding metal and wood as additional elements. However, they did not call them elements but something resembling the smallest unit of an energy form (Bose, 2015; Zhang, 2002). In those early periods, some communities had already started to grapple with the issues surrounding water availability, rainfall patterns, its delivery and quality, all of which were also enmeshed in what was described as observed sciences, mythology and cosmology. The roles of these elements and how they made up all matter was understood differently by different cultures with much alignment into the idea of everything being made up of small units as part of the whole. In the mostly European knowledge systems, the focus was more on the material that could be described on the basis of the human senses, while Asian and especially Chinese and Indian cultures looked at these components of nature as various energy forms that were in continuous interaction and flux with one another. Over the more recent past, the science of water management has been dominated by Western philosophies while the growing knowledge on climate change has pointed to the close relationship between energy and everything else including long-term water balances. Studies on climate change are now showing that everything in a catchment is linked to some form of energy and that the energy balance is changing.

The “Elements”, as defined in the wheel above, have a strong alignment to how the sciences have evolved. The idea of catchment management as a way of balancing the forms of energy in a catchment seems to be the long-term goal, which is not yet receiving attention within ICM except in the discussion of climate change. The water balance is driven by energy and this energy is continuously changing with implications for all elements of the ICM wheel.

The use of the ICM wheel shows that the relationship of the different elements is different at each stage of the water cycle, in different locations, for different stakeholders and uses. At the stage of water falling as rain, it releases some of the energy accumulated when it evaporated into clouds. It is then available to the receiving water sources such as forests, dams, aquifers and rivers in its cleaner form to restart the cycle of use. At this stage, the potability of water is determined by where it falls as rainfall as well as the impurities absorbed in the atmosphere.

7.1.1.4 ICM repository structure

The ICM- R is a representation of the catchment management processes that captures the data and methods for use in catchment-based integrated water management. At the base of the structure are the main elements, captured as Land, Water, Nature and Atmosphere, as illustrated in Figure 7.2 below. The atmosphere has been included in the illustration to capture its role as part of the water cycle in managing water. Most water management boundaries tend to exclude the atmosphere and in so doing, do not recognise the direct role of the atmosphere in issues pertaining to catchment management. There are obvious roles of the atmosphere in the state of water in a catchment. These include its role in the water balance of the catchment, where water in the ground and on the surface evaporates into the atmosphere, and then falls back as rainfall and controls the water balance in the atmosphere. This water balance in the atmosphere affects the moisture in the air, which contributes to the variables affecting evapotranspiration and plant growth as well as other livelihood characteristics of nature. The process of evaporation into the atmosphere also serves as a natural purification process in which the pollution in water is lost as it evaporates and is distilled in rainfall formation. However, there is also a pollution process that takes place as the rainfall cleans out whatever is released into the atmosphere through polluting natural and human-induced causes. In the case study areas, the numerous coal mining activities as well as the coal-based factories and power stations in areas around the Olifants-Steelpoort catchment are known to directly affect the pollution levels in the atmosphere. These pollutants are absorbed from the atmosphere directly into surface water systems and also through polluted rainfall (Munnik, Hochmann, Hlabane & Law, 2010: 19). It is envisaged that the role of managing the atmosphere in water management is set to increase in the future due to the need to manage atmospheric characteristics, especially those responsible for rainfall formation as well as climate change. In NOAA (2019), the USA national environmental centre observed that there is a strong correlation between temperature and concentration of carbon dioxide, with cycles having been detected for periods stretching over hundreds of years. According to NOAA (2019), “when the carbon dioxide concentration goes up, temperature goes up. When the carbon dioxide concentration goes down, temperature goes down”. While these long-term temperature and CO_2 concentrations cannot be linked directly to the few activities taking place in a catchment at the scales dealt with in this study, the management of catchments to reduce the effect of carbon dioxide in the atmosphere is broken down to levels that are applicable to practices and measures at local catchment level. These are expected to be implemented as part of water management. Climate change data for the whole country was also included in the data of the ICM-R. This climate change data is a result of the first African-based Earth System Model at the CSIR. The data was developed through the CSIR’s collaboration with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in which the Variable-resolution Earth System Model (VrESM) was used as part of the Coupled Model Inter-comparison Project (CMIP6) in 2016.

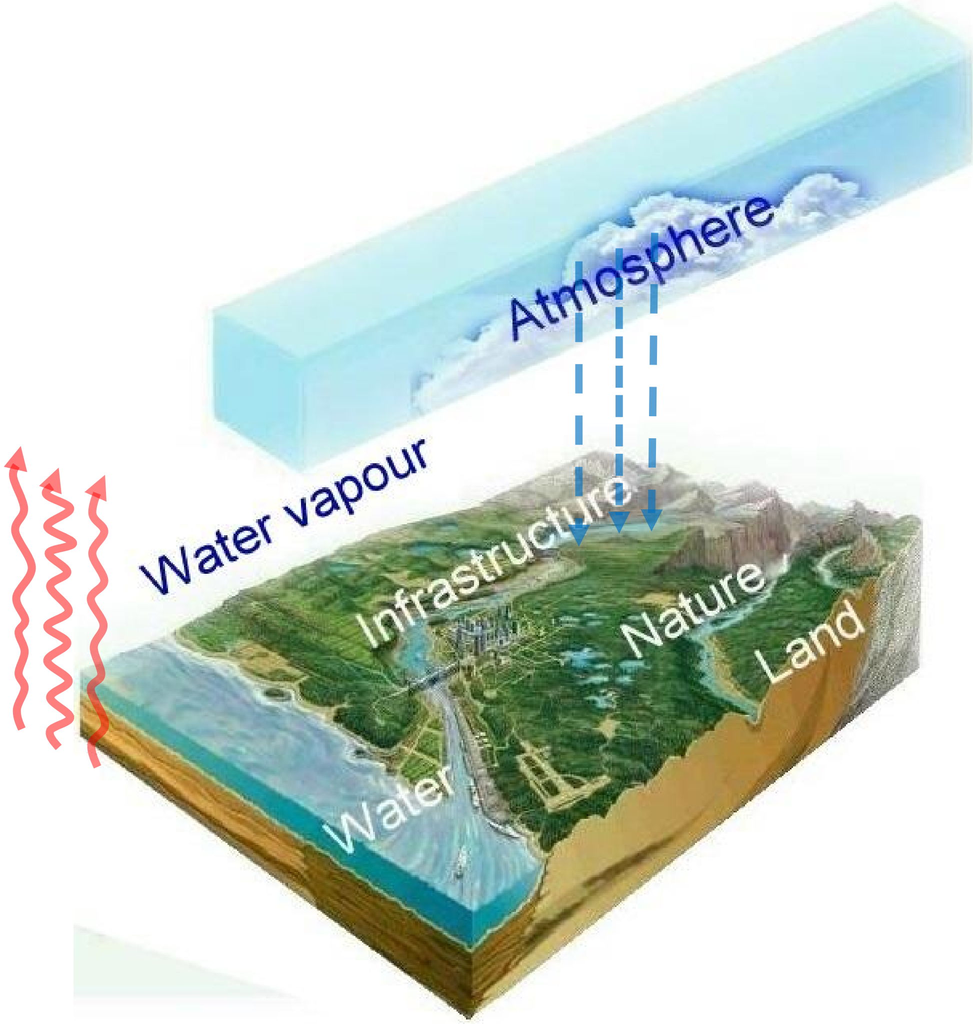

Figure 7.2: Main components in managing water at catchment level (updated and redrawn from USGS, 2013)

Figure 7.2 also captures the relevance of accounting for both groundwater and surface water in the ICM, especially to ensure that the holistic approach relies on all water resources. The structure of the ICM is further described to capture detailed elements associated with the rest of the components into more manageable blocks. In the ICM structure, this breakdown was achieved by conceptualising all management roles and functions as falling under the following the elements referenced in the ICM wheel as illustrated in Figure 7.1.

The ICM elements were organised into eight divisions where ecosystem and environment, health and society, as well as methods and operations were represented in single segments as shown in Figure 7.1 above. Individually, all the ICM elements are considered against each of the four inner components. This is illustrated in how there is legislation for land, water, nature and infrastructure to provide a more realistic perspective of how the actual processes take place in a catchment setting. This structure is set to ensure that anyone dealing with the ICM approach proposed can connect all the components relevant to decisions and actions that are informed by all other elements cutting across the different disciplines.

7.1.2 Modules that are integrated in the ICM-R

The holistic ICM approach, as developed in this research, uses eight elements to define all activities, characteristics and other provisions required to manage a catchment. These elements are broken down into sub-elements that are linked to various modules, datasets, records and other files. The sub-elements are partially populated to demonstrate how the user can extend the content as well as use the ICM-R tool. The breakdown of the elements is presented in Table 7.1 and Figure 7.3 below.

Table 7.1: Sub-elements of the ICM-R that are accessible for user interaction and update

Item	ICM-R Elements	Sub-Elements in holistic ICM-R (Land and Water Approach)
1	Institutions	Government, parastatals, private, academia, NGOs, transboundary, international, local, community
2	Legislation	Acts, policies, regulations, bills, by-laws, legal provisions, courts, judgements, rights
3	Stakeholders	Decision makers, experts, users, population, industry, NGOs, farms, polluters, companies
4	Ecosystem & Environment	Ecosystem health, aquatic habitat, environmental management, rehabilitation
5	Health & Society	Sanitation, recreation/religious/traditional & health roles, water conflicts, inequalities, activism
6	Physical	Catchment, hydrology, spatial, climate, weather, soils, erosion, land cover, hydraulics, data
7	Methods & Operations	Models, water and land tools, climate, water resources, services provision management, water sales, GIS, real-time operations, water purification, storage, conveyance and reticulation, settlement development, land clearing, rehabilitation of water and land
8	Economy	Food, income, livelihoods, GDP, revenue, costs, trade, empowerment, employment, entrepreneurship

Integrated catchment management has tended to be theoretical with parts of it being applied in systems that are limited by a variety of constraints. These constraints have included the maintenance of limited historical water management practices, available resources for managing water as part of a catchment, as well as prevailing objectives and expectations of those in decision-making positions.

In the context of local catchments there are management templates that are applied that have been developed in the past but that have rarely been updated to adequately capture the numerous other variables of relevance in different catchments. This study provides an ICM repository that is set to broaden the scope of what should constitute holistic and integrated management of water in local catchments. The ICM-R is not developed from a historical framework of how things were done in water management and, as such, it presents a platform that calls for stakeholders and users to test the many variables and account for as many aspects of the catchment as applicable in each case. The approach can be illustrated as applying a rolling ICM Wheel (Figure 7.3) along the water cycle within each catchment and using the data and other tools associated with each element at each point.

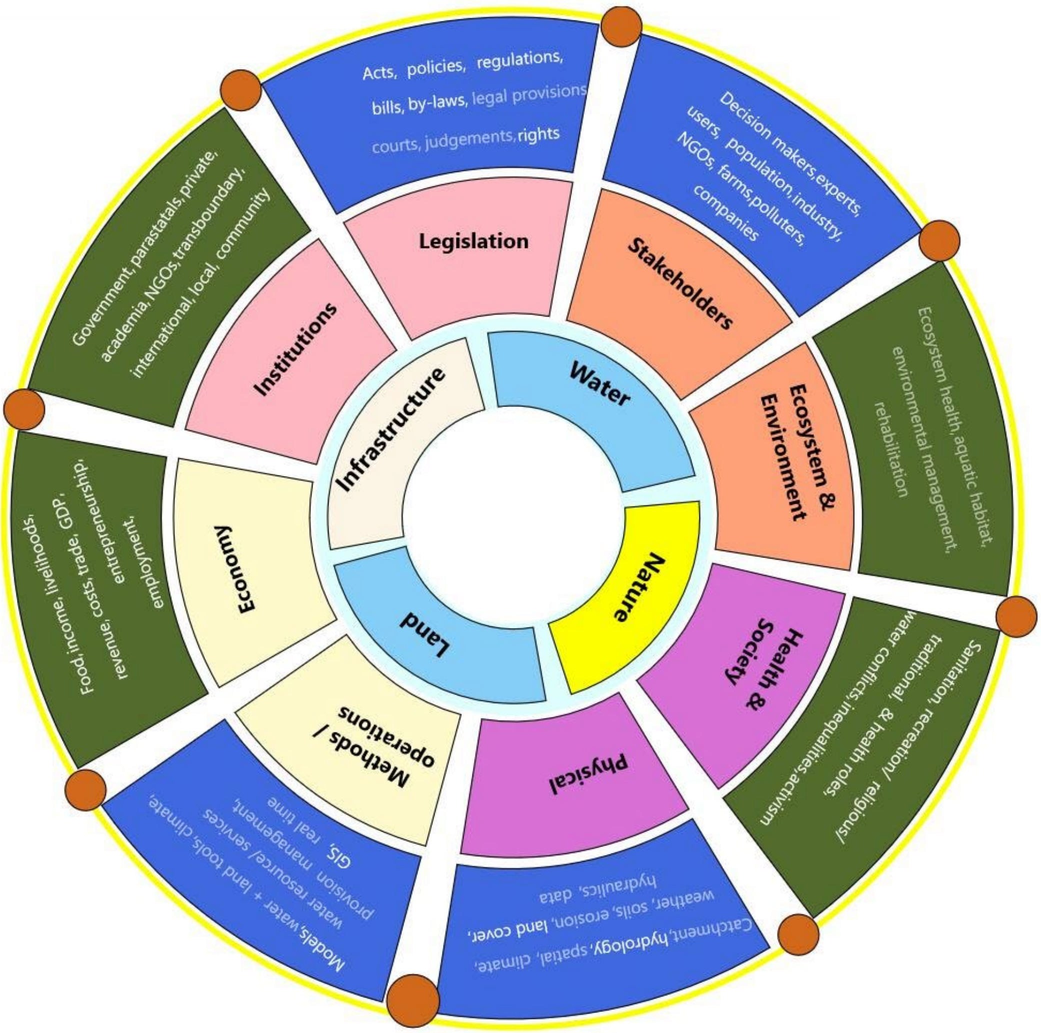

Figure 7.3: Sub-elements of the ICM-R that are developed for user interaction and update

7.1.3 Multi-dimensional perspective of elements in ICM

The catchment area is a piece of land defined by the drainage boundaries of a river and its tributaries. In the first place, it is land before appreciating the water flow and drainage properties such that its land properties should not be divorced from drainage properties. Including a strong link of ICM to land is synonymous with recognising that before appreciating the existence of water for the benefit of people and nature, land has to be there and should be part of the contextual background. The failure of many water system management practices, including the limited progress that characterises water provision in the country, is a result of the omissions in recognising land as the backbone on which the nature of water and its characteristics are experienced. The relationship between land and water suggests that the land where water is found on the surface and in the ground is also the land where it is accessed, where it is stored, where it flows as part of rivers and channels and it is also from this land that it is launched into the atmosphere as water vapour to fall again to the land as rainfall. The NWA dealt with water as complete without appreciating its link to land, especially that which is economically used. Economic water uses consume at least 70% of water resources. Water use in agriculture alone is given as at least 60% according to Le Maitre, Seyler, Holland, Smith-Adao, Nel et al. (2018). Van Niekerk, Jarmain, Goudriaan, Muller, Ferreira (2017), on the other hand, gave an estimate of 63%. Water use in industry, mining, power generation and afforestation is approximately 11% of the total water use in the country (DWS, 2015a). The remaining water uses are rural at 4% and urban water use at 24% (DWS, 2015a). Through the omission of connecting water to land as well as its use in economic activities, the NWA did not address many other dimensions of water existence that could be used to ensure better management of the resource. This omission has also seen the limitations of available knowledge of the water balances for different catchments since much water is locked away in unregulated small dams on private land. Mantel, Hughes and Muller (2010) concluded that unlike medium and large dams whose data was readily available, small dams were more densely populated in catchments and reduced the magnitudes of river flows while trapping much sediments and in so doing affecting the physio-chemistry of rivers to the detriment of macro-organisms, especially the macroinvertebrate. In their national assessments, Mantel et al. (2010) noted that there were in excess of 500 000 small dams when compared to about 500 large dams in the country. They also noted that because of the shallow depth to volume ratio in small dams, they tend to occupy a much larger total area than what is covered by large dams. Other observations made regarding small dams included that they increased mean water temperature in downstream rivers, reduced the invertebrate population in the river, reduced density of cold-water fish such as trout, and caused changes in habitat structure through capturing high volumes of sediments. Investigations by Mantel et al. (2010) also showed that the understanding of effects of dams in catchments tends to be from a hydrological perspective while there are similarly as many implications in other areas that are of interest in other science disciplines such as biology that do not receive as much attention. The idea of the ICM-R is that several dimensions of understanding a catchment and its management are incorporated in the repository with the potential to add other variables or catchment elements by other stakeholders from different disciplines.

The ICM consideration should focus on all aspects of land plus water relationships. These include land degradation, land as the cultural centre, land as the supporting platform for water infrastructure, land ownership in relation to water access, land as a medium where natural resources including water are found and dimensionality of land as constricting, abundant or unsuitable.

7.2 Linking ICM-R within and across institutions

In the ICM-R, the roles of institutions are multi-dimensional and intersecting as well as consolidating in some aspects. At various levels, institutions are involved in the catchment administrative as well as the operational process. On the other hand, institutions are also part of the stakeholder community in a catchment. To illustrate the dynamic roles of the institutions in ICM, roles of national institutions are illustrated in Table 7.2 below. The DWS, which is the main role player in the water sector, has several responsibilities that are directly relevant to the ICM-R. These are also discussed in Table 7.2. Focusing on those that would be directly linked to the ICM-R as developed in the study has resulted in this report. The roles of this water and sanitation unit currently range from what can be achieved at the very local scales dealing with individual households to regional programmes of a national strategic relevance. In water provision, the Water and Sanitation Unit directly provides water to individual households and on a large-scale, it is involved in water provisions for National Power Stations and regional water infrastructure such as the Orange River water transfer schemes.

There are numerous institutions of relevance to the ICM-R where it is envisaged that the institution, once it becomes part of the ICM-R, has to update the ICM-R to capture its roles in the catchment.

Table 7.2: National institutions responsible for operations and methods applied at catchment level

Ministry of Human Settlements, Water and Sanitation	
Department of Water and Sanitation	Water resource development planning -Water use planning and management -Commercial water use – private – e.g. mining, factories -Parastatals- e.g. power generation – Eskom -Domestic: urban & rural Catchment water assessments -Groundwater yield assessments -Water allocation tools -Water quality assessments -Water purification tools -Water availability & risk assessments -Water Boards Water services

Ministry of Human Settlements, Water and Sanitation	
	-Responsibility over Water Services Providers -National water security -Catchment management -Custodian of water -Water allocation -Transformation of water access and allocation
Department of Human Settlements	Housing -Private and national programmes -Provision of sustainable human settlement -Improved quality of life in households -Promote constitutional right to housing
Ministry of Environment, Forestry and Fisheries	
	Environment -Tools for nature and ecological health, air pollution, water and land degradation, climate change projections and environmental services -Administers models and other tools for degradation assessments, control and administration of environmental issues at national level including in catchments -Provides leadership in Oceans and Coastal Management, which are important to coastal catchments South African Weather Services (SAWS) -Providing weather and climate centre of excellence -Providing data and information in meteorology, climate and other related sciences Forestry Tools for providing leadership in forestry Fisheries Tools for supporting, applying the relevant laws and controlling the fisheries sector
Department of Agriculture, Land Reform and Rural Development	
	Agricultural water use Water access and allocation tools Productive land use

Ministry of Human Settlements, Water and Sanitation	
	Tools and data to manage agriculture land Water storage and conveyance Logistics for storing and balancing water in the catchment given other users
Department of Mineral Resources and Energy	
	-Regulating and administrating mining and businesses around mineral beneficiation -Regulating and controlling mining practices that degrade land and water -Provision of sustainable energy. This involves practices that entail catchment water access and management
Department of Cooperative Governance and Traditional Affairs	
	-Administrator of the Disaster Management Act of South Africa -Responsible for flood projection, real-time flood monitoring and fire control
Department of Economic Development	
	-Guiding economic policy, economic planning and economic development -Developing a common cause between all departments and thus seeking to stop ad-hoc policy developments and stop insular (silo) departmental programmes -Administering development tools that are commonly applied in Departments
Department of Planning, Monitoring and Evaluation (DPME)	
	-National Capacity Development Coordination -National Strategic Framework -Performance evaluation for all departments -Service delivery monitoring -Responsible for government performance -Implements DPME evaluations -Tools for accessing the government evaluations repository -Responsible for the National Water Security Framework for South Africa

The ICM-R was developed to allow the different institutions to use the tool and populate it with data and information related to their functions and roles. Different government institutions will have different inputs but could use the same platform such as the same maps and input data to run other tools. As an example, under the models, the different institutions could have their different models linked to the model's sub-element. If the model is dealing with changes in how land is to be used, such information could readily become available to the department or municipality dealing with water supply to that land or other function (Figure 7.4).

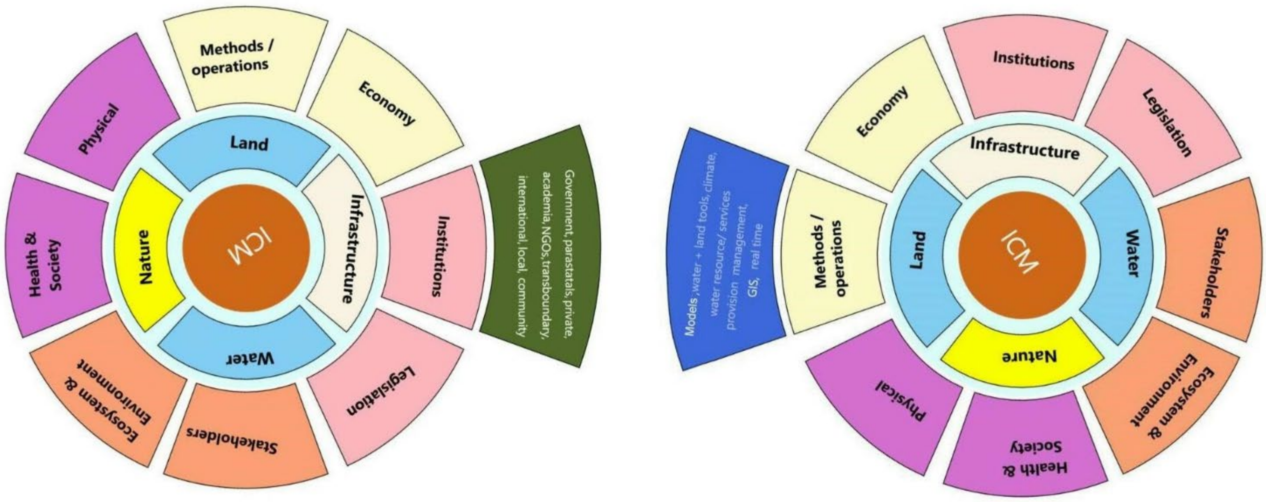

Figure 7.4: Each institution performs its functions and roles in the catchment using a shared ICM-R

The idea is to be able to include the performance analysis and measurement for each institution. The use of a common platform in land and water management at catchment level allows for the possibility of having a bird's-eye view of the real time status of various aspects of the water system under management. The underlying causes of the lack of alignment that has characterised water provision in relation to settlements as well as land uses can be identified easily in a fully functioning ICM-R. Typical problems of major concern in the current state of water affairs include the shortage of water in townships and the degradation of the water quality. These problems have several underlying issues that can be detected at once if all catchment management institutions are using the ICM-R. In addition to being able to extract a flow path of events, roles and baseline conditions resulting in, for example, water shortages, the corrective solutions that rely on other institutions can be identified rather than will be the case when just one institution is dealing with the problem. Water shortage in Calvinia in the Olifants-Doring catchment will be dealt with by several role players as shown in Figure 7.5 and Table 7.3 below.

Figure 7.5: Location of Calvinia, which experienced extreme levels of drought from 2016 to 2018

Table 7.3: Issues of concern and for consideration by different institutions regarding the water shortages in Calvinia town in the Olifants-Doring catchment

ICM issues around Calvinia Town in Olifants-Doring Catchment	Institutions or units involved
Karee Dam dried up in 2016	DWS, Hantam Municipality, Namakwa District, Northern Cape Province
Reduction in borehole yield	DWS, Hantam Municipality, Namakwa District, Northern Cape Province, farmers
Borehole water quality concerns by communities	Communities, Municipality, DWS, DEA
Productivity losses in commercial farming	Farmers, Agri Northern Cape, Department of Agriculture, banks, insurance companies
Reduced employment as high value agriculture is reduced by dry weather	Municipality, community, Department of Labour, Department of Agriculture
Planning of alternative water provision	DWS, Hantam Municipality, Northern Cape Province
Bottled water sales increased demand in area	Private business, communities, local & district municipality
Use of tankers to carry water to resident community	Local & district municipality, Provincial Office
Political differences between local and regional office	DA at municipal level and ANC at provincial level
Lower than usual rainfall (20% of MAP)	Climate Analysts (e.g. UCT), WRC, CSIR, DEA, DWS
Climate Change Projections for area	
Water availability in Game Parks in the area	National Parks, DWS, Northern Cape Province
Land claims in the catchment	Department of Rural Development and Land Reform, Department of Human Settlements
New ELUs and new water license applications	Water & Sanitation, Department of Rural Development and Land Reform, farmers
Servitude through properties for planned pipes	Farmers, water & sanitation, Department of Rural Development and Land Reform

Ideally, the ICM-R should provide access to the data and tools required to handle each of the issues of concern as listed in Table 7.3 above. The institutions or other units identified against each issue will be what falls under the role of institutions as sub-elements of the ICM-R wheel. Each institution is expected to handle the issue using the available tools and provide outputs that can be accessed by the other stakeholders or institutions. Such solutions are not limited to technical assessments, modelling or evaluations but can include social responses such as cases where the community engages with the municipality through formal channels in which data and other decisions are captured and made available through the ICM-R wheel.

7.3 Linking ICM-R elements to actual practices at catchment level

Many institutions perform ICM functions without even recognising the role of their activities in the broader water management within their catchment. There is much to gain from recognising such functions so that the different efforts can be consolidated. The ICM-R provides a consolidated platform for advancing integrated effort and recognising the positive impacts of shared efforts. For integrated catchment management to be achieved, a number of role players at all spheres of government are expected to perform interrelated functions while embracing common identifiable goals. In the case of Olifants-Doring, the farming community headed by Agri-SA is concerned with obtaining water according to what is allocated to the farmers, but in most instances water that is used is not equal to the allocated quarters creating surpluses in the water system. In addition, communities in the Northern parts of the catchment such as Calvinia have very low groundwater reserves, which are their main sources of water, and yet they are close to the Doring River. There is currently no infrastructure to provide water from the Olifants River to the settlements and communities in the northern parts of the catchment. Integrating the needs of the commercial farmers and the towns could see the development of off-river water storage dams for provision of water to the towns while the farmers will still get the water they need. Such a system will take advantage of the flows that end up going to the sea when farmers cannot use their whole water allocation. The challenges faced in this instance demonstrate the limitations of management processes that do not integrate the processes that characterise the catchment.

The functional areas for which each specific sphere of government is responsible are set out in the Constitution of the Republic. As such, a number of legislations have been promulgated in line with the Constitution to provide a mandate to the responsible role players from national to local government level. At national government, the national legislation outlines the framework for the utilisation, development and protection of the country’s land and water resources. The National Water Act gives the power to the DWS for the establishment of institutions to ensure the implementation of an integrated approach in water resource management and to facilitate the involvement of stakeholders within water management areas. Section 63 of the Act (RSA, 1998a) makes further provision for the Minister of Water and Sanitation to delegate powers and duties assigned to him/her in legislation to incumbents and future incumbents of senior water resources management posts in the civil services (RSA, 1998a). This way, the civil servants are directly responsible for the activities to be performed in the catchment to ensure that water resources are protected, managed, shared and used sustainably to benefit the nation and future generations. ICM brings with it the additional obligation in that this role that is delegated to civil servants is done in consultation and agreement with other stakeholders in the catchment.

In practice, the management of land is important to water resources. Important instruments in managing land include the Conservation of Agricultural Resources Act (CARA), which gives the provision for agricultural land users to comply with certain control measures. Agriculture is known to use most of the available fresh water resources. Water as a resource is also linked to the land on which agriculture is taking place. Therefore, agricultural land use could potentially degrade water quality through the various practices that are involved. CARA therefore provides water-related control measures, including the management of irrigated land, the prevention or control of water logging or salinisation of land, the regulation of the flow patterns for run-off water, as well as the protection of water resources against pollution from farming practices (Act 43 of 1983, Government of South Africa). This Act is also complemented by the Mountain Catchment Areas Act, 63 of 1970, which encourages the conservation, use, management and control of mountain catchment areas. The Act provides for the management of mountain catchment areas to maintain sustained streamflow yields. It provides for nature conservation, fire hazard reduction, afforestation, grazing, tourism and recreational opportunity. The National Forest Act, 84 of 1998 (RSA, 1998b), is also important in terms of water resource protection and conservation. The Act also specifies that invaders such as Eucalyptus or Pinus species encroaching the riparian vegetation from forest plantation must be eradicated since they have impact on indigenous flora and river flows.

At provincial level, the framework for the province to fulfil its constitutional mandate related to water management is found primarily in the National Environmental Management Act (NEMA) (Act 97 of 1998) (RSA, 1998c), National Development Plan 2030 (2012), and the Spatial Planning and Land Use Management Act (SPLUMA) (Act 16 of 2013) (RSA 2013). These legislations, which are administered by the Department of Environmental Affairs, give the provincial government the mandate to play roles in functional areas such as agriculture, environmental health, housing, nature conservation, pollution control, regional planning and development, urban and rural development and soil conservation (DWAF, 2004). At local government level, the functional areas relevant to water management are primarily guided by the Municipal Structures Act (Act 107 of 1998), Municipal Systems Act (Act 32 of 2000), and the Water Services Act (Act 108 of 1997). The most important sections of these legislations in support of ICM are those relating to provision of water and sanitation services, integrated development planning, performance management, public participation and cooperative governance aspects. District municipalities are responsible for the provision of water services.

The different role players in different institutions or departments do not necessarily recognise their work as part of a catchment but rather an area designated to their activities or their business reach. As such, the common purpose is lost and an environment that encourages working in silos is created. These role players can utilise ICM-R to access data and decision-making processes associated with other external entities, and emerging initiatives, thereby improving the level of interaction among themselves. The integration of different areas requires participants to have minimum levels of diversity in how they appreciate other areas that contribute to integrated management. In the present organisational structure where the DWS is responsible for most water management functions, role players from DWS, such as decision makers, could extend their ability to link with other stakeholders by engaging field-based catchment advisors. These advisors could be out in the field interacting with local stakeholders such as farmers and other land users. In the long run, this gap could be filled by the CMAs, which are expected to be based in catchments.

7.4 Connectivity of ICM-R tool to national objectives including development

Water is an essential component of our economics and is at the centre of economic and social development. It is vital to maintain health, grow food, manage the environment and create jobs. There is a close link between water and economic growth in a country (Goswami, Choudhary & Bisht, 2017). In South Africa, the National Development Plan (NDP) recognises the essential role of water in reaching social and development goals. Water plays a central role in most national planning initiatives, such as agricultural development, energy security, tourism and recreation, mining, industry and domestic water supply. The reliable supply of water in sufficient quantities and of the required quality is therefore a crucial input to economic growth and job creation. The NDP advocates that by 2030, the effective management of water and the services derived from it will support a strong economy and a healthy environment (RSA, 2012). The National Planning Commission has paid particular attention to water issues and how they impact on and influence our development pathways and opportunities. However, South Africa is a water-stressed country and is already facing a number of water challenges and concerns, including security of supply, water access inequalities, environmental degradation and resource pollution. The estimated demand for water in the country will reach 17.7 billion cubic metres in 2030, while the supply will be limited to 15 billion cubic metres – without accounting for the effects of climate change (Boccaletti et al., 2010). To that end, the second edition of National Water Resource Strategy (NWRS-2) was later adopted to ensure that national water resources are managed towards achieving NDP vision 2030. The NWRS-2 is part of a response to the NDP and outlines the strategy for protecting, using, developing, conserving, managing and controlling South Africa’s scarce water resources towards achieving the 2030 Vision. The “Economic Strategy for South Africa” document released by the National Treasury earlier this year (RSA, 2019), also acknowledged that the country will be unable to support inclusive growth and economic transformation if water supply is constrained.

In March 2018, the National Water and Sanitation Master Plan (NWSMP) was published for consultation, setting out a schedule of prioritised actions for the period to 2030 that will create a water and sanitation sector that can meet the objectives identified in the NDP and the SDGs (DWS, 2018b). The NWSMP recognises that water security is one of the biggest challenges facing South Africa and that the projected deficit by 2030 will be 17% of available surface and groundwater if substantive actions are not taken to balance supply and demand. It also recognises the need to protect and restore ecological infrastructure due to climate change, pollution and poor land use practices and degradation. It further recognises the need to reduce water demand, ensure equitable access to water, diversify water supply, create a financially sustainable water sector, build effective water sector institutions, and improve data and information management (DWS, 2018b).

For the sustainable water resource management to be achieved along with other objectives of National Water Resources Strategy, the country should swiftly advance to a holistic integrated approach for its catchment management. ICM-R therefore becomes a tool that can be efficiently used to achieve this national commitment. As a tool for all sectors and stakeholders who use and impact upon national water resources, ICM-R could provide a perfect platform to accelerate the coordination and implementation of holistic integrated catchment management.

While providing the platform for ICM implementation, the ICM-R tool will not only assist in water resource management, but has the capacity to link different national development objectives. The linkage of water usage to other indicators such as economic indicators (e.g. food, income, livelihoods, revenue, cost, trade, entrepreneurship and employment) will highlight areas where there are constraints. Those constraints with the most significant economic implications will be identified, thereby allowing for the prioritisation of interventions to improve water management and align it to the additional objectives.

An assessment of the Olifants catchment in the Western Cape showed that under several climate change projections made, irrigated agriculture will require more water to remain sustainable. At the same time, urban centres will be expanding and demanding more water (Pengelly, Seyler, Fordyce and van Vuuren, 2017). If economic development is the main objective, it would be crucial to provide for this demand given that the water required for urban areas generates greater value to the regional economy. The 2018 Western Cape drought illustrated that the economic impacts of reduced water availability could be reduced in the future by integrating water sources, user needs and better storage management, while taking advantage of the common goals set for all stakeholders. In the case of the Western Cape, the common goal in the period ending in 2018 was averting Day Zero when the provision of water was envisaged to fail completely.

The situation in the Olifants-Steelpoort catchment area is not much different from the experiences of the Western Cape, as the catchment is highly utilised and regulated. Its water resources are already overcommitted in respect of water quantity and highly stressed in quality. The value of the Olifants River Catchment's agriculture export market is over R1 billion, while mining and power generation also contribute significantly to the economy. Tourism is important in the area, which is home to some of the best known parks and lodges in the world, protecting and commercialising its diverse natural resources. Water resources in the Olifants River System are critical to the continued viability of businesses that contribute significantly to the economy. The ICM-R tool could therefore provide the resources required for multi-criteria decision systems for prioritising new developments and re-engineering existing economic activities to meet national economic objectives.

8 ICM Strategies

8.1 Strategies based on ICM-R Elements

8.1.1 Introduction to strategies and recommendations for ICM, the land and water approach

The principles of ICM have received widespread support in South Africa, but actual implementation is still in its infancy. As yet, no ICM plan under the institutional umbrella of a Catchment Management Agency (CMA) has been implemented in South Africa. However, numerous local equivalents exist throughout the country, which paves the way for providing a model for the development of a catchment plan and a strategy for implementation (Jewitt, Kedge, Schulze, Ndawonde, Hay & Kotze, 2001). Eighteen years later, the situation has not changed much as can be evidenced in the focus areas of the National Water Resources Strategy (DWS, 2013), the National Water and Sanitation Master Plan and the National Water Security Framework for South Africa (DWS, 2018a). This section thus focuses on the sources and pathways towards the successful implementation of the ICM strategies, particularly with reference to the Olifants-Steelpoort and Berg-Olifant catchment areas.

8.1.2 The ICM-R as a strategic common platform and point of reference

Ideally, the implementation of an ICM approach has to take place from a defined base. The ICM-R provides an opportunity for various active processes to be defined from the point of a common perspective where the references are defined in a way that all other role players can access and analyse over time. As such, there are good prospects to handle the dynamic state of water sector elements. The dynamism in the water sector is more visible in times of water stress such as in the current period, where it is easy for different initiatives to become reactionary and lose the potential to contribute to common goals. The ICM-R will capture the sources of challenges across the institutions and other variables in the water sector. In the present water situation, some of the sources of challenge could be captured for the benefit of all role players. This will address a few ongoing challenges such as: (i) the state of vulnerability in the sector due to the ongoing drought, which has added to the deteriorating water sector infrastructure that has been poorly maintained for long periods; (ii) the nature of resources limitations in different institutions working for various aspects of the catchment. This could include the appreciation of funding levels, performance bottlenecks in use of resources, human resources limitations as well as the possibility of misuse of available limited resources by any part of the sectors involved in the catchment; (iii) escalating public disorder due to accumulating socio-economic challenges; and (iv) an understanding of the role of weakening political structures. In recent years, the poor performances in attracting votes by the main political parties has influenced their ability to make and implement various decisions in areas that they serve as they face a stronger opposition with more voting powers. This situation is blamed for the paralysis in some areas including in the implementation of water projects, while the opposition also takes opportunities to address issues of accountability as they participate in decision making. The ICM-R presents an opportunity for improved decision making by all parties through the presentation of varied inputs covering different areas that are part of the catchment management.

8.1.3 Options for integrating stakeholder and other institutional goals

The set up provided though the ICM-R wheel provides a strategic ability for integrating goals and strategies from individual elements through the single platform. It is envisaged that the institutions that are involved as part of stakeholders in a catchment will have their organisational information shared through the platform. A remote user will have the opportunity to see the various documentations provided and assess the potential for integration and the possible options for stopping any possible duplication. The decisions made by one institution could also be shared as appropriate with stakeholders. They can then act to compliment the efforts of another institution or individuals if there is a potential to do so.

8.1.4 ICM and health

The implications of the water sector on health are worsening due to the deterioration of water quality management practices including the state of water quality maintenance infrastructure. A DBSA report pointed to worsening levels of maintenance of water quality infrastructure as well as the deteriorating state of human capacity on its operations (DBSA, 2018). The ICM-R presents a platform where the state of water quality is expected to be available and updated in the physical and environmental elements, the nature of operations taking place at possible polluting institutions is available through the information and data under operations and health elements, while the legislative tools available to control, mitigate and stop the water quality degradation are also available and accessible under legislation. The idea is that any user of the ICM-R can access the different tools, data and other information required to develop good practices or deal with an unfavourable situation.

8.1.5 ICM and society

Treating water as an economic resource that is equally accessible to all citizens irrespective of race is still a major challenge that has seen much discontent engulfing large groups of community members, especially black people, who are starting to react to what they see as a poor pace in reforms. The ICM-R should present the information that is useful to determine the nature of water access distribution at any one point and open the doors for practical ways to redistribute it based on the best available information covering various aspects of water and its use. At present, water is already allocated according to historical rights that date back to colonial times where the country's legislation and governance system was pre-occupied with discrimination and provided economic resources to white people as part of legislated practices. The legislation has changed but carried with it these distortions in access to land, water and other natural resources of economic value. Capturing information through the ICM-R and sharing it across the sectors will enable the different role players to appreciate and seek to address the continued inequalities. The tendency has been that most of the population is usually in the dark when it comes to knowledge of water access distribution patterns and as such, do not allocate time and effort required to improve the distorted state of water access. Moreover, there is a tendency to assume that the information available on water availability and use is accurate, especially when it is obtained from the very structures that established inequalities as a legislated way of life. The use of an ICM-R will enable the availability of a wider source of data and information to make the citizens better informed to contribute to the integrated approaches for resolving societal challenges in the water sector.

8.1.6 ICM-R and institutions

The ICM-R approach seeks to diversify and extend the reach of available data, tools and information. It seeks to bring integration across and within various institutions working in the water sector at catchment level. At least nine CMAs are required to promote and implement a comprehensive ICM. The ICM strategy is centred on local (catchment level) strength contributing to nationwide objectives. This is possible in a system that clearly recognises and is driven at local levels by the needs and circumstances that characterise the locations. The single CMA, as proposed in recent years, is not aligned to a strategy that seeks to build better integrated management especially given the diverse issues prevailing at local levels. CMAs should have resources that give them the capacity to lead the ICM in the catchment areas they are responsible for. Institutions have been known to be duplicating roles at local levels. This problem can easily be resolved since these institutions will have access to the functions and the strategies of the other institutions through an ICM-R.

8.1.7 Strategy on physical elements: Hydrology

The ICM-R is set as a central point for storing and accessing data and information on water including hydrological data. The platform presents the back-end for holistic and more efficient monitoring programmes for groundwater, flows, storage, rainfall, and other weather as well as hydrological variables. The tools allow users to widely disseminate recorded data and information to users in other sectors and locations so that the content of academic and technical material is well informed, leading to better decision making and more appropriate practices. The tool is set to open up the technical water sector practices to other role players who could otherwise fail to access tools and data. It addresses a situation that prevails where there is a prevalence of gatekeepers in technical fields of the water sector and related areas. This stifles creativity and protects the use of outdated methods and approaches in water management. The redistribution of available data, information and tools will enable new role players with fresh ideas to add their perspective and effort to the resources available to address water sector challenges.

8.1.8 ICM-R and the economy

The element on the economy of the catchment is set to define the economic state as well as the economic outlook in the catchment from an angle that presents the role of water and land in an integrated approach. This will entail plans for revenue collection to clear old debts, identification of loopholes in revenue management systems and how the gaps will be addressed, how water infrastructure development and maintenance will be financed and implemented from a basket of sustainable sources that include grants where applicable and sustainable loans and sources based on revenue collection. The economic aspects will deal with addressing duplication of service provision and separating services from policies across the different institutions working in the catchment. When all institutions working in the catchments and their strategies are presented in one ICM-R tool, it becomes easier to identify cases of duplication and to seek to resolve them. Water managers in the catchment will be exposed to the details regarding the use of water, where it is used and the benefits to be derived from its use. In this way, value for money in the use of water can be prioritised. The provision of water based on historical commitments such as ELUs can easily be interrogated against the capacity of recipients to use the resource efficiently and for the best outcomes, which incorporate other values apart from profitability for the individual users. The availability of societal information including livelihoods and unemployment data in the tool will enable decision makers to stretch the assessment of water use returns over a number of potential projects and programmes aimed at addressing social and economic challenges. There are high costs associated with maintaining the infrastructure that provides water to various users therefore the returns from the use should be able to sustain the continued maintenance.

8.1.9 ICM-R and the environment

The ICM approach that seeks to integrate water and land encompasses the environment as part of sustainable land management. The strategy in the ICM-R is to ensure that the benefits of ICM are holistic in how they encapsulate environmental sustainability. The ecosystem as a water user with minimum levels of needs that have to be met in terms of water availability has to be well understood, established and built into water management practices. The use of water needs, as established in ecological water requirement assessments, have to be built into a water management plan for each catchment. The deterioration of capacity to meet EFR in many catchments has to be stopped through implementation of the provisions set out in the National Environmental Management: Waste Act (Act 59 of 2008), Air Quality Act (Act 39 of 2004) and the National Water Act (Act 36 of 1998). The environmental element of the ICM-R has to be populated with the information defining the current state of the environment and the realistic envisaged state over time. This has to be linked to the national goals for the various sectors including development goals.

8.1.10 ICM-R in water use and availability

Information on water use, available resources and returns on national investments is not widely available when it comes to water uses for economic gains, especially agriculture, which uses most of the water. At present, the data on water access rights is not available to the public and also very difficult to access even when one is working on a national research project. The ICM-R should be used to widely distribute such data without constraints as is the practice in the government units tasked with water licensing. The wide distribution of key information regarding the use and access to most of the water improves water sector planning and decision making. In the present state of affairs, the stakeholders are given the impression that to allocate water to black people is near impossible as all water is committed without remaining quantities for new beneficiaries. The National Water and Sanitation Master Plan (NMSMP) shows that the government is seeking to gain marginal water and use peripheral sources to allocate water to black community members. According to the NMSMP, the sources for providing water to black applicants who wish to use it for economic uses include:

- yet to be established alternative sources of water including water that is accumulating in old mines
- small dams and boreholes that are still to be developed for provision to small scale black farmers
- reallocating water savings from irrigation schemes to black applicants
- voluntary contributions that will be requested from white commercial farmers for allocation to black applicants.

Moreover, the National Water and Sanitation Master Plan (DWS, 2018a) also recognises that the ELU rights, unlike licences have no clear boundaries for enforcement and cannot accommodate robust decisions on efficient use and reallocation. This master plan does not have urgent provisions to seek the replacement of ELUs with enforceable licences as provided for in the NWA and thus opens another door for the continuity of ELUs without limiting the committed water and time frame for a longer period which could stretch into perpetuity. The target for licensing ELUs is given as 2028 in the national water master plan, which is several decades after the original provisions that were set out when the NWA was enacted in 1998.

8.1.11 Broader scope of water planning at national level through the ICM-R approach

At national level, water management planning is mostly concerned with water resources planning under the IWRM approach. This approach dissociates water management from other important variables that are also active to development and management of resources at catchment levels. The plans do not go deeply into the economics of water, financial positions, environmental issues, social aspects, state of infrastructure, legal implications and a number of other variables but rather tend to deal with water quality. The ICM-R will present a platform where the various components of the catchment are available in one platform. The potential for a more holistic decision-making process is increased through the use of the ICM-R.

8.2 Realignment of strategies

8.2.1 The transition of thought from established ways in current practices to an ideal holistic ICM

Climate and weather are directly driven by the sun. At local level, a catchment's weather patterns are solar powered while runoff and seepage are driven by the terrain, gravitational forces and harnessed power through pumping mechanisms. Stevens (2010) explained how long-term climate change occurs as a result of changes in intensity and distribution of solar radiation reaching the earth's surface. These differences explain most of the character of rainfall in the two case studies. In the case studies considered here, the Olifants-Doring area receives radiation from the sun, which is not as dramatically different between days when compared to the Olifants-Steelpoort area that is closer to the equator. The rainfall patterns in the two areas are directly linked to this exposure to radiation and to a lesser extent, other variables such as the terrain. The Olifants-Doring area exhibits a temperate climate while the Olifants-Doring has a more tropical climate with a single distinct rain season during summer.

The commonly applied management practices in catchments tend to focus on indicators of the role that the sun plays rather than include some characteristics of the sun and radiation into what happens at catchment level. Rainfall, which is a result of the sun's radiation, is used as the starting point in water management practices rather than starting with radiation and airflow patterns. This approach over-simplifies the natural water cycle and in so doing, makes it difficult to have a closer grip of all the tools that could be used to manage water. This includes the role played by external forces in the local water cycle, which will increase the confidence that can be attached to decisions made at the catchment level.

The option to pursue holistic integrated catchment management has been driven by the appreciation of the potential benefits, including the mix of important variables that have to be accounted for in each catchment. These catchment variables include water as a habitat, water as media for conveyance, water as the source of life in an ecosystem, role of land in local and national economy, land as the basis for prevalent water access inequalities, water as a resource found in nature, water as a scarce resource, water balance, water use, water allocation, pollution, erosion, evaporation, water use management, politics of water, as well as stakeholder engagements. Within water management, issues are further complicated by the presence of an array of different interests, diverse groups of stakeholders, and consequently, several governance challenges (Varis et al., 2014). Ashton (2000) observed that the government has approached water sector governance challenges through a platform that sought to integrate water resources management rather than pursuing a full ICM, which would have required many more resources than were available when the National Water Act was implemented in 1998 (RSA, 1998a).

The current practice in the country is centred on IWRM. This IWRM approach has been criticised for its lack of appreciation of the integration of land and water. This shortcoming could be a direct result of the fact that even after the NWA (RSA, 1998a), land is only discussed in terms of being part of provisions for managing pollution while in reality the role of land is broader than its link to pollution. The Water Act actually fails to acknowledge the problem of land ownership and the resultant land-based inequalities in access and use of water resources, among other economic resources. It essentially excludes the dynamics of economic activities such as land use, which has no part to play in water legislation. The National Water Act does not mention mines and other economic sectors that are so closely linked to water. After many years of working towards reforms, it is still unclear what the place of the Act in the South African economy is. The motivation or description of the NWA is given as: “to provide for fundamental reform of the law relating to water resources; to repeal certain laws; and to provide for matters connected therewith” (RSA, 1998a, p. 1). The Act was specifically developed as a tool for reform. The NWA also was enacted to replace at least 109 other Acts (including amendment Acts) that covered a variety of elaborate variables including provisions for dams, water schemes, water boards, land areas, groups of people, settlements, rivers, public and private waterworks as well as industries. The repealed legal Acts are listed under Section 163(1) of Schedule 7 under the sub-heading “Acts Repealed” (RSA, 1998a). The NWA in its document form is only 94 pages long. There are many gaps for which more detailed legislation is still to be developed and implemented. In the meantime, there are gaps that need to be addressed in many other aspects that are not specifically to do with reform. One area that is important in catchment management is the manner in which the Act addresses water as part of the economy for all citizens. The NWA and

The NWSA barely touch on issues surrounding the economic roles of water. In fact, there is no accounting for intricate details regarding many questions that could result in limiting the actual availability of water. In addition, the water legislation as a reform tool does not adequately address other aspects of reform relating to reallocation of water for non-basic uses for the beneficiaries who previously were excluded from formal water access. The NWA also does not outline practical provisions to address the implications of specific activities including how pollution reduces available water quantities, the role of water pollutants in degrading livelihoods, the nature and cost of damage to the aquatic environment, the long-term implications of inadequate maintenance on water infrastructure, the role of dysfunctional water administration systems and even the implications of poorly developed revenue collection systems in the water sector. The legislation and institutional arrangements in the water sector do not align the value of water to be recognised according to its contribution to other sectors, which are crippled if the sector is functioning poorly. In reality, there is no water institution that is registered on the Johannesburg Stock Exchange and yet the water sector is a multi-billion-rand industry. The water industry is very much undervalued since it provides a core resource for many other industries that are registered on the country's Stock Exchange. The argument that water is a social good is not valid for most uses, especially given that the bulk of water use is for business purposes with commercial agriculture using at least 60% of the water. The implications of the information gaps surrounding the commercial value of water is that most uses do not result in commensurate returns on what is invested in bringing this water to the user as well as accounting for opportunity costs. The majority of water users do not pay for water even when they are using it in commercial ventures. This cripples the funding systems required to maintain water provision structures.

The South African Water Caucus DWS Task Team reported to Parliament that the Department of Water and Sanitation was completely dysfunctional and bankrupt (DWS, 2015d). The report presented various institutional areas that had broken down and made a variety of recommendations. One area that is evident in how these specific problems came about is that the water sector is mostly considered as a national service that is there to consume resources without generating benefits that are equivalent to the resource outlay. In this research, the idea of promoting water as a free resource is also blamed as one of the issues that underline the water sector breakdown. This concept of "water is a free good" requires further investigation to determine its role in perceptions and actions that result in the poor state of the water sector.

The approach in IWRM has separated issues that should otherwise have been considered through integrated processes. The IWRM approach as applied in the country separated water for economic use and water for basic use and in so doing, reduced the prospects of water sector transformation to the provision of basic water. In water for economic use, the system inherited colonial water access structures and maintained the water access within the parameters set during apartheid and the colonial era. According to the analysed DWS register of water use (DWS, 2018b), as much as 98% of registered water access rights belongs to white people, while the rest of the African population is still deprived of access through a variety of mechanisms. The economics of large-scale water use is still motivated based on the “need” to maintain water allocation structure as they are to avoid a situation where the economy is negatively affected. On the other hand, arguments around basic water provision are prioritised when it comes to water allocation for black people, instead of seeking to extend the socio-economic benefits that could be achieved by opening up all water access to a larger population and reducing the escalating unemployment as well as degradation of livelihoods that are affecting a large percentage of the population. This scenario tends to reduce the number of possible role players who participate in the commercial use of water and limit the beneficiaries of water sector activities to a few. A holistic integrated system, such as that provided for through the ICM-R, will encourage the participation of all stakeholders. It will extend access to data and information to all stakeholders in ways that allow for common understanding, development of common goals and integration in water sector practices at all levels, starting with the catchment level.

Table 8.1: Comparison of IWRM and ICM as envisaged when using the ICM-R approach within a South African water sector setting

IWRM	ICM
Little connection to land use and land management	Land and water are linked on one platform for integrated management
Targets are set primarily on the implementation of the National Water Act	Aims for a holistic approach in which other legislation, outside of the Water Act are important to decision making and catchment management
Allows limited number of stakeholder engagement at the catchment level using institutions such as Irrigation Boards	Creates novel avenues for all stakeholders to work towards common objectives using ICM tools and integrated institutions such as CMA
Allows the existence of compartments in how water services are separated from water resource management	Encourages development of national water strategies that embrace both water services and water resources
Places more emphasis on “vertical” integration that is limited to the water sector, where a top-down management practice is practised	Promotes both “horizontal” and “vertical” integration that not only integrate the water sector but also bring into the fray, the roles of other sectors

IWRM	ICM
Small set of catchment variables are accounted for and this mostly limited to water aspects	Wide range of catchment variables are accounted for, not limited to direct water issues but also other secondary and tertiary issues of relevance to both land and water

Table 4.1 above shows that the ICM-R tool provides a clear pathway from our current regulator-led approach to environmental management towards an approach that aims to capture as many of the potential synergies as possible. The platform gives indication for a number of emerging themes that affect how decisions about water and land resources are made, and how these natural resources could be managed and protected in an integrated manner within the catchment. The ICM-R provides a catchment interface, thus improving monitoring systems linked to decision making and planning. Although an ICM-R approach will link mines, power producers, factories and other industries to the connectivity required in the ICM, it will still need the relevant legislation and institutions to make things work.

8.2.2 Boundary issues in physical conceptualisation of ICM

The ICM concept is challenged by the very idea that referring to an area as a catchment tends to exclude other variables that are important to water management at any one point. This physical boundary dilemma entails a number of variables that cross or interact with the “catchment” from outside the “catchment”. This also stems from the definition of a catchment. The catchment area is generally defined as an area of land where rainfall or surface water drains to the lowest point. This lowest point could be a dam, river, bay, sea or other lowest drainage point in the land area under consideration. Other definitions also include groundwater draining to this point. However, in reality, the flow paths followed by groundwater are generally out of alignment with surface water flows. In fact, in the case of a groundwater source such as an aquifer, the catchment is the three dimensional area drained by the aquifer and this aquifer is underground while the point of water accumulation in a catchment area is on the land surface. The ICM approach envisaged in the study attempts to place both groundwater and surface water in the same management system and attempts to deal with the physical boundary conditions through the concepts of how the water bodies and water paths interact to become part of the same system.

In addition to the physical boundary conditions associated with groundwater and surface water, catchments are also known to exist outside of defined administrative boundaries such as in municipalities and government regional office borders. The Olifants-Steelpoort catchment is divided into sections that are in three provinces. In the Olifants-Steelpoort catchment, about 7% of the land area is in Gauteng, while 27% is in Mpumalanga and approximately 66% is in Limpopo (DWS, 2015c; RSA, 2017). In addition to the already defined differences in administrative boundaries, the municipal boundaries are not fixed. There have been changes over the years and there are still changes that are under consideration in some areas. Of direct relevance to the Olifants-Steelpoort catchment is that in 2011, municipal boundary changes increased the size of Limpopo while reducing Mpumalanga in the Olifants-Steelpoort catchment (DWS, 2015c). These changes are usually motivated based on socio-economic and political grounds rather than anything to do with the catchment.

The Olifants-Doring catchment is located partly in the Western Cape and partly in the Northern Cape. Most of the rainfall in the catchment area falls in the south-west sections of the Olifants River, which is in Western Cape, with rainfall exceeding 900 mm annually, in some parts falling to an average of 200 mm per annum in the northern areas that are located in the Northern Cape. Most of the population is also located in the Northern Cape part of the catchment. The rivers flow from the high rainfall areas in the Western Cape administrative area, and cut through the lower lying lands of the other catchment area that is in the Northern Cape. The water use distribution is defined by the topography and administrative boundaries wherein the higher areas in the Western Cape mostly use water from the Doring River, while the settlements in the Northern Cape rely on groundwater. There are plans, although without established timelines, to develop a pumping system that will take water from the Doring River to the settlements around the Northern Cape in the catchment areas that are prone to extreme levels of dry conditions and frequent droughts. What is evident in how the water is managed in the case studies is that, in the absence of functional CMAs, water management occurs according to provincial boundaries. The whole catchment, especially the area that lies in the Northern Cape, stands to benefit from holistic catchment-based development and management.

9 Conclusion and recommendations

9.1 Limitation of the objectives as encapsulated in ICM

The area that is aggregated in the use of the term "Integrated Catchment Management" (ICM) is limiting to what has become the understating of ICM, including the ideal understanding of spatial scales as envisaged here. In hydrology, a catchment is described as an area covering all the land that is drained to a point based on how gravitational forces cause water flow due to the differences in ground elevation. In contrast, ICM seeks to include all water resources connected to an area including groundwater and even moisture in the environment that can be captured to become available for use in the area. To say integrated catchment management and yet seek to build a system where groundwater and surface water are part of unitary systems when the word catchment does not have the same meaning for the two is limiting to the practical possibilities of holistic management of water. What is a catchment in groundwater or in cloud formation is not the usual catchment that is referred to in hydrology where the boundary of surface flow dynamics is the basis of the definition. The goals of Integrated Resource Management or integrated development management are ideally better suited for integration in managing water as well as other resources when the current understanding of holistic management needs is to be fully taken advantage of. The problems of spatial boundaries in ICM extend to the concept of virtual water.

Nevertheless, an ICM as envisaged here is said to be holistic, although it leaves out the added complexities associate with virtual water. Water that becomes available in the catchment through commodities brought into the catchment in question as virtual water is not directly accounted for in ICM. Additionally, water administration takes place in different institutions (Rand Water, DWS, Municipalities, Water Service Provider), at different geographical governance bodies (Municipality, WMA, Water Boards, Regional Government Departments) and for different types of water as raw surface water, potable water, grey water, groundwater, mine effluent, low flows. This is one of the challenges that is evident in the concept of ICM. Again, this calls for the elevation of the ICM concept to integrate development or resources. The ICM as a concept becomes less aligned to the reality of how water exists within other resources and the tools applied to them, such as legislation and governance processes. It is evident that the objectives of ICM are better addressed in a more global approach that accounts for all intended objectives. In the case of South Africa, the focus on development should be used to define the nature of integration.

9.2 The silo effect in water management as a drawback to holistic ICM

In the study, it was evident that different institutions have an interest or mandate to work in specific areas of water management. How these institutions address these areas creates overlaps and even duplications apart from the planned added value. However, there is little that has been put in place or is done to ensure that the different institutions share information and work towards common water sector goals in a holistic way, thus creating an environment of silos. These silos have become intrinsic to how business is done in the water sector due to the many seemingly unrelated legislative tools providing for operations and business practices in the different institutions. The other source of the silos is the nature of national institutions such as government directorates, which tend to have similar competence areas developed independently of each other such that they have no formalised processes for integration on similar or complimentary water management roles. The full implementation of CMAs could address these problems, especially if the CMAs are also defined as institutions providing water management, and constitute a common shared business practice by the various water sector institutions rather than the Department of Water and Sanitation alone. To ensure that this is practical, the legislation, for example, in the Departments of Environmental Affairs, Agriculture, Trade and Industry, Tourism, Fisheries, etc. will have to adopt clauses that link their legal provisions to integration in water management including references to key components of ICM such as CMAs.

9.3 Dealing with water legislation to enhance ICM

The water legislation in its current form was developed for water sector transformation and is not ideal for long term water management. The NWA, having been developed as a transitional legislation, has a direct focus on provisions that seek changes that are meant to drive the water sector from apartheid practices to an era where the legislation equally addresses the needs of all citizens. The focus on addressing other competence areas in the water sector and water management indicators that are of more relevance to an established and transformed water sector have not been adequately addressed and there have been talks to re-develop the Water Act to address several other areas that are evidently required in an established water sector where transformation has been taking place for at least two decades. As an example, the provisions on groundwater in the NWA are not as detailed as they were in the Water Act of 1956; however, a large section of the Act is dedicated to the establishment of CMAs that were not in the past legislation. In spite of the elaborate provisions on the establishment of transformative CMAs, the water sector has continued to exist in a vision that is forever seeking but not achieving transformation. After more than 20 years, CMAs have not been established and the envisaged transformation has not taken place. As such, the NWA has been about good wishes for transformation and less so about the implementation of these wishes. It was noted that the development of the NWA, especially the commitments made to an expanded water sector, which would have many new CMAs adding to the many other water sector institutions, were poorly conceived since it was already evident that the manpower and other resources were going to be inadequate in the future.

Water experts and legislators also face the dilemma that although water legislation is lauded for being transformative and modern, it requires change since the very objectives for its establishment have not been achieved. It is noted that there are other obstacles in the wishes for transformation that were never fully articulated and handled in the legislation. One of these has been the envisaged next step if the implementation of the NWA fails.

The failures in the transformation of water management, e.g. the unestablished CMAs, are a challenge to how investigations on holistic ICM should be drawn out. The ICM, as researched in this study, has been hopeful of the establishment of catchment-based institutions, especially CMAs, and yet there is little evidence that such CMAs will ever be established even though they are articulated in the legislation.

9.4 Building the common good to replace historical inequalities and segregation

In the water sector, participation has always been influenced by the historical background of access and use of land and water resources (Agrawal & Gupta, 2005). The country has a history of segregation and discriminative practices in the access and allocation of resources. The balance of access to resource allocation has always tipped in favour of the minority white population who dominated the political and economic landscape controlling water and land rights over a period of more than 300 years (Tewari, 2009). Participation in water and land management was thus limited to a few stakeholders and decision making was not inclusive of all those affected by the catchment resources and activities. Integration in water management is challenged by the continued existence of different paths for development and the extension of the separations established during colonial and apartheid rule. The study observed that the participation of black people in the water sector is still limited to employment, while the use of water for economic gain is still restricted to white people. Integration in terms of participation is very much along racial lines such that the conceptualisation of an ICM that will cross the racial inequalities can be contemplated on paper but is difficult to envisage in real terms. The ICM, as discussed in this study, tends to present an ideal situation where reference to a person is not racial and yet this is not the case in practice. In practice, a commercial farmer is in all probability a reference to someone who is white and male and owns a piece of land where he can practise his farming. This white farmer is possibly employing a reasonable contingent of black workers whose role is tilling the land and producing agricultural goods to generate profit for the white farmer while they secure wages. This is so, given that approximately 98% of individual commercial water users are white, of which 88% are white males. The narrative in the ICM, or IWRM that does not recognise the continued racial and gender disparities in access to water, especially water for commercial use, is a misrepresentation of reality and a way of continuing with the inequalities. To avoid limiting the prospects of achieving equity in water access and in how it is managed for the benefit of all, ICMs have to be built on the clear understanding of the pervasive water sector inequalities that maintain the nature and structure of water access as established during the colonial and apartheid eras.

9.5 Strategic use of resources to achieve integration

The investigations revealed that ICM was never prioritised in the country because it required more resources than could be availed. ICM also called for integration across different other related sectors with provisions that are provided for outside of the NWA. In the recent past, the idea of having several CMAs being central to ICM was considered to be unsustainable given the limitations in financial and human resources. There have already been moves at national level to initially reduce the planned number of Water Management Areas (WMAs) from 19 to nine. This required changes to the legislation and a bill was drafted to put these changes in place. In the past three years, there have been new calls for having just one CMA. In December 2017, the then Minister of Water and Sanitation gazetted the proposal to establish what was to be called “The Single Catchment Management Agency”, which was to cover all nine WMAs in the country. Following the changes in the Ministry, in which the Ministers were changed, first in February 2018 and again in May 2019, the initiative to establish the single CMA seems to have lost all momentum. Time, financial and other resources have since been lost without anything useful emerging in terms of establishing the very units of water management that were considered central to future water management in the country. The implications of these too many other programmes associated with holistic water management that is based on a catchment approach are that the future outlook remains clouded by the lack of certainty.

9.6 Quality of water sector data and information is central to holistic ICM

The water sector data and information are becoming less abundant and even poorer in quality due to the collapse of data monitoring programmes evident at various units of the DWS. Different units of the DWS have been failing to implement their roles due to lack of resources, poor management and a general lack of capacity. This became common knowledge after the South African Water Caucus (SAWC) launched a report that illustrated the dysfunction and institutional paralysis in the Department of Water and Sanitation (DWS). This report, which was released in November 2017, summarised several weaknesses of the National Water Sector that were developing out of control, engulfing all aspects of the water sector. In terms of data for water management, this breakdown in service provision is most evident in time series data as well as detailed local information. Instead of local content, water management is increasingly relying on international data sources, most of which are not verified locally. Water sector practitioners and other experts also tend to download data from international sources even when there is little available knowledge to prove its accuracy and efficiency in addressing the data gaps experienced locally. Ideally, ICM should rely on data from a variety of sources that has been verified against established local knowledge and captured records at local level. The quality of this data should comply with established standards. The poor data increases the risks to be encountered in solutions that are based on it. It also increases the cost of solutions and thus attracts additional resource outlay in implementing decisions coming out of management strategies and solutions that rely on it.

9.7 Dealing with global or regional ICM tools for application in a single catchment

Most models that are available at large time steps such as monthly steps deal with areas that are larger than a single catchment. In water management, these tools typically include water transfers and linkages to water sources including return flows that are connected to a larger area than the catchment as defined by surface hydrological flows, as is the case in the strict catchment definition. The use of such tools in the ICM should seek to enhance integration between catchments on top of the usual ICM as a way of integrating within the catchment. Over time, with more resources, it adds value to have both tools for modelling and implementation across catchments in addition to tools for processes that are focused on what takes place within each catchment. This is set to improve accuracy and reduce the risks associated with applying regional solutions on small spatial areas, a process that is riddled with larger margins of error bands resulting in costly decisions.

9.8 Opportunities for political initiatives to support the ideal ICM

i. The formation of functional WUAs and dissolution of irrigation boards in accordance with the provisions of the National Water Act: The WUAs should not maintain the structure of irrigation boards, which only serve white farmers, but should see to it that the structure of the WUAs are developed in the spirit of the NWA where all stakeholders are to be represented equally. The involvement of the DWS has to be improved to address the weaknesses already identified where the government resources have been used to benefit a few and are even being misappropriated on a very large scale, as reported in various parliamentary portfolio committees, with several of the shortcomings being summarised by the most recent auditing report (Auditor-General, 2018). The weaknesses of the Department that need to be addressed to ensure the success of WUAs are also highlighted by Mjoli and Nzhelele's (2009) study, as well as by Kimerink (2015), who pointed out that the national institution has to build its credibility to ensure that communities can rally behind what are perceived to be its goals. It is also the Department of Water and Sanitation that is expected to give guidance in terms of the operational needs of the WUAs, which again highlights the need for the Department to lead by example. These initiatives are expected to pave the way for an ICM process that is based on a sound foundation of political leadership.

ii. The formation of CMAs and passing down responsibilities to these units: The issue of the establishment of CMAs has been going back and forth for a long time, which tends to call for increased political will, given that the processes that have not been progressing in CMA formulation had to do with political decisions. In the latest episode, the bill that was expected to fast-track the formation of CMS was withdrawn from Parliament in February 2018. This took place after the new Minister of the Department of Water and Sanitation felt that it needed even more inputs.

iii. The expropriation of water/land to extend water access to those who continue to be discriminated against: The structures defined for water management in catchments contemplate a level playing field where the rights of all citizens are respected, where they can all participate in the management of the common resources including water. However, given the current inequalities in access to water and land, this is not practical. The past provisions of water access have focused on basic water services and excluded addressing inequalities in access to water for economic activities. The settlement patterns also continued to ensure that the past patterns are maintained such that those who were in locations where it was difficult or where there was no value in obtaining water are still experiencing the same constraints.

iv. The restructuring of methods and strategies in water institutions to ensure that other sources of water, apart from surface water, are accounted for and used in a way that extends water provision and access: The limited consideration of GW means that the sources of water are under-estimated, yet GW is an economically viable resource that does not require much water treatment investments (Swatuk, 2017:42).

v. The accommodation of stakeholder participation. This entails addressing a technocratic top-down approach where water access and provisions are decided upon at national levels and communities have to accept decisions that affect them for long periods even when they do not immediately address their needs. For example, building large dams in areas that are already served by good water services while not doing much in areas with the greatest need. This has predominantly been the case in the development of large-scale infrastructure in the country. It is focused on where the greatest economic returns are envisaged rather than where there is a greater potential to uplift depressed economic zones.

9.9 Opportunities in governance of water to achieve ICM

While the current governance systems fail to provide the structural conditions necessary to implement integrated approaches for water management, they equally present the opportunities that can be harnessed to achieve holistic ICM. Among others, some of the opportunities emanate from the following:

- Sticking to one programme and plan: The DWS has seen different programmes being promoted every time a new minister or DG was appointed;
- Addressing poor financial governance in water sector institutions: The failure of several water boards needs to be addressed, especially those in the Olifants catchment. While they have been placed under external management, new governance systems to counter identified weaknesses are required;
- Decentralisation of governance powers to regional and localised structures: In the recent past the DWS started focusing on several very large projects which sucked most of the available human and financial resources. This resulted in the DWS becoming insolvent. The poor financial state of the DWS was recorded in recent auditing reports (Auditor-General, 2018) which showed that the department's financial commitments had outstripped available financial resources in a way that was crippling ongoing and planned programmes and projects at all levels. Separating local water management to become the responsibility of CMAs and other local structures will insulate these from large national initiatives;
- Integrated coordination of land reform and water reform, which have been mostly fragmented: Land and water reform programmes need to be implemented through coordinated efforts to ensure that the reforms in different areas complement each other;
- Prioritising the development of adequate infrastructure and implementing holistic maintenance regimes: A lot of water wastage and contamination is a result of inadequate and aging infrastructure that is also poorly maintained;
- Putting efficient enforcement and strengthening the coordination of environmental governance system. There is growing non-compliance and poor enforcement in different areas of the water sector. This includes pollution, water licence acquisitions, mine closure certificate procedures and many other processes that are important in protecting water resources and
- Increasing coherence between sectors and actors when considering water resource governance. The national and regional institutions and departments with a mandate in water management require coordination and integration in their processes. Legislation and national policy could be used to address this.

The ability to effectively manage water resources is of considerable concern from a governance perspective, due to too frequent changes in management programmes. Sticking to one government programme would therefore bring stability and coherence in water management. Water resource management is a mammoth task that requires huge investment and budget, and thus proper financial management is essential. The ability to make ongoing management decisions is also influenced by the levels of monitoring and the status of supporting information management systems. There are significant concerns regarding the status of monitoring in all catchments. In the Olifants and Berg-Olifants catchments, Knüppe and Meissner (2016) observed the very negative implications of poor monitoring to water using activities. Sufficient water and land monitoring systems are necessary for decision makers, farmers and local water suppliers to maintain their functions toward achieving an ICM.

Widespread land and water degradation as well as poor management of resources reduce availability in the water sector. This is worsened by the more frequently encountered hotter and drier conditions in this region, a result of climate change. While the climate is beyond control, at least those areas that can be addressed have to receive the most attention to build a greater ability to manage water. It is problematic to see that water-polluting entities are not held accountable due to inefficiencies in enforcement and weak coordination in the environmental governance system. There is therefore an urgent need to address fragmented and overlapping institutional and legal responses to ensure the effectiveness of statutory liability for sustainable management of water.

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