water & sanitation

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Water and Sanitation
REPUBLIC OF SOUTH AFRICA

REHABILITATION MANAGEMENT GUIDELINES FOR WATER RESOURCES

SITUATION ASSESSMENT REPORT

Prepared by:

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Republic of South Africa

May 2022

Version 2.3

DEPARTMENT OF WATER AND SANITATION

Rehabilitation Management Guidelines for Water Resources

Situation Assessment Report

Sources Directed Studies Report No: RDM/RMG/00/IHP/SDS/0422

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EXECUTIVE SUMMARY

Chapter 3 of the National Water Act (NWA), 1998 (Act No. 36 of 1998) provides for the protection, use, conservation, management, and control of water resources in an efficient, sustainable and equitable manner in South Africa. Sections 19 and 20 within Chapter 3 of the NWA focuses on *prevention and remedying effects of pollution* and *control of emergency incidents*, respectively.

In 2020, the Department of Water and Sanitation (DWS) Directorate: Sources Directed Studies (SDS) initiated an in-house project for the development of the Rehabilitation Management Guidelines for Water Resources in South Africa. The project responds to one of the objectives of the Chief Directorate: Water Ecosystem Management to conduct sources directed studies.

This Situation Assessment phase of the project involved a comprehensive review of available studies, publications, projects, programmes, and initiatives specifically implemented in support of rehabilitation of water resources. This review gathered detailed progress on rehabilitation work done and identified knowledge gaps.

The review on the **Rivers and Wetlands** theme found that sufficient rehabilitation guidelines and manuals are readily available for providing locally appropriate rehabilitation interventions which enable effective protection and management. A major gap identified is the fragmentation of efforts across different of projects, programmes, and initiatives due to separate mandates and various institutions responsible for this work. This gap does not require development of new guidelines but rather an urgent need to integrate existing rehabilitation work across various disciplines, and institutions. In the interest of efficiency, efforts will not be duplicated.

Extensive studies on **Estuaries** have been undertaken in the country by DWS, Department of Forestry, Fisheries and Environment (DFFE), Cape Nature and the Provincial Department of Environmental Affairs and Development Planning (DEA&DP), that commissioned the development of the Estuarine Management Framework and Implementation Strategy (EMFIS) which prioritises the development of EMPs. Numerous EMPs have been compiled for better management of the whole estuarine functional zone, the adjacent shoreline, and the river catchment upstream of the estuaries. Several programmes and initiatives have been implemented to ensure mitigation of the pressures on estuaries and ensure their resilience. Notwithstanding the multitude of the above-mentioned implementation tools available within the Integrated Management Coastal Act (ICMA), there are no existing Comprehensive Estuary Rehabilitation Guidelines that cover estuaries in SA. EMPs are tools that provide adaptive management approaches for estuaries, however there is a lack of integration of the efforts and the work contained within these plans in relation to other related initiatives.

The review on **Lakes and Dams** found that rehabilitation studies, programmes and initiatives are mainly focused on water resources infrastructure (structural and geotechnical). This is viewed as a gap and limiting factor to the current project. The practices relating to rehabilitation of Lakes and Dams for hydrological and ecological connectivity, decommissioning of dams (*i.e.* demolishing of dams and weirs) for ecological functioning and gain are also not documented in the literature reviewed. It is against these findings that the development of Comprehensive Rehabilitation Guidelines for Lakes and Dams are recommended.

The **Groundwater** review has shown that groundwater resources are subjected to extensive use and continued pollution. In the South African context, legislation and policies that support groundwater resources rehabilitation exist. Though limited, data emanating from research studies, and initiatives undertaken in the country on groundwater resources rehabilitation are available. Various techniques and technologies are available for use in groundwater resources rehabilitation programmes; however, choice of their application depends on their respective advantages and limitations, and the type of contamination. In some instances, these techniques provide a better solution when used in combination. South African groundwater resources rehabilitation activities have been conducted through various forms of practices such as artificial recharge, AMD treatment and in-situ removal of iron from clogged borehole, however such practices do not address the actual rehabilitation of the aquifer systems. These practices are also not coordinated and adequately reported on, and a coordinated approach is necessary to sustain such practices. It is for these reasons that robust, transparent, and implementable guidelines for groundwater resources rehabilitation supported by evidence-based research and practical examples are needed.

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AMD	Acid Mine Drainage
ARC	Agricultural Research Council
AWARD	Association for Water and Rural Development
BLU	Biodiversity Land Use
BRIP	Berg River Improvement Plan
C.A.P.E	Cape Action Plan for the People and the Environment
CARA	Conservation of Agricultural Resources Act
CD: WEM	Chief Directorate: Water Ecosystems Management
CFR	Cape Floristic Region
CGS	Council for Geoscience
CMA	Catchment Management Agency
CMP	Costal Management Programme
CPD	Continuing Professional Development
CSIR	Council for Scientific and Industrial Research
CR	Critically Endangered
DALRRD	Department of Agriculture, Land Reform and Rural Development
DBSA	Development Bank of Southern Africa
DCL	Document Change Log
DCOGTA	Department of Cooperative Governance and Traditional Affairs
DEA	Department of Environmental Affairs
DEA&DP	Department of Environmental Affairs and Development Planning
DEDTEA	Department of Economic Development, Tourism and Environmental Affairs
DFFE	Department of Forestry, Fisheries and Environment
DMP	Disaster Management Plan
DMR	Department of Mineral Resources
DMRE	Department of Mineral Resources and Energy
DSEP	Dam Safety Evaluation Programme
DSRP	Dam Safety Rehabilitation Programme
D: SDS	Directorate: Sources Directed Studies
DWS	Department of Water and Sanitation
EFA	Environmental Flow Assessment
EGI	Electricity Grid Infrastructure
EIS	Ecological Importance and Sensitivity
EI4WS	Ecological Infrastructure for Water Security
EMFIS	Estuarine Management Framework and Implementation Strategy
EMPs	Estuarine Management Plans
EN	Endangered
EPA	Estuarine Protected Area
EPWP	Expanded Public Works Programme
FSL	Full Supply Level
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GEF	Global Environment Facility
HDRP	Hartbeespoort Dam Integrated Biological Remediation Programme
IA	Implementing Agent
ICOLD	International Commission on Large Dams
IDP	Integrated Development Plan
IBTs	Inter-Basin Transfers

IUCN	International Union for Conservation of Nature
IWaSP	International Water Stewardship Programme
IWQM	Integrated Water Quality Management
IWQMS	Integrated Water Quality Management Strategy
IWRM	Integrated Water Resource Management
KNP	Kruger National Park
KZN	Kwazulu-Natal
LUI	Land User Incentive
MEA	Millennium Ecosystem Assessment
MMP	Maintenance Management Plan
MPRDA	Mineral and Petroleum Resources Development Act
MWP	Mondi Wetlands Project
NCC	National Coastal Committee
NEMA	National Environmental Management Act
NEM:BA	National Environmental Management: Biodiversity Act
NEM:WA	National Environmental Management: Waste Act
NEM:PAA	National Environmental Management: Protected Areas Act
NESMP	National Estuarine Monitoring Programme
NFEPA	National Freshwater Ecosystem Priority Areas
NBI	National Business Initiative
NGOs	Non-Governmental Organisations
NHRA	National Heritage Resources Act
NWA	National Water Act
NWMS	National Waste Management Strategy
NWMF	National Wetland Management Framework
NWRS	National Water Resource Strategy
NW&SMP	National Water and Sanitation Master Plan
PEPs	Project Execution Plans
PES	Present Ecological State
RDI	Research, Development, and Innovation
RDM	Resource Directed Measures
RESLIM	Resilience in the Limpopo Basin Program
RMA	Responsible Management Authority
RMG	Rehabilitation Management Guidelines
RMP	Resource Management Plan
RQOs	Resource Quality Objectives
RU	Rhodes University
SA	South Africa
SACLAP	South African Council for the Landscape Architectural Profession
SACNASP	South African Council for Natural Scientific Professions
SAHRA	South African Heritage Resources Agency
SALGA	South African Local Government Association
SANCOLD	South African National Committee on Large Dam
SANBI	South African National Biodiversity
SANParks	South African National Parks
SAWS	South African Weather Service
SDCs	Source Directed Controls
SDF	Spatial Development Plan
SDGs	Sustainable Development Goals
SDS	Sources Directed Studies
SuDS	Sustainable Drainage Systems
SMMEs	Small, Medium and Micro Enterprises

SSP	Save the Sand Programme
SWELL	Securing Water to Enhance Local Livelihoods Programme
TNC	The Nature Conservancy
VU	Vulnerable
UEIP	uMngeni Ecological Infrastructure Partnership
UFH	University of Fort Hare
UFS	University of the Free State
UN	United Nations
UNDP	United Nations Development Programme
US	United States
USAID	United States Agency for International Development
UWC	University of the Western Cape
UWASP	Water and Nature Initiative
WANI	Water and Nature Initiative
WfW	Working for Water
WfWet	Working for Wetland
WMAs	Water Managements Areas
WRC	Water Research Commission
WWF	World Wide Fund
MWP	Mondi Wetlands Programme
WESSA	Wildlife and Environment Society of South Africa

1. PROJECT BACKGROUND AND INTRODUCTION

1.1. OVERVIEW

The Department of Water and Sanitation (DWS) is the custodian of water resources in South Africa. The Chief Directorate Water Ecosystems Management (CD: WEM) within the DWS is mandated in terms of Chapter 3 of the National Water Act (Act 36 of 1998) (NWA) to ensure protection, use, conservation, and management of water resources in an efficient, sustainable, and equitable manner. Furthermore, the NWA is founded on the principle that the National Government has overall responsibility and authority over water resource development for the benefit of the public without adversely affecting their functionality.

In 2020, the DWS Directorate Sources Directed Studies (SDS) initiated an in-house project for the development of Rehabilitation Management Guidelines for Water Resources (*i.e.* rivers, wetlands, lakes, dams, estuaries, and groundwater) in South Africa. The project responds to one of the objectives of the CD: WEM which is to conduct sources directed control to ensure water resource protection.

The sustainable management of water resources requires that water quality degradation be avoided, minimised, and remedied where applicable. Sections 19 and 20 of the NWA, respectively, make provision for environmental polluters to carry the responsibility to remedy their pollution. Furthermore, in case of an emergency where the responsible person fails to comply or inadequately complies, the Catchment Management Agency (CMA) and / or DWS (where a CMA is not yet established) may take the necessary remediation measures and recover the cost from every responsible person. The development and use of water resources (and the ecosystems within them) must not exceed the level beyond which their integrity is jeopardized. Sensitive and vulnerable water resources require specific attention in management and planning procedures, especially where they are subjected to human use and development pressures.

In order to achieve this objective, Chapter 3 of the NWA provides for the protection of water resources through the implementation of Resource Directed Measures (RDM) and Source Directed Controls (SDCs) which are founded on principles of sustainable development & use, water resource protection and preventing water resource deterioration where applicable. This is aligned with the 2030 Agenda for Sustainable Development Goals (SDGs) which aim to end poverty, conserve biodiversity, combat climate change and improve livelihoods for everyone, everywhere, "*under the theme, leave no one behind*". These objectives are unlikely to be met unless ecosystem degradation is prevented, and ecosystem rehabilitation is undertaken at the immense scale of hundreds of millions of hectares globally (UN, 2020).

1.2. PROJECT OBJECTIVES

The project aims to:

- Establish the status quo and integrate various initiatives and practices on rehabilitation management for water resources (rivers, wetlands, estuaries, lakes, dams, and groundwater).
- Map out the legislative framework supporting rehabilitation management for water resources in South Africa; and
- Develop best practices guidelines for rehabilitation management of water resources.

1.3. MOTIVATION OF THE PROJECT

This project is aimed at the development of rehabilitation management guidelines and thereafter translation of these guidelines into Practice. The development of the guidelines is a tool to effect RDM, particularly the Resource Quality Objectives (RQOs) and SDCs. Inherently encompassed in the RDM outputs is the Present Ecological State (PES), Ecological Importance and Sensitivity (EIS) tools and other ecological water resource monitoring tools utilized in the determination of RQOs and water resource classes. The DWS Resource Directed Measures (Reserve, Classification and RQOs) have been determined for rivers, wetlands, estuaries, groundwater and in some cases lakes and dams as part of the work of the CD: WEM. **Figure 1** below provides an overview of RDM studies conducted by the CD: WEM to date for the whole country.

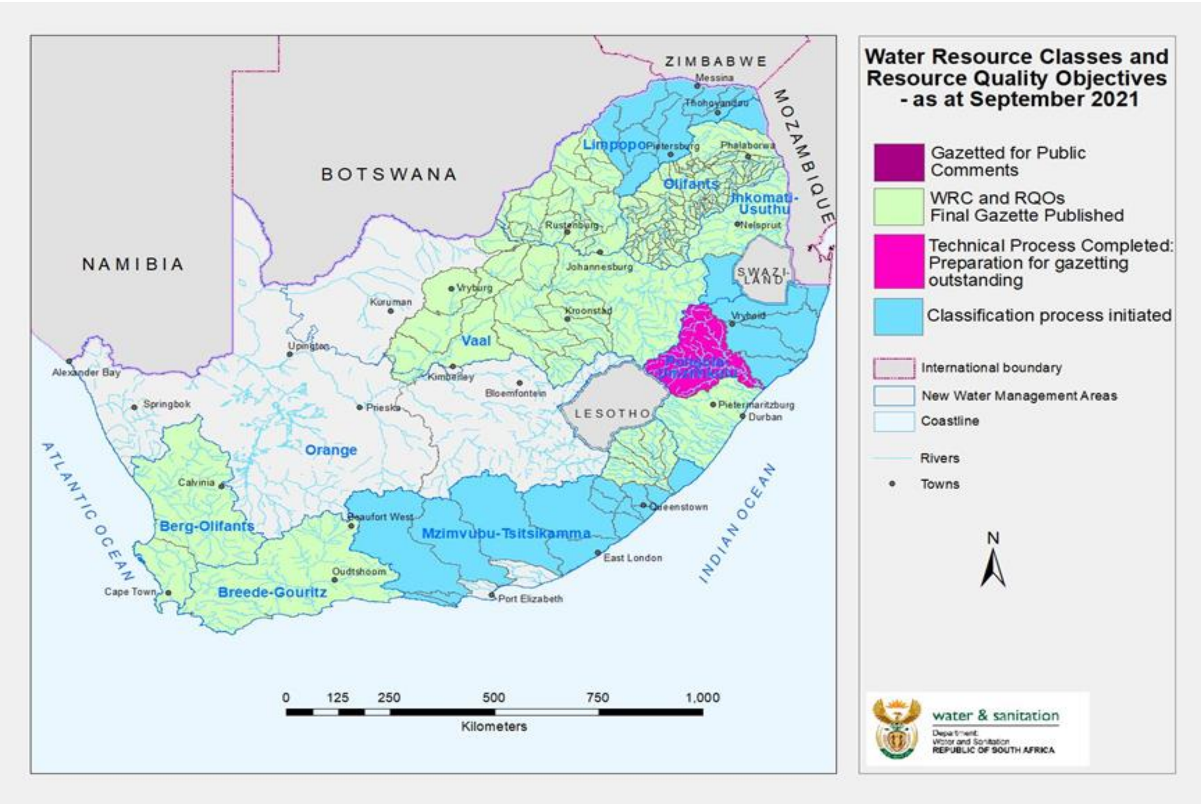

Figure 1: A map providing an overview of RDM studies conducted country wide (DWS, 2021).

These guidelines will also give effect to broader DWS strategic objectives and actions, particularly **strategic objective 5.3** of the National Water and Sanitation Master Plan (NW&SMP) which requires protection and maintenance of existing freshwater ecosystem priority areas in good functional condition by managing riparian zones, wetland buffers, critical groundwater recharge areas and carrying out rehabilitation of strategic water ecosystems such as rivers, wetlands, estuaries, lakes, dams, and groundwater resources (NW&SMP, 2018). The guidelines are also in line with Objective 1 of the National Water and Sanitation Master Plan (NW&SMP, 2018) which calls for 'resilient and fit-for use water supply'.

The development of Rehabilitation Management Guidelines is therefore informed, but not limited, by the policies and strategies below.

- The National Water Resource Strategy (NWRS) which calls for the development of government policies and strategies for proactive measures to mitigate water resource quality degradation and address legacy deterioration while maintaining healthy water ecosystems (*i.e.* rivers, wetlands, estuaries, lakes, dams and groundwater) to ensure their continued provision of ecosystem services.
- The National Water and Sanitation Master Plan (NW&SMP) Volume 1 (2018) which prioritizes the protection and restoration of ecological infrastructure to maintain water ecosystems.
- The Draft Environmental Rehabilitation Policy (2014) which is aimed at addressing other types of environmental rehabilitation which were not previously covered by the DWS and ensure inclusion of the rehabilitation of all characteristics of watercourses which include flow drivers in the landscape, namely surface flows, interflows, groundwater flows, water quality and geomorphology and responses such as habitat and biota.
- The Integrated Water Quality Management (IWQM) Policies (2016) and Strategies for South Africa (2017), amongst the guiding concepts of IWQM is **Principle 10** which focusses on the promotion of ecological infrastructure restoration and rehabilitation.
- The implementation of RDM, particularly the Reserve, RQOs and SDCs is founded on principles of improving water resources quality and reducing deterioration where applicable, and the Rehabilitation Management Guidelines are tools to effect such a need.
- DWS Level 1 Disaster Management Plan (DMP) which promotes the principle of disaster risk reduction planning by reducing hazards that impact water resources by reducing either the severity of the hazard or the vulnerability of the receiving water resource by changing the physical, social, economic, or environmental characteristics of the receiving water resource. The Level 1 DMP promotes increasing the capacity of the affected community, society, or organization by implementing disaster risk

reduction plans and initiatives.

Additionally to the above-mentioned policies and strategies highlighted, the DWS Summit held on 18-19 February 2022, Commission 6: Managing Pollution and Water Quality recommended the "Review of the Regulation Approach" as one of the water quality improvement actions.

1.4. REPORT PURPOSE AND SCOPE

1.4.1. Purpose

The primary objective of this report is to conduct a comprehensive review of available studies, publications, reports, projects, programmes, and initiatives that are specific to South Africa and have been implemented in support of rehabilitation of water resources. This review is expected to gather detailed progress made in terms of rehabilitation of water resource and identify knowledge gaps.

1.4.2. Scope

The situation assessment task will be executed on a desktop level utilizing existing information. The outcome of this task will guide the rest of the project programme in terms of the extent of work required to develop the said guidelines. In the case where guidelines, manuals or best practices guidelines are readily available for certain water resources, no duplication will be made. Efforts will be put into integration of existing work across various disciplines, government, and non-government institutions in order to ensure the harmonization and centralisation of the existing work to date. In cases where there are no guidelines in place or any other previous rehabilitation work done for other water resources, further investigation will be conducted to assist in identifying gaps that will underpin development of proper management guidelines for water resources.

1.5. LAYOUT OF THE REPORT

The report is divided into four (4) main sections as follows:

- **Section 1** contains the document signatories, document index and status, acknowledgements, table of contents, list of figures, tables, and acronyms. The section further provides project background and introduction, motivation, objectives, report purpose and scope.
- **Section 2** defines the concepts of rehabilitation that have been studied and explored by various authors around the globe. An indication is also provided with regards to the preferred and relevant terminology to be used in the current report.
- **Section 3** is subdivided into five (5) main water resource themes as follows:
    - **Theme 1: Rivers**

  - **Theme 2: Wetlands**
  - **Theme 3: Estuaries**
  - **Theme 4: Lakes and Dams**
  - **Theme 5: Groundwater**
  - The last part of this section discusses cooperative governance and partnership within the water sector; and
- **Section 4** presents the bibliography and list of appendices.

2. INTRODUCTION TO REHABILITATION

2.1. CONCEPTS AND DEFINITIONS

The concept of rehabilitation has been studied, explored, and defined by many authors around the globe. Various descriptions and definitions have been documented from several studies.

According to Rutherfurd *et al.,* (2000), *rehabilitation* refers to the process of restoration/return/recovery to natural or former state/conditions in which part of the original ecosystem elements have not been recovered.

The two most commonly used concepts on rehabilitation of water resources are *rehabilitation* and *restoration*. In most literature, both are aiming for the same outcome, the return of the structure and function of a degraded ecosystem to the *closest achievable approximation* of its natural (pre-impact) state (WRC, 2003a). Several authors (NRC, 2002; Roni *et al.,* 2008; Åberg and Tapsell, 2013) have since defined restoration of the components of an ecosystem as rehabilitation.

According to the Comprehensive River Rehabilitation Manual developed by Water Research Commission (WRC, 2016a), there is no consensus on the strict definitions of the descriptions and distinctions between *river restoration, rehabilitation, and remediation* internationally. All these terms indicate activities undertaken to improve or enhance river ecosystems in some way or the other. **Figure 2** below illustrates the different concepts as generally understood in the South African rehabilitation perspective.

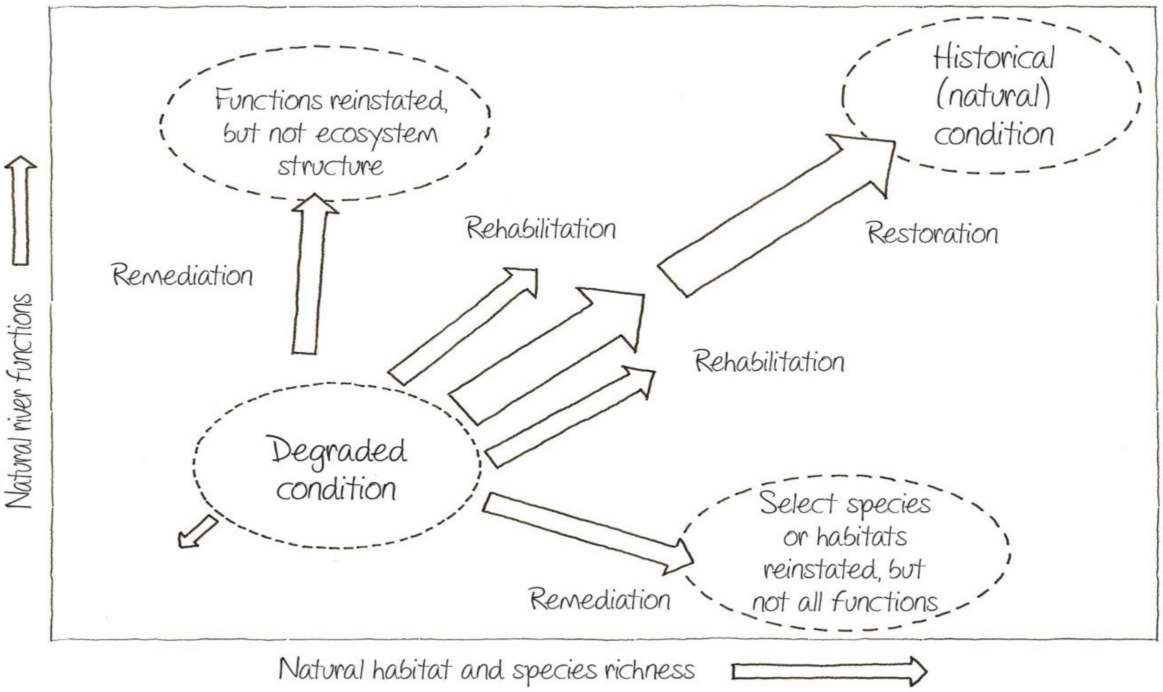

Figure 2: *The distinction between rehabilitation (towards natural), restoration (the achievement of the natural or historical condition) and remediation (select mitigation of degradation) (WRC, 2016a)*

Rehabilitation is defined as the process of promoting the recovery of ecosystem functions and values in a degraded system to regain some of the value the system previously had to society (WRC, 2016a). *Restoration* on the other hand, is different from *Rehabilitation* and *refers* to the manipulation of a site to revert the watercourse back to its full range of natural (historic) processes and functions. *Restoration* attempts to restore habitats back to their natural (historic also known as the Reference State) conditions. In the South African context, this means restoring rivers back to an A Reference State Ecological Category whilst *Rehabilitation*, by comparison, only aims to improve aspects of the degraded state such as some of the identified assets and processes of a system (WRC, 2016a).

The term *remediation* is appropriate in cases where it is not possible to rehabilitate due to ecosystems being irretrievably degraded, or where a system has been fundamentally altered in character but has, overtime, adjusted and achieved a state of dynamic equilibrium (WRC, 2004). The aim of *remediation* is to improve the ecological condition of the ecosystem, while not aiming for an outcome which resembles its original condition (WRC, 2004).

In general, the term gaining favour in Britain and Australia is rehabilitation (Rutherfurd *et al.,* 2000), while restoration remains preferred in the United States. Rutherfurd *et al*. (2000) argued that to achieve true restoration, the natural range of water quality functioning, natural sediment and flow regime, natural channel geometry and stability, natural riparian communities and native aquatic plants and animals would have to be fulfilled.

Other concepts such as *enhancement, improvement, mitigation, ecological reclamation, and habitat creation*, are part of restoring an ecosystem to its natural condition (Roni *et al.,* 2002). When these activities do not completely restore an ecosystem, they are referred to as rehabilitation (Stanford *et al.,* 1996; Roni *et al.,* 2005).

In this Situation Assessment Report, the term *rehabilitation* has been adopted because *restoration* implies a return to natural pre-impact state which is often not achievable. The goal of *rehabilitation* is the process of improvement of important aspects of the ecosystem with the aim of the system eventually resembling its pre-impact state, which resonates with DWS goal for sustainable usage of water resources.

2.2. DEFINITION OF WATERCOURSES

In terms of the definition contained within the National Water Act, Act 36 of 1998, a watercourse means:

- A river or spring;
- A natural channel which water flows regularly or intermittently;
- A wetland, dam, or lake into which, or from which, water flows; and
- Any collection of water which the Minister may, by notice in the Gazette, declare to be a watercourse; and
- A reference to a watercourse includes, where relevant, its bed and banks.

2.3. INTRODUCTION TO CHARACTERISTICS OF WATERCOURSES

A comprehensive rehabilitation process of water resources requires attention to be given across the board for characteristics of watercourses, namely:

- Surface flows;
- Interflows in the soils;
- Groundwater flows;
- Water quality;
- Geomorphology of watercourses;
- Habitat; and
- Biota.

For all the above-mentioned characteristics, rehabilitation of watercourses is limited, and a practical case is that some dams are not catered for ecological releases. Generally, rehabilitation concerning shaping, re-vegetation, and alien eradication is limited under the NWA. Rehabilitation interventions and practices that focus and include water quality issues such as pollution from Wastewater Treatment Works (WWTWs) is also limited There are myriad concerns around issues of rehabilitation and the main contributors are mines and

WWTWs as well as poor legislation in terms of buffers to watercourses and water resources. Therefore, the need for development of rehabilitation guidelines with a focus on characteristics of watercourses is enormous.

It must however be noted that rehabilitation of some of the characteristics of watercourses will be challenging. An example is groundwater, due to limited work done on groundwater rehabilitation in South Africa; however, groundwater flow is important and will be taken into cognizance in the current project. The other themes will include the characteristics to be addressed as part of rehabilitation.

Figure 3 below depicts the Ecological Water Requirements (EWRs) components for ecosystems. This figure demonstrates that water flow, water quality and geomorphology are the main drivers of EWRs and the habitat (vegetation) and biota (fauna) being the responses. The figure also depicts the relationship between flow drivers and responses - characteristics of watercourses which will be explored and addressed in the upcoming Rehabilitation Guidelines to be developed.

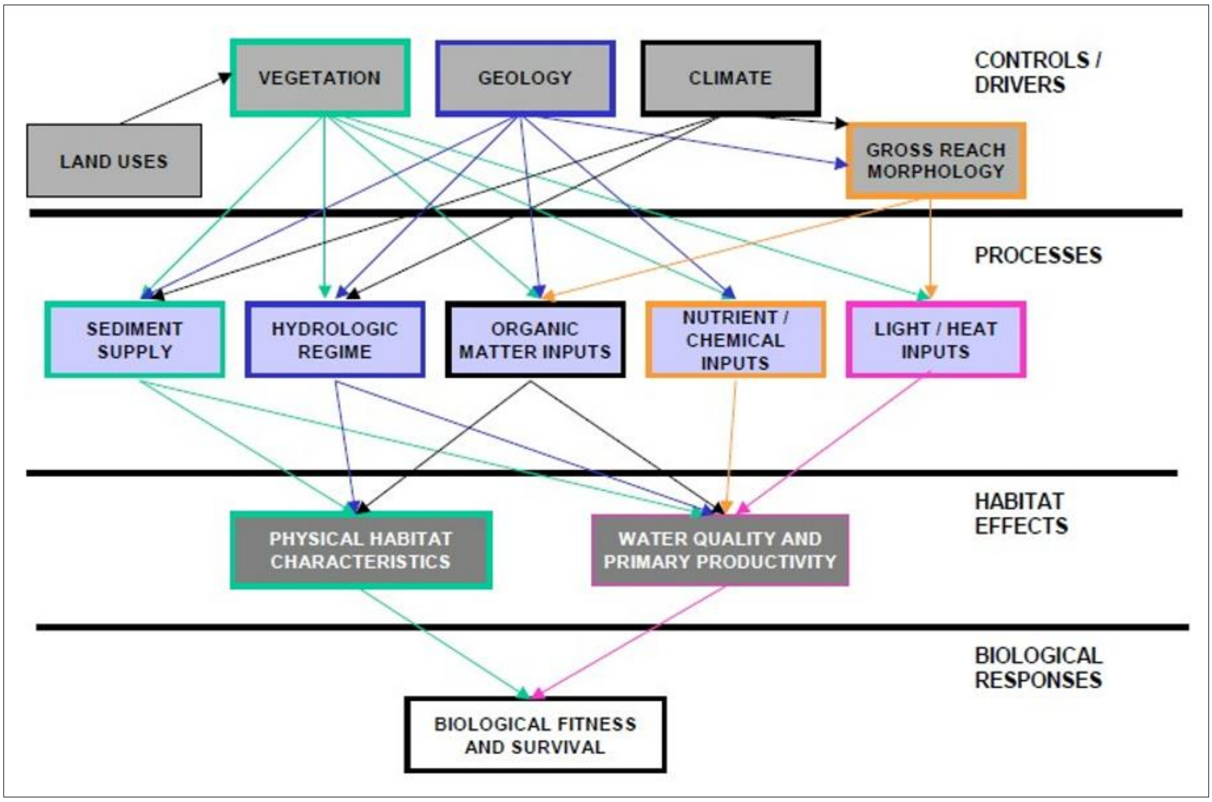

Figure 3: *The Ecological Water Requirements of the Reserve including drivers and responses (Beechie and Bolton, 1999). *Black boxes indicate controls not affected by land use. (Beechie and Bolton, 1999)*

The envisaged rehabilitation of water resources must incorporate or be linked to the rehabilitation of the abovementioned characteristics of watercourses (drivers and responses) because impacts on water resources may be as equally prevalent on all these characteristics. A point in case is that instream dams are considered as watercourses as well as part and parcel of the watercourses because all characteristics of watercourses come into play when dealing with a dam *e.g* surface flow, interflow, groundwater, water quality, geomorphology, habitat, and biota. The other reason is that dams share the same characteristics as rivers with similar operating rules, ecological flow releases, hydrological and geomorphological connectivity, whilst alien species, habitat, and buffers around them are as equally important. **Figure 4** below illustrates the link between water resources and characteristics of watercourses.

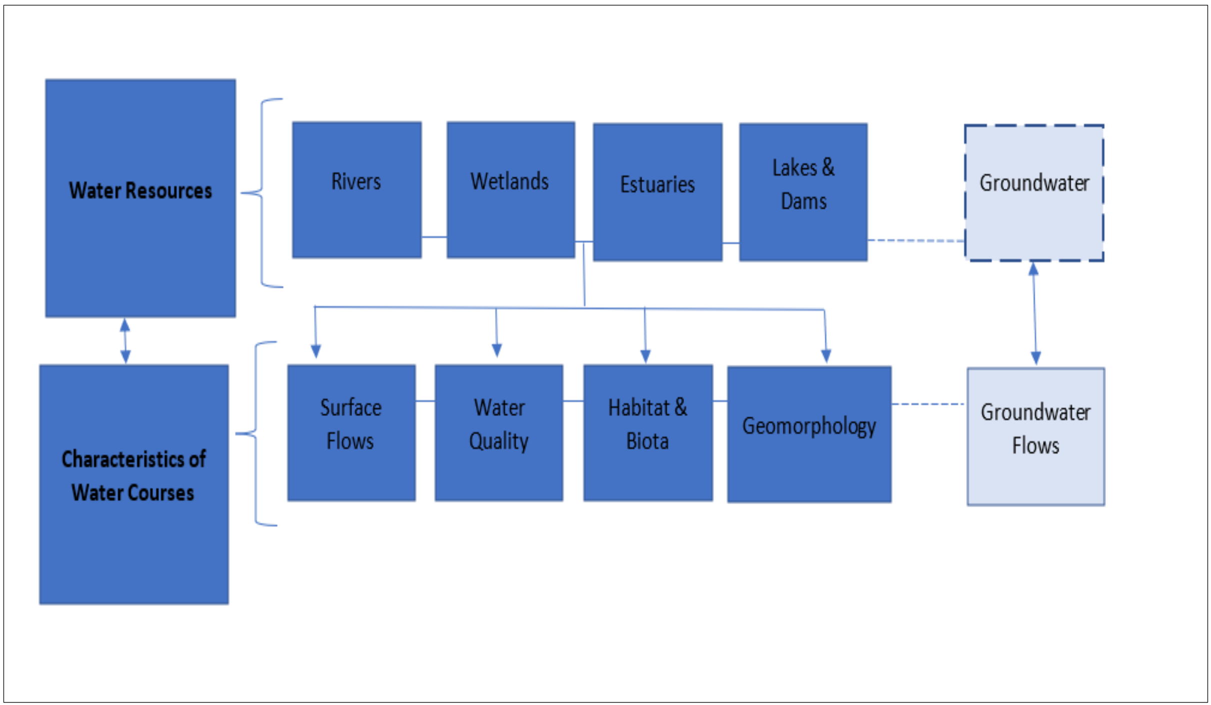

Figure 4: *Diagram depicting the link between water resources and characteristics of watercourses.*

2.4. PROPOSED REHABILITATION PROCESS/APPROACH

The preceding Section 2.2 demonstrated the link between water resources and characteristics of the watercourses (flow drivers and responses). Water resource impacts are also prevalent in the characteristics of watercourse and therefore comprehensive rehabilitation interventions must be undertaken on both these components. It is for these reasons that the following generic rehabilitation approach steps are critical prior to the execution of any rehabilitation work:

- Diagnostic Phase;
- Planning and Assessment Phase;
- Defining the rehabilitation objectives; and
- Execution of rehabilitation

3. WATER RESOURCE THEMES FOR REHABILITATION

3.1. THEME 1: RIVERS

3.1.1. CONTEXTUALIZATION OF RIVER REHABILITATION

An account of river rehabilitation management practices of water resources at a global, regional, and local level will be presented. **Global scale** perspective will cover best management practices implemented around the world in the United States, Britain, parts of Europe, China, Germany, Australia, New Zealand, and Asia. **Regional scale** perspective will encompass rehabilitation interventions that have been undertaken in Southern African Development Community (SADC) countries such as Angola, Botswana, Lesotho, Malawi, Mozambique, Swaziland, United Republic of Tanzania, Zambia, and Zimbabwe. **Local scale** cover rehabilitation work that has been conducted in South Africa. This contextualization approach will also be followed for the other water resource themes to follow.

3.1.1.1. Global and Regional River Rehabilitation Context

The rapid urbanization during 1950s and 1960s particularly in developing countries led to floods which required various preventative interventions and techniques such as planting of vegetation, terracing to slow down landslides, and building of channels to divert the rivers (Simsek, 2012). Other traditional techniques employed to achieve flood control measures were to straighten concrete channels. Consequently, these traditional methods of flood control failed (Kondolf *et al.,* 1991). During the 1970's, river management was primarily focused on the water resource itself rather than the health of the ecosystem (Simsek, 2012).

Sustaining a freshwater ecosystem has become a struggle for environmental legislators, scientists, and activists due to the rapidly increasing human population around the world and anthropogenic activities which cause ecological damage (Morley and Karr, 2002). As a result, concerned authorities are creating initiatives to recover natural river systems; however, proper effective methods cannot be implemented without sufficient information on river rehabilitation (Del Tanago *et al.,* 2012).

The practice of rehabilitating degraded river systems has recently been supported and further directed by large government agencies and public-private partnerships, through various programmes and initiatives in the United States, Europe, parts of China, Singapore, Spain, and Turkey. River restoration has become a critical and increasingly essential activity in Europe and North America, benefiting both humans and river environments (Nuruzzaman *et al.,* 2017). **Figure 5** below summarizes the transition of river rehabilitation practices in time in developing countries, whilst **Annexure A** presents some major river rehabilitation efforts around the world reported after Simsek (2012) and several other authors. **Annexure B** provides a summary of the regional river rehabilitation projects reviewed.

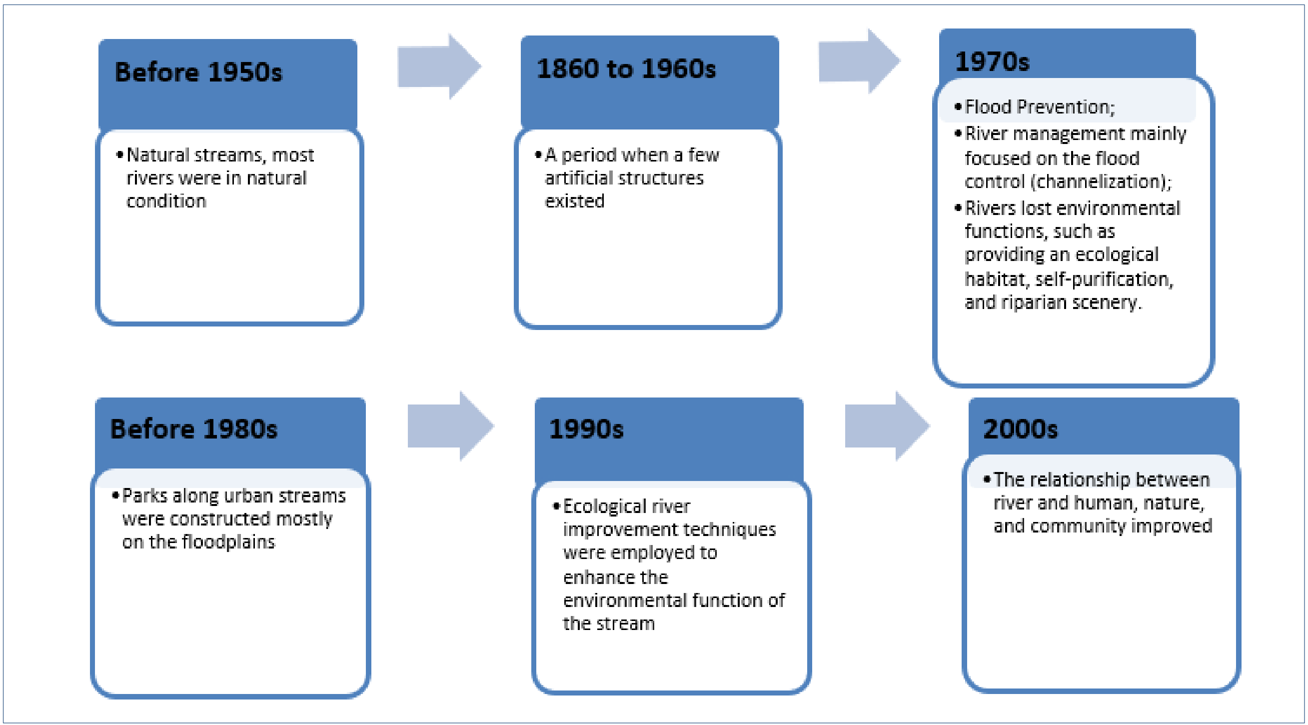

Figure 5: Transition of River Rehabilitation in developing countries (Simsek, 2012)

3.1.1.2. Local River Rehabilitation Context

River rehabilitation started to gain attention during 2003 and 2004 in South Africa. During this time, there were major concerns regarding the lack of understanding of what rehabilitation means; the insufficient research and funding directed towards it; the inadequate attention to scientific methods; the inattention to bio-engineering approaches; and the lack of planning processes in individual rehabilitation projects. Therefore, there was an urgent need for a coordinated programme which could guide research and the development of principles and processes appropriate to South African rivers to address these issues (WRC, 2003a). The WRC undertook a three-year project which aimed to contribute towards the development of a South African pool of expertise on river rehabilitation. The project focused on the review of the world literature on river rehabilitation (WRC, 2003b). The study found several programmes and projects that could link to and support the development of a standardised and scientifically founded approach to river rehabilitation in the country. The initiatives included the South African River Health Programme, Working for Water, Mondi Wetlands Programme, the Development of Geomorphological and Ecological Principles for River Rehabilitation Project, Cape Metropolitan Council Project, and the Indigenous People's Knowledge Programme.

To date, a Comprehensive River Rehabilitation Manual has been developed by WRC for effective protection and management of watercourses. The manual comprises of several new case studies dealing with rehabilitation of various river related impacts. Numerous studies have also been conducted on the Sabie-Sand River, Umzimvubu River Catchment and

Greater Cape Town Rivers. During 2014, the Department of Water and Sanitation developed a draft ***Environmental Rehabilitation Policy*** aimed to address all types of environmental rehabilitation which were not previously covered by the DWS. The scope of the policy focused on rehabilitation of water resources, and other forms of environmental rehabilitation such as rehabilitation concerning shaping, re-vegetation, and alien eradication. The policy was halted and has not been resuscitate to date.

Working for Water program is also the best example of a successful rehabilitation program which clears invasive non-native vegetation from catchments across the country (Buch and Dixon, 2008; Marais and Wannenburgh, 2008). The detailed list of river rehabilitation studies, programmes and initiatives will be presented in **Section 3.1.4** of the report.

3.1.2. RIVER REHABILITATION LEGISLATIVE FRAMEWORK

3.1.2.1. Legal Framework

According to WRC (2016a), there is a variety of acts which can potentially be triggered when undertaking river rehabilitation activities. The two main pieces of overarching legislation in South Africa are the National Environmental Management Act (NEMA) (Act 107 of 1998) and National Water Act (NWA) (Act 36 of 1998). These two legislative tools in some instances give provision for some small-scale activities to be undertaken without prior authorization (NEMA) or are eligible for General Authorization (under the NWA). To undertake small-scale activities appropriately, the Maintenance Management Plan (MMP) are applicable and restricted to sediment removal and infrastructure maintenance but to a certain extend also include alien management and other rehabilitation measures. There is other related environmental legislation that can apply to river rehabilitation activities depending on the cause for rehabilitation and different activities of rehabilitation that may need to be carried out (different approvals may be required). The overarching pieces of legislation applicable to river rehabilitation are as follows:

- National Water Act, Act 36 of 1998;
- National Environmental Management Act, Act 107 of 1998;
- National Heritage Resources Act, Act 25 of 1999 (NHRA);
- National Environmental Management: Waste Act, Act 59 of 2008 (NEM: WA);
- National Environmental Management: Biodiversity Act, Act 10 of 2004 (NEM: BA)
- National Environmental Management: Protected Areas Act, Act 57 of 2003 (NEM: PAA);
- Conservation of Agricultural Resources Act, Act 43 of 1983 (CARA); and
- Mineral and Petroleum Resources Development Act, Act 28 of 2002 (MPRDA).

3.1.2.2. Alignment with Policies and Strategies

Various policies and strategies inform River Rehabilitation Management in South Africa, and these include, but not limited, to the items below as elaborated in **Section 1.3** of this report:

- The National Water Resource Strategy (NWRS)
- The National Water and Sanitation Master Plan (NW&SMP) Volume 1 (2018).
- The Draft Environmental Rehabilitation Policy (2014)
- The Integrated Water Quality Management (IWQM) Policies (2016) and Strategies for South Africa (2017).
- The implementation of RDM, particularly the Reserve, RQOs and SDCs is founded on principles of improving water resources quality and reducing deterioration where applicable.
- Integrated Water Resource Management (IWRM).
- The Catchment Management Strategy is informed by the National Water Policy and promotes the sustainable balance between utilisation and protection of water resources in a catchment.

3.1.3. RIVER ECOSYSTEM STATUS AND DEGRADATION IMPACTS

There are 223 river ecosystem types in South Africa of which 26% are critically endangered, 19% endangered and 13% vulnerable (SANBI, 2014). Generally, river ecosystems are mainly threatened and impacted by flow alteration (amongst other factors) which is regarded as a major impact to river ecosystems. Flow alteration is driven by activities such as unlawful damming, irrigation, and poor catchment management; continuous and excessive amounts of pollutants from domestic, agricultural, and industrial sources upstream; and infestation of alien invasive species. **Figure 6** illustrates the ecosystem status and impact status for river ecosystem types in South Africa.

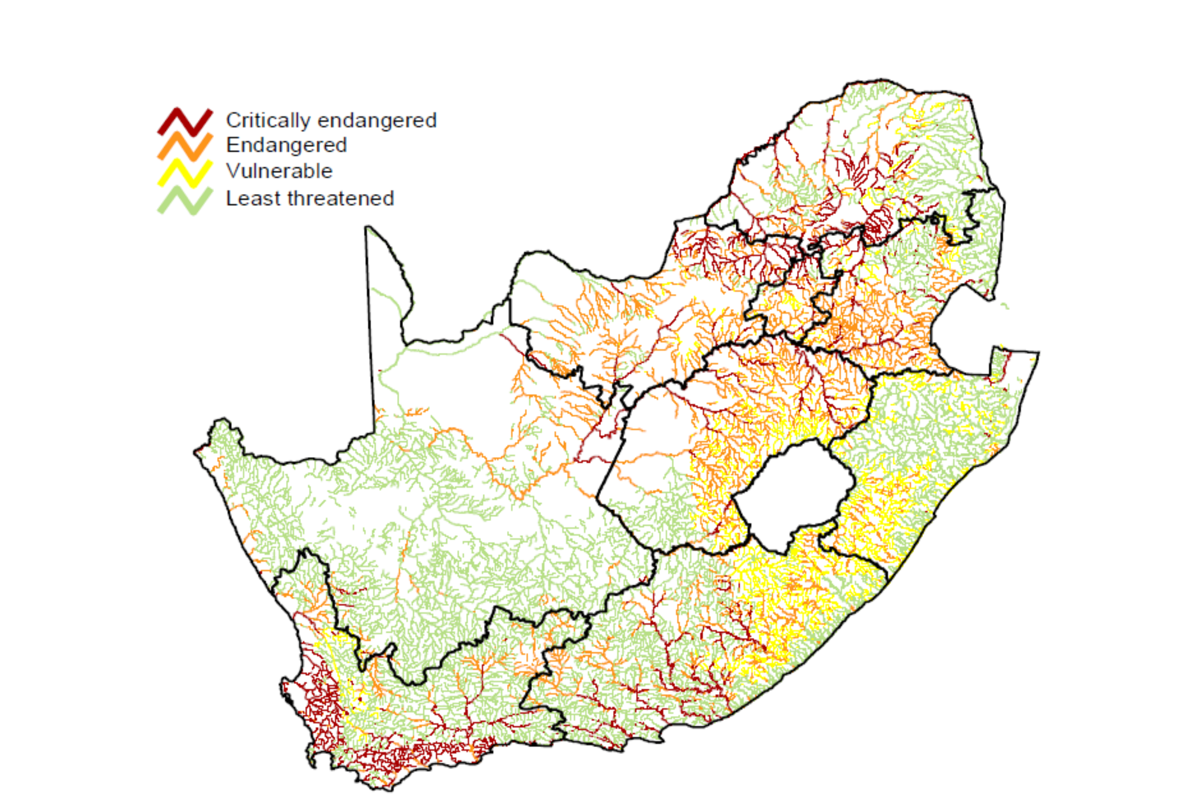

Figure 6: *Map of ecosystem impact status for river ecosystem types (SANBI, 2014).*

Table 1 provides the three main broad categories of impacts on river systems that are reported by WRC (2003b), namely **physical disturbance** associated with human induced interventions either within the broader catchment or the river channel itself; **hydrological manipulations** involving human interventions in all land-based parts of the hydrological cycle; and **chemical disturbances which** relate to the variation of water quality in rivers due to climate and the underlying geological formations, seasonal changes in flow and temperature and responding biological activity.

Table 1: *Description of the three (3) main broad categories of impacts on river systems (WRC, 2003b)*

Impacts Category	Description of impacts	Affected Characteristics of Watercourses
Physical Disturbance	• River channel disturbance - re-shaping the bed or banks, or straightening, widening, deepening or narrowing the channel in other ways; • Changes in the river channel affect the sediment & flow regimes of the channel; • Two common channel disturbances are channelization & canalization; ○ Channelization involves straightening, deepening, widening or narrowing the channel, maintaining the banks in some desired (unnatural) form, or erecting embankments;	• Surface flows; • Interflows in the soils; • Water quality; • Groundwater flows • Geomorphology of watercourses; • Habitat; & • Biota.

	Canalization is an extreme form of channelization, whereby the channel bed & banks are lined with concrete. The ecological repercussions of channelization are many & complex	
Hydrological manipulations	- Construction of instream dams & mining are two major examples of the greatest impacts to rivers. Other impacts include unlawful damming, water use and over abstraction - Inter-basin transfers of water (IBTs), direct abstraction, agricultural activities and urbanization are also other forms of interventions that have vast impacts on rivers; - In general, these interventions change the pattern of flows & sediment regimes of rivers, which have in turn led to changes in channel morphology, water quality and the biota; - Abstraction rates from groundwater aquifers also lowers the water table, reduce stream flow, possibly causes an intrusion of saline water in coastal areas and a decrease in water quality. Similarly, abstraction of interflow causes Streamflow Reduction (SFR) and result in forestry related impacts.	
Chemical Disturbances	- Chemical disturbances are caused by human impacts on both water quality & quantity through changing drainage patterns to rivers & the chemical constituents and sediments the water may be carrying; - Chemical disturbances due to human activities e.g agricultural return flows, waste discharges from industries, WWTW effluent & AMD decant; - Pollutants impact aquatic ecosystems by reducing abundances & biodiversity, & their general ability to function efficiently. Rehabilitation of degraded systems requires that attention be paid to the quality of the water, as well as the quantity & the physical attributes of the channel. Unless all three are suitable, planned rehabilitation may be unsuccessful.	

3.1.4. STATUS QUO AND INTERGRATION OF REHABILITATION INITIATIVES AND PRACTICES FOR RIVERS IN SOUTH AFRICA

3.1.4.1. River Rehabilitation Studies and Practices

Several River Rehabilitation studies have been conducted by the Water Research Commission (WRC), DWS, Wildlife and Environment Society of South Africa (WESSA) and various authors to investigate impacts on river systems and propose best management practices to ensure the systems are appropriately rehabilitated. An example is the Integrated River Management - Sabie-Sand Catchment Study conducted by Van Wilgen *et al.* (2003) to investigate the coordination of upstream and downstream activities relating to river and catchment management. Some of the impacts observed were land use changes and degradation along rivers and infestation of invasive alien plants. The study promoted development, description and communication of principles and processes that support effective, integrated, and cooperative participation in river management. Below is a list of other studies that were conducted:

- River Rehabilitation: Literature Review, Case Studies and Emerging Principles (WRC, 2003b);
- Development of River Rehabilitation in Australia: Lessons for South Africa (WRC, 2003a);
- A Consultative Project to Situate, Contextualise and Plan for a Water Rehabilitation Program (WRC, 2004);
- State of River Report: Greater Cape Town's Rivers (City of Cape Town, 2005);
- Controlling Invasive Alien Species from Rondegat River Ecosystem, Cederberg Region, Western Cape Province, South Africa (Impson *et al*., 2013);
- Draft Environmental Rehabilitation Policy (DWA, 2014);
- Restoring Urban Rivers from their Source to the Sea (WESSA, 2015);
- The Development of a Comprehensive Manual for River Rehabilitation (WRC, 2016a);
- Buffer Zone Guidelines for Rivers, Wetlands and Estuaries (WRC, 2017);
- Adaptive Integrated Water Resource Management (IWRM) in South Africa (WRC, 2019) – aimed to address water resource impacts such as over-allocation and over-use of water; deterioration of water resource health, instream flows and water quality; and
- The Green Village: Community-Based Catchment Management Guidelines (WRC, 2019c) - aimed to provide information on the basics of conservation agriculture, wise use, green energy, land restoration, and rehabilitation.

Annexure C of the report presents a detailed summary of the key impacts identified, rehabilitation methods and techniques employed for each of the abovementioned studies and other related projects. **Annexure D** highlights the key lessons learnt from each of the studies.

3.1.4.2. River Rehabilitation Initiatives and Programmes

In this sub-section, an account on the various river rehabilitation related programmes and initiatives such as Working for Water, LandCare and SANBI Freshwater Programme will be provided. The sub-section aims to:

- Gather the most up to date available information relating to river rehabilitation initiatives and programmes; and
- Identify and highlight progress made to date in order to draw conclusions and map a way forward for the development of the rehabilitation guidelines.

- **Working for Water**

  Working for Water (WfW) is programme that was launched in 1995 and administered previously through the DWS (previously known as DWAF) and now the Department of Forestry, Fisheries and Environment (DFFE). This programme works in partnership with local communities, to whom it provides jobs, and national departments including the Departments of Tourism, Agriculture, Trade and Industry, provincial departments of agriculture, conservation and environment, research foundations and private companies. WfW currently runs projects in all nine of South Africa's provinces with the aim of improving water supply by clearing alien invasive species from river basins using a range of methods that include mechanical, chemical, and biological methods as well as integrated controls.

- **South African National Biodiversity (SANBI) - Freshwater Programme**

  The Freshwater programme is a SANBI initiative which recognises the value and threatened status of South Africa's freshwater biodiversity, and the need to build competence and leadership in this area. Initiatives falling within the Freshwater Programme to date includes:

  - Working for Wetlands (WfWet), which focus on the rehabilitation, protection, and sustainable use of wetlands;
  - National Wetland Inventory, which is involved in mapping the extent, distribution, and diversity of freshwater ecosystems; and
  - National Freshwater Ecosystem Priority Areas (NFEPA) project, which aims to identify a national network of freshwater conservation areas and to explore institutional mechanisms for their implementation.

- **SANBI Living Catchments Project**

  The primary aim of the project is to establish better-resourced communities of practice that are involved with managing the built and ecological infrastructure within important water catchments. The project is implemented in the uMzimvubu, Tugela, Berg-Breede, and the Olifants rivers catchments. SANBI is leading the implementation of the project in partnership with the WRC through funding from the Department of Science and Innovation. The project was developed in response to the Water Research, Development, and Innovation Roadmap (Water Research, Development and Innovation - RDI Roadmap) which is a national planning intervention aimed at addressing water scarcity in South Africa over a 10-year period between 2015 and 2025.

- **Tsitsa Project**

  The project is a multi-stakeholder initiative centred on a partnership between the DFFE, Rhodes University (RU), LIMA Rural Development Foundation, University of Fort Hare (UFH) and University of the Free State (UFS). Other involved non-partner universities include the universities of Stellenbosch and Wits with participating student representatives. The project aims to develop and manage both land and water by using sustainable development principles. Sustainable development involves improving the environmental, economic, and the social conditions of the people who live in the Tsitsa catchment.

- **Berg River Improvement Initiative**

  The Berg River Improvement Plan (BRIP) was developed by the Western Cape Government to address water quality concerns in the Berg River. The programme was motivated by pollution in the Berg River catchment which is of great concern especially to communities, farmers, and industry in the various municipalities of the West Coast and Cape Winelands regions. To that end, various stakeholders have implemented initiatives to address the pollution concerns raised. The aim of the Improvement Plan is to have aspects of Water Stewardship Programmes and supportive water quality and economic research for the Berg River Catchment to assist the community in understanding and finding solutions to the above pollution concerns. The outcome will be a Berg River, where its value for ecosystem services is recognised, and platforms for engagement around these matters have been create (Western Cape Government, 2012).

- **Resilient Cities Pilot Project: Community Based Interventions to Improve River Health**

  Many rivers in the eThekwini Municipal Area are under stress due to invasive alien plants, waste pollution and sewage spills. These are regarded as threats to human health and the environment. To address this problem, eThekwini Municipality commissioned a pilot project on a 5.8 km stretch of the Aller River and other selected rivers. The objective of the project was to restore river health through assessments, rehabilitation, various restoration strategies and resource mobilisation. Significant progress was made in the clearing and reduction of alien plants and waste in the section of the Aller River. There was an improvement sharing information on the status quo updates and incident reports (*i.e.* sewage spills) to stakeholders, project managers and relevant municipal departments such as the eThekwini Water and Sanitation Pollution control unit.

- **LandCare Programme**

The LandCare Programme is a national government (Department of Agriculture, Land Reform and Rural Development) supported community-based initiative, driven by both the public and private sectors through partnerships and cooperation. It seeks to conserve natural resources, use them in a sustainable way, create a conservation ethic through education and awareness, create jobs and address poverty by launching various natural resource rehabilitation, improvement, and conservation projects. Through its efforts, the programme has identified serious concerns about land and water degradation in all South African provinces and specific projects address these issues. The projects are implemented through the LandCare Conditional Grant, whereby ring-fenced funding is transferred to provinces. Four sub-programmes, namely WaterCare, VeldCare, SoilCare and JuniorCare are all part of the programme.

- **Living Lands - Landscape Project**

Through collaboration with WfW, WfWet and local community farmers, the projects are undertaken to rehabilitate degraded ecosystems. The projects are active in the Eastern and Western Cape of South Africa, more specifically, in the Baviaanskloof, Langkloof and Cape Town Catchments. The projects enable improved functioning and resilience of the land and catchments which are vital water sources for important agricultural, environmental, and industrial value. The projects have built a knowledge base that has informed restoration and catchment management.

- **Biodiversity Land Use (BLU) Project**

The SANBI, together with its partners, with funding from the Global Environment Facility (GEF) through the United Nations Development Programme (UNDP) initiated the project in 2015 to support municipalities in effectively regulating land use to ensure improved biodiversity that provide essential ecosystem services to municipal residents. The overarching objectives of the project are to minimise the multiple threats to biodiversity by increasing the capabilities of authorities and landowners to regulate land use and manage biodiversity in threatened ecosystems at the municipal scale.

- **Land User Incentive (LUI) Programme**

  The programme pursues the objectives of the objectives of DFFE Natural Resource Management (NRM) and aims to invest in areas with important biodiversity, ecological infrastructure, and high levels of poverty. LUI programme provides wage support for projects (*i.e*. Non-Governmental Organizations - NGOs and private landowners) for the following activities:
  - Rehabilitation of degraded areas with erosion dongas;
  - Alien clearing in priority catchments;
  - Employment of Eco rangers to work with farmers to control grazing of livestock and ensure rotational grazing is enforced;
  - Protection of cattle through mobile kraaling and gathering of data on cattle and biodiversity;
  - Monitoring of veld condition and determination of when an area needs to be closed from grazing;
  - Ensuring compliance with rested areas and report those not compliant;
  - Protection of biodiversity against poaching.

- **Baviaanskloof-Tsitsikamma Payment for Ecosystem Services Project**

  A project through which SANBI and its Cape Action Plan for the People and the Environment (C.A.P.E) Programme in association with WfW assess the feasibility of establishing Payment for Ecosystem Services systems in the Baviaanskloof and Tsitsikamma watersheds focused on water and carbon sequestration services.

- **Maloti-Drakensberg Transfrontier Project**

  The project aims to conserve the global biodiversity which contribute to community development through income generation from nature-based tourism. The project is subdivided into several components. The project included:
  - Management conservation of existing protected areas, focusing on the control of alien invading plant species, the rehabilitation and improvement of flora and fauna conservation, prioritizing on endangered species;
  - Management conservation of planned protected areas, following strategies as devised under component 4, prioritizing on the issue of overgrazing, and loss of wetlands.

- **Ecological Infrastructure for Water Security Project (EI4WS)**

  EI4WS is a multi-stakeholder project between the Development Bank of Southern Africa (DBSA), in partnership with SANBI, the DFFE and WRC implemented over five years, nationally in the Berg/Breede and uMngeni Catchment Areas. The project is funded by the GEF through the DBSA to support integrating biodiversity and ecosystem services into the water value chain to contribute to improved water security.

- **Association for Water and Rural Development (AWARD) Projects**

  AWARD has a range of innovative projects, approaches and programmes aimed to build social and ecological resilience. Through programmes, AWARD builds institutional, community and individual capacity to manage and restore water, land, and biodiversity sub-systems in the context of climate change within the Upper, Middle and Lower Olifants Catchments. Current programmes include
  - Resilience in the Limpopo Basin Program (RESILiM) Olifants Programme;
  - Networks for Farmers Programme;
  - Wise Use of Wetlands Programme;
  - The Save the Sand Programme (SSP); and
  - The Securing Water to Enhance Local Livelihoods (SWELL) Programme.
- In 2004, the WRC in partnership with the City of Cape Town, undertook a study to determine the cost and benefit analysis of urban river and wetland rehabilitation projects through selection of three river case studies based on relevance and availability of data. The aim was to choose case studies that offered the greatest number of potential lessons and covered a variety of rehabilitation actions and outcomes.

- Three pilot projects spearheaded by three municipalities in the eThekwini Municipality in partnership with WWF and WESSA to rehabilitate the Palmiet River which was highly compromised due to impacts from massive informal settlements built in wetland areas and along the banks of the Palmiet River.

The presented river rehabilitation programmes and initiatives currently in place are sufficient and ensure effective river rehabilitation improvement and management. The main gap identified is the fragmentation of efforts across different of projects, programmes, and initiatives due to separate mandates and various institutions responsible for this work.

3.1.5. FINDINGS AND GAPS FOR THEME 1: RIVERS

Below is a list of the main findings from the review conducted.

- The current guidelines, manuals, or best practices (*i.e.* ***The Development of a Comprehensive Manual for River Rehabilitation and Buffer Zone Guidelines for Rivers, Wetlands and Estuaries***) are readily available and suffice in as far as providing locally appropriate river rehabilitation interventions which enable more effective protecion and management of rivers. It is also noted that the Buffer Zone

Guidelines does not take into consideration hydrological functions of a river which has a direct impact on rehabilitation effects. **Annexure D** provides a detailed summary of key lessons learnt from the information presented in **Section 3.1.4.**

- Water resources are under extreme impacts and pressures. Rivers are drying up and becoming too polluted to use with the major contributor being the quality of stormwater entering the rivers and wetlands especially from the metropolitan cities. Climate change is also altering patterns of weather and that of water resources, causing water shortages and droughts in some areas and floods in others.
- There is growing realization around the impacts and the costs of rehabilitation for poorly functioning water resources. Examples are the decline of fisheries, the increasing need for expensive water quality treatment, sedimentation of reservoirs, increasing severity of floods, and the loss of recreational and biodiversity assets. Due to these impacts and challenges, rehabilitation of water resources has gained attention over the years in the country.
- A great deal of research has been conducted in South Africa to understand the discipline of river rehabilitation to provide locally and site-specific rehabilitation interventions to enable more effective protection and management of rivers and wetlands. There are several existing river rehabilitation guidelines that detail the technical methods for undertaking rehabilitation activities and provide an overarching legislative framework to consider for the planning, designing, implementation and monitoring phases of rehabilitation interventions.
- There are also programmes and initiatives that are currently in place to ensure natural river rehabilitation improvement and management. The impacts on rivers were also clearly identified and contextualised for each of the studies reviewed. A range of management options have been implemented to address the various impacts identified.

Below is a list of the gaps found from the review conducted.

- Fragmentation of efforts across different projects, programmes, and initiatives due to separate mandates and various institutions conducting rehabilitation work.
- Rehabilitation initiatives conducted experience challenges with the interpretation of the legislation and compliance and enforcement which is inconsistent within the various branches of the authorizing agencies It is always not possible to obtain consistent opinion from the relevant Departments on what needs to be complied with and when. This presents a huge risk for users, especially landowners given the large fines associated with contravention of the Acts.

- Most of the river programmes do not address all characteristics of watercourses namely surface flow, interflow, groundwater flow, geomorphology, water quality, habitat, biota, and sections should be included for all these.

The summary of the key findings and results on the status quo of river rehabilitation studies, programmes and initiatives are presented in **Annexure C**

3.1.6. WAY FORWARD FOR REHABILITATION GUIDELINES FOR THEME 1: RIVERS

This review conducted has gathered detailed progress made in terms of rivers rehabilitation in South Africa. The current guidelines, manuals, or best practices which are readily available suffice in as far as providing locally appropriate river rehabilitation interventions which enable more effective protection and management of rivers. Having reviewed river rehabilitation work completed to date, the major gap identified is the fragmentation of efforts across different of projects, programmes, and initiatives due to separate mandates and various institutions responsible for this work. This gap does not require development of new guidelines but rather there is an urgent need to integrate existing river rehabilitation work across various disciplines, government, and non-government institutions respectively.

River rehabilitation work has been extensively covered in South Africa. The WRC has developed a useful suite of guidelines for sector use. In the interest of efficiency, these efforts will not be duplicated. The current study will therefore strive for the integration, alignment, harmonization, centralisation of the existing work to date and documenting lessons for future endeavours.

3.2. THEME 2: WETLANDS

3.2.1. CONTEXTUALIZATION OF WETLANDS REHABILITATION

3.2.1.1. Global Wetland Rehabilitation Context

On a global scale, wetlands are considered to be the most valuable natural resources, providing a range of ecosystems services and benefits to society (Zhu *et al.,* 2019). However, numerous key functions and benefits of wetlands are degraded and destructed at a more rapid rate than other ecosystems. Examples of wetlands of Kakadu National Park in Australia include mangroves, salt flats, freshwater floodplains, small lakes (billabongs) as well as springs and pools (Finlayson and Woodroffe 1996). These wetlands are threatened by climate change and sea-level rise with increased saltwater intrusion into freshwater wetlands and inland movement of mangroves. The Ramsar Convention, to which South Africa is 136 signatories parties, emphasized the importance of wetland rehabilitation. Yu *et al.* (2017) estimated that approximately more than 200 million ha of wetlands around the world have been designated as Wetlands of International Importance. Following the convention, many countries have implemented wetland conservation and restoration projects, together costing billions of dollars. **Annexure E** provides an account of a few examples of wetland rehabilitation projects that have been implemented and reported around the world by various authors.

3.2.1.2. Regional Wetland Rehabilitation Context

Wetlands in Africa have not been well mapped, and the cover is estimated at a total of 4,856 to 13,210 km^2 or almost 1.3 to 3.4% of the world wetland area (Food and Agriculture Organization, 2013) and 1 to 2% of the continent's land surface. Ongoing threats to wetlands include deforestation, agriculture, mineral exploitation, pollution, and peat mining (for energy) and have resulted in regional carbon emission hotspots such as in eastern Africa. The continent's wetlands contain 2.4% of global carbon in peat and release about 4% of global peatland emissions. A variety of peatland types ranging from tropical peat swamp forest to temperate bogs occur predominantly across the lower lying western and central regions (*e.g* Gulf of Guinea and the lower Congo basin) and the high-altitude regions in Ethiopia southwards across central Africa (*e.g* Rwanda and Burundi) into southern Africa (*i.e.* Lesotho and South Africa). Elsewhere coastal peat deposits are of note such as those on the Indian ocean seaboard (*e.g* the Mfabeni mire in South Africa is about 45,000 years old with 12m of peat (Grundling *et al.* 2013), whilst extensive mires occur associated with inland delta's such as the Okavango Delta and the Sudd in Botswana and South Sudan respectively (McCarthy 1993). **Annexure F** provides examples of wetland rehabilitation projects that have been implemented and reported in Lesotho by various authors.

3.2.1.3. Local Wetland Rehabilitation Context

Wetlands in South Africa play an important role in sustaining the country's ecology and economy, however wetlands have been severely affected by the anthropogenic activities that have dramatically altered landscapes over the past few centuries (Dini & Bahadur, 2016). According to Nel and Driver (2015) in NW&SMP (2018), more than 50% of wetlands have been lost in South Africa, and of those that remain, 33% are in poor ecological condition.

In 2000, the DFFE commenced with the restoration of wetlands in an effort to protect, promote their wise-use and rehabilitate them. Since 2004, the DFFE with its programme WfWet, has rehabilitated wetlands thereby improving their conditions. In the process, the program has created employment for an average of 1,650 people each year (Dini & Bahadur, 2016). Below are some of the key milestones achieved through the WfWet programme and summarized after Dini and Bahadur (2016):

- Rehabilitation of 79 wetlands per year, thereby securing the condition of approximately 6,150 ha of wetland area per year;
- Rehabilitation interventions such as building concrete, earthening, or gabion structures

to arrest erosion and trap sediment, and re-saturate drained wetland areas;

- Addressing other causes of degradation, such as poor agricultural practices and invasive alien plants;
- Plant propagation, revegetation, and bioengineering;
- Building boardwalks, bird hides, and interpretive signboards to enhance the recreational, tourism, and educational value of rehabilitated wetlands
- Concluding contractual agreements with landowners to secure the rehabilitation work, prevent further degradation of wetlands, and influence land use practices;
- Providing community members with part-time employment and training to monitor completed rehabilitation once the work is completed.

During 2007-2008, the WRC also developed a series of integrated tools (guidelines) to assist users to achieve well-informed and effective wetland management and rehabilitation of wetlands. The detailed information on the status quo of wetland rehabilitation studies, programmes and initiatives which have been undertaken over the years is reported in Section **3.2.4** of this report

3.2.2. WETLAND REHABILITATION LEGISLATIVE FRAMEWORK

3.2.2.1. Legal Framework

The South African government policy on wetlands recognizes that, in order to be truly effective, strategies for wetland conservation need to include a combination of proactive measures for maintaining healthy wetlands, together with actions to reverse past degradation. This latter aspect forms the core business of the government led wetlands programme. According to Section 24 of the Constitution of South Africa, '*everyone has the right to an environment that is not harmful to their health or well-being, and to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that prevent pollution and ecological degradation, promote conservation, and secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development'*. Below are the overarching pieces of legislation applicable to wetland rehabilitation:

- The National Water Act 36 of 1998 (NWA) - Chapter 3 provision for the *Protection of Water Resources*, with Part 3 pertaining to *Pollution Prevention*
- Conservation of Agricultural Resources Act of 1984 - substantial legal instrument for protecting wetlands and remains in force to this day.
- The National Environmental Management Act 107 of 1998. Principles such as the 'duty of care', enshrined in section 28 of the NEMA), require that landowners must take reasonable measures to prevent, minimize and rectify environmental degradation on

their properties. WfWet also offers technical expertise to landowners and collaborates with local partners to set rehabilitation objectives with the intention of improving the integrity and functioning of ecosystems. Rehabilitation measures address both the causes and effects of degradation;

- Environmental provisions of the Mineral and Petroleum Resources Development Act 28 of 2002 (MPRDA) to ensure that urban and commercial developments do not significantly affect or alter the natural state and function of wetlands.

3.2.2.2. Alignment with Policies and Strategies

Similarly, to the previous theme, various policies and strategies inform Wetland Rehabilitation Management in South Africa and these include, but is not limited, to the items below as elaborated in **Section 3.1.2.2** of this report:

- The National Water Resource Strategy (NWRS);
- The National Water and Sanitation Master Plan (NWSMP) Volume 1 (2018);
- The Draft Environmental Rehabilitation Policy (2014); and
- The Integrated Water Quality Management (IWQM) Policies (2016) and Strategies for South Africa (2017)
- Integrated Water Resource Management (IWRM); and
- Catchment Management Strategy.

3.2.3. WETLAND ECOSYSTEM STATUS AND DEGRADATION IMPACTS

Approximately 300 000 wetlands are reported to make up 2.4% of South Africa's surface area, excluding many wetlands that have already been irreversibly lost to a range of other land use activities. Of the nearly 800 wetland ecosystem types, 65% are threatened, 48% critically 7endangered, 12% endangered and 5% vulnerable (SANBI, 2014). **Figure 7** below depicts the ecosystem status and impact status for wetland ecosystem types in South Africa.

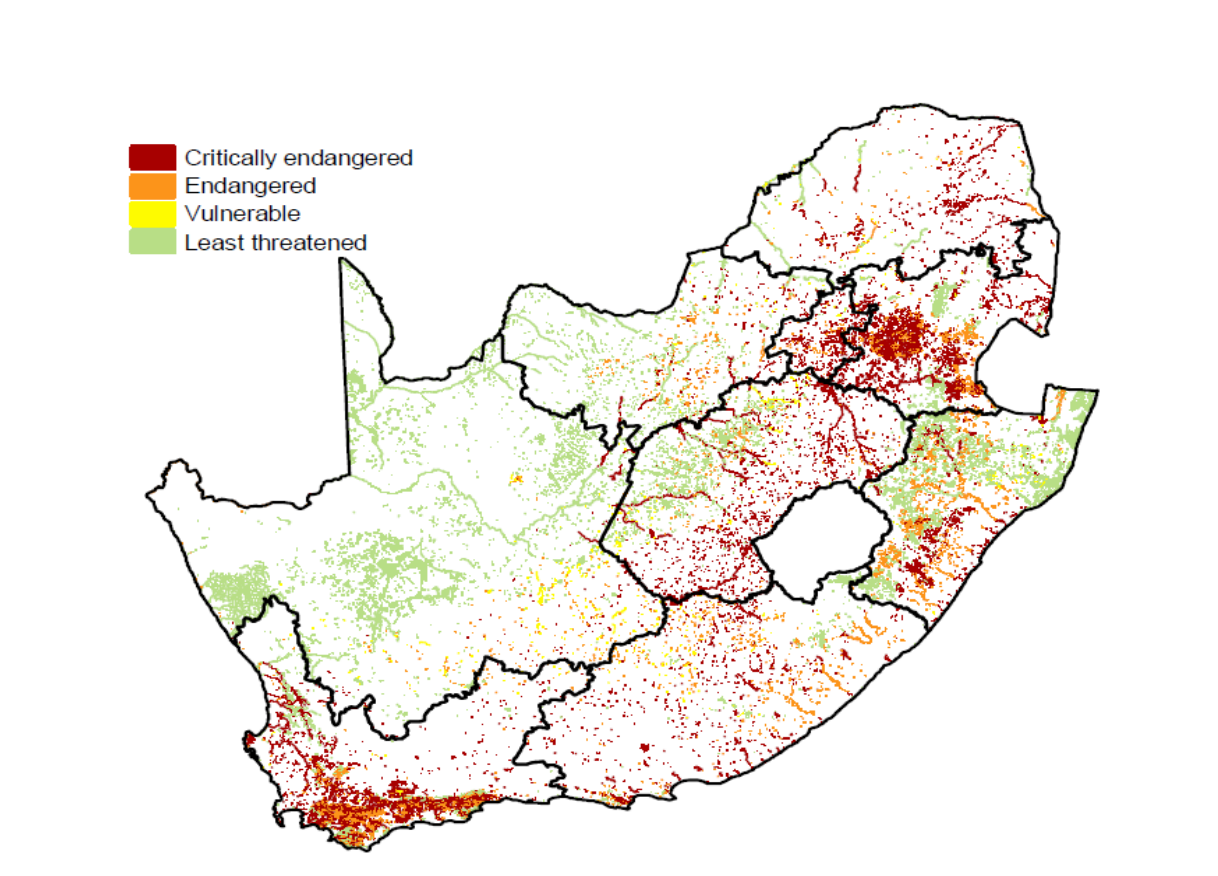

***Figure 7:** Map of ecosystem impact status for wetland ecosystem types (SANBI, 2014).*

The WfWet programme aims to prevent loss, rehabilitate, and restore degraded wetlands. The DFFE compiled Provincial Strategic Plans for 2019-2024 to address the identified impacts associated with wetlands per province. The tables on **Annexure G** of this report were adapted from DEA (2019) and modified to provide a summarized overview of the type and level of impacts affecting the wetland systems within each of the WMAs. The identified impacts have been informed by existing studies, spatial data informing land cover and land uses and development densities. These identified impacts include afforestation, mining, surface and groundwater abstraction, agriculture, siltation of canals, sewage discharge, alien invasive species, urbanization and Infrastructure development. It must be noted that the impacts on water resources may be as equally prevalent on all characteristics of watercourses such as surface flows, interflows in the soils, water quality, groundwater flows, geomorphology of watercourses, habitat, and biota.

3.2.4. STATUS QUO AND INTEGRATION OF REHABILITATION INITIATIVES AND PRACTICES FOR WETLANDS IN SOUTH AFRICA

3.2.4.1. Wetlands Rehabilitation Studies

This sub-section of the report aims to provide evidence from literature on water resources rehabilitation related studies that have been undertaken with specific reference to wetlands. Existing rehabilitation guidelines will be assessed to ascertain whether they provide sufficient details on the technical methods for undertaking wetland rehabilitation activities and interventions.

- **Guideline to the Wetland Management Series (2007-2008)**

  WRC (2007; 2008) developed integrated tools (guidelines) for assisting users to achieve well-informed and effective wetland management and rehabilitation of wetlands. The guidelines emanate from the Wetlands Research Programme project titled Wetland Rehabilitation (WRC Project No. K5/1408). The series of wetland management and rehabilitation tools comprise of the following guidelines

  - **WET-Road Map (Report No: TT321/07)** provides a brief outline of the documents and tools in the WET-Management series and describes how they inter-relate. It also provides an index to the wetland rehabilitation tools.
  - **WET-Origins (Report No: TT335/08)** describes the geological and geomorphological processes that give rise to wetlands, and provides a background description of the geology, geomorphology, climate, and drainage of southern Africa.
  - **WET-Management Review (Report No: TT335/08)** guides in providing an assessment of effectiveness at programme level, including a national overview of land-uses affecting the status of wetlands and the institutional environment that affects wetlands.
  - **WET-Rehabilitation Plan (Report No: TT336/08)** offers a process that can be followed to develop comprehensive wetland rehabilitation plans.
  - **WET- Prioritise (Report No: TT 337/08)** helps to identify where rehabilitation should take place once the objectives of rehabilitation are identified. It works at three spatial levels. At national and provincial levels, an interactive GIS modelling tool assists in identifying priority catchments by evaluating a range of scenarios based on different combinations of 13 socio-economic and bio-physical criteria.
  - **WET-Legal (Report No: TT 338/08)** presents South African legislation that is relevant to wetland rehabilitation, including the Conservation of Agricultural Resources Act (CARA), National Environmental Management Act (NEMA), and National Water Act (NWA), as well as relevant international agreements such as the Ramsar Convention on Wetlands.
  - **WET- Eco Services (Report No: TT 339/08)** used as a tool to assess the goods and services that individual wetlands provide, thereby aiding informed planning and decision making. It is designed for a class of wetlands known as palustrine wetlands (*e.g.* marshes, floodplains, vleis or seeps). The tool provides guidelines for scoring the importance of a wetland in delivering each of 15 different ecosystem services.
  - **WET- Health (Report No: TT 341/08)** assists in assessing the health of wetlands using indicators based on geomorphology, hydrology, and vegetation.

- **WET-Rehabilitation Evaluate (Report No: TT 342/08)** used to evaluate the success of rehabilitation projects and is designed with the understanding that monitoring and evaluation are closely tied to planning, which, in turn, should accommodate monitoring and evaluation elements.
- **WET-Outcome Evaluate (Report No: TT 343/08)** evaluates rehabilitation outcomes at six wetland sites in South Africa, including an evaluation of the economic value of rehabilitation.

- **Prioritizing Catchments for Wetland Rehabilitation Planning at a National Level (2015)**

Macfarlane and Atkinson (2015) initiated a study to support Working for Wetlands in achieving its mandate which is to rehabilitate damaged wetlands and to protect pristine wetlands throughout South Africa, with an emphasis on complying with the principles of the Expanded Public Works Programme (EPWP) and using only local Small, Medium and Micro Enterprises (SMMEs). The study undertook an initial prioritization of areas for wetland rehabilitation on a national scale based on the opportunity and need for rehabilitation whilst also taking socio-economic factors and opportunities for partnership with other organizations into account.

- **Wetland Rehabilitation in Mining Landscapes: An Introductory Guide (2016b)**

WRC (2016b) developed an introductory guide that aims to promote the standardised application of tools in wetland rehabilitation and improve clarity with respect to wetland rehabilitation planning, design, and implementation in mining landscapes. The guide is intended to provide appropriate practical and strategic approaches to wetland rehabilitation, and to support the development of wetland rehabilitation and management commitments and license conditions that are realistic, achievable and can be monitored. The guide was structured to provide users with the core principles that should inform planning and decision-making at different phases of wetland rehabilitation, namely planning, implementation, and monitoring and long-term management phases. Key elements integral to wetland rehabilitation in each phase are summarised in easy-reference checklists that help users ensure that the guidelines provided in this document are adhered to. The study further makes recommendations on well planned and implemented wetland rehabilitation to avoid a range of risks for proponents, government and affected communities and ensure compliance with environmental legislative provisions and authorisation requirements.

- **Rehabilitation Plan as part of the Working for Wetlands Programme (2017)**

Wetland Rehabilitation Projects for the 2016/2017 planning cycle were identified during

Phase 1 activities associated with the WfWet Programme conducted the formerly Department of Environmental Affairs: Natural Resource Management. These projects were informed by the catchment and wetland prioritisation assessment studies undertaken by Macfarlane and Atkinson (2015) whereby the objective was to identify priority catchments and associated wetlands within which rehabilitation work needed to be completed. A review was undertaken to determine local knowledge and identify existing studies of the quaternary catchments in each province. The programme's five-year strategic plans were further used as a guide to identify wetlands, as well as data from the NFEPA project. Decisions on priority areas were informed by input from wetland forums, biodiversity/conservation plans, municipalities, state departments and various other stakeholders. To date, the following wetlands have been successfully rehabilitated in some Provinces:

- Hogsback Wetland Project - Eastern Cape Province;
- Sterkfontein, Ararat, Boschkloof and Monontsha wetland systems of the Maluti–A-Phofung - Free State Province;
- Tweefontein and Enkangala wetlands of the North of Gauteng Province;
- Kruger National Park, Mapungubwe National Park and Sekhukhune wetlands - Limpopo Province; and
- Steenkampsberg and Wakkerstroom wetlands, Mpumalanga

- **Draft Wetland Management Guidelines within Municipalities (2018)**

ICLEI – Local Governments for Sustainability (2018) conducted a project aimed at the protection of priority natural wetland resources, thus enabling the supply of ecosystem services, and promoting resilient communities under a changing climate within South Africa. The project was funded by the United States Agency for International Development (USAID) and implemented by ICLEI – Local Governments for Sustainability. The project is currently being implemented in nine district and two metropolitan municipalities across the country. The lesson drawn from the study is that the draft guidelines which are a component of a series of project outputs designed to support municipalities has improved wetland management in the municipalities.

- **Draft Provincial Strategic Plan: 2019 – 2024 (DEA, 2019)**

The Provincial Strategic Plans for the WfWet programme are plans which have been compiled in support of the WfWet mandate to achieve strategic objectives related to the conservation of wetlands and poverty alleviation. WfWet is undergoing a strategic shift from focusing on heavily degraded wetland systems to lightly degraded ones. This will enable the programme to achieve a wider footprint with less complex, "softer" and cheaper interventions. The draft plans have been completed to date for the Gauteng, North-West, Western Cape, Northern Cape, Easter Cape, and Limpopo Provinces. Previous statistics (2005-2018) from the plans reveal that approximately 1 500 wetlands (about 68 000 ha) are currently under rehabilitation with a target of 61 900 wetlands to be rehabilitated by 2030. Approximately R1.1 billion has been spent with an average of R 730 000 spend per wetland and about 33 000 jobs created for poverty alleviation and skills development.

- **Development of the National Wetland Management Framework (NWMF) (2021)**

  A **draft NWMF** was developed in August 2021 which outlined the key problems that needed to be addressed and the objectives and strategic (level1) actions that DWS, Department of Agriculture, Land Reform and Rural Development (DALRRD) and DFFE as well as their institutions need to undertake. Through a series of national workshops held to improve the draft framework, challenges and priority actions were identified *i.e.* **17 Objectives and 95 Actions** towards a mission of working together to protect and restore wetlands and their functions. The framework is set to be tabled for support and buy-in by top management in the departments. The following are the next steps to be pursued:

  - Initiate a process to update the draft DWS **wetland policy** so that it includes new thinking and biodiversity and agriculture aspects;
  - Undertake a process to unpack the NWMF - *i.e.* develop an implementation plan which will entail ***(i)*** Determine activities (level 2), ***(ii)*** Determine responsibilities (National vs. provincial/agencies, which section in each department), ***(iii)*** Determine time lines, costs and, ***(iv)*** Determine priorities.

3.2.4.2. Wetland Rehabilitation Initiatives and Programmes

In this sub-section, an account on the various wetland rehabilitation related programmes and initiatives such as Working for Wetland will be provided. The sub-section aims to:

- Gather the most up to date available information relating to wetland rehabilitation initiatives and programmes; and
- Identify and highlight progress made to date in order to draw conclusions and map a way forward for the development of the rehabilitation guidelines.

- **Working for Wetland**

  WfWet is a joint initiative of the DFFE and DWS. WfWet pursues its mandate of wetland rehabilitation and wise use in a manner that maximises employment creation, supports small emerging businesses, and transfers skills to its beneficiaries. In line with EPWP norms, the programme targets those groups most excluded from the mainstream economy, with particular emphasis on women, youth, and people with disabilities. WfWet is based on key interlinked concepts that ensure effective and sustainable wetland rehabilitation through Wetland Protection, Wise Use and Rehabilitation, Skills and

Capacity Development, Co-operative Governance and Partnerships, Knowledge Sharing and Communication as well as Education and Public Awareness.

- **People and Parks Programme**

  The aim of the programme is to address issues at the interface between conservation and communities in particular the realization of tangible benefits by communities who were previously displaced to make way for the establishment of protected areas. To date eight co-management agreements have been signed between different conservation agencies and local communities, and an annual plan of operation has been developed. To ensure that communities understand co-management agreements, DFFE in partnership with Resource Africa has trained 837 beneficiaries on co-management in 24 protected areas around the country.

- **World Wide Fund (WWF) - Mondi Wetlands Programme (MWP)**

  This programme has had three name changes since its inception; 1991-2000 - Rennies Wetland Project; 2001-2012; 2013 to present - WWF- MWP. MWP was established by the WESSA and WWF. The aim of the programme is to work towards the social change required to improve wetland sustainability practices of communal wetlands in rural areas through raised awareness (wetlands through the generation of publicity on wetland importance, topical wetland issues, their rehabilitation, sustainable utilization, and management), increased capacity and competence. The programme provides some best examples of partnerships and cooperative governance which will be summarized in Section 3.6 of the report.

The presented wetland rehabilitation programmes and initiatives currently in place are sufficient and ensure natural wetland rehabilitation improvement and management. The main gap identified is the fragmentation of efforts across different of projects, programmes, and initiatives due to separate mandates and various institutions responsible for this work.

3.2.4.3. Wetland Rehabilitation Practices

In 2009, the Agricultural Research Council (ARC) – Animal Production Institute based at the University of the Western Cape (UWC) initiated a project in collaboration with the Leliefontein Methodist Church and Agri-Kameelkrans Farmers Union to rehabilitate the Leliefontein Wetland in the Northern Cape Province which was degraded due to grazing, plant harvesting and the alien invasive poplar trees that were planted by the missionaries to provide additional sources of fire wood to the community (ARC, 2010).

The Working for Wetlands programme undertook various Wetland Rehabilitation Projects following the identification of impacts associated with wetlands per province. These projects were informed by the catchment and wetland prioritisation assessment studies undertaken by Macfarlane and Atkinson (2015) whereby the objective was to identify priority catchments and associated wetlands within which rehabilitation work needed to be completed.

Dini and Bahadur (2016) provided an account of a series of rehabilitation case studies produced through a four-year research programme implemented by Working for Wetlands that illustrates some of the benefits of the work, including improved livelihoods, protection of agricultural resources, enhanced biodiversity, cleaner water, and reduced impacts from flooding.

The Freshwater Research Centre, in collaboration with The Nature Conservancy (TNC) and Anchor Environmental Consultants undertook a desktop prioritisation of wetlands located within catchments upstream of the major dams supplying water to the City of Cape Town – Steenbras Dams (Upper and Lower), Theewaterskloof Dam, Wemmershoek Dam, Berg River Dam and Voëlvlei Dam - in the Western Cape (Snaddon *et. al.,* 2018). The wetlands were assessed and prioritized to inform their respective rehabilitation plans and costs. **Annexure H** provide a summary of the key impacts identified, rehabilitation practices and techniques implemented for each of the abovementioned projects and case studies.

It is evident that several wetland rehabilitation best management practices available have been implemented on various impacted wetland systems, from the information presented above. The practices implemented also demonstrates that successful wetland rehabilitation management require institutional collaboration and cooperative participation.

3.2.5. FINDINGS AND GAPS FOR THEME 2: WETLANDS

Below is a list of the main findings drawn from the review conducted in **Section 3.2.4** and succinctly summarized in **Annexure I.**

- The **Wetland Management Series** guidelines is the first of its kind to be developed in SA for effective wetland management and rehabilitation. However, through various trials and experiences gained in the application of these tools during the last ten years, there was an urgent need to update some of these tools. **The WET-Rehab Evaluate, WET-Health and WET-Eco Services were updated during 2019, 2020 and 2021 respectively.**
- Water resources are under extreme impacts and pressures. In South Africa, more than 50% of wetlands have been lost, and of those that remain, 33% are in poor ecological condition. Climate change is also altering patterns of weather and that of water resources, causing water shortages and droughts in some areas. There is growing

realization around the impacts and the costs of rehabilitation for poorly functioning water resources. Due to these impacts and challenges, rehabilitation of water resources has gained attention over the years in the country.

- A great deal of research has been conducted in South Africa to understand the discipline of wetland rehabilitation to provide locally and site-specific rehabilitation interventions to enable more effective protection and management of wetlands.
- There are several existing wetland rehabilitation guidelines that detail the technical methods for undertaking rehabilitation activities and also provide an overarching legislative framework to consider for the planning, designing, implementation and monitoring phases of rehabilitation interventions.
- There are also programmes and initiatives that are currently in place to ensure natural wetland rehabilitation improvement and management. The impacts on wetlands were also clearly identified and contextualised for each of the studies reviewed. A range of management options have been implemented to address the various impacts identified.

Below is a list of the gaps found from the review conducted**.**

- Fragmentation of efforts across different projects, programmes, and initiatives due to separate mandates, and various institutions conducting rehabilitation work
- Many wetlands rehabilitation programmes do not address all characteristics of watercourses namely surface flow, interflow, groundwater flow, water quality, geomorphology, habitat biota.
- Most wetland studies/ programmes do not address the roles of constructed wetlands in the landscape. A good example is the man-made RAMSAR wetland Barberspan or proposed large scale wetland construction to treat non-compliant WWTW discharges. Another example is constructed wetlands in parks to enhance the ecological category of a watercourse or for recreational purposes

The detailed summary of the key findings and results on the status quo of wetlands rehabilitation studies, programmes and initiatives are presented in **Annexure J.**

3.2.6. WAY FORWARD FOR REHABILITATION GUIDELINES FOR THEME 2: WETLANDS

This review conducted has gathered detailed progress made in terms of wetland rehabilitation in South Africa. The current guidelines, manuals, or best practices which are readily available suffices in as far as providing locally appropriate wetland rehabilitation interventions which enable more effective protection and management of wetlands. Having reviewed wetland rehabilitation work completed to date, the major gap identified is the fragmentation of efforts across different programmes and initiatives due to separate mandates and various institutions responsible for this work. However, this gap does not require development of new guidelines but rather there is an urgent need to integrate existing wetland rehabilitation work across various disciplines, government, and non-government institutions.

Wetland rehabilitation work has been extensively covered in South Africa. The WRC has development useful suite of guidelines for sector use. In the interest of efficiency, these efforts will not be duplicated. The current study will therefore strive for the integration, alignment, harmonization, centralisation of the existing work to date and documenting lessons for future endeavours.

3.3. THEME 3: ESTUARIES

3.3.1. CONTEXTUALISATION OF ESTUARY REHABILITATION

3.3.1.1. Global Estuary Rehabilitation Context

Geographically, an estuary is described as a semi-enclosed coastal body of water with a connection to the open sea, whereby the seawater salinity is measurably diluted with river water (Pritchard,1967; Elliot and McLusky, 2002). Recent research uncovering the extent of marine habitat degradation has sparked a global surge in rehabilitation projects. For example, in Northwest Europe (Scheldt Estuary) objectives were developed and incorporated from three main perspectives: port accessibility, flood protection in dense population catchments and ecosystem health. The goal of this research was to rehabilitate estuary ecology and create a natural sustainable environment, looking for potential collaboration with flood-prevention protective measures, as well as improvements to the estuary's educational and recreational values. The estuary targets by the Dutch-Flemish plan are still currently ongoing and set to be achieved by the year 2030 (Van den Bergh *et al*., 2005).

In the United States, oyster reef restoration efforts by the National Estuaries Restoration Inventory (NERI) were investigated to assess restoration progress and identify challenges in the estuary. The analysis confirmed a lack of monitoring data or project-specific assessments of success as a major issue hindering the field of rehabilitation ecology (Blomberg *et al.*, 2018). Several factors have been highlighted in the literature as a necessity for effective estuarine rehabilitation programs. These conditions are grouped as follows:

- the presence of experimentation options;
- using the correct communication strategies;
- pro-activity of key-role individuals;
- sufficient project support;
- integration of information and active participation of stakeholders.

3.3.1.2. Regional Estuary Rehabilitation Context

The Zambezi Delta, Maputo, Incomati, and Pangani (estuaries) are just a few of the countries in the subcontinent that have conducted Environmental Flow Assessments (EFAs) for their estuaries (Brown *et al.*, 2020). Major regional pressures on estuaries include pollution, freshwater inflows, exploitation of resources etc **(See Annexure L).** Thus, estuary restoration and their associated ecosystems, such as salt marshes, have been identified as management priority in the recent South African National Biodiversity Assessment (van Niekerk *et al*., 2019). A national socio-ecological systems framework for the restoration of salt marsh was presented in which the level of pressure was identified, and viable rehabilitation initiatives outlined. This framework was presented in the South African context, but contains critical components derived from global rehabilitation frameworks (Gann *et al*., 2019; Rendón *et al*., 2019), thus making it globally relevant to salt marshes.

In tropical and subtropical parts of the world, mangroves make up the coastal and estuarine wetland ecosystem. This intertidal ecosystem protects coastlines from severe storms, erosion, and flooding. The primary objective of this research was to evaluate changes in forest cover, structure, and conservation status in the mangroves of the Incomati Estuary, a peri-urban forest in Maputo city using GIS techniques (Macamo *et al*., 2015). By identifying the most vital areas of the Incomati Estuary and describing forest condition, this study demonstrated the poor condition of peri-urban mangroves in locations such as this in eastern Africa and highlighted the need for further understanding of estuary regimes that may influence mangrove community changes other than deforestation.

The objectives of the (EFA) were to generate baseline data on the condition of the estuary against which the impact of water-related decision-making can be monitored in the future, develop simple tools to help guide water-resource management and water allocation, and to support the National Water Policy (NAWAPO 2002) and the National Environmental Management Act (2004). Information from EFA was utilized in the organization of ecological, social, and economic knowledge of the basin in aiding future management of its water resources.

3.3.1.3. Local Estuary Rehabilitation Context

In South Africa, the DWS Classification and RQOs assessments have been successfully completed for approximately 40% of the estuaries (**see Table 4 below**). **Annexure K** provides the PES and REC status overview for estuaries in the country *i.e.* Mzimvubu Estuary, Mvoti to uMzimkulu Estuaries and Estuaries of the Breede Overberg Region.

Estuary restoration is not without its challenges, as the management interventions at the St Lucia Estuary have shown. In 2012, the uMfolozi River was reconnected to St. Lucia Estuary (**Table 2**). The iSimangaliso Wetland Park Authority initiated this with financial assistance from the GEF. This reconnection further increased the freshwater inflow into the St. Lucia system (Forbes *et al.*, 2020), but also resulted in a prolonged oligohaline state, severely reducing the abundance and diversity of estuarine fish and invertebrates. Additionally, the high silt load carried by the uMfolozi River has negatively influenced the fish communities (Cyrus *et al.*, 2020), and caused a shift in zooplankton and macro-fauna composition, with knock-on effects at higher trophic levels (Jones *et al.*, 2020). These changes highlight the importance of intensive monitoring of and research on the recovery options, if restoration efforts in South Africa and elsewhere are to achieve their desired outcomes (Forbes *et al.*, 2020).

Table 2: *Examples of past activities to protect estuaries in South Africa (Adams et al., 2020)*

Pressure	Recent successes	Reference
Freshwater inflow restoration	1) Classification completed and Ecological Reserve and Resource Quality Objective set for ~40% of estuaries. 2) Reconnection of uMfolozi River to St Lucia system to improve salinity conditions.	Adams et al. (2016a) Whitfield et al. (2013)
Pollution	1) Ban on new effluent discharges in estuaries. 2) Littering targeted through the Working for the Coast Programme and International Coastal Clean-up Campaign.	Department of Environmental Affairs (2014, 2019)
Exploitation of living resources	1) Ban on night fishing in the Breede Estuary and Zandvlei. 2) Ban on commercial gillnetting in the Great Berg Estuary.	Turpie and Goss (2014) Hutchings et al. (2008)
Land-use and urban development	1) Application for estuaries to be listed as Critical Biodiversity Areas.	Van Niekerk et al. (2019)
Mouth manipulation	1) Twelve estuary mouth management plans finalised in the Western Cape.	Van Niekerk et al. (2019)
Invasive alien plants and animals	1) Successful eradication of the invasive grass *Spartina alterniflora* from the Great Brak Estuary.	Adams et al. (2016b) Riddin et al. (2015)

3.3.2. ESTUARIES REHABILITATION LEGISLATIVE FRAMEWORK

3.3.2.1. Legal Framework

Estuaries are influenced by marine, riverine and terrestrial ecosystems, thus making estuarine management difficult. As a result, estuaries require integrated cross-sectorial planning and management since they engage stakeholders involved in land use planning, freshwater, and marine resource management. The following are the major pieces of legislation that apply to estuary rehabilitation.

Table 3: *Key legalisation for rehabilitation of estuaries in South Africa*

Legal Tool	Estuary Rehabilitation Provisions
National Environmental Management Act (NEMA)	Reduce and minimise all sources of urban pollutants to the estuary; Allow the estuary mouth to function naturally as part of the local coastal dynamic processes and intervene only under specific defined and documented circumstances;
Integrated Coastal Management Act (ICMA)	Reduce and minimise all sources of urban pollutants to the estuary;
National Environmental Biodiversity Act (NEMBA)	Remove alien invasive species from the estuary;

Legal Tool	Estuary Rehabilitation Provisions
National Waste Act	Reduce and minimise all sources of urban pollutants to the estuary;
National Water Act (NWA)	Reduce and minimise all sources of urban pollutants to the estuary;
Conservation of Agricultural Resources Act (CARA)	Remove alien invasive species from the estuary;

3.3.2.1.1 Integrated Coastal Management Act (ICMA)

The Integrated Coastal Management Act (Act No. 24 of 2008) ("the ICM Act"), promoted in December 2009, requires estuaries of the Republic to be managed in a co-ordinated and efficient manner, in accordance with a National Estuarine Management Protocol. Section 33(2) of the ICM Act empowers the Minister responsible for Environmental Affairs with the concurrence of the Minister responsible for Water Affairs to publish a Protocol that will provide guidance for the management of estuaries through the development and implementation of estuarine management plans (EMPs). The EMPs aim to promote better harmony between ecological processes and human activities while allowing for the orderly and balanced use of estuarine resources.

3.3.2.1.2 National Environmental Biodiversity Act (NEMBA)

The National Environmental Management: Biodiversity Act (Act 10 of 2004) (hereafter referred to as the Biodiversity Act) provides for the classification of vulnerable or protected ecosystems in one of four groups critically endangered (CR), endangered (EN), vulnerable (VU) or protected. Furthermore, in terms of alien and invasive species, the biodiversity act aims at preventing their unauthorized introduction and spread into ecosystems where they are not naturally occurring. This is achieved through proactive management such as rehabilitation programs to prioritize listed ecosystems.

3.3.2.1.3 National Environmental Management Act (NEMA)

The NEMA (Act 107 of 1998) establishes national laws and standards for integrated environmental management (Section 24), in which all sectors of government and organizations of State must collaborate, consult, and assist one another. The act imposes a responsibility of environmental remediation on anybody who causes, has caused, or is likely to cause severe pollution or degradation to the environment.

3.3.2.1.4 National Waste Act

The National Waste Act is made effective by the National Waste Management Strategy (NWMS) which aims at protecting the health and well-being of the environment through waste management. The NWMS is organized around eight strategic goals and objectives which are:

- Promote waste minimisation, re-use, recycling, and recovery of waste
- Ensure the effective and efficient delivery of waste services
- Grow the contribution of the waste sector to the green economy
- Ensure that people are aware of the impact of waste on their health, wellbeing, and the environment
- Achieve integrated waste management planning
- Ensure sound budgeting and financial management for waste services
- Provide measures to remediate contaminated land
- Establish effective compliance with and enforcement of the Waste Act

3.3.2.2. Alignment with Policies and Strategies

Estuaries are interconnected to Rivers and the marine environment by virtue of their nature. Therefore, various policies and strategies that are applicable to Rivers and the Coastal environment inform Estuary Rehabilitation Management in South Africa and these include, but are not limited to, the items below as elaborated in **Section 1.3** of this report:

- The National Water Resource Strategy (NWRS);
- The National Water and Sanitation Master Plan (NWSMP) Volume 1 (2018);
- The Draft Environmental Rehabilitation Policy (2014);
- The Integrated Water Quality Management (IWQM) Policies (2016) and Strategies for South Africa (2017); and
- Estuarine Management Plans.

3.3.3. IMPACTS CAUSING DEGRADATION OF ESTUARIES

South Africa has nearly 300 estuaries classified into 46 estuarine ecosystem types, collectively covering an area of 90 000 ha including the open water area and adjacent habitats such as salt marshes and mangroves. Forty-three percent of the 46 estuary ecosystem types are threatened, 39% critically endangered, 2% endangered and 2% vulnerable (SANBI, 2014). **Figure 8** represents the ecosystem impact status for coastal, inshore, and offshore benthic habitat types. Anthropogenic stressors on estuaries can be categorized into twelve (12) major groups. **Annexure L** provides a summarized account of the impacts and their effects reported by several authors. It must be noted that the impacts on water resources may be as equally prevalent on all characteristics of watercourses such as surface flows, interflows in the soils, water quality, groundwater flows, geomorphology of watercourses, habitat, and biota.

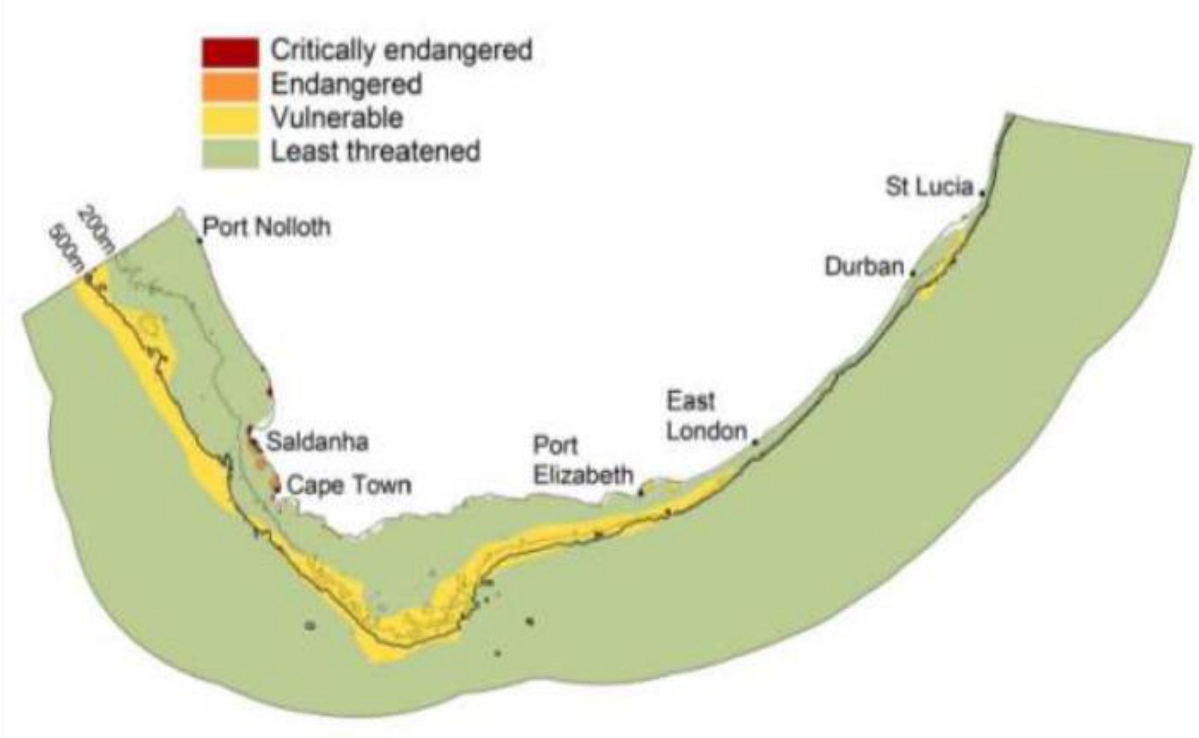

Figure 8: *Map of ecosystem impact status for coastal, in-shore and offshore benthic habitat types (SANBI, 2014)*

3.3.4. STATUS QUO AND INTERGRATION OF REHABILITATION INITIATIVES AND PRACTICES FOR ESTUARIES IN SOUTH AFRICA

3.3.4.1. Estuary Rehabilitation Studies and Practices

This sub-section of the report aims to provide evidence from literature on water resources rehabilitation related studies that have been undertaken with specific reference to estuaries. The studies and practices undertaken will be assessed to ascertain whether they provide sufficient details on the technical methods for undertaking estuary rehabilitation interventions. The evidence gathered will be used to identify best management practices available for application in the rehabilitation guidelines envisaged to be developed.

- **An Evaluation of the potential for restoring degraded estuaries in South Africa (1992)**

  Wiseman and Sowman (1992) evaluated the potential for restoring degraded estuaries by applying a proposed restoration procedure to the severely degraded Eerste-Kuils Estuary in the Western Cape. Degradation has resulted from inappropriate development adjacent to the estuary and other effects of urban and rural activities in the river catchment. Despite the diffuse causes of degradation, numerous restoration opportunities were seen to exist. These included the application of a "receiving water quality objectives" approach to waste-water effluent standards and the regional functions to the Western Cape Regional Services Council.

- **Managing Estuaries in South Africa: An Introduction (2001)**

  WRC (2001) compiled an introductory document comprising of six chapters for Estuary Management in South Africa informed by the increased pressures on the coastal zone. The document met the two real needs the time when coastal zone policy and legislation were revised. The document provides a good basic understanding of estuaries and their management. It also provides water resource managers the necessary information to engage estuary management and expand their knowledge and understanding.

- **Managing Estuaries in South Africa: A Step-by-Step Guide (2005)**

  WRC (2005) developed a guide to assist in management of the activities associated with estuaries to improve co-operative use and reduce the conflict that results from competing uses. The guide refers to the case study of the Mdloti Estuary that required significant rehabilitation due to inappropriate development and flooding. As with general estuarine management, rehabilitation was undertaken within a legal and management framework. The guide explicitly stated that no such framework existed for estuarine rehabilitation at the time the rehabilitation intervention was undertaken and general guidance in this regard was derived from a range of legislation. The guide further provides a summarized step by step plan which was aimed at assisting water managers in developing a rehabilitation plan at the local estuary scale.

- **Development of a Conservation Plan for temperate South African Estuaries (2007)**

  Turpie and Clark (2007) in collaboration with estuarine managers, scientists and the broader stakeholder community, undertook a study to identify which Cape Floristic Region (CFR) Estuaries should be assigned Estuarine Protected Area (EPA) status to prioritise estuaries in need of rehabilitation. This was done based on an updated classification of estuaries in terms of health, conservation importance and socio-economic value. Under the C.A.P.E Programme, this covered the estuaries from the Olifants to the Swartkops. The study made recommendations as to the final set of estuaries to be afforded some level of protection, and how much protection there should be. The next step towards implementing an estuarine protected area system was to develop a set of management plans for each of the estuaries in the region.

- **DWS Resource Directed Measures studies on Estuaries (2013-2021)**

  The DWS Resource Directed Measures (Reserve, Classification and RQOs) have been determined for approximately 40% of the estuaries as part of the work of the Chief Directorate: Water Ecosystems Management (CD: WEM). A detailed overview of all classification studies conducted by the CD: WEM to date is presented in **Annexure K**.

- **Development and Implementation of a Monitoring Programme for South African Estuaries (2016)**

  Cilliers and Adams (2016) designed and implemented a National Estuarine Monitoring Programme (NESMP) for South African estuaries. The DWS is mandated in terms of the NWA to undertake monitoring for the protection of water resources. Monitoring also forms an integral component of **Estuarine Management Plans which are a requirement of the ICMA (Act No. 24 of 2008).** The design of the programme was based on a review of international best practice, a critical evaluation of existing national monitoring programmes implemented by DWS and workshop input from a group of national experts.

- **The benthos of the Siyaya estuary: Species composition, density, and distribution (University of Zululand 1992-1994)**

  The primary objectives of the study were to show that good catchment management can minimize estuarine degradation, which would serve as a foundation for the rehabilitation of other degraded catchments in the province. Salinity, temperature, dissolved oxygen concentration, depth and turbidity of the water were measured annually. Mackay (1996) found the principle difficulties surrounding the degradation in the estuary to be inadequate water flow, poor water quality due to upstream industrial and social effluent, and the effect of the littoral zone. It was concluded that the impacts in the improvement of catchment management practices have had beneficial impacts ecology of the estuary, especially the state of the zoobenthos (Mackay, 1996).

- **Salt Marsh Restoration for the Provision of Multiple Ecosystem Services (Nelson Mandela University - 2021)**

  Adams *et al.* (2021) presented a socio-ecological systems framework for the restoration of salt marshes in which the magnitude of the pressure was determined, and feasible restoration initiatives were proposed. Furthermore, changes in the condition and magnitude of South African marsh habitat were studied in relation to identified pressures. Seven priority estuaries were investigated in depth to see if removing these pressures could assist in the restoration of salt marshes. The six categories of pressures were identified in South African estuaries as 1) exploitation of fish and invertebrates; 2) pollution and changes in water quality; 3) alien invasive species invasions; 4) Habitat degradation due to coastal development; 5) modification of freshwater inflow; 6) manipulation of estuary mouths South African estuaries (van Niekerk *et al.*, 2019). Identification of areas suitable for restoration, suitable restoration interventions, and funding opportunities are all critical knowledge gaps which were identified in the restoration of coastal ecosystems.

- **Community-based natural resource use monitoring at the Olifants River Estuary (University of Cape Town; 2012- 2013)**

The overall aim of this research was to evaluate the strengths and drawbacks of the community monitoring system at the Olifants River estuary (Soutschka, 2014). The research further examined fishery indicators from data collected by monitors from 1st September 2012- 31st August 2013. The data suggested the inclusion of resource users in monitoring, decision-making and management of water resources. Lessons learned from the Olifants River estuary community monitoring program can be applied in the development of reliable and effective monitoring systems, which serves as a crucial step in the rehabilitation of estuaries.

- **An estuary ecosystem classification that encompass biogeography and a high diversity of types in support of protection and management (CSIR; 2020)**

The purpose of this study was to create a national classification scheme for South African estuaries at the ecosystem level which considered key processes and patterns across biogeographic regions and can better guide broad-scale assessments of estuary resilience to human pressures. Classification is essential in estuary rehabilitation planning as it identifies important biodiversity areas and initiates the establishment of targets for species and habitats to ensure the species conservation (Turpie and Clark, 2007; Turpie *et al*., 2012). Overall, the 290 estuaries in South Africa were divided into 22 estuarine ecosystem categories resulting from the interaction of four biogeographical zones with nine estuary types. This revised classification represents a “blueprint” for the International Union for Conservation of Nature (IUCN) red listing for South Africa’s estuarine ecosystem types which facilitates the identification of endangered ecosystem types, *i.e.* Critically Endangered, Endangered or Vulnerable (Van Niekerk *et al*., 2019), which further highlights ecosystem types that are in urgent need of management intervention, protection and thus, rehabilitation (Van Niekerk *et al*., 2020).

- **Application of the relative risk model for evaluation of ecological risk in selected river dominated estuaries in KwaZulu-Natal, South Africa (University of KwaZulu-Natal; 2019)**

This study described the assessment that was conducted for the evaluation of the relative risks of multiple anthropogenic stressors acting on the catchments of uMvoti, Thukela and aMatikulu/Nyoni estuaries (Vezi *et al.*, 2019). This was carried out using Bayesian Network Relative Risk (BN-RRM) framework. Four socio-ecological endpoints selected in the study included the safety of the environment, habitat biodiversity, productivity, and fisheries. This research laid the groundwork for assessing the risks of multiple stressors in these estuaries. The study further suggested that the focus of the management options and research should be on gathering data and information for the development of RRM. Stakeholders together with government organizations will be able to make informed management decisions pertaining to the rehabilitation and restoration of the uMvoti, Thukela and aMatikulu/Nyoni estuaries.

3.3.4.2. Estuary Rehabilitation Initiatives and Programmes

In this sub-section, an account on the various estuarine rehabilitation related programmes and initiatives such as Land and Coast Care Management Programme will be explored. The sub-section aims to:

- Gather the most up to date available information relating to estuarine rehabilitation initiatives and programmes; and
- Identify and highlight progress made to date in order to draw conclusions and map a way forward for the development of the rehabilitation guidelines.

- **The iSimangaliso Wetland Park Authority Projects**

  Lake St Lucia Estuary Restoration Project - iSimangaliso raised funding through the GEF to investigate and formulate long-term solutions to restore the natural hydrological and ecological functioning of this important system. Using the best available scientific knowledge, current management activities are focused on diverting fresh water from the Mfolozi into the lake and allowing the Mfolozi and St Lucia mouths to join.

- **Land and Coast Care Management Programme**

  This programme in collaboration with DFFE NRM is aimed at the removal/control of alien invasive plants that threaten sites and subsequent rehabilitation of disturbed environments. iSimangaliso is also implementing a Coast Care programme which focuses on the coastal areas of the park. The programme employs people living in the coastal areas to keep the beaches clean, to build infrastructure and for alien vegetation control. Below are other programmes implemented by Isimangaliso:

  - In partnership with **Siyaqhubeka (Mondi)** - Removal of pine/gum plantations on the eastern and western shores and subsequent rehabilitation of degraded environments;
  - **Environmental education and awareness** - through a schools programme (environmental education fieldtrips/school awards) and an adult awareness programme (mobile workshops in the park);
  - **Rural enterprise programme**: building and supporting entrepreneurs through an Arts and Crafts programme; training tourism guides and chefs, front and back house of staff as well as placing them in jobs;
  - **Other related projects** include harvesting of the below listed natural resources by communities living in and around the park:
    - Marine such as mussels and fish;

- Estuarine (crabs and fish);
- Forest such as iLala palm and wood for building, fuel wood and carving;
- Grasslands such as for cattle grazing)
- Wetland species such as iNcema).

- **Development of Estuary Management Plans (EMPs)**

  The EMP is the primary document used by any Responsible Management Authority (RMA) to facilitate coordination of the identified management interventions to ensure the longevity of the estuarine system concerned. This document is a critical reference for incorporation of estuarine management into the Municipal Integrated Development Planning (IDP) and Spatial Development Framework (SDF) processes. The development of an EMP is a three-phase process**,** comprising an initial scoping phase, followed by an objective setting phase, and finally an implementation phase. An adaptive management approach should be adopted during the latter phase with detailed reviews being conducted at five-yearly intervals. **Annexure M** presents some of the EMPs that have been developed for Western Cape, Eastern Cape and KwaZulu Natal estuarine systems to date.

- **National Estuarine Monitoring Programme (NESMP) for South African Estuaries**

  The Programme has three tiers. **Tier 1** focuses on basic data, **Tier 2** makes use of the methods used for determining estuarine freshwater inflow requirements, and **Tier 3** is usually of a short temporal scale and dependent on the issue at hand, such as a sewage spill or fish kill. **Tier 1** monitoring commenced on 21 priority estuaries between 2012 and 2014 in collaboration with government conservation authorities, conservation forums and local and district municipalities. Available financial and human resources guided the selection of the priority estuaries.

- **Coastal Management Programme (CMP)**

  CMP sets out priorities for coastal management and provides a five-year prioritised programme of implementation. The CMP and its Priority Area 7: Estuaries Management are aligned to the national environmental sector and provincial long and medium-term strategies and enable a coordinated strategic and operational response to the implementation of the legal mandate and roles and responsibilities of the province concerned.

- **(C.A.P.E.) Regional Estuarine Management Programme**

  The programme is hosted by SANBI at Kirstenbosch in Cape Town and is a partnership programme aimed at developing a strategic conservation plan for a several priority estuaries of the CFR and to prepare detailed EMPs for each estuary. The estuary programme was divided into **three phases**. The **first phase** is to establish the overarching conservation plan and to prepare detailed management plans for a few selected systems. The later phases involve piloting the proposed National Estuarine Management Protocol, paving the way for preparation of management plans for the remaining systems.

The presented estuarine rehabilitation programmes and initiatives currently in place are sufficient and ensure estuarine rehabilitation improvement and management. The main gap identified is the lack of integration of existing EMPs with other related projects, programmes & initiatives.

3.3.5. FINDINGS AND GAPS FOR THEME 3: ESTUARIES

Below is a list of the main findings drawn from the review conducted.

- In estuaries, unlike the terrestrial environment, degradation or loss of habitat seldom means a complete loss of system health or function. This can only happen if an estuary becomes completely degraded*, i.e.* changed into a parking lot or golf course. In most cases, degradation means loss of processes or loss of biological functionality, *i.e.* the estuarine space is filled with a different salinity condition or different species composition. This loss of functionally happens on a continuum, with estuaries which retain more than 90% of their natural processes and pattern being rated as Excellent and estuaries degraded to less than 40% of natural functionality rated as Poor (DWS, 2015).
- Physical conditions in estuarine systems are more dynamic than those of other aquatic ecosystems which means that severe degradation of an estuary may involve a shift from a dynamic to a more stable, or unidirectional, system. Therefore, the loss of dynamic function per se is an important indication of declining estuarine health (DWAF, 2008). Thus, in an estuarine health assessment, measures of these different states need to be sufficiently robust so that different practitioners/disciplines will arrive at the same categorisation.
- Over longer time scales the total area occupied by the various estuarine habitat types tends to remain more or less constant, while the actual spatial location of the various estuarine habitats is highly likely to change between resetting events (*e.g* larger floods). This relatively ephemeral nature of estuarine habitat presents an assessment and planning challenge. Water resource protection requires the delineation of the geographical boundaries of the resource. To do this, it is important to define the space within which estuaries function to ensure their present and future health (DWA, 2013b).

Below is a list of the gaps found from the review conducted.

- Lack of comprehensive Rehabilitation Guidelines for Estuaries.
- Lack of integration of existing EMPs with other related projects, programmes & initiatives.
- It is also noted that there is no generic rehabilitation process guideline to consider when to open river mouths to the sea to better ecological category or for flood protection.

Key lessons learnt, are drawn from the various developed EMPs for a range of different management issues which required to be addressed **(Table 4)**. The process was guided by the Generic Framework, which provides a consistent format for the EMP. For each estuary, the EMP development process was initiated with a desktop situation assessment, covering aspects such as the biophysical and socioeconomic environment, the exploitation of living resources, water quality and quantity issues (resource directed measures), legal requirements and institutional structures.

Other lessons are drawn from the studies discussed in **Section 3.3.4.** An example is the study conducted by Wiseman and Snow (1992) on restoring degraded estuaries; some of the constraints to restoration were found to include its cost. There were also challenges of relocating existing inappropriate land uses and the lack of a coordinating river authority. Although legal, administrative, and economic restoration opportunities existed, it was important to demonstrate to communities and landowners the results from the restoration programme. The existence of tangible benefits is a key prerequisite for the commitment and co-operation needed to implement possible restoration strategies.

The analysis from the study conducted by Cilliers and Adams (2016) on the Implementation of the NESMP showed that collaboration between all relevant role-players was central to the successes achieved during the first three years of the programme and will continue to be critical for the success of the programme, although funding remained a challenge.

Table 4: *Summary of key lessons learnt from estuarine management studies*

Estuary	Description	Key lessons
Olifants Estuary	The estuary ranks among the country's top five in terms of conservation importance in the west coast	• Marine protected area was established in the estuary, with zones allowing for different activities; • Gillnetting, which targets harders (mullet) but has a high bycatch of juvenile line fish, was banned from the mouth to 12 km upstream;
Klein Estuary	Situated at Hermanus and popular for recreational activities such as dinghy sailing, windsurfing, canoeing, and water-skiing	• Swimming banned due to faecal pollution from leaking sewers; • Artificial breaching takes place to protect the adjacent low-lying properties from flooding; • Spatial implications of the EMP were integrated into the local municipality's Spatial Development Framework in the 2011 review. The interest generated in the EMP development process, together with the municipality's commitment, has encouraged the

Estuary	Description	Key lessons
		environmental NGO WWF to fund a newly created position for an estuary manager to oversee this and the neighbouring Bot and Onrus estuaries
Heuningnes Estuary	Smallest of the six estuaries and located near Cape Agulhas – the continent's southern tip	• Cape Nature kept the mouth of the estuary artificially open. This management strategy is in line with a long-standing agreement with local farmers, whose land was flooded in the past when the mouth closed during periods of low flow due to shifting sand; • Sensitive wetland habitat occurs on these farmlands, where it is threatened by grazing and other agricultural activity. A more holistic approach to estuary management is therefore needed.
Breede Estuary	The estuary was one of the first estuaries for which an EMP was compiled as part of a pilot study under the C.A.P.E. Estuaries Management Programme with funding from the World Bank	• Involvement of well-established stakeholders through the Lower Breede River Conservancy - employs a team of law enforcement officers to oversee compliance with the Marine Living Resources Act and local bylaws passed by the Swellendam Municipality. • Monitoring studies were conducted by the CSIR, MCM and DWEA. During 2006, it is anticipated that these initiatives would facilitate implementation of the EMP, which includes measures to protect sensitive habitats and rehabilitate degraded areas.
Knysna Estuary	Also known as Knysna Lagoon and managed by SANParks	• EMP was drafted as a Low-level Operational Plan according to the planning format used by SANParks for protected areas to cover the water area only and does not address highly sensitive saltmarshes away from the main water body. • SANParks provided input to Knysna's revised Spatial Development Framework and recommended proper integration with the EMP for the estuary to protected from further development impacts
Gamtoos Estuary	The estuary is located near Jeffrey's Bay in the Eastern Cape & is renowned as a prime location for catching large 'dusky kob' – a species so overfished that its population is now less than 5% historical numbers	• A proposal was made to limit 'kob' angling to a catch-and-release fishery. There was however opposition from local angling clubs, and it was agreed that effort would instead focus on better enforcement of the existing legislation, which stipulates a bag limit of one kobper per day when caught in estuaries and from the shore east of Cape Agulhas; • The interest generated by this issue meant that the Gamtoos Estuarine Management had to be established first

3.3.6. WAY FORWARD FOR REHABILITATION GUIDELINES FOR THEME 3: ESTUARIES

Extensive studies have been undertaken in the country by DWS, DFFE, Department of Cape Nature and specifically the Provincial Department of Environmental Affairs and Development Planning (DEA&DP), which commissioned the development of the Estuarine Management Framework and Implementation Strategy (EMFIS) that prioritise the development of EMPs as per Priority Area 7. To coordinate management actions, ICM Act prescribes that EMPs be compiled for all estuaries in accordance with guidelines found in the National Estuarine Management Protocol. Numerous EMPs have been compiled for better management of the whole estuarine functional zone, the adjacent shoreline, and the river catchment above the estuaries (**See Annexure M**).

There are also several programmes and initiatives that have been implemented to ensure mitigation of the pressures on estuaries and ensure their resilience. The CMP is an example of a programme that prioritise water quality improvement interventions for the Berg, Breede and Olifants estuaries through the establishment of a monitoring and reporting system. The CMP is a policy directive for the management of the coastal zone, inclusive of strategies and plans for the effective implementation of the ICM Act that enable organs of state to plan accordingly and address current management problems and user-conflicts (DEA, 2014)

Notwithstanding the multitude of the abovementioned implementation tools that are available within the IMC Act, there are no existing Comprehensive Estuary Rehabilitation Guidelines for South African Estuaries. EMPs are tools that provide adaptive management approaches for estuaries, however there is a lack of integration of the efforts and the work contained within these plans in relation to other related projects, programmes, and initiatives.

Another finding is on guidelines called the '***Western Cape Estuarine Management Framework and Implementation Strategy (EMFIS): Best Practice Activity Guidelines (2019)'*** that provide clear and practical management principles to deal specifically with erosion and accretion; erosion protection and bank stabilisation; dune environments; and physical structures built in littoral active zones. The only drawback with these guidelines is that they only focus on one specific province which is a limiting factor for the current project. It is therefore recommended that such guidelines must be adopted and be developed country wide.

Although the EMP and CMP promote cooperative governance (relationship between the Responsible Management Authority (RMA), government, organs of state, community members/NGOs, or any other supporting structures or organisations with estuarine-related duties and functions), the co-ordination of mandates for the development and implementation of EMP by RMA is a significant challenge. It is therefore recommended that the current lack of integration of mandates must be aligned and strengthened.

3.4. THEME 4: LAKES AND DAMS

3.4.1. CONTEXTUALISATION OF REHABILITATION of LAKES AND DAMS

3.4.1.1. Key differences between natural lakes and man-made lakes

There are two types of lakes, viz: natural lakes and man-made lakes (reservoirs and dams). These resources play an important role in, water supply, flood control and they are also important culturally and aesthetically. Water supply is one of the factors necessary for economic development and it plays an important role in development of society. Water source (*i.e.* contribution of groundwater vs surface water) is one of the key differences between these waterbodies. Natural lakes are generally subdivided based on hydrology, whereas man-made lakes are often categorized based on their size and their primary reason for being constructed (Hayes, et. al. 2017). **Figure 9** provides key differences between lakes and reservoirs.

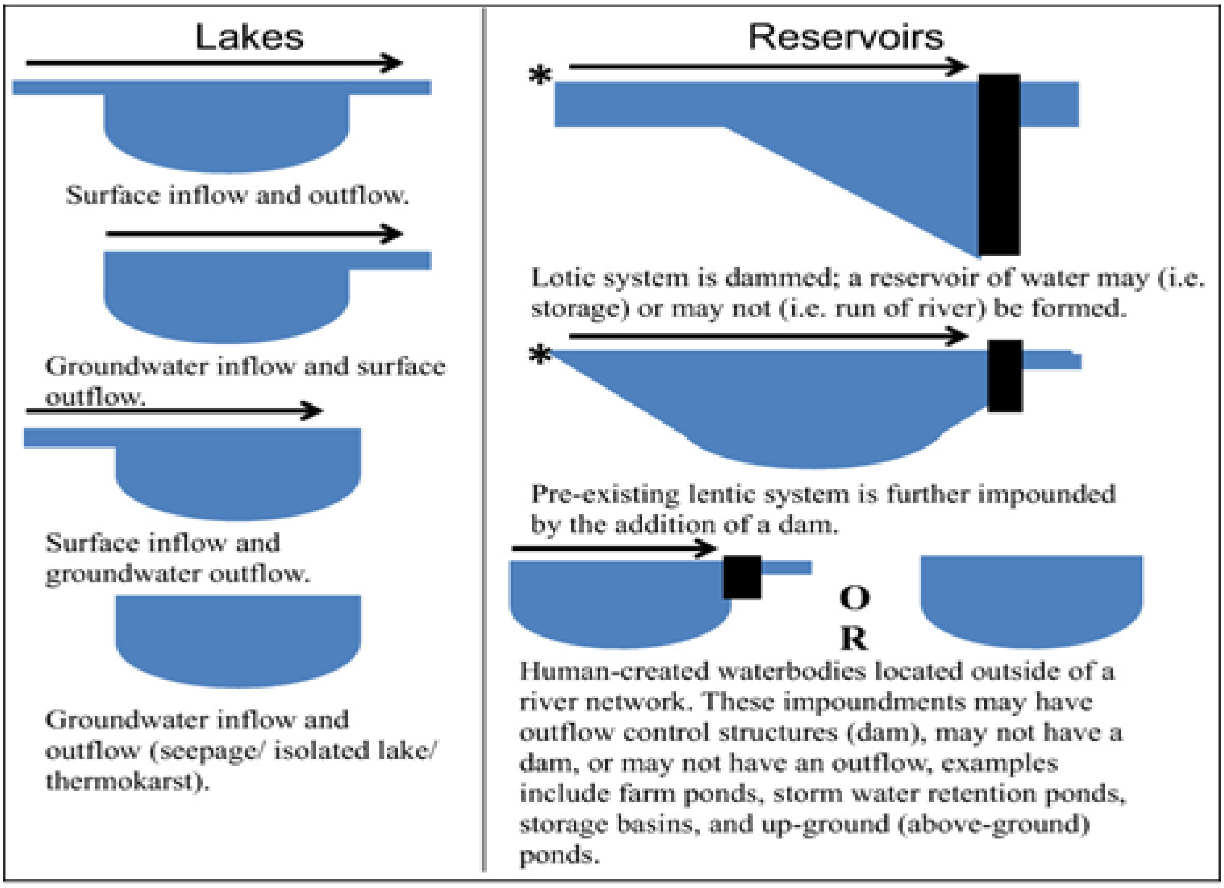

Figure 9: *Key differences between lakes and reservoirs (Hayes, et. al. 2017)*

It is important to highlight that there are two types of man-made lakes namely, dams and reservoirs. It is commonly hard to tell the difference between these waterbodies. A dam refers to the structural barrier that is constructed across a river or a valley with the aim of ensuring that water is prevented from flowing. This causes water to overflow after reaching a certain level of the dam. Whereas a reservoir is a large waterbody that forms behind a wall constructed across a river or a large valley, which may sometimes accumulate large amount to form a human-made lake. Differences between a dam and a reservoir are provided in **Table 5.**

Table 5: The differences between Dams and Reservoirs

Description	Dam	Reservoir
Physical appearance	Wall constructed across a river or valley	Water accumulating behind the dam
Ecological impacts	Prevents migration of fish	Causes displacement of people
Uses of Dams and Reservoirs	- Electricity generation - Storage of water for water supply - Flood control	Supply of water for consumption and agriculture
Tourist attraction and transport	It is a tourist attraction site	Facilitates water transportation

The familiar term for man-made lakes in South Africa is dams. Therefore, for the purpose of this project "Rehabilitation Management Guidelines and for convenience, man-made lakes will be referred to as dams. It must also be noted that natural lakes and man-made lakes will be grouped in one theme which is **Rehabilitation Management Guidelines for Lakes and Dams**

3.4.1.2. Global Lakes and Dams Rehabilitation Context

Due to the acute water scarcity around the globe, water resource management, and lake rehabilitation has attracted global interest (El-Rayis *et al.,* 2019); and prioritization in many countries around the world, due to an increasing awareness on environmental degradation and sustainable development that is being motivated by the 2030 Agenda for Sustainable Development. Rehabilitation of lakes and dams is in line with Sustainable Development Goal (SDG) – 6, **target 6.6**, which makes provision to the protection and restoration of water-related ecosystems such as **lakes**. The widespread recognition of lake degradation as a major environmental concern has led to accelerated efforts to better protect and manage lake resources. In cases where it is too late for avoidance strategies, **lake rehabilitation** has been opted as a natural resource management option.

Two decades ago, lake rehabilitation was not recognized as a "ready-to-go" technology as it was still regarded as partly experimental. Born (1979) conducted a study on Lake rehabilitation, whereby, it was discovered that there have been significant number of lake rehabilitation experiences and most experiences were accomplished by diversion and/or wastewater treatment. Born (1978) further indicated that several in-lake strategies were also employed to rehabilitate degraded lakes; strategies that were often part of an overall restoration plan and techniques that appeared to be most useful included dredging and nutrient inactivation.

In recent years, most lake restoration projects have been conducted to combat **eutrophication** which causes water quality deterioration, and **sedimentation** that affects the safety of dams and reduces energy production, storage, discharge capacity and flood attenuation capabilities. However, in many countries the focus is on eutrophication.

Lake restoration is generally a broader term used for different methods aiming to bring a body of water back to or closer to anthropogenically undisturbed conditions (Bartoszek & Koszelnik, 2015). However, it must be noted that lakes can never be restored to their initial complex physical, chemical, and biological status, but only conditions of the lakes can be improved.

Lakes differ in area, depth, water and transparency and quality. However, they are experiencing similar threats to their integrity from changes in global climate, irregularities of the development of Earth and the anthropogenic economic activities (Butorina, 2005). According to Abbaspour (2011) the rate of increase in the complexity of water quality problems will exceed the rate of development in the long run. Loan profiles of major lending institutions revealed remediation of degraded water quality as a major developing trend. This trend falls into two types of projects namely, remediation of highly eutrophic lakes and remediation of contaminated river systems, many of such projects have been conducted in China.

On a global scale, it is reported that only a few developing countries such as South Africa, who have the technical knowledge or experience to come-up with appropriate interventions and approaches for remediation and rehabilitation of large lakes and complex river systems. Some of these include problem identification, setting of rational and program objectives and implementation methods. Therefore, understanding of the characteristics of a Lake and Dam is the critical step to take before choosing and applying an appropriate rehabilitation approach. Hence, it is advisable to carry-out a feasibility study first to diagnose problems and causes. The most widely used methods of lake restoration include direct (preventive) methods which comprises both in-lake treatment and catchment management methods and indirect (ameliorative) methods which are usually important in serving a lake to recover to its long-range vitality (Zamparas and Zacharias, 2014; El-Rayis *et al.,* 2019).

Lake/lagoon Chilika situated India is another example of restoration that was implemented. Chilika was designated as a Ramsar site in 1981. The livelihoods of some 200 000 fishers and 400 000 farmers depend on the lake but were threatened when increased sediment from a degrading catchment reduced the connectivity of the lagoon to the sea, causing a rapid decline in fisheries (Mohapatra *et al.* 2007). To restore the lake/lagoon, in 1991 the government implemented programs for catchment restoration, hydrobiological monitoring, sustainable development of fisheries, wildlife conservation, community participation and development and capacity-building. In 2000 a channel was created to reconnect the lake/lagoon to the sea, and restoration of the hydrological and salinity regimes (Ghosh *et al*. 2006) led to the recovery of the fisheries and biodiversity.

The Draft Environmental Rehabilitation Policy (DWA, 2014) also refers to the United States of America (USA) whereby its 1000th dam was demolished in 2011 with 430 dams removed in last 10 years for ecological and economic gain.

3.4.1.1. Regional Lakes and Dams Rehabilitation Context

The future well-being of the human population, especially in Africa will depend upon a balance between exploitation and conservation of all-natural resources, to achieve an appropriate sustainable production system and avoid environmental degradation (O'Sulliva and Reynolds, 2005). Generally, water in lakes and reservoirs is one of the most precious of all resources, and hence the great importance attached to this increasingly scarce resource. El-Rayis *et al., (*2019), conducted a study on "*Steps for rehabilitation of a Lake suffering from intensive pollution; Lake Maruit as a case study – Egypt".* The aim of this study was to establish suitable solutions for the Lake Maruit Main Basin. Restoration was chevied through studying general characteristics of its drainage water systems and their downstream part for reaching the lake and to the adjacent non-polluted Lake Fishery Basin, as well to discuss the applicability of two proposed improvements solutions.

The African region has many freshwater systems that are rich in aquatic resources, particularly fish **(Figure 10)**. However, human activities, including misguided agricultural practices, urbanisation, domestic and industrial waste disposal, have affected water quality, biological diversity, and fish stocks. Environmental degradation and water-resource depletion have been increasing in the region in the past decades. With regards to environmental damage for fisheries, only a few states or countries in Africa seem to be sufficiently aware of the problems and are attempting to solve them. In the case of the fisheries, where damaging fishing practices persist, there are often considerable difficulties in enforcing regulations and laws and fishermen are reluctant to change their practices (Bugenyi, *2005;* O'Sulliva and Reynolds, 2005).

Several major problems have emerged to confront policy makers, as the complexity of management has become increasingly understood. They often include a lack of adequate information relating to key biological and physico-chemical data, such as the assimilative capacity of the resources to economic parameters. Awareness of harm to the aquatic environment from human activities has led to the political and legislative authorities of industrially developed countries to introduce or review regulations to protect the environment (Bugenyi, 2005; O'Sulliva and Reynolds, 2005).

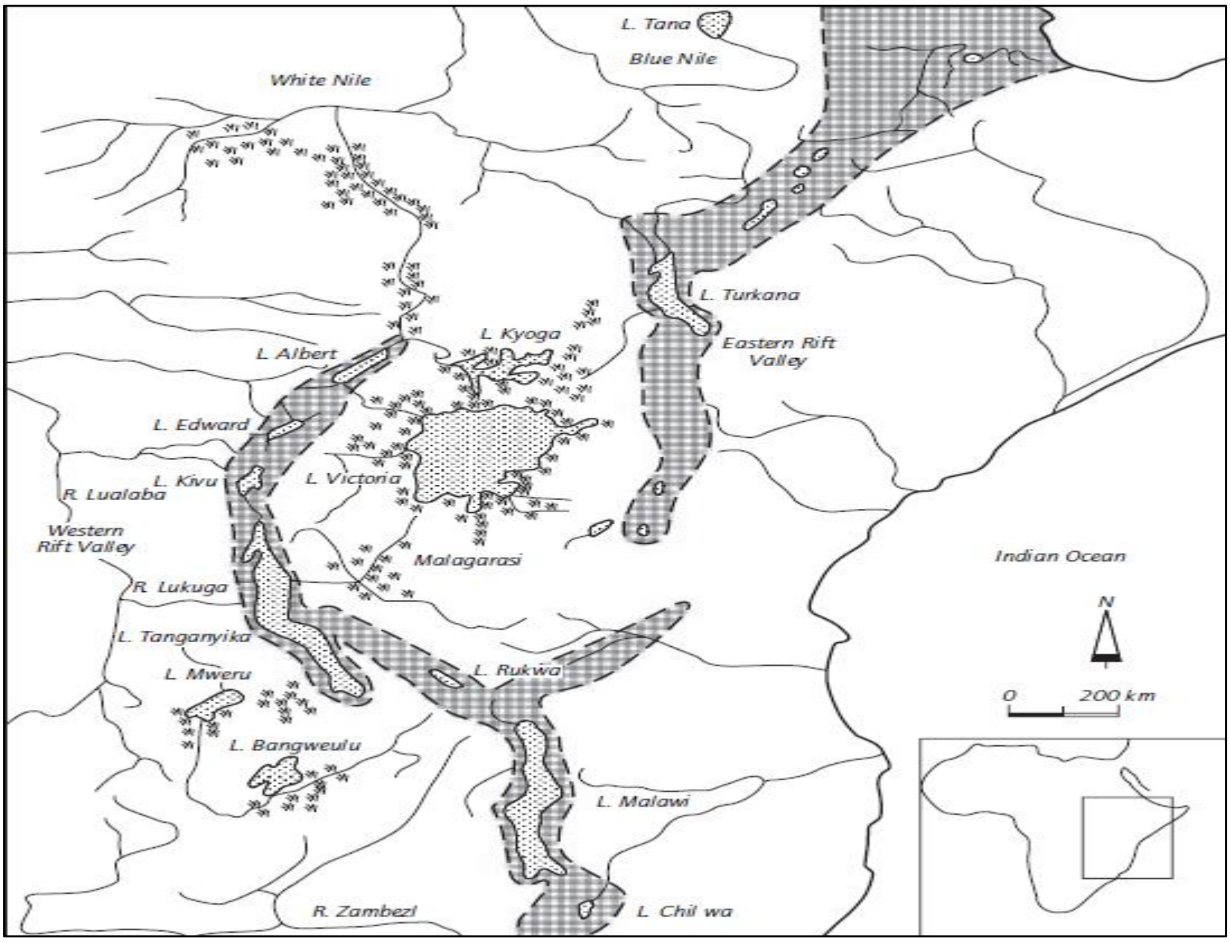

Figure 10: *East African Great Lakes and other freshwater systems (Bugenyi, 2005)*

3.4.1.2. Local Lakes and Dams Rehabilitation Context

The NWRS-2 provides a summary of water resource management challenges and solutions for South Africa. The Strategy acknowledges that the resource (lakes and dams) is not receiving the attention and status it deserves, due to a rapid rate of wastage, pollution, and degradation. Major contributors to these challenges are eutrophication and sedimentation (DWS, 2017). According to DWS (2021) poor water quality including eutrophication is already having significant impacts on economic growth and on the well-being of South Africans, whereas, WRC (2021), indicated that many storage reservoirs in South Africa have experienced ongoing loss of capacity because of high sediment yields within their catchment area which is a major environmental and economic concern as it intensifies water management problems.

The sustainability of South Africa's freshwater resources has reached a critical point – viewed against the observation that SA's water security is mainly reliant on surface water and its development (DWS, 2014; Harding, 2015).

It is noted from the literature that most dam rehabilitation projects in SA are focusing more on dam engineering rather than the pollution and degradation of the resource. For instance, Viljoen and Reynolds (2015), evaluated 11 case studies of dam rehabilitation projects in SA, in terms of quantitative risk assessment criteria and Society's Willingness to Pay (SWTP). It is evident from the Study that South African and international authorities base their decisions to rehabilitate dams based on several criteria, of which risk to human lives is the most important one. Which means that in most regions, the priority is more on dam safety. However, South Africa is now shifting towards the rehabilitation of aquatic ecosystems. Therefore, for the purpose of this project "Rehabilitation Management Guidelines", focus will be more on the rehabilitation that is related to wastage, pollution and degradation of the resource which is in-line with Chapter 3 of the NWA. This because lot of work has been done on the dam engineering and there are gaps on the aquatic ecosystem rehabilitation.

3.4.2. LAKES AND DAMS REHABILITATION LEGISLATIVE FRAMEWORK

3.4.2.1. Legal Framework

South Africa is a country which finds itself on the bridge between the first and the third world, having both strong and competitive industrial component as well as a large rural population dependent on a subsistence economy. With the change in government from the apartheid system to a democratic system, South African legislators have been provided with an exceptional opportunity to revise all their laws, many of which were deemed inadequate and confusing at best (O'Sulliva and Reynolds, 2005). DWS is one of the Government Departments that has taken it upon its shoulders to review, revise and update their policies, strategies, guidelines, and systems to align with the laws of the new Democracy and the Constitution of the country. Hence, the development of *Rehabilitation Management Guidelines* for water resources.

Table 6 provides pieces of legislation that relates to lake and dam management. It must be noted that there is no single legislative system specifically for lake management, however, they have been catered for in various legislations (acts) which have been enforced by a wide range of authorities with differing objectives and approaches. These authorities include but is not limited to DWS, DEA, DFFE, SANParks Board and nature conservation departments.

Table 6: *Authorities responsible for lake management and objectives of relevant acts*

Act	Description
Constitution of the Republic of South Africa, 1996	The Bill of Rights contained in Chapter 2 of the Constitution applies to all law and binds the legislator, the executive, the judiciary, and all organs of the state. Section 24 makes provision to the right of an environment that is not harmful to their health or well-being; and have the environment that is protected for the benefit of present and future generations, through reasonable legislative and other measures that (i) prevent pollution and ecological degradation; (ii) promote conservation; and (iii) secure ecologically sustainable

Act	Description
	development and use of natural resources while promoting justifiable economic and social development. Whereas Section 27(1)(c) makes specific provision to access of sufficient water.
The Lake Areas Development Act, 1975 (Act 39 of 1979)	The Minister of Environment Affairs may, by notice in the Government Gazette, declare any land comprising or adjoining a tidal lagoon, a tidal river or any part thereof, or any other land comprising or adjoining a natural lake or river or any part thereof which is within the immediate vicinity of a tidal lagoon or a tidal river, to be a Lake Area. This Act may serve to protect the natural habitats in and around lakes.
National Water Act, 1998 (Act 36 of 1998)	The National Water Act provides the legal framework for the effective and sustainable management of our water resources. The Act aims to protect, use, develop, conserve, manage and control water resources as a whole, promoting the integrated management of water resources with the participation of all stakeholders. **Chapter 3** specifically provides for the protection of water resources. The aim of protecting water resources is to ensure that water is available for current and future use. This is achieved by leaving enough water of a certain quality in the water resources to maintain the overall ecological functioning of the rivers, lakes and dams, wetlands, groundwater, and estuaries. Protection of the water resource is therefore about the quantity and quality (overall health) of the nation's water resources. Some water resources are already overused and polluted, the available water is already taken, and the surrounding environment is in a poor state. Hence, there is a need for rehabilitation and protection of water resources.
Environment Conservation Act, 1989 (Act 73 of 1989)	Provides for the protection and controlled utilisation of the environment and the determination of policy to protect, use sustainably, and rehabilitate the environment
National Environmental Management Act, 1998 (Act 107 of 1998)	NEMA provides for co-operative environmental governance by establishing principles for decision-making on matters that are affecting the environment and provide for certain aspects of the administration and enforcement of other environmental management laws. Environmental law encompasses the following three distinct but interrelated areas of general concern (DWS, 2021): • Land-use planning and development; • Resource conservation and utilisation; and • Waste management and pollution control. The provisions and regulations of Government Notice NR. 543 to R. 547, dated 18 June 2010, promulgated in terms of NEMA regarding control over activities which may have a detrimental effect on the environment must be complied with. Normally it will be required that an Environmental Impact Assessment (EIA) be carried out before any works *i,e, rehabilitation, restoration, enlargement or repair,* of an existing dam will be authorised. Written authorisation must be obtained from the relevant provincial government department before commencement
National Environmental Management: Biodiversity Act, 2004 (Act 10 of 2004)	aims to provide for the management and conservation of South Africa's biological diversity, the protection of both ecosystems and species in need of protection and the sustainable use of indigenous biological resources. In terms of its relevance to protecting lakes, the Act gives effect to relevant international agreements which South Africa is a party of (*i.e.* the Ramsar Convention on Wetlands and the Convention on Biodiversity), as well as providing for co-operative governance, which is important when there are a number of agencies

Act	Description
	at different tiers of government responsible for the management of ecosystems (O'Sulliva and Reynolds, 2005).
National Parks Act, 1976 (Act 57 of 1976)	South African National Parks is responsible for inclusive nature conservation and to advance nature conservation policies in line with the National Development Framework for Sustainable Development and the National Development Plan; and the objective of the NPA is to establish national parks for the preservation and study of wild animal, marine and plant life and objects of geological, archaeological, historical, ethnological, oceanographic, educational and other scientific interest and objects relating to the life, events or history of the park, which is retained in its natural state for the benefit of visitors.

3.4.2.2. Alignment with Policies and Strategies

The section below provides a summary of the most prominent policies and strategies that give direction to the rehabilitation of lakes and dams in South Africa and to highlight some important aspects to align rehabilitation of lakes and dams with.

Table 7: *Alignment of policies and strategies with the rehabilitation of lakes and dams*

Policies and Strategies	Alignment with the Rehabilitation of Lakes & Dams
National Water Resource Strategy	The NWRS is a statutory strategy, required in terms of the NWA, is binding on all authorities and institutions implementing the Act and provides the framework for integrated water resource management for the country as a whole, and within which water resources will be managed at the regional or catchment level.
National Water and Sanitation Master Plan	NW&S MP constitutes the roll-out mechanism for NWRS implementation and specifies, inter alia, priority budget items, scheduled up to 2030 and beyond, for the entire water sector (DWS, 2021).
Draft Rehabilitation Policy	Laid a foundation for DWS to implement, regulate and facilitate Environmental Rehabilitation within its mandate as custodian of water resources. One of the objectives of this initiative was to perform environmental rehabilitation that is associated with water resources development impacts to acceptable international standards.
Integrated Water Quality Management Strategy (IWQM), 2017	The IWQM Strategy sets out strategic actions which are required to be undertaken to realise the vision and goals for water quality in South Africa. It articulates the broader process of Integrated Water Quality Management and provides the prioritised strategic actions that need to take place in relation to management of water quality in a holistic manner such as coming up with strategies and guidelines to manage water resource and water quality issues.
Eutrophication Management Strategy for South Africa (EMSA)	The EMSA gives direction with the respect to the management of eutrophication, specifically, the control anthropogenic sources of excessive nutrient enrichment from a strategic country-perspective. EMSA vouches for the rehabilitation and restoration of ecological infrastructure, rehabilitation of hard infrastructure as well as adequate maintenance of water resources and services infrastructure as some of the responses to drivers of the degradation of water resources. Further to that, it promotes the rehabilitation and restoration of affected water

Policies and Strategies	Alignment with the Rehabilitation of Lakes & Dams
	resources, including the implementation of bio-remediation initiatives, such as the Harties Metsi-a Me/ Hartbeespoort Dam Biological Remediation Project, in affected water resources which should be supported to attain more innovative and progressive solutions to address issues such as eutrophication problems.

3.4.3. IMPACTS CAUSING DEGRADATION OF LAKES & DAMS

Dams are degraded and made shallow faster than lakes. This problem applies particularly to small retention reservoirs, localized at strongly anthropogenic and agricultural areas. The phenomenon is due to natural conditions of water catchment areas and supply of external organic and mineral matter, as well as their low resistance. The degree of natural resistance to the impact of the water catchment area depends on the depth of the reservoir, it's capacity ratio and the length of the coastline (Bartoszek and Koszelnik, 2015).

In South Africa water reservoirs have been reportedly impaired by, sedimentation, mineralisation/salinization, nutrient enrichment (at an excessive rate leads to eutrophication) and acid mine drainage (AMD). Additionally, in 2017, the DWS developed the Integrated Water Quality Management (IWQM) Policies and Strategies, which identified priority water quality issues that require intervention as a matter of urgency. **Table 8** below provides contributing factors to degradation of reservoirs in South Africa (SA).

Table 8: *Factors contributing to the degradation of SA reservoirs*

Contributing factors	Sources of pollution / Driver	Root Cause	Impacts	Affected Characteristics of Watercourses
Eutrophication	• Wide-spread discharge of raw or inadequately treated municipal sewage. • Raw sewage overflows. • Diffuse runoff and drainage from fertilized cultivated land	<u>**Natural Causes:**</u> • Nutrient leaching from local geology and soils <u>**Unnatural causes:**</u> • Atmospheric emissions of Ammonia (NH_3) and nitrogen dioxide (NO_2) resulting in increased loads of NH_3 and NO_2 in precipitation. • Increased nutrient loads in discharges from WWTWs. • Increased nutrient loads in agriculture and urban runoff. • Excessive nutrient loads in industrial wastewater.	• **Ecological impacts:** disturbance to biodiversity • **Human and Aesthetic impacts:** odour and taste problems, morbidity, and mortality due to potential toxic cyanobacteria • **Recreational impacts:** decreased recreational use, and decreased access to water ways • **Socio-**	• Surface flows; • Interflows in the soils; • Water quality; • Groundwater flows • Geomorphology of watercourses; • Habitat; and Biota.

Contributing factors	Sources of pollution / Driver	Root Cause	Impacts	Affected Characteristics of Watercourses
			economic impacts: increased, stock losses, corrective action costs, and loss of property value	
Salinization	• Diffuse drainage and wash-off of rainfall-mobilised natural in-situ salts and soils • Diffuse source sub-surface irrigation return flows • Mine water drainage and atmospheric deposits	• Inappropriate farming practices, such as inappropriate dry-land tillage, inappropriate dry-land crops, over-irrigation, inappropriate irrigation technology, lack of intercepting drainage and related evaporation pond infrastructure, and inappropriate irrigation water conveyance practices.	• Salinization changes the chemical composition of natural water resources such as lakes, rivers, and ground water, degrading the quality of water supply to the domestic and agricultural sectors, contributing to loss of biodiversity, taxonomic replacement by halotolerant species (Vengosh, 2003) and creating sever health problems	• Surface flows; • Interflows in the soils; • Water quality; • Groundwater flows • Geomorphology of watercourses; • Habitat; and Biota.
Acidification	• Mining sources • Industrial sources and emissions • Contaminated seepage, leaching, runoff and spills • Wash-off and leaching of widespread acidic atmospheric deposits.	• Lakes become acidic when the input of hydrogen ions exceeds the amount of bases produced in the catchment, by the weathering of rocks, or in the lake itself, through the reduction of acid anions, such as sulphate and nitrate • Historical and recent lack of precautionary planning, regulation, and enforcement by the relevant authorities, and of ring-fenced rehabilitation financing for the necessary rehabilitation by the relevant mining companies. • Heavy metal contamination and	• Changes in the structure and functioning of ecosystems, • increased pollution from sulphuric and nitric acids • Damage to forests • chemical, physical, and biological changes the extinction of aquatic organisms	• Surface flows; • Interflows in the soils; • Water quality; • Groundwater flows • Geomorphology of watercourses; • Habitat; and Biota.

Contributing factors	Sources of pollution / Driver	Root Cause	Impacts	Affected Characteristics of Watercourses
		related issues • Acidic atmospheric deposits.		
Sedimentation / Siltation	• Natural runoff • Agricultural sources • Urban runoff	• Erosion: inappropriate crop cultivation and silviculture practices; over-grazing; destruction or encroachment of riparian vegetation buffer zones; destruction or encroachment of wetlands; physical modification of river channels and banks; excessively dense less-formalised human settlements; careless construction activities; amongst others. • Lack of suitable qualification criteria for farmers entering the field, combined with inadequate support from Government and the sector.	• Decreased storage capacity • Reduction in reliability of the reservoir • Affects: ○ Water supply ○ Irrigation ○ Flood management services; ○ Degrades aquatic habitat	• Surface flows; • Interflows in the soils; • Water quality; • Groundwater flows • Geomorphology of watercourses; • Habitat; and Biota.

3.4.4. STATUS QUO AND INTERGRATION OF REHABILITATION INITIATIVES AND PRACTICES FOR LAKES AND DAMS IN SOUTH AFRICA

This next sub-section zooms into rehabilitation of Lakes and Dams done in South Africa. As mentioned in **subsection 3.4.1.2** that, in SA the focus has mainly been on Dam Safety rather than aquatic ecosystem rehabilitation. However, recently the focus is also shifting towards rehabilitation of aquatic ecosystems. For instance, in 2010/11, WRC conducted a study on **Bio-manipulation** to determine the potential impact of fish-harvesting on improving eutrophication conditions. Bio-manipulation is well known as a management tool for eutrophic systems. WRC (Project K5/1918) funded project on ***"Food-web interactions in South African Reservoirs"***, investigated the food-web structure in the hypertrophic Rietvlei Dam based on stable isotope analysis and its implications for reservoir bio-manipulation.

3.4.4.1. Lakes and Dams Rehabilitation Studies and Practices

The DWS undertook studies for rehabilitation of a number of dams from 2007 to 2011 for which safety concerns existed. ARQ Consulting Engineers (Joint Venture) firm specialising in dams, hydro, geotechnical and advance numerical analysis was appointed for rehabilitation of the Group 1 dams:

- Nami Dam at Guyana;
- Modjadji Dam near Duiwelskloof;
- Molepo Dam near Haenertsburg;
- Chuniespoort Dam near Polokwane; and
- Bospoort Dam near Rustenburg.

ARQ's involvement in the design phase of the project included the conceptual design for all rehabilitation and improvements works, leadership of the design team for all works and the full detailed design for Molepo Dam, Bospoort Dam and Chuniespoort Dam, the first two being provided with a fourfold increase in spillway capacity. During construction, ARQ was responsible for assistance on all dams and full supervision at Bospoort Dam, which has filled and spilled, with the combined new spillways operating very successfully.

ARQ has undertaken other rehabilitation work on various dams around the country. Some of the studies, projects and best management practices that have been conducted by the consulting firm are mentioned below:

- **Pongolapoort Dam -** safety evaluations and related analyses were undertaken from March 2019 - April 2019 and found several problems, the most critical being an inadequate spillway capacity. ARQ was appointed to conduct a full dam evaluation to ensure restoration of the dam to operation at Full Supply Level (FSL). A clear delineation of the various rehabilitation requirements and a broad definition of the options in respect of the existing works was developed to facilitate and inform further phases of dam betterments.
- **Berg River Dam -** the Supplement Scheme comprised of an abstraction works undertaken during January 2003 - December 2007 on the Berg River 9 km downstream of the dam, two pump stations with capacities of 6 and 4m$^{3/}$s respectively and two steel pipelines of 1 500 mm diameter with a total length of 12.4 km. The abstraction works included a sand trap that could be hydraulically flushed to remove deposited sand and gravel**.**
- **Midmar Dam –** the project involved a 3.5 m raising of the FSL of Midmar Dam using a reinforced concrete labyrinth spillway from June 1999 - December 2003. No raising of the flank embankments was required, and the work was limited to demolishing the spillway bridge and piers, a modification of the spillway crest and the construction of 3.5 m high reinforced concrete labyrinths. The raised spillway has now been successfully operating since 2003.

The Marico Bosveld Dam in the North-West Province is another example of a dam that was rehabilitated due to its classification as a Category III dam with a high hazard potential and medium size according to the national Dam Safety Legislation. The dam was originally constructed by the DWS in 1935 and raised in 1965. The dam urgently required rehabilitation to improve its safety and address other several maintenance issues. The DWS commenced with the rehabilitation of the dam in September 2019 as part of the Department's Dam Safety Rehabilitation Programme (DSRP) in a bid to repair water infrastructure and create job opportunities. Rehabilitation entailed two main broad works namely, installation of sub-surface drain and reinstatement of the main embankment.

It is noted from the literature that most dam rehabilitation projects in SA are focusing more on dam engineering rather than the pollution and degradation of the resource. For instance, Viljoen and Reynolds (2015), evaluated 11 case studies of dam rehabilitation projects in SA, in terms of quantitative risk assessment criteria and Society's Willingness to Pay (SWTP). It is evident from the Study that South African and international authorities base their decisions to rehabilitate dams based on several criteria, of which risk to human lives is the most important one. Which means that in most regions, the priority is more on dam safety. However, South Africa is now shifting towards the rehabilitation of the aquatic ecosystems. Therefore, for the purpose of this project "Rehabilitation Management Guidelines", focus will be more on the rehabilitation that is related to wastage, pollution and degradation of the resource which is in-line with Chapter 3 of the NWA. This because lot of work has been done on the dam engineering and there are gaps on the aquatic ecosystem rehabilitation.

3.4.4.2. Lakes and Dams Rehabilitation Initiatives and Programmes

The DWS in partnership with different stakeholders initiated the development of in-lake eutrophication management projects in some areas of the country with the aim of controlling eutrophication and rehabilitation systems that are experiencing eutrophic waters (DWS, 2020). Some of these initiatives include the following:

- **Hartbeespoort Dam Integrated Biological Remediation Programme (HDRP) -** this programme is also known as the **Harties Metsi-a-Me Programme:** Phase 1 of HDRP took place between 1996 – 2013, and it was based on the Integrated Biological Remediation Programme that looked at a wide variety of short-term and long-term methods and techniques to control the status of eutrophication in the Hartbeespoort Dam. The Resource Management Plan (RMP) for Hartbeespoort was based on the basic principles of ecosystem improvement for both human and environmental needs. The rehabilitation process of food web reconstruction supported the development of *Spirogyra* algae and indigenous aquatic plants which consumes more nutrients and in return suffocate the notorious blue-green algae. Several biological control agents were also introduced to control the water hyacinth. These bio controls target only the water hyacinth and do not affect other plants.

- **Solar-Powered Reservoir Circulator / Solar Bees:** floating solar-powered reservoir long distance circulation pump system used to mix water columns and greatly accelerates the biological and solar processes that clean up water. Both horizontal and vertical circulation patterns are created for improved distribution of oxygen, enhanced water clarity, elimination of cyanobacterial (blue-green algae) blooms and reduced nuisance aquatic weed growth. In 2018, Tshwane Metropolitan Council installed these plants at Rietvlei Dam as a step towards finding solutions to in-lake eutrophication. It has been proven to improve water quality (increase oxygen levels throughout the dam) and reduced algal toxins (high phosphorus reduction) in the water. The system is very economical, requires minimum maintenance, and can operate day and night using only solar energy.
- **Water Research Commission (WRC)** is in the process of developing **the National Siltation Management Strategy for Dams in South Africa (*NatSilt*).** This programme aims to produce tools and know-how to arrest the situation and mitigate against future increases in siltation through the deployment of social, economic, technological, engineering and management tools and systems; and to control the impact of sedimentation. Therefore, the overall aim of this programme is to expand the footprint of a dam to include all upstream activities, to improve the understanding of the current status quo of dam sedimentation in SA and to develop support tools for the cross-departmental co-ordination of activities to combat dam sedimentation. Dam sedimentation is one of the priority issues that were identified by IWQM as an issue of priority in our dams, which needs an urgent attention. Hence, the development of the Strategy.
- **Standards and Guidelines for Improved Efficiency of Irrigation Water Use from Dam Wall Release to Root Zone Application (WRC, 2010)**

  The study was undertaken by Agricultural Research Council on behalf of Water Research Commission to develop guidelines are therefore aimed to assist both water users and authorities to obtain better understanding of how irrigation water management can be improved, thereby building human capacity, so that targeted investments can be made with fewer social and environmental costs. Using lessons learnt during the project, best practices and technologies were introduced and illustrated. The guidelines consist of 4 modules addressing the fundamental irrigation concepts, in-field irrigation systems, on-farm conveyance systems and irrigation schemes. Below are practical examples of each of the abovementioned components covered:

- In-field irrigation system involves applying the right **amount of water** at the **correct application rate** to all the plants in the field with as little non-beneficial consumption (losses) as possible – **timing of applications, application rate (accuracy) and distribution uniformity** is therefore characteristics of system that should be considered
- On-scheme system entail reliable and sustainable source as well as conveyance system of water – **quantity and quality** of the water delivered.

It is our opinion that the in-field and on-scheme irrigation systems are two important site-specific tools for the current RMG project because they consider important aspects such as quantity and quality of water to be used for irrigation which ensures measures are in place for the protection of critical water resources.

3.4.5. FINDINGS AND GAPS FOR THEME 4: LAKES AND DAMS

Below is a list of findings identified from the review conducted.

- Majority of the studies and practices conducted on rehabilitation of Lakes and Dams in South Africa are mainly structural and geotechnical related. This presents a challenge to the current project since the focus is on rehabilitation of water resources for ecological functioning.
- Despite abovementioned challenge, a few key lessons are drawn from the review of Phase 1 of the Hartbeespoort Dam Integrated Biological Remediation Programme (HDRP) that was conducted by Water Research Commission in 2016.
- The HDRP Phase 1 has achieved many successes which include a large-scale hyacinth and other alien plant removal, the testing of floating reedbed systems, a fisheries programme, and the clearing of debris from the system.
- HDRP Phase 1 experienced two main challenges, namely, lack of phosphate management and weakness in technical and financial governance. As a result, key lessons learnt for implementation of the next Phase 2 of the HDRP is the need to focus on the catchment upstream of the dam, specifically on improving the quality of the water flowing into the dam and for programme to be set within an adaptive management framework.
- The DWS plays a major role in regulating the use of our water resources and ensuring the safe operation of dams in the country. This is achieved through two programmes namely, the Dam Safety Evaluation Programme (DSEP) and Dam Safety Rehabilitation Programme (DSRP). The DSEP include conducting 5 yearly dam safety valuation on the dams owned by the department. The DSRP is informed by the recommendation from the 5 yearly dam safety evaluation. The DSRP implement the

recommendations from the DSEP by rehabilitating dams to comply with the dam safety regulations. These programmes ensure that the South African National Committee on Large Dams (SANCOLD) and International Commission on Large Dams (ICOLD) dam safety guidelines are adhered to.

Below is a list of gaps identified from the review conducted.

- Dam Safety Guidelines in place but only address engineering related rehabilitation.
- No comprehensive Rehabilitation Guidelines for Lakes & Dams.
- The review of studies, programmes and initiatives relating to rehabilitation of Dams is mainly focused on water resource infrastructure components such as spillways, gates, pumps and associated equipment that need regular maintenance and occasional major rehabilitation to ensure safe and reliable operating capability. Concrete and heavy steel Dam structures may have an extremely long-life span, but it was recently reported that the DWS Officials from the Limpopo Provincial Office, Engineers employed under Dam Safety unit together with members from the Provincial Disaster Management to assist with the prevention of the recent collapse of the dam wall. The Dam which is owned by the provincial Department of Agriculture had filled up to full capacity and was spilling, thereby threatening the potential collapse of the dam wall.
- The review has also found that reservoir sedimentation is a main impact to most South African dams, but the rehabilitation and management thereof is not documented in the literature reviewed. This is viewed as gap and limiting factor to the current project. Another gap identified is that priority is more on the safety of human lives than aquatic ecosystems. According to the draft Rehabilitation Policy (2014), South Africa needs to acknowledge the ecological mistakes made and learn from other first world countries mistakes and do not need to wait for ecological degradation/catastrophe because of insufficient planning, ignorance, or poor vision. Where there are opportunities to demolish dams or weirs as part of environmental ecological infrastructure and functioning, it must be done.
- It was also noted in the literature that there is no single legislative system that is specific to Lakes and Dams management, which makes it challenging to manage these water resources because the mandates are residing within different Government Departments (refer to **Table 6**).
- Lastly, rehabilitation measures/interventions/best management practices relating to rehabilitation of Dams for hydrological and ecological connectivity, decommissioning of dams (*i.e.* demolishing of dams and weirs) for ecological functioning and gain are also not documented in the literature reviewed.

The below are other gaps identified and requiring urgent attention:

- There is no rehabilitation programme to address all watercourse characteristics of dams like surface flow, interflow, groundwater flow, geomorphology, habitat, biota;
- There is no one stop shop to address impacts to dams and impacts caused by dams;
- Dam operation and maintenance manuals fail to address all impacts;
- Operation manuals don't include updated ecological flow releases;
- Lack of institutional arrangements between countries and treaties; and
- Water allocation reform doesn't take into account rehabilitation;

3.4.6. WAY FORWARD FOR REHABILITATION GUIDELINES FOR THEME 4: DAMS AND LAKES

Based on the gaps and shortcoming identified in **Section 3.4.5**, it is evident that there are Dam Safety Guidelines in place but they only address engineering related rehabilitation. It is against this backdrop that the development of Comprehensive Rehabilitation Guidelines for Lakes and Dams is recommended (*e.g* Rehabilitation guidelines for hydrological and ecological connectivity, decommissioning of dams & weirs for ecological functioning and gain). These guidelines will afford DWS an opportunity to rectify past mistakes and address the abovementioned gaps by developing a two-legged approach that is going to prioritise both human lives and aquatic ecosystems.

3.5. THEME 5: GROUNDWATER

3.5.1. OVERVIEW

Groundwater is an increasingly important source of water supply for agriculture, households, industry, and it has been used for centuries to sustain not only human life, but also the aquatic environment, especially during dry seasons (Ahring and Steward, 2012). It has been argued that continuous increase in groundwater dependence without proper protection measures put in place may lead to over exploitation and degradation (Vainu and Terasmaa, 2016; Lund *et al.,* 2016). While groundwater use is considered as a pressing issue in water resources management, many analysts are emphasizing the role that states has to play in groundwater resource protection (Meinzen-Dick *et al.,* 2016). However, groundwater contamination has been cited as a global problem that has a significant impact on human health and ecological services (Brouwer *et al.,* 2018; Li *et al.,* 2021). As an example, many countries around the world reported nitrate pollution in groundwater with several remediation techniques being explored and recommended for use as part of intervention measures (Zhao *et al.,* 2021). Therefore, it is not surprising that the International Union for Conservation of Nature and Natural Resources (IUCN) identifies groundwater overuse and pollution as two major threats to groundwater resources which require management interventions for groundwater resources protection and remediation (Smith *et al.,* 2016). In this section, a brief reflection on groundwater resources utilization is provided. Such a reflection is critical in the contextualization and development of rehabilitation management guidelines linked to groundwater resources.

3.5.1.1. Reflection on groundwater resources utilization

Groundwater is the world's most extracted raw material with withdrawal rates currently in the estimated range of 982 km^3 per year, with almost 70% of this amount used for agriculture (Margat and van der Gun, 2013). In the state of California within the United States (US), over-reliance on groundwater has led to significant overdraft, affecting long-term water supply reliability and groundwater pumping costs, which has caused subsidence and infrastructure damage, and harmed groundwater-dependent ecosystems (Ke and Blum, 2021). Considering that many regions in the European area already suffer from water stress conditions (Stavridis *et al.,* 2017), the deliberate recharge of depleted aquifer storage and later recovery, known as Managed Aquifer Recharge (MAR), has been considered as one of the important approaches for groundwater management and sustainability (Grinshpan *et al.,* 2021). It has been argued that MAR supports higher water demands, overcoming the temporal mismatch between water supply and demand, and water quality improvements (Hartog and Stuyfzand, 2017). Furthermore, MAR is known for protection of water against evaporation losses, algal blooms, and atmospheric fallout of pollutants during sub-terranean storage, especially in arid and semi-arid regions where challenges linked to water resources availability and pollution are prevalent (Zhang, *et al.,* 2020).

Nevertheless, irrespective of the choice of an intervention measure, rehabilitation of groundwater resources for either quantity and/or quality is central towards effective and efficient groundwater resources management for water resource security.

3.5.2. GROUNDWATER RESOURCES REHABILITATION: THE CONCEPT AND ITS APPLICATION IN PRACTICE

In this sub-section, a brief overview of groundwater resources rehabilitation in practice is presented. Through literature examination, a definition of groundwater resource rehabilitation is provided, and various aspects applicable in groundwater resources rehabilitation practice, such as rehabilitation methods, and level of application are reflected upon.

3.5.2.1. Defining groundwater resource rehabilitation

The word *rehabilitation* means an action of restoring using a set of interventions designed to optimize functionality of a system. Some authors argue that precise meaning of the word "*rehabilitation*" can mean very different things to different people, contending that there are many forms and conceptions depending on the context and the field in which the term is used such as the field of health services, and criminal justice, just to name the few examples (Bonnechère and Van Sint Jan, 2019; Antonio and Price, 2021). For the purpose of this project, *groundwater resource rehabilitation* can be understood as an act of restoring functionality of an aquifer and its characteristics in order to continue deriving benefits associated with that system. A similar term "*remediation"* is also frequently used to describe the same action of restoring functionality of a system. According to DWAF (2000) "*remediation* involves restoration of areas that historically have had unacceptable impacts and of underground water resources or areas where impacts on such resources have become unacceptable". Although the terms *rehabilitation* and *remediation* may be used to describe similar actions, depending on the choice of a user, these terms are often used interchangeably in practice.

3.5.2.2. Methods for groundwater resource rehabilitation

Sustainable management of groundwater should aim to prevent groundwater from becoming severely depleted or highly polluted, since prevention is always less expensive than trying to remediate problems once they have occurred. However, sometimes groundwater degradation may have to be mitigated with technical measures, either because the aquifer will not recover on its own, or because other pressures mean that groundwater will continue to be exploited from an increasingly degraded system. A key aspect of any remediation programme is a clear agreement on the targeted end point and on how it will be monitored and measured. Rehabilitation measures can be applied in situ (introducing oxygen, nano particles, or bacteria to help speed up natural biogeochemical processes) or ex-situ (commonly pumping contaminated groundwater to the surface and treating it or erecting barriers to contain contaminated groundwater) (Smith *et al.,* 2016). Bioremediation, chemical, and physical methods are examples of classes for groundwater rehabilitation technologies (Azubuike *et al.,* 2016; Pi *et al.,* 2020; Zhang, *et al.,* 2020). The choice of groundwater rehabilitation method depends on a good understanding of the hydrogeologic regime.

3.5.3. LEVEL/SCALE OF APPLICATION FOR GROUNDWATER RESOURCE REHABILITATION

Projects on groundwater rehabilitation can be undertaken at local level for borehole rehabilitation, or at regional level for aquifer rehabilitation. Transboundary aquifers may also be subjected to heavy utilization of the resource for livelihoods and such activities have a profound effect on the groundwater quantity and quality which may trigger the need for rehabilitation. Groundwater resources rehabilitation projects for transboundary aquifers may require operation under existing or devolved bilateral or multilateral agreements.

3.5.4. CONTEXTUALIZATION OF GROUNDWATER REHABILITATION

3.5.4.1. Global Groundwater Rehabilitation Context

A brief global perspective on groundwater resources rehabilitation/remediation is provided. This reflection touches on policies, strategies, and other relevant initiatives linked to groundwater remediation, and is outlined in detail in **Annexure N.**

3.5.4.2. Regional Rehabilitation Context

The literature search was not successful in obtaining reported practical case studies on groundwater resources remediation with specific reference to SADC countries. Nevertheless, the regional perspective on groundwater resources rehabilitation is provided based on available reported research studies in one SADC country (Tanzania) and two north African countries (Algeria and Egypt). Although not much has been published on the subject matter, especially on policy practice for groundwater resources remediation, however the reflection is able to build on few reported studies conducted in Egypt (Abdelhafiz *et. al.,* 2021), Tanzania (Mwegoha, 2008), and Algeria (Khechekhouche *et. al.,* 2020) and the summarised in **Table 9**.

Table 9: *Summary of findings on groundwater resource rehabilitation and remediation practices, regional perspective*

Settings/Country	Studies, Programmes, and Initiatives	Impacts Identified	Summary of Interventions and Best Management Practices Conducted
Egypt	Investigated feasibility of using photocatalytic treatment techniques in the presence of modified nano-titania and solar radiation for groundwater remediation	In-situ Groundwater remediation	Organic contaminants and microbial pollutants in shallow groundwater resources can be removed using photocatalytic treatment technique,
Tanzania	Treatment of polluted groundwater was investigated using a technique of phytoremediation which is considered as a low-cost technology.	In-situ Groundwater remediation	The findings of the study provide critical evidence of the suitability and feasibility of using this treatment technology in groundwater resources remediation projects when assessing the choice of a treatment technology.
Algeria	The capabilities of Solar Distillator as an alternative treatment technology for treatment of contaminated groundwater was investigated.	Ex-situ Groundwater treatment	The Solar Distillator showed to be capable of removing impurities and pollutants.

Egypt

In Egypt, feasibility of groundwater remediation was investigated within northeastern Cairo (Abdelhafiz *et. al.,* 2021). The study applied a photocatalytic treatment technique in the presence of modified nano-titania and solar radiation to assess remediation efficiency of polluted shallow groundwater. The analysis of the study pointed out that most of the water samples (96.4%) were characterized as Na_2SO_4 and $NaHCO_3$ type, indicating its meteoric origin. Furthermore, the analysis indicated contamination with human and animal fecal substances, NO_3^-, and NH_4^+ originating from anthropogenic activities. In terms of remediation efficacy, the study found that the photocatalytic technique efficiently eliminated more than 82-95% of organic contents and microbial pollutants, respectively, but it was inefficient in reducing heavy metal levels. The study concluded that shallow groundwater injected into the deep aquifer can be constrained and reusable after treatment. The key message derived from this study is that it is possible to remove organic contaminants and microbial pollutants in shallow groundwater resources using a photocatalytic treatment technique, and that aquifers can be used as storage reservoirs for excess water which can later be recovered for various uses.

Tanzania

In Tanzania treatment of polluted groundwater has been investigated using in situ approach of phytoremediation which is considered as a low-cost technology. It has been shown that it is possible to achieve great success for in-situ cleanup of large volumes and expansive areas of contaminated soils and/or waters, including groundwater without excavation or other pretreatment trains. Although phytoremediation technology is promoted in research, in practice challenges have been reported. For example, Mwegoha (2008) reported that in Tanzania introduction of invasive species for phytoremediation purposes may affect the local biodiversity. The study noted that phytoremediation of different types of contaminants requires different general plant characteristics for optimum effectiveness. Furthermore, the study found that a long time is often required for remediation; may take up to several years to remediate a contaminated site. The findings of the study provide critical evidence of the suitability and feasibility of using this treatment technology in groundwater resources remediation projects when assessing choice of a treatment technology.

Algeria

Khechekhouche *et al.* (2020) conducted a study to investigate feasibility of using a Solar Distiller as an alternative treatment technology in the treatment of contaminated groundwater. The technology is based on a pump-and treat approach which is an ex-situ technique. The solar distillation technique is deemed environmentally friendly, cheap, and simple to assemble and use as indicated in **Figure 11**. Findings of the study proved that the technique of solar distillation is effective in removing impurities and pollutants when electrical conductivity changed from 0.471 s/m before solar distillation to 0.0231 s/m after solar distillation. Moreover, the technique did not use any external energy, as it relied on free solar rays, and it did not show any negative impact on the environmental and ecological ecosystem disturbance (Khechekhouche *et. al.,* 2020).

Figure 11: *Assemblage of a Solar distiller (Source: Khechekhouche et al., 2020)*

3.5.4.3. Local Groundwater Rehabilitation Context

In South Africa, groundwater is recognized as one of the strategic water sources. It is estimated that more than 50% of the communities in country depend on groundwater for domestic needs, especially those communities living in arid and semi-arid areas (DWS, 2016). Groundwater resources availability for sufficient, potable water is critical in fostering water supply and vigorous ecosystems services, agricultural production, industrial activities, and for food security in South Africa (Masindi and Abiye, 2018). Although groundwater has been habitually perceived as a safe and dependable source of water, this is often not the case since it is prone to pollution from both anthropogenic and natural processes (Masindi and Foteinis, 2021). Water quality problems associated with groundwater resources have also been reported in the country. For example, several villages such as Siloam Village, Milaboni, and Tshikombani located within the Nzhelele River catchment in the Limpopo Water Management Area have been reported to be vulnerable to water quality problems such as elevated levels of calcium, magnesium, and nitrate in private boreholes, attributed to the agricultural practices and washing of clothes in the vicinity of the boreholes (Odiyo and Makungo, 2012).

Protection measures to safeguard groundwater resources contamination exist in the country, however, in cases where such systems have deteriorated beyond the state of natural recovery, appropriate intervention activities such as groundwater resource remediation becomes a necessity. Therefore, policy implementation practice especially for water resources protection should not only be about operationalization of water resources protection strategies such as resource directed measures (RDMs), but it should also provide water resources remediation management guidelines. Mere implementation of water resources protection strategies without proposing supporting water resources remediation plans and guidelines for use in cases of excessive water resources degradation, limits improvement on sustainable water resource utilization and management practice.

In this context, several studies have been conducted in the country to elucidate groundwater resources remediation. For example, when hydrogeochemical characteristics of groundwater in rehabilitated coalmine spoils were investigated by Gomo and Masemola (2016), it was found that Dolomite Acid Mine Drainage (AMD) neutralization was the main hydrogeochemical process controlling the evolution of the groundwater chemistry in the study area. The evolution was driven by the release of sulphate, calcium, and magnesium ions from the carbonate-AMD neutralization process (Gomo and Masemola, 2016). Such a revelation is critical in the decision-making process especially in the selection of an appropriate remediation technique for groundwater resources remediation. Although guidelines for the rehabilitation of mined land exist in the country, Weyer *et al.* (2017) noted that at the mine approval phase, there is logically a focus on mine start-up and operational requirements with insufficient attention given to rehabilitation planning aspects. Although studies on groundwater resource remediation are prevalent in the country, practical application of the outcomes emanating from such studies has been **limited**, possibly due to unavailability of a comprehensive water resource remediation guideline. Such a knowledge gap in water resources protection practice is central to the current project.

3.5.5. GROUNDWATER REHABILITATION LEGISLATIVE FRAMEWORK

It is important that groundwater resources rehabilitation activities are undertaken within the context of a legal framework to support legitimacy of such activities. This section reflects briefly on the components of legislation that support rehabilitation of groundwater resources to give stakeholders confidence about the comparability and reliability of the outcomes that would emanate from this project, especially as far as groundwater resources rehabilitation is concerned. **Table 10** outlines some of the key legal documents that were scrutinized in support of groundwater resources rehabilitation.

Table 10: *Illustration of key legal documents on groundwater resource rehabilitation, restoration, remediation in South Africa*

Legal Framework	Context
White paper on water policy of 1997 (NWP, 1997)	Principle 16 of the NWP (1997) on water resources management approaches proposed that water quality management options shall include the use of economic incentives and penalties to reduce pollution; and the possibility of irretrievable environmental degradation because of pollution shall be prevented.
National Water Act (Act 36 of 1998) (NWA, 1998)	Chapter 3, Part 4 of the NWA (1998) deals with prevention and remedying effects of pollution. Section 19(2)(e)(f) stipulates measures that must be taken to prevent any pollution of water resources from occurring, continuing, or recurring. Such measures include remedying the effects of pollution and remedying the effects of any disturbance to the banks of a watercourses.

National Environmental Management Act (Act 107 of 1998) (NEMA, 1998)	Section 28(3)(f) of the NEMA requires that e very person who causes, has caused, or may cause significant pollution or degradation of the environment must take reasonable measures such as remedying the effects of the pollution or degradation.
Minerals and Petroleum Resources Development Act (Act 28 of 2002) (MRPDA, 2002).	The Minerals and Petroleum Resources Development Act of 2002 lays out new obligations for the mining and other industries in terms of the monitoring and remediation of pollution of water resources.

3.5.5.1. White paper on water policy of 1997 (NWP, 1997)

The analysis of the documents collated indicates that required policies and legislation which support groundwater resources rehabilitation are available in the country. The White paper on water policy developed in 1997, outlines the direction to be given to the development of water law and water management systems (DWAF, 1997). The White Paper forms a foundation for development of other water resource protection policies and legislation such as the National Water Act (Act 36 of 1998) (NWA, 1998). Its objective is to set out the policy of the government for the management of both quality and quantity of the country's scarce water resources through a series of stipulated principles. Principle 16 of the NWP (1997) on water resources management approaches proposed that water quality management options shall include the use of economic incentives and penalties to reduce pollution; and the possibility of irretrievable environmental degradation because of pollution shall be prevented. The aforementioned economic incentives and penalties could also be used to fund rehabilitation projects for the environment or water resources that have degraded beyond natural state of recovery. The NWP (1997) does not separate water resources in terms of their types, and therefore it is in this principle where groundwater resources rehabilitation is supported.

3.5.5.2. National Water Act (Act 36 of 1998) (NWA, 1998)

The purpose of the NWA (1998) is to ensure that the nation's water resources are protected, used, developed, conserved, managed, and controlled in ways which take into account amongst other factors: promoting equitable access to water; redressing the results of past racial and gender discrimination; promoting the efficient, sustainable and beneficial use of water in the public interest; facilitating social and economic development; protecting aquatic and associated ecosystems and their biological diversity and meeting international obligations (NWA, 1998). It is in Chapter 3 of the NWA where water resources protection and rehabilitation are entrenched. Specifically, Chapter 3, Part 4 of the NWA (1998) deals with prevention and remedying effects of pollution. Section 19(2)(e)(f) stipulates measures that must be taken to prevent any pollution of water resources from occurring, continuing, or recurring. Such measures include remedying the effects of pollution and remedying the effects of any disturbance to the banks of a watercourses. When the NWA is implemented especially for water resources protection, an integrated approach is adopted which encompasses protection of all types of water resources with groundwater included. It is in this context that the NWA supports implementation of measures for groundwater resources rehabilitation.

3.5.5.3. National Environmental Management Act (Act 107 of 1998) (NEMA, 1998)

The National Environmental Management Act (Act 107 of 1998) was formulated to provide for co-operative environmental governance by establishing principles for decision-making on matters affecting the environment. Section 28(3)(f) of the NEMA requires that every person who causes, has caused, or may cause significant pollution or degradation of the environment must take reasonable measures such as remedying the effects of the pollution or degradation (NEMA, 1998). Considering that water resources with groundwater included form part of the environment, it is under this section of the NEMA where groundwater resources rehabilitation is supported.

3.5.5.4. Minerals and Petroleum Resources Development Act (Act 28 of 2002) (MRPDA, 2002)

The purpose of the Minerals and Petroleum Resources Development Act (Act 28 of 2002) is to make provision for equitable access to and sustainable development of the nation's mineral and petroleum resources, and to provide for matters connected therewith (MRPDA, 2002). The Act lays out new obligations for the mining and other industries in terms of the monitoring and remediation of pollution of water resources. Therefore, the Act supports remediation of polluted groundwater resources, especially pollution resulting from industrial and mining operations.

3.5.6. ALIGNMENT WITH POLICIES AND STRATEGIES

A guideline on rehabilitation management for water resources acts as a reference material or as a standard guide controlling water resources rehabilitation activities. However, such a guide must be relevant and be aligned with existing policies and strategies. Therefore, this section provides an overview of existing policies and strategies, and it highlights the context in which these policies and strategies influence or will influence groundwater resources rehabilitation practice. Furthermore, the overview will assist in developing groundwater resources rehabilitation guideline that is relevant and appropriate for policy implementation using existing strategies. Summary of this reflection is provided in **Table 11**.

Table 11: *Summary of policies and strategies relevant to groundwater resource rehabilitation, restoration, remediation in South Africa*

Legal Framework	Context
Policy and Strategy for Groundwater Quality management in South Africa (2000)	Policy and Strategy for Groundwater Quality Management (2000) emphasises on groundwater remediation which is not sufficiently covered in the NWA. It draws on the experience of countries that already have guidelines for known contaminants. It further suggests a site-specific, needs-based approach to remediation of degraded groundwater.
Artificial Groundwater Recharge: Recent Initiatives in Southern Africa (DWA, 2010)	The booklet provides an overview of the status of artificial recharge in Southern Africa and lists resources that are easily accessible to anyone considering this water storage, treatment, and conservation measure.
Second National Water Resource Strategy of 2013 (NWRS II, 2013)	The NWRS II (2013) notes that much still needs to be done in the areas of implementation of water resource protection programmes and monitoring of ecosystem health to proactively minimize degradation of the resource, focus on rehabilitation efforts and ensure compliance to sustainability.
National Groundwater Strategy, 2nd Edition (NGS, 2016)	The NGS (2016) notes that the mining sector is faced with legacy issues of past pollution, for example, acid mine drainage. It further stipulates that the development of new mines in water-scarce areas requires planning to decide for the transfer of water and development of new sources, and appropriate attention to waste processing and remediation.
Integrated Water Quality Management Strategy (IWQMS, 2017)	Principle 10 of the IWQMS dwells on the promotion of green/ecological infrastructure restoration and rehabilitation and restoration of degraded catchments. However, the IWQMS also note that the costs associated with rehabilitation of degraded water resources, or of emergency responses to pollution incidents can be extremely high.
Department of Water Affairs: Environmental Rehabilitation Policy (DWA, 2014)	The discussion document highlights the need for an environmental rehabilitation policy linked to water resources. The policy is envisioned to lay the foundation and clarify the approach for DWS to implement, regulate and facilitate environmental rehabilitation within its mandate as custodian authority over water resources.
National Water and Sanitation Master Plan (NW&SMP, 2018)	The NW&SMP (2018) states that implementation of the waste discharge charges strategy is of critical importance to increase the funding available for the management and rehabilitation of polluted catchments, but also to incentivize the reduction of pollution.

3.5.6.1. Policy and Strategy for Groundwater Quality management in South Africa (2000)

The mission of the Policy and Strategy for Groundwater Quality management in South Africa is “to manage groundwater quality in an integrated and sustainable manner within the context of the National Water Resource Strategy and thereby to provide an adequate level of protection to groundwater resources and secure the supply of water of acceptable quality” (DWAF, 2000). In addition to other approaches proposed such as source-directed strategies, and resource-directed strategies **(Figure 12),** it puts emphasis on groundwater remediation which is conceived as not sufficiently covered in the NWA. It draws on the experience of countries that already have guidelines for known contaminants, and it suggests a site-specific, needs-based approach to remediation of degraded groundwater resources.

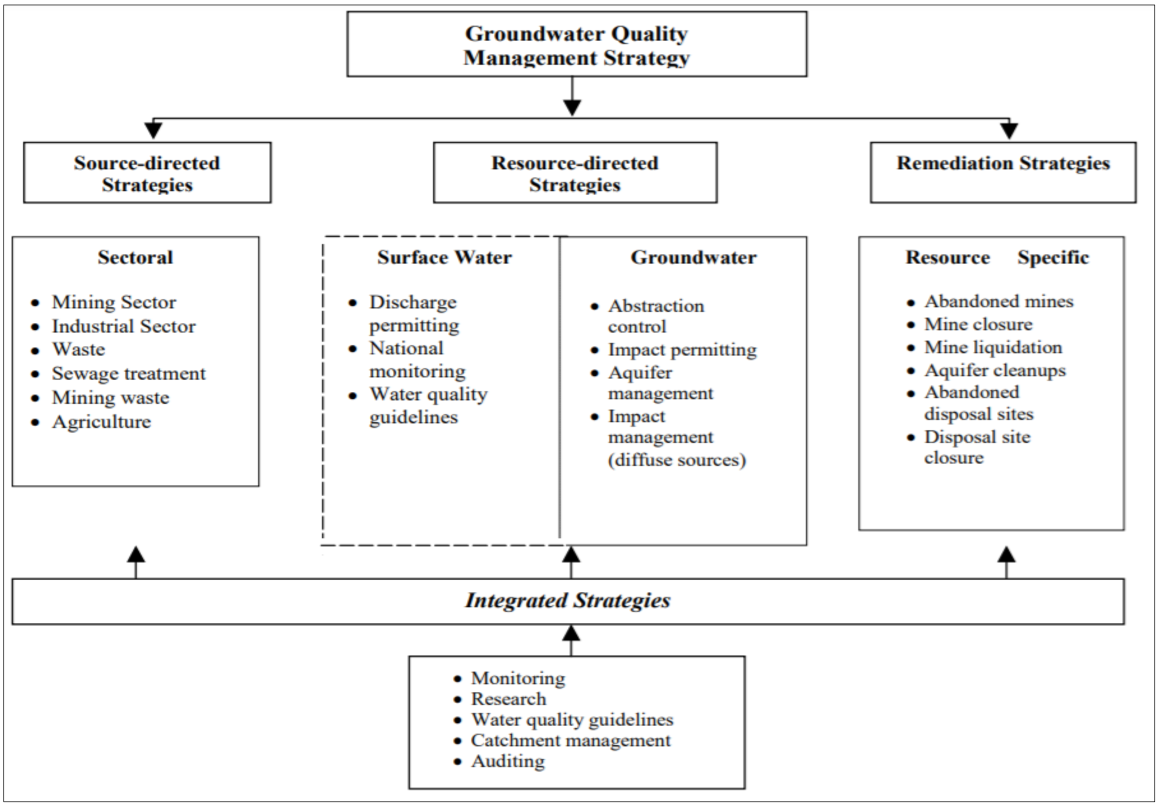

Figure 12: *Relationship between source-directed, resource-directed, and remediation approaches (Adapted from DWAF, 2000)*

3.5.6.2. Artificial Groundwater Recharge: Recent Initiatives in Southern Africa (DWA, 2010)

In 2010, the then Department of Water Affairs (DWA) compiled a booklet outlining initiatives that have been undertaken in Southern Africa regarding artificial groundwater recharge. The booklet defines artificial recharge as the process whereby surface water is transferred underground to be stored in an aquifer. Existing artificial recharge schemes such as Atlantis with storm and wastewater recharge of 7 500 m^3/day, Polokwane with artificial recharge potential of 3-4 million m^3/a of treated wastewater, Williston: with doubling wellfield yield obtained by transferring groundwater between aquifers, Kharkams with opportunistic artificial recharge which triples borehole yield, Windhoek which is a large-scale water banking, and the Omdel where desert floods are captured and stored underground. These are all Namibian initiatives regarding artificial groundwater recharge presented in the booklet.

3.5.6.3. Second National Water Resource Strategy of 2013 (NWRS II, 2013)

In the context of groundwater resources protection and remediation, the **Second** National Water Resource Strategy of 2013 (NWRS **II**, 2013) emphasises the need to protect our freshwater resources, which are under threat because of pollution from many sources. Land use activities such as hydraulic fracturing, coalmines groundwater infiltration, and on-site sanitation have a potential for groundwater pollution. Through undertaking of resource directed measures studies and implementation of the outcomes thereof, such activities will assist in determining the nature and the extent of pollution to provide appropriate rehabilitation solutions (NWRS II, 2013). Nonetheless, the strategy indicates that while the policies and programmes for water resource protection have been endorsed and adopted, the difficulty remains in how to implement them in a cost effective and sustainable manner within a reasonable time frame. It further notes that, much still needs to be done in the areas of implementation of water resource protection programmes and monitoring of ecosystem health to proactively minimise degradation of the resource, focusing on rehabilitation efforts, and ensuring compliance to sustainability (NWRS II, 2013), a critical aspect for groundwater resources rehabilitation practice.

3.5.6.4. National Groundwater Strategy, 2nd Edition (NGS, 2016)

One of the aspirations of the National Groundwater Strategy (2016) is to develop and maintain approaches for pro-active protection of groundwater resources and aquifer dependent ecosystems to secure a sustainable supply of water for various uses. The strategy considers groundwater recharge zones as critical areas requiring urgent need for protection from pollution and degradation. In the context of groundwater resources protection and remediation, the strategy makes a revelation that the mining sector is faced with legacy issues of past pollution, making a reference to acid mine drainage. It proposes that the development of new mines in water-scarce areas will require planning to make arrangements for the transfer of water and development of new sources, and appropriate attention to waste processing and remediation.

3.5.6.5. Integrated Water Quality Management Strategy (IWQMS, 2017)

The Integrated Water Quality Management Policy and Strategy (2017) notes a wide range of water quality challenges faced by South Africa impacting not only surface water, but also on groundwater such as waste products disposed of in landfills or slag heaps which may release pollutants that seep into groundwater, especially dolomitic groundwater resources. Principle 10 of the IWQMS dwells on the promotion of green/ecological infrastructure restoration and rehabilitation and restoration of degraded catchments. However, the IWQMS also notes that the costs associated with rehabilitation of degraded water resources, or of emergency responses to pollution incidents can be extremely high. South Africa faces a particular challenge in relation to its mining legacy, and the costs to the private sector and the state of treating acid mine drainage from closed mines, including abandoned mines which are the sole responsibility of the state (NGS, 2016; DWS, 2017a). The monetary challenges which lead to inadequate implementation of environmental provisions related to rehabilitation of mines and other polluted areas is noted as one of the resultant factors promoted by lack of funding to address the significant impacts of declining water quality (DWS, 2017a).

3.5.6.6. Department of Water Affairs: Environmental Rehabilitation Policy (DWA, 2014)

The Department of Water Affairs Environmental Rehabilitation Policy (2014) gives an indication that various environmental agencies have realized the value of restoring the ecosystems of rivers and the services that these ecosystems provide such as groundwater recharge, hence rehabilitation activities are observed as profitable. For instance, impervious structures are known to influence higher peak discharges, flashier stream flows, and reduced groundwater-surface water exchange due to the reduction in groundwater recharge (DWA, 2014). This revelation is central to the use of artificial recharge approaches in groundwater resource remediation practice.

3.5.6.7. National Water and Sanitation Master Plan (NW&SMP, 2018)

In terms of prioritized focus on maintaining or improving water quality, the National Water and Sanitation Master Plan (2018) states that the implementation of the waste discharge charges strategy is of critical importance to increase the funding available for the management and rehabilitation of polluted catchments, but also to incentivise the reduction of pollution. In terms of the priorities for the future, the Master Plan proposes implementation of the polluter-pays principle and rehabilitation of water quality impacts including acid mine drainage for long term actions, and it also highlights the need to develop rehabilitation systems.

3.5.7. LINKAGES TO RELATED WORK

As outlined in Section 1.1, Rehabilitation Management Guidelines are used as tools to effect implementation of RDM (GRDM in the context of groundwater resources), as per the legislative objective. In this regard a significant progress has been made in terms of the number of GRDM studies undertaken. However, progress on the implementation of GRDM requires strategic mechanisms for incorporating relevant scientific advances and tools into policy practice towards groundwater resources protection and rehabilitation. Therefore, this section focuses on GRDM work and establishes how this work relates to groundwater resource rehabilitation practice. When groundwater resources are classified in the overall water resources classification processes, the stress index is used for quantity component. Stress Index is calculated by dividing total abstraction in a catchment by the recharge for the catchment which is converted to a resource category (Dennis and Wentzel, 2007; Seward, 2008). Depending on the severity of groundwater use, areas experiencing overutilization of groundwater resources are identified, and mapped accordingly, and these areas require tight protection measures. For instance, due to water scarcity challenges experienced in some parts of the country with recent crisis brought on by the Cape Town's "Day Zero" drought, studies have documented the need for policy intervention such as strategies to enhance management of water supply and water resources sustainability (Booysen *et al.,* 2019;

Scheihing *et al.,* 2020).

3.5.8. GROUNDWATER PRESENT ECOLOGICAL STATUS (PES)

In **Section 3.5.9.1.** overutilization of groundwater resources was identified as one of the impacts causing degradation of groundwater resources, which may trigger rehabilitation interventions. As an example, the water resource classification study undertaken for the Berg Water Management Area provided insight on quaternary catchments that may need prioritization for groundwater rehabilitation projects related to quantity **(Table 12).** The G21B quaternary catchment is considered as a highly stressed catchment in terms of groundwater use which may call for immediate attention in terms of rehabilitation. The G21D, G22D, and G30D are considered as moderately stressed catchment and may be potential catchment candidate catchment for future rehabilitation projects. The rest of the catchments are not considered as moderately or stressed catchment.

Table 12: *Groundwater Balance, Use/recharge (Stress), and Present Status per Quaternary catchment (Source: DWS 2017c)*

Quaternary	Recharge ($Mm^{3/}a$	Use (Mm^3/a)	GWBF (Mm^3/a)	Balance Mm^3/a)	Use/Recharge (%)	Present Status
G10A	21.09	3.90	7.25	9.93	19	I
G10B	12.27	0.36	5.34	6.57	3	I
G10C	22.88	2.64	2.26	17.98	12	I
G10D	31.03	3.87	5.00	22.15	12	I
G10E	16.05	4.65	2.25	9.14	29	II
G10F	15.05	0.98	4.33	9.74	7	I
G10G	8.84	0.00	2.73	6.11	0	I
G10H	17.18	1.62	3.28	12.28	9	I
G10J	23.74	0.38	2.36	21.00	2	I
G10K	39.34	7.50	1.18	30.66	19	I
G10L	44.35	4.17	1.99	38.19	9	I
G21M	55.50	1.97	5.7	47.83	4	I
G21A	14.77	0.77	0.29	13.71	5	I
G21B	7.50	6.33	0.53	0.64	84	II
G21C	8.84	0.57	1.95	6.32	6	I
G21D	14.25	6.97	3.27	4.02	49	I
G21E	21.85	3.97	4.21	13.67	18	I
G22F	5.07	0.13	1.71	3.23	3	II
G22A	6.81	0.06	3.24	3.51	1	II
G22B	4.22	0.04	0.65	3.52	1	I
G22C	13.07	3.54	2.56	6.97	27	I
G22D	13.08	7.31	2.40	3.37	56	I
G22E	12.27	0.92	2.63	8.71	8	I
G22F	8.54	0.50	2.41	5.63	6	I
G22G	6.57	0.82	1.10	4.66	12	I
G22H	14.03	1.25	2.08	10.70	9	I
G22J	11.28	0.51	1.58	9.20	4	I
G22K	4.78	0.24	1.06	3.48	5	I
G30A	27.88	3.81	1.19	22.88	14	I
G20D	15.61	8.23	0.62	6.76	53	II
G40A	15.26	0.00	3.17	12.09	0	I

The situation of certain parts of the Western Cape experiencing water resource availability challenges triggered an increase in the number of water use license applications as indicated by the number of Reserve requests received by the Directorate: Reserve Determination. When groundwater Reserves are determined, protection levels in terms of groundwater quantity and quality are determined for basic human needs and for ecological ecosystem requirements by taking into consideration prevailing conditions of the area.

For example, **Table 13** outlines groundwater quality Reserve limits established for quaternary catchment D12B. Using water quality parameters presented in the first column in **Table 13**, prevailing groundwater quality conditions are established and presented in the second column as ambient groundwater quality. Basic human needs Reserve prescribed as water quality requirements for domestic use in water quality guidelines is presented in the third column of **Table 13**. Based on the prevailing conditions of the catchment, groundwater quality Reserve limits for the catchment are determined and presented in the last column. Groundwater quality monitoring in the catchment needs to take place to establish compliance or deviations from the established groundwater quality Reserve limits. Any long-term deviation from such limits may trigger rehabilitation of the resource after consideration of other relevant factors such as reviewing of license conditions for water users in the catchment.

Table 13: *Groundwater quality Reserve for quaternary catchment D12B (Source: DWS, 2021c)*

Parameter	Ambient Ground Water Quality	Basic Human Needs Requirements	Ground Water Quality Reserve
Calcium (mg/l)	36.30	<150	39.93
Magnesium (mg/l)	9.13	<100	10.05
Sodium (mg/l)	20.30	<200	22.33
Chloride (mg/l)	5.00	<200	5.50
Sulphate (mg/l)	9.16	<400	10.08
Nitrate (mg/l)	0.16	<10	0.18
Fluoride (mg/l)	0.16	<1.0	0.18
pH	8.12	5.0 – 9.5	8.93
Electrical Conductivity (mS/m)	33.80	< 150	37.18

To date, studies on GRDMs have produced several resource quality objectives (RQOs) with numerical limits and narrative statements that are deemed necessary to protect groundwater resources in country, thereby enabling sustainable water resource utilization when these measures are operationalized. Similar to the Reserve limits, numerical limits for RQOs linked to groundwater resources are considered as baseline conditions that must be met by an authority responsible for their implementation. Any deviation or non-compliance to the established RQOs may trigger groundwater resources rehabilitation activities using the concept of adaptive management to water resources.

In consideration that RDM must be implemented at a catchment level where water resources are located and where their utilization takes place, the CD: WEM undertook an initiative to assist in kick-starting with the operationalization of RDM at catchment level. The main objective of this initiative was to develop an information starter-pack which is conceived a set of tools or combined information that will enable practical implementation of the RQOs, Classes and the Reserves at catchment level (DWS, 2021b). The information starter-pack contains information that will provide guidance to the Regions on the implementation of the RDM. It provides high level guidance and information on implementation requirements, activities, and actions necessary to achieve compliance.

In a similar conception, the Directorate: Mine and Industry Water Quality Regulation embarked on a project to develop a framework that can be used as a guide in the implementation of RQOs. The purpose of the framework is to outline the requirements and procedures for monitoring compliance to the Resource Quality Objectives (RQOs) with a specific focus on the water quality parameters for surface water (DWS, 2021a). This project is on-going, and it has been indicated that the framework will in future be updated to include all four drivers for both surface and groundwater resources. These projects, studies, and initiatives are fundamental to the current project.

3.5.9. IMPACTS CAUSING DEGRADATION OF GROUNDWATER

Global availability of sufficient good quality water is important in meeting agricultural, domestic, industrial developments and environmental requirements to ensure sustainable food security for all (Cole *et al.* 2018; Masindi and Abiye 2018; Gomez *et al.* 2019). However, recurring population growth, land-use changes, and anthropogenic activities threatens the water resource systems reliability and resilience (Elmhagen *et al.* 2015; Dlamini *et al.* 2019; Morris 2019). In this section three main impacts causing groundwater resources degradation are briefly discussed, namely: i) overutilisation impact; ii) water quality impact; and iii) climate change impact.

3.5.9.1. Over-utilization Impact

Overexploitation resulting from mismanagement and increase in the demand for water has a profound effect on frequent aquifer failure, which in turn leads to the drying up of boreholes. It is not surprising that groundwater use is a pressing issue in global water management with many analysts emphasizing the role of the state in groundwater resource protection (Meinzen-Dick *et al.,* 2016). The consequences of overexploitation in the long-term are well articulated in Knüppe, (2011). The study makes a revelation that lowered groundwater tables result in a decoupling of the groundwater and surface water system, including water exchange between rivers, wetlands, and springs. The study further notes that lowered groundwater levels lead to increased costs brought about by the need for water pumping, the failure of borehole supplies and saline water intrusion in coastal zones. It is stated that the critical reduction in the volume of available subsurface water reserves due to the permanent increase in water demand will represent a major environmental trend of the next 25 years. The trend is expected to be exacerbated by global population growth, agricultural practices, and landscape alterations, increases in urban areas and in the demand for domestic and public drinking supplies, industrial activities including thermoelectric production, intensive agriculture, and mining (Knüppe, 2011). Forestry uses interflow and impact groundwater resources by lowering the groundwater levels. Maputaland is a good example of forestry impacting on groundwater resources. There is a pressing need for protection and monitoring of groundwater systems to establish whether they are excessively depleted or progressively polluted due to current regimes of withdrawal for municipal water supply and other various land use impacts on their quality (Bhaduri *et al.* 2016; Gupta and Misra 2018).

3.5.9.2. Water Quality Impact

Studies agree that groundwater contamination induced by anthropogenic activities will reduce its availability and aggravate water crisis in the arid and semi-arid regions, hence several concerns have been raised with regards to quality and sustainability of drinking water supplies (He and Li, 2019; Wu *et al.,* 2020). Knüppe, (2011) stated that the issue of groundwater quality, particularly of shallow groundwater, is becoming more prominent, and this is attributed to increasing populations, contamination caused by anthropogenic activities such as mining (acidification and increased metal content), urban development (salinization, eutrophication, microbial pollution), industry (infiltration of chemicals and toxins), and the intensification of agricultural practices (sedimentation, infiltration of agro-chemicals and salinization through irrigation return flows).

3.5.9.3. Climate Change Impact

Climate change can be seen as a systematic change in climatic variables (such as temperature and precipitation) beyond the average state, either above or below natural variability limits which causes intense storms, heavy rainfall events and droughts (Mukheibir, 2007; Kusangaya *et al.,* 2014; Mussá *et al.,* 2015). Hydrological variability induced by climate change has an effect on groundwater resources, and ultimately affects ecosystems dependent on such resources (Majola *et al*., article in press). Research suggests that the temperature is expected to increase by a factor of 1.5°C along the coast and 2 to 3°C inland of the coastal mountains in South Africa by 2050 (Dennis and Dennis, 2012). Therefore, water resource managers are required, when managing water resources to take into account the effects of climate change and variability on water resources as rainfall variability is likely to increase in future (Mukheibir, 2007).

South Africa's aquifer systems are characterized by a large variety of geological structures and climatic conditions that influence regional hydrogeological settings (Knüppe, 2011). Groundwater aquifers are recharged mainly by precipitation, and surface water ultimately affects groundwater systems, and it is therefore increasingly recognized that groundwater cannot be considered in isolation from the landscape above or from the hydrological cycle (Kumar, 2012). Although groundwater is affected much more slowly, but climate change does have impact on groundwater as it may influence the resource by reducing recharge (which is a sensitive function of climatic factors such as evaporative, transpirative and runoff losses of the precipitation), groundwater levels, discharge (groundwater contribution to baseflow) or even impacting on the water quality (Knüppe, 2011; Dennis and Dennis, 2012; Moseki, 2018). Research on climate change impact to South African aquifers has shown that a 20% decrease in mean annual rainfall volumes could translate to an 80% decline in recharge for areas that currently receive 500 mm rainfall per annum or less, and that those areas currently experiencing stress in their groundwater resources might experience failure of their groundwater resources in future for certain months of the year (Dennis and Dennis, 2012; Moseki, 2018).

All the characteristics of water resources such as surface flows, interflows in the soils, water quality, groundwater flows, geomorphology of watercourses, habitat and biota were linked to the preceding themes, however they are not applicable to the groundwater theme. The only characteristic important in this theme is the flow towards groundwater which must be taken into cognizance.

3.5.10. STATUS QUO AND INTERGRATION OF REHABILITATION INITIATIVES AND PRACTICES FOR GROUNDWATER IN SOUTH AFRICA

This section of the report provides an analysis of the current situation in the country with regards to groundwater resources rehabilitation initiatives and their uptake in practice, especially in the subject of water resources protection. The analysis is pivotal in fostering successful preparation and implementation of the guidelines linked to groundwater resources rehabilitation. The analysis focuses on groundwater resources rehabilitation studies and practices, drawing largely on lessons learned from such activities. Linkages to other related works within the frameworks of water resources protection and management are also presented. Additionally, the analysis reflects on cooperative governance and partnerships, trying to establish how the concept can be used to enhance groundwater resources remediation practice. Lastly, findings and knowledge gaps established from the analysis are presented along with recommendations and way forward.

3.5.10.1. Groundwater Rehabilitation Studies

- **Policy-Based Research on Groundwater Management and Use in South Africa (2020)**

  The Specialist Unit: Water Services Strategy & Evaluation (former Directorate: Policy) within the DWS embarked on research with the primary purpose to conduct a systematic search and mapping of all available policy and regulatory tools for groundwater management and use in South Africa. A review of local and international (Denmark, Australia and California) literature on groundwater management and use was undertaken to identify gaps from the identified literature and highlight lessons on how the gaps are addressed in other parts of the world. The research makes the following recommendation relating to rehabilitation: "There is a need to develop a regulation governing rehabilitation of boreholes that are no longer in use as such boreholes tend to become a point source of pollution for underground water during rainfall seasons".

- **Artificial Recharge:**

  Two main artificial recharge studies will be presented below:

  - **A Technology for Sustainable Water Resources Development (WRC, 1998) -** Artificial recharge, which is generally regarded as the process whereby surplus surface water is transferred underground to be stored in an aquifer for later abstraction and use, and for improving water quality is growing in importance in South Africa and internationally (WRC, 1998). The most common recharge methods used involve injecting water into boreholes and transferring water into spreading basins where it infiltrates the soil subsurface and percolates down into the groundwater (DWA, 2010). Underground water storage is efficient in that the reserves are not vulnerable to evaporation losses and are relatively safe from contamination (NWRS II, 2013). The Water Research Commission conducted a study on artificial recharge, with the objective of assessing the feasibility of using artificial recharge technologies in South Africa for community water supplies. The study noted that artificial recharge for water supply rapidly replenish aquifers with water that would otherwise be lost through evaporation and stream flows. The study paid special attention to the identification of suitable fractured aquifers for pilot recharge studies as large parts of the subcontinent are underlain by such aquifers (WRC, 1998). The availability of raw water and the ability of the aquifer to physically receive surplus water were identified by the study as two main hydrological factors which determine the potential for artificial recharge in the country.
  - **Artificial Groundwater Recharge: Recent initiatives in Southern Africa (DWA, 2010) -** In 2010, the then Department of Water Affairs (DWA) produced a booklet which

provides an overview of the status of artificial recharge in Southern Africa and lists resources that are easily accessible to anyone considering this water storage, treatment measure. Potential artificial recharge areas provided in the booklet are illustrated in **Annexure O**. Such information is important when groundwater rehabilitation projects are proposed or conceptualized for degraded aquifers. Murray and Tredoux (2009) argued that artificial recharge is a technology that maximizes the use of available water and natural storage, and that the technology can be applied on a large scale if the geological conditions are favorable, and in local aquifers as well. The authors consider the technology as far more cost effective to store water than to build new dams or transfer water over lengthy distances.

- **Preventing Production Borehole Clogging by In-situ Iron Removal in South African Aquifer Systems (WRC, 2014)**

Although existence of iron and manganese in water generally do not cause health complications, problems associated with water coloring and taste, clothes staining, and encouragement of bacterial growth in water distribution networks which affect pipes transfer efficiency have been reported (El-Sheikh *et al.,* 2018). Lately, in 2014, the Water Research Commission undertook a study to investigate the feasibility of the in-situ iron removal treatment technique in preventing clogging of production boreholes in a South African context by removing Iron (Fe^{2+}) and Manganese (Mn^{2+}) from the groundwater. The study found that Iron removal by the in-situ iron removal method is feasible, even at small-scale application. The study also found that the in-situ iron removal treatment using ozone has the potential to increase the removal efficiency of Fe and Mn in groundwater, particularly in areas with high organic carbon and/or silica concentrations, which complexes with Fe and Mn (WRC, 2014). The findings of the study are critical for groundwater remediation, especially in areas experiencing excessive concentrations of Iron and Manganese.

- **Risk Based, Site-Specific, Irrigation Water Quality Guidelines: Volume 1 Description of Decision Support System (WRC, 2017)**

The study was undertaken with the general aim of developing a software-based Decision Support System (DSS) able to provide both generic and site-specific risk-based irrigation water quality guidelines for South Africa. Tier 2 of the DSS allows for site specificity, the extent of which is predetermined by the site-specific variables that are provided for as part of the DSS. The DSS allows a user to conduct a more in-depth water quality assessment and guideline generation, by making use of a relatively sophisticated crop growth - soil water balance and chemistry model which uses selectable site-specific input parameters, to simulate the response of soils, crops and irrigation equipment to irrigation water composition under different climatic and water management conditions. The study is significant to the current project since it will control and limit the impacts that irrigation has on groundwater resources.

- **Management of Winery Wastewater by Re-using it for Crop Irrigation - A Review (Howell and Myburgh, 2017)**

  The study was conducted by Howell and Myburgh (2017) for the Fruit, Vine and Wine Institute of the Agricultural Research Council in South Africa with the primary aim to investigate the potential use of winery effluent for crop irrigation. The results of the study found that considering the variation in wastewater quality parameters between wineries, as well as a strong seasonal variation, the use of winery wastewater for vineyard irrigation could have many potential benefits for the wine industry. The below list are some of the recommendations put forth for the study:

  - Irrigation with wastewaters containing high levels of K+ could be beneficial to soil fertility, although long-term application could have negative effects on soil chemical properties;
  - In terms of guidelines, wineries must register their intended wastewater use with the DWS;
  - The quantity of wastewater irrigated on a weekly basis has to be monitored and wastewater quality measured monthly;
  - Weekly water balances should be drawn up with the assistance of a soil scientist.;
  - When selecting crops for irrigation with winery wastewater, soil characteristics and climatic conditions as well as wastewater quality and quantity should be considered; and
  - It is important to quantify soil chemical responses to application of winery wastewater every three months.

Based on the above results, this study is significant for the current project because it provides the necessary management measures which are viewed as critical for protection of groundwater resource from.

3.5.10.2. Groundwater Rehabilitation Practices

Actions that support the application of research findings and other evidence-based knowledge into policy and practice are critical in water resources protection. In **Section 3.5.9.1**, the analysis provided insight on selected scientific investigations and associated findings linked to groundwater resources rehabilitation. However, it has been argued that the role of scientific research should not be merely a matter of producing results, instead it should also concern the reciprocal relationship, such as the extent to which science-based knowledge and advice is adequately used in policy implementation processes (Mejlgaard *et al.,* 2012). In support of the argument made by Mejlgaard *et al* (2012), practical implementation of environmental rehabilitation practice in the country is needed.

Closure of mining operations and rehabilitation is a continuous series of activities that begin with planning prior to the project's design and construction, and end with achievement of long-term site stability and the establishment of a self-sustaining ecosystem (Nana and Coutts, 2019). Part of the mining authorization process is an assessment of evidence provided on how the applicant is going to account for environmental rehabilitation and when that rehabilitation is going take place. As an example, in 2019 Sasol Mining (Pty) Ltd appointed Digby Wells and Associates (South Africa) (Pty) Ltd to develop a Rehabilitation Strategy and Implementation Plan for the Sasol Sigma Mooikraal Operations, as one of the requirements of the approved water use license. Part of the recommendations proposed in the Rehabilitation Strategy and Implementation Plan was that groundwater quality must be monitored in accordance with the groundwater monitoring plan to detect any contamination (Nana and Coutts, 2019). Furthermore, in-situ rehabilitation on mining footprints with appropriate designed capping was recommended. This case example provides practical evidence on how environmental rehabilitation linked to groundwater resources remediation is ensured in practice as required in a water use license.

Insight about the three managed aquifer recharge sites that are in operation in the Great Karoo, Northern Cape Province of South Africa is provided by Hohne *et al.* (2021). The authors indicated that the managed aquifer recharge systems have been supporting groundwater supply to the communities in the Karoo since 2014, when a crippling drought hit this area (Hohne *et al.,* 2021). The use of chemistry and groundwater level monitoring data is important to assess effectiveness of the managed aquifer recharge operations and ensure. Monitoring of the operations is also important for their optimal functioning. As part of the optimization recommendations, the study advised that managed aquifer recharge systems should be monitored weekly during periods of drought to ensure effective management, with chemical analysis on water being done bi-annually before and after the rainy season.

Acid Mine Drainage (AMD) treatment in the country provides another practical example of groundwater remediation. AMD is highly acidic water, usually containing high concentrations of metals such as iron, manganese uranium, and sulphides, free acid, and salts, as a consequence of mining activity. This wastewater from the mine is detrimental to the environment, water and human as well as animal health. To mitigate the risks associated with AMD, South Africa has begun to intervene in the various areas affected by the AMD challenge such as Gauteng and Mpumalanga (Mujuru, 2014). For example, in the gold Western Basin of the Witwatersrand, where the risks need urgent attention because of the huge surface decant, emergency intervention is ongoing using partial treatment by neutralization and metal removal of about 30 to 50 million liters of AMD waste which is being pumped and treated daily. Additionally, research continues, where new technologies are being developed related to active treatment technologies, passive treatment technologies and in-situ treatment technologies (Mujuru, 2014).

3.5.11. LESSONS LEARNT FROM THEME 5: GROUNDWATER

Below are few lessons drawn from the analysis of groundwater rehabilitation studies and practice in South Africa:

- Firstly, studies on groundwater remediation exist in the country. An example is provided where WRC conducted a study on artificial recharge;
- Secondly artificial recharge requires large volumes of water which the country doesn't always have;
- Thirdly, it is impossible to apply artificial recharge technology everywhere in the country as it requires fractured aquifers which do not occur everywhere;
- Fourthly, managed aquifer recharge schemes require active and proper management to harness benefits associated with their operation;
- Fifthly, groundwater aquifers can provide safe storage of water for use, if they are protected and not over-abstracted or polluted, for example, by untreated effluent and Acid Mine Drainage;
- Sixthly, technology to remediate polluted groundwater exist in the country such as in-situ iron removal from groundwater resources;
- Seventhly, conditions that are incorporated into water use licenses especially for mining operations offer some form of responsibility for groundwater remediation by water users, however rehabilitation does not need to be restricted to post mining activities but rather can be applied to current operations as well;
- Eighthly, AMD treatment seem to be very expensive especially when the reverse osmosis technique is applied. This could be avoided by undertaking remediation activities concurrently with mining operations instead of waiting until mining operation closes. This point is directly linked to the seventh point; and
- Lastly, there are various activities related to groundwater resources remediation in the country, however, there seem to be a lack of a coordinated approach for such practice to report and evaluate their effectiveness.

3.5.12. FINDINGS AND GAPS FOR GROUNDWATER

Several success and shortcomings in terms of the current practice in groundwater resources rehabilitation have been identified in this review, however only the key findings and knowledge gaps necessary to drive development of groundwater resources rehabilitation guidelines are highlighted in this section.

- In many areas groundwater resources are subjected to extensive use and continued pollution. Such conditions limit groundwater availability which is critical for food security, and for ecological ecosystem sustainability. Globally, several groundwater systems require remediation to improve the situation.
- Several countries have put various measures in place such as guidelines for the assessment and remediation of contaminated sites, supported by legislation. These initiatives are most widespread in Europe.
- Although groundwater resource challenges linked to water availability and quality deterioration are prevalent in Africa, studies and initiatives around groundwater resources remediation are still limited on the Continent.
- In the South African context, legislation and policies that support groundwater resources rehabilitation exist.
- Data, though limited, emanating from research studies, and initiatives undertaken in the country on groundwater resources rehabilitation are available.
- Various techniques and technologies are available for use in groundwater resource rehabilitation programmes; however the choice of their application depends on their respective advantages and limitations, and the type of contamination. For example, toxic heavy metals can be removed by extraction, whereas hydrocarbons and chlorinated compounds can be removed by degradation (Azubuike *et al.,* 2016). In some instances, these techniques provide a better solution when used in combinations.
- Although groundwater resource rehabilitation activities through various forms of practice are evident in South Africa, such practices are not coordinated and adequately reported. A coordinated approach is necessary to sustain such practice.

3.5.13. WAY FORWARD FOR REHABILITATION GUIDELINES FOR THEME 5: GROUNDWATER

To ensure that groundwater resource rehabilitation management practice is sustained, and provide desired aspirations, the following recommendations are put forward: (i) strengthen capacity development and skills sharing towards GRDM implementation at catchment level, hence improvement on groundwater resource protection practice. Based on this recommendation water resources managers would be able to assess compliance with established conditions and identify areas requiring groundwater rehabilitation interventions. (ii) Create a robust, transparent, and implementable guideline for groundwater resources rehabilitation supported by evidence-based research and practical examples. This recommendation is directly linked to the development of the groundwater resources rehabilitation guideline and the need of putting it into practice. (iii) Improve inter-governmental and social co-ordination which reinforces synergies among the government, private sector, NGOs, and communities, while at the same time trying to discourage institutional fragmentation which hinders progress on policy implementation programmes.

3.6. REHABILITATION CORPORATIVE GOVERNANCE AND PARTNERSHIPS

This section aims to demonstrate that rehabilitation of various water resources require institutional collaboration and cooperative governance given the large number of organizations, institutions and government departments that play a role in the rehabilitation of water resources. An example of partnerships in rehabilitation River and Wetlands is evident from the World Wide Fund (WWF)- Mondi Wetland Programme (MWP). WWF-MWP existed since 2001 with the aim of improving wetland/river sustainability practices. It is a partnership between national and provincial governmental departments, NGOs, and other related institutions The programme has established wetland governance structures and implementation for better management practices. It provides some examples of partnerships and cooperative governance which are related largely to rivers and wetlands. Furthermore, the programme also demonstrates the linkages of work between the rehabilitation of rivers and wetlands. The other components of cooperative governance and partnerships for Estuaries, Dams, Lakes and Groundwater is presented in **Annexure O**

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ANNEXURE A: Rehabilitation efforts on major rivers around the world (Simsek, 2012)

Project Name	Description of Rehabilitation Project
South America (Brazil) - Cuenca (Ecuador) and Belo Horizonte - 2021	There is no legislation that requires the implementation of rehabilitation programs or projects. There are, however, post environmental accidents such as oil spillages or dam failures which are dealt with through existing legal statutes. The main measures were sewage collection system implementation, riverbank rehabilitation using engineering and bioengineering techniques, riparian vegetation rehabilitation and flood alleviation (Da Cruz and Rios-Touma, 2018; Wantzen *et al.,* 2019). Successful local initiatives included the rehabilitation of streams and other rehabilitation strategies such as monitoring of the streams over a period of 10 years (Feio *et al.,* 2021). The results indicated that water quality, species richness, and appearance of new sensitive taxa had improved.
Central and North America - 2005	The majority of rehabilitation initiatives were localized and a few have been accompanied with intensive ecological before & after control impact monitoring, with billions in financial investments (Bernhardt *et al.,* 2005). For example, in the United States (US) alone, about $30 billion has been spent on more than 30 000 river rehabilitation projects (Palmer *et al.,* 2005). The rehabilitation activities in the US are largely aimed at enhancing riparian zones, improving water quality, improving stream ecosystems, strengthening banks etc.
London, United Kingdom - London Rivers Action Plan - Since 2002 (target year: 2015)	A restoration plan was implemented for 15 kilometers of tributaries of the Thames River to their natural state, creating a sustainable city and reducing the flood risk and improving the environment for all. The Thames River is currently considered to be one of the world's cleanest metropolitan tideways, a major turnaround from once being a biologically dead river. To this end, it won the world's biggest environmental prize in 2010.
Turkey - Porsuk River Rehabilitation - 2001	*Eskişehir's Porsuk River* was restored in 2001. The project prevented flooding damage with restructuring the riverbed, renewing canals and urban water system infrastructure. These main objectives were reinforced by renewing water system infrastructure which involved renewing the wastewater treatment plant, renewing the water treatment facility, reinforcing drainpipes and water supply pipes.
Chengdu, China - Funan River's Comprehensive Revitalization Project - 2001	The river passes through the center of *Chengdu*, a city of nine million people. The Park workings started in 1996 and completed in 1998. Since the park opened, it has become the most popular park in the whole city. To raise awareness of the pollution in the Funan River, the park was improved with measures including installation of pumps, settling ponds and reconstructed wetlands. Furthermore, other measures included the preservation of a natural water purification system, various plant species and construction of steps going down to the river to provide public access and various sculptures as public arts.
Barcelona, Spain - Restoration of Besòs River - 1999	*Besòs River* is a river flowing through the urban area of Barcelona. It was named the most contaminated river in Europe during the 1970s and 1980s. Since the mid-1990s, the river has been in the process of recovery. The design and construction of a meandering low flow channel within the floodway was completed. Constructed wetlands were put in place to improve water quality.
Singapore River of 1990s	The river was the economic artery of Singapore where pioneers lived and worked together. Starting in the 1880s, there was heavy traffic on the Singapore River due to rapid urbanization and expanding trade. In the late 1970s, the government started taking action to clean up the river. Key impacts of the 1990s' restoration efforts were water purification and river development unified with the City. After purification, land value was raised, fish returned to river, some catchments were opened to the public for boating and swimming.

ANNEXURE B: Regional River Rehabilitation Projects

Project Name	Descriptions of Rehabilitation Project
Nairobi River Basin, Kenya - Riparian Zone Conservation in a Changing Urban Land Use Environment - 2014	A study was conducted on the state of the Nairobi River Basin. The riparian ecosystems were encroached on and degraded in a short period of time by urban land users. The riparian vegetation was cleared, wetlands drained and rivers straightened and canalized to increase spaces for urban activities and structures. This rapid change caused the loss of a great amount of biodiversity and had effects on both the physical appearance and the ecological health of these zones and their associated rivers. The study concludes that there is improper determination, use and management of riparian zones in the basin. The following main areas were identified as possible causes: policy and institutional factors, land use and biophysical factors professional and land users factors influence (Mwiti, M. S. 2014)
Tanzania Mlalakua River Restoration Project, Tanzania - 2012	The International Water Stewardship Programme (IWaSP) was implemented for the Mlalakua River Restoration Project. This project was initiated to engage with relevant stakeholders on improving water quality and governance in the Mlalakua River. Various measures were implemented to enhance healthy living conditions of the riverine communities and prevent further waste pollution. The partnership was also aimed at addressing industrial and institutional wastewater management and implementing environmental regulations and best practices for industrial waste management along the river (IUCN Eastern and Southern Africa Programme, 2010)
Integrated Flood Management, Uganda 2012 - 2013.	Flooding is a recurring and major problem in Kampala due to the fact that the city is predominantly built on former low-lying valleys. The Action Plan for Integrated Flood Risk Management for Kampala was adopted to address the flood risk. The plan included improving drainage maintenance together with Sustainable Drainage Systems (SuDS) measures; enhancing the data and information services needed to plan and manage development in flood-prone areas, formulating stormwater management policy; implementing legal, planning and information awareness measures and legally defining and protecting the remaining natural flood plains through hazard zonation.
Ghana and Burkina Faso - Transboundary Water Management through Multi-Level Participatory Governance and Community Projects, Volta River Basin - 2005	The basin faces numerous development challenges such as poverty and increasing population growth which lead to exploitation of natural resources, water scarcity, land degradation and the siltation of river channels. To address these challenges, Water and Nature Initiative (WANI) which is run by the International Union for Conservation of Nature (IUCN) launched a project which facilitated change in how the basin was managed. WANI and its partners were mandated to improve water governance by creating an agreement on new key water management principles. They also aimed to institutionalize and improve coordination mechanisms.
Senegal River Basin Establishing a Transboundary Organization for Integrated Water Regional Management (IWRM)	The Integrated Water Resource Management Plan was established to provide an inter-governmental structure through which activities in the river basin can be linked to better management of resources. This was due to a considerable amount of population migration towards the basin, added pressure of a worsening drought and desertification, loss of arable and pasture land and pollution from industrial and domestic waste, degraded water quality and loss of biodiversity became evident

ANNEXURE C: Summary of the key findings and results on the status quo of river rehabilitation studies, programmes and initiatives

<table>
<tr><th>STUDIES, PROGRAMMES, INITIATIVES</th><th>IMPACTS INDENTIFIED</th><th>SUMMARY OF INTERVENTIONS AND BEST MANAGEMENT PRACTICES CONDUCTED</th></tr>
<tr><td colspan="3">THEME 1: Rivers:</td></tr>
<tr><td>Studies and Reports:
Integrated River Management, Sabie-Sand Catchment (2003)
River Rehabilitation: Literature Review, Case Studies and Emerging Principles (2003b)
Development of River Rehabilitation in Australia: Lessons for South Africa (2003a)
Restoring Urban Rivers from their Source to the Sea (2005)
A Consultative Project to Situate, Contextualise and Plan for a Water Rehabilitation Program (2004)
State of River Report: Greater Cape Town's Rivers (2005)
Umzimvubu Catchment Restoration of Local Ecosystem Services (2011)
Adaptive Integrated Water Resource Management (IWRM) in South Africa (WRC, 2019)
The Green Village: Community-Based Catchment Management Guidelines (WRC, 2019c)
Policy/Guidelines/Manuals:
DWS Environmental Rehabilitation Policy (2014)
The Development of a Comprehensive Manual for River Rehabilitation (2016a)
Wetland Rehabilitation in Mining Landscapes: An Introductory Guide (2016b)
Buffer Zone Guidelines for Rivers, Wetlands and Estuaries (2017)</td><td>Sabie-Sand River Catchment (Mpumalanga): global climate change, population growth and distribution, overutilization, changes in land use along the rivers and invasive alien plants which led to water scarcity, land degradation, siltation of canals and affected riparian zone health.

River in the Greater Cape Town Province: impacts relating to flood management, water quality impacts, sedimentation, and erosion, modified rivers and flows, canalisation and abundant alien fish and plant life.

uMzimvubu River Catchment (Eastern Cape): rapid rates of degradation in the watershed, presence of alien plants, population growth, increased economic activity and intensification of land use practices.

Rondegat River Ecosystem (Western Cape): dense infestations of the invasive species (alien trees and predatory alien fish)

Aller River (Kwazulu-Natal): invasive alien plants, waste pollution and sewage spills.</td><td>Initial assessment of available literature shows that a great deal of research has been conducted in South Africa to get a better understanding on the discipline of river rehabilitation providing local and site-specific river rehabilitation interventions to enable more effective protection and management of rivers.

There is a number of existing river rehabilitation guidelines which have been developed with the knowledge gained over the years that detail the technical methods for undertaking rehabilitation activities and also provide an overarching framework to consider for the planning, designing, implementation and monitoring phases of rehabilitation interventions.

There are also programmes and initiatives that are currently in place to ensure natural river rehabilitation, improvement and management.

The impacts on rivers have been clearly identified and contextualised for each of the studies reviewed. A range of management options have been implemented to address the various impacts i.e. the Diep, Hout Bay and Keysers Rivers were upgraded. Bank rehabilitation undertaken on the Kuils River, improvement of Moddergat River and flood control measures for Silvermine River. Other interventions include clearing of alien invasive species from the riparian zone followed-up by the eradication of the smallmouth bass using pesticide rotenone (a commonly used pesticide to eradicate fish populations).</td></tr>
</table>

STUDIES, PROGRAMMES, INITIATIVES	IMPACTS INDENTIFIED	SUMMARY OF INTERVENTIONS AND BEST MANAGEMENT PRACTICES CONDUCTED
Programmes and Initiatives: • Working for Water • LandCare Programme • South African National Biodiversity Institute (SANBI) Living Catchments • Tsitsa Project • SANBI GEF projects • Harties-Metsi-A-Me (Hartbeespoort Rehabilitation Initiative). • Resilient Cities Pilot Project: Community Based Interventions to Improve River Health • Berg River Improvement Initiative • Living Lands - Landscape Project • Biodiversity Land Use (BLU) Project • Land User Incentive (LUI) Programme • Baviaanskloof-Tsitsikamma PES Project • Maloti-Drakensberg Transfrontier PES Project • Ecological Infrastructure for Water Security Project (EI4WS) • Association for Water and Rural Development (AWARD) Projects		

Summary of rehabilitation practices and techniques implemented for various projects/case studies (WRC,2004 & 2006)

Project	Impacts Identified	Rehabilitation Practices & Techniques
Kuils River Rehabilitation Project	Floods	The City of Cape Town's Catchment Management department implemented the canalization and rehabilitation of the river to reduce flood risks in the area to an acceptable level. The upgrade was planned and implemented to ensure that 1: 50-year flood line lay below existing houses. This was mainly achieved through engineering and landscaping works. A new river channel was excavated and the river banks shaped to reduce flooding.
Silvermine River Rehabilitation Project	Floods	The river was degraded and in need of rehabilitation. The open space areas in and around the river required to be upgraded and formalized to ensure access to these areas by the neighbouring communities. This

Project	Impacts Identified	Rehabilitation Practices & Techniques
		also called for appropriate measures to alleviate flooding of properties in Fish Hoek and Clovelly areas. Flood control measures included the excavation of a floodplain and the use of excavated material to fill adjacent properties until they were above the 1: 50-year flood line. Two large gabion structures were designed to act as weirs. Berms and channels were constructed to minimize flood risk.
Westlake River Rehabilitation Project	Damming	The river rises along the slopes and flows to the south of the Westlake golf course and Pollsmoor prison. Near Pollsmoor, it is dammed before flowing under the Simon van der Stel freeway and into the Suburb of Kirstenhof. The City of Cape Town undertook rehabilitation of the river in Kirstenhof. The landscaping of the area was improved, paths were laid, bridges and benches installed as well as a play park for children.
Palmiet River Rehabilitation Project	Informal Settlements, increased surface run-off, pollution from waste materials, alien invasive species	The river was highly compromised due to impacts from massive informal settlements built in wetland areas and along the banks of the Palmiet River (a tributary to the uMngeni River). Critical wetlands and riparian zones were severely modified. Increased surface run-off from informal settlements and flushing of various waste materials directly into water sources deteriorated water quality. The municipality identified strategic positions along the Palmiet River to construct artificial wetlands aimed to restore watershed services along the river. The artificial wetlands emulated the features of natural wetlands and acted as bio-filters, removing/trapping sediments and pollutants before entering the uMngeni river system. The other plans included the removal of alien plants and re-vegetating of the Palmiet River banks with indigenous plants to stabilize the riparian zones.

ANNEXURE D: Summary of lessons learnt from the river rehabilitation studies.

Studies & Guidelines	Authors & Year	Lessons Learnt
The Development of a Comprehensive Manual for River Rehabilitation	WRC (2016a)	• The guidelines provide locally appropriate river rehabilitation objectives and structures that enable more effective protection and management of watercourses. Furthermore, the guidelines also provide a wide range of river related impacts and step-by-step techniques of how to manage them.
Buffer Zone Guidelines for Rivers, Wetlands and Estuaries (2017)	WRC (2017)	• The guidelines provide guidance for activities planned around and adjacent to rivers, wetlands and estuaries. They are to be used and applied as part of a broader suite of tools to ensure that **water resource management is appropriately integrated into development planning and land use management.**
Integrated River Management, Sabie-Sand	Van Wilgen *et al.* (2003)	• Collaborative research; • Diverse knowledge sources and partnership between the Kruger National Park (KNP) Rivers Research Programme and communities and staff from the WfW programme are key to coordinate upstream and downstream activities relating to river and catchment management.
River Rehabilitation: Literature Review, Case Studies and Emerging Principles	WRC (2003b)	• Partner up with similar groups globally to develop hypothesis-testing rehabilitation projects relevant for SA; • Synthesise findings of the research and rehabilitative activities and further develop a set of rehabilitation principles; • Develop a scientific research programme for river rehabilitation; • Develop practical guidelines from the principles; • Develop close liaison between scientists and managers; • Develop appropriate policy and regulatory frameworks; • Create a centre of expertise on river rehabilitation within South Africa; • Provide structured funding for rehabilitating rivers and evaluating outcomes.
Development of River Rehabilitation in Australia: Lessons for South Africa	WRC (2003a)	• Australian river rehabilitation process and related methodologies were recommended for trial on a number of different river types in South Africa as a first step towards the development of guidelines for rehabilitation; • The links between the generic processes of RDM and River Rehabilitation were emphasised and as a means of developing and building on these linkages were recommended for investigation; and • A review of national-level legislation on river rehabilitation and conflicts between different national acts, and between acts and regional/local-level laws which are implemented by authorities must be investigated; and • Clarification on the interface between national level and local-authority level jurisdictions.
Restoring Urban Rivers from their Source to the	WESS (2005)	• The importance of an integrated approach. This is necessary to promote coherence within government and between

Studies & Guidelines	Authors & Year	Lessons Learnt
Sea		government and non-government collaborations. It builds metaphorical bridges between communities and stakeholders, and creates physical linkages between nodes along the rivers.
A Consultative Project to Situate, Contextualise and Plan for a Water Rehabilitation Program	WRC (2004)	• Urgent need to implement integrated approaches to terrestrial, wetland, river and estuarine rehabilitation; • Investing energy and resources in the development of a central programme (or aquatic ecosystem) rehabilitation; • Focussed cooperative governance and the creation of structures to enable practical linkage of relevant programmes and processes and information; • Expertise sharing both at a national and international level; • The initiation of pilot rehabilitation projects at a catchment or sub-catchment scale for addressing all ecosystems was also recommended.
State of River Report: Greater Cape Town's Rivers	State of River Report (2005)	• The study demonstrated various rehabilitation and restoration techniques employed for bank rehabilitation of Kuils River and the improvement of Moddergat River, flood control measures in Silvermine River and restoration of Rondevlei wetland
Controlling Invasive Alien Species from Rondegat River Ecosystem	Impson *et al*. (2013)	• Close and enthusiastic collaboration between affected state and private landowners; • Public participation to address concerns; • Simultaneous and coordinated application of mechanical, chemical and biological control of alien plants and chemical control of alien fish; and direction by qualified ecologists
Resilient Cities Pilot Project: Community Based Interventions to Improve River Health	Martel *et. al.,* 2017	• The importance of the natural environment in providing the foundation for human well-being, development and resilience; • Active and engaged citizens in contributing towards said strategy; • Capacity building was also shown to play a key role in creating awareness, building knowledge and equipping citizens with the skills they need to find employment and contribute towards building a resilient society and economy

ANNEXURE E: Wetland Rehabilitation Projects around the world.

Project Name & Location	Description of Rehabilitation Project
Restoration of fen landscapes, Netherlands -	Fen peatlands represent a large array of ecosystem services and their biodiversity is among the highest found among wetlands (Lamers *et al.,* 2015). The assemblages of plant communities associated with the succession from open water to terrestrialized fen have become increasingly rare, because many peatland areas have been modified strongly and lost their natural dynamics. Fen ponds for restoration of the open-water habitats suitable for early-succession plant communities have been created or restored in the past 30 years. First monitoring of their species composition has shown that colonization by plant species has been slow and issues of deteriorated water quality and dispersal barriers are among the causes identified (Sarneel *et al.* 2011).
Mire and wetland restoration in Sweden Sweden	This project aimed to stop the decrease of habitats and species through hydrological restoration and vegetation measures on 3852 ha.
Wetlands of Kakadu National Park, Australia	The Kakadu National Park management plan for threatened wetlands supported joint management amongst stakeholders and aimed to maintain a strong and successful partnership between traditional owners, governments, the tourism industry and Park user groups, providing world's best practice in caring for country and sustainable tourism (Pittock *et al.,* 2015).
Murray–Darling Basin Ramsar wetlands, Australia	Vast areas of wetlands were impacted by changes in water flows, desiccation, salinity and acid sulphate generation (Pittock and Finlayson 2011). In 2007–08 the national *Water Act* was adopted based on Australia's obligations to implement the Convention on Biological Diversity and the Ramsar Convention and requires conservation of key environmental assets and ecosystem functions and services (Pittock *et al.,* 2010). Engineering interventions known as 'environmental works and measures' were deployed to conserve wetland biodiversity with less water (Pittock *et al.,* 2015).

ANNEXURE F: Regional Wetland Rehabilitation Projects.

Project Name & Location	Description of Rehabilitation Project
Lesotho – Alpine Wetlands	The wetlands consist primarily as peatlands and are dominated by many small sedges and grasses and it is the decomposition of these plant types that contribute to the development of peat in the bogs (Schwabe, 1995). The main impacts on these wetlands is overgrazing which led to reduced vegetative cover and compacted the soil surface, resulting in increased surface runoff. Mokhabuli (2012) states that the altered hydrologic condition of the watershed has resulted in the formation of gullies, which are now functionally draining the wetland. The following interventions are reported by Mokhabuli (2012) for the on-going rehabilitation and conservation project: Concrete Structure, Gabion Structure, Sack Gabion and Rock Packs, Ecologs, Bio-Jute, Road Cross- Drains and Revegetation.
Lesotho Ministry of Natural Resources through the Department of Water Affairs and MCC/USAID - Wetlands Restoration and Conservation Project -2009 to 2013	The initiative under the US funded Millennium Challenge Corporation (2009 to 2013) targeted the restoration and conservation of wetlands. The project piloted the restoration activities in three areas: **(i)** Khalong-la-Lithunya in Botha-Bothe; **(ii)** Koti-se-phola in Mokhotlong; and **(iii)** Letseng-la-Letsie in Quthing. The five-year initiative entailed the installation of hydro-met instrumentation at the sites, exploration grazing regime changes and developed best practice approaches. The implementation of best practices restored wetlands integrity and surrounding catchments. This benefited the communities as they have access to revived wetlands systems and their products, such as craft making grasses, forage for livestock leading to productivity tourism as aesthetic quality increased (Malieh and Perkins, 2011)
Lesotho (Semonkong) - Wetland Restoration and Conservation Project - 2015	The project commenced in May and ended in December 2015 with the aim to restore the hydrology of the critical wetlands to improve the quantity and quality of water and to establish healthy wetland plant community through sustainable rehabilitation and management approaches in Semonkong. The wetlands were successfully restored using technical measures targeted at stabilizing erosion within and in the vicinity of the wetlands, improving the water holding capacity of the wetlands, reducing pollution within the wetlands and maintaining species (both fauna and flora) diversity of the wetlands using the following approaches: • Awareness raising and capacity building to local stakeholders on issues related to sustainable land use practices, the socio-economic and environmental value of wetlands; • Effective and efficient project management through close co-ordination and integration between all stakeholders involved;

ANNEXURE G: Summarized overview of the type and level of impacts affecting the wetland systems in Gauteng and North-West Province (modified after DEA, 2019a,b)

Sub-WMA	Urbanization (formal and informal)	Mining	Groundwater Abstraction	Surface Water Abstraction	Intensive Agriculture	Extensive Agriculture (Grazing)	Informal Agriculture	Invasive Alien Species (IAPs)	Discharge of sewage effluent	Dams
Gauteng Province										
Apies/Pienaar	***	*	***	**	**	**	**	**	***	**
Middle Olifants		*			*	*	*	**	*	
Upper Olifants	*	*	*	*	**	*	*	**	*	*
Upper Crocodile	***	**	**	*	**	**	**	**	***	*
Downstream Vaal Dam	***	***	**	**	**	**	**	**	***	**
Upperstream Vaal Dam				**	**	*		**		**
North-West Province										
Apies/Pienaar	**			*	*	***	**	**	**	*
Lower Crocodile	*	*	*	*	*	**	**	**	*	
Upper Crocodile	***	**	*	***	***	*	*	**	**	**
Elands	**	**	*	**	**	**	*	**	**	**
Marico	*	*	**	*	*	**	**	*	*	*
Downstream Vaal Dam	*	*	*	**	*	**	*	**	*	**
Middle Vaal	**	**	**	**	**	**	*	**	**	**
Upper Molopo	**	*	***		**	**	*	**	*	*
Molopo						**	*	*		
Harts	*	*	*	*	**	**	*	*	*	*
Vaal Downstream Bloemhof	*	***	*	**	**	**	*	*	*	

Summarized overview of the type and level of impacts affecting the wetland systems in Eastern Cape and Western Cape West Provinces(modified after DEA, 2019c,f)

Sub-WMA	Urbanization	Coastal Development	Surface Water Abstraction	Ground-water Abstraction	Infrastructure Development	Intensive Agriculture	Extensive Agriculture (grazing)	Afforestation & Mining	IAPs	Discharge of sewage effluent
Eastern Cape Province										
Algoa	**	**	**	*	***	**	*	*	***	**
Amatole	*	**	**	*	*	**	**	*	**	**
Bushmans	*	**	**	*	*	***	**	*	**	**
Coastal Mvoti	*	*	**	*	*	**	**	*	**	**
Fish	**		***	*	*	***	**	*	**	**
Gamtoos	**		***	*	*	***	**	*	*	**
Kei	*		**	*	*	***	**	*	**	**
Kraai	**		**	*	*	**	**	*	*	***
Mbashe	**	**	**	*	*	**	**	**	***	**
Mtata	***	**	**	*	*	**	**	**	**	***
Mzimvubu	**		***	**	*	****	***	***	***	**
Olifants	*		*	*	*	*	*	*	*	*
Sundays	**		***	*	*	**	**	*	*	**
Tsitsikamma	**	**	***	**	*	***	**	***	***	**
Vanderkloof	*		**	*	*	**	**	**	*	**
Wild Coast	**	**	***	*	*	**	**	**	***	**
Western Cape Province										
Coastal Gouritz	*	***	*			**		**	***	
Coastal Orange			*	*		*	***	** diamond mining	*	
Doring			**	***	*	**		*shale gas	*	

Sub-WMA	Urbanization	Coastal Development	Surface Water Abstraction	Ground-water Abstraction	Infrastructure Development	Intensive Agriculture	Extensive Agriculture (grazing)	Afforestation & Mining	IAPs	Discharge of sewage effluent
Gamka			*		*			*shale gas		
Gamtoos			*	**	*	*	**	*shale gas		
Gouritz		**	**					*	***	
Greater Cape Town	***	***	***	*	*		**	*sand mining	***	***
Groot			**	**	*	**		*shale gas	*	
Knersvlakte				**	*					
Koue Bokkeveld			**	**	*	***			**	
Lower Berg			**		*			*phosphate mining	***	**
Lower Breede		**	**					*	***	**
Olifants			**			***	**			
Olifants/ Doring			**		*	**		*sand mining		
Olifants Tributaries			*	**	*		***		**	
Overberg East			***		*		*	*	**	**
Overberg West			***		*		*	*	**	**
Riviersonderend			***		*		*	**	***	**
Sandveld			*	***	*	***		*phosphate mining		
Sundays			*	*			*			
Upper Berg			***		**	**		**	**	*
Upper Breede			***	**	**	***		**	**	*

Summarized overview of the type and level of impacts affecting the wetland systems in Northern Cape Province (modified after DEA, 2019e)

Sub-WMA	Urbanization	Sewage effluent & other pollution	Water Abstraction	Infrastructure Development	Mining	IAPs	Livestock Grazing
Northern Cape Province							
Coastal Orange			*		**	*	***
Doring			*			**	**
Harts	*	**	*		*	**	**
Knersvlakte			*			*	**
Molopo			***		**	*	***
Orange	*		**	*	**	**	**
Orange Tributaries			**	*	*	**	***
Riet/Modder	*	*	*	*	*	***	**
Vaal Downstream Bloemhof	*	**	**		*	***	**
Vanderkloof			*		*	***	**

Summarized overview of the type and level of impacts affecting the wetland systems in Limpopo Province (modified after DEA, 2019d)

Sub-WMA	Urbanization (formal and informal)	Mining	Water Abstraction	Infrastructure Development	Intensive Agriculture	Extensive Agriculture	Afforestation	IAPs	Discharge of sewage effluent
Limpopo Province									
Apies/Pienaar	*			**	*	**		*	***
Groot Letaba	**		**	*	*	**	**	*	*
Klein Letaba	**		***	**	*	*	*	*	*
Lephalale	**	*	***	*	*	*		*	
Lower Crocodile	*	**	***	*	*	**		*	*
Lower Letaba				*	*			*	
Lower Olifants	**	*	*	*	*	*	*	*	*

Luvuvhu/Mutale	**	*	***	**	**	**	**	**	**
Matlabas/Mokolo	*	*	*	**	*	*		*	
Middle Olifants	***	***	***	***	*	*		*	*
Mogalakwena	**	**	**	**	*	*		*	*
Nzhelele/Nwanedzi	**	*	*	*	*	*	*	*	*
Sand	**	*	**	**	*	**		*	**
Shingwedzi	*		*	*	*			*	
Steelpoort	**	***	**	***	*	*		*	*

ANNEXURE H: Summary of rehabilitation practices and techniques implemented for various projects/case studies.

Project	Impacts Identified	Rehabilitation Interventions & Techniques	Source
Leliefontein Wetland Rehabilitation Project	Grazing, plant harvesting and the alien invasive poplar trees that were planted by the missionaries to provide additional sources of fire wood to the community	Populus trees were selectively cut down mainly to prevent infrastructure damage and prevent soil erosion. A weir with an outlet leading to the wetland was built to create a pool of fresh water. The top section of the historic wells was restored with sandstone and was waterproofed to prevent leaking	ARC (2010)
Hogsback Wetlands Rehabilitation Project	Historic agricultural activities, alien invasive species encroachment, erosion, Other impacts identified were drains and berms within the wetland; alteration to water flow in the catchment	The rehabilitation interventions implemented were to divert flows within the wetland so as to promote diffuse movement of water through the system and enhance water quality and biodiversity ecosystem services within the landscape; deactivate the drain and raise the water table within the system; and to remove alien plants to reduce the uptake of water and improve the biodiversity of the system	Working for Wetlands (2016)
Maluti-A-Phofung Wetlands Rehabilitation Project	The biophysical drivers of the wetlands significantly impacted upon by historical activities such as headcut erosion; grazing pressure within the wetlands; and direct disturbance and degradation associated with cattle crossing through the wetland.	The interventions implemented is the stabilization of headcut erosion and unstable banks along the edge of the gully. The extended wing walls were constructed to divert surface flows away from the unstable sections and into the concrete lined geocell chute	Working for Wetlands (2017a)
Sekhukhune Wetland Rehabilitation Project	Modification of hydrology, extensive grazing, trampling and cultivation within the catchment. Grazing and trampling affect the preferential flows and the vegetation's roughness coefficient	Hard interventions such as stone masonry weirs, and chutes with gabion structures were implemented. Soft interventions on the other hand entailed earth works for sloping and infilling with rock and soil blankets to stabilise surfaces and promote further vegetation stabilisation with re-vegetation	Working for Wetlands (2017c)
Wakkerstroom Wetlands Rehabilitation Project	Large gully in the upper section of the wetland with several direct and indirect impacts including excessive sediment deposition; discharge of high velocity, concentrated surface flow which leads to erosion of lower wetland sections; and erosion creating channelled flow within the wetland and causing desiccation of	The rehabilitation interventions involved the stabilization of instream erosion and trap sediment. Gabion structures were also selected to deal with the high energy levels experienced and relative ease of construction compared to concrete structures.	Working for Wetlands (2017e)

Project	Impacts Identified	Rehabilitation Interventions & Techniques	Source
	hydric soils. Other impacts include artificial drainage channels; channel erosion; grazing and trampling; and infrastructure (roads).		
Rietvlei Wetland System Rehabilitation Project	Wetlands were heavily eroded and desiccated, having been drained for cultivation and peat mining before the area was proclaimed a nature reserve. In recent years, the dam became severely overloaded with nutrients and other pollutants due to the highly urbanized catchment receiving increased volumes of treated domestic sewage and industrial effluent	**In 2000, Working for Wetlands formed a partnership with the municipality** to rehabilitate wetlands upstream of the dam, with the primary objective of improving their ability to purify the water flowing into the dam. Interventions included gabion, concrete and earthen structures to control erosion; rewetting the organic soils to increase retention time of water; and ensuring even distribution of flow across the wetland;	Dini and Bahadur (2016)
The Manalana Wetland Rehabilitation Project	The wetland was severely degraded by erosion that threatened to consume the entire system.	Working for Wetlands partnered with a locally based NGO in 2006 to stabilize erosion and improve the wetland's ability to continue providing its beneficial services, while the NGO worked with wetland users to implement more sustainable cultivation practices;	Dini and Bahadur (2016)
Krom River Wetlands Rehabilitation Project	Infestation by alien vegetation and destructive human activities such as large-scale cultivation on floodplains..	Since 2001, ten large structures have been built to combat erosion that threatened the remaining large intact wetlands. In 2006, the Krom River experienced its most severe floods since measurements began in 1938, resulting in heavy loss of life and property. The remaining wetlands played a key role in managing the floods, slowing the velocity and destructive potential of the floodwaters, and trapping sediment.	Dini and Bahadur (2016)
Riviersonderend Wetland System Rehabilitation Project	Erosion of organic soils and loss of wetland vegetation was a major concern which led to channelization of flows in erosion gullies. This further led to the draining and desiccation of wetland areas. Rapid changes in water level around the margins of Theewaterskloof Dam trigger head-cut erosion into the wetlands feeding the dam.	Geo-cell concrete chute, extension of an existing earthen berm, sloping of the right bank and active revegetation with Palmiet along toe of banks are interventions which were implemented to rehabilitate the wetland system	Snaddon *et. al.,* 2018
Du Toits River Wetland Rehabilitation	During the early 2000s, there was an erosion event in the catchment that led to the deposition of considerable	The wetland has largely recovered from this impact, with a mixed plant community growing quite rapidly over	Snaddon *et. al.,* 2018

Project	Impacts Identified	Rehabilitation Interventions & Techniques	Source
	sediment in the wetland (Kotze, 2015).	the deposited sediment. There has been extensive invasive alien species removal over the past few years and the vegetation now appears to be in good condition	
Zuurvlak Wetland Rehabilitation Project	Erosion around plantation roads, exacerbated by afforestation with pines, and their subsequent removal are major concerns for the wetland. Erosion gullies led to the draining of seeps feeding into the main wetland.	Replacing the road crossing with a drift, stabilising with gabions, series of sediment fences and rock packing where gully was shallower and narrower are the key interventions that were implemented for rehabilitation of the wetland.	Snaddon *et. al.,* 2018

ANNEXURE I: Summary of lessons learnt from the wetland rehabilitation studies.

Study Name	Authors & Year	Lessons Learnt
Guideline to the Wetland Management Series: • **WET-Road Map (Report No: TT321/07)** • **WET-Origins (Report No: TT335/08)** • **WET-Management Review (Report No: TT335/08)** • **WET-Rehabilitation Plan (Report No: TT336/08)**. • **WET- Prioritise (Report No: TT 337/08)** • **WET-Legal (Report No: TT 338/08)**. • **WET- Eco Services (Report No: TT 339/08)**. • **WET- Health (Report No: TT 341/08)** • **WET-Rehabilitation Evaluate (Report No: TT 342/08)**. • **WET-Outcome Evaluate (Report No: TT 343/08)**	WRC (2007; 2008)	The guidelines series is the first of its kind to be developed in SA for effective wetland management and rehabilitation. However, through various trials and experiences gained in the application of these tools during the last ten (10) years, there was an urgent need to update some of these tools. **The WET-Rehab Evaluate, WET-Health and WET-Eco Services were updated during 2019, 2020 and 2021 respectively.**
Wetland Rehabilitation in Mining Landscapes: An Introductory Guide (2016)	WRC (2016b)	These guidelines are specific to wetland rehabilitation in *mining landscapes* through consolidation of existing guidelines, knowledge and experience in wetland rehabilitation
Draft Wetland Management Guidelines within South African Municipalities	Eco Pulse Environmental Consulting (2018)	The draft guidelines are that they that there are designed to support municipalities with improving wetland management going forward and were planned for implementation in nine (9) district and two (2) metropolitan municipalities across the country
Prioritizing Catchments for Wetland Rehabilitation Planning at a National Level	Macfarlane and Atkinson (2015)	There are key opportunities for wetland rehabilitation at a national scale which represents a top-down approach to catchment prioritization which lacks local-level information which is critical for implementation at a local level. As such, there is a need to integrate the outputs of this study with a bottom-up approach that takes practical considerations into account together with local-level information that cannot be adequately accounted for in a national-level prioritization exercise of this nature.
Rehabilitation Plan as part of the Working for Wetlands Programme (2017)	Working for Wetlands (2017a,b,c,d,e,f)	The Hogsback, Sekhukhune, Steenkampsberg and Wakkerstroom wetlands are amongst some of the wetlands which were successfully rehabilitated using various rehabilitation and restoration techniques which are detailed in Section 3.2.4.3 of this report.

ANNEXURE J: Summary of the key findings and results on the status quo of wetlands rehabilitation studies, programmes and initiatives

STUDIES, PROGRAMMES, INITIATIVES	IMPACTS INDENTIFIED	SUMMARY OF INTERVENTIONS AND BEST MANAGEMENT PRACTICES CONDUCTED
THEME 2: Wetlands:		
Studies and Reports: • Prioritizing Catchments for Wetland Rehabilitation Planning at a National Level (2015) • Rehabilitation Plan as part of the Working for Wetlands Programme (2016, 2017a-f) • Draft Provincial Strategic Plan: 2019 – 2024 (2019) • Development of the National Wetland Management Framework (NWMF) (2020) **Policy/Guidelines/Manuals:** • DWS Environmental Rehabilitation Policy (2014) • Guideline to the Wetland Management Series (2007a-b -2008a-g): ○ WET-Road Map ○ WET-Origins ○ WET-Management Review ○ WET-Rehabilitation Plan ○ WET- Prioritise) ○ WET-Legal ○ WET- Eco Services (version 2, 2021) ○ WET- Health (version 2, 2020) ○ WET-Rehabilitation Evaluate ○ WET-Outcome) • Buffer Zone Guidelines for Rivers, Wetlands and Estuaries (2017) • Draft Wetland Management Guidelines within South African Municipalities (2018); **Programmes and Initiatives:** • Working for Wetlands;	**Gauteng:** urbanisation (formal and informal), gold mining, surface and groundwater abstraction, agriculture (intensive), agriculture (extensive *i.e.* grazing), informal Invasive alien species, discharge of sewage and effluent dams **North-West:** urbanisation (formal and informal), mining, surface and groundwater abstraction, agriculture (intensive and extensive), informal invasive alien species, discharge of sewage and effluent dams. **Eastern Cape:** coastal development, urbanisation surface and ground water abstraction, surface mining, infrastructure development (solar, wind, Electricity Grid Infrastructure-EGI), invasive alien species (often plants), afforestation and discharge of sewage effluent. **Limpopo:** urbanisation, water abstraction, mining infrastructure development, invasive alien species, afforestation, agriculture (intensive and extensive) and sewage discharge. **Northern:** urbanisation, sewage, effluent and other pollution, water abstraction, mining, infrastructure, invasive alien species, agriculture (intensive) and livestock grazing	Similar to theme 1, the assessment of literature shows there is existing knowledge and experience gained in the field of wetland rehabilitation in South Africa. There are existing integrated tools for assisting users to achieve well-informed and effective wetland management and rehabilitation. Numerous wetlands rehabilitation guidelines are in place providing appropriate practical and strategic approaches to wetland rehabilitation. The guidelines also promote wetland rehabilitation and improve insight on wetland rehabilitation planning, design and implementation. There are programmes and initiatives in place to better manage wetlands and come up with measures and plans to rehabilitate different types of wetlands in various provinces. Impacts on wetlands around the country are well understood and documented. There is knowledge in terms of wetland rehabilitation priority areas and successful rehabilitation interventions that have been implemented *i.e.* • Hogsback Wetland (Eastern Cape); • Sterkfontein, Ararat, Boschkloof and Monontsha wetland systems (Free State); • Tweefontein and Enkangala wetlands (Gauteng); • Kruger National Park, Mapungubwe National Park and Sekhukhune wetlands (Limpopo); • Steenkampsberg and Wakkerstroom wetlands, (Mpumalanga)

STUDIES, PROGRAMMES, INITIATIVES	IMPACTS INDENTIFIED	SUMMARY OF INTERVENTIONS AND BEST MANAGEMENT PRACTICES CONDUCTED
• SANBI - Freshwater Programme; o Mondi Wetlands Programme	**Western Cape:** coastal development, urbanization mining, infrastructure development (solar, wind, EGI) invasive alien species, afforestation, agriculture, intensive agriculture, extensive (grazing), discharge of sewage effluent, water abstraction, surface and ground water abstraction.	

ANNEXURE K: Overview of DWS Resource Directed Measures studies on Estuaries

Classification Study	Description of Study
Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to uMzimkhulu WMA: Desktop Estuary Eco Classification and Ecological Water Requirement Report (DWS, 2013)	The study determined status quo of the 64 estuaries occurring within the Mvoti to uMzimkhulu Water Management Area (WMA). The processes could not addressed at a detailed level for all the systems within the time frames of this study, therefore a process of prioritization had to be followed to determine which of the estuaries must be addressed at higher than desktop levels. The produced desktop level of information on EcoClassification available for all estuaries; including hotspots identified and levels of EWR assessment determined for each estuary. The output of this task served as a strategic tool to guide current and future monitoring requirements, and ultimately EWR determinations.
Classification of Water Resources and Determination of the Comprehensive Reserve and Resource Quality Objectives in the Mvoti to uMzimkhulu Water Management Area: Volume 4: Estuary Resource Quality Objectives (DWS, 2015)	The study was initiated during 2012 and forms part of Step 6, *i.e.* the development of RQOs and provision of numerical limits. This step was closely linked to the class configuration and RQOs which were envisaged to gazetted and implemented. The output of the study was the Comprehensive Reserve, RQOs and classification of all significant water resources.
Reserve Determination Studies for the selected surface water, groundwater, estuaries and wetlands in the Gouritz Water Management Area (DWS, 2015)	This study determined the preliminary Reserve determination on the Hartenbos, Blinde, Piesang, Groot (Wes) and Bloukrans estuaries conducted at Desktop levels. Using this rating system, the Goukou, Gouritz and Duiwenhoks estuaries showed highest priority (best attainable: Intermediate level) followed by the Klein Brak and Wilderness estuaries (best attainable: Rapid level). The Hartenbos, Blinde, Piesang, Groot (Wes) and Bloukrans estuaries clustered as the lowest rated systems (best attainable: Desktop assessment).
Determination of Water Resource Classes and Resource Quality Objectives for Water Resources in the Mzimvubu Catchment. Estuary EWR Report (DWS, 2017)	This study was informed by the results of the preliminary reserve determination at an intermediate level done on this estuary in 2014 (DWS, 2014a and 2014b). The study confirmed the (PES and REC allocated to the estuary in 2014, as well as the ecological consequences of the scenarios provided for this Classification study. Also included was the Ecological Specification (EcoSpecs) for the PES and REC.
Determination of Water Resource Classes, Reserve and the Resource Quality Objectives in the Keiskamma and Fish to Tsitsikamma Catchments (DWS, 2021	Initiated in 2021, the determined **(i)** appropriate Water Resource Classes, **(ii)** the Reserve and **(iii)** associated Resource Quality Objectives (RQOs) and gazetting of these for all significant water resources in the Keiskamma and Fish to Tsitsikamma catchment area that would facilitate sustainable use of the water resources while maintaining ecological integrity. All the water resource components, including rivers, wetlands, **estuaries** and groundwater will be considered during this study and where applicable, integration between these components will be done.
Determination of Water Resource Classes and Associated Resource Quality Objectives in the Berg Catchment: Linking the Value and	The study coordinated the implementation of the WRCS, as required in Regulation 810 in Government Gazette 33541, by classifying all significant water resources in the Berg catchment area as part of the Berg and Olifants Water Management Area (WMA). The study also

Condition of the Water Resource (DWS, 2016)	determined RQOs using the DWS Procedures to Determine and Implement RQOs for all significant water resources
Classification of significant water resources in the Olifants-Doorn WMA (2012)	The study determined the Management Class (MC) of an aquatic ecosystem to reflect the future desired condition or health of the system and used to guide the amount and quality of water to be reserved for that ecosystem. Deciding on the MC of a system involved consideration of a broad range of issues and a set of related processes that included water resource planning, catchment management planning as well as the Classification Process itself.
Determination of Water Resources Classes and Resource Quality Objectives in the Breede-Gouritz Water Management Area: Linking the Value and Condition of the Water Resource (DWS, 2016)	The study determined Water Resource Classes and associated RQOs for all significant water resources Following Delineation and Status Quo, Linking the Value and Condition of the Resource through: • Quantification of the EWR and changes in ecological EGSAs (ecological goods, services and attributes) • Ecological Base Configuration Scenarios • Evaluation of Classification Scenario
Determination of Water Resource Classes and associated Resource Quality Objectives in the Thukela Catchment (DWS, 2021)	The study classified all significant water resources through a classification process which include assessing the ecological and socio-economic value and condition of the water resources, quantifying the ecological water requirements, and defining the ecological sustainable base scenarios for the water resources per IUA

SA Estuaries Present Ecological State (PES) and identified impacts for rehabilitation (DWS, 2015)

Estuary	PES	REC	Aspects that needs targeting for restoration/rehabilitation
Mvoti to uMzimkulu Estuaries			
Mtamvuna	B	A or BAS	Flow modification, water quality, some habitat destruction.
Zolwane	B	B	
Sandlundlu	C	C	
Ku-Boboyi	B	B	
Tongazi	B	B	
Kandandhlovu	B	B	
Mpenjati	B	A or BAS	Water quality, habitat destruction.
Umhlangankulu	C	C	
Kaba	C	C	
Mbizana	B	B	
Mvutshini	B	B	
Bilanhlolo	C	C	

Estuary	PES	REC	Aspects that needs targeting for restoration/rehabilitation
Uvuzana	C	C	
Kongweni	D	D	
Vungu	B	B	
Mhlangeni	C	C	
Zotsha	B	A/B or BAS	Water quality, habitat destruction.
Boboyi	B	B	
Mbango	E	D	Flow modification, very poor water quality, severe habitat destruction.
Umzimkulu	B	A/B or BAS	Poor water quality, habitat destruction, medium-high fishing pressure.
uMthente	C	C	
Mhlangamkulu	C	C	
Damba	C	A/B or BAS	Flow modification, habitat destruction.
Koshwana	C	A/B or BAS	Flow modification, habitat destruction
Intshambili	C	A/B or BAS	Flow modification, poor water quality, some habitat destruction
Mzumbe	C	C	
Mhlabatshane	B	A/B or BAS	Significant flow modification, some habitat destruction.
Mhlungwa	C	C	
Mfazazana	C	A/B or BAS	Flow modification, poor water quality, habitat destruction.
Kwa-Makosi	B	A/B or BAS	Some habitat destruction.
Mnamfu	C	C	
Mtwalume	C	C	
Mvuzi	C	C	
Fafa	C	C	
Mdesingane	C	C	
Sezela	C	C	
Mkumbane	C	C	
uMuziwezinto	C	C	
Nkomba	B	B	
Mzimayi	C	C	
Mpambanyoni	C	C	
Mahlongwa	C	A/B or BAS	Medium fishing pressure, poor water quality, habitat destruction.
Mahlongwane	C	A/B or BAS	Poor water quality, significant habitat destruction.
uMkhomazi	**C**	B	Significant flow reduction, poor water quality, habitat destruction.
Ngane	C	C	
Umgababa	**C**	A/B or BAS	Flow modification, poor water quality, habitat destruction.
Msimbazi	**B**	A/B or BAS	Habitat destruction.
Lovu	**C**	A/B or BAS	Significant flow reduction, poor water quality, habitat destruction.
Little aManzimtoti	**E**	D	Significant flow increase, poor water quality, habitat destruction.
aManzimtoti	D	D	Poor water quality, habitat destruction.
Mbokodweni	E	D	Very significant flow modification, very poor water quality, severe habitat destruction (restoration of the existing mouth and lower reaches of the estuary required).

Estuary	PES	REC	Aspects that needs targeting for restoration/rehabilitation
Sipingo	F	E	Very significant flow modification, very poor water quality, severe habitat destruction.
Durban Bay	E	D	High fishing pressure, significant flow modification, poor water quality, severe habitat destruction (port development), reduced food availability.
uMngeni	**E**	D	Significant flow modification, very poor water quality, severe habitat destruction.
Mhlanga	**D**	B*	Significant flow modification, poor water quality, habitat destruction.
uMdloti	D	C*	Flow modification, poor water quality, habitat destruction.
uThongathi	D	D*	Very poor water quality, severe habitat destruction.
Mhlali	C	B	Poor water quality, habitat destruction.
Bob's Stream	B	B	
Seteni	B	B	
Mvoti	D	D	Poor water quality, habitat destruction.
Mdlotane	B	A/B or BAS	Water quality, some habitat destruction.
Nonoti	C	B	Poor water quality, some habitat destruction.
Zinkwasi	B	A/B or BAS	Habitat destruction.
Breede Overberg Region			
Rooiels	B	B	
Buffels (oos)	B	B	
Palmiet	C	B	
Bot/Kleinmond	C	B	
Onrus	D	D	
Klein	C	B	
Uilkraals	E	C	
Ratel	C	C	
Klipdrifsfontein	A	A	
Heuningnes	C	A	
Breede	B	B	
Mzimvubu Estuary			
Mzimvubu Estuary	B		Most of the ecological modification in the Mzimvubu Estuary has been a result of non-flow related pressures such as habitat destruction, alien invasive plants, nutrient enrichment (pollution), over-fishing and global/human disturbances to birds, rather than flow modification".

ANNEXURE L: Description of 12 major groups of impacts on estuarine systems

Impacts	Effects
Sewage and pathogenic inputs	Inputs of sewage and other organic wastes can exacerbate estuarine eutrophication problems by delivering excess nutrients and organic carbon to estuaries. These wastes may enter estuarine systems via malfunctioning septic systems, stormwater, domestic wastewater discharges, industrial effluents, farmlands, mariculture, wildlife, livestock and fish processing operations, dredged materials, marinas, and other sources. Hypoxia and anoxia of estuarine and shallow coastal marine environments have increased worldwide over the past 50 years largely due to anthropogenic activities (Diaz, 2015). Pathogens (bacteria, viruses, protozoans, and helminths) increase in estuaries receiving sewage wastes. In these polluted waters, they pose a health risk to swimmers and humans consuming contaminated shellfish. Consumption of raw, viral-tainted shellfish can cause hepatitis and serious gastroenteritis. Pathogenic bacteria in estuaries are particularly threatening to human health. For example, Vibrio cholerae causes cholera-like infection (diarrhea, dehydration, and vomiting), and other pathogenic bacteria (Shigella spp. and Salmonella typhi) are responsible for dysentery and typhoid. Escherichia coli causes gastroenteritis and other maladies (Kennish *et al.,* 2017).
Habitat loss and alteration	Estuaries are particularly susceptible to habitat loss and alteration caused by human activities. The construction of permanent structures on the waterfront, recreational and commercial use which changes bottom habitats due to boat engine prop scarring seagrass beds and shellfish dredging of bay bottoms, have consequences (Kennish *et al.,* 2008; Kennish, 2017). Dredged material disposal at selected sites in estuarine basins causes longer term alteration of habitat, albeit in restricted areas. The development of coastal watersheds has converted extensive natural habitat to compacted soils and impervious cover that decrease infiltration of rainwater while increasing runoff, erosion, and nonpoint pollution to estuarine water bodies. Furthermore, changes in land use and land cover in these developed areas frequently result in higher nutrient and sediment loads, which have an impact on the water and sediment quality of estuaries (Arnold and Gibbons, 1996).
Chemical contaminants	Chemical pollutants are stored in the bottom sediments of estuarine and coastal marine habitats, particularly near densely populated metropolitan regions and other urbanized places (Kennish, 2017). Chemical pollutants accumulate in bottom sediments because many of them are particle reactive and settling to the floor of the estuarine. Some chemical pollutants gather in high concentrations in estuarine organisms or in the estuarine environment. The main delivery systems into estuaries include farming and urban runoff, sewage and industrial waste, river inflow and air deposition (Kennish, 2015b). The main chemical groups found in estuaries are metals, halogenated hydrocarbons, and polycyclic aromatic (Kennish, 2017). Polycyclic aromatic hydrocarbons (PAHs) are another common pollutant found in estuarine settings around the world and they originate from the combustion of fossil fuel, and oil spills
Human-induced sediment/particulate inputs	The use and covering of land in coastal watersheds facilitate sediment inputs into estuaries, which contributes to biotic and habitat impacts. During the construction process, the removal of natural vegetation and other structure increase erosion and the delivery of sediments to rivers and estuaries (Kennish, 2017). Sediment delivery to estuaries via these processes typically increases water column turbidity, light attenuation, and shading of the estuarine floor. This results in the decrease in production of seagrass beds and other benthic habitat that supports numerous faunal populations including many commercially and recreationally important finfish and shellfish species (Moore et al., 2012). The elevation of turbidity has proven to be responsible to seagrass

Impacts	Effects
	loss which supports benthic communities (Moore *et al.,* 2012).
Dredging and dredging-material disposal	Dredging causes mechanical damage and smothering of organisms in the sediments, which typically leads to mass mortality (Donázar-Aramendía *et al.,* 2020). Dredging results in elevated turbidity levels, which reduces light penetration in the water environment, adversely affecting the phytoplankton aquatic vegetation (Cabrita *et al.,* 2020). The roiling of sediments at the dredged site also releases nutrients and chemical contaminants from the bottom sediments, remobilizing them to other areas of the system. Thus, water quality can be adversely affected as well.
Overfishing	The overfishing of fish populations leads to decreased supplies as well as changes in supplies in the foodweb structure of estuaries. For example, the decrease of major fish populations may lead to the increase its prey species, which creates an imbalance in the ecosystem (Briggs, 2012). Examples of overexploited estuarine fisheries include the striped bass (Morone saxatilis), chinook salmon (Oncorhynchus tshawytscha), and delta smelt (Hypomesus transpacificus) in San Francisco Bay. The sea trout fishes (Cynoscion arenarius and Cynoscion nebulosus) in Sarasota Bay, Florida, also appear to be overfished, with landings having declined by 50% since 1960. Several fish and shellfish species likewise appear to be overfished in the Albemarle-Pamlico Sound system of North Carolina (Kennish, 2017).
Human-altered hydrological regimes	The demand for freshwater to meet domestic, industrial, and agricultural demands grows as the population of coastal regions grows. The urbanization of coastal watersheds also results in greater impervious land cover leading to accelerated freshwater runoff and higher river discharges. With an increase in freshwater flow, there is a decrease in water residence time in estuaries, which increases their capacity to dilute, transform or get rid of pollutants (Kennish, 2017). Other changes that can significantly alter water-flow regimes along coasts include channelization, marsh impoundment, and wetland habitat destruction which affect natural water storage capacity.
Invasive/introduced species	Imported organisms that invade the water body can have a major impact on the ecosystem. Introduced and/invasive species can be a danger to the stability and biodiversity of an estuarine ecosystem. In cases where native controls are lacking, these species can have a significant competitive advantage, often rapidly dominating plant or animal communities. Introduced and/invasive species can be a danger to the stability and biodiversity of an estuarine ecosystem. The food web structure is commonly disrupted, and native species may be displaced or greatly reduced in abundance. The introduction or invasion of exotic species is expected to increase in the future due to an expanding world population, the effects of climate change, and greater shipping and other human activities at sea and in estuaries. These changes will likely promote additional ecological disruption.
Climate change effects	Humanity has been, over the years, a significant driver of world climate change (Skinner, 2012). Increasing global temperatures, ascribed in large part to carbon dioxide emissions, have been linked to greater frequency and severity of damaging storms, coastal flooding, droughts and fires, and other hazards projected by climate forecasting models for the twenty-first century (IPCC, 2007). Extreme climate events and ongoing sea-level rise will be hazardous to coastal communities worldwide. Rising sea level and coastal inundation will lead to significant loss of some coastal wetlands, eliminating buffer and rendering coastal communities more vulnerable to extreme events. Human-induced climate change will also alter temperature and salinity regimes and the structure and function of biotic communities in estuaries (Kennish, 2017). Configurations of estuarine basins will be modified as they widen and deepen. Shifts will occur in nutrient and sediment supply as well as freshwater inputs. Tidal prisms and tidal ranges will change in many systems. More frequent flooding and inundation of bayshore areas will

Impacts	Effects
	pose hazards to vulnerable coastal communities worldwide (Kennish *et al.,* 2008).
Coastal subsidence	The subsidence of coasts results in the same impacts as rising sea level on estuarine and wetland systems. For instance, with the increase of coastal subsidence, estuarine shoreline recedes and submergence of land is accelerated, resulting in the loss of wetland habitat. Estuary surface area expands together with basin volume, thus altering system bathymetry and form (Kennish, 2017). Estuary salinity regime, circulation and other physical-chemical features can significantly be altered which affects biotic populations. The issue of coastal subsidence has been accelerated due to an increase in human population growth through the excessive withdrawal of groundwater for domestic and farming use.
Floatable/debris	In estuarine and marine ecosystems, marine waste, particularly plastics, has become a global problem. The use of plastic products has reached an all-time high in many countries due to their lack of degradation which pollutes habitats. Many organisms, particularly fish, turtles, birds, and mammals that consume some of the pollutants or are exposed to them, are at risk. Some organisms mistake the floating material for prey (Verster and Hindrik, 2020). The ingestion of plastics and other marine debris can suffocate the animals or obstruct their digestive systems, causing death (Verster and Hindrik, 2020; Kennish, 2017).

ANNEXURE M: Estuarine Management Plan

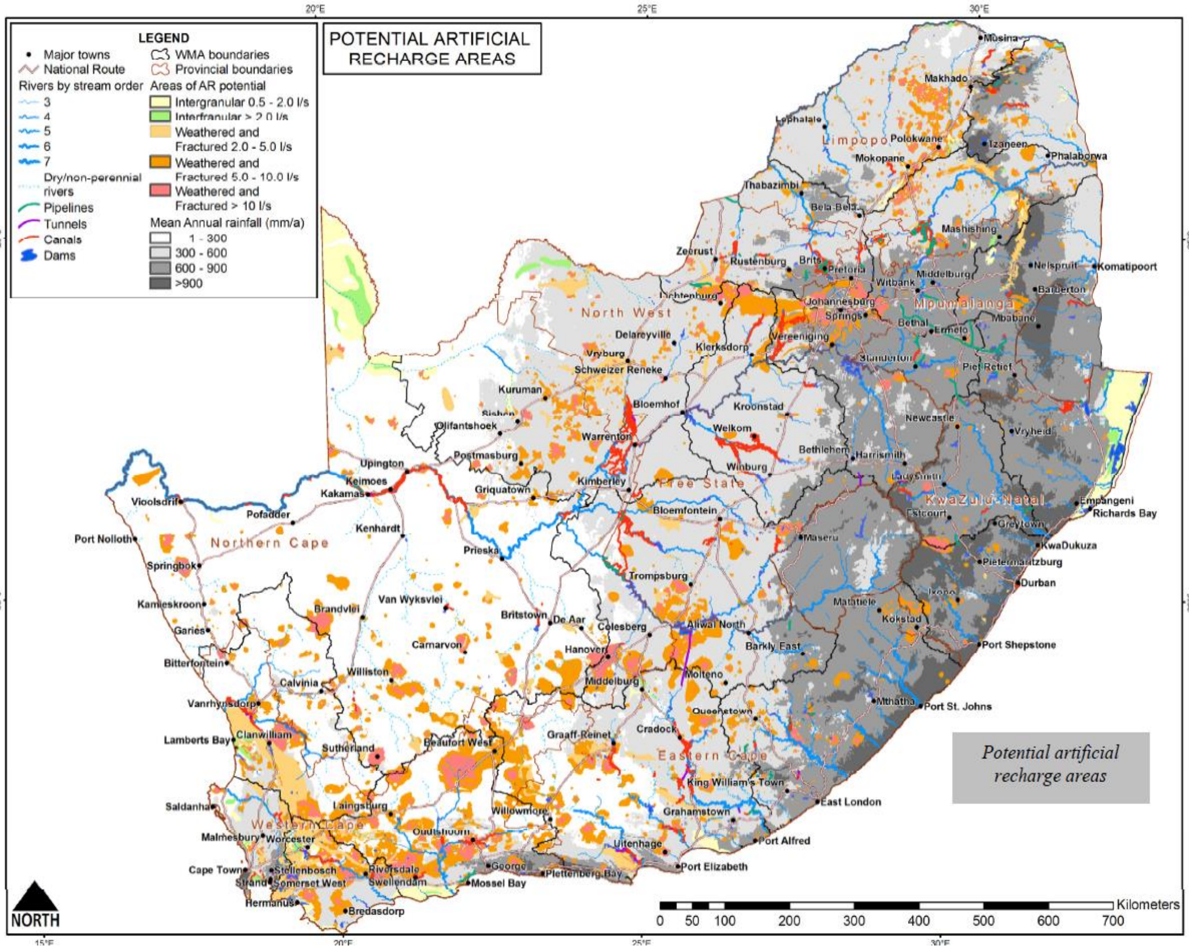
Province	Estuarine Management Plan
Western Cape	• Diep River Estuarine Management Plan • Zandvlei Estuarine Management Plan • Eerste River Estuary Management Plan • Hout Bay Estuary Management Plan • Lourens River Estuarine Management Plan • Silvermine River Estuarine Management Plan • Sir Lowry's Pass River Estuarine Management Plan • Zeekoevlei Estuarine Management Plan • Sout River Estuarine Management Plan • Uitkraals River Estuarine Management Plan • Klein Estuarine Management Plan • Heuningnes Estuarine Management Plan • Breede Estuarine Management Plan • Knysna Estuarine Management Plan • Olifants Estuarine Management Plan • Gouritz River Estuarine Management Plan
Eastern Cape	• Draft Buffalo River Estuarine Management Plan • Draft Qinira Estuarine Management Plan • Draft Seekoei Estuarine Management Plan • Gamtoos Estuarine Management Plan
Kwazulu-Natal	• Mgobozeleni Estuarine Management Plan • Preliminary Draft Uhongathi Estuarine Management Plan • Lake St Lucia Estuarine Management Plan

ANNEXURE N: Summary of findings on groundwater resource rehabilitation and remediation practices, globally.

SETTINGS/ COUNTRY	STUDYIES, PROGRAMMES, AND INITIATIVES	IMPACTS IDENTIFIED	SUMMARY OF INTERVENTIONS AND BEST MANAGEMENT PRACTICES IMPLEMENTED
India	Development of a Guidance document for assessment and remediation of contaminated sites in India by the Ministry of Environment, Forest, and Climate Change (MEFCC, 2015)	Land bound solid phase contamination; Water bound sediments solid phase contamination; Land bound liquid phase contamination; NAPL contaminants in soil (Non-Aqueous Phase Liquids); Groundwater contaminations	The guidelines provide a classification system which distinguishes different types of contaminated sites such as Type P2 Pathway which is associated with groundwater contaminations
France	Classified installations for the protection of the environment (ICPE)	Soil and groundwater remediation	Remediation plan which establishes different scenarios for remediation; Use of cost-benefit analysis (CBA) is an approach which is considered for the choice of remedial solution
Netherlands	Soil Remediation Circular 2013 (SRC, 2013); Soil Protection Act (SPA, 2013).	Human health risk, ecosystem, and groundwater risk assessment for remediation projects.	The circular provides for soil remediation process (SRC, 2013); The Netherlands remediation strategy used to establish contamination levels (urgent and non-urgent) in groundwater for remediation
Italy	Legislative Decree no.22 of 1997; Ministerial Decree of 1999	Soil, surface water, and groundwater remediation	The Legislative Decree no.22 of 1997Provides legislative requirements for waste management and contaminated soil management; The Ministerial Decree of 1999 defines the terms of contaminated sites, potentially contaminated sites, safety measures, remediation environmental recovery, and establishes the criteria for the remediation and monitoring operations, and
United States	Regulations 7:26D - remediation standards 7:26E - technical requirements for site remediation.	Soil and groundwater remediation	Remediation projects are undertaken in three phases a) Initial Assessment (called Preliminary Assessment and Site Investigation), b) Remedial Investigation (where the site is studied to determine the full extent of the contamination) and c) Remedy Construction (the actual physical remediation phase).
United Kingdom	Environmental Protection Act 1990 (EPA, 1990)	Land protection and remediation	Contamination on a site can be identified using regulation Part IIA of the EPA, 1990; A risk-based and reasonable approach is taken in respect of remediation, and clean-up

			requirements are set out in the remediation notice
Australia	The South Australian Environment Protection Authority (SAEPA) Guidelines for the assessment and remediation of site contamination of 2019; Environment Protection (Water Quality) Policy 2015 (WQEPP)	Remediation of contaminated areas; Groundwater remediation	SAEPA Guidelines of 2019 requires that when undertaking remediation, specific obligations must be complied with to ensure that water quality is not degraded. It also notes that groundwater remediation is generally complex, and time consuming

ANNEXURE O: Map showing potential artificial recharge areas in South Africa (Source: DWA, 2010))



Examples partnerships and cooperative governance drawn from the WWF-MWP Programme (WWF-MWP 2016)

Province	Area	Period	Partnership/Co-operative Governance
Western Cape	Nieuwoudtville area	2011–2013	**WWF** rehabilitated wetlands through strengthening farmer wetland management practices and formal biodiversity **stewardship agreements**. There are also guidelines which were developed for with Rooibos farmers for the wise use of wetlands especially rich in biodiversity and rare species
	Breede River	2010–2013	**CapeNature in collaboration with working with local farmers and the Department of Agriculture**, assessed the condition of wetlands in the upper catchment near Worcester to develop biodiversity management plans for farmer use and securing biodiversity stewardship sites.
	Betty's Bay - Hermanus - Breede area	2010-2013	CapeNature evaluated the priority wetlands, validated provincial wetland information and strengthened wetland-related capacity within CapeNature;
	George area and Groot Brak River	1997 & 2015	Wetland capacity of **conservation agencies, forestry staff and local volunteers** in the George area was strengthened through working with **WESSA** to assess the management of ecological infrastructure in the Groot Brak catchment.
Eastern Cape	Krom River	1997–2001	Large parts of this river were assessed and rehabilitated in **partnership with local and provincial government conservation and water affairs agencies** and **Working for Wetlands**
	Ugie–Maclear area	1997-2001	Assessment of the health and rehabilitation of multiple wetlands were conducted in the upper reaches of the Mzimvubu River on Mondi forestry plantations. This wetland rehabilitation played a key role in demonstrating to government the value of wetland rehabilitation. It also helped catalyse Working for Wetlands.
Limpopo	Mutale River	2009-2013	**Working with Association for Water and Rural Development (AWARD)**, **Working for Wetlands and local communities** to strengthened the capacity of **communal farmers** in the upper catchment to manage their wetland wisely
	Nylsvlei wetland	1997-2001	The health of South Africa's largest inland floodplain was assessed by **WWF** with teams from **relevant government departments**.
	Mokolo River–Waterberg	1998-2001	Wetland health assessments and rehabilitation in the upper Mokolo catchment were conducted by **WWF** with **Working for Water and local farmers**. This was one of the first examples of large-scale wetland rehabilitation which helped to catalyse Working for Wetlands.
Gauteng	Elands River	1997-1998	Wetland health assessments were conducted by **WWF** with **Gauteng Department of Agriculture and Rural Development** in the area around the town of Cullinan in the upper reaches of the Elands River.
Mpumalanga	Crocodile, Klip and Olifants rivers	1997-2000	Wetland health assessments and rehabilitation of multiple wetlands were conducted by **WWF** with **Working for Wetlands** in upper catchment of three important rivers arising in the Dullstroom/Belfast area. Other stakeholder who participated include **Endangered Wildlife Trust, farmers and**

Province	Area	Period	Partnership/Co-operative Governance
			Mpumalanga Department of Economic Development, Environment and Tourism.
	Blyde and Sand rivers	1998-2000	Health assessments and rehabilitation of multiple wetlands in the upper catchment of these two rivers was conducted by **WWF** with **Working for Water, AWARD and Mpumalanga Department of Economic Development, Environment and Tourism.**
	Hlelo River	1998-2000	Wetland health assessments and the highly successful rehabilitation of Zoar and Driepan wetland systems were undertaken by **WWF** with **Mondi** near Piet Retief.
Free State	Klip River	1998–2001	Health assessment and rehabilitation of multiple wetlands in the upper Klip catchment (one of the major water sources for Gauteng) near Vrede, were conducted **with Rand Water and Free State Department of Economic Development, Tourism and Environmental Affairs.**
	Wilge River	1997–2001	Health assessment and rehabilitation of multiple wetlands in the upper Wilge catchment (another major water source for Gauteng) near Harrismith, were conducted with **Rand Water and Free State Department of Economic Development, Tourism and Environmental Affairs**
	Phuthaditjhaba wetland	1999–2000	Health assessments and rehabilitation of this wetland near Phuthaditjhaba in QwaQwa, were undertaken in **partnership with Rand Water and Free State Department of Economic Development, Tourism and Environmental Affairs.**
Kwazulu-Natal	Upper uMfolozi River	1997–2000	Health assessment and rehabilitation of Lenjane, the largest wetland in the upper White uMfolozi River, were carried out by **WWF** with **Mondi, Sappi and private farmers** near Vryheid, and assessment of Gladstone vlei and Paddavlei near Dundee.
	Melmoth and KwaMbonambi areas	(2010–2014):	Wetland health assessments, research and management advice were undertaken with Mondi foresters, focusing on how to burn wetlands wisely to maintain ecosystem integrity.
	Mbongolwane wetland	(2001–2004):	**Supported the communal wetland users** of this important wetland near Eshowe to improve the wise use of wetland resources through capacity building and rehabilitation initiatives. This work was done **in partnership with the University of KwaZulu-Natal and Working for Wetlands.**
	Durban to Richards Bay coastal areas	1991–1995):	Extensive work with **Ezemvelo KZN Wildlife and sugar farmers (among others)** was undertaken during the beginning of the **WWF MWP**; wetland assessment and management techniques were developed which led to the development of the **Wetland Fix series of field guides.**
	Mooi, uMngeni and Umvoti rivers	(1996–present):	Working in the upper reaches of these catchments has been a core area of the WWF-MWP's work over the past 20 years. Many thousands of hectares of wetlands and riparian areas have been assessed and rehabilitated with **multiple government, NGO, communal and private land users.** Currently the WWF-MWP focuses on catalysing and supporting improved water stewardship practices with the plantation forestry and dairy industries and their associated

Province	Area	Period	Partnership/Co-operative Governance
			value chain organisations.
	Ntsikeni wetland	1997-2001	Assessment and rehabilitation of the Ntsikeni wetland in **partnership with Eastern Cape Department of Economic Development and Environmental Affairs and Working for Wetlands**. The groundwork was completed for gaining Ramsar status for the wetland. Two new Ramsar sites were designated – Ntsikeni Nature Reserve in 2010 and uMngeni VleiNature Reserve in 2013 – bringing the total number of Ramsar sites in South Africa to 21.

RIVERS AND WETLANDS

- ***The uMhlathuze Water Stewardship Partnership (UWASP)***

The uMhlathuze Water Stewardship Partnership (UWASP) is a collaboration between the National Business Initiative (NBI), the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), the World Wide Fund for Nature South Africa (WWF-SA), the City of uMhlathuze, Mondi, the Department of Water and Sanitation (DWS) and Tongaat Hulett. The partnership aims to:

- Serve as a coordination hub for collective action on water security across the uMhlathuze region
- Collaborate with all key stakeholders and water users in the region
- Implement short and medium-term measures to improve water security for industry, agriculture, and communities
- Use water as a focal point for transformation and economic development to strengthen resilience and adaptive capacity
- Work with public sector institutions to support improved service delivery and natural resource management.

The partnership's initiatives include developing an online water balance tool/ dashboard with data from resources and users to assist authorities in making informed strategic decisions on water management; installation of reliable, accurate meters and telemetry at all necessary abstraction points to understand daily and seasonal water use by irrigators in the catchment; and the development of a single water user association to strengthen irrigation governance through an improved management structure (NBI, 2020).

- ***GEF 6 Ecological Infrastructure for Water Security (EI4WS) Project***

SANBI is the project lead for the 6th GEF EI4WS project. The project is executed in partnership with the DBSA, GEF, WRC, NBI, Rhodes University, CLCB, WWF and DFFE. The three focus areas of the project as are summarized below.

Component 1 focuses on strengthening the enabling environment for improving water security through the integration of biodiversity and ecosystem services in the water value chain. Component 2 focuses on the application of policies and financial mechanisms in the water value chain to improve water security in critical catchments. The two pilot catchments are the Berg-Breede Catchment and the Greater uMngeni Catchment. Component 3 entails application of social learning, credible evidence, and knowledge management to improve the integration of biodiversity and ecosystem services into the water value chain.

- ***uMngeni Ecological Infrastructure Partnership (UEIP)***

UEIP partnership was formally established in November 2013 upon signing of a Memorandum of Understanding (MoU) by key organizations committed to finding ways of integrating ecological infrastructure solutions to support built infrastructure investments in addressing challenges of water security in the uMngeni catchment. Growing population and economic development in the catchment have led the uMngeni system being unable to meet the demand for delivery of water services in the area. The partnership currently comprises over 20 organizations from national, provincial, and local government departments, business, and academic institutions as well as civil society. The SANBI, as a co-founder of the UEIP, has been the center of coordination for the partnership since its inception. The primary focus of the UEIP is to explore the role that ecological infrastructure can play in improving water security in the catchment.

ESTUARIES

The success of estuary management and conservation depends on cooperative governance. In South Africa, the collaboration is in the form of the National Coastal Committee (NCC) as defined by the Integrated Coastal Management Act (ICMA; Act 24 of 2008). This is further overseen by the DFFE, with participation by the Department of Water and Sanitation (DWS), provincial authorities, Department of Agriculture, conservation agencies and other relevant stakeholders (Cilliers, 2017; *Adams et al.,* 2020). Cooperative governance cannot function in isolation; EMPs are necessary to guide action. EMPs are available in various stages of completion for less than 15% of South African estuaries, however, even in cases when they have been finalized, implementation takes time. For example, Izegaegbe *et al.* (2020) clearly demonstrated the biodiversity significance of the uMhlathuze Estuary, yet its EMP, which is complete, has not been formally signed off for implementation. CapeNature, for instance, has played an invaluable role in setting up advisory forums for the Berg, Breede, Bot and Klein

Estuaries. In other systems, non-governmental organisations, such as the Zwartkops Conservancy, have taken a lead in estuary management. The Western Cape Provincial Government has established an estuary management programme in collaboration with CapeNature and the City of Cape Town. The SA-NBA outlines a National Estuary Biodiversity Plan, led by national government, which maintains and controls estuarine resources and sets short- and medium-term goals for Estuarine Protected Areas (Van Niekerk *et al.,* 2019). Regardless of these advancements, there are still several areas that require action, whereby progress is hindered by lack of political will and policy confusion (Taljaard *et al.,* 2019; Strydom and Kisten 2020). For example, Claassens *et al.* (2020) state that for intergovernmental cooperation it is crucial for effective implementation of compliance monitoring and legislation in order to address the rapid deterioration of the Knysna Estuary. Other authors call for a holistic multidisciplinary approach to address connectivity issues and conserve vulnerable life history strategies of fish (Strydom and Kisten 2020).

LAKES AND DAMS

The DWS, with Rand Water as Implementing Agent (IA) have been responsible for the development and implementation of the remediation project of the Hartbeespoort Dam Hartbeespoort Dam Integrated Biological Remediation Programme (HBPD) since 4 June 2006. Rand Water is the main Regional Water Services Provider in the catchment of the HBPD working together with a core group of service providers and specialists have been identified and agreed with the DWS to assist Rand Water to prepare a management structure, Project Execution Plans (PEPs) and reporting mechanisms for facilitating the execution of the programme.

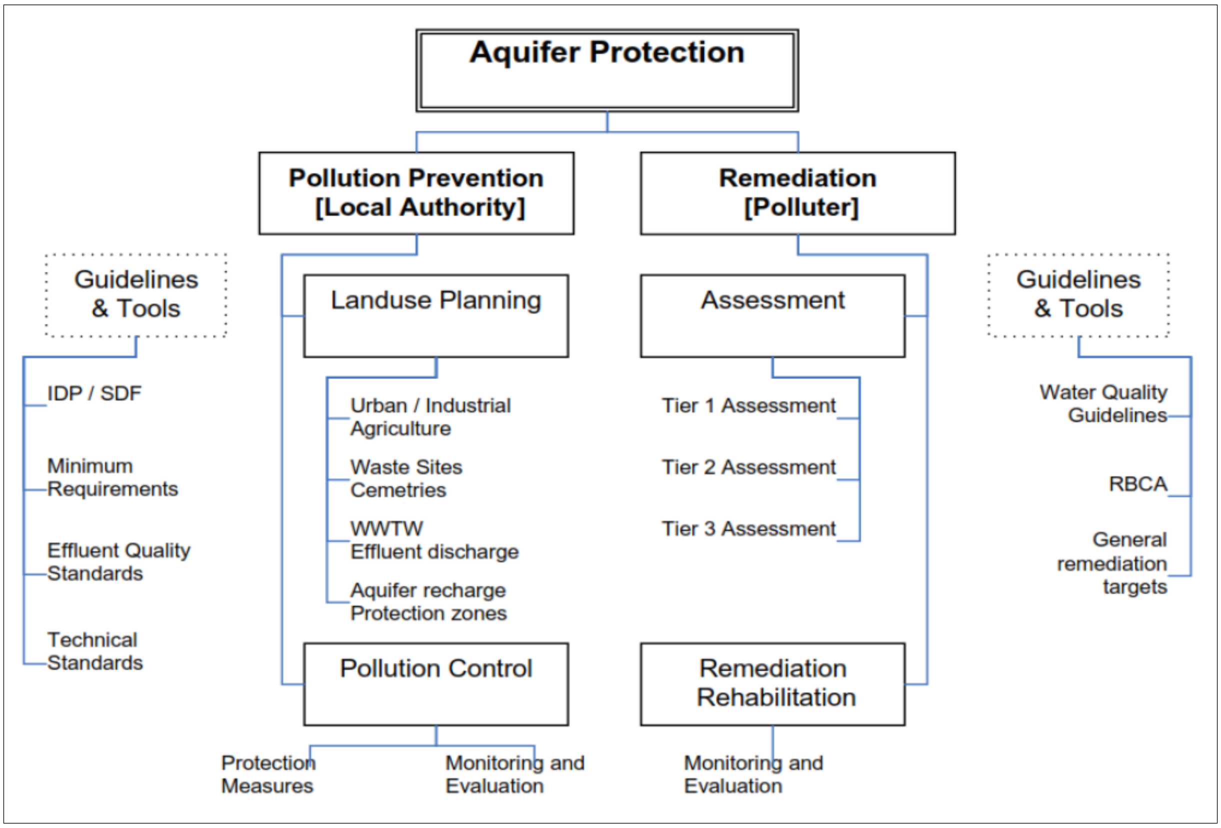
GROUNDWATER

Turton *et al*. (2002) defines governance as the process of informed decision-making that enables trade-offs between competing users of a given resource to balance protection and use in such a way as to mitigate conflict, enhance security, and ensures sustainability. Collaboration across institutions forming partnerships improves connectivity and learning across scales and it also enables well-connected governance structures to swiftly deal with challenges at hand. Use of cooperative governance and partnerships known as polycentric governance enables broader levels of participation and facilitates decision making at different levels of policy implementation (Carlisle and Gruby, 2021). Such an approach is relevant in guiding groundwater resources rehabilitation practice which requires consideration of different levels in which water resource protection practice and reporting operates. Because groundwater resources rehabilitation addresses aspects of people (roles and responsibilities) and the environment and it involves multiple centers of autonomous decision making, challenges and opportunities that exist in cooperative governance and partnerships must be explored. Knowledge generated from such exploration is relevant in guiding how the concept of cooperative governance and partnerships could be applied in groundwater resource rehabilitation projects.

A study on the South African Groundwater Governance was conducted in 2011 by the then Department of Water Affairs and the Water Research Commission at national and local levels. (DWA and WRC, 2011). At the national level, the case study included an analysis of the policy, legal and institutional frameworks for groundwater provisions, knowledge and capacity availability, gaps and financing arrangements to strengthen groundwater governance. At local level, the study focused at technical, legal, institutional, cross-sector policy coordination, operational groundwater governance provisions and institutional capacity for implementation. The findings of the study indicated that technical, legal, and institutional and operational governance provisions were reasonable but weak for cross-sector policy coordination at a national level. Institutional capacity was found to be weak across all thematic areas considered for assessment except for the technical provisions (DWA and WRC, 2011).

Although basic technical provisions such as hydrogeological maps and aquifer delineation with classified typology were found to be in place for all case study aquifers at local level, other governance provisions across all thematic areas were found to be weak or non-existent. The findings of the study suggest that there are existing limitations associated with cooperative governance between national and local levels because of the challenges mentioned earlier related to institutional capacity. Something which needs to be taken into consideration when groundwater resources rehabilitation projects are initiated.

Various guidelines for groundwater management in South Africa have been developed which serve as valuable sources of information in terms of the requirements and steps to protect and manage aquifers, however, it has been noted that an overarching groundwater management framework was still lacking especially at local level (WRC, 2011). Consequently, Riemann *et al.* (2011) proposed a Groundwater Management Framework that incorporates all aspects of groundwater management at municipal level. The framework is aimed to improve management of groundwater resources by equipping the responsible authorities with the required tools and capacity. This goes beyond data collection and monitoring, and requires human and capital resources (Riemann *et al.,* 2011). Furthermore, the Framework incorporates the aspect of pollution prevention, and remediation/rehabilitation. In the context of the current project, the Framework serves as a guide on how the concept of cooperative governance and partnerships could be used to facilitate coordinated groundwater resources rehabilitation practice at both national and local level (municipal level).



Structure of Groundwater Management Framework with sub-categories pollution prevention and remediation (Source: Riemann et al., 2011)

Recently, the Water Research Commission undertook a project to develop a training manual for groundwater resource management and groundwater governance for municipalities in South Africa (WRC, 2019a). The training manual aimed at increasing capacity for groundwater management at a local level, and incorporates modules on the hydrological cycle, water law, groundwater management, groundwater regulation, groundwater quality, groundwater quantity, groundwater monitoring, data and information recording and management, as well as operational and maintenance related to bulk groundwater supply schemes (WRC, 2019a). It is encouraging to note that most of these aspects covered in the training manual are important in groundwater resource rehabilitation practice. As a result, it is hoped that use of cooperative governance and partnerships by the DWS, municipalities and other relevant stakeholders will enhance groundwater resource rehabilitation practice.

Within the same context of cooperative governance and partnerships, it has been reported that policy implementation programmes have been experiencing challenges primarily because of limited capacity, and other related factors associated with costs (Jabeen *et al.,* 2015; Harwood *et al.,* 2018; Tuokuu *et al.,* 2018). Such arguments have been supported by Barbosa *et al*. (2016) who noted that policy implementation challenges are common in water resources planning and management and are characterized by difficult process of moving from policy to action. Willaarts *et al.* (2020) agreed with Barbosa *et al.* (2016) and stated that in many arid and semi-arid regions, water scarcity is not just a growing environmental challenge but also a structural problem. The concept of citizen science where citizens play an active role in the scientific process and policy implementation programs has emerged in the last decade as a new approach for policy implementation especially in low-income countries where data scarcity is predominant and where conventional methods are expensive and logistically challenging (Hyder *et al.* 2017; Paul and Buytaert, 2018; Njue *et al.,* 2019). In the South African context within the field of water resource protection, successful projects where local communities play a critical role in policy implementation activities have been reported such as the case of the uMngeni and Msunduzi River Catchments (Cele, 2015), and the Tsitsa River catchment (Bannatyne *et al.,* 2017). However, these case studies were applied in water resources protection activities for surface water resource. Although not much has been published in terms of citizen science application in groundwater resource management, there is evidence indicating some form research outputs (Ajoge, 2019), and practical application of the concept (Dennis, 2020). Application of the citizen science concept in groundwater resources rehabilitation practice through cooperative governance and partnerships with local communities may enhance and improve project implementation.