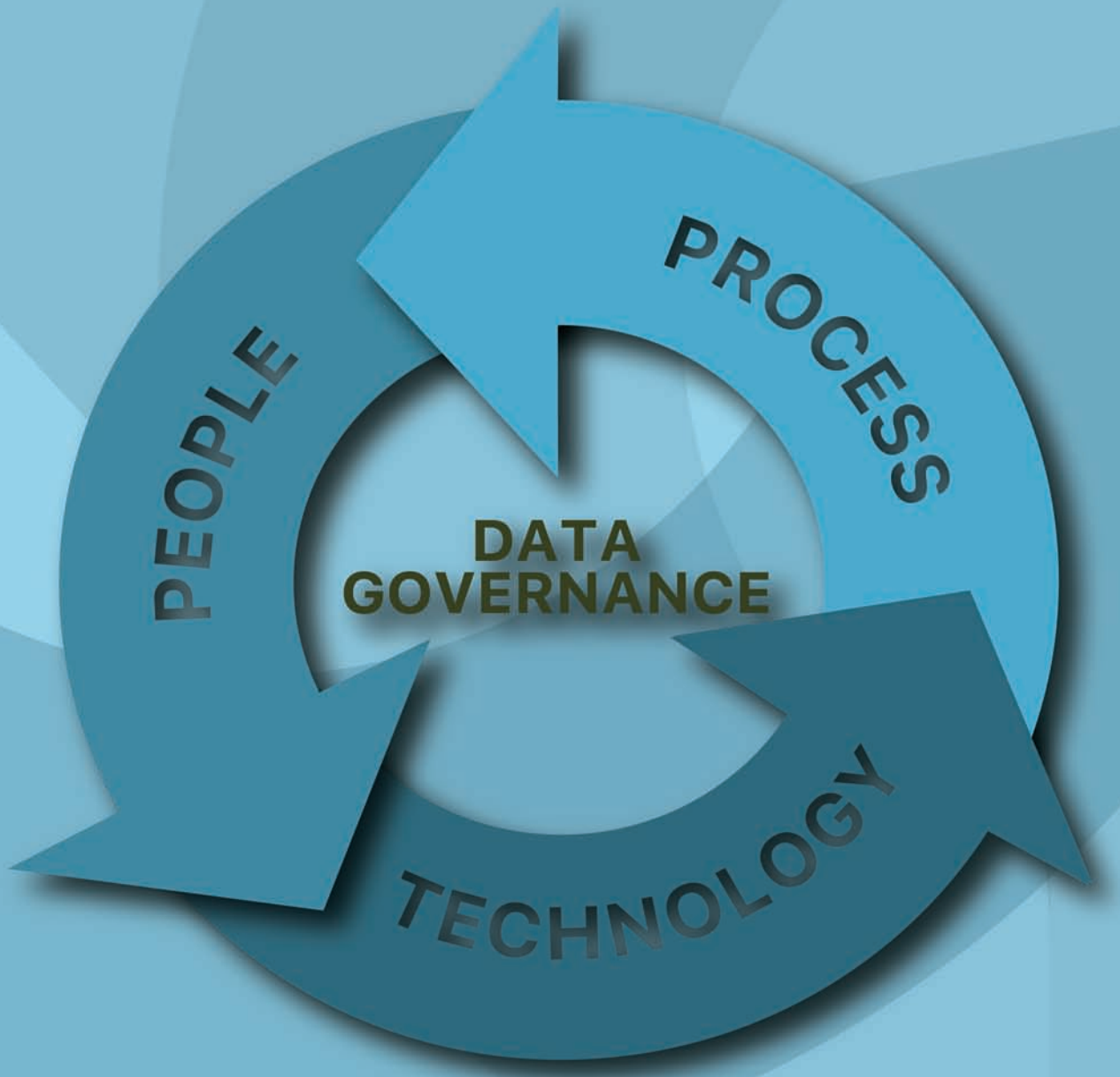
DATA MANAGEMENT STRATEGY FOR WATER AND SANITATION IN SOUTH AFRICA

First Edition



WATER IS LIFE - SANITATION IS DIGNITY

water & sanitation
Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

2030 NDP

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ABBREVIATIONS & ACRONYMS

AI	Artificial Intelligence
ANN	Artificial Neural Networks
ARC	Agricultural Research Counsel
BRS	Business Requirement Specifications
CMA	Catchment Management Agency
CMF	Catchment Management Forum
CSI	Committee for Spatial Information
CSIR	Counsel for Scientific and Industrial Research
DAFF	Department of Agriculture, Forestry and Fisheries
DAM	Data Acquisition and Management
DAMA	Data Management Association
DAM-CC	Data Acquisition and Management Control Committee
DAM-PC	Data Acquisition and Management Planning Committee
DEA	Department of Environmental Affairs
DMSs	Data Management Systems
DSS	Decision Support System
DT	Decision Trees
DWS	Department of Water and Sanitation
GA	Genetic Algorithms
GIS	Geographical Information System
E-WULAAS	Electronic Water Use License Application and Authorisation System
HRHE	Hydrological Risks, Hazards and Extremes
IP	Information Programs
IR-WMC	Integrated Regional Water Monitoring Committee
IWIS	Integrated Water Information Systems
IWQM	Integrated Water Quality Management

KDD	Knowledge Discovery from Databases
KOBWA	Komati Basin Water Authority
ML	Machine Learning
MoA	Memorandum of Agreement
MoU	Memorandum of Understanding
NGS	National Groundwater Strategy
NDP	National Development Plan
NIWIS	National Integrated Water Information System
NSP	National Sanitation Policy
NWA	National Water Act
NWMC	National Water Monitoring Committee
NWRM	National Water Resources Monitoring
NWRS	National Water Resources Strategy
O-CIO	Office of Chief Information Officer
PAIA	Protection of Access to Information Act
QMS	Quality Management Strategy
RSA	Republic of South Africa
RQIS	Resource Quality Information Services
SAEON	South African Environmental Observation Network
SANBI	South African National Biodiversity Institute
SANParks	South African National Parks
SASDI	South African Spatial Data Infrastructure
SAWS	South African Weather Services
SAP	Systems Application Products
SDGs	Sustainable Development Goals
SDI	Spatial Data Infrastructure
ToR	Terms of Reference
USGS	United States Geological Survey
WARMS	Water Authorisation, Registration and Management System
WISA	Water Institute of South Africa

WSA	Water Services Act
WIM	Water Information Management
WMS	Water Management System
WQM	Water Quality Management
WRC	Water Research Commission
WRM	Water Resources Modelling
WSNIS	Water Services National Information System
WUI	Water Use Information

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TAKEHOLDERS CONSULTED

Table 1: Key Water Sector Stakeholders Consulted

DWS STAKEHOLDER CONSULTATION
DAM Strategy Regional Workshops: DWS Regional Offices and Respective CMAs
DAM Strategy National Workshops: DWS H/O; Regional Offices; CMAs
DAM Strategy Meetings with Planning and Information (P&I) Branch
DAM Strategy Meetings with O-CIO
DAM Strategy Discussions during DWS Groundwater DAM Workshops
DAM Strategy Discussions at National Water Monitoring Committee (NWMC) Meetings
DAM Strategy Discussions during Integrated Regional Water Monitoring Committees (IR-WMCs) Meetings
DAM Strategy Discussions during WARMS user Forum Meetings
DAM Strategy Discussions during Catchment Management Forum Meetings
DAM Strategy Discussions during Wetlands Management User Group Meetings
CONFERENCES/WORKSHOPS
14th Biennial Groundwater Division Conference and Exhibition, 2015
2nd African Water Symposium and 6th Orange River Basin, Symposium, 2015
Water Institute of Southern Africa (WISA) Biennial Conference, 2016
Wetlands Imbizo, 2017
Spatial Data Infrastructure Sub-Committee Meetings 2017/18
National Wetlands Data Acquisition and Management Workshop, July 2018
KEY WATER SECTOR STAKEHOLDERS CONSULTED
Counsel for Scientific and Industrial Research (CSIR)
South African Environmental Observation Network (SAEON)
The South African Water Board: Rand Water

1 EXECUTIVE SUMMARY

The Department of Water and Sanitation (DWS) is mandated by the National Water Act No. 36 of 1998 and the Water Services Act No. 108 of 1997 to provide useful water related information to decision makers and water practitioners. It has thus established data and information management systems for decision makers to address the management, use, development, conservation, protection and control of the South African water resources. Furthermore, as mandated by the second edition of the National Water Resource Strategy (NWRS), the DWS has initiated a project to develop and implement a Data Management Strategy for Water and Sanitation in the Republic of South Africa (RSA). Since the DWS is currently developing a number of policies and strategies that contain sections that address issues related to data management, the Data Management Strategy may thus become the main reference when addressing issues related to data management in these policies and strategies.

The vision for the Data Management Strategy is for the water and sanitation sectors to have a national data management model that will be used to coordinate and facilitate the sector wide management of data and information required to feed into the national information systems. The mission of the Data Management Strategy is to develop strategic guidelines and framework for data management in water and sanitation in order to improve the credibility, availability, accessibility, timeliness, and the security of water and sanitation data. The objectives are therefore to develop and implement methods and procedures to strengthen the four pillars of data acquisition and management; viz. data governance, data life cycle management, data management systems and collaboration amongst stakeholders in the water and sanitation sectors.

The state of data management in the water and sanitation sectors has been evaluated and the following main data related challenges have been identified; uncoordinated data management in water and sanitation, lack of common approaches for resolving data needs and issues, duplication of functions between the DWS and other stakeholders in the water and sanitation sectors, water quality and quantity data stored into data management systems with errors, fragmented Data Management Systems (DMSs) used to manage water quality and quantity data, water quality and quantity data not stored in structured data management Systems, underutilisation and none utilisation of the Water Management System (WMS), most water quality and quantity data management systems are not current, lack of collaboration with external institutions for data and infrastructure sharing.

Chapter 14, Section 141 of the NWA (1998) stipulates that the Minister may require in writing provision of any data or information from any person for the purposes of any national monitoring network or national informal systems. In pursuance of this requirement the Department has established a number of Memorandum of Understanding or Agreements with several organisations. In spite of this, a number of challenges have arisen including data not being exchanged due to expired agreements or due to lack of clear legislation to provide data on regular basis except in cases where a request has been made by the Minister through the Memorandum of Understanding (MOU) or Memorandum of Agreements (MOA).

To resolve or alleviate the above challenges, the Data Management Strategy proposes the following model for data management for water and sanitation in the RSA;

1) Establish/amend national legislation/policies/regulations to enforce data, infrastructure and skills sharing amongst all the stakeholders in water and sanitation.
2) Establish departmental and sector wide data governance programs for all planning and control activities in water and sanitation data acquisition and management.

3) Develop Data Life Cycle Management plans (standard operating procedures) for all Water and Sanitation Data.

4) Develop integrated and interoperable data management infrastructure that will provide single platforms for managing data in the various focus areas in water and sanitation management.

5) Strengthen collaboration amongst water and sanitation stakeholders for data, infrastructure and skills transfer.

Since managing data and information is listed as one of the enablers for water and sanitation management in the DWS master plan, it is proposed that the Data Management Strategy be utilised as the main tool for achieving the data management objectives of the master plan. Furthermore, since the Sustainable Development Goal 6 (SDG 6) are one of the main drivers of the Master Plan, the Sustainable Development Goals (SDGs) target indicators must be domesticized and used to identify focus areas for the Data Management Strategy when developing the implementation plan.

In order to fulfil some of the objectives in the NWA No. 36 of 1998, the Data Management Strategy recommendation will be applied of the following focus areas; protection of water resources (chapter 3), water use (chapter 4), financial provisions (chapter 5), international water management (chapter 10), government waterworks (chapter 11), dam safety (chapter 12), and monitoring, assessment and information (chapter 14).

In preparation for the future use of Artificial Intelligence (AI) to manage water resources in RSA, the DWS as the sector leader must investigate areas in water resource management, particularly data management where AI may be employed. In other words there must be an understanding of the basic nature of the problem to be solved. Furthermore, the DWS must ensure that adequately sized, validated data is available in order to apply AI in water resource management.

2 INTRODUCTION AND BACKGROUND

2.1 Data Management

Data Management is the development, execution and supervision of plans, policies, programs and practices that control, protect, deliver and enhance the value of data and information assets (DAMA-DMBOK, 2009). Data is the foundation on which our knowledge of the environment is built; hence data management is essential to ensure effective and efficient use of this resource (McGuirk, 2003).

In the water sector, water-related data is used for decision making in all aspects of water resources management, in a wide range of operational applications, as well as in research (WMO, 2015). Water-related data is commonly used to provide information on the state of the water resources, water related hazards such as floods and droughts, water related public health issues, planning water resources development, planning infrastructure development, effects of water use, effects of economic activities, effects of regulation measures, the state of the climate system, etc. (Wenninger and Venneker, 2015).

Thus, poor management of water-related data may lead to negative economic effects and disastrous situations such as; unpreparedness for extreme water related events (floods, droughts, contamination, etc.), lack of account for water use, non-compliance on international agreements for water sharing, etc.

Thus, generally, the benefits of efficient data management include the following;

- It enables efficient integration of data from different sources with different formats.
- Results in better quality data and more timely information, i.e. Access to the right information at the right time.
- Results in improved access to data.
- Results in improved understanding of which data is available for current and future use.
- Improved data acquisition and management of effectiveness and efficiency through coordination of efforts.

Data Management can therefore be described as a group of activities relating to the planning, development, implementation and administration of systems and people for the acquisition, storage, archiving, security, retrieval, and dissemination of data (IGGI, 2005). Data Management plays a crucial role in the DWS water resources management because it determines the quality of data that is used to generate information for water related decision making (DWAF Project Number: 2005-325). Thus data acquisition plays a major role is inherent in the overall processes for water data management. Hence, the terms Data Management and Data Acquisition and Management (DAM) will be used interchangeably in this document.

2.2 Pillars of Data Management

Figure 1 illustrates the main processes in a water resources management value chain. These processes are identified as data governance, business requirements specification; information needs assessment, data requirements assessment, data acquisition and management as well as information management and dissemination.

Since data is the foundation for any decision making in water resources management, data acquisition and management is thus considered a critical process in the water resources management value chain. If data is not credible, available, accessible, timely and secure; water resources cannot be managed effectively and efficiently. The following have been identified as the main pillars for effective and efficient DAM, viz. Data Governance, Data Life Cycle Management, Data Management Infrastructure/Systems and collaborations and alignment between stakeholders.

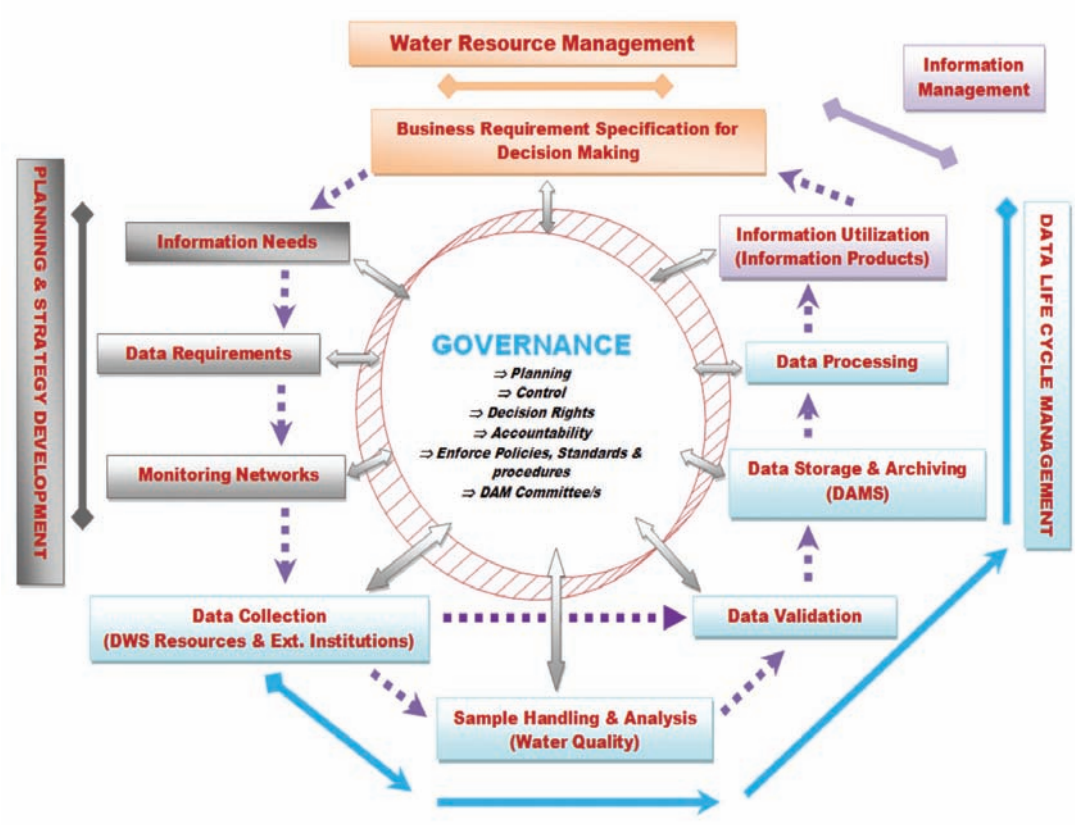

Figure 1: Water Resources Management Value Chain

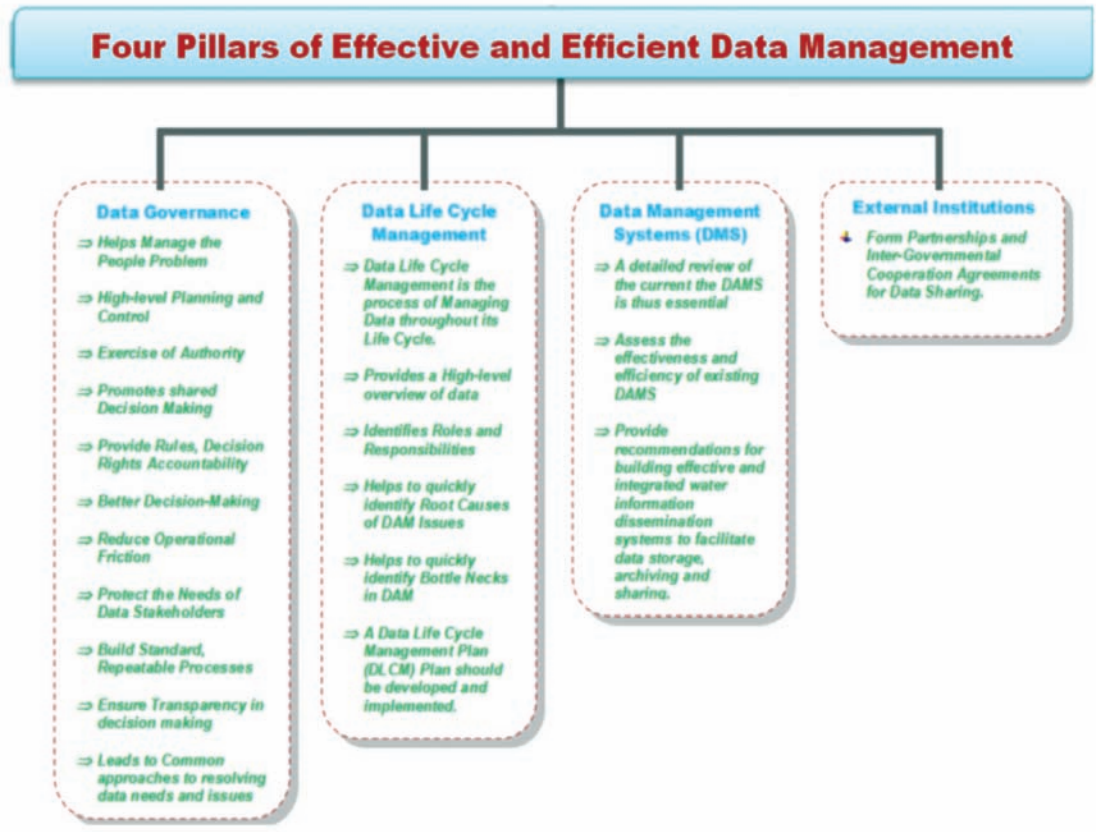

Figure 2: Four Main Pillars of Data Management

These four main pillars of DAM (Figure 2), when executed efficiently and effectively, will ensure that authoritative data is available, accessible, timely and secure.

2.2.1 Data Governance

The Data Management Association (DAMA) defines data governance as: "The exercise of authority, control and shared decision-making (planning, monitoring and enforcement) over the management of data assets; thus, data governance is high-level planning and control over data management (DAMA-DMBOK, 2009). Data Governance is a system of decision rights and accountabilities for information-related processes, executed according to agreed-upon models which describe who can take what actions with what information, and when, under what circumstances, using what methods (AICPA, 2015). Data Governance is therefore a key component of any DAM program.

Data management alone tends to focus more on solving technical problems, which is usually achieved by purchasing or introducing new tools and technologies. Whereas, data governance enables an organisation to effectively manage the "people problem", which is always built into

any data acquisition and management approach. Thus, the aim of data governance is to bring together people from across an organization to create a consistent view and an integrated approach for managing data, so that the data may be utilized effectively and efficiently. Data governance objectives are to provide rules, decision rights and accountability when making data management decisions (ResTech, 2008). Hence, improved data governance should lead to the following benefits;

- Better decision-making and transparency when resolving data issues.
- Adoption of common approaches to resolving data needs and issues.
- Reduction of operational friction.
- Protection of the needs of all stakeholders.
- Building of standard, repeatable processes for generating and disseminating data.
- Reduction of data acquisition and management costs.
- Improved data acquisition and management effectiveness and efficiency through coordination of efforts.

i) Typical Data Governance Program

Typical data governance programs are made up of two main components, viz. data management planning and data management control. The data management planning and control usually consist of the activities listed in Table 2.

Table 2: Data Management Planning and Control

Data Management Planning	Data Management Control
» Establish best practices for DAM in the DWS and Water Sector	» Enforce best practices for DAM in the DWS and the Water Sector
» Develop, Review and Implement DAM Strategy	» Coordinate Data Governance activities
» Evaluate & Understand Strategic Business Goals (Business Analysis)	» Manage and Resolve data related Needs and Issues
» Update Data Requirements according to Evolving Business Needs	» Communicate, Monitor and Enforce Conformance with Data Policies, Standards and Procedures
» Develop, Review & Approve Data Policies, Standards & Procedures	» Enforce Regulatory Compliance to Data Acquisition, Storage, Archiving, and Dissemination
» Planning and sponsoring of DAM projects and activities	» Oversee DAM Projects and Services
» Negotiations with External Stakeholders for Data Sharing	» Approve and sponsor data management meetings, workshops, etc.

In order to implement the proposed data management planning and control activities, the Input-Activity-Output model as outlined in Figure 3 may be applied.

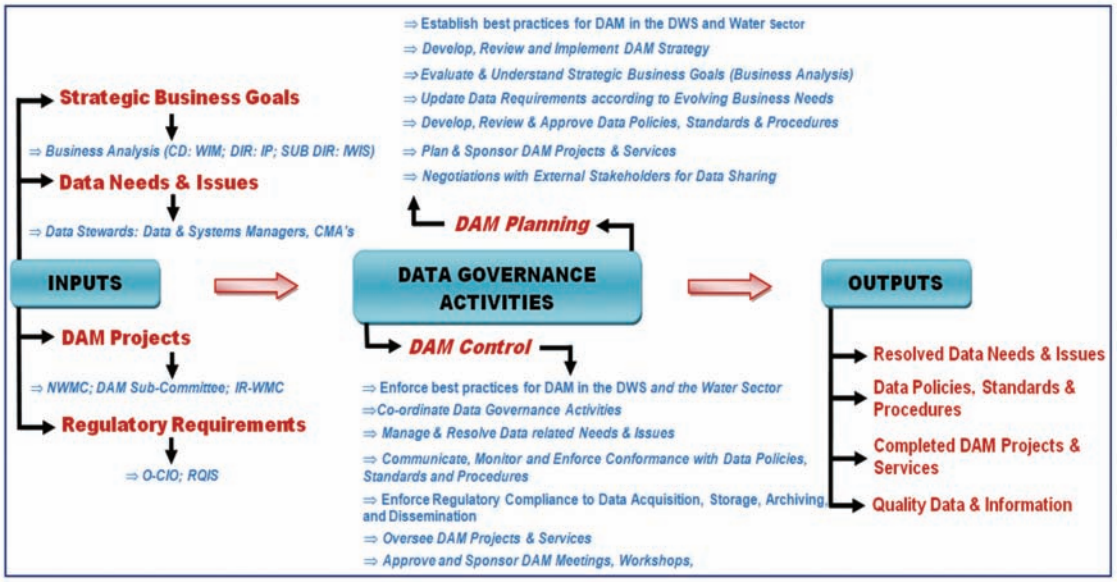

Figure 3: Summary of the Input - Activity - Output Model

Inputs are typically determined by the governing committees and may include activities such as defining and continuously reviewing strategic business goals of the DWS and the water sector (information needs vs. data requirements) (Plummer et al., 2007), continuously identifying and reviewing data needs and issues, planning of DAM projects to address specific data needs and issues, defining and reviewing regulatory requirements, etc.

Activities are also typically determined by the governing committees and may include actions as listed in Figure 3.

Outputs define the business goals of the DWS as well as the water sector. It should clearly outline the expected deliverables of DAM, such as (1) established, approved and enforced data policies, standards and procedures, (2) resolved data needs and issues, (3) successful DAM projects and services, (3) quality data and information (data is available, accessible, timely and secure), etc.

ii) Data Governance Committees

In order to insure that the proposed Input-Activity-Output model is implemented and maintained successfully, Data Governance Committees (DGCs) or working groups may be established. These DGCs may be responsible for overseeing all aspects of DAM activities. The overall objective of the DGCs is to ensure that data is managed strategically, in order to fulfil the business needs. The DGCs should develop, enhance and approve a data governance charter (best practice) and policies; in which the purpose of the data governance, the responsibilities of the committee and the processes involved are documented (ResTech, 2008; Faundeen et al, 2013).

iii) Guiding Principles of Data Governance

The following are the principles that may help stakeholders come together to resolve the various types of current and future data-related needs and issues. (Data Governance Institute, 2015).

» **Integrity:** Data Governance participants should practice integrity with their dealings with each other; they should be truthful and forthcoming when discussing drivers, constraints, options and impacts for data-related decisions.

» **Transparency:** It should be clear to all participants and auditors how and when data-related decisions and controls were introduced into the processes.

» **Auditability:** Data-related decisions, processes, and controls subject to Data Governance will be auditable; they should be accompanied by documentation to support compliance-based and operational auditing requirements.

» **Accountability:** Data Governance should define accountabilities for cross-functional data-related decisions, processes and controls.

» **Standardization:** Data Governance should introduce and support standardization of data acquisition and management.

» **Change Management**: Data Governance should support proactive and reactive Change Management activities.

Establishing a data governance approach improves the synergy between people, systems and technology; which subsequently improves data credibility, availability, accessibility, timeliness and security.

2.2.2 Data Life Cycle Management

Data Life Cycle Management is the process of managing data throughout its life cycle. In order to develop a data life cycle management plan, the following should be completed; viz. evaluation of data requirements, analysis of data life cycles (data generation processes), development of gap analysis, and develop a mitigation plan (Data Life Cycle Management Plan).

i) Data Requirements Specification

Identifying data requirements involves an intensive investigation on the data required to generate information. The investigation should aim to answer questions such as the following:

» Who requires the data?
» Where is the required data?
» What is the required data used for?
» How accurate and/or precise should the required data be?
» How frequent should the required data be updated?
» In what format should the required data be accessed?

ii) Data Life Cycle Analysis

Data life cycle describes the flow of data from acquisition to dissemination. It provides a high-level overview of data, outlining all activities, operations and processes that take place at different stages of data production (Faundeen et al., 2013). Analysing data life cycle helps to achieve the following:

» To clearly identify roles and responsibilities for managing the different processes and activities during data generation.
» To quickly identify root causes of data issues and bottle necks in data acquisition, management and dissemination (Faundeen et. al., 2013).

A data life cycle may be analysed in the following manner:

» Identify the data life cycle stages (acquisition, validation, storage, archiving and dissemination),
» Identify all the processes and procedures associated with each data life cycle stage,
» Identify roles and responsibilities for executing the processes and in each stage, and
» Perform a gap analysis of available vs. required resources (human, financial, etc.).

iii) Gap Analysis

The comparison of the data requirements vs. Data life cycle analysis should lead to a gap analysis report (GAR). In the GAR, all the factors preventing the organisation to meet data requirements and proposed mitigations should be clearly stated.

iv) Data Life Cycle Management Plan

The mitigation plan presented in the GAR is essentially a data life cycle management plan. The developed data life cycle management plan must contribute to improving data credibility, availability, accessibility, timeliness and security. The process for developing the plan is summarised in Figure 7.

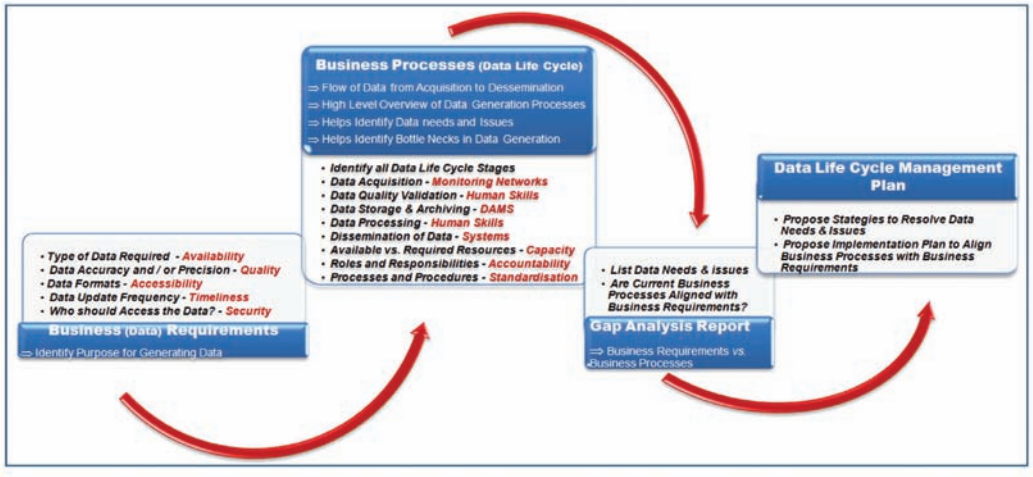

Figure 4: Summary of the Process for Developing a Data Life Cycle Management Plan

2.2.3 Data Management Infrastructure (Systems)

A study of the current electronic systems in the DWS reveals that water information systems (Figure 5) were developed or acquired to support isolated business functional units of the DWS. This has resulted in data duplication, incompatible data formats, multiple unsynchronised reporting, complications due to different IT architecture and technology, etc. A detailed review of the current DMS is thus essential. The main goal of this review is to assess the effectiveness and efficiency of existing DAMS in order to determine whether there is a need to revise or introduce new methods, approaches, technologies and supporting electronic systems.

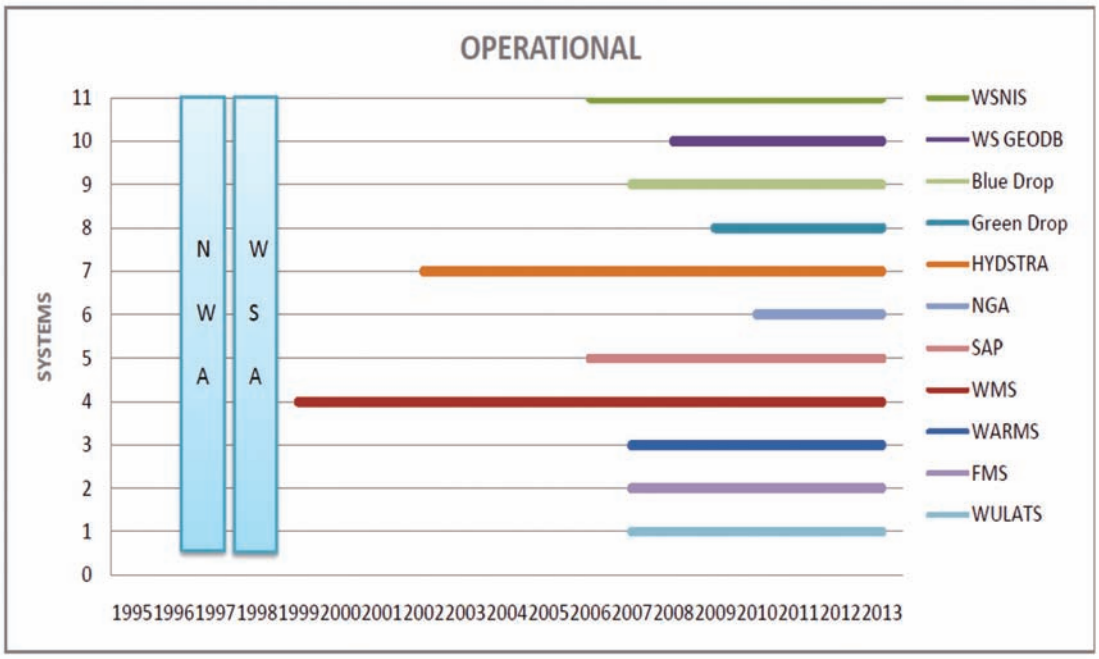

Figure 5: Historical Development of some Major DMSs in the DWS

The proposed framework in Table 3 may be used to conduct a review of how the DAMS currently capture, validate, store, share and disseminate data.

Table 3: Guidelines for Evaluating DMSs

Business Requirements Specification	Information Needs Specification	Data Requirement Specification	Gaps Analysis	Recommendations and Action Plan
» State all Business Requirements.	» Identify Information Required to fulfil Business Requirements	» Identify Data Required to generate required information. » List Data Sources. » Evaluate Current Data Collection Strategy/ Processes. » What is the current data architecture? » Does data fulfil current business requirements? (relevance) » What is the quality of the current data? (Describe missing data, duplications, timeliness, etc.) » Are there any new data sources that could improve quality? » Data Formats?	» List all gaps and deficiencies that affect data Quality, Availability, Accessibility, Security and Timeliness. » List all IT related challenges for publishing the data.	» Propose methods, procedures and technology required to enhance data management systems. » The proposed methods should improve data credibility, availability, accessibility, timeliness and security.

This review enables an organisation to effectively achieve the following NWRS2 goals; build effective and integrated water information dissemination systems to facilitate sharing of data and information, develop a National Data Management Model to coordinate and facilitate the sector wide management of data and information required to populate the national information system(s).

2.2.4 Collaboration and Alignment between Water Sector Stakeholders

» Form Partnerships and Inter-Governmental Cooperation Agreements for Data Sharing.
» Negotiate Data Sharing Agreements.
» Ensure Adherence to Data Sharing Agreements.

3 THE DATA MANAGEMENT STRATEGY RATIONALE

3.1 The Legislative Framework

The development of the Data Management Strategy for Water and Sanitation in RSA is guided by the following legislative framework:

3.1.1 The National Water Act and the Water Services Act

The DWS is mandated by the National Water Act (NWA) No. 36 of 1998 and the Water Services Act (WSA) No. 108 of 1997 (chapter 14 and chapter 10 respectively), to provide useful water related information to decision makers and water practitioners (NWA, 1998) (WSA, 1997). In order to achieve this, the DWS has established various national water information systems which are aimed at assisting decision makers to address the management, use, development, conservation, protection and control of the South African (RSA) water in the most possible sustainable and equitable manner.

Chapter 14, Section 141 of the NWA (1998) stipulates that the Minister may require in writing provision of any data or information from any person for the purposes of any national monitoring network or national informal systems. In pursuance of this requirement the Department has established a number of Memorandum of Understanding or Agreements with several organisations. In spite of this, a number of challenges have arisen including data not being exchanged due to expired agreements or due to lack of clear legislation to provide data on regular basis except in cases where a request has been made by the Minister through the MoU or MoA.

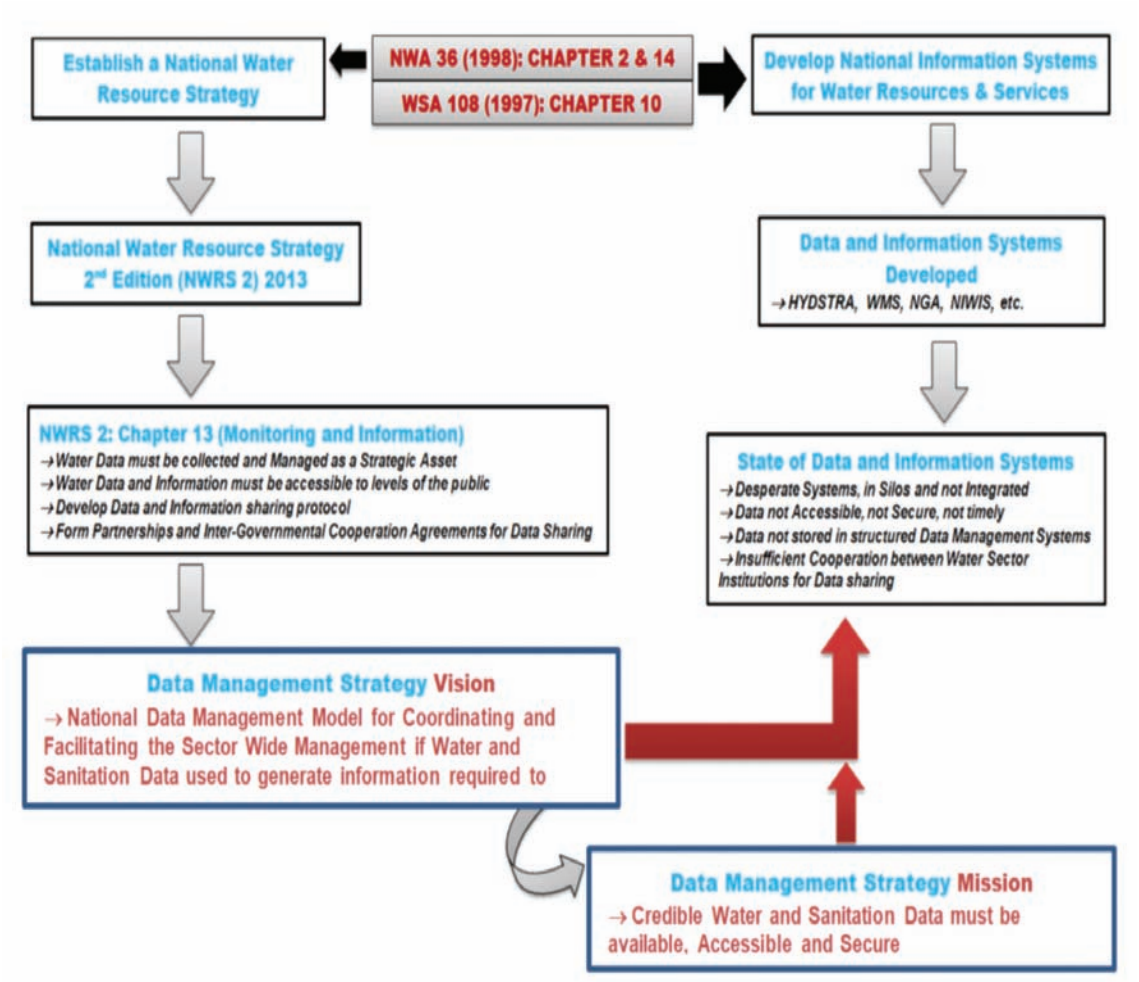

Figure 6: DWS Mandate to Develop the Data Management Strategy

As illustrated in Figure 6, the DWS must develop a Data Management Strategy for Water and Sanitation in order to fulfil the mandates and guidelines from the NWA, the WSA and the NWRS 2.

3.1.2 The National Water Resources Strategy

As illustrated in Figure 6, the second edition of the National Water Resources Strategy (NWRS 2) highlights the urgent need for a well-designed, coordinated and managed programme for collecting, assessing and disseminating data and information on water recorded by all entities in the water sector, including state departments, provincial governments, municipalities, water management institutions and Water Services Authorities and providers, as well as by other water users (NWRS 2, 2013).

3.1.3 The Spatial Data Infrastructure Act

The Spatial Data Infrastructure (SDI) Act 54 of 2003 has the following objectives: Establish the South African Spatial Data Infrastructure (SASDI), establishes the Committee for Spatial Information (CSI), establishes an electronic metadata catalogue, provides for policies, standards and prescriptions to facilitate the sharing of geospatial information, provides for avoidance of duplication of data capture, and appointment and responsibilities of data custodians.

The Data Management Strategy must therefore provide a framework and strategic guidelines for developing national data acquisition and management system/s for collecting, storing, archiving and dissemination of data by all stakeholders in the water and sanitation sectors.

3.1.4 The Protection of Access to Information Act

The aim of the Protection of Access to Information Act (PAIA) of 2000 is to give effect to the constitutional right of access to any information held by the state and any information that is held by another person and that is required for the exercise or protection of any rights; in order to foster a culture of transparency and accountability in public and private bodies by giving effect to the right of access to information and to actively promote a society in which the people of South Africa have effective access to information to enable them to more fully exercise and protect all of their rights.

The Data Management Strategy model should therefore ensure that all water and sanitation data is readily available and accessible to the right stakeholders at the right time, in a secure manner.

3.1.5 The DWS Master Plan

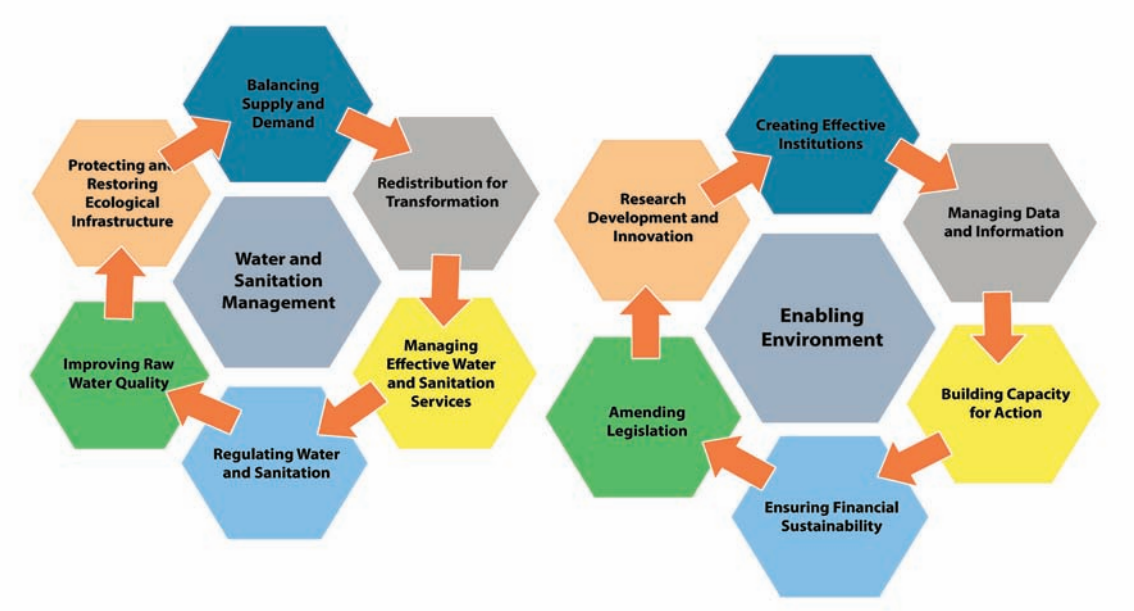

Figure 7: Objectives of and enabling Environment for the DWS Master Plan

As shown in Figure 7, the DWS Master Plan states that having an effective and efficient data and information management program is one of the key enabling environments for successful water and sanitation resource management. Hence, the Data Management Strategy is aimed at improving data acquisition and management in the DWS and the water and sanitation sectors; which is a mandate from the DWS Master Plan.

3.2 The Data Management Strategy Alignment with other Strategies and Policies

The Department of Water and Sanitation (DWS) is currently in the process of developing various policies and strategies. They include the National Groundwater Strategy (NGS), the Wetlands Policy and Strategy, the Integrated Water Quality Management (IWQM) Strategy, the Knowledge Management Strategy (KMS) and the DWS Master Plan.

As indicated in Figure 8, all the policies and strategies mentioned above have sections that aim to address issues related to data acquisition and management. The Data Management Strategy may thus become the main reference when addressing issues related to data acquisition and management when developing and implementing the other policies and strategies in the DWS.

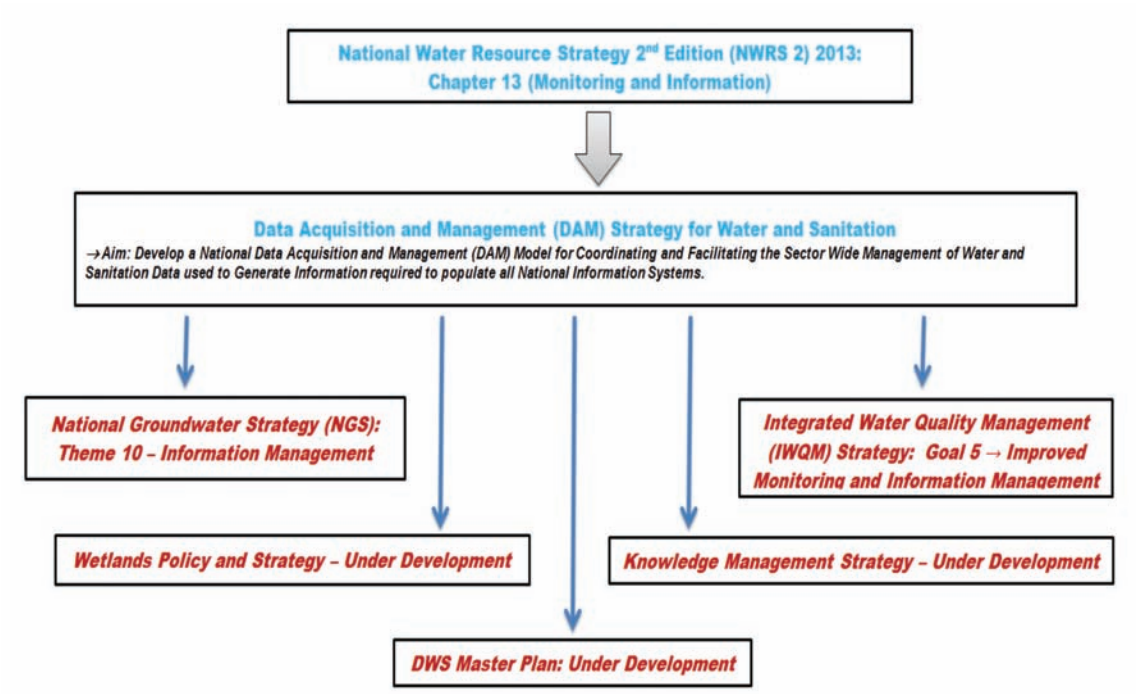

Figure 8: Alignment between the Data Management Strategy and other Policies and Strategies

3.3 Problem Statement

- Due to the large number of both internal and external data sources, numerous silos of data from various functional areas exist. The data extracted from the different sources is stored using different formats. As a result, data is fragmented, disintegrated and not easily accessible, making it time consuming and costly for water managers to use it for decision making.
- There exist data that is stored in personal computers within the DWS, making it not easily accessible and may compromise the security of critical and sensitive data. Hence, there is a need to develop data management systems for such data or transfer the data to relevant databases.
- Some business units in the DWS do not have strategies in place to plan and implement the monitoring, measurement, analysis and improvement processes to continually improve the effectiveness of data quality management systems; as mandated by Section 7.6 (Control of Monitoring and Measuring Equipment) of the national quality standards.
- Standard procedures for data acquisition, storage, archiving and dissemination are either not available or not enforced by the relevant business units within the DWS.
- There exists no clear data architecture for the data stored in the various data management systems in the DWS.
- The DWS currently has insufficient collaboration and agreements with external institutions in the South African water sector for the purpose of data sharing. As a result there exists data collected by consultants and other external institutions that is inaccessible to the DWS.

4 VISION, MISSION AND OBJECTIVES OF THE DATA MANAGEMENT STRATEGY

The vision, mission and objectives of the Data Management Strategy for water and sanitation in RSA is summarised in figure 3.

Figure 9: Vision, Mission and Objectives of the Data Management Strategy

4.1 Vision

To develop a national data management model that will be used to coordinate and facilitate the sector wide management of data and information required to populate the national information systems.

4.2 Mission

To develop strategic guidelines and framework for data management in water and sanitation in order to improve the authoritativeness, availability, accessibility, timeliness, and the security of water and sanitation data.

Data **authoritativeness** ensures that water related data is accurate so as to o provide accurate assessment of the status of water resources and sanitation services for decision makers.

Data **availability** is the degree to which data can be instantly accessed. Data timeliness leads to timely decision making on water related matters.

Data **accessibility** ensures that data is presented in formats that make data easy to retrieve in order to generate information in a timely manner.

Data **timeliness** leads to timely dissemination of information that is used for decision making.

Data **security** ensures that security measures are in place and enforced to protect data from unauthorised access.

4.3 Objectives

As discussed in section 4, the main pillars for efficient and effective data acquisition and management have been identified as follows;

- Data Governance,
- Data Life Cycle Management,
- Data Management Systems, and
- Alignment between stakeholders in the water and sanitation sectors.

It has therefore been concluded that enhancing the main pillars of data acquisition and management should improve the authoritativeness, availability, accessibility, timeliness and security of data.

Hence, the objective of the Data Management Strategy is to develop and implement methods and procedures to enhance data governance, data life cycle management, data management infrastructure and alignment between stakeholders in the water and sanitation sectors.

5 REVIEW OF THE STATE OF DATA MANAGEMENT IN WATER AND SANITATION

In previous section, the four main pillars of Data Management have been discussed. It is thus proposed that in order to improve data acquisition and management, these pillars must be reviewed for the DWS. The aim of the review is to identify gaps, make recommendations for filling the gaps, and prescribe action plan for implementing the recommendations. The outcome of this review is used to develop a Data Management Model for water and sanitation in RSA.

The following methodology has been followed for reviewing the four main pillars of Data Management.

- **Firstly, perform a review of the following:**
  - The business requirements of the DWS,
  - The information needs for fulfilling business requirements in the DWS, and
  - Data required for generating the needed information used for decision making.

The purpose of this review is to identify and list all the factors that drive the water and sanitation business in the DWS, the information needed to meet the business needs and the data required for generating information.

- Secondly, perform a review of the four main pillars of Data Management.

The purpose of this review is to identify gaps in current methods and approaches, make recommendations for filling the gaps, and prescribe action plans for implementing the recommendations.

5.1 Review of Business Requirements, Information Needs and Data Requirements in the DWS

The review process is described as follows:

- **Review of Water and Sanitation Business Requirements and Information Needs**
  - Conduct a review of all data required to generate the information required to meet business needs by means of consultation with key DWS stakeholders at the Head Office as well as the satellite regional offices. External stakeholders may be consulted. The data requirements information includes the following:

- **Review of Water and Sanitation Data Requirements**
  - » Conduct a review of all data required to generate the information required to meet business needs by means of consultation with key DWS stakeholders at the head office as well as the satellite regional offices. External stakeholders may be consulted. The data requirements information includes the following;
    - » Data type,
    - » Data source,
    - » Methods and approaches used to collect, store, archive and disseminate the data,
    - » Roles and Responsibilities when collecting, storing, archiving and disseminating the data, etc.

5.2 Review of the Pillars of Data Management in the DWS

After reviewing the water and sanitation business requirements, information needs and data requirements, the four main pillars of data management may be reviewed. The review process is described as follows;

5.2.1 Review of the Data Governance in the DWS

Data governance provides rules, decision rights and accountability when making data management decisions. Improved data governance should lead to better decision making and transparency when resolving data related issues. It should also lead to the adoption of common approaches to resolving data related needs and issues.

The aim of this part of the review is to identify current data governance practices in the DWS, identify gaps in the current practices, make recommendations for filling the gaps, and prescribe action plan for implementing the recommendations.

5.2.2 Review of the Data Life Cycle Management in the DWS

In this discussion, data life cycle management refers to the management of the methods used to collect, validate, store, archive, process and disseminate water and sanitation data. Data life cycle management ensures that data is available when required, is fit for purpose (credible) and timely.

The aim of the review is to identify gaps (gap analysis) in the methods used to collect, validate, store, archive, process and disseminate data; make recommendations for filling the gaps, and prescribe action plans for implementing the recommendations.

5.2.3 Review of the Data Management Systems in the DWS

Data management systems refer to systems or data sources that are used to acquire, store, archive and disseminate water and sanitation data. These systems ensure that data is available, accessible and secure.

The aim of this part of the review is to identify gaps (gap analysis) in the performance of the data sources, make recommendations for filling the gaps, and prescribe action plans for implementing the recommendations.

5.2.4 Review of Alignment between the DWS and Key Stakeholders

External institutions are those institutions in the water and sanitation sectors that are collecting, acquiring and managing water and sanitation related data.

The aim of this part of the review is to identify these institutions and the data they possess, make recommendations on how to improve access to their data, and prescribe action plan/s for implementing the recommendations.

5.2 The Scope for the Review Process in the Context of the DWS

The review process described in sections 5.1 and 5.2 has been applied on the following categories of data in the DWS; viz. Hydrology and Geohydrology Water Quality Data as well as Hydrology and Geohydrology Water Quantity Data. It is illustrated in Figure 10.

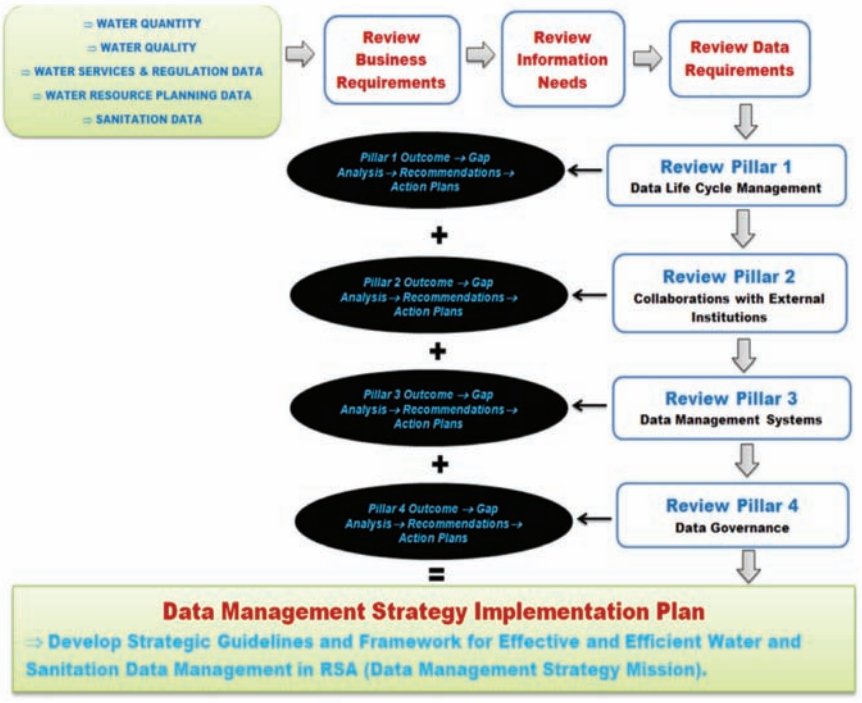

Figure 10: Methodology used to develop the Data Management Strategy

The outcome of the review of the state of Data Management in RSA is presented in Appendix A. The proposed mitigation is presented in section 6, as follows;

6 THE PROPOSED MITIGATION FOR DATA MANAGEMENT IN WATER AND SANITATION

6.1 Data Governance Program: Who should do What, When and How?

In summary, the outcome of the review of data governance for Hydrological and Geohydrological (quality and quantity) data in Appendix A revealed that there is insufficient leadership and accountability for data management within the DWS and the water sector as a whole, resulting in the following critical issues:

- Uncoordinated data acquisition and management.
- Lack of common approaches for resolving data needs and issues.
- Lack of standard, repeatable processes for generating and disseminating water and sanitation data.
- Duplication of functions between the DWS and other stakeholders in the water and sanitation sectors.

In order to improve the coordination of data management in the water and sanitation sectors, the proposed Data Management Strategy Model proposes that the DWS, as a sector leader, must establish a data governance program. The aim of this program is to improve decision making and accountability in the execution of DAM processes.

6.1.1 Data Governance Committees for Water and Sanitation

As discussed in section 6, a typical data governance program is made up of data governance committees responsible for managing the planning and control activities in data acquisition and management. The Data Management Strategy Model thus proposes that the data governance program to be established by the DWS be made up of two main committees, i.e. the Data Management Planning Committee (DM-PC) and the Data Control Committees (DM-CC).

- The purpose of the DM-PC should be to execute the following Data Management planning activities:
  - Establish best practices (charter) for Data Management in water and sanitation.
  - Evaluate and continuously update DWS Strategic Business Goals (Business Analysis), Information needs and data requirements and communicate it to the IR-WMCs and the Data Management committees.
  - Develop, review and update Data Management strategies, policies, standards and procedures.

- Regularly communicate Data Management strategies, policies, standard and procedures to the IR-WMCs, the Catchment Management Agencies (CMAs), Data Management committees and all relevant government institutions.
- Plan and execute data acquisition and management projects.
- Establish agreements with key stakeholders in the water and sanitation sectors for data sharing.

» The purpose of the DM-CC should be to execute the following Data Management control activities:

- Coordinate all data management processes within the DWS and its satellite regional offices in order to enforce best practice.
- Enforce regulatory compliance to data acquisition, storage, archiving, and dissemination.
- Communicate, monitor and enforce conformance with data policies, standards and procedures
- Develop and ensure implementation of common approaches for resolving data needs and issues in the DWS.
- Develop and ensure implementation of standard, repeatable processes for generating and disseminating water and sanitation data.
- Enforce the collection of data from key stakeholders in line with data sharing agreements.

If a data governance approach is developed, it will alleviate the data related issue revealed when assessing the state of Data Management in the DWS. Data governance for the DWS will ensure accountability by answering the following important question in DAM.

Who should do What, When and How?

6.2 Data Life Cycle Management Plan: Right Resources at Right Place in the Right Time

In summary, the outcome of the review of data life cycle management for Hydrological and Geohydrological (quality and quantity) data in Appendix A revealed the following critical issues:

- Insufficient human resources to execute the data life cycle management processes.
- Insufficient budget for procuring monitoring instrumentation.
- Delays procurement of monitoring instrumentation and renewal of laboratory contracts.
- Vandalism of monitoring instrumentation and lack of access to private land.
- Water quality and quantity data stored into data management systems with errors.
- Data collected by consultants not accessible.
- Lack of adequate data collection skills at municipalities.

To improve the effectiveness and efficiency of data acquisition and management in water and sanitation, it is therefore imperative that strategic data life cycle management plans be developed for the different types of water quality and quantity data used. The data life cycle management

plans will ensure effective and efficient use of available resources to ensure that data is available, credible, accessible, secure and timely.

6.2.1 Data Life Cycle Management Planning

The Data Management Model proposes the following criteria for developing data management plans for both hydrological and geo-hydrological data:

- Update DWS Business Requirements (e.g. managing floods and droughts)
  - Who requires the data? (E.g. disaster management? public? research Institution?)
  - Where is the source of the required data? (E.g. DWS? external institutions?)
  - How accurate and/or precise should the required data be? (E.g. standards)
  - How frequent should the required data be updated? (E.g. hourly, daily, monthly, etc.)
  - In what format should the required data be accessed? (E.g. spread sheets, web, secure data management systems, etc.)
- Generate a gap analysis (required vs. available resources) report highlighting gaps in current data life cycle planning, recommendations for filling gaps and mitigation plan for implementing the recommendations.

The process for developing a data life cycle management plan is summarised in Figure 10;

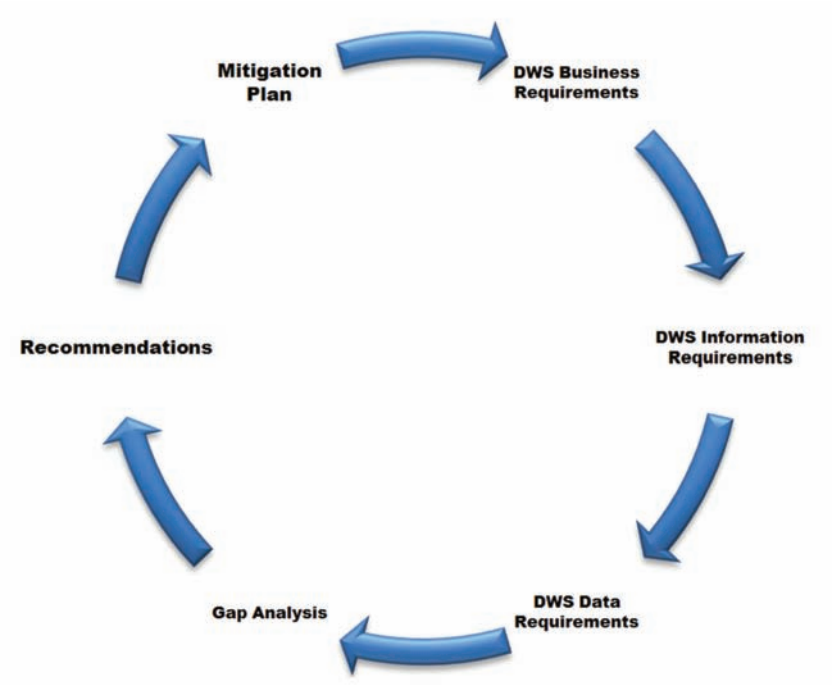

Figure 11: Data Life Cycle Management Development Process

If data management plans are developed and updated regularly, they will alleviate the data related issue revealed when assessing the state of Data Management in the DWS. Data life cycle management planning will help identify areas where human resources, skills and budget should be prioritised; thus enabling the DWS to make efficient and effective use of the minimum available resources.

Right Resources in the Right Place at the Right Time.

6.3 Data Management Systems

In summary, the outcome of the review of Data Management Systems (DMSs) for hydrological and geo-hydrological (quality and quantity) data in section 6 revealed the following critical issues:

- Fragmented DMSs used to manage water quality and quantity data.
- Some water quality and quantity data not stored in structured data management Systems.
- Lack of structured DMS for wetlands water quality and quantity data.
- Underutilisation and none utilisation of the WMS.z
- Most water quality and quantity data Management systems are not current.

In order to improve the effectiveness and efficiency of data management systems in water and sanitation, the Data Management Model proposes the following:

- Develop and integrated approach for managing the many data management systems in the DWS, and/or
- Develop a single national platform or data management system for Hydrological and Geo-hydrological (quality and quantity) in the DWS.

6.3.1 Integration of the Data Management Systems

In order to improve data accessibility and security, it is recommended that an integrated approach or method to efficiently and effectively manage the data management systems in the DWS be developed. The main aim of this exercise should be to develop single platforms for managing data in various focus areas in water and sanitation sector.

An integrated approach to the management of data systems makes it possible to access data stored in separate systems in a timely manner, while a single platform for integrated data makes it easy to locate access and disseminate data. Integration of DMSs and creating a single platform eliminates fragmentation of DMSs, underutilisation of some DMSs, lack of DMSs for some data, etc.

According to the United States Geological Survey (USGS), In order to achieve this, the following requirements are to be taken into consideration and investigated (Ladimo CC, 2013):

- **Data uploading:** User-friendly interfaces for storing and archiving different type of data, potentially in various formats must be designed. A data uploading tool needs database structure and database management system software to store, organize, and provide access to datasets. Additionally, an intuitive nontechnical graphical interface is needed to allow interaction between data producers and the database.

- **Data searching:** A data search engine, a graphical interface for finding and obtaining copies of datasets in the data repository must be designed. The components of a data search engine needs to include functionality for querying the data repository and functionality for allowing users to obtain a copy of the stored data.
- **Long term use:** The system must be designed to manage data for long term use to maintain data availability, integrity and security for an indefinite length of time. The system must be designed to cope with degradation of hardware with constant use over a relatively short period of time. Additionally, to protect from malicious acts, the system must be designed to have a user account system that keeps track of who uploads and modifies data.
- **Integrating Data Management Systems into one Platform:** The system must be capable of accepting data collected by other key stakeholder in the water and sanitation sectors. To avoid overwhelming the system, it must be capable of using web links to stakeholder databases and other systems within the DWS.

In view of the above mentioned complexities and challenges associated with developing a single platform or system for storing, archiving and disseminating data, careful planning is required to avoid developing a system that will overtime become redundant and unstable.

The Data Management Model therefore proposes that a project be initiated to investigate the risks associated with developing the single structured data management system as well as the costs implications. An Investigation on the feasibility of storing time series data in the single structured data management system using different software in different formats should be conducted.

6.4 Alignment with all Water and Sanitation Stakeholders

The review led to the identification of the following institutions for data and infrastructure sharing opportunities; the Komati Basin Water Authority (KOBWA), ESKOM, SASOL, Counsel for Scientific and Industrial research (CSIR), Agricultural Research Counsel (ARC), South African Weather Services (SAWS), Department of Environmental Affairs (DEA), Water Research Centre (WRC), Working for Wetlands, Department of Agriculture, Forestry and Fisheries (DAFF), South African National Biodiversity Institute (SANBI), Municipalities, Water boards, and South African National Parks (SANParks).

6.4.1 National Legislation for Data, Infrastructure and Skills Transfer

The current trend for executing data and infrastructure sharing amongst stakeholders is the establishment of Memoranda of Understandings (MoU) and Memoranda of Agreements (MoA). These approaches have thus far proven to be ineffective.

Hence, in order to promote and enforce data, infrastructure and skills sharing amongst stakeholders, the DWS should take the lead in establishing a legally binding legislation that will act as a national technical, institutional and policy framework to facilitate the capture, management, maintenance, integration, distribution and use of water and sanitation data.

The aim of the legislation should be to achieve the following:

- Facilitate the capture of water and sanitation data through co-operation and in collaboration with all water and sanitation stakeholders in RSA.
- Promote effective management and maintenance of water and sanitation data in RSA.
- Promote the use and sharing of water and sanitation data in support of water resource management, socio-economic development and related activities in RSA.
- Create an environment which facilitates co-ordination and co-operation among all stakeholders regarding access to water and sanitation data in RSA.
- Minimise duplication in the capturing of water and sanitation data.
- Promote universal access to water and sanitation data.
- Facilitate the protection of the copyright of the state in works relating to water and sanitation data.

7 THE PROPOSED DATA MANAGEMENT STRATEGY FOR WATER AND SANITATION IN RSA

The aim of the Data Management Strategy is to develop a national data acquisition and management model to be used to coordinate and facilitate the sector wide management of data and information required to populate the national information systems. This should be achieved by developing strategic guidelines and framework for Data Management in water and sanitation that should improve the authoritativeness, availability, accessibility, timeliness, and the security of water and sanitation data. Hence, the objectives of the Data Management Strategy are to develop and implement methods and procedures to enhance the main pillars of DAM, viz. data governance, data life cycle management, data management systems and collaboration amongst stakeholders in the water and sanitation sectors.

The review of the state of Data Management in the DWS revealed a number of data related issues as and leads to a number of proposals to resolve the issues. In order to apply the proposed measures (section 8) for resolving the data related issues discussed in section 7, the following Data Management Model is proposed:

1) Establish/Amend national legislation/policies for data, infrastructure and skills sharing amongst all the stakeholders in water and sanitation.

2) Establish Departmental and sector wide data governance programs for all planning and control activities in water and sanitation data acquisition and management.

3) Develop an integrated and interoperable data management infrastructure or approach that will provide a single platform to access water and sanitation data.

4) Strengthen Collaboration amongst Water and Sanitation Stakeholders for data, infrastructure and skills transfer.

7.1 Establish a National Legislation for Data, Infrastructure and Skills Transfer

In order to promote and enforce data, infrastructure and skills sharing amongst stakeholders, the DWS should take the lead in establishing a legally binding legislation that will act as a national

technical, institutional and policy framework to facilitate the capture, management, maintenance, integration, distribution and use of water and sanitation data.

7.2 Establish Departmental and Sector wide Data Governance Programs

As a sector leader, the DWS should establish a data governance program that will ensure that all planning and control activities in data acquisition and management for water and sanitation are carried out effectively and efficiently. Within the DWS, the planning and control activities include ensuring that data life cycle management plans are developed and implemented. The planning and control activities should also include those used for data, infrastructure and skills sharing amongst stakeholders in water and sanitation.

7.3 Develop Integrated and Interoperable Data Management Infrastructure

An integrated approach or method to efficiently and effectively manage data management data must be developed for the water sector as a whole, leading to the development of a single platform or an integrated and interoperable data management portal for the various focus areas in water and sanitation management.

7.4 Strengthen Collaborations amongst Water and Sanitation Stakeholders

Memoranda of understanding and of agreement must be established and strengthened between all stakeholders in water and sanitation.

7.5 The Proposed Data Management Strategy Model for Water and Sanitation in RSA

Figure 12 is a presentation of the proposed DAM model for water and sanitation in RSA. The model can be summarised as follows;

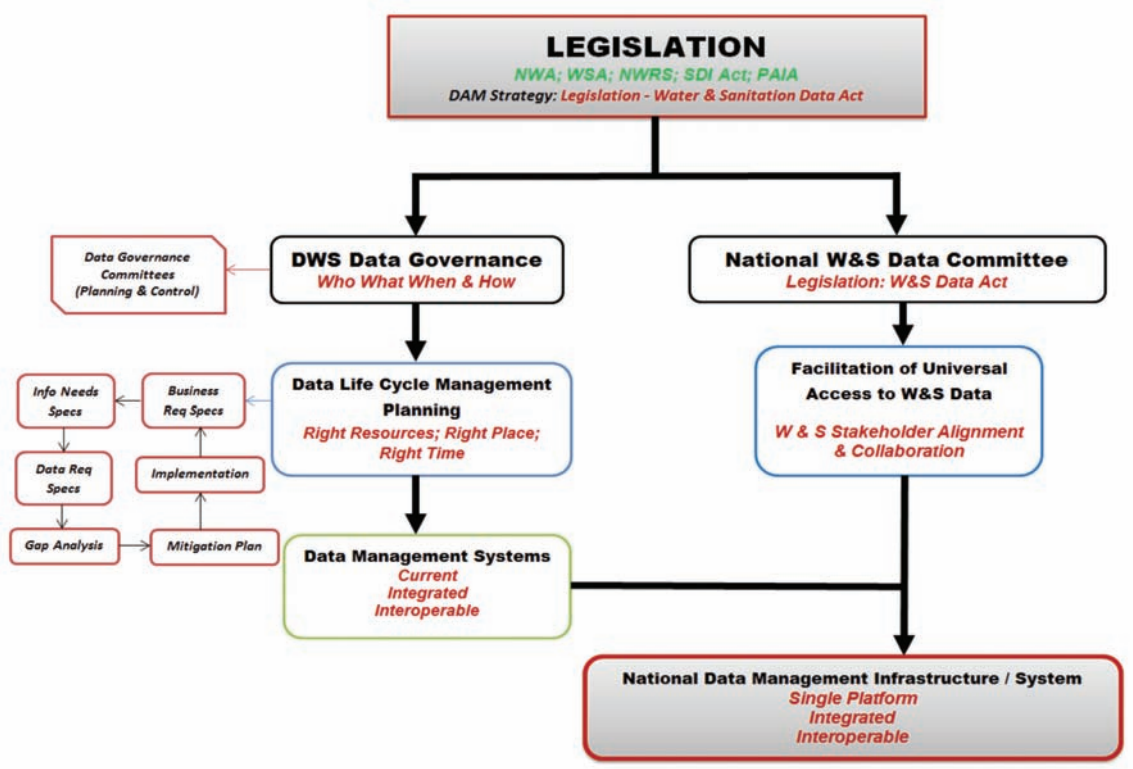

Figure 12: The Proposed Model for Data Management for Water and Sanitation

- The water and sanitation sector should establish legislation for water and sanitation data, infrastructure and skills transfer; which should lead to the establishment of a national water and sanitation data committee.
- The national water and sanitation data committee should facilitate universal access to data.
- The DWS should establish a data governance program made up of data governance committees responsible for monitoring planning and control activities in data acquisition and management.
- The planning and control activities for the DWS include data life cycle management planning and ensuring the data management systems are current, integrated and interoperable.
- The DWS Governance committees and the National water and sanitation data committee should cooperate to develop an integrated and interoperable National Data management Infrastructure or System that will provide a single platform for water and sanitation data acquisition and management.

8 IMPLEMENTATION OF THE DATA MANAGEMENT STRATEGY

It is proposed that the implementation of the Data Management Strategy be executed in alignment with the Sustainable Development Goal 6 (SDG 6), the National Water Act (NWA) No. 36 of 1998 as well as the National Sanitation Policy (NSP) of 2016, as follows:

8.1 Data Management Strategy Implementation in alignment with the SDG 6

Since managing data and information is listed as one the enablers for water and sanitation management in the DWS master plan, it is proposed that the Data Management Strategy be utilised as the main tool for achieving the data management objectives in the master plan. Furthermore, since the Sustainable Development Goal 6 (SDG 6) is one of the main drivers of the Master Plan, the Sustainable Development Goals (SDGs) target indicators will be used as focus areas for the DAM Strategy when developing a roll out plan as well as the implementation plan.

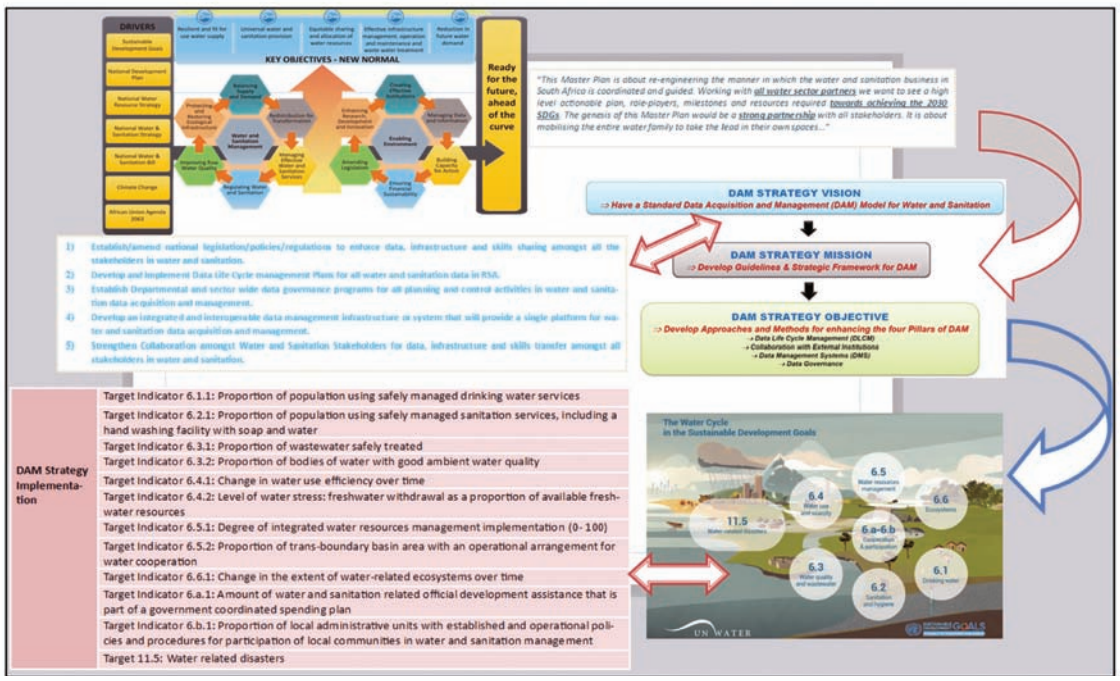

Figure 13: Link between the Data Management Strategy, the Master Plan and the SDGs

As summarised in figure 13, during the implementation phase of the Data Management Strategy, it is proposed that the following SDG 6 target indicators be used as focus areas for applying the Data Management Strategy recommendations:;

- **Target Indicator 6.1.1**

  Proportion of population using safely managed drinking water services.

- **Target Indicator 6.2.1**

  Proportion of population using safely managed sanitation services, including a hand washing facility with soap and water.

- **Target Indicator 6.3.1**

  Proportion of wastewater safely treated.

- **Target Indicator 6.3.2**

  Proportion of bodies of water with good ambient water quality.

- **Target Indicator 6.4.1**

  Change in water use efficiency over time.

- **Target Indicator 6.4.2**

  Level of water stress: freshwater withdrawal as a proportion of available freshwater resources.

- **Target Indicator 6.5.1**

  Degree of integrated water resources management implementation (0- 100).

- **Target Indicator 6.5.2**

  Proportion of trans-boundary basin area with an operational arrangement for water cooperation.

- **Target Indicator 6.6.1**

  Change in the extent of water-related ecosystems over time.

- **Target Indicator 6.a.1**

  Amount of water and sanitation related official development assistance that is part of a government coordinated spending plan.

- **Target Indicator 6.b.1**

  Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management.

- **Target 11.5**

  Water related disasters.

8.2 Data Management Strategy Implementation in alignment with the NWA No. 36 of 1998

The NWRS 2 proposes that in order to fulfil some of the objectives of NWA No. 36 of 1998, a well-designed, coordinated and managed programme for collecting, assessing and disseminating data and information on water recorded by all entities in the water sector must be developed. The objective of this programme should be to compile and maintain easily accessible accurate data to support decision making, reduce and manage risks and deal with emerging climate change impacts.

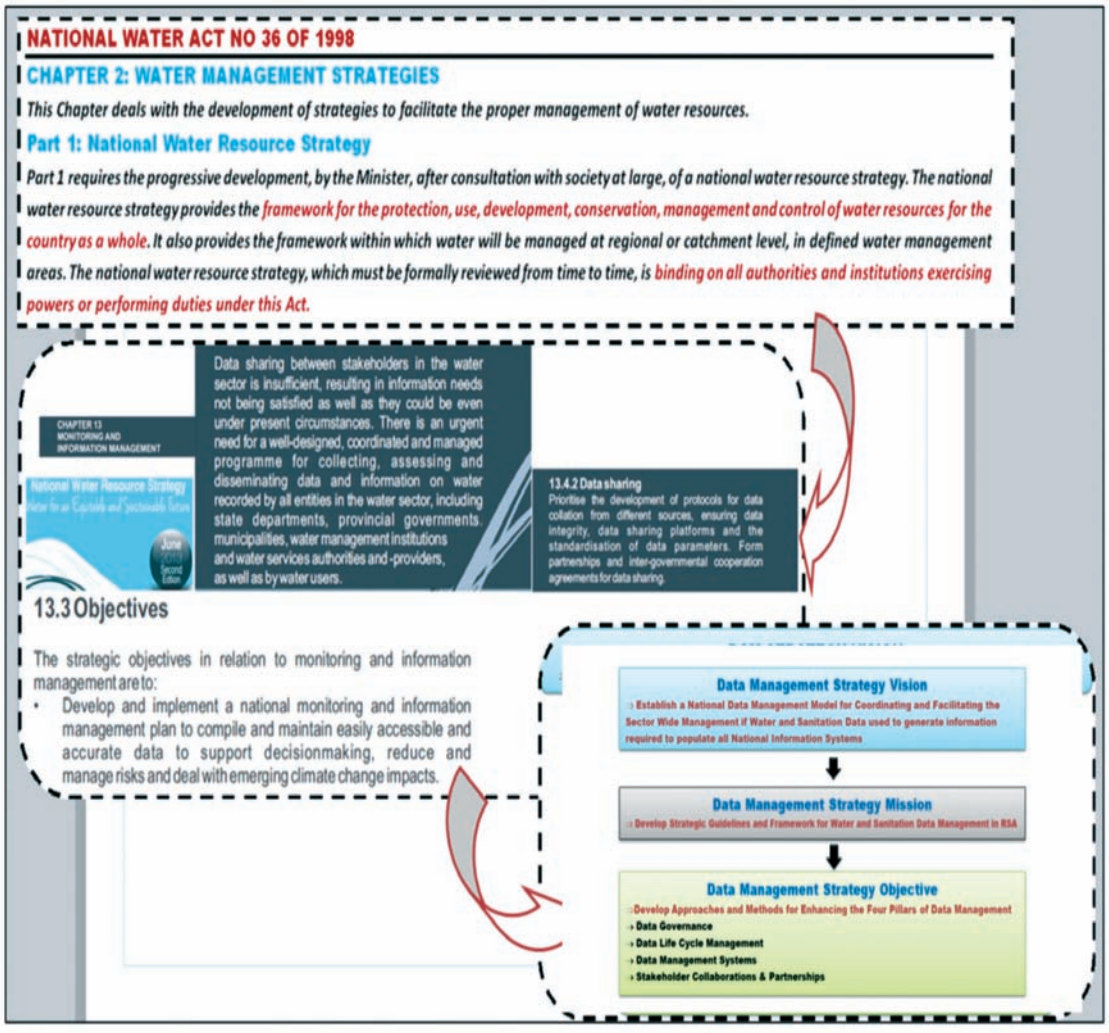

Figure 14: Link between the Data Management Strategy and the Objectives of the NWA No. 36 0f 1998

The Data Management Strategy has thus been developed and as shown in figure 14 and its recommendations will be applied on the following NWA focus areas;

- **Chapter 3: Protection of Water Resources**
  Part 1: Classification system for water resources
  Part 2: Classification of water resources and resource quality objectives
  Part 3: The Reserve
  Part 4: Pollution prevention
  Part 5: Emergency incidents
- **Chapter 4: Use of Water**
  Part 2: Considerations, conditions and essential requirements of general authorisations and licences
  Part 3: Existing lawful water uses
  Part 4: Stream flow reduction activities
  Part 5: Controlled activities
  Part 6: General authorisations
  Part 7: Individual applications for licences
  Part 8: Compulsory licences for water use in respect of specific resource
  Part 9: Review and renewal of licences, and amendment and substitution of conditions of licences
  Part 10: Contravention of or failure to comply with authorisations
- **Chapter 5: Financial Provisions**
  Part 1: Water use charges
- **Chapter 10: International Water Management**
- **Chapter 11: Government Waterworks**
  Environmental Impact assessments
  Water from government waterworks
  Access to and use of government waterworks for recreational purposes
- **Chapter 12: Safety of Dams**
  Control measures for dam with safety risk
  Responsibilities of approved professional persons
  Registration of dam with safety risk
  Factors to be considered in declaring dam or category of dams with safety risk
  Regulations regarding dam safety
- **Chapter 14: Monitoring, Assessment and Information**
  Part 1: National monitoring systems
  Part 2: National information systems on water resources
  Part 3: Information on flood-lines, floods and droughts

9 THE ROLE OF ARTIFICIAL INTELLIGENCE IN WATER RESOURCE MANAGEMENT

Currently, monitoring water resources requires the use of analytical tools and methods, consideration of a number of parameters, human and financial resources to acquire data, human and financial resources to establish and maintain monitoring networks, etc. As a result, water resource monitoring has become costly, resulting in decreasing monitoring networks over time. The time it takes to complete the value chain from data collection to decision making has become longer, leading to deteriorating quality of water resources management. Due to these constraints, the development of data mining-based models in conjunction with the development of Decision Support Systems (DSS) seems to be a better alternative for the management processes of water resources, leading to an era of Knowledge Discovery from Databases (KDD) (Couto et al. 2012).

Several innovative computational intelligence approaches have been used to and patterns in water quality databases, such as Artifcial Neural Networks (ANNs) and Decision Trees (DTs). The analysis and development of forecast models, based on Artifcial Intelligence-based tools and the new methodologies for problem solving, has proven to be an alternative, having in mind a pro-active behaviour that may contribute decisively to diagnose, preserve, and rehabilitate the water reservoirs (Couto et al. 2012). For example, in their case study, Dawood et al. developed Neural Networks Models for the prediction of monthly values of the two water quality parameters, electrical conductivity and turbidity at selected monitoring points along a river reach. According to their results, they concluded that the Neural Network models can be used for the prediction of water quality parameters (Dawood et al. 2016).

There currently is a growing need for predictive capability to effectively and efficiently manage water resources. It has been reported that Artificial Intelligence (AI) advancements such as Artificial Neural Networks (ANN), Genetic Algorithms (GA) and Machine Learning (ML) will offer the water sector substantial benefits. According to Hill 2017, some of the questions that may be answered by AI in water resources management are as follows (Hill 2017):

Water Infrastructure Management: Can we maximize the concept of just-in-time infrastructure? Can we identify where the next budget should be spent, based on growth, age of infrastructure, condition of existing infrastructure, the environment of existing infrastructure, the potential for public health crises or other data points? In other words, can we make 1, 2, 5, 10, 25 and 50 year plans that are correct and continuously updated?

Water Demand vs. Supply: Can we use real-time water availability signals and dynamic intra-day pricing as alternatives to increased supply? By engaging and informing our customers about water supply crises with resource availability data, influencing their behaviour with time-of-use rate structures and offering the tools to manage both demand and customer costs, can we offset

the requirement to seek higher cost supply alternatives such as desalination or direct-to-potable reuse?

Water Quality Management: Can we use hydraulic modelling, piping properties, soil characteristics, pressure and flow data and low cost sensors strategically placed throughout the distribution to create a real-time, optimized water quality model to minimize chemical usage and maximize water quality?

Water Tariffs: Can we predict how our customers are reacting to current economic conditions using consumer confidence, localized jobless rates, census and other demographic data? Can we use that information to predict if new or standby payment procedures should be implemented? Can we become an agent of positivity by establishing a finely tuned usage-payment program for our customers?

Disaster Management: Can we use climate, weather, demand and demographic data to predict water related hazards?

In preparation for the future use of AI to manage water resources in RSA, the DWS as the sector leader must investigate areas in water resource management, particularly data acquisition and management where AI may be employed. In other words there must be an understanding of the basic nature of the problem to be solved. As Hill 2017 further recommended for the water sector, the DWS must ensure that adequately sized, validated data is available in order to apply AI in water resource management (Hill 2017).

10 CONCLUSION

The vision for the Data Management Strategy is for the water and sanitation sector to have a national Data Management Model that will be used to coordinate and facilitate access to sector wide management of data and information required to populate the national information systems. The mission of the Data Management Strategy is to develop strategic guidelines and framework for data acquisition and management in water and sanitation in order to improve the credibility, availability, accessibility, timeliness, and the security of water and sanitation data. The Data Management Strategy's objectives are therefore to develop and implement methods and procedures to strengthen the four pillars of data acquisition and management; viz. data governance, data life cycle management, data management systems and collaboration amongst stakeholders in the water and sanitation sectors.

The state of Data Management in the DWS has been evaluated and the following main data related challenges have been identified; uncoordinated Data Management in the DWS, lack of common approaches for resolving data needs and issues, duplication of functions between the DWS and other stakeholders in the water and sanitation sectors, water quality and quantity data stored into data management systems with errors, fragmented DMSs used to manage water quality and quantity data, water quality and quantity data not stored in structured data management Systems, underutilisation and none utilisation of the WMS, most water quality and quantity data Management systems are not current, lack of collaboration with external institutions for data and infrastructure sharing.

To resolve or alleviate the above challenges, the Data Management Strategy proposes the following model for Data Management for water and sanitation in the RSA:

Establish/amend national legislation/policies/regulations to enforce data, infrastructure and skills sharing amongst all the stakeholders in water and sanitation.

Establish Departmental and sector wide data governance programs for all planning and control activities in water and sanitation data acquisition and management.

Develop Data Life Cycle Management plans (standard operating procedures) for all Water and Sanitation Data.

Develop an integrated and interoperable data management infrastructure/ portal that will provide access to water and sanitation data for integrated reporting and populating national data information systems.

Strengthen Collaboration amongst Water and Sanitation Stakeholders for data, infrastructure and skills transfer.

In order to fulfil some of the objectives in the NWA No. 36 of 1998, the Data Management Strategy recommendation will be applied to the following focus areas; protection of water resources (chapter 3), water use (chapter 4), financial provisions (chapter 5), international water management (chapter 10), government waterworks (chapter 11), dam safety (chapter 12), and monitoring, assessment and information (chapter 14).

In preparation for the future use of AI to manage water resources in RSA, the DWS as the sector leader must investigate areas in water resource management, particularly data acquisition and management where AI may be employed. In other words there must be an understanding of the basic nature of the problem to be solved. Furthermore, the DWS must ensure that adequately sized, validated data is available in order to apply AI in water resource management.

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12 APPENDIX A: THE STATE OF DATA MANAGEMENT IN WATER AND SANITATION

As discussed in Section 5, the outcome of the review of the Data Management pillars in the DWS is used to determine the state of Data Management in the DWS. The outcome of the review process is presented as follows:

12.1 Outcome of the Review of Water quality and Quantity Data Life Cycle Management

The outcome of the review of water quality and quantity data management systems for hydrological and Geo-hydrological data is presented in Table 5

Table 5: Outcome of the Review of Water Quality and Quantity Data Management Systems

GAP	RECOMMENDATION/S	PROPOSED MITIGATION
Insufficient Human Capacity / Shortage of Staff » The processes required to collect data used to generate information that is used to manage surface and groundwater resources are summarised as follows; Continuous maintenance of monitoring networks and monitoring points, Field Data Collection in line with approved monitoring methodologies, Data editing, validation and storage into data management systems such as WMS and HYDSTRA. » As reported during the DAM Strategy regional workshops and the IWQM Strategy, there is inadequate numbers of suitably skilled staff at the regional offices to perform and manage	» Plan an awareness campaign to the DWS Top Management Committee to highlight the consequences of vacant positions and lack of skills transfer.	» The DWS regional offices should prepare lists of all vacant water quality related positions and positions where officials require training. Report on the data backlogs that are directly or indirectly caused by the vacant positions or lack of skills, and present to the DWS Top Management Committee. » A training program should be developed for the DWS regional offices where staff will be equipped with the required skills to acquire and manage different types of data.

GAP	RECOMMENDATION/S	PROPOSED MITIGATION
these processes. This is caused by lack of advertisement for vacant positions resulting from resignations and retirements, lack of transfer of skills from senior officials and contractors and lack of continuous training of officials on the scientific aspects behind the collection, validation and processing of data.		
Delays in Procurement of Instrumentation and Renewal of Laboratory Contracts » The DWS is currently experiencing very long procurement processes for purchasing new and replacement instrumentation as well as renewal of laboratory contracts, resulting in the lack of hydrological instrumentation used to collect data as well as laboratories for sample analysis. As reported in the IWQM Strategy, there exists an uneven availability of access to accredited laboratories for testing of samples across the RSA.	» As proposed in the IWQM Strategy, the DWS must support the monitoring network expansion with an initiative to ensure that accessible accredited laboratories are available to ensure efficient and effective analyses » Procurement procedures must be reviewed and improved in order to improve the turnaround time for renewal of laboratory contracts. Current procurement procedures prevent laboratories from analysing water quality samples on time or at all. » Expired contracts should be extended until new contracts are finalised.	» The DWS regional offices and Head Office should prepare lists of all instrumentation and laboratory contracts that have not been renewed and report on the consequent data backlogs, and present to the DWS Top Management Committee.

GAP	RECOMMENDATION/S	PROPOSED MITIGATION
Delays in Procurement of Instrumentation and Renewal of Laboratory Contracts » The DWS is currently experiencing very long procurement processes for purchasing new and replacement instrumentation as well as renewal of laboratory contracts, resulting in the lack of hydrological instrumentation used to collect data as well as laboratories for sample analysis. As reported in the IWQM Strategy, there exists an uneven availability of access to accredited laboratories for testing of samples across the RSA.	» As proposed in the IWQM Strategy, the DWS must support the monitoring network expansion with an initiative to ensure that accessible accredited laboratories are available to ensure efficient and effective analyses » Procurement procedures must be reviewed and improved in order to improve the turnaround time for renewal of laboratory contracts. Current procurement procedures prevent laboratories from analysing water quality samples on time or at all. » Expired contracts should be extended until new contracts are finalised.	» The DWS regional offices and Head Office should prepare lists of all instrumentation and laboratory contracts that have not been renewed and report on the consequent data backlogs, and present to the DWS Top Management Committee.
Some Water Quality Data Stored into DMSs with Errors » Surface and Groundwater quality data used for decision making is stored without validation, leading to errors and ultimately negatively affecting its credibility.	» Standard Operating Procedures (SOP's) should be established for data collection, processing, validation and dissemination of water quality data.	» Establish or revive data acquisition and management committees for the entire DWS where SOPs for water quality data are developed, agreed upon, endorsed and regularly reviewed and revised.

GAP	RECOMMENDATION/S	PROPOSED MITIGATION
Vandalism of instrumentation and lack of Access to Private Land » A number of instrumentation across the RSA are vandalised by members of the community. Some private land where monitoring points such as boreholes are situated is inaccessible due to locked gates or access refusal by the private land owners.	» Create awareness to communities and private land owners about the importance of water resources monitoring in RSA.	» Organise awareness campaigns to communities and private land owners to create awareness about the implications of vandalism and lack of access to private land on the quality and availability of water resources in RSA. » Establish a memorandum of understanding between the DWS and private land owners for access to private land. Establish a standard procedure for gaining access to private land. » Establish memorandum of understanding between the DWS and community leaders to prevent vandalism of monitoring instrumentation.
Lack of adequate data collection skills in Municipalities » In order to monitor aquifer responses to activities such as abstraction, data such as groundwater levels and abstraction volumes is required. Some of this data used for local groundwater monitoring is collected monthly by operators at municipalities. Municipal technical managers are expected to edit and validate the data and DWS regions provide final recommendations and store the data in HYDSTRA. It has been reported that there is lack of skills at municipalities to collect the required data as well as lack of cooperation from municipalities for DWS to train data collectors.	» Establish a memorandum of agreement with municipalities for skills transfer and data sharing.	» Organise workshops or meetings with municipalities to establish memorandum of understanding for skills transfer and data sharing.

GAP	RECOMMENDATION/S	PROPOSED MITIGATION
Inaccessibility of Water Quality and Quantity Data Collected by Consultants » There exist data collected by consultants and other external institutions that are not easily accessible as the data stored in the DWS owned systems. For instance, the RAMSAR and NFEPA data used in generating information for the national state of wetlands is reported to be collected mainly by the DEA/ SANBI and the CSIR. Wetlands research data is collected mainly by the WRC, wetlands health and protection data is collected mainly by SANBI and GIS data is collected mainly by the DWS in partnership with SANBI.	» Enable access to water quality data collected by external institutions and consultants.	» Identify the different types of missing data as well as the external institutions and consultants that are collecting the missing data. » Participate in workshops and meetings with the external institutions and consultants to discuss the sharing of water quality data. » When appointing consultants, the Terms of Reference (ToR) should include the handover of project raw data to DWS. The ToR should also include an obligation for technicians and Graduate Trainees (GTs) to receive field training while the consultants are collecting the raw data.

12.2 Outcome the Review of Water quality and Quantity Data Management Systems

The outcome of the review of water quality and quantity data management systems for hydrological and Geo-hydrological data is presented in Table 5.

Table 5: Outcome of the Review of the Water Quality and Quantity Data Management Systems

GAP	RECOMMENDATION/S	PROPOSED MITIGATION
Fragmented DMSs used to Manage Water Quality and Quantity Data » In the assessment of business objectives and information needs for water quality, the following objectives for managing water quality data have been identified; i.e. to provide information on the state of water resources in RSA, surface and groundwater reserves, point and non-point pollution sources, drinking water quality, water quality regulation, wetlands information, water quality monitoring programmes and trend analysis information. These business objectives combined require information generated from a number water quality data management systems and supporting systems; with WMS being the main water quality system. The other systems used in water quality management are; GIS data management systems, BDS, GDS, GRIP, HYDSTRA, EWULAAS, NGA, Rivers DB, ECMS, NCIMS, WARMS. As a result, the data in these DMSs are fragmented and stored in multiple formats.	» Develop an integrated approach or method to efficiently and effectively manage water quality data management systems in the DWS.	» Investigate the types of data stored in the ± 10 data management systems and identify any possible risk of duplication of datasets among the data management systems. Where duplication may exist, it must be established which data management systems are the most capable for handling the different types of data in order to eliminate duplication. » Investigate the types of data (formats) stored in the water quality data management systems to establish which systems are most capable of providing the best accessibility, security as well as the best timeliness in disseminating data. » Review the WMS technical specifications and the technical specifications of the other Water Quality data management systems in order to develop an integrated approach for managing the data stored in the all the Water Quality data management systems. » Develop a central database for River health data to improve data accessibility.

GAP	RECOMMENDATION/S	PROPOSED MITIGATION
Some Water Quality and Quantity Data not stored in structured Data Management Systems » ==> There exist data stored into personal computers, hard drives and as hard copies within the DWS, making it not easily accessible, compromising the security of critical and sensitive data. For instance, some of the data required for generating information on river health and ecostatus in rivers, point and non-point water pollution sources and state of water information is stored in personal computers across the different business units and regional offices in the DWS, and on computers in other departments and independent research organisations.	» Identify and retrieve data stored in personal computers, hard drives and as hard copies; and transfer into relevant DMSs for water quality.	» Investigate the types of data stored in personal computers and identify water quality data management systems where the data should be stored. Make recommendations on how to transfer the data depending on the type of data and the design of the data management systems. The following types of data have been prioritized during the 2nd DAM Strategy National workshop; viz, Groundwater Hard copy data storage and arching system required; no structured system currently exists, groundwater quality data currently in personal computers, regional spreadsheet data currently in personal computers that should be stored into the WMS, etc. » Task teams should be established at all the DWS regions and head office facilitate the collection of all the data that is currently in network drives and personal computers that should be stored in the WMS and other relevant systems.
No Structured DMS for Wetlands Water Quality and Quantity Data » There currently exists no structured DMS in the DWS for wetlands data. Wetland data acquisition, storage and management are a relatively new mandate of the DWS and as a result it is the least well developed field. No previous assessments of	» ==> Develop a structured data management system for wetlands data.	» A workshop between key DWS Directorates should take place to achieve the following; » Investigate the current wetlands data governance structure. The following questions should be answered; what is the role of DWS in wetlands monitoring and data management and how does this differ or compare / align with the role of DEA and SANBI.

GAP	RECOMMENDATION/S	PROPOSED MITIGATION
the data and information produced and required by the DWS for wetlands has been undertaken. Although DWS has yet to implement the wetland health monitoring programme and wetlands still need to be integrated into catchment management plans, the DWS determination of management objectives and authorisation of water uses that impact on wetlands has been undertaken since its mandate for managing wetlands first arose in 1998 (i.e. for the past 20 years). In order to contribute to information on the state of wetlands in RSA and to improve decision making by DWS and its institutions with regards to wetland management GIS data, research data, data on resource directed measures that have been put in place, ecosystem services data, compliance monitoring and enforcement data, data for wetlands health monitoring wetlands use authorisation and offsets data, hydrological data and water quality data, amongst others, is required. In addition, given the inter-governmental nature of wetland management, where both DEA and DAFF also have mandates to sustainably manage and protect wetlands, numerous data from other government departments (in particular data from the ARC, DEA,		» Develop information needs and data requirement specification by identifying the following; information users, required information, data requirements and identify where the required data is stored. » Perform a gap analysis and determine whether there is a need to develop standalone data management systems for wetlands data or whether other currently existing water quality data management systems such as the WMS may be used. » After the completion of activity 3.1, an inter-departmental workshop should be held with the ARC, DEA, WRC, Working for Wetlands, DAFF and in particular SANBI (who are the current champions for wetland data acquisition and management in South Africa). The aim will be to understand the data they require from DWS, and to understand the availability of wetlands data that they are responsible for, their existing systems, their governance arrangements and opportunities for linkages and alignment. The outcomes from this engagement should further inform the requirement for a DWS based DMS for wetlands. » The following external stakeholders should be consulted;

GAP	RECOMMENDATION/S	PROPOSED MITIGATION
SANBI and Working for Wetlands) are required to ensure aligned and integrated decision making.		» External Stakeholders viz. SA Wetland Society; CSIR; KNP/SANPARKS; STATSSA; International research institutions such as IWMI NGOs (such as WWF) and the Private sector (businesses and public enterprises, including SANRAL, Eskom, Sappi, Mondi, Sasol, etc.). » The following platforms may be used to communicate the wetlands DAM Strategy; the Freshwater Ecosystem Network (FEN),the DWS Wetland Task Group, the Wetland Prioritisation Imbizo and the National Wetland Indaba. » A task team should be established at all the DWS regional offices to perform a review of wetlands data in collaboration with the DWS head office. The outcome and recommendations from this review should contribute to the overall review of wetlands data.

GAP	RECOMMENDATION/S	PROPOSED MITIGATION
Underutilisation and none utilisation of the WMS » ==> It was reported that the WMS is not fully utilised at some regions and not utilised at all at other regions due to perceived lack of user friendliness; hence, not all the officials from the various DWS regions are able to capture water quality data. It has been reported that some water quality data collected in the DWS regions has not been stored into the WMS for years due to the lack of user friendliness of the WMS.	» Improve the ease of use of the WMS.	A DWS regional audit of the WMS usage must be conducted where the following must be performed: » usage must be conducted where the » following must be performed; » An analysis of regions that are fully utilising the WMS versus those not fully utilising it. » Where WMS is not fully utilised, investigate gaps and propose mitigation activities. » Escalate the gaps and proposed mitigation activities to the Top Management committee, for approval to implement. » Evaluate the current procedures for entering and retrieving data using the WMS in order to identify possible new tools, methods or technologies for improving the user friendliness of the WMS. » The Directorate: RQIS must provide training at the DWS regional offices and develop standard operating procedures (SOPs) and business process for capturing and retrieving data using the WMS. » The Directorate: RQIS should investigate and make recommendations on how to improve the WMS user interface. Monitor the progress of the current update of the WMS. » Create an internet connection to WMS in order to integrate WMS with Laboratory management systems. This must be accompanied by training for Labs and stakeholders to enable them to transfer data.

GAP	RECOMMENDATION/S	PROPOSED MITIGATION
Most Water Quality and Quantity Data Management Systems are not Current » As reported in the IWQM Strategy, most of the DMSs currently used in the DWS are not current and accessible to support adoptive and latest methods and techniques for WQM such as citizen based monitoring.	» As reported in the IWQM Strategy, the DWS and other water sector stakeholders must develop data and information systems that are current and accessible to support adoptive WQM and accommodate latest methods and techniques such as citizen based monitoring.	» A task team from the DWS, the WRC and CMAs must be established to lead the development of a programme for developing DMSs that are compatible to citizen-based monitoring programmes.
Lack of Documented Data Architecture for Water Quality and Quantity Data Management Systems » It appears that not all data management systems used in water quality and quantity have documented data architecture.	» Document a Data Architecture for the data management systems used in water quality and quantity.	» Investigate methods for documenting data architecture for water quality and quantity data management systems.

12.3 Outcome of the review of Collaboration between the DWS and key Stakeholders

The outcome of the review of collaboration between the DWS and key stakeholders is presented in Table 6.

Table 6: Outcome Review of the Collaboration amongst Water Sector Stakeholders

GAP	RECOMMENDATION/S	PROPOSED MITIGATION
Lack of Collaboration and Cooperation between the DWS and Water Sector Stakeholders for sharing of and Monitoring Infrastructure.	» The DWS Mpumalanga, the Inkomati-Usuthu Catchment Management Agency (UCMA) and the Mpumalanga Tourism and Parks Agencies should establish a Memorandum of Agreement (MoA) for cooperation on the sharing of Wetlands data.	» The proposed DAM-PC and DAM-CC should plan discussions with the mentioned institutions to review or negotiate new Memorandum of Agreements (MoA) for data and infrastructure sharing.
	» The DWS Mpumalanga, the Komati Basin Water Authority (KOBWA) and the IUCMA are sharing the same infrastructure for collecting data in Mpumalanga. A collaboration agreement must be reached with KOBWA for data sharing and establishment of an integrated approach for managing data and information. Possibly, a central point must be developed for the DWS, IUCMA and KOBWA to store and disseminate data and information.	
	» The ARC generates Standard Precipitation Index (SPI) data using rainfall and groundwater data; this data is not accessible to the DWS. The memorandum of agreement (MoA) must include free access to processed data, in addition to raw data. This type of data sharing should be standard for all other collaborations with other institutions.	

GAP	RECOMMENDATION/S	PROPOSED MITIGATION
	» An opportunity for collaboration with ESKOM and SASOL must be explored as they are collecting water quality data in the Upper Vaal that could be shared with the DWS.	
	» The existing Memorandum of Understanding (MoU) with the Counsel for Scientific and Industrial research (CSIR) for sharing of water quality data must be reviewed in order to clarify the procedures to be followed for water quality data sharing.	
	» The City of Tshwane and other municipalities in Gauteng collect water quality data for the mining industry. An agreement must be established with all these municipalities to share this data with the DWS.	
	» A data exchange agreement should be established between the DWS, the Agricultural Research Counsel (ARC), the Department of Environmental Affairs (DEA), the Water Research Centre (WRC), working for Wetlands, the Department of Agriculture, Forestry and Fisheries (DAFF) and the South African National Biodiversity Institute (SANBI) must be established for sharing of Wetlands data.	

GAP	RECOMMENDATION/S	PROPOSED MITIGATION
Reservoir Data Collected by municipalities not accessible to the DWS » The state of reservoir data from municipalities, i.e. small and stand-alone	» Establish a Memorandum of Agreement (MoA) between the DWS and Municipalities for the exchange and sharing of reservoir related data.	» The proposed DAM-PC and DAM-CC should organise workshops to create awareness to municipalities and establish data sharing MoA's.
dams in the Northern, Eastern, Southern and the Western Clusters, are currently not accessible. The following information is urgently required in order to gain access to this data; Contact person responsible for each dam, Dam Surveys, Capacity Tables, and Daily or Weekly Readings.		

12.4 Outcome of the Review of Data Governance in the DWS

The outcome of the review of collaboration between the DWS and key stakeholders is presented in Table 7.

Table 7: Outcome of Review of Data Governance

GAP/S	RECOMMENDATION/S	PROPOSED MITIGATION
» Lack of leadership and accountability in Data Acquisition and Management.	» As the sector leader, the DWS should regulate these institutions by establishing a data governance program to determine who should do what when and how in data acquisition and management.	» The NWMC and the IR-WQMC should initiate discussion for establish a data governance program for water and sanitation in RSA.
» Fragmentation of Data Acquisition and Management Functions, resulting in duplication of functions between the DWS and other institutions.		
» Uncoordinated data acquisition and management.		
» Lack of common approaches for resolving data needs and issues.		
» Lack of standard, repeatable processes for generating and disseminating water and sanitation data.		

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