DEPARTMENT OF WATER & SANITATION

Sources Directed Studies

NATIONAL EUTROPHICATION MANAGEMENT STRATEGY

June 2021 Edition 01 (Version 12.0)

Project Report No. 4.1

WATER IS LIFE – SANITATION IS DIGNITY

water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

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DEPARTMENT OF WATER AND SANITATION

NATIONAL EUTROPHICATION

MANAGEMENT STRATEGY

Edition 01 (Version 12.0)
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PROJECT REPORT NUMBER 4.1
SOURCES DIRECTED STUDIES REPORT NUMBER RDM/EMP&S/00/IHS/SDS/0420

Main cover page:

The photos, on the document cover, were kindly supplied by Mr Petrus Venter, Department of Water and Sanitation.

Main photo (taken on 16 May 2012)**:**
Excessive hyacinths, green and blue-green algae collecting behind a floating biomass retaining barrier, extending to a depth of ±7 m below surface, in the upstream vicinity of the Hartbeespoort Dam wall. The buoyed barrier, visible further upstream, is the safety barrier that limits recreational access too close to the dam wall.

Insert photo, bottom-left (taken on 26 January 2010)**:**
The release of nutrient-laden, algae-rich, green in colour water from a full dam over the Hartbeespoort Dam wall.

Insert photo, bottom-middle (taken on 5 May 2011)**:**
The removal of excessive hyacinths and debris from the Hartbeespoort Dam surface over one of the sluice gates.

Insert photo, bottom-right (taken on 4 February 2013)**:**
Excessive primary production in the vicinity of Estate D'Afrique, downstream of the Hartbeespoort Dam wall.

Mr Venter is thanked for giving us permission to use his photos on the document cover.

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

Published by

the Department of Water and Sanitation
Private Bag X313
PRETORIA, 0001
Republic of South Africa

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This report should be cited as:

Department of Water and Sanitation (DWS), 2021. National Eutrophication Management Strategy. Edition 01 (Version 12.0), Project Report Number 4.1, Sources Directed Studies Report Number RDM/EMP&S/00/IHS/SDS/0420. PRETORIA.

Document Index

Reports, as part of the strategy development project:

Project Report Number	Sources Directed Studies Report Number	Project Reports
1	RDM/EMP&S/00/IHS/SDS/0120	Inception Report
2	RDM/EMP&S/00/IHS/SDS/0220	Framework Report
3	RDM/EMP&S/00/IHS/SDS/0320	Situation Assessment and Gap Analysis Report
4.1	**RDM/EMP&S/00/IHS/SDS/0420**	**National Eutrophication Management Strategy (Edition 1)**
4.2	RDM/EMP&S/00/IHS/SDS/0520	National Eutrophication Management Strategy (Edition 2)
5	RDM/EMP&S/00/IHS/SDS/0620	Capacity Building Report
6	RDM/EMP&S/00/IHS/SDS/0720	Strategy into Practice Report
7	RDM/EMP&S/00/HIS/SDS/0820	Project Close-Out Report

Foreword

[To be drafted on completion of the document and to be checked by DWS Comms.]

<Name>

Minister: Human Settlements, Water and Sanitation /

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Preface

The National Eutrophication Management Strategy development process was initiated in April 2019. It was presented for approval at the Department of Water and Sanitation (DWS)'s Branch: Planning and Information 1st Quarter Performance Review Session held on 25-26 July 2019. This strategy was developed through the collective and committed efforts of the DWS personnel, and participation of all the water and sanitation sector's stakeholders.

To this end, the focus of the National Eutrophication Strategy for South Africa is to ensure and strengthen:

- direction-giving with respect to the management of eutrophication31, in particular the control of anthropogenic5 sources of excessive nutrient enrichment56, from a strategic country-perspective;
- the provision of a reference for the control of triggers that cause excessive primary production68 in receiving water resources and for eutrophication management, in general, in South Africa;
- the foundation for operational consistency at the Water Management Area (WMA), sub catchment and local levels, by stipulating ground rules and prescribing overarching implementation approaches for the management of eutrophication;
- To address pertinent issues of eutrophication management integration and alignment with other processes;
- The facilitation of improved eutrophication management cooperation and participation;
- The provision of the basis for identifying priority actions and interventions necessary to control significant triggers of anthropogenic eutrophication; and their root causes of failure, acknowledging the need for the efficient and wise utilisation of scarce resources;
- The facilitation of capacity building in respect of the control of the causes of excessive nutrient enrichment and eutrophication management; and
- The point of departure for the monitoring and evaluation of Eutrophication Management Strategy implementation progress.

The strategy was developed towards the implementation of the National Water Act, 1998 (Act No. 36 of 1998), National Water Resource Strategy 3, 2020, "Integrated Water Quality Management Policies and Strategy for South Africa, 2017" and "National Water and Sanitation Master Plan, 2018".

I would like to acknowledge and thank everyone who contributed and participated in the National Eutrophication Strategy development. A crucial step further will be the implementation of this strategy, which requires a collaborative effort from the whole sector.

Ms Tovhowani Nyamande
Director: Sources Directed Studies

Departmental Approval

TITLE:	National Eutrophication Management Strategy
VERSION CONTROL:	Edition 01 (Version 12.0)
DATE:	June 2021
PROJECT REPORT NO.:	4.1
SDC REPORT NO.:	RDM/EMP&S/00/IHS/SDS/0420
MAIN AUTHOR:	Jurgo van Wyk
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FORMAT:	MS Word and PDF
WEB ADDRESS:	https://www.dws.gov.za/RDM/SDCCO.aspx

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Acknowledgements

The following individuals and organisations are thanked for their contributions towards the development of the National Eutrophication Management Strategy:

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List of Acronyms

A	**APP**	Annual Performance Plan
B	**BC**	Before Christ
	BMP	Best Management Practice
	BOD	Biological Oxygen Demand
	BPEO	Best Practicable Environmental Option
	BPG	Best Practice Guideline
C	**Capex**	Capital expenditure
	CBA	Cost-Benefit Analysis
	Chl-A	Chlorophyll a
	CMA	Catchment Management Agency
	CMF	Catchment Management Forum
	CMS	Catchment Management Strategy
	COD	Chemical Oxygen Demand
	COGTA	Department of Cooperative Governance and Traditional Affairs
D	**DALRRD**	Department of Agriculture, Land Reform and Rural Development
	DEFF	Department of Environment, Forestry and Fisheries
	DHET	Department of Higher Education and Training
	DMRE	Department of Mineral Resources and Energy
	DNA	Deoxyribonucleic acid
	DO	Dissolved Oxygen
	DPSIR	Driver-Pressure-State-Impact-Response framework
	DSI	Department of Science and Innovation
	DWA	Currently DWS, previously the Department of Water Affairs
	DWAF	Currently DWS, previously the Department of Water Affairs and Forestry
	DWS	Department of Water and Sanitation
E	**EIA**	Environmental Impact Assessment
	ELU	Existing Lawful water Use
	EMF	Environmental Management Framework
	EMI	Environmental Management Inspector
	EMPR	Environmental Management Programme Report for mining
	EONEMP	Earth Observation National Eutrophication Management Programme
	EPMDS	Employee Performance Management and Development System
	ERA	Environmental Risk Assessment
	EWR	Ecological Water Requirement

F	FEPA	Freshwater Ecosystem Priority Area
G	GA	General Authorisation
	GDP	Gross Domestic Product
	GDS	Green Drop System
	GEMS	Global Environmental Monitoring System
	GEMStat	Global Freshwater Quality Database
	GG	Government Gazette
	GN	Government Notice
	GNP	Gross National Product
H	HETMIS	Higher Education and Training Management Information System
I	IDP	Integrated Development Plan
	IHI	Index for Habitat Integrity method
	IRiS	Integrated Regulatory information System
	ISO	International Organisation for Standardisation
	IUCMA	Inkomati-Usuthu Catchment Management Agency
	IUA	Integrated Units of Analysis
	IWQM	Integrated Water Quality Management
	IWRM	Integrated Water Resource Management
L	LCA	Life Cycle Assessment
	LIMCOM	Limpopo Watercourse Commission
O	O&M	Operation and Maintenance
	OECD	Organisation for Economic Cooperation and Development
	Opex	Operational expenditure
	ORASECOM	Orange Senqu River Commission
M	MC	water resource Management Class
	MDG	Millennium Development Goal
N	NDP	National Development Plan, 2030
	NEMA (107:1998)	National Environmental Management Act, 1998 (Act No. 107 of 1998)
	NEMP	National Eutrophication Management Programme
	NFEPA	National Freshwater Ecosystem Priority Areas
	NGO	Non-Governmental Organisation
	NIWR	National Institute of Water Research
	NLO	Nutrient Load Objective
	NPC	National Planning Commission
	NPDF	National Policy Development Framework

	NPS	Non-Point Source
	NTU	Nephelometric Turbidity Unit
	NW&S MP	National Water and Sanitation Master Plan
	NWA (36:1998)	National Water Act, 1998 (Act No. 36 of 1998), as amended
	NWRS	National Water Resource Strategy
	NWSF	National Water Security Framework
P	**PMC**	Project Management Committee
	PSC	Project Steering Committee
R	**R&D**	Research and Development
	RDM	(statutory) Resource Directed Measure
	RDP	Reconstruction and Development
	RNA	Ribonucleic acid
	RQO	Resource Quality Objective
	RSA	Republic of South Africa
	RU	Resource Unit
	RWQO	Resource Water Quality Objective
S	**S.**	Section
	SABS	South African Bureau of Standards
	SADC	Southern African Development Community
	SALGA	South African Local Government Association
	SAWQG	South African Water Quality Guideline
	SDBIP	Service Delivery Budget and Implementation Plans
	SDC	Source Directed Control
	SDG	Sustainable Development Goal
	SEA	Strategic Environmental Assessment
	SEIAS	Socio-Economic Impact Assessment System
	SEMA	Specific Environmental Management Act
	SIA	Social Impact Assessment
	SO	Strategic Objective, as per the IWQM Strategy for South Africa (2017)
	spp.	Botanical shorthand for multiple species
	SRP	Soluble Reactive Phosphorus
	SSC	Strategy Steering Committee
T	**TDS**	Total Dissolved Solids
	THM	Trihalomethane
	TMDL	Total Maximum Daily Loads
	TN	Total nitrogen
	TNS	The Natural Step, as in TNS funnel

	TON	Threshold Odour Number
	TP	Total phosphorus
	TPTC	Tripartite Permanent Technical Committee
	TSI	Trophic State Index
	TSP	Trophic Status Project
	TTT	Technical Task Team
U	UN	United Nations
	UNCED	United Nations Conference on Environment and Development (1992)
	UNEP	United Nations Environment Programme
	URL	Uniform Resource Locator, colloquially termed an internet web address
V	V&V	Validation and Verification of water use
	VIP	Ventilated improved pit latrine
W	w	Weight
	WAR	Water Allocation Reform
	WARMS	Water use Authorisation and Registration Management System
	WDCS	Waste Discharge Charge System
	WDS	Waste Discharge Standard
	WLO	Waste Load Objective
	WMA	Water Management Area
	WMS	Water Management System
	WQPL	Water Quality Planning Limit
	WRCS	Water Resources Classification System
	WSA	Water Services Authority
	WSA (108:1997)	Water Services Act, 1997 (Act No. 108 of 1997)
	WSDP	Water Services Development Plan
	WSP	Water Services Provider
	WSSD	World Summit on Sustainable Development (2002)
	WTWs	Water treatment works
	WWTWs	Wastewater treatment works

List of Chemical Symbols

B	**B**	boron	Strengthens plant cell walls. Is only required in small amounts, with excess being toxic.
C	**C**	carbon	Forms the backbone of most plant biomolecules, including proteins, starches and cellulose. Carbon is fixed through photosynthesis, whereby carbon dioxide from the air is converted into carbohydrates which are used to store and transport energy within the plant.
	Ca	calcium	Regulates the transport of other nutrients into the plant; is involved in the activation of certain plant enzymes; and is involved in photosynthesis and plant structure.
	CH_4N_2O	urea	Serves an important role in the metabolism of nitrogen-containing compounds by animals and is the main nitrogen-containing substance in the urine of mammals.
	Cl	chlorine	Highly reactive and never found as a free element on Earth. The negatively charged ionic form of chlorine is chloride (Cl^-). The only way it can be found in nature is when it reacts with other chemicals and creates compounds. As compounded chloride, it is necessary for osmosis and ionic balance; and also plays a role in photosynthesis. Is only required in small amounts.
	CO_2	carbon dioxide	A colourless gas produced by aerobic organisms and used by autotrophs during photosynthesis.
	Co	cobalt	Beneficial to some plants; and is essential for nitrogen fixation by the nitrogen-fixing bacteria associated with legumes and other plants. Is only required in small amounts.
	Cu	copper	Is important for photosynthesis; and is involved in many enzyme processes. Is only required in small amounts.
F	**Fe**	iron	Is essential for chlorophyll synthesis; and is present as an enzyme cofactor in plants.
H	**H**	hydrogen	Most abundant element in the universe; is necessary for the building of sugars; and is imperative for the proton gradient to help drive the electron transport chain in photosynthesis and for respiration.
	H_2S	hydrogen sulfide	A colourless, toxic, corrosive, and flammable gas with a characteristic foul rotten egg odour that is produced from the microbial breakdown of organic matter in the absence of oxygen.
	H_2S_2	hydrogen disulfide	Decomposes readily to H_2S and elemental sulfur.
K	**K**	potassium	Has many roles in plants, including being involved in carbohydrate and protein synthesis; the regulation of internal plant moisture; acting as a catalyst and condensing agent of

			complex substances; acting as an accelerator of enzyme action; and contributing to photosynthesis.
M	**Mg**	magnesium	Is necessary for chlorophyll synthesis and photosynthesis; and is involved in many enzyme processes.
	Mn	manganese	Is necessary for photosynthesis. Is only required in small amounts.
	Mo	molybdenum	Is a cofactor to enzymes important in building amino acids; and is involved in nitrogen metabolism. Is only required in small amounts.
N	**N**	nitrogen	Most abundant element in the earth's atmosphere; and plays an important role in plant biochemistry and physiology.
	NH_3	ammonia	Un-ionized ammonia is a colourless, acrid-smelling toxic gas at ambient temperature and pressure.
	NH_4^-	ammonium	Non-toxic ionised form of ammonia.
	NO_2^-	nitrite	A pervasive intermediate in the nitrogen cycle in nature.
	NO_3^-	nitrate	Salts containing this ion are called nitrates.
O			
	O	oxygen	Produced during photosynthesis and required during aerobic cellular respiration to metabolise glucose.
P	**P**	phosphorus	Highly reactive and never found as a free element on Earth.
	PO_4^{3-}	orthophosphate	Important component in ATP, DNA and RNA.
S	**S**	sulphur	Is a structural component of some amino acids and vitamins; plays a role in photosynthesis; and is needed for N_2 fixation by legumes, and the conversion of nitrate into amino acids and then into protein.
	Se	selenium	Is beneficial to flowering plants; stimulates plant growth in some plants; improve tolerance of oxidative stress; and increase resistance to pathogens. Selenium, however, is essential to animals and humans. Is only required in small amounts.
	Si	silicon	Strengthens cell walls; and improves plant strength, health, and productivity.
	SiO_2	silicon dioxide	Also known as silica, silicic acid or silicic acid anhydride is an oxide of silicon. Strengthens cell walls; and improves plant strength, health, and productivity.

V	**Va**	vanadium	May be required by some plants, but at very low concentrations. It may also be substituting for molybdenum.
Z	**Zn**	zinc	Participates in chlorophyll synthesis, and the activation of many enzymes. Is only required in small amounts.

Glossary of Terms and Explanations

Selected key concepts and terminology, in support of the *National Eutrophication Management Strategy*, are explained here. The interpretations provided, apply throughout the main document. In the main document text, where these key concepts and terminology are used, a *[red reference number in red square brackets]* has been added in superscript immediately after the particular terms. The red reference numbers in the main document text link to the corresponding numbered alphabetically listed terms and their explanations provided in the *Glossary of Terms and Explanations*, below:

[1] **Aerobic:** Presence of free oxygen, *i.e.* O_2 (g).

[2] **Abioseston:** (or tripton): Is the non-living particulate matter in waterbodies and includes detritus or bits of mineral matter or humus or organic remains.

[3] **Allocatable Water Quality:** The maximum worsening change in any water quality attribute away from its present value that maintains it within a pre-determined range reflecting the desired future state, typically defined by the Resource Quality Objective(s). If the present value is already at or outside the pre-determined range, this indicates that none is allocatable, and that (1) reduced pollution loads relating to the affected attribute(s); and/ or (2) remediation of water resources, may be necessary.

[4] **Anaerobic:** Without free oxygen, *i.e.* O_2 (g).

[5] **Anoxic:** Without oxygen.

[6] **Anthropogenic:** Negative impacts of human activities on the environment.

[7] **Aquatic ecosystem(s):** Complex of biotic and abiotic components associated with water resources. The aquatic ecosystem is an ecological unit that includes the physical characteristics (such as flow or velocity and depth), the biological community of the water column and benthos, and the chemical characteristics such as dissolved solids, dissolved oxygen, and nutrients. Both living and non-living components of the aquatic ecosystem interact and influence the properties and status of each component.

[8] **Assimilative capacity:** Refers to the capacity of water resources to assimilate discharged or disposed waste through processes, such as dilution, dispersion, and chemical and biological degradation, without water quality changing to the extent that fitness-for-use or ecosystem health is impaired.

[9] **Atmosphere:** Is the layer or set of layers of gases surrounding the Earth that is held in place by the Earth's gravity. It composes of nitrogen (±78%), oxygen (±21%), argon (±0.9%), carbon dioxide (±0.03%) and other gases in trace amounts. Oxygen is used by most organisms for respiration; nitrogen is fixed by bacteria and lightning to produce ammonia used in the construction of nucleotides and amino acids; and carbon dioxide is used by plants, algae and cyanobacteria in photosynthesis. Additionally, the atmosphere helps to protect living organisms from genetic damage by solar ultraviolet radiation, solar wind and cosmic rays.

[10] **Basin:** See *"Catchment"*.

[11] **Benthic zone:** Is the ecological zone association with the stream, river or lake bottom, including the sediment surface and some sub-surface layers.

[12] **Benthos:** Is the community of organisms that live in, on, or in close association with the stream, river or lake bottom, also known as the benthic zone. The main food sources for benthic organisms are algae and organic wash-off from land. Benthos can be categorised according to–

- **Size**, *i.e. macrobenthos* (comprising the larger, visible to the naked eye, benthic organisms greater than ± 1 mm in size; *meiobenthos* (comprising tiny benthic organisms that are less than ± 1 mm but greater than ± 0.1 mm in size); or *microbenthos* (comprising benthic organisms that are less than ± 0.1 mm in size).

- **Type**, *i.e. zoobenthos* (comprising animals belonging to the benthos) or *phytobenthos* (comprising plants belonging to the benthos, *e.g.* benthic diatoms).
- **Location**, *i.e. hyperbenthos* (living just above the sediment); *epibenthos* (living on top of the sediment); or *endobenthos* (living buried in the sediment, often in the oxygenated top layer).

[13] **Best Practicable Environmental Option:** The option that provides the most benefit, or causes the least damage to the environment as a whole, at a cost acceptable to society, in the long-term, as well as in the short-term.

[14] **Biomass:** Renewable organic material that originates from organisms, such as plants and animals. Biomass contains stored chemical energy from the sun. Plants produce biomass through photosynthesis. Biomass can be burned directly for heat or converted to renewable liquid and gaseous fuels through various processes.

[15] **Bio-physico-chemical:** Relating to biological, physical and chemical properties or biophysical and biochemical.

[16] **Bioprospecting:** Or biological diversity prospecting, is the exploration of natural sources for small molecules, macromolecules and biochemical and genetic information that could be developed into commercially valuable products by industry for use, *inter alia* in agriculture, aquaculture, bioremediation, cosmetics, nanotechnology, or pharmaceuticals.

[17] **Bioseston:** Is the living particulate matter suspended in waterbodies, and is often regarded as plankton, although it includes nekton as well.

[18] **Carcinogen:** Is any substance, radionuclide, or radiation that promotes carcinogenesis, *i.e.* the formation of cancer.

[19] **Catchment:** A catchment, in relation to a watercourse or watercourses or part of a watercourse, is defined as the geographical area from which any rainfall will drain into the watercourse or watercourses or part of a watercourse, through surface flow to a common point or common points. This land area from which a river or reservoir is fed is also known as a drainage region, basin or watershed.

[20] **Chlorophyll-α:** Chlorophyll used in oxygenic photosynthesis, which contributes to the green colour of most plants, such as algae.

[21] **Command and control:** The application of command-and-control, also referred to as direct regulatory, approaches has traditionally been the dominant method of pollution control, and later also of water quality management. This approach affords legal authority and direction to responsible authorities over land and water users for the accomplishment of the integrated water quality management Vision, Mission and eutrophication management goal, which are all rooted in Bill of Rights, most notably the rights to an environment that is not harmful and sufficient water for potable purposes.

[22] **Conservative pollutant(s):** (or conservative constituents) Are pollutants that are not lost due to chemical reactions or biochemical degradation. Such pollutants may include, for example, Total Dissolved Solids (TDS) and chlorides. Conservative pollutants accumulate along the length of a water body in the direction of motion, so that amounts added at the most upstream point are still present at the most downstream point. Concentrations of conservative pollutants can be reduced only by dilution with water with a lower concentration.

[23] **Compliance monitoring**: Monitoring to measure, assess and report, on a regular basis, the degree to which individual water users are complying with the conditions defined in their water use authorisations (*e.g.* licences).

[24] **Cost-Benefit Analysis:** Is a systematic decision support process, used to measure the benefits of a decision or taking action minus the costs associated with taking that action. A Cost-Benefit Analysis involves measurable financial metrics such as revenue earned or costs saved, as a result of the decision to pursue a project.

[25] **Cyanobacteria:** (also called blue-green algae or blue-green bacteria) is a phylum of prokaryote bacteria that obtain their energy through photosynthesis. They are a significant component of the marine nitrogen cycle and an important primary producer in many areas of the ocean, but are also found to occur in freshwater systems where they can have major effects on water quality and aquatic ecosystems. They may produce taste, odour, toxins and noxious bloom.

[26] **Deoxygenation:** is a chemical reaction involving the removal of oxygen atoms from a molecule.

[27] **Detritus:** Is dead particulate organic material that is suspended in the water column and that accumulates in depositions on the benthic floor. Detritus typically includes the bodies, or fragments of bodies, of dead organisms and/ or faecal material. Detritus typically hosts communities of microorganisms that colonize and decompose (*i.e.* re-mineralize) it.

[28] **Diatom(s):** Are photosynthetic eukaryotic micro-algae that occur in inland waters, oceans and soils. In water resources, diatoms can occur as phytoplankton, living in the water column; or as phytobenthos, living in the benthic zone. They are unicellular species which exist individually, or in chains or in groups. Depending on the species, their sizes can range from a few micrometres (µm) to a few hundred micrometres. Living diatoms make up a significant portion of the earth's biomass and annually generate ± 20 - 50% of the oxygen produced on the planet and annually take in over 6.7 billion metric tons of silica from the waters in which they live. Diatoms are used as indicator organism to monitor past and present aquatic health conditions, and are commonly used in water quality studies.

[29] **Diazotroph(s):** Diazotrophs are bacteria and archaea that fix atmospheric nitrogen gas into a more usable form, such as ammonia. A diazotroph is a microorganism that is able to grow without external sources of fixed nitrogen.

[30] **Diffuse pollution:** See *"Non-point source pollution"*.

[31] **Differentiated approach:** Acknowledges that catchments differ fundamentally-

- in an ecological sense; and
- in the way they are used; and
- in the extent of such use;

the differentiated approach strives to ensure that catchment-specific conditions are taken into account in all management decisions.

[32] **Dissolved oxygen:** The amount of oxygen dissolved in water. This term also refers to a measure of the amount of oxygen available for biochemical activity in a water body, an indicator of the quality of that water.

[33] **Drainage region:** See *"Catchment"*.

[34] **Ecosystem:** An interactive system that includes the organisms of a natural community, associated together with their abiotic physical, chemical, and geochemical environment.

[35] **Ecological resilience:** Is the capacity of an ecosystem to respond to a disturbance by resisting damage and recovering quickly.

[36] **Ecological water requirement:** Are the quantity and quality of water required to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource.

[37] **Economic Instrument(s):** Aim(s) to bridge the gap between private and social costs by internalising all external costs, both depletion costs (user-pays principle) and pollution costs (polluter-pays principle). Economic instruments offer an alternative to the traditional *"command-and-control"* instruments used in direct regulation.

[38] **Effluent:** Municipal sewage or industrial wastewater (untreated, partially treated, or fully treated) that flows out of a waste water treatment works, septic system, pipe, etc.

[39] **Enforcement:** The actions taken by government to achieve full implementation of environmental requirements (compliance) within the regulated community, and to

correct or halt situations or activities that endanger the environment or public health.

[40] **Environment:** Is the surroundings within which humans exist and that are made up of—

- the land, water and atmosphere of the earth;
- micro-organisms, and plant and animal life;
- any part or combination of aforementioned and the interrelationships among and between them; and
- the physical, chemical, aesthetic and cultural properties and conditions of the foregoing that influence human health and well-being.

[41] **Environmental Impact Assessment:** Is a systematic decision support process, aimed at-

- identifying, predicting and evaluating the ecological, social and economic impact(s) of development activities;
- providing information on the environmental consequences for decision making; and
- promoting environmentally sound and sustainable development through the identification of appropriate alternatives and mitigation measures.

[42] Evaluates the potential impact of human actions, for example, development proposals, on the receiving environment, and how the opportunities and constraints in this environment influence the intended human actions.

[43] **Environmental offsetting:** Is the process of establishing and quantifying the negative effects on the environment resulting from an activity that remain after every effort has been made to avoid and prevent, minimise and then remediate impacts and then counterbalancing these remaining impacts through interventions that avoid and prevent, minimise and remediate impacts or impacted areas elsewhere in order to achieve a net environmental gain.

[44] **Environmental Risk Assessment**: Overall process to-

- identify environmental hazards and risk factors that have the potential to cause harm (hazard identification);
- analyse the probability and extent of the risks associated with those hazards (risk analysis); and
- Determine appropriate ways to mitigate the hazards, or control the risks when such hazards cannot be eliminated (risk control).

[45] **Epilimnion:** (or surface layer) Is the top-most water layer in a thermally stratified waterbody, above the thermocline. The epilimnion is generally warmer, more prone to mixing due to wind action and typically has a higher pH and higher dissolved oxygen concentration than the deeper hypolimnion. Because the epilimnion receives the most sunlight it contains the most phytoplankton. As they grow and reproduce they absorb nutrients from the water. When they die, they sink into the hypolimnion resulting in the epilimnion becoming depleted of nutrients.

[46] **Eutrophic:** Is a state of an aquatic ecosystem rich in minerals and nutrients, very productive in terms of aquatic plant life and exhibiting increasing signs of water quality problems.

[47] **Eutrophication:** (from the Greek *"eutrophos"* meaning "*well-nourished*") Is the process of over-enrichment of waterbodies with minerals and nutrients, which (at the right temperatures, substrate availability, flow velocity and light penetration) increasingly induce primary production, *e.g.* algal and macrophyte growth. Eutrophication can be regarded as either a natural aging process in waterbodies or to be accelerated by anthropogenic impacts.

[48] **Existing Lawful water Use:** Means the lawful use of water authorised by, or under any law, and which took place at any time during the period from 1 October 1996 to 30 September 1998, *i.e.* the two years before the National Water Act, 1998 (Act No. 36 of 1998) came into effect.

If a water user discontinued a water use, or took steps to implement a water use, but did not begin the water use before 30 September 1998, the water use can be declared an existing lawful use.

Certain stream flow reduction activities and controlled activities also fall under the requirements of existing lawful use.

[49] **Facultative anaerobic bacteria:** Can make ATP by aerobic respiration, if oxygen is present, but is capable of switching to fermentation, if oxygen is absent.

[50] **Freshwater:** Water that contains minimal quantities of dissolved salts (not sea water or brackish water). It comes from precipitation of atmospheric water vapour or melting snow, reaching inland surface and groundwater bodies.

[51] **Frustule(s):** Is the hard and porous cell wall or external layer of diatoms. The frustule is composed almost purely of silica (SiO_2), made from silicic acid, and is coated with a layer of organic substance, which is composed of several types of polysaccharides.

[52] **Hydrosphere:** Is the combined mass of water found on, under, and above the surface of the Earth. It has been estimated that there are ±1 386 million cubic kilometres of water on Earth, including water in liquid and frozen forms in groundwater, oceans, lakes and streams. Saltwater accounts for ±97.5% of this amount, whereas fresh water accounts for only ±2.5%. Of this fresh water, ±68.9% is in the form of ice and permanent snow cover in the Arctic, the Antarctic and mountain glaciers; ±30.8% is in the form of fresh groundwater; and only ±0.3% of the fresh water on Earth is in easily accessible lakes, reservoirs and river systems.

[53] **Hypertrophic:** Refers to a high degree of nutrient over-enrichment of surface water resources and excessive amounts of biological productivity that can be sustained. The fitness-for-use of such water resources for many water users, such as the ecology, irrigated agriculture, domestic water use and recreation, is significantly impaired.

[54] **Hypolimnion:** (or bottom layer) Is the bottom-most water layer in a thermally stratified waterbody, below the thermocline. The hypolimnion is generally cooler, relatively stagnant and typically has a lower pH and lower dissolved oxygen concentration than the higher epilimnion. During nutrient-rich conditions, dying phytoplankton may sink from the epilimnion into the hypolimnion to cause or to exacerbate anaerobic conditions.

[55] **Hypoxia:** Lack of oxygen or deprived of adequate oxygen.

[56] **In-aquifer water quality objective(s):** Is the collective name for Resource Water Quality Objectives, Water Quality Planning Limits and the water quality components of Resource Quality Objectives that are determined for groundwater resources, only.

[57] **In-stream water quality objective(s):** Is the collective name for Resource Water Quality Objectives, Water Quality Planning Limits and the water quality components of Resource Quality Objectives that are determined for surface water resources, only.

[58] **In-water resource water quality objective(s):** Is the collective name for Resource Water Quality Objectives, Water Quality Planning Limits and the water quality components of Resource Quality Objectives that are determined for both surface and groundwater resources.

[59] **Inversion:** Inversion, or turnover, is the process of a water column turning over from top (epilimnion) to bottom (hypolimnion). During the summer months, due to the sun's radiation, the epilimnion, or surface layer, is warming faster. The deepest layer, the hypolimnion, is the coldest, because of the sun's radiation not reaching this cold, dark layer. During cooler periods, such as during fall, the warm surface water begins to cool down. As water cools, it becomes denser, causing it to sink. The dense water forces the oxygen poor water of the hypolimnion to rise, *"turning over"* or *"inverting"* the layers. Inversion is more pronounced in water columns of greater depth, such as in deep lakes or dams. A sudden Inversion of the water layers can cause the death of aquatic fauna, *e.g.* fish kills, when introducing them to the oxygen poor water of the hypolimnion.

[60] **Integrated Units of Analysis:** Are a combination of the socio-economic zones and catchment boundaries, within which ecological information is provided at a finer scale.

[61] **Life Cycle Assessment:** Is a systematic decision support process, aimed at analysing potential environmental impacts associated with products or services during their entire life cycle.

[62] **Lithosphere:** Is the solid outermost shell of the Earth and is composed of the crust and the portion of the upper mantle that behaves elastically on time scales of thousands of years or greater. The crust and upper mantle are distinguished on the basis of chemistry and mineralogy. The lithosphere is bounded by the atmosphere, above, and the asthenosphere (another part of the upper mantle), below.

[63] **Macrophyte(s):** Are aquatic plants that grow in or near water and is either emerged, submerged, of floating.

[64] **Maintenance of infrastructure:** Must be included into the whole-life-cycle costing of infrastructure development at the planning stage and includes planned maintenance; repair; refurbishment and renewal; and provisioning for replacement.

[65] **Management Unit(s):** (or water resource Management Unit) are geographical areas, principally defined by drainage region boundaries that are delineated by considering inherent catchment and socio-economic attributes, and for which one, or more in-water resource water quality objective(s), such as Resource Water Quality Objectives or Water Quality Planning Limits, and Waste Load Objectives, have been determined.

The Management Unit for water resource classification is the *"Integrated Unit of Analysis"* and for the determination of Resource Quality Objectives, it is the *"Resource Unit"*.

[66] **Mean annual runoff:** The average amount of water that flows in a river per year (annum), expressed as cubic meters per annum.

[67] **Mesotrophic:** Refers to a moderate degree of nutrient enrichment of surface water resources and a fair amount of biological productivity that can occur with emerging signs of water quality impairment.

[68] **Metalimnion:** (or middle layer) Is the zone of rapid temperature change occurring between the upper epilimnion and the deeper hypolimnion in a thermally stratified waterbody. The matalimnion houses the thermocline.

[69] **Methemoglobinemia:** Due to their very high solubility and because soils are highly unable to retain anions, nitrates can enter groundwater. Elevated nitrate in groundwater is a concern for drinking water use because nitrate can interfere with blood-oxygen levels in infants and cause methemoglobinemia or blue-baby syndrome.

[70] **Monitoring:** Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.

[71] **Mutagen:** Is a physical or chemical agent that changes the genetic material, RNA or DNA, of an organism, increasing the frequency of mutations above the natural background level. As many mutations can cause cancer, mutagens are often also carcinogens. All mutagens have characteristic mutational signatures with some chemicals becoming mutagenic through cellular processes.

[72] **Nekton:** (or necton) Refers to the actively swimming aquatic organisms in waterbodies. The term is used to differentiate between active swimmers and passive organisms, such as plankton, that were carried along by the water current.

[73] **Nitrogen**: (or N) Is a colourless and odourless element found in the soil, gas and water. In fact, nitrogen is the most abundant element in the Earth's atmosphere – approximately 78% of the atmosphere is nitrogen! Nitrogen supports growth and reproduction.

[74] **Non-conservative pollutant(s):** (or non-conservative constituents) Are pollutants that decay with time due to mechanisms, such as chemical reactions; bacterial degradation; radio-active decay; or settling of the particulates out of the water column. Many pollutants exhibit non-conservative behaviour, including nutrients, oxidisable organic matter, volatile chemicals and

bacteria. The amount of a non-conservative pollutant decreases with time and/ or over distance from the point of input.

[75] **Non-point source pollution**: (or diffuse pollution) Pollution that originates from wash-off over a relatively large area. Non-point sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.

[76] **Noxious:** Harmful, poisonous, or very unpleasant.

[77] **Nutrient(s):** A nutrient is a substance used by an organism to survive, grow, and reproduce. In aquatic biology, the most important nutrients are nitrogen, phosphorus, silica and carbon.

[78] **Nutrient depletion:** Reduction of essential nutrients through uptake and removal of plant and animal residues. Nutrients are usually the first link in the food chain, thus a loss of nutrients in a habitat will affect nutrient cycling and eventually the entire food chain.

[79] **Nutrient enrichment:** A form of water pollution, which refers to contamination by excessive inputs of nutrients. It is a primary cause of eutrophication of surface waters, in which excess nutrients, usually nitrogen or phosphorus, stimulates growth of algae and other aquatic plants.

[80] **Nutrient limitation:** Phosphorus is usually considered the *"limiting nutrient"* in aquatic ecosystem. The available quantity of this nutrient controls the pace at which algae and aquatic plants are produced.

[81] **Nutrient-loading:** Refers to the input of nutrients into the aquatic ecosystem from numerous anthropogenic and non-anthropogenic sources.

[82] **Nutrient cycle:** (or ecological recycling) is the movement and exchange of organic and inorganic matter back into biomass production. Energy flow is a unidirectional and non-cyclic pathway, whereas the movement of nutrients is cyclic.

[83] **Oligotrophic:** Refers to surface water resources, low in nutrients and low levels of biological productivity that can be sustained.

[84] **Oligotrophication:** The process of nutrient depletion, or reduction in rates of nutrient cycling, in aquatic ecosystems. It often arises as a consequence of acidification, typically the result of pollution and most notably associated with air pollution and acid precipitation.

[85] **Optioneering:** Is a hybrid-term created by combining the words *"option"* + *"engineering"* and refers to the iterative process between options identification, assessment and definition.

[86] **Participatory management:** Is the practice of empowering members of a group, such as community members, to participate in decision-making. It is used as an alternative, or to support traditional vertical management approaches, which has shown to become less effective when participants grow less interested in authorities' expectations, due to a lack of recognition of participant's efforts or opinions.

[87] **Periphyton:** Is a complex mixture of algae, cyanobacteria, heterotrophic microbes, and detritus that is attached to submerged surfaces in most aquatic ecosystems. Periphyton serves as an important food source for invertebrates, tadpoles, and some fish. It can also absorb contaminants, removing them from the water column and limiting their movement through the environment and is also an indicator of water quality.

[88] **Phosphorus**: (or P) Is a chemical element that is highly reactive and, consequently, is never found as a free element on earth. Phosphorus is essential for life. Phosphates (compounds containing the phosphate ion PO_4^{3-}) are found in genetic material, *i.e.* deoxyribonucleic acid (DNA) and ribonucleic acid (RNA), the energy-carrying molecule adenosine triphosphate (ATP) that fuels cellular processes, and phospholipids that constitute a key component of cell membranes.

[89] **Physico-chemical:** Relates to physics and chemistry, or to physical chemistry.

[90] **Phytoplankton:** Are the autotrophic (self-feeding) component of the plankton community found floating in freshwater and marine ecosystems. Most phytoplankton are too small to be individually seen with the unaided eye. However, when present in high enough numbers, some varieties may be noticeable as coloured patches on water surfaces due to the presence of chlorophyll within their cells. About 1% of the global biomass consists of phytoplankton and they are an important source of atmospheric oxygen. Diatoms and cyanobacteria are examples of phytoplankton.

[91] **Plankton**: Are the diverse collection of small organisms drifting in water, which are unable to propel themselves against a current. Plankton can be divided into the following broad functional groups:

- Phytoplankton (autotrophic algae);
- Zooplankton (protozoans or metazoans);
- Mycoplankton (fungi);
- Bacterioplankton (bacteria and archaea); and
- Virioplankton (viruses).

[92] **Point source pollution:** Pollutant loads discharged at a specific location by means of pipes, outfalls, or conveyance channels *inter alia* delivering wastewater from municipal and industrial Wastewater Treatment Works. Point sources can also include pollutant loads contributed by tributary streams to main-stem streams or rivers.

[93] **Polluter-pays principle:** The principle that those responsible for environmental damage must pay the repair costs, both to the environment and to human health, and must also pay the costs of preventive measures to avoid and prevent and/ or minimise further pollution and environmental damage.

[94] **Precautionary principle:** An approach that exercises caution when uncertainties exist, generally assuming a worst-case scenario.

[95] **Primary production:** In ecology, primary production is the synthesis of organic compounds from atmospheric or aqueous carbon dioxide. It principally occurs through the process of photosynthesis, which uses light as its source of energy, but can also occur through chemosynthesis, which uses the oxidation or reduction of inorganic chemical compounds as its source of energy. Almost all life on earth relies directly or indirectly on primary production. The organisms responsible for primary production are known as primary producers or autotrophs, and form the base of the food chain.

[96] **Primary productivity:** The rate at which light energy is incorporated into plant cells.

[97] **Quinary drainage region:** Are altitudinally based fifth level sub-quaternary drainage regions that are utilised as planning units for operational decision making and general coordination purposes; hydrological modelling; and integrated water resource management.

[98] **Receiving Water Quality Objectives approach:** This approach recognises that many receiving water resources have a certain dilution capacity that can accommodate both point and diffuse sources of pollution without serious detriment to the water quality requirements of recognised water users. Appropriate source controls must be instituted upstream in order to ensure compliance to the downstream water resource Management Class (and RQOs/ Reserves), as may be supported by Resource Water Quality Objectives and/ or Water Quality Planning Limits.

[99] **Recycle:** Utilization of treated or untreated wastewater for the same process that generated it, *i.e.* it does not involve a change of user. For instance, recycling the effluents in a paper and pulp mill.

[100] **Reserve:** Means the quantity and quality of water required to satisfy basic human needs and the aquatic ecosystem.

[101] **Resource quality:** Means the quality of all the aspects of a water resource, including–

- the quantity, pattern, timing, water level and assurance of instream flow;
- the water quality, including the physical, chemical and biological characteristics of the water;
- the character and condition of the instream and riparian habitat; and

- the characteristics, condition and distribution of the aquatic biota;

[102] **Resource Quality Objective(s):** May relate to–

- the Reserve;
- the instream flow;
- the water level;
- the presence and concentration of particular substances in the water;
- the characteristics and quality of the water resource and the instream and riparian habitat;
- the characteristics and distribution of aquatic biota;
- the regulation or prohibition of instream or land-based activities which may affect the quantity of water in or quality of the water resource; and
- any other characteristic, of the water resource in question.

Resource Quality Objectives provide a balance between the need to use and develop water resources, and the need to protect them.

Resource Quality Objectives are gazetted.

[103] **Resource Unit:** Is the Management Unit of assessment for the Resource Quality Objective. A stretch of a river that is sufficiently ecologically distinct to warrant its own specification of Ecological Water Requirement.

[104] **Resource Water Quality Objective(s):** Are the water quality component of the Resource Quality Objective. Are numeric and/ or descriptive objectives, which address the physical, chemical and/ or microbiological properties of waterbodies that should be met in receiving water resources to ensure that the water quality requirements of the recognised water users and the aquatic ecosystem are sufficiently protected.

Resource Water Quality Objectives are not gazetted, *per se*.

[105] **Respiration:** In physiology, constitutes the movement of oxygen from the outside environment to the cells within tissues, and the transport of carbon dioxide in the opposite direction.

[106] **Reuse:** Utilization of treated or untreated wastewater for a process other than the one that generated it, *i.e.* it involves a change of user. For instance, the re-use of municipal wastewater for agricultural irrigation. Water re-use can be direct or indirect, intentional or unintentional, planned or unplanned, local, regional or national in terms of location, scale and significance, involve various kinds of treatment (or not) and be used for a variety of purposes.

[107] **Root nodules:** Are found on the roots of plants that form a symbiosis with nitrogen-fixing bacteria. Under nitrogen-limiting conditions, capable plants form a symbiotic relationship with a host-specific strain of bacteria known as rhizobia.

[108] **Runoff:** Runoff is the flow of water occurring on the ground surface when excess rainwater, stormwater, meltwater, or other sources, can no longer sufficiently rapidly infiltrate in the soil. Surface runoff replenishes groundwater and surface water resources as it percolates through soil profiles or moves into streams and rivers.

[109] **Secchi disk depth:** Is a 20cm disk with alternating black and white quadrants. It is lowered into the water of a river or dam until it can no longer be seen by an observer. The depth of disappearance is called the Secchi depth. Secchi disk depth is a measure of the clarity or turbidity of water.

[110] **Self-regulation:** An organization regulating itself without intervention from external bodies.

[111] **Seston:** Are the organisms (bioseston) and non-living matter (abioseston) swimming or floating in a waterbody.

[112] **Social Impact Assessment:** Is a systematic decision support process of research, planning and management of social change or consequences (positive and negative, intended and unintended) arising from policies, plans, developments and projects.

[113] **Strategic Environmental Assessment:** Is a systematic decision support process, aimed at ensuring that sustainability aspects are considered in policy-strategy, plan and

program making. The focus is deliberately wide because many of the pressures are as a result of custom, tradition, and institutional factors.

[114] **Stratification:** Occurs when water with different properties, viz. salinity (halocline), oxygenation (chemocline), density (pycnocline), temperature (thermocline), form layers that can act as barriers to water mixing.

[115] **Thermocline:** Is a thin, but distinct layer in a large body of water in which temperature changes more drastically with depth than it does in the layers above or below. The thermocline divides the upper generally warmer and mixed layer (epilimnion) from the deeper cooler and more stagnant layer (hypolimnion) and occurs in the matalimnion.

[116] **Total Maximum Daily Load**: (or pollutant load allocation) Is the total maximum daily load of a pollutant that a waterbody can assimilate before undesirable physical, chemical and/or biological thresholds are exceeded and the 'fitness for use' of the water resource becomes impaired.

[117] **Trophic status:** Refers to the degree of nutrient enrichment of surface water resources and the associated amount of primary productivity that can be sustained.

[118] **Turnover:** See inversion.

[119] **User-pays principle:** Variation of the polluter-pays principle that calls upon the user of a natural resource to bear the cost of running down natural capital.

[120] **Waste discharge standard(s):** Are rules, criteria or limits that are established to-regulate the unnatural altering of the water quality of wastewater that needs to be discharged; and ensure that such discharges are compatible with receiving water quality requirements.

[121] **Waste Load Objective(s):** Are objectives relating to incremental reduction; maintenance; or under special circumstances, incremental increase in waste loads, calculated to give effect to relevant in-water resource water quality objectives. Waste Load Objectives refer to the water resource Management Unit as a whole and not to specific water users, though they do consider technical, economic and administrative realities.

[122] **Wastewater:** Any water used from domestic, industrial, commercial or agricultural activities, surface runoff or stormwater, which may contain physical, chemical and biological pollutants.

[123] **Wastewater treatment:** Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water to remove, reduce, or neutralize contaminants.

[124] **Water course:** Means –

- a river or spring;
- a natural channel in which water flows regularly or intermittently; and
- a wetland, lake or dam into which, or from which, water flows;

A reference to a watercourse includes, where relevant, its bed and banks.

[125] **Water Pollution:** Means the direct or indirect alteration of the physical, chemical or biological properties of water resource so as to make it less fit for any beneficial purpose for which it may reasonably be expected to be used; or harmful or potentially harmful to:

- the welfare, health or safety of human beings:
- any aquatic or non-aquatic organisms;
- the resource quality; or
- property.

[126] **Water quality:** The biological, chemical, and physical conditions of a waterbody. It is a measure of a water body's ability to support beneficial water use.

[127] **Water Quality Planning Limit(s):** Are Resource Water Quality Objectives utilised for water quality planning purposes.

[128] **Water resource(s):** Includes a watercourse, surface water, estuary, or an aquifer.

[129] **Water user group(s):** (or water user sectors) There are five recognised broad water user groups, some with sub-groups, namely the-

- **Agricultural water user group:**

  - *Irrigation* according to soil and crop type;
  - *Stock water*ing; and
  - *Aquaculture*.
- **Domestic water user group:**
  - Drinking water, and water used for washing and cleaning, gardening, etc.
- **Industrial water user group:**
  - *Category 1* – Strictest requirement, *e.g.* evaporative cooling (high rate of recycling);
  - *Category 2* – *E.g.* water heating;
  - *Category 3* – *E.g.* firefighting; and
  - *Category 4* – Water of more or less any quality, *e.g.* dust suppression.
- **Recreational water user group:**
  - *No-contact recreation*, *e.g.* fishing;
  - *Intermediate contact recreation*, *e.g.* boating and water skiing; and
  - *Full contact recreation*, *e.g.* swimming.
- **Aquatic ecosystem:**
  - Although not a water user, *per se*, the aquatic ecosystem's instream and riparian habitat and biota water quality requirements (the Reserve, where available) are being co-considered with the water quality requirements of the other water user groups.

[130] **Watershed:** See "Catchment".

[131] **Zooplankton:** Are the heterotrophic (other-feeding) component of the plankton community in freshwater and marine ecosystems and consists of small protozoans (single-celled eukaryotes) and metazoans (multicellular eukaryotic organisms). Zooplankton are generally larger than phytoplankton, mostly still microscopic, but some are a few millimetres long and can be seen with the naked eye.

[On completion of the document, we will make sure that all terms are referenced in the main text with the red reference numbers.]

Executive Summary

[To be completed on completion of the document.]

Table of Contents

Figures

Tables

Page

Insert Boxes

Insert Photos

Annexures

ANNEXURE A	Human health, and other effects of water resources that are unfit-for-use, with respect to some eutrophication-related water quality parameters.
ANNEXURE B	Supporting National Environmental Management Principles.
ANNEXURE C	The 28 Fundamental Principles and Objectives for a New Water Law in South Africa (1996), from eutrophication management perspective.
ANNEXURE D	The role of the National Water Act, 1998 (Act No. 36 of 1998) and the Water Services Act, 1997 (Act No. 108 of 1997) in eutrophication management.
ANNEXURE E	Existing provisions in the National Water Act, 1998 (Act No. 36 of 1998) for the making of regulations, which can be employed to enhance the control and management of anthropogenic eutrophication.
ANNEXURE F	Short summary of the purpose and nature of the National Eutrophication Monitoring Programme (NEMP).
ANNEXURE G	Potential legislative amendments, necessary to improve eutrophication management.
ANNEXURE H	Summary table: Eutrophication management policy.
ANNEXURE I	Summary table: Eutrophication management strategy.

PART 1: THE SOUTH AFRICAN CONTEXT

PHOTO 1: *"SOME FOR ALL FOR EVER!"* © J.J. VAN WYK

CHAPTER 1: THE EUTROPHICATION CHALLENGE

BOX 1: *"What is eutrophication?"*

Eutrophication is the process of nutrient enrichment of waters which results in the stimulation of an array of symptomatic changes, amongst which increased production of algae and aquatic macrophytes, deterioration of water quality and other symptomatic changes found to be undesirable and to interfere with water users [OECD, 1982].

This document will focus on ways to control eutrophication that is caused by human activities – also known as *"anthropogenic eutrophication"*!

1.1 Key challenges associated with eutrophication

Anthropogenic[6] nutrient[77] enrichment[79] of water resources is a global water resource problem [Rast & Thorton, 1996]. It is most evident in highly populated and developed areas where industrial effluent, water-borne sewage systems, wash-off from built-up areas, fossil fuel combustion and atmospheric fall-out, and agricultural practices contribute to elevated loads of nutrients entering receiving water resources. Elevated nutrient-loading promotes excessive primary production[95] in natural systems, causing a wide array of biological diversity [Cook, et al., 2018] and water quality problems [Dunst, et al., 1974]. South Africa itself has some of the most highly enriched surface waters in the world [Ashton, et al., 1985; Van Ginkel, et al., 2000a].

Eutrophication[47] challenges in South Africa are exacerbated by insufficient wastewater infrastructure maintenance[64] and investment; deteriorating ecological infrastructure; recurrent droughts, driven by climatic variation, and an inescapable need for water resource development; inequities in access to safe sanitation, against the backdrop of a growing population; water use regulation that is not consistently and adequately protecting South Africa's water resources against eutrophication; and a lack of skilled water scientists and engineers. Poor water quality, including eutrophication, is already having significant impacts on economic growth and on the well-being of South Africans [DWS, 2017b].

1.1.1 Insufficient wastewater infrastructure maintenance

One of the most often quoted opening lines on water issues in South Africa typically reads *"… South Africa is a water scarce (or semi-arid) country with severely limited water resources …"*. What is not so often mentioned is that wastewater return-flows comprise a major component of the country's water budget and that discharges of water containing waste are required to be returned to surface water resources for indirect reused further downstream [Harding, 2017].

The importance of well-functioning municipal wastewater treatment works (WWTWs) is embedded within the fact that they act as the last barriers and final interface between untreated urban wastewater and healthy aquatic ecosystems[7]; other receiving water users[129] that optimally contribute towards economic growth; and the health of the country's population. Whereas poor wastewater handling is known to be a lead cause of nutrient over-enrichment, this cause of eutrophication is also intertwined with other water quality challenges, such as microbial pollution and concomitant health risks; elevated Chemical Oxygen Demand (COD); and others that affect wastewater reuse[106] and recycling[99] strategies. It was found that up to 70%, and sometimes even more, of the water abstracted by cities, returns as polluted effluent [SA Commission of Enquiry into Water Matters, 1970]. Municipal urban wastewater return-flow profiles include residential, commercial, business and industrial users, as well as schools, hospitals, sports and recreation facilities, parks and government institutions, implying that poor urban wastewater handling affects society at multiple levels.

South Africa possesses a vast network of collection and sewer network systems; pumping stations; and WWTWs that, collectively, must ensure that the quality of urban wastewater complies with the authorised levels prior to it being discharged and/ or reused or recycled. However, approximately 56% of the over 1 150 municipal WWTWs in the country are in a poor or critical condition and in need of urgent rehabilitation [DWS, 2018b, p. 5.1]. Additionally, the facilities previously provided to some households have become inadequate due to various factors, including poor facilities operation; infrastructure operated above its design capacity; ageing infrastructure and insufficient maintenance; and ventilated improved pit latrine (VIP) pits not being emptied regularly. Compliance with the Green Drop requirements, previously measured in 2014, was generally very poor, with a 119 of the 144 Water Services Authorities (WSAs) achieving less than 80% compliance [DWS, 2014].

In addition, South Africa is one of the most unequal countries in the world, with extremely high levels of poverty. Sixty-three percent of households earn less than R 38 000 per year (indigent level) resulting in high levels of grant dependency with related impacts on affordability and services viability. Some 77% of rural households are indigent and are not required to pay for basic municipal services. The percentage of individuals that benefited from social grants consistently increased from 12.7% in 2003 to 29.7% in 2016 [DWS, 2018b], placing an ever increasing burden on limited government financial resources to finance the operation and maintenance of municipal WWTWs. Today, effective administrative and management practices are also hampered by systemic corruption that is associated with many municipalities in South Africa [Muller & Erasmus, 2020].

This resulted in a lack of proper operation and maintenance of WWTWs in most municipalities, and the discharge of sub-standard return-flows or untreated sewage is a frequent occurrence that significantly contributes towards nutrient-loading of water resources and the prevalence of eutrophication. Well operated and maintained wastewater infrastructure and good practices must enhance the principles of health, dignity and the protection of water resources, ensuring an improved quality of life for all in South Africa.

1.1.2 Deteriorating ecological infrastructure

The basic hydrological unit for water resource quality[101] management is the catchment[19] and it is necessary to recognise the unity of the water cycle and the interdependence of its elements, where evaporation, clouds and precipitation are linked to groundwater, rivers, lakes, wetlands and the sea [DWAF, 1997]. Every catchment relies heavily on extensive ecological infrastructure to maintain healthy functioning aquatic ecosystems[7] and to provide much needed services, or *"nature-based solutions"*, to people. Ecological infrastructure includes, for instance, mountain catchment areas, streams, rivers and sub-surface water movement, floodplains, lakes, wetlands, estuaries, coastal dunes, and the marine environment, as well as beds and banks of water resources, and nodes and corridors of natural habitat, which together form a network of interconnected structural elements in the landscape [SANBI, 2014]. The ecological infrastructure in catchments renders valuable services, such as fresh water for domestic, industrial, agricultural and recreational use; ecotourism; soil formation; medicine and food (including fish, wild foods and others) provisioning; hydropower generation; climate variability regulation; flood and drought risk reduction; purification of air; crop pollination; pest and disease control; waste decomposition and detoxification; and water quality improvement functions (including nutrient cycling and dispersal); and much more! It is the nature-based equivalent of built or hard infrastructure, and is just as important for providing services, ensuring water security and underpinning socio-economic development. Because the services derived from ecological infrastructure are effectively *"free services"*, we tend to take their benefits for granted. Indeed, few, if any, authorities or utilities list catchments as assets anywhere on their books, and landowners aren't rewarded for good management practices that result in downstream user benefits [WRC, 2014].

A healthy aquatic ecosystem[7] is one that is intact in its physical, chemical, and biological components and their interrelationships, such that it is resilient to withstand changes and stressors. It is a system that is not experiencing the abnormal growth or decline of native species, persistence of elevated concentrations of contaminants, or drastic anthropogenic[6] changes to its landscape or ecological processes [Baron & Poff, 2004].

Unfortunately, much needed social development and economic growth are often synonymous with adverse impacts on ecosystem health and concomitant ecological infrastructure. **FIGURE 1** shows a worrying trend observed in major impoundments across the country………… ……….

Need some factual representation on a graph to demonstrate worsening eutrophication trends that need to be arrested.
This is essential to show that the problem is real!!!
Look at the annual P, N and Chl-A loading of major dams in SA over time.

[Samkele to assist with number crunching]

FIGURE 1: Annual P, N and Chl-A loading of major South African dams over time.

Eutrophication, as one of the importunate environmental hazards of aquatic ecosystems[7], causes pronounced cascading deterioration of water qualities and risk to biotic components, which, amongst others, include [Schmutz & Sendzimir, 2018; Clark, et al., 2017; Padedda, et al., 2017; Chamier, et al., 2012; Baron & Poff, 2004; Walmsley, 2000]:

- Increased occurrences of floating and rooted aquatic macrophytes[62];
- Native plant species loss and replacement with alien plant species, often also affecting resource water quality through reduced dilution capacity, resulting from increased evapotranspiration; altered nutrient cycling, especially due to nitrogen fixers such as *Acacia* spp.; and increased occurrences of soil erosion, associated with the increased fire hazards;
- Increased occurrences and intensity of nuisance algal blooms;

- Increasing dominance of cyanobacteria[25] and the occurrence of toxic cyanobacteria;
- Undesirable aesthetic conditions (*viz.* discolouration, increased turbidity and loss of clarity, foaming, presence of odours, etc.);
- Severe shading and light attenuation caused by blooms of both macro-algae and phytoplankton[90] and the presence of debris hinder the photosynthetic processes in benthic[11] plants and leads to benthic habitat destruction;
- Loss of benthic[11] diversity affects and lead to stressed bottom-feeding fish and other animals;
- Increased occurrences of deoxygenation[26] in reservoir bottom waters leads to elevated levels of hydrogen sulphide and heavy metals;
- The decomposition of organic matter leads to an over-supply of CO_2, which, in turn, also enhances water acidification;
- Excessive algal blooms are harmful to, and lead to injury of aquatic animals, such as the clogging of fish's gills, poisoning by toxins secretion, and localized anoxia[5] that effects subsistence and sports fishing;
- Increased fish and invertebrate mortality;
- Changes of ecological community structure and loss of biological diversity; and
- Mortality of domestic and wild animals, drinking hypertrophic[53] waters that contains toxins.

The White Paper on a National Water Policy for South Africa (1997) states: *"The sustainable use of water resources means that, even where the immediate demands for development are very high, society must find different development approaches which make sure that the use of water resources does not destroy their ability to recover"* [DWAF, 1997]. Protecting our ecological infrastructure is not optional, but obligatory!

1.1.3 Recurrent droughts, driven by climatic variation, and an inescapable need for water resource development

Large parts of South Africa suffer from relatively low rainfall and water resources are highly developed, especially surface water systems, through a myriad of large dams around the country [DWS, 2018b, p. 3.9]. Dams are a *"necessary evil"* that, together with many other water supply interventions, must assist to ensure continued water security in the country [Venter, 1971, p. 29; DWA, 1986, p. 6.45]. However, the damming of surface water resources greatly modifies the ecological functioning of river systems. In particular, dams sequester nutrient elements and, hence, reduce downstream transfer of nutrients to floodplains, wetlands, lakes and the coastal marine environment. Additionally, damming influence regional nutrient limitation patterns, food web dynamics and trophic conditions, often resulting in the presence of hypertrophic conditions in reservoirs [Maavara, et al., 2015].

Drought conditions in South Africa, driven by climate variation is expected to have a major impact on South Africa, with resulting consequences for ecosystems, people and the economy. Water is the primary medium through which the impact of climate change is going to be experienced [DWS, 2013, p. 75]. Climate change is expected to result in changing rainfall patterns; changing storm intensities and the extremes of floods and droughts; higher solar radiation intensities; higher ambient air temperatures; increasing evaporation; changes in soil moisture and runoff; higher demands for water in some areas and changes in water availability; changing water quality conditions (including the water temperature of aquatic systems); and increasing climate variability [DWS, 2015]. Climate change is expected to amplify deteriorating trophic conditions in water resources by changing the internal and external nutrient loadings, as an impact of ambient temperature rise; and changing precipitation patterns; altering solar radiation intensity; and wind speed [Nazari-Sharabian, et al., 2018].

Warmer water temperatures, resulting from heat exchange between a warmer ambient atmosphere and the water column, influence the chemical and physical properties of water. For instance: pH decreases; salinity decreases; the solubility of solids increases and the solubility of gasses, such as oxygen, decreases; diffusion rates increase; and the rates of biochemical processes initially increase as water temperatures start to rise. When water temperature and nutrient concentrations increase, primary production is stimulated, leading to eutrophic conditions and algal blooms [Mooij, et al., 2007], especially within stratified reservoirs that act as nutrient traps [Schmutz & Sendzimir, 2018].

As temperatures rise, precipitation is expected to not change uniformly. In areas with projected higher precipitation, it is possible that intense precipitation events will occur and cause more erosion and resuspension of sediments and mobilisation of diffuse sources of pollution, ultimately resulting in higher concentrations of sediments and nutrients ending up in receiving water resources [Whitehead, et al., 2009; Vogel, et al., 1999]. In areas with projected lower precipitation, it is possible that lower minimum flows, coupled with higher rates of evaporation and evapotranspiration, will occur, resulting in less dilution capacity in receiving water resources. As a result, increased concentrations of contaminants can cause deoxygenation, by lowering dissolved oxygen (DO) concentrations and increasing biological oxygen demand (BOD). Consequently, the risk of eutrophication, especially in water resources with limited re-aeration capacity, will be increased. Therefore, under climate change conditions and due to the alteration of regional precipitation patterns, water resources can be expected to be exposed to increased nutrient-loading, which can ultimately lead to increased primary production and hypertrophic conditions [Whitehead, et al., 2009].

Global warming and solar radiation have mutual connections. As an important source of energy, solar radiation plays a crucial role in photosynthesis in different ecosystems and is an essential factor for the growth of phytoplankton[90] and other aquatic plants. If such phytoplankton[90] and aquatic plants do not receive sufficient amounts of sunlight, they start to consume oxygen leading to the depletion of DO in the water column. Under anaerobic[4] conditions, phosphorus[88] released from sediments can lead to eutrophication. Algae distribution is also dependent on the intensity of solar radiation received at different depths, resulting in increased algae growth up to a maximum growth rate [Craig, et al., 2014].

The wind will also be affected by climate change and will have direct and indirect effects on the trophic status[117] of water resources[128]. The direct effects of wind refer to the blowing of algae near the water surface to shores, forming algal blooms and changing environmental conditions. The indirect effect relates to the mixing effects created in the water column that enhances the mixture of nutrients[77] and accelerates the release of nutrients from sediments. Also, as the air temperatures rise, wind mixes the warmer upper layers of water with the colder lower layers, which can speed up solubility, diffusion and transformation of pollutants. Changing wind action can also cause inversion[59] of stratified layers[114] in water columns to occur more or less frequently, causing oxygen starvation near the water surface. On the other hand, intense and high-speed winds can also restrain the formation of algal blooms by dissipating algal blooms and weakening their aggregation [George, et al., 2007].

Therefore, poor trophic conditions[117] in water resources is likely to be exacerbated by climate change and the protection of our invaluable water resources in a changing climate is a big and significant challenge for policymakers today, and deserves considerable attention for the sake of future generations. However, three important questions related to eutrophication in a changing climate remain to be addressed, *viz.* (1) Which are the critical climate change factors that affect eutrophication in freshwater ecosystems the most; (2) How to completely differentiate the impact of climate change from that of anthropogenic[6] activities on eutrophication and feedback mechanism; and (3) What are the best and most feasible adaptation countermeasures for dealing with climate change's effects on eutrophication? [Nazari-Sharabian, et al., 2018].

1.1.4 Inequities in access to safe sanitation, against the backdrop of a growing population

The provision of safe sanitation is a key requirement for the establishment of sustainable and healthy communities, the protection of water resources, the promotion of social and economic benefits that are aligned to the national development goals [NPC, 2012] and to meet the human rights [RSA, 1996] of all who live in South Africa.

While population growth is, on average, 1.2% per annum, this varies from negative to positive across communities. The growth in the number of households, however, is much higher and is currently at around 3% per annum, nationally. This is due to migration, mainly urbanisation, and the dedicated housing programme of government that *inter alia* lead to the sub-division of previous large households. Urbanisation continues to have a major impact on sanitation provision, with many rural people moving to urban centres in search of jobs and improved services. Additionally, while only 33% of the population currently live in rural areas, they represent 81% of the national count of settlements due to their small and scattered nature, making it spatially challenging to provide a good coverage of sanitation services to all [DWS, 2018b; Stats SA, 2016].

Baseline figures on access to reliable sanitation service delivery are regularly collected by Statistics South Africa through the national census and through their General Household Surveys. Since 1994, and particularly after 2001, an estimated 5.15 million households have been provided with safe and acceptable sanitation facilities. In 2008, approximately 27% of the population received sanitation services, below the Reconstruction and Development (RDP) standard (**FIGURE 2**). [Schreiner & Hassan, 2011].

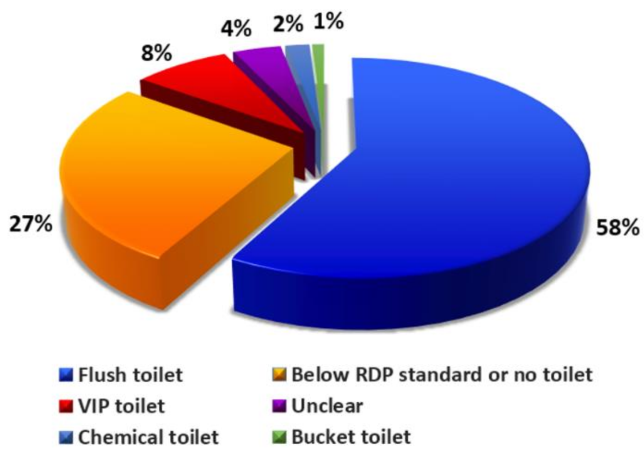

FIGURE 2: Access to sanitation in South Africa, 2008 [Stats SA, 2007; DWAF, 2008].

The backlog in 1994 was estimated at 4 million households, whereas at April 2017 it was estimated that there were still 3.96 million unserved households [DWS, 2018b]. The South African population increased from around 40 million, in 1994, to a total of 55.6 million, as recorded in the 2016 Census [Stats SA, 2016]. Progress in the reduction of this moving backlog has been hampered by the substantial population growth and by households becoming smaller (*i.e.* growing at a faster rate than the population), and it is estimated that approximately 14.1 million people do not have access to safe sanitation in South Africa, today [DWS, 2018a]. The sanitation crisis, in particular, threatens the health and well-being of the poor and vulnerable in South Africa, while also contributing towards eutrophication of water resources and impacting negatively on the country's economic growth.

1.1.5 Water use regulation not consistently and adequately protecting South Africa's water resources against anthropogenic eutrophication

In the Republic of South Africa (RSA), government is constituted as national, provincial and local spheres of government which are distinctive, interdependent and interrelated [RSA, 1996, S.40(1)].

The Constitution designates the executive authority to provide water and sanitation services to local government [RSA, 1996, S.156(1)(a)]. In terms of the Water Services Act, 1997 (Act No.108 of 1997), the responsibility for ensuring access to water and sanitation services resides with WSAs (municipalities). It is the responsibility of WSAs, through Water Services Providers (WSPs), to ensure access to safe water and sanitation services [RSA, 1997].

The lawfulness of a discharge of water containing waste, including municipal wastewater, is essentially determined by whether such a discharge is permissible in terms of the NWA (36:1998) and whether it complies with applicable authorisation requirements, such as relevant Waste Discharge Standards (WDSs), as may be stipulated in the Municipal Approval, in the case of Schedule 1 water use; or an authorisation issued within the 24 month period prior to 30 September 1998 to an Existing Lawful water Use[48] (ELU); or the applicable General Authorisation (GA); or the water use licence in question; or an alternative authorisation, if dispensing with the requirement for a licence to be issued under the NWA (36:1998) [RSA, 1998, S.22(1)].

One of the biggest causes of excessive nutrient enrichment of water resources by a single water use sector in the country can be ascribed to poor municipal wastewater handling [Harding, 2017; Mudaly & van der Laan, 2020]. The socio-economic impacts associated with poor resource water quality can be severe! The authorisation of municipal water uses and the enforcement of conditional water use authorisations, thus, are critical!

Although the Constitution calls on all spheres of government and all organs of state within each sphere to co-operate with one another in mutual trust and good faith by fostering friendly relations; assisting and supporting one another; and avoiding legal proceedings against one another [RSA, 1996, S.41(1)(h)], the Constitution also grants citizens specific rights to access to sufficient water, an environment not harmful to health and well-being and the protection of the environment from degradation [RSA, 1996, S.27 and 24]. The right to basic sanitation is not an explicit constitutional right. However, the right to sanitation could be derived from the right to a clean environment, read together with the right of access to clean water. Many other constitutional rights in the Bill of Rights overlap with, and support the rights to water supply and sanitation services. These include the rights to equality, dignity, of access to information and just administrative action [Algotsson, et al., 2009, p. 2].

The NWA (36:1998) designates the authority to act as the trustee of the nation's water resources to National Government, acting through the Minister of Human Settlements, Water and Sanitation to ensure that water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner, for the benefit of all persons [RSA, 1998, S.3(1)]. Part of the purpose of the NWA (36:1998) is to prevent and to reduce pollution[125] and degradation of water resources [RSA, 1998, S.2(h)]. Any person that unlawfully and intentionally or negligently commit any act or omission which pollutes or is likely to pollute a water resource is guilty of an offence [RSA, 1998, S.151(1)(i)]. The Act, further, compels responsible authorities to give effect to any determination of a class of a water resource and the associated Resource Quality Objectives (RQOs) [RSA, 1998, S.15] in order to ensure that South Africa’s water resources remain fit-for-use.

Although legislation should be applied in a just, fair and consistent manner to both private and public sector water users alike, the constitution also places an obligation on national and provincial governments to, by legislative and other measures, support and strengthen the capacity of municipalities to manage their own affairs, to exercise their powers and to perform their functions [RSA, 1996, S.154(1)]. The intention, however, was not to make it possible for municipalities in contravention of environmental legislation to avoid accountability through continuous appealing for support, especially in cases where such support is required post compliance monitoring and enforcement, as undertaken by the DWS.

A notable degree of dysfunction in many municipalities, due to a range of institutional, technical and/ or management incapacity, financial and political reasons, exists [DWS, 2017a]. The fact that only 60 WWTWs (**FIGURE 3**) could achieved Green Drop certification in 2013, is a reflection of the poor condition of municipalities in South Africa [DWA, 2013]. There is an urgent need to address issues of accountability, coordination and leadership, poor cooperative governance and inadequate cross-regulatory interfacing with the DWS, as well as the appropriate actions to be put in place where WSAs show consistent failure in the delivery of universal and reliable water services.

Challenges with the authorisation of water use, that have significant impacts on aquatic ecosystems, or other receiving water users, include– the prevalence of water uses that are not permissible under the NWA (36:1998); incidences of poor authorisation administration; lack of regulatory integration and poor cooperation amongst relevant authorities; periodic backlogs with the issuing of water use authorisations; the poor quality of some water use authorisations, authorisation conditions that do not appropriately integrate with water resource requirements, as well as ELU with inadequate or outdated conditions; and poor compliance with water use authorisation conditions, coupled with insufficient compliance monitoring and inadequate enforcement.

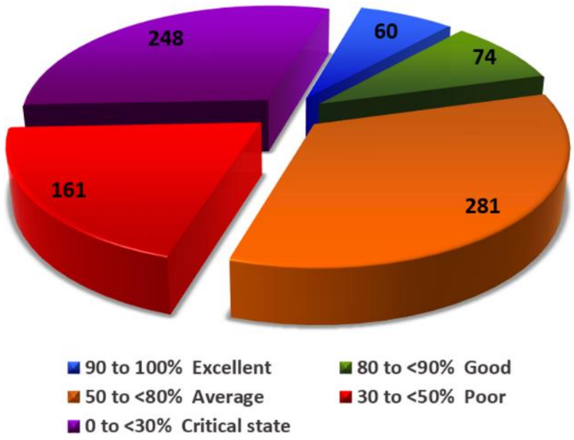

FIGURE 3: Wastewater Treatment Works that have been awarded different Green Drop scores, ranging from *"excellent"* to *"critical state"* [DWA, 2013].

ANNEXURE A provides a summary of some eutrophication-related water quality parameters, the associated water user concentration requirements and effects on human and aquatic ecosystem health and on other water users, should such parameters be present at unacceptable high levels in receiving water resources.

1.1.6 Lack of skilled water scientists and engineers

Skilled water scientists and engineers are indispensable to the development and implementation of eutrophication management solutions. This is particularly true when dealing with complex systems; having to engineer infrastructure solutions; conducting multi-criteria decision-making and forward planning; or when having to devise interventions that integrate with receiving water resource requirements. Skilled water scientists and engineers are an essential resource to be drawn upon by both the public and private sectors, as well as by civil society in the battle against water pollution[125] and eutrophication[47].

In the public sector, the Department of Water and Sanitation (DWS), from a national and sector leader perspective, and local government, from a municipal and Water Services Authority perspective, are key role-players that must collectively oversee and regulate the water value chain. Additionally, a number of other public water institutions, such as water services providers, water boards, catchment management agencies and water user associations must also be suitably staffed to complement the water resource and services function of government, especially with respect to the implementation of measures. In the private sector, knowledgeable scientists and engineers must see to environmental compliance management; the engineering of processes and infrastructure solutions; and to innovate approaches to address technical challenges.

The water sector is inter-sectoral and multi-disciplinary in nature [DWS, 2018b, p. 11.1]. When dealing with eutrophication, at an inter-sectoral level, collaboration with sectors, such as water and sanitation; agriculture; health; education; forestry; aquaculture; industry; mining and the environment; and government, whether it be national, provincial or local government, may be necessary. From a multi-disciplinary perspective, a range of focus areas, such as policy and regulation; planning and information; capital works design, construction, operation and maintenance; ecological protection; chemistry and microbiology; social and economic analysis; financial and project management, to name but a few, may need to be resourced.

In 2015, the Water Research Commission (WRC) conducted a sample public sector skills gap analysis with the aim of developing an integrated water sector skills intervention map. The skills gap analysis distinguished between *"capacity"*, which was used in the context of the number of staff per job title within an institution, and *"skills"* referring to the ability of the individuals. The capacity and skills gaps were determined by subtracting the supply from the demand, *i.e.* by considering the capacity necessary *vs.* capacity available and the skills necessary *vs.* skills available to manage water resources and services. It was found that the capacity gaps for the analysed Catchment Management Agency (CMA) and local municipality were 44% and 92% respectively, and that the skills gaps for the analysed CMA, water board and local municipality were 36%, 60% and 55% respectively [Vienings, et al., 2015, p. 220]. In a staff members' own rating exercise to analyse available skills in the DWS, a rating of 71% was recorded [Win-SA, 2015, p. 9]. The vacancies in the technical departments of the water institutions that were analysed by the WRC, averaged at 24% [Vienings, et al., 2015].

In local government, 144 municipalities have been assigned the function of Water Services Authorities (WSAs). At least 33% of municipalities are regarded as dysfunctional and more than 50% have no or very limited technical capacity [DWS, 2018b] – this in spite of the legal requirement that process control at Wastewater Treatment Plants (WWTPs), for instance, are required to be performed by skilled personnel [GN R.813, 2013].

It is critical to define skills and capacity building beyond individual capacity (**FIGURE 4**), to include institutional capacity, as well as the enabling environment [Morgan, 1998]. Capacity at the individual level is the most fundamental element of capacity. It becomes the foundation for organizational capacity and refers to the will and ability of an individual to set objectives and to achieve them using own knowledge and skills. Capacity at the organization level will determine how individual capacities are utilized and strengthened. It refers to anything that will influence an organization's performance. Capacity at the environment level refers to the environment and conditions necessary for demonstrating capacity at the individual and organizational level [JICA Task Force on aid approaches, 2004, p. 16].

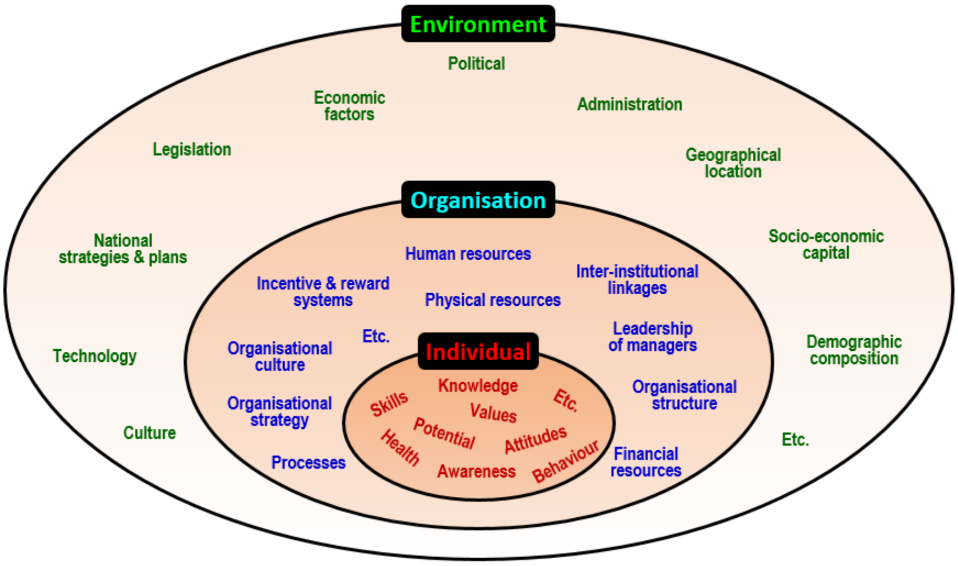

FIGURE 4: Levels of capacity [Adapted from Matachi, 2006].

Data from the Department of Higher Education and Training's (DHET) management information system (HETMIS) showed that the supply of Civil Engineering graduates has doubled over a five year period from approximately 1 000 to 2 000 graduates per year. All other graduate numbers with qualifications that apply to the water sector have also increased dramatically over the same period, with there no longer being a shortage of science graduates. Albeit that the supply of science graduates has improved significantly, water institutions remain to be plagued by a lack of skilled water scientists and engineers, and the environment and organisational capacities associated with many of these water institutions continue to hinder effective service delivery.

Management capacity on eutrophication issues has become diminished throughout the country as staffing transformation and human resource turnover within institutions has meant that there is limited background knowledge or practical experience of the problem. There have been few capacity-building special projects aimed at rehabilitating the eutrophication status of any aquatic system. The country has regressed in terms of its capacity and ability to deal with eutrophication [Moss, 1999].

A progressive water sector requires skilled individuals, empowered by a conducive organisational cultures and an enabling external environment that supports excellence and "batho pele" (Sotho-Tswana: *"People First"*). Without the necessary intervention, the trends of poor service delivery; increasing procrastination; and growing incidences of fruitless, wasteful, irregular and unauthorised expenditure of public funds in many water institutions are expected to continue, and even intensify.

1.2 Problem declaration and potential policy and strategy responses

Causal chain analysis [Rogers, 2000], often also called root cause analysis [Rooney & Van den Heuvel, 2004], is closely related to systems thinking [Arnold & Wade, 2015], life cycle assessment [Guinee, et al., 2011] and the Driver-Pressure-State-Impact-Response (DPSIR) approach [Kristensen, 2004]. At its most basic, a causal chain is an ordered sequence of events linking the causes of a problem with its effects. Each link in the causal chain is created by repeatedly answering the question: *"Why?"*

FIGURE 5[1] shows a simple theoretical causal chain example for phosphorus-loading of receiving water resources. It is interesting to note that the causes of water quality issues, as well as their ultimate effects, almost always reside within the socio-economic domain, implying that poorly planned and un-managed human development and progress, often, also are the enemy of prosperous and healthy societies.

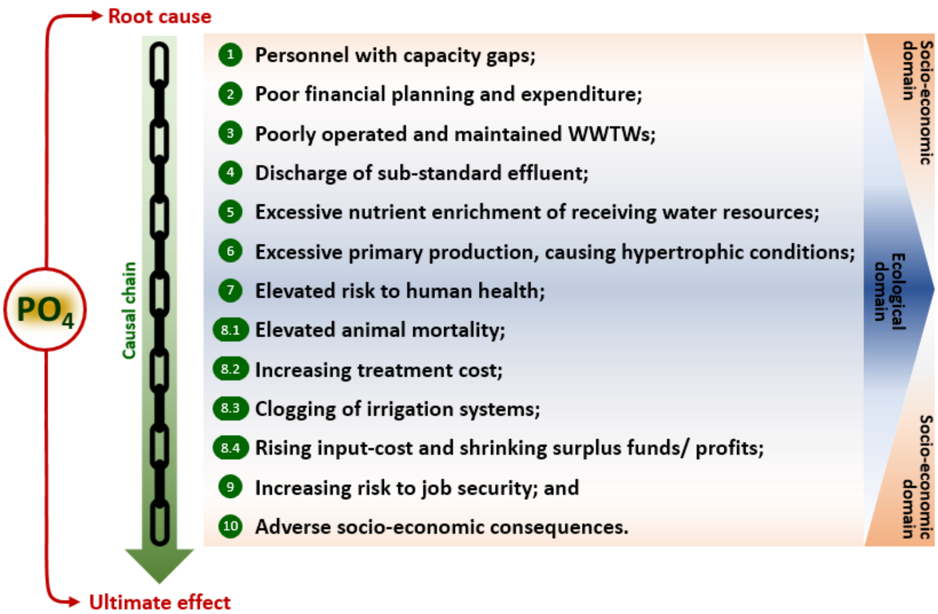

FIGURE 5: Example of a possible causal chain for phosphorus-loading.

[1] More complex causal chains are usually depicted in tree-format with a particular *"cause"* that can branch-off into one or more *"effects"*. The numbering of the cause-and-effect elements in **FIGURE 5** reflects this relationship. *"Cause"* 7 branches-off into *"Effects"* 8.1 up to 8.4. *"Effects"* 9 can follow on from any of the *"Causes"* 8.1 to 8.4. The *"effect"* following a preceding *"cause"*, constitutes the *"cause"* of the next *"effect"*, forming a causal chain.

The Driver-Pressure-State-Impact-Response (DPSIR) framework constitutes a structured approach to describe environmental problems, by defining relationships between anthropogenic activities and the environment[40] [Smeets & Weterings, 1999, p. 7]. According to the DPSIR framework, there is a chain of causal links, starting with *"driving forces"*, leading to *"pressures"*, that alter the *"state"* of bio-physico-chemical[15] conditions, causing *"impacts"* on the environment and eventually necessitating appropriate policy and/or political *"responses"* [Kristensen, 2004].

An analysis of eutrophication[47] in South Africa, based on the DPSIR framework and, in part, utilising input obtained from a country-wide survey which involved the nine DWS regional offices having completed questionnaires that addressed areas concerning eutrophication policy and strategy [Walmsley, 2003], are presented in **TABLE 1**.

TABLE 1 provides a succinct definition of the eutrophication PROBLEM in South Africa, incorporating causes, effects and their causal relationships in tabular format. Additionally, **TABLE 1** provides a *"bridge"* between *"problem"* and *"potential solution"* (addressed in Parts 2 and 3 of this document) by proposing potential eutrophication management policy, strategy and intervention solutions in the last column. These potential solutions are to be developed in Parts 2 and 3 of the document, in order to establish a concrete framework for the reduction of excessive nutrient enrichment[79] of water resources and the control of anthropogenic[6] eutrophication[47] in South Africa.

TABLE 1: An analysis of anthropogenic nutrient enrichment and the effects of eutrophication in South Africa, based on the DPSIR framework.

DRIVER ⇨	PRESSURE ⇨	STATE ⇨	IMPACT ⇨	RESPONSE ↺
i.e. the socio-economic needs, and production or consumption practises that trigger *"pressures"*.	*i.e.* the anthropogenic activities that disturb the *"state"* of ecosystems, such as effluent being discharged, etc.	*i.e.* the physical, chemical or biological condition of ecosystems that causes further *"impacts"* on the environment[40].	*i.e.* further effects on habitats, biota and society.	*i.e.* the societal measures aimed at preventing, minimising or mitigating *"impacts"* by feeding back to the *"drivers"*, *"pressures"* and *"state"* – arranged in accordance with the Shewhart-Deming Cycle [Moen & Norman, 2009].
Agriculture: ▶ Increased dry-land and irrigated crop production to maintain food security; ▶ More dairies and intensive animal feeding units needed to maintain food security; and ▶ Growing aquaculture to maintain food security.	▶ Fertilizer-laden diffuse[30] runoff from agricultural fields; ▶ Prevalence of erosion, mobilising sediments on which chemical elements are adsorbed; ▶ Feedlot waste disposal and wastewater discharged; and ▶ Organic waste, food leftovers, and excreta associated with aquaculture.	▶ Elevated P; ▶ Elevated N, also in groundwater resources that feed surface water resources; ▶ Elevated Chl-A; ▶ Occurrences and intensity of nuisance algal blooms; ▶ Occurrences of floating and rooted aquatic macrophytes[62];	▶ Shading leads to benthic habitat destruction; ▶ Stressed fish and other aquatic animals, susceptible to parasites; ▶ Bacterial infections of aquatic animals; ▶ Excessive algal blooms are harmful to, and lead to injury of aquatic animals, such as the clogging of fish's gills, poisoning by toxin	**Plan:** ▶ Holistic water resource system and catchment planning; ▶ Structured planning to ensure that WWTWs are timeously upgraded to not exceed design capacities; ▶ Validation and verification of all water uses with a water quality impact potential (V&V);

DRIVER ⇨	PRESSURE ⇨	STATE ⇨	IMPACT ⇨	RESPONSE ↺
Industry: ▶ Industrialisation; ▶ Poor industrial waste and wastewater handling; and ▶ Poor air quality management.	▶ Atmospheric emissions of NH_3 and NO_2 affecting the nutrient content of precipitation; ▶ Atmospheric emissions of NO_2 and SO_2 generate acid precipitation; and ▶ Untreated and/ or substandard wastewater.	▶ Native plant species loss and replacement with alien invasive plant species; ▶ Dominance of cyanobacteria[25] and the occurrence of toxic cyanobacteria; ▶ Undesirable aesthetic conditions (viz. discolouration, increased turbidity and loss of clarity, foaming, presence of odours, etc.); ▶ Severe shading and light attenuation caused by blooms of macro-algae, phytoplankton[90] and the presence of debris hinder the photosynthetic processes in benthic[11] plants; ▶ Elevated COD; ▶ Oxygen depletion, especially in the deeper layers of water resources during the end of summer; ▶ Loss of benthic[11] diversity affects and lead to stressed bottom-feeding fish and other animals; ▶ The decomposition of organic matter leads to an over-supply of CO_2, which, in turn, also enhances water acidification; ▶ Increased occurrences of deoxygenation[26] in reservoir bottom waters leads to elevated levels of	secretion, and localized anoxia[5] that effects subsistence and sports fishing; ▶ Changes of ecological community structure and loss of biological diversity; ▶ The proliferation of alien invasive plant species affects resource water quality through reduced dilution capacity, altered nutrient cycling and increased occurrences of soil erosion; ▶ Increased occurrences of taste and odour problems in final drinking water; ▶ Increased water treatment costs to run water treatment works (WTWs) to remove odours, tastes, toxins, etc.; ▶ Inorganic chemicals, such ammonia, nitrites, hydrogen sulphide, etc. that induce the formation of harmful substances, such as nitrosamines, suspected of being mutagenic[71], during the production of potable water; ▶ Increased occurrence of human health problems (i.e. gastroenteritis, skin irritations, etc.); ▶ Increased interference with recreational activities	**Do:** ▶ Integration of authorisation conditions with planning and water resource requirements; ▶ Improved water use authorisation and administration; ▶ Publishing of regulations for water uses in other sectors, such as the agricultural, municipal and industrial sectors, similar to Government Notice 704 for mines; ▶ Enforcement of conservation agriculture; ▶ Enforcement of buffer zones; **Check:** ▶ Improved monitoring programmes and reporting for local and national government; **Act:** ▶ Rehabilitation of ecological and hard infrastructure; ▶ Adequate maintenance[64] of water resource and
Mining: ▶ Opencast; and ▶ Underground mining operations.	▶ Blasting.			
Tourism: ▶ Seasonal trends peaking during holiday periods; and ▶ Increased demands for water services during peak times.	▶ Fluctuating and increased waste and wastewater production; and ▶ Fluctuating and increasing pressure on urban wastewater handling.			
Human settlement areas: ▶ Stormwater.	▶ Nutrient-laden diffuse[30] runoff from built-up areas.			
Municipal wastewater handling: ▶ Poor industrial wastewater handling feeding municipal sewer network systems; and ▶ Poor urban wastewater handling.	▶ Inadequate maintenance of onsite sanitation systems; and ▶ Discharge of untreated and/ or substandard wastewater.			
Other land uses: ▶ Poorly managed golf courses.	▶ Fertilizer-laden diffuse runoff from golf courses.			

DRIVER ⇨	PRESSURE ⇨	STATE ⇨	IMPACT ⇨	RESPONSE ↺
Population dynamics: ▶ Increasing urbanisation; ▶ Depopulation of rural areas; and ▶ Inadequate levels of education or absorbing of skilled, aspiring employees into the market.	▶ Increased urban waste production; ▶ Pressure on urban wastewater handling; ▶ Negative effect on the affordability of rural water services infrastructure, affecting operation and maintenance (O&M); ▶ Lack of skilled water scientists and engineers; and ▶ Inadequately capacitated water institutions.	hydrogen sulphide and heavy metals; ▶ Increased fish and invertebrate stress and mortality; ▶ Sequestration of nutrients in the sediment; and ▶ Soil properties, such as pH, affects P availability. Under some condition a high soil pH can increase P mobility and availability, whereas, acid precipitation can reduce P mobility, holding P back until the pH rises again.	(i.e. boating, fishing, swimming, etc.); ▶ Struggling tourism due to foul odour and turbidity issues, skin irritations, etc.; ▶ Loss of property values; ▶ Interference with irrigation and livestock agriculture (i.e. clogging of irrigation nozzles and livestock mortalities); ▶ Mortality of domestic and wild animals, drinking hypertrophic[53] waters that contains toxins; ▶ Reduced income from agriculture, tourism and other effected sectors; and ▶ Economic loss.	services infrastructure; ▶ Development of Best Practice Guidelines (BPGs) and other supporting instruments; ▶ Revision of nutrient standards; ▶ Skills development training; ▶ Behavioural change communication programmes to facilitate behavioural change and a sense of responsibility in communities. [Will come back to this, during Parts 2 and 3. Some cross-linking with the NW&S MP is also necessary]
Climate variability: ▶ Extended dry spells; ▶ Increasing demands for water resources development; and ▶ Expected climate change.	▶ More frequent mixing of stratified layers and inversion of epilimnion and hypolimnion; ▶ Impoundments acting as nutrient sinks; and ▶ Exacerbated poor trophic conditions.			
Poverty and criminality: ▶ Increasing vandalism of water services infrastructure; and ▶ Declining affordability of social infrastructure.	▶ Washing in streams and in rivers; ▶ Inappropriate onsite sanitation and bush-toileting; ▶ Theft and destruction of sanitation services infrastructure; ▶ Overflowing manholes caused by sewer system blockages; and ▶ Discharge of untreated and/ or substandard urban wastewater.			

DRIVER ⇨	PRESSURE ⇨	STATE ⇨	IMPACT ⇨	RESPONSE ↺
Administrative and political instability: ▶ Service delivery protests; ▶ Systemic corruption; ▶ Poor management; ▶ Insufficient funding to finance necessary capital (capex) and operational expenditure (opex); and ▶ Poorly operated and/ or maintained water resource and services infrastructure.	▶ Destruction of water resource and services infrastructure; and ▶ Discharge of untreated and/ or substandard urban wastewater.			

The above summation of causes, effects and challenges that are associated with over enrichment and the occurrence of hypertrophic conditions in water resources in South Africa, has highlighted multiple inter-causal-linkages. **FIGURE 6** is a graphical representation of some of these inter-causal-linkages. Most importantly, it has been shown that uncontrolled, and poorly planned and managed development ultimately affects the sustainability of such development to the detriment of society. The cumulative effects of water pollution[125] on aquatic ecosystems, society and the economy is significant, and measures need to be put in place to control and to manage the occurrence of anthropogenic eutrophication.

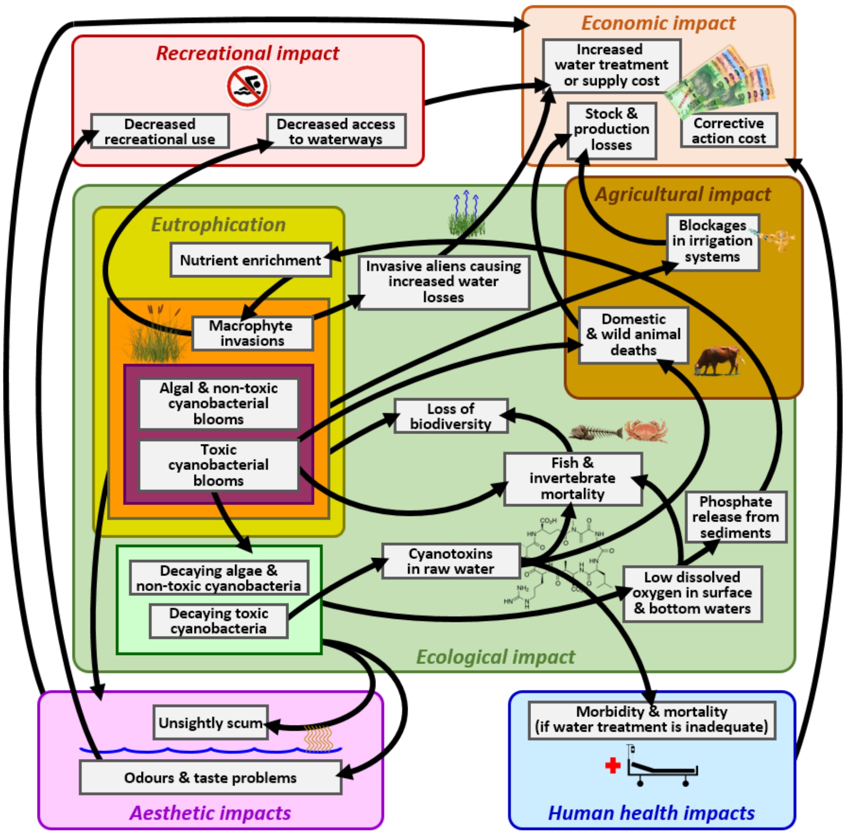

FIGURE 6: Prominent detrimental impacts associated with eutrophication [Adapted from DWAF, 2002].

South Africa's 56 million inhabitants live in more than 28 thousand communities [Stats SA, 2016]. All the citizens in each of these communities have basic rights that are guaranteed in the Constitution through the Bill of Rights that enshrines the rights of all people in South Africa and that affirms the democratic values of *human dignity*, *equality* and *freedom* [RSA, 1996, Bill of Rights: Section 7(1)]. The slogan: *"Water is life! Sanitation is dignity!"* is the embodiment of the contribution of water, as a common good, towards achieving these lofty democratic values. Eutrophication is incompatible with these values and, thus, also with the slogan: *"Water is life! Sanitation is dignity!"*, quoted above, since poor sanitation constitutes a significant source of nutrient over-enrichment that leads to eutrophication which, in turn, are one of the leading causes, threatening the fitness-for-use of the country's water resources. Water is a basic necessity of life!

CHAPTER 2: DEFINING THE SUBJECT

2.1.1 Eutrophication

"Eutrophication" is a traditional ecological term used to describe the process by which a water body becomes enriched with plant nutrients[77] [Walmsley, 2000, p. 4]. During this process the water body accumulates organic matter (both living and decaying) and progressively changes its character from that of a deep water body to that of a wetland and, ultimately, to that of a terrestrial system. Eutrophication[47] is therefore a term that is primarily associated with the process of natural ageing of lakes [Holdren, et al., 2001]. Under natural conditions this process (**FIGURE 7**) takes place over tens of thousands of years. However, over the last 100 years, human influences have greatly accelerated the rate of enrichment, thereby shortening the lifespan of water bodies. Importantly, two types of eutrophication[47] can be distinguished [Walmsley, 2000], *viz*.:

- ***Naturally occurring eutrophication*** that is dependent on the geology and natural features of a catchment[19]. It is not reversible and continues *ad infinitum*, albeit at a slow rate; and
- ***Human-induced eutrophication*** that is related to anthropogenic[6] activities. Some references also refer to the latter process as *"cultural eutrophication"*, as it is associated with human activities (social and economic), and accelerates the rate of ageing of water bodies. Anthropogenic[6] eutrophication[47] is reversible, albeit at a cost!

Anthropogenic[6] eutrophication[47] was first recognised as a problematic environmental process when scientists were able to associate problem conditions in water bodies with increased nutrient enrichment[79] from human activities [Stewart & Rohlich, 1967; Vollenweider, 1968]. The process of eutrophication[47] also became associated with a wide array of water resource problems [Dunst, et al., 1974]. This led to many definitions of the term and a rather confused understanding of what it meant. One of the most widely accepted definitions of eutrophication is that of the Organisation for Economic Cooperation and Development [OECD, 1982] which describes the process as: ***"... the nutrient enrichment[79] of waters which results in the stimulation of an array of symptomatic changes, amongst which increased production of algae and aquatic macrophytes, deterioration of water quality and other symptomatic changes are found to be undesirable and interfere with water users"***.

By controlling the anthropogenic[6] triggers of excessive nutrient enrichment[79], eutrophication[47] can be managed. In contrast to anthropogenic eutrophication, natural eutrophication cannot be readily managed, though, in some instances, it may be possible to influence naturally occurring eutrophication with management measures, such as stream-flow manipulation and remediation strategies.

Some parties see nutrient enrichment as having far wider implications than just water quality[126] problems in water resources[128]. This is because of the extent by which flows of anthropogenic[6] nutrient-containing materials have impacted on continental air, and terrestrial and aquatic eco-systems[7]. The issue is, therefore, perceived as being one of sustainable natural resource use (*i.e.* material sources of nutrients), nutrient flow through ecosystems, and multiple impacts on air, land and water [EPA, 2008; EPA, 2001; EPA, 2000a; EPA, 2000b].

- Oligotrophication[84] is *"eutrophication in reverse"* and refer to the process of nutrient depletion and reducing levels of primary production[95]. Oligotrophication can result [Stockner, et al., 2000], *inter alia*, from– the removal of primary nutrient inputs, such as the decommissioning of wastewater treatment works (WWTWs); inter-basin transfers; vegetation clearance and removal; the channelization and drainage of wetlands and streams; acidification or liming of waterbodies, and soils; etc.

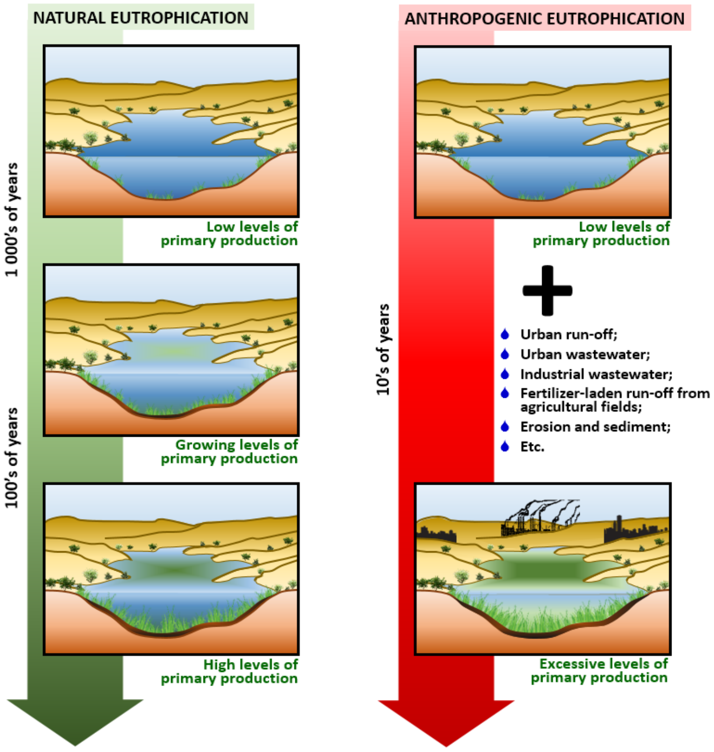

FIGURE 7: Illustration of *"natural"* and *"anthropogenic"* eutrophication [Holdren, et al., 2001, p. 42].

2.1.2 Nutrients

In previous discussions general references were made to nutrient-loading[81] as the cause of both natural and anthropogenic[6] eutrophication[47], in order to introduce the concept. Next, it is important to clarify the relative importance of the individual nutrient elements[77] in this process.

Living organisms require approximately 40 nutrient elements[77], which naturally occur, collectively in both the earth's crust, *i.e.* the lithosphere[62], and in the atmosphere[9], to sustain growth and reproduction. These essential nutrient elements are usually considered in two groups [Harper, 1992], *viz.*:

- ***Macronutrients*** (or major elements), such as calcium (Ca), magnesium (Mg), potassium (K), carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), sulphur (S), iron (Fe), as well as silica (Si), used in cell frustules[51] by diatoms[28] and a few other algal species, being the most important of the macronutrients, are required in larger quantities; and
- ***Micronutrients*** (or trace elements), such as copper (Cu), cobalt (Co), molybdenum (Mo), manganese (Mn), zinc (Zn), boron (Br), vanadium (Va), chlorine (Cl), selenium (Se) and vitamin complexes, being the most important of the micronutrients, are required in smaller quantities.

The most important nutrient element[77], carbon, is usually considered separately from the others, because it is the energy locked into the chemical bonds between carbon atoms and those with oxygen and hydrogen atoms, which is the basis of the photosynthetic conversion of solar energy into living tissue [Post, et al., 1990]. Additionally, oxygen and hydrogen are freely available in water under most circumstances [Miller, 1998].

Out of all the nutrient elements[77] derived from the lithosphere[62], and that are present in plant tissue, phosphorus and selenium are those whose proportional abundance is lower in the lithosphere than in plant tissue [Harper, 1992]. Phosphorus[88], thus, is a prime candidate for a macronutrient that would potentially limit primary production. Selenium, followed by zinc, molybdenum and manganese are potentially likely to be limiting micronutrients [Atlas & Bartha, 1987].

Out of all the nutrient elements derived from the atmosphere[9] or hydrosphere[52], such as carbon, nitrogen, oxygen and hydrogen – nitrogen[73] is regarded as a prime contender to potentially limit primary production. This is due to nitrogen's prevalent gaseous form, *i.e.* nitrogen gas (N_2), making up the lion's share of nitrogen on the planet, and because nitrogen gas (N_2) cannot be assimilated directly by plants, whereas carbon is unlikely to be limiting because of its prevalent gaseous form, *i.e.* carbon dioxide gas (CO_2), being water soluble and bio available under most circumstances [Harper, 1992].

2.1.3 Nutrient cycling and anthropogenic interference

Cycling of the limiting nutrients, phosphorus and nitrogen, are discussed next.

On land, over thousands of years, phosphorus[88] is gradually becoming less available to plants, since it is slowly lost in runoff to the marine environment. Humans have caused major changes to the global bio-geochemical phosphorus cycle through mining and the utilisation of phosphorus minerals, *inter* alia, as phosphorus fertilizer; in detergents; and also the export of food from farms to cities, where it is lost as effluent. Phosphorus does enter the atmosphere[9] in very small amounts when dust is dissolved in rainwater and seaspray, but remains mostly on land and in rock and soil minerals. Phosphates move quickly through plants and animals. However, the processes that move phosphorus through the soil or oceans are very slow, making the phosphorus cycle, overall, one of the slowest bio-geochemical cycles. The global bio-geochemical phosphorus[88] cycle (**FIGURE 8**) includes five major processes [Miller, 1998; Atlas & Bartha, 1987], *viz.*:

- ***Tectonic uplift***, leading to exposure of phosphorus-bearing rocks, such as apatite, to surface weathering;
- ***Geological cycling*** caused by physical erosion, and chemical and biological weathering of phosphorus-bearing rocks, enhanced by anthropogenic activities, such as mining, to expose dissolved and particulate phosphorus in soils and water resources[128];
- ***Cycling through terrestrial organisms***, causing sedimentation of particulate phosphorus (*e.g.* phosphorus associated with organic matter and oxide/ carbonate minerals) and eventually burial in soils on land;
- ***Riverine and subsurface transportation*** of phosphorus to receiving lakes and runoff to the ocean; and
- ***Cycling through aquatic organisms*** to cause sedimentation of particulate phosphorus (*e.g.* phosphorus associated with organic matter and oxide/ carbonate minerals) and eventually burial in the sediments in freshwater resources and the marine environment.

Phosphorus occurs as orthophosphate, polyphosphates and organic phosphates, either dissolved or bound to particulate material. Orthophosphate (PO_4^{3-}) is generally considered to be the most immediately available form of phosphorus. However, mineralisation; absorption onto suspended material or sediment; desorption under aerobic conditions; assimilation by plants; and precipitation with calcium or iron, are all processes that play important roles in influencing the concentration of available phosphorus in fresh and marine waters [Walmsley, 2000].

The majority of the Earth's atmosphere (±78%) consist of atmospheric nitrogen, making it the largest source of nitrogen. Nitrogen occurs in surface waters in several forms, *e.g.* ammonium (NH_4^+), nitrite (NO_2^-), nitrate (NO_3^-), urea (CH_4N_2O), and nitrogen gas (N_2). All freshwater algae are able to assimilate the first four forms, but nitrogen gas can only be utilised by certain species of blue-green algae (cyanobacteria such as *Anabaena* species) [Brock & Madigan, 1988].

The nitrogen cycle is extremely important in determining the availability of nitrogen (timing and quantity) in surface waters [Walmsley, 2000]. Human activities, such as fossil fuel combustion, the use of artificial nitrogen fertilizers, and the release of nitrogen in wastewater have dramatically altered the global nitrogen cycle. Human modification of the global bio-geochemical nitrogen cycle can negatively impact on ecosystems[34] and also adversely affect human health.

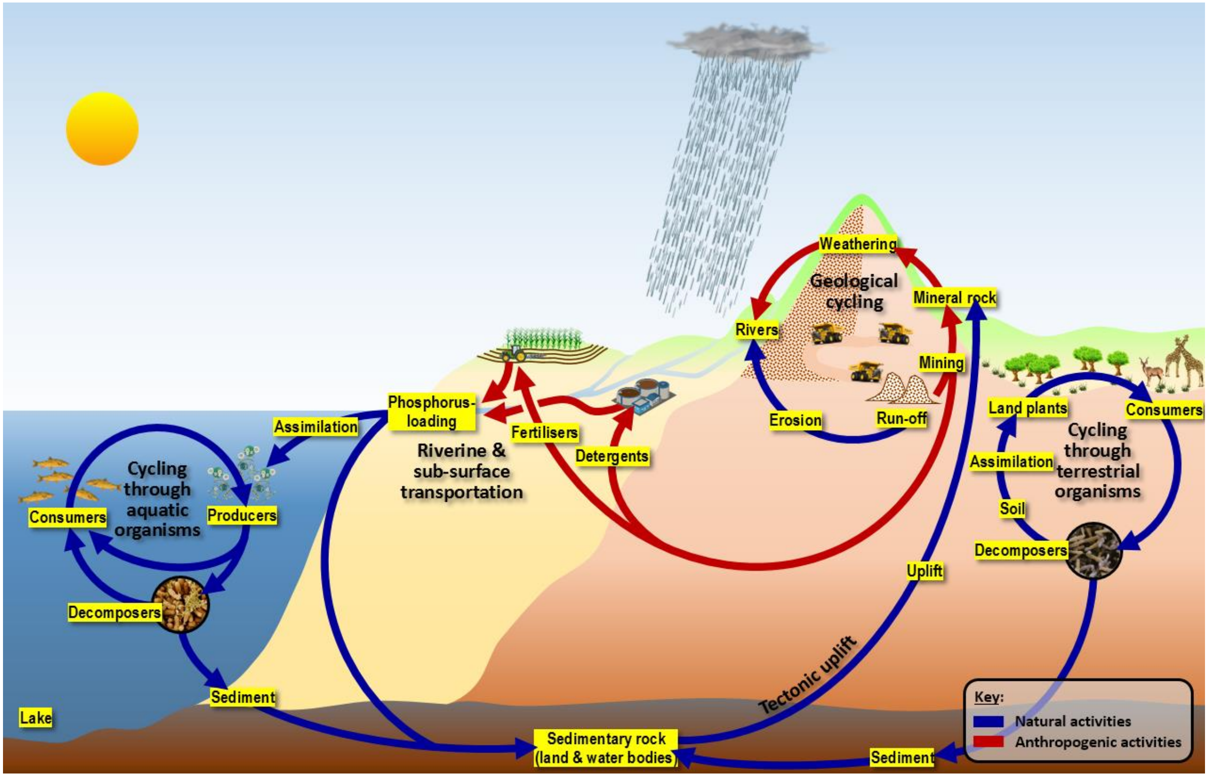

FIGURE 8: The bio-geochemical phosphorus cycle.

The bio-geochemical nitrogen[73] cycle (**FIGURE 9**) incorporates processes by which nitrogen is converted into the other chemical forms, as it circulates among the atmosphere[9], terrestrial, and marine ecosystems.

The bio-geochemical nitrogen cycle [Miller, 1998; Brock & Madigan, 1988; Atlas & Bartha, 1987; Davis, et al., 1980] includes:

- ***Nitrogen fixation,*** which entails the conversion of nitrogen gas (N_2) into nitrites (NO_2^-) and nitrates (NO_3^-) through atmospheric, industrial and biological processes. Atmospheric nitrogen must be processed, or *"fixed"*, into a usable form before it can be assimilated by plants. A significant amount of nitrogen is fixed by lightning strikes, but most fixation is done by free-living or symbiotic bacteria known as diazotrophs[29];
- ***Assimilation*** by which plants absorb nitrates (NO_3^-) or ammonium (NH_4^+) from the soil through their root hairs. When nitrate (NO_3^-) is absorbed, it is first reduced to nitrite ions (NO_2^-) and then ammonium ions (NH_4^+) for incorporation into amino acids, nucleic acids, and chlorophyll. In some plants, nitrogen (N_2) can be assimilated in the form of ammonium ions (NH_4^+) directly from the root nodules[107];
- ***Ammonification*** or mineralisation, which takes place when a plant or animal dies, or when an animal expels waste, and bacteria or fungi convert the initial organic nitrogen within the remains back into ammonium (NH_4^+);

- ***Nitrification***, constituting the conversion of ammonium (NH_4^+) to nitrate (NO_3^-), is performed primarily by soil-living and other nitrifying bacteria. In the primary stages of nitrification, the oxidation of ammonium (NH_4^+) is performed by bacteria, such as the *Nitrosomonas* species, which converts ammonia (NH_3) to nitrites (NO_2^-). Other bacterial species, such as *Nitrobacter*, are responsible for the oxidation of the nitrites (NO_2^-) into nitrates (NO_3^-). It is important for the ammonia (NH_3) to be converted to nitrites (NO_2^-) or nitrates (NO_3^-), because ammonia (NH_3) gas is toxic to plants; and
- ***Denitrification***, by which nitrates (NO_3^-) are reduced back into nitrogen gas (N_2), which is inert and mostly unavailable to plants, completes the bio-geochemical nitrogen cycle. This process is performed by bacterial species, such as *Pseudomonas* and *Paracoccus*, under anaerobic[4] conditions, *e.g.* in waterlogged soils. These facultative anaerobic bacteria[49] can also live in aerobic[1] conditions.

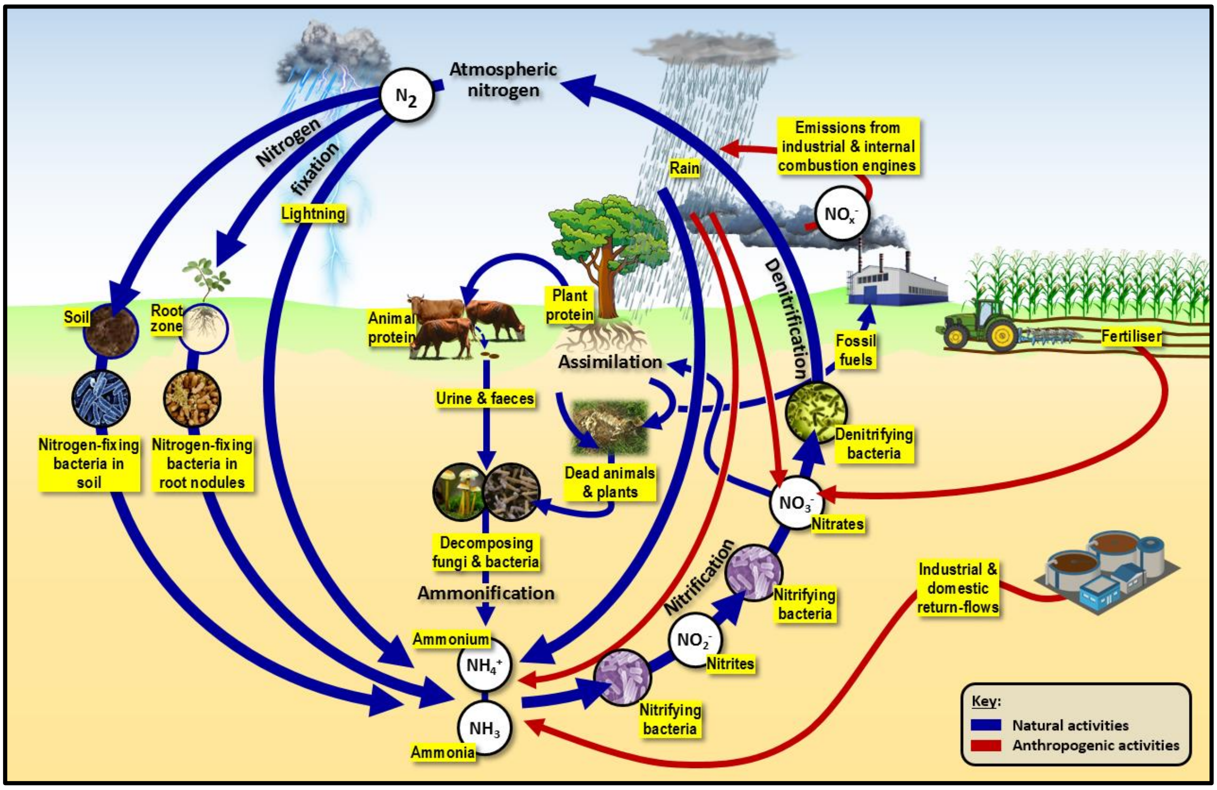

FIGURE 9: The bio-geochemical nitrogen cycle.

2.1.4 Phosphorus and nitrogen as limiting factors for biomass proliferation

The rate and extent of aquatic plant growth is dependent on the concentration and ratios of the nutrients present in the water. Plant growth is generally limited by the concentration of that nutrient that is present in the least quantities relative to the growth needs of the plant [Walmsley, 2000]. This is known as the *limiting nutrient concept* and is the basis of the National Eutrophication Management Strategy.

The overall composition of aquatic plant tissue is C_{106}; H_{263}; O_{110}; N_{16}; and P, yielding a C:N:P w (weight):w:w ratio of 41:7:1. The ambient optimal N:P, w:w ratio for algal growth in surface waters is in the range of between 8:1 and 12:1. Because of nutrient supply and demand in nature, it has been observed that phosphorus and nitrogen are the most frequent limiting nutrients in freshwater systems. Increases in the levels of either of these two nutrients in a water body will raise the risk (extent and frequency) of experiencing eutrophication problems. Control of nitrogen and phosphorus inputs to the aquatic environment, therefore, is regarded as the key to the management of catchment eutrophication problems.

Other nutrients can be important as limiting nutrients, but usually only under special circumstances [Walmsley, 2000].

In freshwater systems, phosphorus is normally limiting, whereas nitrogen is normally limiting in marine waters. This is mostly caused by centuries of phosphorus supply through surface runoff from land and the enhanced iron (Fe) sequestration by sulfide (S) in high sulphate (SO_4^{2-}) containing marine waters, which reduces the availability of iron for phosphate (PO_4^{3-}) precipitation in marine waters, in comparison to freshwater systems. In the oxidative hydrolysis of iron and the concomitant precipitation of phosphate, a minimum of two iron (Fe) atoms are needed to precipitate one phosphate (PO_4^{3-}) molecule, *i.e.* Fe:P=2. However, dissolved Fe:P<2 predominates in anoxic marine waters, whereas most freshwater lakes show Fe: P>2, allowing almost complete phosphate sequestration on oxygenation in freshwater systems [Blomqvist, et al., 2004].

2.1.5 Trophic status of waterbodies

Trophic status refers to the degree of nutrient enrichment[79] of surface water resources and the amount of primary productivity[96] that can be sustained. Importantly, the trophic status of water resources are affected by multiple abiotic, biotic, physico-chemical and biological factors (**FIGURE 10**) – not just by nutrient concentrations. The natural factors [Carlson & Simpson., 1996] that influence the trophic status[117] of waterbodies, include:

- Atmospheric precipitation, such as rainfall, hail, snow, etc., containing soluble nutrients (predominantly nitrates) that promotes primary production;
- The properties of the geology and the soils, and the extent of essential nutrient(s) mobilisation, that contribute to high natural background levels of phosphorus and nitrogen from mineral sources, and the promotion of primary production;
- Geohydrological and hydropedological characteristics that enable and assist with nutrient transport to promote primary production;
- Hydrology that causes either the flushing or the concentration of nutrients in aquatic ecosystems. Well-flushed systems, generally, tolerate higher nutrient inputs;
- Residence time and hydraulics that affect cell growth and primary production;
- Ecological infrastructure, such as wetlands, that provide natural attenuation and water quality improvement functions;
- Water chemistry, primarily the concentrations of the limiting nutrients – phosphorus or nitrogen – that affect primary production;
- The remobilisation of nutrients from the bottom sediments into the water columns of rivers and reservoirs, which often exacerbates and/ or prolongs eutrophication problems. The release rates from sediments for phosphorus and nitrogen, however, differ;
- The availability of sunlight that affects plant growth. An abundance of sunlight supports primary production;
- Inorganic turbidity, water clarity and light penetration that affects the amount of available light for plant growth. Turbid systems can tolerate higher levels of nutrients;
- Changing temperature regimes, which can affect stratification of the water column and algal growth patterns;
- Seasonal variation that causes the responses of algae and aquatic macrophytes to available nutrient increases to vary according to the time of the year;
- The morphology of the water body, which influences the impacts of eutrophication through both depth and shape. Deep water bodies can tolerate higher inputs of nutrients; and
- Primary production.

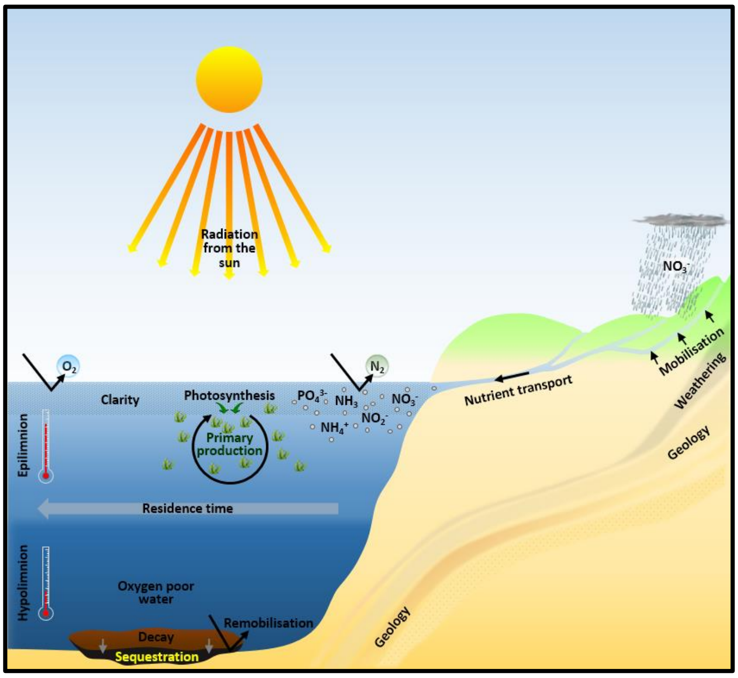

FIGURE 10: Natural factors that affect the trophic status of water resources.

The causes and effects of eutrophication are very complex and vary somewhat for different aquatic systems. However, there are some general trends in lakes becoming eutrophic. The relationships among phosphorus[88] input; primary production[95], usually phytoplankton[90] biomass[14]; density of benthos[12]; submerged macrophytes[63]; dissolved hypolimnetic[54] oxygen[32]; biodiversity; and trophic status[117] are shown conceptually in **FIGURE 11**.

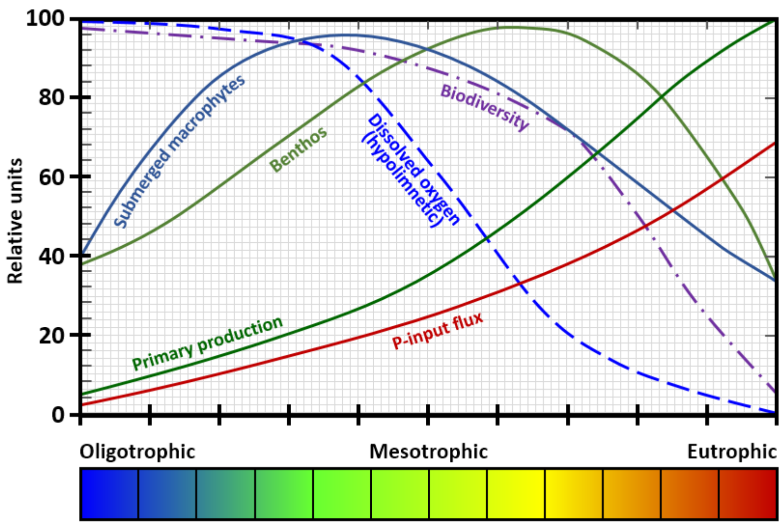

FIGURE 11: Conceptualisation of freshwater eutrophication [Adapted from Roos, 2009 and Correll 1998].

The observation, that the trophic status of water resources are affected by multiple abiotic, biotic, physico-chemical and biological factors, highlights the dangers of applying blanket and uniform approaches to eutrophication management.

A Trophic State Index (TSI) is a classification system designed to rate water bodies based on the amount of biological productivity they sustain. Although the term *"trophic index"* is commonly applied to lakes, any surface waterbody may be indexed. Trophic classification makes it possible to describe waterbodies in terms of the primary production continuum, to predict system behaviour, to judge fitness-for-use and to assign perceived utility [Fosberg & Ryding, 1980].

Unfortunately, the biological structure of most waterbodies does not respond in a linear fashion to nutrient additions. For instance, algal biomass is usually concentrated in the benthos[12] of fast-flowing, gravel or cobble bed streams (*i.e.* periphyton[90] dominated) and measured as benthic Chl-A per unit area of stream substrate, whereas in slow-moving, sediment-depositing rivers and lakes (*i.e.*, plankton dominated), algal biomass is suspended in the water column and measured as sestonic[111] Chl-A per unit water volume [EPA, 2000a, p. 26].

Toerien, et al (1975) noted the importance of classifying South Africa's water resources according to their trophic status for eutrophication management purposes. Carlson (1977), followed by Fosberg & Ryding (1980) and Walmsley (2000), proposes the following definitions to describe the degrees of nutrient enrichment and the primary production that it can sustain:

- ***Oligotrophic*** means the presence of low levels of nutrients, the least amount of biological productivity and *"good"* water quality;
- ***Mesotrophic*** means intermediate levels of nutrients, moderate level of biological productivity and *"fair"* water quality;
- ***Eutrophic*** means high levels of nutrients, high levels of biological productivity and *"poor"* water quality; and
- ***Hypertrophic*** means excessive levels of nutrients, excessive levels of biological productivity, plant production being governed mostly by physical factors and water qualities ranging between *"poor"* and *"unacceptable"*. The water quality problems in hypertrophic waterbodies are almost continuous.

Vollenweider and Kerekes (1980) used a statistical approach to quantify probability ranges for several variables within each trophic designation, and produced bell-shaped curves per trophic class for each variable. The overlap that resulted, emphasized that waterbodies of the same concentrations may be in more than one trophic class [EPA, 2000b]. **FIGURE 12** depicts the primary production continuum for total phosphorus (TP) in lakes [OECD, 1982].

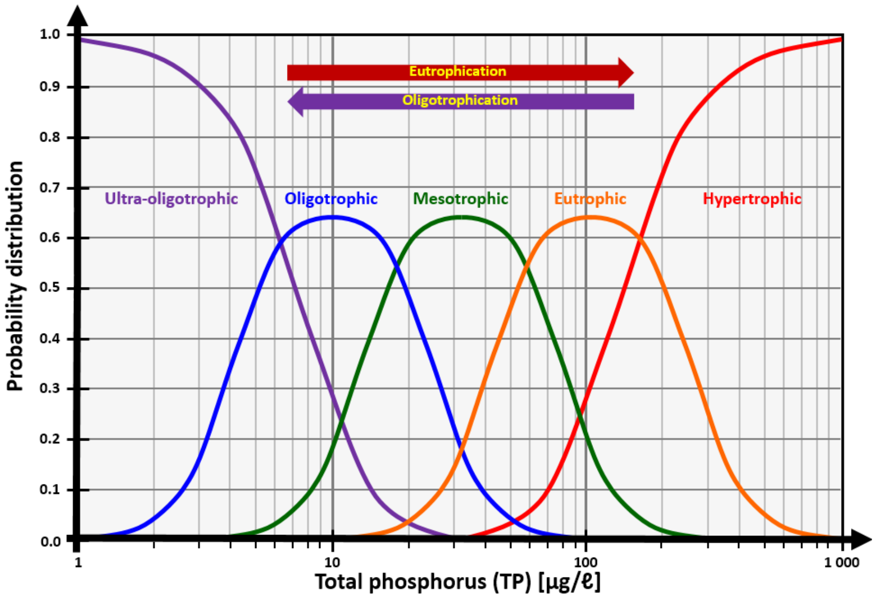

FIGURE 12: The primary production continuum [adapted from OECD, 1982].

Although probabilistic curves are handy to typify water bodies in terms of the relationships of selected parameters and trophic status, its usefulness, as basis for the development of a general TSI, is limited because of the number of parameters that must be measured and the assumption that specific waterbody types exist [Carlson & Simpson., 1996]. **TABLE 2** lists examples of key physical, chemical and biological parameters and their expected changes in response to increasing eutrophication. Initially, biological activity is expected to increase as eutrophication increases. This will be the case up to a point where after increasing biological stress is likely to be incurred as eutrophication continuous to increase.

TABLE 2: Trophic criteria and their responses to increased eutrophication [2] [Rast, et al., 1989].

PHYSICAL	CHEMICAL	BIOLOGICAL [3]
Transparency (Secchi transparency) ↓	Nutrient concentrations ↑	Algal bloom frequency ↑
Suspended Solids ↑	Chlorophyll-α ↑	Algal species diversity ↓
Electrical conductivity (EC) ↑	Dissolved solids ↑	Phytoplankton biomass ↑
	Hypolimnetic[54] oxygen deficit ↑	Littoral vegetation [4] ↑
	Epilimnetic[45] oxygen supersaturation ↑	Zooplankton ↑
		Fish [5] ↑
		Bottom fauna [6] ↑
		Bottom fauna diversity ↓
		Primary production ↑

Multi-parameter indices are onerous and the linear relationship assumed between the parameters in some of these indices does not hold [Carlson, 1977]. On the other hand, indices based on a single criterion potentially could be both unambiguous and sensitive to change. However, there is currently no consensus as to what should be the single criterion of trophic status, and it is doubtful that an index based on a single parameter would be widely accepted. The ideal TSI should incorporate the best of both approaches, retaining the expression of the diverse aspects of trophic state found in multi-parameter indices, yet still having the simplicity of a single parameter index. This can be done if the commonly used trophic criteria are interrelated.

Carlson (1977) developed such a TSI that is both simple, in terms of the limited number of parameters being considered, as well as being appreciative of the multi-dimensional nature of the *"trophic status"* concept, by considering the interrelatedness of the selected parameters and others factors that influence biological activity. According Carlson (1977)'s TSI, waterbodies are rated on a scale from zero to one hundred. Each major division (10, 20, 30, etc.) represents a doubling in algal biomass. The index number can be calculated from any of several parameters, including Secchi disk transparency [7], chlorophyll-α, and total phosphorus (**TABLE 3**). The TSI can be a valuable tool in the management of surface water resources, but it is also a valid scientific tool for investigations where an objective for trophic state is necessary.

2 ↑ signifies that the value of the parameter generally increases with the degree of eutrophication; whereas ↓ signifies that the value generally decreases with the degree of eutrophication.

3 Biological criteria have important qualitative (*e.g.* species) changes as well as quantitative (*e.g.* biomass) changes, as the degree of eutrophication increases.

4 Aquatic plants in shallow, nearshore areas may decrease in the presence of high densities of phytoplankton.

5 May be decreased in numbers and species in bottom waters (hypolimnion) beyond a certain degree of eutrophication, as a result of hypolimnetic oxygen depletion.

6 Bottom fauna may be decreased in numbers and species in high concentrations of hydrogen sulphide (H_2S), methane (CH_4) or carbon dioxide (CO_2), or low concentrations of oxygen (O_2) in hypolimnetic waters.

7 Parameters, such as clarity and transparency, should be used with circumspect in cases where dissolved organic compounds (*e.g.* tannins) or suspended solids are present in significant amounts, as such results may be misleading — giving the impression that the waterbody is more biologically productive than it actually is.

TABLE 3: Trophic State Index (TSI) and associated parameters for waterbodies [Carlson, 1977, p. 365; Carlson & Simpson., 1996].

TROPHIC STATE INDEX (TSI)	SECCHI DISK [m]	TP [µg/ℓ]	CHL-A [µg/ℓ]	Trophic Class
0	64	0.75	0.04	*"Oligotrophic"*
10	32	1.5	0.12	
20	16	3	0.34	
30	8	6	0.94	
40	4	12	2.6	*"Mesotrophic"*
50	2	24	6.4	*"Eutrophic"*
60	1	48	20	
70	0.5	96	56	*"Hypertrophic"*
80	0.25	192	154	
90	0.12	384	427	
100	0.062	768	1183	

The trophic state of waterbodies affects its use or perceived utility (**FIGURE 13**).

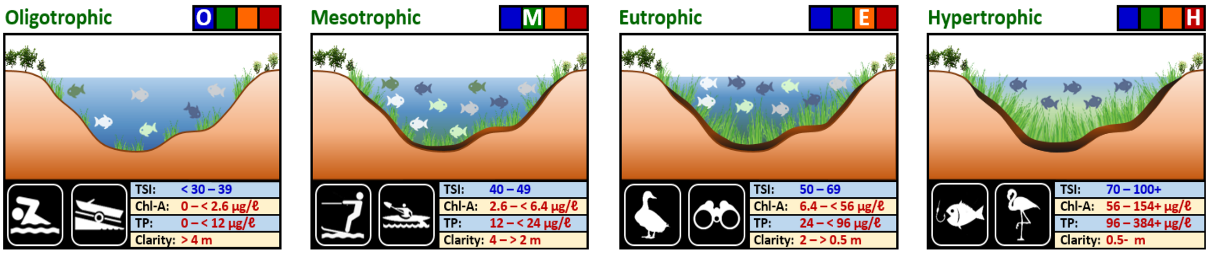

FIGURE 13: The trophic state of waterbodies affects their use and perceived utility [adapted from Fosberg & Ryding, 1980 and Carlson, 1977].

TSI = Trophic State Index; Chl-A = Chlorophyll-a; TP = Total Phosphorus; Clarity = Secchi Depth
O = Oligotrophic; M = Mesotrophic; E = Eutrophic; H = Hypertrophic

TABLE 4 summarises the perceived utility of waterbodies, residing in different trophic classes:

TABLE 4: Trophic classes and their associated perceived utility [Fosberg & Ryding, 1980].

TROPHIC STATE INDEX (TSI)	UTILITY OF THE WATERBODY
< 30	Such waterbodies are good for water sports and good sources for drinking water. These waterbodies exhibit clear water with good visibility, but may potentially not provide the necessary nutrients and algae to maintain a healthy environment for fish and wildlife.
between 30 to 45	Such waterbodies have an adequate amount of nutrients, which supports a fair amount of algae, aquatic plants, birds, fish, insects and other wildlife.
between 46 to 70	Such waterbodies have a greater amount of nutrients, which are able to support an abundance of algae, aquatic plants, birds, fish, insects and other wildlife.
between 71 to 100	Such waterbodies have the highest levels of nutrients, and have the potential to support the highest levels of biological productivity (*e.g.* an abundance of algae, aquatic plants, birds, fish, insects, and other wildlife.) These waterbodies, however, have the greatest potential for widely ranging dissolved oxygen conditions, which can have a detrimental effect on biological diversity, and natural plants and animals.

Van Ginkel, et al (2000b) uses the criteria, noted in **TABLE 5** below for the concentrations of phosphorus (as total phosphorus); and planktonic algae and cyanobacteria (as chlorophyll-α), to classify the trophic status of rivers, and natural and man-made lakes in South Africa [DWAF, 2002]:

TABLE 5: South African classification of trophic status according to total phosphorus (TP) and chlorophyll-α (Chl-A) concentrations in lakes [DWAF, 2002].

VARIABLE	UNIT	OLIGOTROPHIC	MESOTROPHIC	EUTROPHIC	HYPERTROPHIC
Mean annual Chl-A	µg/ℓ	0 < **Chl-A** ≤ 10	10 < **Chl-A** ≤ 20	20 < **Chl-A** ≤ 30	**Chl-A** > 30
% of time Chl-A > 30 µg/ℓ	%	**%Chl-A** = 0	0 < **%Chl-A** ≤ 8	8 < **%Chl-A** ≤ 50	**%Chl-A** > 50
Mean annual TP	mg/ℓ	**TP** ≤ 0.015	0.015 < **TP** ≤ 0.047	0.047 < **TP** ≤ 0.130	**TP** > 0.130

Applying the above trophic status classification criteria (**TABLE 5**) to 393 important South African dams, 37.7% of the reservoirs were classified as hypertrophic; 28.2% as eutrophic; 21.9% as mesotrophic; and 12.2% as oligotrophic, for the 2019/2020 hydrological year (**FIGURE 14)**. Additionally, **FIGURE 14** shows a consistent deterioration in the tropic status of these dams for the 2019/2020 hydrological year, compared to the 2016/2017 hydrological year.

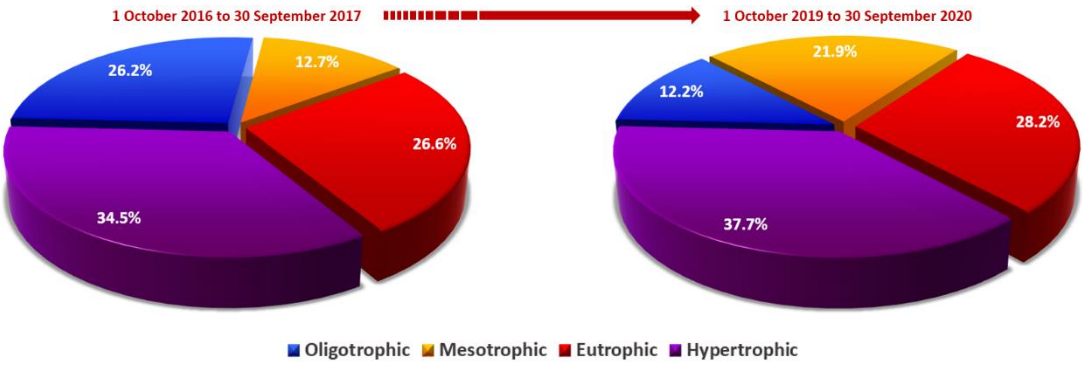

FIGURE 14: Comparison of the trophic status of 393 important South African dams for the 2016/2017 and 2019/2020 hydrological years.

2.1.6 Role of the catchment

It is often said: *"A waterbody is a reflection of its catchment!"* [Holdren, et al., 2001].

A river or a lake is not an isolated body of water, but part of a larger system that includes the surrounding land that drains into such waterbodies. The geographical area from which rain and surface water drain toward a common receiving water resource is called a basin[10], drainage region[33], watershed[125], or catchment[19]. In addition to the natural factors affecting the trophic status[117] of waterbodies (mentioned in **Section 2.1.5**, **Part 1**), anthropogenic[6] activities within a waterbody's catchment have a significant effect on the amount of nutrients[77] that enter the waterbody and, therefore, the primary productivity[96] [EPA, 2000b]. This constitute the primary reason why appropriate nutrient standards and objectives are required to control human activity and to manage eutrophication in catchments.

A natural waterbody's nutrient concentration is affected, primarily, by the nutrient content of precipitation, and the rate of weathering of geologic formations and the dissolution of natural minerals from soils in the catchment[19]. If the underlying geology is mostly granitic, then the rates of weathering will be slow and both the productivity of the terrestrial vegetation and the concentration of nutrients[77] in the runoff from the catchment will be low. On the other hand, if the underlying bedrock is sedimentary, the weathering rates will be higher and the fertility of the soil and the nutrient content of the runoff water will be higher, as well [EPA, 2000b].

Human activity has at least two effects [EPA, 2000b] on the nutrient[77] load input to waterbodies:

- It disturbs the overlying vegetation, exposing the soil to increased weathering and erosion; and
- It adds easily erodible nutrient-containing material, such as fertilizers, and human and animal waste, into the catchment[19].

As the biological surface of an undisturbed catchment[19] is disrupted, and as people move into the catchment, it can, thus, be expected that there will be increased soil and nutrient[77] runoff. Of course the degree of disturbance relative to the size of the waterbody will affect the impact of the disturbance; building a summer cottage would not have the same impact on a lake as would clear-cutting of natural vegetation or dense urban development. Sometimes the term *"assimilative capacity"* is used to imply that the waterbody has a certain capacity to absorb the impact of disturbance. In an eutrophication context, this concept, although comforting, probably has little basis in fact. Impact, until demonstrated otherwise, is probably better thought of as a continuous response to nutrient[77] increases (**FIGURE 15**). The degree of change will depend on other factors, such as the size of the waterbody, and the change may not be immediately or even ever detectable to humans or their monitoring instruments. However, whether detected or not, changes do occur. It is for this reason that catchment disturbance is a sensitive early warning of waterbody change. Clearly, biological impact within the waterbody will be directly related to the increased amount of nutrient-loading, and that impact will occur, whether or not it is detected [EPA, 2000b].

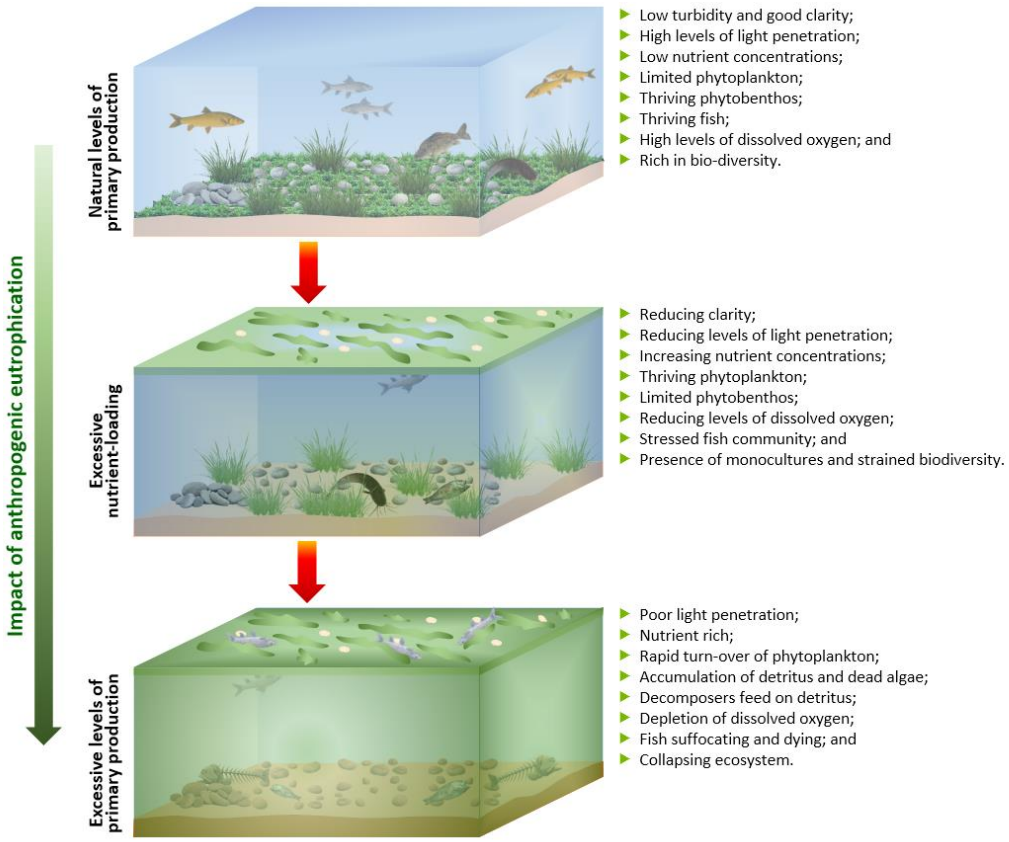

FIGURE 15: The effects of eutrophication on aquatic ecology and biological diversity.

Human population growth and associated economic activities are the main driving force behind eutrophication[47] problems. Humans use numerous products and resources which contain phosphorus[88] and nitrogen[73], converting them into elemental compounds (or, available phosphorus and nitrogen) and ultimately releasing them through various pathways into the aquatic environment [Walmsley, 2000]. **FIGURE 16** illustrates the linkages between human activity and eutrophication.

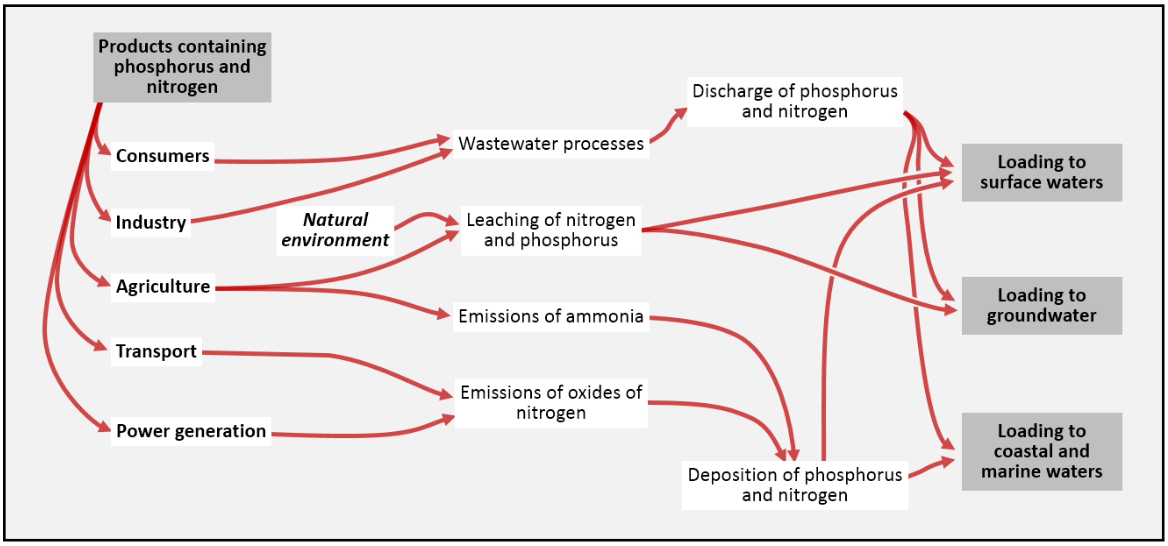

FIGURE 16: The routes by which nutrients from various sources enter water bodies [Walmsley, 2000].

There are two main ways in which nutrients are introduced to the aquatic environment, *viz.* point[92] and diffuse[30] (non-point) sources of nutrients (**FIGURE 17**):

- **Point sources** of pollution are directly discharged to receiving water resources at a discrete location, such as pipes and ditches from WWTPs, industrial sites and confined intensive livestock operations. The most severe water quality impacts from point source pollution typically occur during summer or dry periods, when river flows are low and the capacity for dilution is reduced, and during storm periods when combined sewer overflows operate more frequently; and
- **Diffuse sources** of pollution are indirectly discharged to receiving water resources, via overland and subsurface flow and atmospheric deposition to surface waters and leaching through the soil structure to groundwater during periods of rainfall and irrigation. Soil properties, such as the soil pH, and iron, aluminium and calcium content, affects the mobility of nutrients, such as phosphorus, through soils. The most severe water quality impacts from diffuse source pollution occur during storm periods, particularly after a dry spell, when rainfall induces hillslope hydrological processes and runoff of pollutants from the land surface [Reese, 2020].

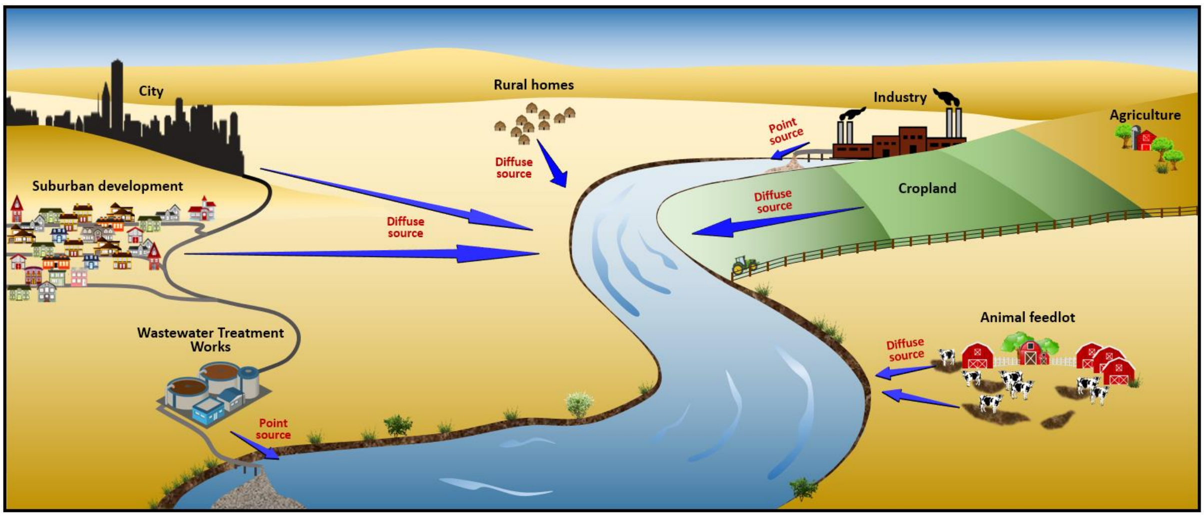

FIGURE 17: Point and non-point sources of nutrients in a catchment context [Rossouw & Forster, 2008].

Models are useful when engaging in forward planning and comparing scenarios on a catchment basis with the aim of pro-actively recommending and implementing appropriate management interventions and timeously preventing and addressing the effects of eutrophication. Nutrients, unlike salts and other conservative pollutants[22], however, acts in a non-conservative[74] manner (**FIGURE 18**). This is due to nutrients, such as phosphorus[88] and nitrogen[73], changing concentration naturally. Some react chemically to result in different salts. Sometimes oxygen is taken out of the water to release hydrogen gas, which is more volatile and escapes. Oxygen in water is the cause of many changes. For example, ammonia is oxidized to nitrites, and these in turn are oxidized to nitrates. The nitrates cannot be eliminated, except by chemical replacement, absorption or biochemically, as is now done in some waste water treatment processes. Simple mass balance modelling, therefore, is mostly not readily possible.

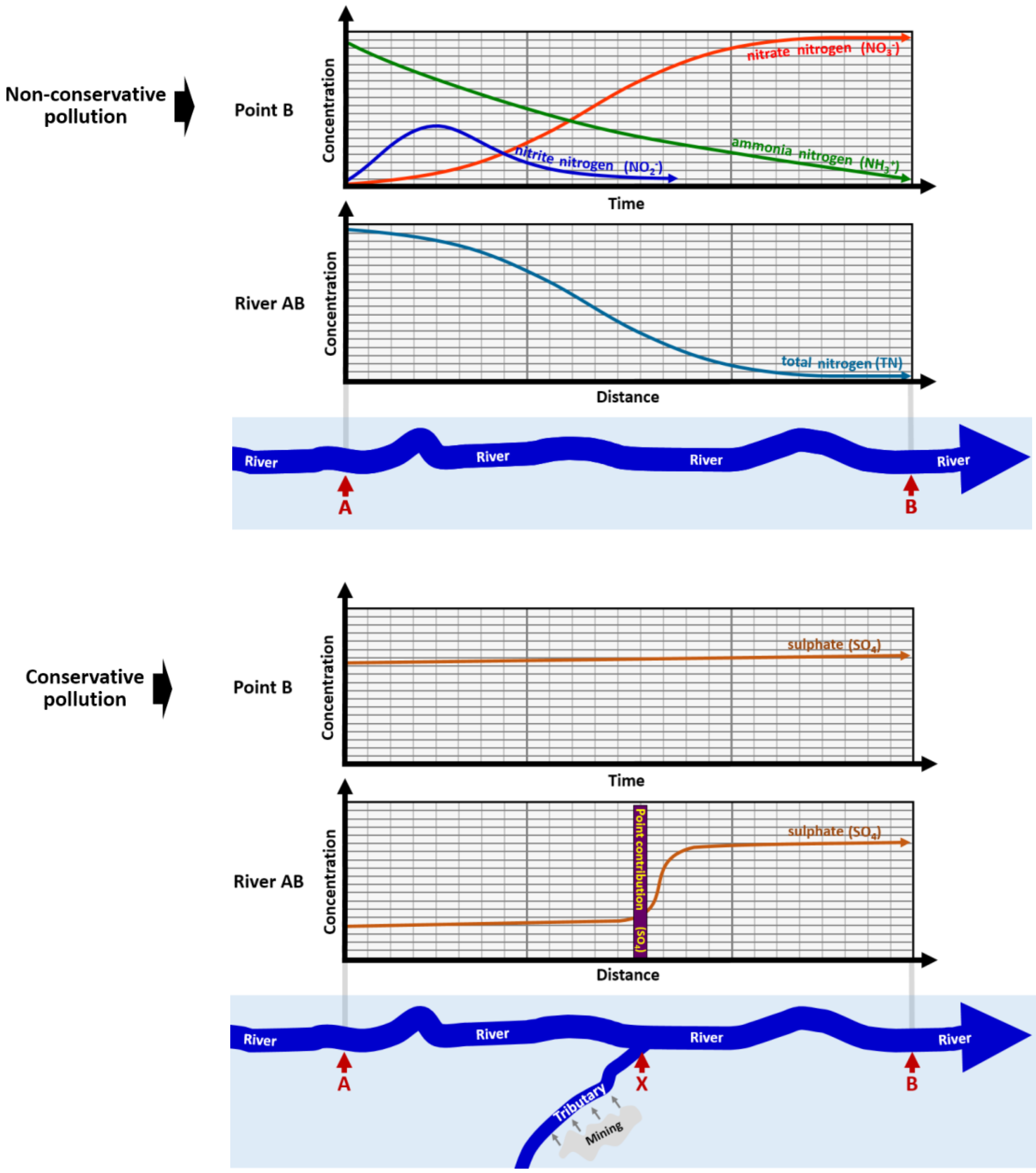

FIGURE 18: A comparison between non-conservative and conservative pollution, depicting nitrogen, in the contexts of nitrogen cycling, and sulphate on *concentration-over-time*, and *concentration-over-distance* graphs.

The term *"mass balance modelling"* comes from the assumption that a substance, such as phosphorus[88], cannot just appear or disappear from a reservoir; it must come from somewhere and it must go somewhere. The phosphorus going into the reservoir must either go out again through some outflow, be sedimented to the bottom, incorporated into biomass, or remain in the waterbody in either dissolved or particulate forms. It is this phosphorus that remains in the water that is of interest because it is the amount that is available for primary production[95].

Thornton (2013) outlines eutrophication as a complex– or *"wicked problem"* facing society, which cannot simply be fixed with only engineering solutions, such as the application of suitable wastewater treatment technology. By adopting a blanked approach to eutrophication management, the characteristics of this *"wicked problem"* would be ignored. In other words, *"wicked problems"*, such as eutrophication, can have multiple resolutions, depending on a variety of factors [Thornton, et al., 2013], and a national approach to eutrophication management must include catchment– and focused water resource planning.

CHAPTER 3: TOWARDS NATIONAL EUTROPHICATION MANAGEMENT STRATEGY

3.1 Purpose of the eutrophication management strategy document

To date, eutrophication[47] in South Africa, had been attended to under the broad guidance of the overarching Integrated Water Quality Management Policy and Strategy for South Africa, 2017 [DWS, 2017b; DWS, 2017d] and the other general policies for water quality management and pollution control before it [DWAF, 1991]. Due to deteriorating water quality[126] trends observed in recent years, specifically worsening occurrences of eutrophication, the need had been identified to develop the first dedicated policy and strategy for a particular type of water pollution[125], *viz.* to explicitly and decisively address the escalating effects of excessive nutrient enrichment[79] observed in many hot-spot areas in the country.

To this end, the purpose of the eutrophication management strategy document is:

(1) To be direction-giving with respect to the management of eutrophication[47], in particular the control of anthropogenic[6] sources of excessive nutrient enrichment[79], from a strategic country-perspective;
(2) To provide a reference for the control of triggers that cause excessive primary production[95] in receiving water resources and for eutrophication management, in general, in South Africa;
(3) To provide the foundation for operational consistency at the Water Management Area (WMA), sub-catchment and local levels, by stipulating ground rules and prescribing overarching implementation approaches for the management of eutrophication;
(4) To address pertinent issues of eutrophication management integration and alignment with other processes;
(5) To facilitate improved eutrophication management cooperation and participation;
(6) To provide the basis for identifying priority actions and interventions necessary to control significant triggers of anthropogenic eutrophication; and their root causes of failure, acknowledging the need for the efficient and wise utilisation of scarce resources;
(7) To facilitate capacity building in respect of the control of the causes of excessive nutrient enrichment and eutrophication management; and
(8) To provide a point of departure for the monitoring and evaluation of eutrophication management strategy implementation progress.

3.2 Scope of the eutrophication management strategy

The general practice of utilising **policy** to define ground rules, to delineate intent and to specify desired outcomes, coupled with **strategy** to map out overarching implementation approaches in order to realise the said policy objectives, is also applicable here. In addition to the **eutrophication management policy** that seeks to review and express the South African government's policy objectives with respect to eutrophication management and nutrient[77] reduction, the **eutrophication management strategy** pursues concomitant approaches to implement the objectives of the eutrophication management policy over time.

As such, the National Eutrophication Management Strategy–

- applies nationally;
- to address issues of nutrient-loading (*i.e.* predominantly phosphorus and nitrogen-related);
- which might affect the country's water resources (including surface and/ or groundwater resources);
- mostly due to anthropogenic[6] impacts;
- that might lead to excessive nutrient enrichment[79] and eutrophication[47];
- of surface water resources and eventually the marine environment;
- causing nuisance concerns, affecting property, impairing fitness-for-use and potential utility, and risking ecologically sustainable development;
- ultimately resulting in undesirable social and economic impacts.

The management measures in the *National Eutrophication Management Strategy*–

- predominantly deals with the regulation and control of anthropogenic[6] sources of nutrient-loading;
- describes resource water quality planning and management measures to balance the needs for water use with the needs to protect water resources; and
- outlines remedial measures (whether water resource focused or focussing on the remediation of sources of impacts) that must be implemented reactively in order to control nutrient-loading and manage eutrophication.

The national strategy for eutrophication management should ideally be complemented with a water resource planning programme that schedule the development and implementation of water resource system and/ or sub-catchment planning strategies. This is essential to accommodate differing and changing catchment and local dynamics expected to unfold over time, when evaluating, selecting and prioritising suitable operational intervention options for roll-out in eutrophication hotspot areas. Additionally, day-to-day eutrophication management related water resource and services activities will have to be executed in accordance with the outline provided in this Policy and Strategy.

Whilst the Department of Water and Sanitation (DWS) is the custodian of the country's water resources, the *National Eutrophication Management Strategy* is directed at all three spheres of government. Furthermore, in support of the Integrated Water Quality Management Policy and Strategy for South Africa, it speaks to South Africa as a whole, including non-governmental organisations, the private sector, the research community and civil society. This document is aimed at all that have a role to play in South Africa's socio-economic growth and development; that impacts on, or that is impacted upon by eutrophication; or that have a stake in the country's future.

The DWS is gradually adapting its water resource management approach to review and develop policy and strategy, where lacking, to convert policy and strategy into action, where in existence, progressively shifting to planning more strategically, overall regulatory oversight, institutional support, coordination in aid of enhanced co-operative governance and improved regulatory control. This changing emphasis aims for greater involvement of water services and management institutions, and other role players within the water sector.

3.3 Anatomy of the eutrophication management strategy document

The document consists of five consecutive parts. Parts 1 to 4 (**FIGURE 19**) contains the technical narrative, whereas Part 5 (not depicted in **FIGURE 19**) contains the bibliography. Collectively, these individual parts of the document strives to systematically empower the reader in developing an understanding of the measures necessary to manage eutrophication country-wide, and ultimately to control and to reduce eutrophication in hot-spot areas.

Part 1 starts off with a focused discussion to highlight key eutrophication-related challenges in South Africa, followed by a broad problem declaration that takes the form of an analysis of eutrophication-related causes and effects in South Africa. The introduction to Part 1, also, defines a number of important concepts pertaining to the subject of eutrophication. An ensuing discussion on document and process sheds light on the scope, purpose, anatomy and the development process of the *National Eutrophication Management Strategy*. This is followed by focused discussions on relevant international commitments and key policy and legislative provisions that give guidance to eutrophication management in South Africa. Part 1 concludes with an assessment of the evolution of eutrophication measures in South Africa, in an attempt to extrapolate the past and current eutrophication management paradigms and trends to an enhanced paradigm for the future management and control of eutrophication in South Africa.

Part 2, consequently, builds on Part 1 by considering the broad context sketched there and by converting the broad problem declaration of Part 1 into an overall policy vision and solution orientated policy statements for eutrophication management in South Africa.

Part 3 focusses on advancing the eutrophication management policy, as elaborated under Part 2, in order to prepare the way for full implementation. A series of core, functional and supporting strategies for eutrophication management in South Africa are discussed and are related to achieving the overall policy vision, given in Chapter 2, Part 2. Governance requirements are explored with the aim of identifying governance responsibility and accountability.

Part 4 pursues short, medium and long-term implementation imperatives and ends with concluding remarks.

FIGURE 19: The anatomy of the *National Eutrophication Management Strategy* document.

3.4 Eutrophication management strategy development process and stakeholder involvement

An iterative four phase process (**FIGURE 20**), supported by consultation at multiple levels, was adopted to develop the *National Eutrophication Management Strategy*. This process commenced with an inception phase that had been used to define a final and mutually agreed description of the scope of work, project programme and project resource requirements to effect efficient and structured project execution. The Inception Phase was followed by Phase 2, which consisted of a high-level literature review of available documented information; an identification and evaluation of the emerging causes, effects and challenges associated with eutrophication; and a data and information gaps analysis that had been accompanied by the formulation of measures to overcome such identified gaps. Utilising the information base put together during the Situation Assessment and Gaps Analysis Phase, Phase 3 set out to develop an *National Eutrophication Management Strategy*. The development approach followed during Phase 3 culminated in two editions of the policy and strategy document; a first edition that had been presented to various groups of stakeholders and the final edition that had been produced subsequent to the various consultative exercises. The project concluded with Phase 4, which had as its goal to investigate measures and to produce a plan to ensure policy and strategy roll-out and implementation.

Due to the important roles of the public and private sectors, as well as civil society, in eutrophication management, a Stakeholder Consultation and Communication Strategy were developed to inform; consult; involve; collaborate with; and, where possible, empower relevant key role-players to take part in the development of the *National Eutrophication Management Strategy*. Additionally, the Stakeholder Consultation and Communication Strategy had to establish ownership of, and buy-in in both project process and outcomes, and information sharing had to take place throughout the project duration to ensure robust debate and scientific rigour (**FIGURE 21**). A database of stakeholders consulted and a comments register had been maintained and was compiled.

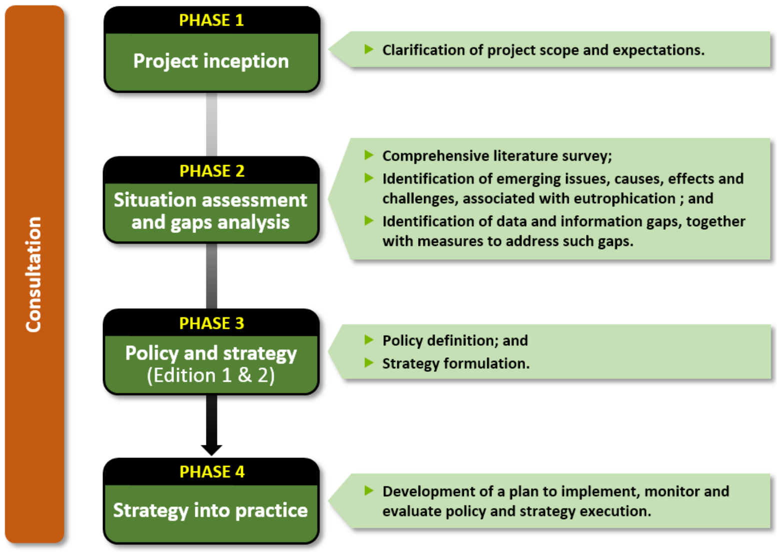

FIGURE 20: *National Eutrophication Management Strategy* development process.

The abbreviated terms of reference of the various project structures that had to oversee the policy and strategy development process, were as follows:

- ***Project Management Committee (PMC):*** Responsible for day-to-day project administration and project management tasks;
- ***Project Steering Committee (PSC):*** Responsible for indicating overall direction and sanctioning of all project deliverables prior to departmental endorsement;
- ***Technical Task Team with Sub Task Teams:*** Responsible for thematic specialist support; and
- **External stakeholder group/ public:** Responsible for wider stakeholder input and public participation.

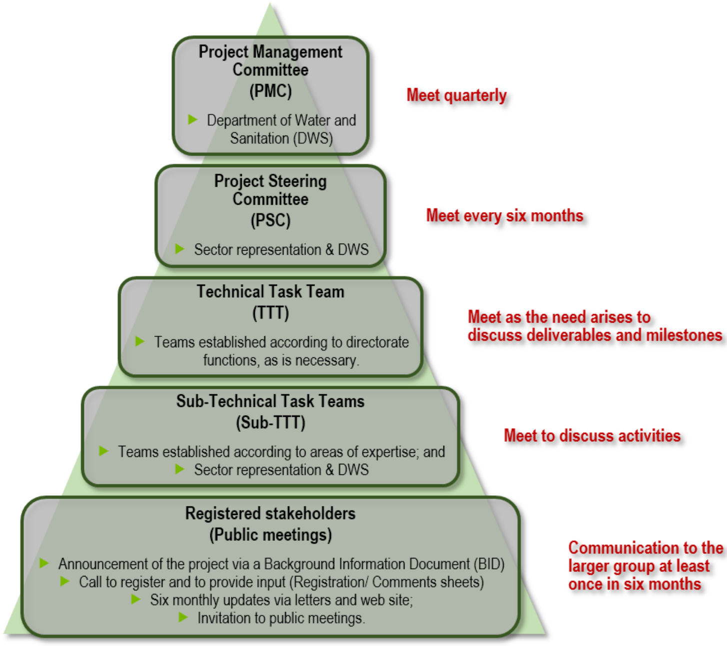

FIGURE 21: Stakeholder consultation.

CHAPTER 4: THE WIDER POLICY, STRATEGY AND LAW CONTEXT

The purpose of the ensuing discussion is to highlight the most prominent policy, strategy and pieces of legislation, deemed to be direction giving to eutrophication management, and to highlight some important aspects to align eutrophication management with. To this end, linkages with the international sustainable development agenda; key pieces of national legislation, with respect to applicable law principles; selected executive strategies; and the Integrated Water Quality Management Policy and Strategy for South Africa (2017) are pursued next:

4.1 International sustainable development agenda

The concept of sustainable development formed the basis of the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992. The summit marked the first international attempt to draw up action plans and strategies for moving towards a more sustainable pattern of development. Agenda 21 had been one of the key outputs of UNCED and Chapter 18 of this agenda identifies freshwater resources as an essential component of the Earth's hydrosphere and as an indispensable part of all terrestrial ecosystems [UNCED, 1992].

Sustainable development was the solution to the problems of environmental degradation discussed by the Brundtland Commission in their preceding 1987 report – Our Common Future [Brundtland, 1987]. According to Brundtland (1987), *"sustainable development"* is: ***"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"***. This interpretation of sustainable development has been adopted in the Bill of Rights in the Constitution of democratic South Africa, and forms a central theme in all our environmental legislation and policy.

The Natural Step Framework, colloquially known as The Natural Step (TNS) Funnel (**FIGURE 22**), provides a conceptual model for easy reference and discussion of the concepts of sustainable- and unsustainable development. The TNS Funnel is based on four system conditions, also known as the principles of sustainability (**TABLE 6**), to be met if sustainability is to be reached and maintained [Nathan, 2018].

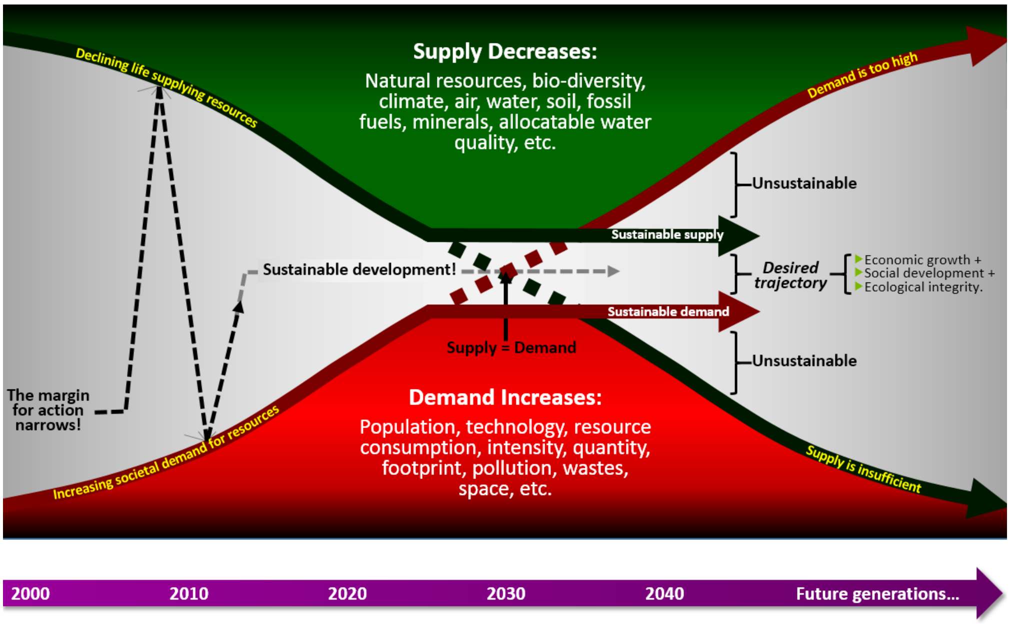

FIGURE 22: Natural Step Funnel demonstrating converging global supply & demand [Adapted from The Natural Step].

TABLE 6: The four principles of sustainability [The Natural Step], related to eutrophication.

	IN A SUSTAINABLE SOCIETY –
Principle 1	***nature is not subjected to systematically increasing concentrations of substances extracted from the earth's crust;***
	Explanation: Ecosystem functions and processes are altered when society mines and disperses materials at a faster rate than they are being redeposited back into the Earth's crust. (Examples of these materials are phosphorus, coal, and metals such as lead.)
Principle 2	***nature is not subjected to systematically increasing concentrations of substances produced by society;***
	Explanation: Ecosystem functions and processes are altered when society produces substances faster than they can be broken down by natural processes, if they can be broken down at all (for example, a built-up of nutrients in the environment causing eutrophication).
Principle 3	***nature is not subjected to systematically increasing degradation by physical means; and***
	Explanation: Ecosystem functions and processes are altered when society extracts resources at a faster rate than they are replenished (for example, overharvesting trees or fish), or by other forms of ecosystem manipulation (for example, causing soil erosion or paving over fertile land).
Principle 4	***human needs are being met worldwide.***
	Explanation: By considering the first three principles of sustainability, within which human life-supporting structures and functions are being altered, three basic principles for maintaining essential ecological processes have been defined. Principle 4 recognizes that social and economic dynamics fundamentally drive the actions that lead to ecosystem changes. Principle 4, therefore, focuses on the socio-economic dimension, in terms of the importance of meeting human needs worldwide, as an integral and essential part of sustainability.

In September 2000, the historic Millennium Declaration, in which countries commit to achieving a set of eight measurable goals, called the Millennium Development Goals (MDGs), which included halving the population that had no sustainable access to water and basic sanitation before 2015 (Target 7c), were signed into action [UN, 2015a]. More recently, the World Summit on Sustainable Development (WSSD) was held in Johannesburg in 2002 to assess progress since Rio. The Johannesburg Summit delivered three key outcomes: a political declaration, the Johannesburg Plan of Implementation, and a range of partnership initiatives. Key commitments included those on sustainable consumption and production, water and sanitation, and energy [WSSD, 2002]. The Rio^{+20} conference (UNCED) in Rio de Janeiro, June 2012, subsequently galvanized a process to develop a new set of 17 Sustainable Development Goals (SDGs) to carry on the momentum generated by the MDGs, beyond 2015, and fit into a global development framework, called Agenda 2030 [UN, 2015b].

The SDG programme, endorsed by Heads of State (including by South Africa), serves as reporting platform to measure the sustainability of countries; to prompt action in cases where poor performance or where deteriorating trends emerge; to bolster local accountability; and for global comparison purposes. SDG 6 focuses on clean water and sanitation, and must ensure availability and sustainable management of water and sanitation for all. SDG 6 was unpacked into six SDG targets and 2 additional supporting SDG targets. Of these, the following three SDG Targets specifically relate to eutrophication management (**TABLE 7)**. A series of eleven indicators, some global, some domesticated and others additional indicators[8], were proposed to collectively measure progress against the said three SDG targets:

TABLE 7: SDG 6 targets and indicators, with direct relevance to eutrophication management.

SDG 6:	**Ensure availability and sustainable management of water and sanitation for all.**
SDG TARGET 6.3:	**WATER QUALITY AND WASTEWATER**
By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.	
Indicator 6.3.1D:	Proportion of water containing waste lawfully discharged.
Indicator 6.3.2D:	Proportion of bodies of water that complies with water quality objectives.
Indicator 6.3.3A:	Proportion of water containing waste recycled or reused.
Indicator 6.3.4A:	Proportion of waste lawfully disposed of.
Indicator 6.3.5A:	Proportion of waste recycled or reused.
SDG TARGET 6.5:	**WATER RESOURCES MANAGEMENT**
By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate.	
Indicator 6.5.1:	Degree of integrated water resources management implementation (0 - 100).
Indicator 6.5.2:	Proportion of transboundary basin area with an operational arrangement for water cooperation.
SDG TARGET 6.6:	**WATER-RELATED ECOSYSTEMS**
By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.	
Indicator 6.6.1D(1):	Change in the spatial extent of water-related ecosystems over time, including wetlands, reservoirs, lakes and estuaries as a percentage of total land area.
Indicator 6.6.1D(2):	Number of systems affected by high trophic and turbidity states.
Indicator 6.6.1D(3):	Change in the national discharge of rivers and estuaries over time.
Indicator 6.6.1A(1):	Change in the ecological condition of rivers, estuaries, lakes and wetlands.

Importantly, it has been observed that water pollution[125] affects each of the other 16 SDGs, underscoring the inter-relatedness and importance of water resources that are fit for use in sustainable development.

8 The annotation: "D" for *Domestic* and "A" for *Additional*, as per UN convention, is used to identify the indicators in **TABLE 7**. In cases where neither D nor A is used, the global indicator wording had been retained, as proposed by the UN.

Potential synergy between the SDG programme, specifically the SDG targets and indicators summarised in **TABLE 7**, and eutrophication management exists, and includes:

- Reporting on compliance to phosphorus and nitrogen Waste Discharge Standards (WDSs);
- Reporting on the fitness-for-use of water resources, with respect to phosphorus and nitrogen;
- Reporting on the application of wastewater recycling and reuse strategies;
- Reporting on the degree of integration of water resource management efforts; and
- Reporting on ecological systems affected by phosphorus and nitrogen loading.

4.2 Key pieces of national legislation

4.2.1 Constitution of the Republic of South Africa, 1996 (Act No. 108 of 1996)

The Bill of Rights contained in the Constitution of the Republic of South Africa, 1996 (Act No. 108 of 1996)[9] applies to all law, and binds the legislature, the executive, the judiciary and all organs of state.

Section 24 (**TABLE 8**) in the Bill of Rights places a duty on the state to implement reasonable legislative and other measures in order to protect water resources, to ensure that it is not harmful to anyone's health and wellbeing. *"Other measures"*, in this case, includes the roll-out and implementation of eutrophication management strategy to protect water resources and, to ensure that it is not harmful to anyone's health and wellbeing.

TABLE 8: Constitution of the Republic of South Africa, 1996 (Act No. 108 of 1996): Bill of Rights: Implications for water resources

ENVIRONMENT Section 24 addresses the *"environment"* in its broad context, considering the ecology, social and economic dimensions.	WATER RESOURCES Section 24 paraphrased to address the *"freshwater environment"*, as a subset of the *"environment"*[10], considering the ecology, social and economic dimensions.
Everyone has the right-	**Everyone has the right-**
(a) to an environment that is not harmful to their health or well-being; and	**(a)** to water resources that are not harmful to their health or well-being; and
(b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that-	**(b)** to have water resources protected, for the benefit of present and future generations, through reasonable legislative and other measures that-
(i) prevent pollution and ecological degradation;	**(i)** prevent pollution and ecological degradation;
(ii) promote conservation; and	**(ii)** conserve water; and
(iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.	**(iii)** secure ecologically sustainable development and use of water resources while promoting justifiable economic and social development.

Additionally, Section 27 in the Bill of Rights places a duty on the state to take reasonable legislative and other measures, within its available resources, to achieve the progressive realisation of providing sufficient

[9] Hereafter referred to as the Constitution.

[10] NEMA (107:1998) defines the environment as to mean the surroundings within which humans exist and that are made up of—
- the land, **water** and atmosphere of the earth;
- micro-organisms, plant and animal life;
- any part or combination of above and the interrelationships among and between them; and
- the physical, chemical, aesthetic and cultural properties and conditions of the foregoing that influence human health and well-being.

water to everyone. The right to basic sanitation is not an explicit constitutional right. However, the right to sanitation could be derived from the right to a clean environment (Section 24), read together with the right of access to clean water (Section 27). Again, it is inferred that *"other measures"* include the roll-out and implementation of eutrophication management strategy to ensure fitness-for-use of receiving water resources, *inter alia* through effective sanitation services.

Many other constitutional rights in the Bill of Rights overlap with, and support the rights to clean water resources, and water supply and sanitation services. These include the rights to equality (Section 9), dignity (Section 10), of access to information (Section 32) and just administrative action (Section 33) [Algotsson, et al., 2009, p. 2].

Rolling-out and implementing the National Eutrophication Management Strategy, certainly, should promote these Constitutional rights. It must protect water resources[128] against the effects of eutrophication[47], thereby contributing towards securing ecologically sustainable development and use of water resources while promoting justifiable economic and social development.

4.2.2 National Environmental Management Act, 1998 (Act No. 107 of 1998)

According to Glazewski (2005), environmental law encompasses the following three distinct but interrelated areas of general concern:

- Land-use planning and development;
- Resource conservation and utilisation; and
- Waste management and pollution control.

Overseeing these three areas affects eutrophication[47] management. The National Environmental Management Act, 1998 (Act No. 107 of 1998)[11] is a framework Act and, therefore, provides for overarching mechanisms, principles and procedures which inform other acts, particularly the Specific Environmental Management Acts (SEMAs) of which the National Water Act, 1998 (Act No. 36 of 19198) is part, and subordinate or subsidiary regulations. Additionally, the statutory mechanisms, principles and procedures so established by NEMA (107:1998) would also apply to subsequent environmental policy and strategy being established, including the National Eutrophication Management Strategy.

NEMA (107:1998) defines *"sustainable development"* as *"the integration of social, economic and environmental factors into planning, implementation and decision-making so as to ensure that development serves present and future generations"*. NEMA (107:1998), further, provides that sustainable development requires the consideration of all relevant factors including-

- that the **disturbance of ecosystems and loss of biological diversity** are avoided, or, where they cannot be altogether avoided, are minimised and remedied;
- that **pollution and degradation** of the environment are avoided, or, where they cannot be altogether avoided, are minimised and remedied;
- that the **disturbance of landscapes and sites** that constitute the nation's cultural heritage is avoided, or where it cannot be altogether avoided, is minimised and remedied;
- that **waste** is avoided, or where it cannot be altogether avoided, minimised and re-used or recycled where possible and otherwise disposed of in a responsible manner;
- that the **use and exploitation of non-renewable natural resources** is responsible and equitable, and takes into account the consequences of the depletion of the resource;
- that the **development, use and exploitation of renewable resources** and the ecosystems of which they are part do not exceed the level beyond which their integrity is jeopardised;

[11] Hereafter referred to as NEMA (107:1998).

- that a **risk-averse and cautious approach** is applied, which takes into account the limits of current knowledge about the consequences of decisions and actions; and
- that **negative impacts** on the environment and on people's environmental rights be **anticipated and prevented**, and where they cannot be altogether prevented, are minimised and remedied.

NEMA (107:1998), further, sets out a number of supporting national environmental management principles, also having relevance to eutrophication management, and that serve as guidelines by reference to which any organ of state must exercise any function when taking any decision concerning the protection of the environment (see **ANNEXURE B**).

In addition, NEMA (107:1998) calls for *"co-operative environmental governance"*; a phrase derived from the Constitutional mandate [RSA, 1996, Chapter 3] that all spheres and organs of government are obliged to co-ordinate their actions by establishing principles to be taken into account in all decision making-processes affecting the environment.

NEMA (107:1998) plays a crucial role in providing for co-operative environmental governance by-

- establishing principles for decision-making on matters affecting the environment; and
- establishing institutions that will promote co-operative governance and procedures for co-ordinating environmental functions exercised by organs of state.

Key environmental regulatory authorities include:

- Department of Environment, Forestry and Fisheries (DEFF);
- Department of Mineral Resources and Energy (DMRE); and
- Department of Water and Sanitation (DWS).

All spheres of government and all organs of state must co-operate, consult and support one another on matters involving or affecting the environment.

4.2.3 National Water Act, 1998 (Act No. 36 of 1998) and Water Services Act, 1997 (Act No.108 of 1997)

The National Water Act, 1998 (Act No. 36 of 1998)[12], together with the Water Service Act, 1997 (Act No. 107 of 1997)[13] promotes sustainability and equity, as central guiding principles, in dealing with water resources and services. The NWA (36:1998) deals with the protection, use, development, conservation, management and control of water resources[128] and is focused, *inter alia,* on promoting efficient, sustainable and beneficial use of water in the public interest; facilitating social and economic development; protecting aquatic and associated ecosystems and their biological diversity; and reducing and preventing pollution[125] and degradation of water resources, whereas the WSA (108:1997) makes provision for basic water supply and sanitation services.

Water law in South Africa is based on 28 fundamental principles and objectives, as approved by Cabinet in November, 1996 [DWAF, 1997]. Eutrophication management policy and strategy should thus conform to these fundamental principles and objectives, especially the 13 principles and objectives that are of foremost relevance (**ANNEXURE C**). Accordingly, eutrophication management policy and strategy must[14]–

- acknowledge that eutrophication management is nested within the broader concept of catchment management [links to *Principle 5* and finds expression in the NWA (36:1998) *inter alia* in Chapter 2];

[12] Hereafter referred to as the NWA (36:1998).

[13] Hereafter referred to as the WSA (108:1997).

[14] A consolidated summary of the 13 principles and objectives, regarded as most relevant to eutrophication management policy and strategy, as listed in **ANNEXURE C**.

- strive to contribute towards long-term ecologically sustainable social and economic development [links to *Principles 7 and 9* and finds expression in the NWA (36:1998) *inter alia* in Chapters 3 and 4];
- contribute towards water resource use, development, management and control that is in the public interest, sustainable, equitable and efficient, while also honouring relevant international obligations [links to *Principle 13* and finds expression in the NWA (36:1998) *inter alia* in Chapter 2 and 4];
- where desirable, promote wastewater reuse and recycling [links to *principle 14* and finds expression in the NWA (36:1998) *inter alia* in Chapter 4];
- acknowledge interrelatedness between eutrophication and water quantity, *i.e.* water flow, level and pattern [links to *Principle 15* and finds expression in the NWA (36:1998) *inter alia* in Sections 13];
- employ financial incentive systems, such as the Waste Discharge Charge System (WDCS), to limit and prevent excessive primary production in receiving water resources [links to *Principle 16* and finds expression in the NWA (36:1998) *inter alia* in Chapter 5];
- consider land use management and management cooperation, as a means of limiting and preventing anthropogenic eutrophication [links to *Principle 18* and finds expression in the NWA (36:1998) *inter alia* in Sections 12 and 26(1)(g)];
- promote effective water use authorisation [links to *Principle 19* and finds expression in the NWA (36:1998) *inter alia* in Chapter 4];
- acknowledge the roles of disaster management in limiting danger to life and property [links to *Principle 21* and finds expression in the NWA (36:1998) *inter alia* in Chapter 14];
- enable role-players and other stakeholders to participate [links to *Principle 23* and finds expression throughout the NWA (36:1998)] and
- ensure that water services are provided in a manner consistent with the goals of water resource management [links to *Principles 25 and 27* and finds expression in the NWA (36:1998) *inter alia* in Chapter 2 and in the WSA (108:1997) *inter alia* in Chapter 3].

The water law provisions, as paired above with the implications of the 13 fundamental principles and objectives that are most relevant to eutrophication management, are further contextualised in Section 5.2.1 of Part 1, specifically **ANNEXURE D**.

4.3 Selected executive strategies, plans or frameworks

4.3.1 National Water Resource Strategy and National Water and Sanitation Master Plan

The National Water Resources Strategy (NWRS) is a statutory strategy, required in terms of the NWA (36:1998), is binding on all authorities and institutions implementing the Act and provides the framework for integrated water resource management for the country as a whole, and also within which water resources will be managed at the regional or catchment level. The National Water and Sanitation Master Plan (NW&S MP) constitutes the roll-out mechanism for NWRS implementation and specify, *inter alia,* priority budget items, scheduled up to 2030 and beyond, for the entire water sector [DWS, 2018c]. Collectively, the NWRS and NW&S MP is the primary mechanism to manage water across all sectors towards achieving the national government's development objectives [NPC, 2012].

The National Eutrophication Management Strategy and the NWRS – NW&S MP duo have a bidirectional relationship. On the one hand, the National Eutrophication Management Strategy supports the NWRS - NW&S MP with greater resolution on eutrophication management, whereas, on the other hand, the NWRS - NW&S MP informs eutrophication management on the big-picture integrated water resource management priorities and perspective.

4.3.2 National Development Plan (2030) and National Water Security Framework

The National Development Plan (NDP), finalised in 2012, articulates the vision of development for the country and identifies key milestones and targets to be achieved in the various sectors. It sets out a detailed blueprint for how the country can eliminate poverty and reduce inequality by the year 2030. It was endorsed by Cabinet as a strategic framework to form the basis of future government detailed planning. The NDP envisions a South Africa where everyone feels free yet bounded to others; where everyone embraces their full potential, a country where opportunity is determined not by birth, but by ability, education and hard work [DWS, 2018b].

The NDP recognises the role of water in contributing to poverty eradication and social development. The most relevant programmes and targets articulated by the NDP in this regard include:

- Ensure people have access to clean, potable water and that there is sufficient water for agriculture and industry, recognizing trade-offs in the use of water;
- Reduce water demand in urban areas to 15% below business-as-usual scenario by 2030;
- Implement a comprehensive management strategy including an investment programme for water resource development, bulk supply and wastewater management for major centres by 2012, with review every five years;
- Develop regional market for food, energy and water and put in place water management agreement with neighbouring countries; and
- Develop regional utilities to deliver some local government services on an agency basis where local or district municipalities lack capacity.

Additionally, the National Water Security Framework (NWSF) for South Africa reflects high level principles, scope and recommendations, distilled from the NDP and the work of the National Planning Commission (NPC), tasked with reviewing and ensuring its implementation. The NWSF endorses the UN Water definition of water security [UN Water, 2013], *viz. "the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability"*. The NWSF, further, supports the view of Jepson, *et al.* (2017) that *"… water security is less about obtaining water, and more about fostering human capabilities as they relate to water... It is not simply a state of adequate water – however defined – to be achieved, but rather a relationship that describes how individuals, households, and communities navigate and transform hydro-social relations to access the water that they need and in ways that support the sustained development of human capabilities and wellbeing in their full breadth and scope"*. This resonates with the ultimate vision espoused by the NDP of rising living standards, falling poverty and inequality, as well as restoring the dignity of the people of South Africa. The NWSF seeks to ensure the water security of the nation, and considers all the water uses that are important, as depicted in **FIGURE 23**. The NWSF endeavours to focus on national priorities, underpinned by a thriving economy [Nepfumbada & Seetal, 2020].

Increasing incidents of over-enrichment of water resources constitute a threat to all seven socio-economic water uses depicted in **FIGURE 23**, and hence also to a thriving South Africa economy, requiring the National Eutrophication Management Strategy to echo the sentiments of the NWSF: *"there now has to be a deliberate and concerted effort to ensure water security for South Africa's current and future socio-economic development needs"*.

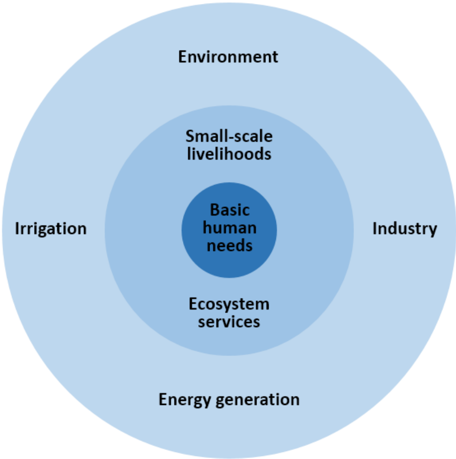

FIGURE 23: Important socio-economic water uses requiring water security [Nepfumbada & Seetal, 2020].

4.4 Integrated Water Quality Management Policy and Strategy for South Africa (2017)

As of 2017, the Integrated Water Quality Management (IWQM) Policy and Strategy constitutes the apex policy and strategy for water quality management in South Africa (**FIGURE 24**).

The IWQM Policy aims [DWS, 2017c, p. 4]-

- to provide a coherent, consolidated, current and inclusive approach to water quality management;
- to align water quality management policy with current legislation and overarching policy, and provide resolution on matters not adequately addressed in current policy;
- to guide the further development of legislative and regulatory instruments;
- to inform the water resource management function;
- to address key operational aspects, such as adopting an integrated approach, broadening finance mechanisms, and improving knowledge and information in the execution of water quality management;
- to provide guidance on sustainable water use, especially in as far as it relates to water quality management; and finally
- to provide the required framework for the development of related policies and sub-strategies related to water quality management, as the aim that enabled the development of this document – *i.e.* the National Eutrophication Management Strategy.

Additionally, the IWQM Strategy considers and outlines the short, medium and long-term actions and interventions that need to be implemented to move the country forward towards achieving the IWQM Policy, and to ensure that the trajectory of declining water resource quality is arrested and turned around [DWS, 2017e, p. 3]. The IWQM Strategy identified eutrophication as a priority water quality issue, requiring intervention as a matter of urgency [DWS, 2017d, p. 9]. Various Strategic Objectives[15], in the IWQM Strategy [DWS, 2017d], relate to eutrophication management and the roll-out of an National Eutrophication Management Strategy; these being:

- Policies and Strategies impacting upon IWQM are harmonized (SO1a);
- IWQM is effectively supported by the NWA (36:1998) and/ or the WSA (108:1997) (SO2a);

[15] The Strategic Objective (SO) unique identifier numbers, used in the Integrated Water Quality Management Strategy for South Africa (2017), are given in brackets for ease of reference.

- IWQM is effectively supported by other legislation (SO2b);
- Partnerships/stewardships established and maintained (SO4a);
- Targeted/strengthened compliance monitoring and enforcement of key polluting sectors (SO6b);

Sustained capacity for Government /CMA/sector to effectively manage and support IWQM through improved education and training (SO11b).

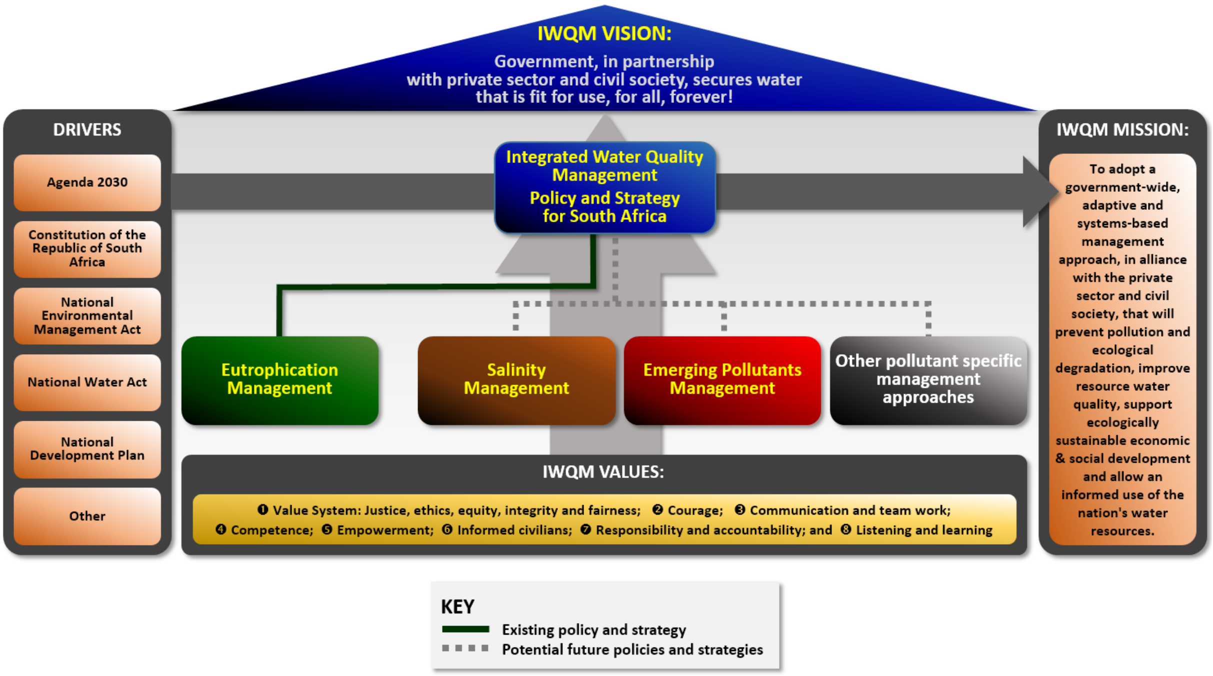

FIGURE 24: Relationship between the Integrated Water Quality Management Policy and Strategy for South Africa and the *National Eutrophication Management Strategy*.

The IWQM Strategy also calls for the development of policy and strategy to address diffuse sources of pollution and care should be taken to align the *National Eutrophication Management Strategy* with this vision.

Whereas the role and guidance of the IWQM Policy and Strategy, soon to be supported by policy and strategy at the resolution of eutrophication management specifically, to innovate; to present broad outlines of the best water quality management approaches; and to ensure consistent application nationally is acknowledged, it should also be acknowledged that such policy and strategy must be supported through water resource planning at the level of the water resource system and the catchment. This is a critical aspect that is necessary to integrate and address unique local and catchment characteristics; to pro-actively influence management interventions through informed options analysis; and to facilitate ecologically sustainable development.

CHAPTER 5: EVOLUTION OF EUTROPHICATION MANAGEMENT IN SOUTH AFRICA

The consideration of historic advancement together with an analysis of the present, and the extrapolation of past knowledge to the future, often assists with the development of a better understanding of trends, and forward thinking. The discussions following next, reflect on eutrophication management related thinking that has emerged over time and recollect on where we stand today. An understanding of the evolution of eutrophication management and its weaknesses will be used to propose potentially improved ways of tackling problem areas and to develop progressive policy (**Part 2**) and appropriate roll-out approaches (**Part 3**) that should seize current worsening nutrient over-enrichment trends; and limit and prevent excessive anthropogenic eutrophication in future.

5.1 Past paradigm

BOX 2: *"The past paradigm – summarised in a few words!"*

The past paradigm is typified by gaining awareness of the effects caused by nutrient-laden wastewater and waste. In the past paradigm pollution control slowly emerged and initially took many forms – at first struggling to find traction as the universal approach to combat pollution and being restricted to areas of unacceptable impact; and later gaining momentum as the generally accepted approach to deal with pollution caused by nutrient-laden wastewater and waste. The past paradigm concludes with the realisation that the pollution control approach had to be substituted with a water quality management approach and that water resource requirements need to link with end-of-pipe effluent control.

5.1.1 The period prior to the industrial age

In the early years, the measures closest resembling eutrophication management world-wide, if at all, were limited to general waste and wastewater handling practices. Even though municipal water supply and sanitation goes back as far as 600 BC to ancient Rome [Havlíček & Morcinek, 2016], the use of inventions, such as the water closet in Elizabethan times (second halve of the 16th Century), was adopted by only a very few households [Wall, 2018].

The first recorded proclamation in South Africa that dealt with water pollution and wastewater handling goes back to 10 April 1655. On this day the Dutch Administration in the Cape of Good Hope issued a *"placcaet"* (public notice) that prohibited pollution of selected streams draining the slopes of Table Mountain [Thompson, 2016]. According to the public notice, fines would be imposed on people washing in, or dumping refuse into, the streams that supplied freshwater through *"grachts"* (canals) to the downstream settlements [Wall, 2018]. However, during these days water quality received limited attention, with the bulk of the focus on consumptive water use and related matters.

5.1.2 The 19th Century

From the late 18th Century, the pace of change started to increase rapidly in response to far-reaching social and institutional change, together with medical, scientific and technological advances. With the first recorded discovery of diamonds in 1867, near the town of Hopetown [Shigley, 2017], and gold in 1886, on the banks of the Witwatersrand [Richardson & Van Helten, 1984, p. 319], South Africa was converted from a predominantly agricultural society to the largest producer of gold and one of the largest producers of diamonds in the world. However, in much of the 19th Century South Africa, particularly the rural areas, significant change was slow. The all-inclusive population count of just over 5 million people at the turn of the 19th Century [Hancock, 1962] were sufficiently dispersed that the disposal of waste of all forms could take place with very little chance of harming anyone else – thus little, to no need for any kind of regulation of the causes of anthropogenic eutrophication [Wall, 2018].

5.1.3 The 20th Century up to 1956

With the advent of the 20th Century, urban centres and mining towns, such as Johannesburg and its sister gold mining towns, started to expand more rapidly. With the establishment of the first engineered schemes, early in the 20th Century, to bring water from more distant places to where it was needed in urban centres [Wall, 2018], more return-flows also started to be generated. The first statute containing water quality management related provisions, was the Public Health Act of the Union of South Africa, 1919

(Act No. 36 of 1919)[16], which prohibited local authorities from discharging effluents into natural water courses, irrespective of the quality. This legislation also permitted the Minister of Health to lay down standards for purified effluent, but these powers were never exercised [Wall, 2018]. Additionally, in 1951, the South African Bureau for Standards (SABS) published standards for the discharge of effluent to streams, although these were more in the form of guidelines with no obligation to enforce them [Osborn, 1988].

The first municipal WWTWs commissioned in South Africa – by today's standards, extremely small and using primitive technology – commenced operations in Bloemfontein (November 1904) and in Wynberg (January 1905), followed by Pietermaritzburg (1908) [Osborn, 1988]. In these cases, the improved resultant effluent was irrigated over adjacent land. In all other urban centres, wastewater, if it was collected at all, was irrigated on land in an untreated state [Wall, 2018].

5.1.4 The period following 1956 up to 1994

By 1956 it was becoming apparent that reconciling water supply with water demand would be increasingly difficult and that the reuse[106] of growing volumes of wastewater would have to play a major role in the management of the country's scarce water resources. The Water Act, 1956 (Act No. 54 of 1956)[17] brought radical changes to how wastewater was viewed and basically reversed the prohibition on the discharge of effluent into natural water courses, as was previously enforced through the Union Health Act (36:1919) [DWAF, 1991]. The 1956 Act, consequently, made it mandatory that effluent must be treated to acceptable standards and returned to the water course from which the water was originally obtained.

As time passed, riverine ecosystems have been systematically modified on increasingly large scales. A growing population of just over 44 million people at the turn of the 20th Century [Stats SA, 2003], with increasing needs for food supply and wastewater handling, progressive industrialisation and infrastructure programmes, such as the building of large dams for water security purposes, were amongst the factors that increasingly started to contributed towards the prevalence of anthropogenic eutrophication of surface water resources in the period following 1956.

The linkages between aquatic plant growth, nutrients and human activities (eutrophication) was recognized as a threat to South African surface waters almost seven decades ago and the first impacts thereof became apparent in the 1950s and reaching problematic levels in the 1960s [Walmsley & Butty, 1980; Zohary, et al., 1988; Van Ginkel, 2011].

In 1962, the then Department of Water Affairs[18] (DWA) published the Regional Standards for Industrial Effluent; specifying a series of uniform Waste Discharge Standards (WDSs). This was the first rendition of what are today known as the *General and Special Standards for the purification of Wastewater or Effluent*. Importantly, the Notice included a Special Standard for phosphorus of 2 mg/ℓ orthophosphate [GN R.553, 1962].

Eutrophication monitoring in South Africa commenced in the early 1970's – at the time, mostly being done as *ad hoc* monitoring surveys and research projects supported by the Water Research commission (WRC) up to about 1985 [Toerien, et al., 1975].

In 1980, a revised Special Standard, based on best available wastewater technology [Taylor, et al., 1984], for phosphorus of 1mg/ℓ orthophosphate was published [GN R.1567, 1980] and in 1984 this Special Standard for phosphorus of 1mg/ℓ orthophosphate was included in the *General and Special Standards for the purification of Wastewater or Effluent* (**TABLE 9**) [GN R.991, 1984].

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[16] Hereafter, referred to as the Union Health Act (36:1919).

[17] Hereafter, referred to as the WA (54:1956).

[18] Currently the Department of Water and Sanitation (DWS).

TABLE 9: General and Special Standards for the purification of Wastewater or Effluent: Selected constituents, relevant to excessive primary production.

CONSTITUENT	GENERAL STANDARD for less sensitive catchments	SPECIAL STANDARD for more sensitive catchments
Chemical Oxygen Demand *(after applying the chloride correction)*	≤75 mg/ℓ	≤30 mg/ℓ
Suspended solids	≤25 mg/ℓ	≤10 mg/ℓ
Free and saline ammonia (as N)	≤10 mg/ℓ	≤1 mg/ℓ
Nitrates (as N)	-	≤1.5 mg/ℓ
Orthophosphate (as P)	-	≤1 mg/ℓ

These Special Standards for phosphorus was made applicable in specific catchment areas by means of specifying them in schedules in the relevant regulations, *viz.* 73 catchment areas, as listed in GN R.533 (1962); and 7 catchment areas, as listed in both GN R.1567 (1980) and GN R.991 (1984).

Pretorius (1983) and Toerien (1984) both criticised the decision to include a blanket (uniform) phosphorus standard of 1 mg/ℓ orthophosphate for all sensitive catchments, on the grounds that the differences in phosphorus-receiving capacity of impoundments have been ignored and that in some catchments the contributions from diffuse sources has been so high that removal of point sources have negligible effects on the trophic status of impoundments [Grobler & Silberbauer, 1985].

Later legislative amendments, notably the Water Amendment Act, 1984 (Act No. 96 of 1984), broadened water quality management. Industrial effluent, and sources other than effluent, *e.g.* water which arises as a by-product from industrial and mining activities and seepage or storm water runoff from a site, were made subject to pollution control regulations. The State was also given powers to prevent pollution before it takes place [DWAF, 1991].

In 1985, the DWA initiated the first eutrophication-focused monitoring programme, *i.e.* the Trophic Status Project (TSP), which covered the 7 sensitive catchments, as listed in GN R.1567 (1980) and GN R.991 (1984), respectively. The TSP would lay a solid foundation for the National Eutrophication Monitoring Programme (NEMP), to be designed and implemented years later, in that it highlighted the extent of the problem at a national scale, and also providing a database to be used during the design of the NEMP [DWAF, 2002].

In 1991, the then Department of Water Affairs and Forestry[19] (DWAF), adopted its new water quality management policy, entitled *Water Quality Management Polices and Strategies in the Republic of South Africa*, concluding an era of pollution control and entering an era typified by the Receiving Water Quality Objectives approach [DWAF, 1991]. With the adoption of this approach, water quality management would hence forth focus on cumulative impacts on water resources, rather than on individual point sources of pollution [DWS, 2017b]. Full implementation of this approach in the absence of supporting legislation, *i.e.* until the promulgation of the NWA (36:1998) in 1998, however, would proof to be difficult.

[19] Currently the Department of Water and Sanitation (DWS).

5.2 Current paradigm

BOX 3: *"The current paradigm – summarised in a few words!"*

The current paradigm starts off with the new democratic dispensation for South Africa that saw the advent of a new world-class Constitution, amongst others, establishing the human rights to an environment that is not harmful and to sufficient water. In the current paradigm, the foundation for integrated water quality management had been laid with the promulgation of new world renowned environmental and water legislation. Water quality management would be characterised by a notion to integrate water quality management efforts in the context of ecologically sustainable development and attempts to operationalise the Receiving Water Quality Objectives approach.

5.2.1 The years leading up to present-day eutrophication management, 1994 to 1998

1994 heralded a turning point in the history of South Africa. The *"interim"* Constitution of the Republic of South Africa, 1993 (Act No. 200 of 1993), at the time, and the *"new"* Constitution (108:1996) – in particular Sections 24 on *"an environment that is not harmful …"* and 27 on *"access to sufficient water"* – prompted a revision of national water policy and legislation. The White Papers on *Water Supply and Sanitation Policy* (1994) and a *National Water Policy for South Africa* (1997) paved the way for the promulgation of the WSA (108:1997) and the NWA (36:1998) on 27 November 1997 and 20 August 1998, respectively, the latter act replacing the WA (54:1956). Collectively these statutes addresses the entire water value chain – *"from resource to source to resource"*.

ANNEXURE D provides a synopsis of important provisions in these two acts and their roles in eutrophication management.

All water, hence forth, would be regarded as being part of a common good, kept in public trust on behalf of all persons by the Minister of Human Settlements, Water & Sanitation [DWAF, 1997; NWA, 1998, S.3]. As such, the DWS is mandated, *inter alia*, to protect water resources and water users; to meet the basic human needs of present and future generations; to promote equitable access to water; and to manage the water quality of all water resources, while supporting ecologically sustainable development.

The NWA (36:1998), furthermore, recognises that water quality is inextricably linked with water quantity (typically water flow), in stream and riparian habitat and aquatic biota integrity, all of which are collectively referred to in the Act as the "*resource quality*". For water resources to be able to continuously sustain economic growth and social development, the quality (or *"resource quality"*) of such water resources needs to be maintained within certain pre-determined parameters. These water resource parameters, or statutory Resource Directed Measures (RDMs), are represented by the water resource Management Class (MC), Resource Quality Objectives (RQOs) and the Reserve. The NWA (36:1998), additionally, makes provision for Source Directed Controls (SDCs) to control sources of negative impacts on resource quality, aiming to comply with determined RDMs. SDCs include measures such as water use registration, authorisation, directives, prosecution and economic incentives such as levies and fees. This approach recognises both the needs for upstream water use and development, and downstream protection of aquatic ecosystems and user water quality requirements.

The National Eutrophication Monitoring Programme (NEMP) (**ANNEXURE F**) gained momentum and was implemented in 2002. In 2003, the Strategic Framework for Water Services was published to serve as an umbrella framework for the water services sector. This Framework set overall goals, and outlined institutional and operational frameworks necessary for achieving the Framework's goals. In 2006, the Resource Directed Management of Water Quality Policy and Strategy series was published to give substance to resource water quality management. With the publication of the IWQM Policy and Strategy in 2017, a new integrated approach to water quality management across key government departments and the sector was introduced. The IWQM Policy and Strategy serves as an umbrella policy and strategy for water quality management and, thus, also for eutrophication management policy and strategy, in South Africa.

The evolution of the water quality management supporting legislation and policy over time, and some implications for eutrophication management, are summarised in **FIGURE 25**.

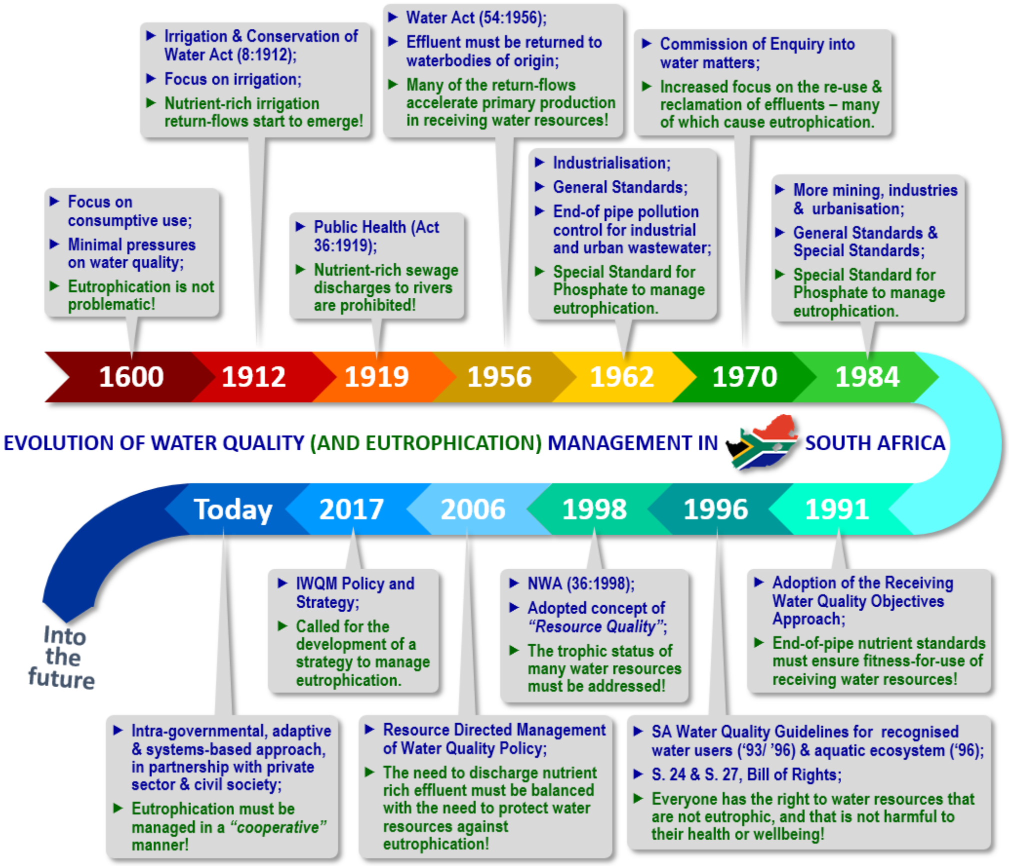

FIGURE 25: Evolution of water quality management in South Africa with some implications for the management of eutrophication.

5.2.2 Contemporary eutrophication management

Although excessive nutrient-loading of water resources is caused by both point[92] and diffuse[30] sources of water pollution[125], eutrophication measures, currently, mostly focusses on the regulation of point sources of nutrient-loading. The water value chain (**FIGURE 26**), consisting of upstream supply chain operations, consumptive water use, and downstream discharge of wastewater return-flows, some with a high nutrient content, provide a handy basis from which present day point source-focused eutrophication management can be conceptualised. The ensuing discussion aims to evaluate whether the statement: "No value chain is stronger than its weakest link" also holds true for the water value chain, especially in the context of escalating anthropogenic eutrophication observed in multiple receiving water resources.

The water value chain has a two leg configuration, *i.e.* (1) a municipal supply and return-flow leg; and (2) a raw water supply and return-flow leg. Regulatory responsibilities are shared across these two legs, with WSAs (municipalities) generally holding regulatory responsibility over leg (1); and the DWS over leg (2), often presenting cooperative governance challenges. WSAs are required to register the qualifications of operators of WWTWs. Up to recently, DWS, from an effluent point of view, had only been interested in the final end-of-pipe discharge quality of the wastewater return-flows from both legs. DWS, thus, has little insight in the volumes and qualities of feed-water being received by WSAs at municipal WWTWs from their client sectors.

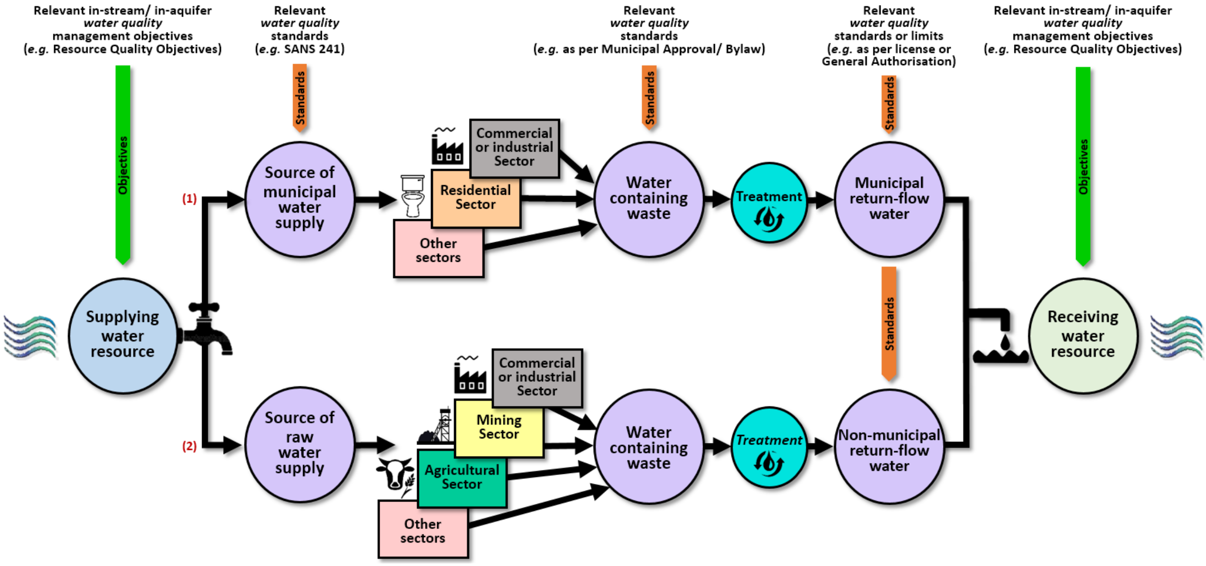

FIGURE 26: The water value chain: *"From resource to source to resource"*.

In contemporary eutrophication management, there are many provisions in the NWA (36:1998), today, which are at the disposal of the regulator to facilitate improved eutrophication management and water resource protection, but which are for some reason not being employed. Some of these provisions are important, and include:

- The WDCS, which could facilitate the limiting and prevention of nutrient-loading by application of the polluter-pays principle [NWA, 1998, S.56];
- The establishment of Catchment Management Strategies (CMSs), containing eutrophication specific interventions – tailor-made for each Water Management Area (WMA) to address specific eutrophication management needs [NWA, 1998, S.8];
- Regulations to regulate the design, construction, installation, operation and maintenance of WWTWs, owned by both the private and public sectors [NWA, 1998, S.26(1)(e)]. These regulations will specifically help to improve the current situation with respect to municipal WWTWs and poor maintenance, timeous upgrading, and utilisation of works over their design-capacity;
- Regulations to regulate or prohibit any activity in order to protect a water resource, or instream or riparian habitat from the effects of excessive nutrient-loading [NWA, 1998, S.26(1)(g)];
- Regulations prescribing waste standards, which specify the quantity, quality (concentrations of nutrients) and temperature of waste which may be discharged or deposited into, or allowed to enter a water resource [NWA, 1998, S.26(1)(h)];
- Regulations requiring that waste discharged or deposited into or allowed to enter a water resource be monitored and analysed, and prescribing methods for such monitoring and analysis [NWA, 1998, S.26(1)(j)]. Such data and information should be uploaded onto the DWS's Integrated Regulatory information System (IRiS);
- Albeit that the NWA (36:1998) has introduced various statutory Resource Directed Measures (RDMs) [NWA, 1998, S.15] to, *inter alia*, ensure fitness-for-use of receiving water resources, the operationalising of the Receiving Water Quality Objectives approach has proven to be elusive. It is critical that receiving water quality requirements for nutrient reduction must be integrated with water use authorisations in order to address the effects of anthropogenic eutrophication; and

- In many cases, room for better integration exist with a number of WSA (108:1997) provisions, for instance integration with Municipal Approvals of water use [WSA, 1997, S.7(2)], Water Services Development Planning (WSDPs) [WSA, 1997, S.16] and information management [WSA, 1997, S.67].

5.3 Future paradigm

BOX 4: *"The future paradigm – summarised in a few words!"*

The future paradigm, in the short-term, will probably be typified by a consolidation of water quality management efforts, striving to fully utilise and to refine all available legal and policy instruments. In the longer term, the future paradigm will have to yield innovative solutions and approaches to appropriately address anthropogenic eutrophication and to realise and guarantee ecologically sustainable development for generations to come.

5.3.1 Matters to receive attention in the short-term

Van Niekerk (2000) observed that there has been widespread non-compliance of WWTWs to the phosphorus standard of 1 mg/ℓ orthophosphate, whereas Harding (2017) noted that a phosphorus standard of 1 mg/ℓ orthophosphate may, in some circumstances, be too lenient. These two related observations raise a number of important points that should be addressed in the near future, *viz.*:

- Feasible and appropriate Waste Discharge Standards (WDSs) should be developed and implemented;
- The Receiving Water Quality Objectives approach must be operationalised. Harding (2008) proposed an approach that includes the calculation of Total Maximum Daily Loads (TMDLs) for dams;
- The role and feasibility of technology to treat nutrient-laden wastewater should inform processes to improve eutrophication management. The Best Practicable Environmental Option (BPEO) should be implemented;
- All water uses must be lawful and where necessary valid water use authorisations must be in place;
- Compliance monitoring and enforcement must be intensified to deal with unlawful and non-complying water uses; and
- Water users should assume duty of care and in cases where they do not, the regulator should step in.

Additionally, heading for the future, in the short-term, would require addressing priorities, such as:

- Protection of high yield water source areas and related ecological infrastructure that offer water quality improvement functions;
- The implementation of buffer areas to protect water resources against diffuse sources of nutrient-laden pollution;
- Ensuring that national and regional eutrophication monitoring programmes resume full operation. *"If you cannot measure it, you cannot manage it"* [Peter Drucker];
- Resource water quality data and information must be paired with water resource flow data and information to allow for the consideration of nutrient-loading;
- The integration of earth observation into eutrophication monitoring, making use of satellite earth observation (remote sensing) for the monitoring of cyanobacterial blooms and eutrophication in South Africa's large- and medium-sized fresh waterbodies should be supported. The chlorophyll-α (Chl-A) estimates from satellite have been integrated into the Water Management System (WMS) of the DWS in order to supplement and fill-in National Eutrophication Monitoring Programme (NEMP) information gaps [Matthews & Bernard, 2015];
- Compliance monitoring should be extended to also include volumetric effluent data and information, in addition to water quality data and information, to allow for the consideration of nutrient-loading from WWTWs;

- It must be made compulsory that water users upload both volumetric and water quality data and information on IRiS, instead of submitting hard copy records to the regulator, as may be required by the applicable water use authorisations;
- Water quality and volumetric data and information, originating earlier within the water value chain, have the potential to put additional water quality intelligence in the hands of the DWS that could assist with nation-wide improving of the performance of municipal WWTWs. This data and information must be uploaded for interrogation on a national information management system;
- Better cooperation with government, private sector civil society roll-players needs to be put into action; and
- Providing technical support to local government, where necessary, and ensure that municipalities have appropriate bylaws in place to manage causes of eutrophication early on in the water value chain and to provide for the monitoring of water quality and volume.

5.3.2 Potential innovation in the longer-term

Heading for the future, in the long-term, the focus can shift to attaining more innovative and progressive solutions to address eutrophication problems. These may include the following:

- The regulation of diffuse water pollution mostly relates to land care and land-use management. Innovative arrangements and approaches to address this source of nutrient-loading is necessary;
- Escalating water demands being supplied, often translate into the increasing generation of wastewater return-flow volumes, which require treatment prior to being discharged. More emphasis is required on mechanisms to promote reuse and recycling strategies, as a measure to reduce demand, and hence to reduce the contributions of wastewater return-flows to nutrient-loading of receiving water resources;
- The rehabilitation of affected water resources, including the implementation of bio-remediation initiatives, such as the Harties Metsi-a Me/ Hartbeespoort Dam Biological Remediation Project, in affected water resources should be supported;
- The use of technology solutions, such as the use of Solar-Powered Reservoir Circulators (Solar-Bees), which are floating solar-powered reservoir long distance circulation pump system, used to mix water columns and greatly accelerates the biological and solar processes that clean up water, can be considered as a feasible reactive intervention;
- Bio-manipulation, fish-harvesting and food-web manipulation to address the symptoms of eutrophication [Harding & Hart, 2013] can be considered; and
- The introduction of zero-phosphate detergents into South Africa [Quayle, et al., 2010] should be pursued.

CHAPTER 6: CONCLUSION

Outstanding text.

To be added when the Executive Summary is finalised.

PART 2: NATIONAL EUTROPHICATION MANAGEMENT POLICY

PHOTO 2: *"WATER POLLUTION AFFECTS EVERYONE!"* © J.J. VAN WYK

CHAPTER 1: INTRODUCTION

In general terms, *"policy"* defines ground rules, delineate intent and an expression of political mandate, and specify desired outcomes [Presidency, 2020]. This part of the document identifies a number of succinct policy statements that are regarded as most pertinent to eutrophication management in South Africa. Collectively these policy statements provide an extension of the over-arching Integrated Water Quality Management (IWQM) Policy – at the resolution of eutrophication management, nationally[20]. As such, some eutrophication management policy statements are complementary to the IWQM Policy, *i.e.* rephrased or adjusted to reflect and add an eutrophication focus, whereas others are supplementary and new[21]. Albeit that the policy on eutrophication management has a standing in its own right, it is supported with a strategy on eutrophication management (**Part 3**) that assists implementation. For convenience, relevant policy statements are referenced only within the eutrophication management strategy, instead of repeating them throughout.

The eutrophication policy making process follows that of Sector Policies [Presidency, 2020], which are policies that departments and municipalities must strive to execute, and which are derived from their respective mandates. These policies find expression for implementation *inter alia* through Strategic Plans, municipal Integrated Development Plans (IDPs), Annual Performance Plans (APPs) and municipal Service Delivery Budget and Implementation Plans (SDBIPs) [Presidency, 2020]. The eutrophication strategy is to assist in linking policy with catchment and other strategies and plans for expression.

With the rolling-out of the IWQM Policy and Strategy for South Africa, and the implementation of formalised eutrophication management, lessons are being learned, old views are being renewed, and new approaches are forged. All this is necessary to stay abreast of changing circumstances in a dynamic environment, and to *"stay ahead of the curve"*!

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[20] Care was taken to develop harmonising policy. In an unlikely event of contradicting policy views – the higher policy prevails.

[21] The National Policy Development Framework (NPDF), as adopted by Cabinet on 2 December 2020, makes provision for six broad categories of generic policy. Policy directives are amongst these and constitute formal instructions that must be executed by all affected policy implementers. A policy directive usually encapsulates instructions of a technical nature that do not require changes to higher level policies. Additionally, policy directives may reflect significant strategic or policy decisions. A policy directive communicates changes to the interpretation or application of policies and legislation. They can come in different forms, such as prescripts that interpret and clarify legislation regarding procedures, processes and practices that must be followed. The Eutrophication Policy follows the prescripts associated with policy directives [Presidency, 2020, p. 11].

CHAPTER 2: VISIONARY PERSPECTIVE

It is imperative that public policy must have a clear vision and that it must set out its ultimate intention [Presidency, 2020]. Eutrophication management in South Africa subscribes to the IWQM Vision and Mission [DWS, 2017b], *viz.*:

Vision: ***"Government, in partnership with private sector and civil society, secures water that is fit-for-use, for all, for ever!"***

Mission: ***"To adopt a government-wide, adaptive and systems-based management approach, in alliance with the private sector and civil society, that will improve resource water quality, prevent pollution and ecological degradation, support ecologically sustainable economic & social development and allow an informed use of the nation's water resources."***

As such, eutrophication management has an important and specific role to play in the advancement of the above stated vision and mission. This role is embodied in the following goal for eutrophication management in South Africa:

Goal: ***"To manage eutrophication effectively in order to protect aquatic ecosystems and to secure water resources that are fit-for-use."***

A collage of different objectives offers further context to the Goal, and to subsequent policy development. This collage of different objectives can be grouped into two *"layers"* of objectives and associated policy statements, pertaining to eutrophication management. For practicality purposes, distinction is made between a *"first layer"* consisting of Chief-Objectives, and a *"supporting layer"* consisting of Complementing Objectives for eutrophication management. Collectively, these two distinct *"layers"* of objectives for eutrophication management must strive to contribute towards realising the IWQM vision and mission and the national eutrophication management goal. These objectives are listed below:

Chief-Objectives for eutrophication management:

- To limit anthropogenic nutrient-loading of water resources;
- To reduce excessive primary production in surface water resources;
- To protect aquatic ecosystems and their biological diversity;
- To secure water resources that are fit-for-use on a continuous basis; and
- To support ecologically sustainable development and justifiable socio-economic growth.

Complementing Objectives for eutrophication management:

- To appropriately resource eutrophication management, *inter alia*, by securing funding, providing human capital and equipping responsible parties;
- To promote research in relation to the management of eutrophication and the control of anthropogenic sources of nutrient enrichment;
- To promote management cooperation within and between government, private sector and civil society;
- To promote transparency through stakeholder consultation, eutrophication-related communication and awareness creation; and
- To facilitate capacity building and the empowerment of role-players.

Policy statements supportive of the objectives, as listed above, and that are regarded as most pertinent to eutrophication management in South Africa, are listed in **TABLE 10**, below. The table also gives indications of whether the policy statements are regarded as *"existing"*, *i.e.* complementary to the IWQM Policy and rephrased or adjusted to reflect and add an eutrophication focus; or as *"new"*, *i.e.* supplementary to the IWQM Policy:

TABLE 10: List of pertinent policy statements for eutrophication management in South Africa.

STATEMENT #	POLICY STATEMENT	STATUS
Policy statements in support of the Chief Objectives for eutrophication management		
POLICY STATEMENT 1	Application of management instruments for environmental compliance in eutrophication management	*New*
POLICY STATEMENT 2	The mitigation hierarchy for decision-making on eutrophication	*Existing*
POLICY STATEMENT 3	The differentiated approach for the control of excessive nutrient-loading	*Existing*
POLICY STATEMENT 4	The application of the precautionary principle	*Existing*
POLICY STATEMENT 5	The Receiving Water Quality Objectives approach applied to eutrophication management	*Existing*
POLICY STATEMENT 6	A life cycle view on nutrient-loading	*New*
POLICY STATEMENT 7	Incentive-based regulation	*Existing*
POLICY STATEMENT 8	Nature-based solutions	*New*
POLICY STATEMENT 9	The application of the Best Practicable Environmental Option	*New*
POLICY STATEMENT 10	Holistic eutrophication management	*New*
POLICY STATEMENT 11	Eutrophication management responsibility and accountability	*New*
POLICY STATEMENT 12	Monitoring	*Existing*
POLICY STATEMENT 13	Information management	*Existing*
POLICY STATEMENT 14	Water resource assessment and planning to inform decision-making	*Existing*
Policy statements in support of the Complementing Objectives for eutrophication management		
POLICY STATEMENT 15	Resourcing of eutrophication management	*New*
POLICY STATEMENT 16	Promotion of eutrophication-related research	*Existing*
POLICY STATEMENT 17	Transparency	*Existing*
POLICY STATEMENT 18	Increased capacity	*Existing*
POLICY STATEMENT 19	Cooperative management	*Existing*

FIGURE 27 provides a contextual outline of the Eutrophication Management Policy.

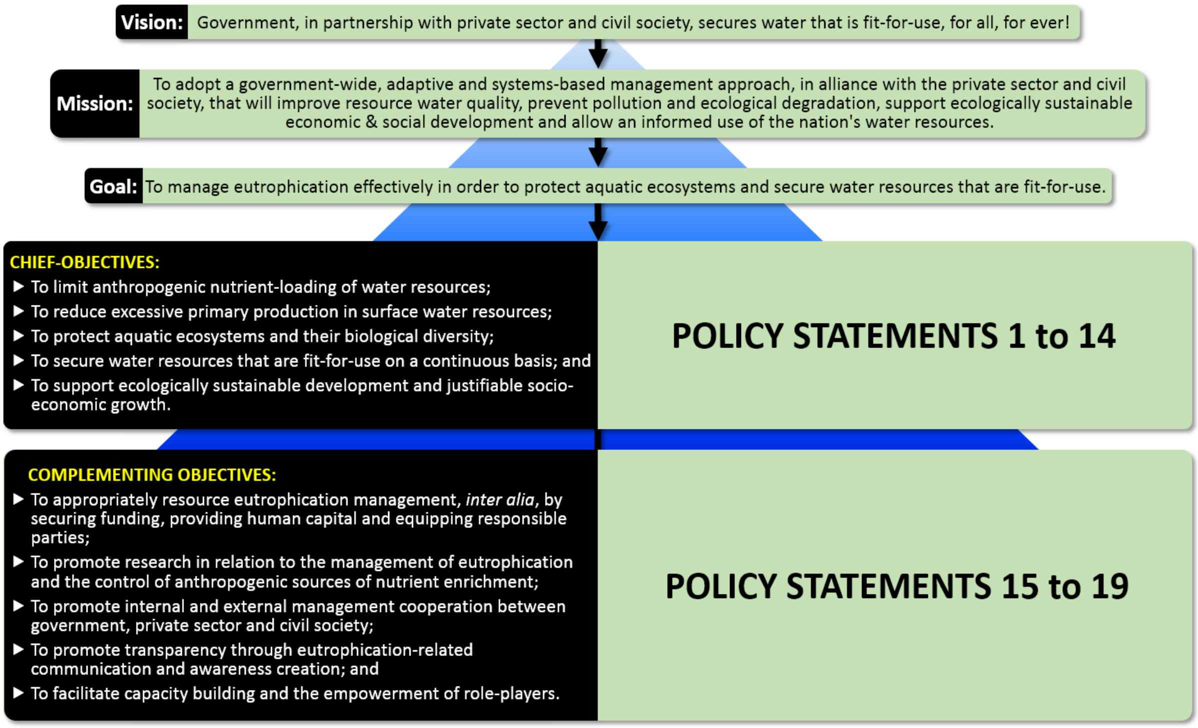

FIGURE 27: Outline of the Eutrophication Management Policy.

The individual policy statements are unpacked in more detail, next in Chapter 3, which provides the policy premise, definitions of policy intent and a concluding statement on the status of the particular policy statement.

CHAPTER 3: POLICY INTENT

Recognising that:

(1) Nutrient over-enrichment of water resources from an anthropogenic origin represents a water resource pollution threat that impacts on the integrity of most South African aquatic ecosystems, and the fitness-for-use of receiving water resources; and

(2) Excessive nutrient-loading originating from both point and diffuse sources of pollution, causes an adverse impact on social development and economic growth; and

(3) Anthropogenic eutrophication is considered to be a problem that will contribute towards an increasing occurrence of water quality challenges country-wide, and has the potential to become a crisis, unless appropriate national policies and strategy are implemented; and

(4) Eutrophication management has been neglected over the past decade and that this has resulted in a loss of human resource capacity, institutional memory, management information and a general understanding of eutrophication within institutions, throughout the country.

And acknowledging whereas:

(1) Anthropogenic eutrophication is reversible – there are no quick fixes and long-term, sustainable and lasting solutions are necessary; and

(2) Engineered and technical interventions will not fully solve all eutrophication-related problems – social and economic trade-offs are necessary; and

(3) All water uses must be permissible in terms of the NWA (36:1998) – the cumulative impact of land and water use activities need to be addressed in a catchment context; and

(4) Eutrophication problems mostly do not occur in isolation from other water quality issues – eutrophication management should be undertaken in the context of integrated water quality management; and

(5) Data and information gaps exist – monitoring, research, reporting and transparency are pre-requisites to effective decision-making and policy implementation; and

(6) Eutrophication management requires government cooperation, vertically, between spheres of government and, horizontally, between government departments – collaboration is also required with the private sector and civil society; and

(7) Government, private sector and civil society collaboration is essential – the DWS has a lead role to play with respect to eutrophication management.

Therefore:

(1) As trustee of the country's water resources, and in conjunction with all applicable legislation, including the NWA (36:1998), the WSA (108:1997) and the NEMA (107:1998), and in collaboration with government, private sector and civil society, the DWS wishes to emphasise the following intentions and policy commitments with respect to eutrophication management, nationally:

POLICY STATEMENT 1

3.1 Application of management instruments for environmental compliance in eutrophication management

Premise

There are four broad universally accepted categories of management instruments for environmental compliance, *viz.*:

- Command-and-control[21], or regulatory, management instruments;
- Economic[37], or marked-based, management instruments;
- Self-regulatory[110] management instruments; and
- Societal participation[86] management instruments.

Each of these instruments are vital to the management of water quality; specifically also eutrophication.

Application of the management instruments

In order to limit anthropogenic eutrophication, joint and separate application of these management instruments must facilitate the aims of the mitigation hierarchy for decision-making on eutrophication[22]. To advance eutrophication management there is a need to align, improve and strengthen these instruments, as well as to ensure that these instruments for compliance are effectively and consistently being supported and/ or applied. The availability of suitable data and information[23] is a prerequisite.

Command-and-control, or regulatory, management instruments

The direct regulation of land and water use constitutes an inseparable part of environmental and water resource management, and will continue to play a key role in eutrophication management. There is a pressing need to shape command-and-control[21] approaches to effectively address anthropogenic point and diffuse sources of nutrient-laden water pollution in order to

[22] Refer to **POLICY STATEMENT 2**: The mitigation hierarchy for decision-making on eutrophication.

[23] Refer to **POLICY STATEMENT 12**: Monitoring.

consistently realise the eutrophication management goal. However, when pursuing this goal, the Constitutional need for ecologically sustainable social development and economic growth must also be acknowledged. Cooperative regulation[24], vertically between spheres of government and, horizontally between government departments, must be pursued and strengthened, since more than one regulatory mandate influence the control of anthropogenic eutrophication. The One Environmental System and its objective to synchronise the overall process for the issuing of environmental authorisations within the prescribed period, is supported.

Examples of command-and-control instruments include environmental authorisation following Environmental Impact Assessments (EIAs), water use authorisation, Environmental Management Programme Reports (EMPRs), compiled by mines, atmospheric emission licensing, waste management licensing, the control of land and water use activities through regulations, prohibition of activities to protect water resources, or instream or riparian habitat, land use development planning mechanisms and others.

Economic, or marked-based, management instruments

Economic instruments[37] for eutrophication management complement the traditional command-and-control approaches and must incentivise positive behavioural change; stimulate innovation; tackle anthropogenic eutrophication priorities from both point and diffuse pollution sources; promote economic efficiency; and raise revenue for, among other things, eutrophication management related expenditures. External cost caused by anthropogenic eutrophication must, where appropriate, be internalised, considering economic incentive-based regulation[25] to limit nutrient-loading.

Examples of economic instruments include the WDCS.

Self-regulatory management instruments

Self-regulation[110] is well-suited to promote both corporate responsibility – which means selecting particular production methods, processes and waste streams that will have the least impact on water resources (*i.e. "environmental morals"*), and corporate accountability – which means ensuring that products and operations do not violate prescribed norms, standards and laws (*i.e. "legal compliance"*).

Self-regulation supports command-and-control, or direct regulation, and lessens pressure on Government resources, specifically with respect to regulatory compliance monitoring and enforcement. Schemes promoting responsible self-regulation must be investigated, supported and encouraged.

Examples of self-regulatory instruments include ISO 14001 [ISO, 2015], and others.

Societal participation management instruments

Partnerships with civil society must be employed, alongside traditional governmental mechanisms, for increased decentralised and participatory management[26] and to promote an increasingly participatory, bottom-up method of governing anthropogenic eutrophication. Societal participations for eutrophication management must be voluntary and based on shared responsibility; complement, rather than substitute, governmental strategies;

[24] Refer to **POLICY STATEMENT 19**: Cooperative management.

[25] Refer to **POLICY STATEMENT 7**: Incentive-based regulation.

[26] Refer to **POLICY STATEMENT 19**: Cooperative management.

preferably consist of a range of multi-level stakeholders; ensure transparency and accountability; produce tangible results; be adequately funded; and integrate with the application of other eutrophication management instruments. Societal participation provides a good platform for non-economic incentive-based regulation [27] to facilitate a reduction of nutrient-loading.

Examples of societal participation instruments include Catchment Management Forums (CMFs), citizen-based monitoring and reporting on compliance to water quality standards.

Policy status

Although the application of the management instruments for environmental compliance is not novel, the formalised requirement for the synchronized application of the individual management instruments in eutrophication management, to achieve common goals and policy objectives, is. This is a new policy statement.

POLICY STATEMENT 2

3.2 The mitigation hierarchy for decision-making on eutrophication

Premise

In any situation where several policies determine management goals, it is important to establish priorities.

Mitigation hierarchy for decision-making

To ensure consistency in reaching and implementing management decisions, a mitigation hierarchy for decision-making on eutrophication applies. This hierarchy for decision-making reflects present government policy and requires the following mitigation options to be considered sequentially in a hierarchy of increasing risk:

- Anthropogenic nutrient-loading, excessive primary production and degradation of aquatic ecosystems **must be avoided and prevented**!
- Or, where anthropogenic nutrient-loading, excessive primary production and degradation of aquatic ecosystems cannot be altogether avoided and prevented, **are minimised**!
- Or, where undue anthropogenic nutrient-loading, excessive primary production and degradation of aquatic ecosystems have occurred, **are remedied**!
- Or, where anthropogenic nutrient-loading, excessive primary production and degradation of aquatic ecosystems cannot be altogether avoided and prevented, or sufficiently minimised or remedied, **are offset, elsewhere**.

Most importantly – the mitigation hierarchy for decision-making on eutrophication (**FIGURE 28**) must always be considered within a catchment context by pursuing both the differentiated[28] and Receiving Water Quality Objectives (RWQOs) [29] approaches, by opting for the Best Practicable

[27] Refer to **POLICY STATEMENT 7**: Incentive-based regulation.

[28] Refer to **POLICY STATEMENT 3**: The differentiated approach for the control of excessive nutrient-loading.

[29] Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives approach applied to eutrophication management.

Environmental Option (BPEO)[30] and by applying the precautionary principle[31], as stipulated in the policy.

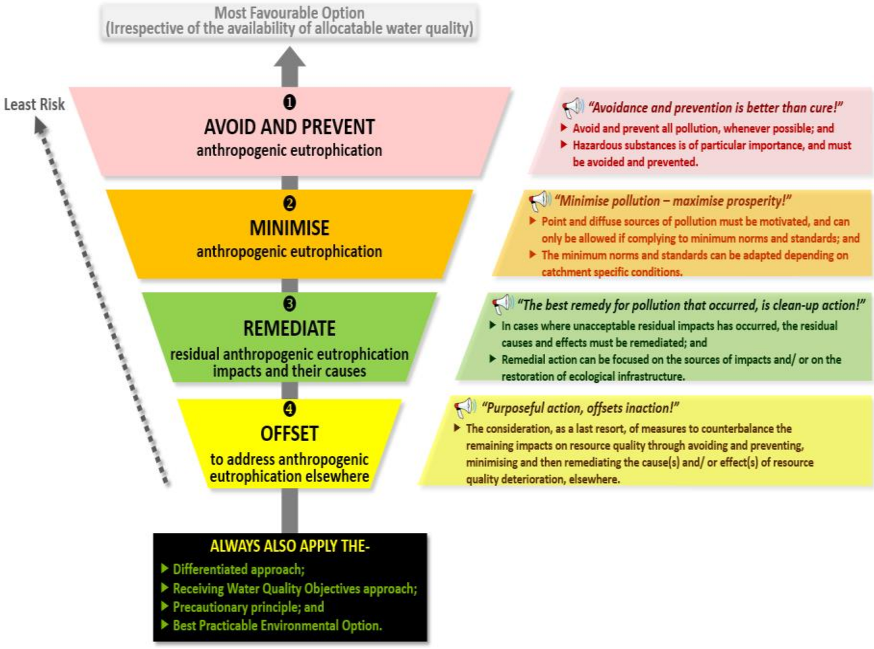

FIGURE 28: The mitigation hierarchy for decision-making on eutrophication.

Avoidance and prevention of anthropogenic eutrophication

Irrespective of the amount of allocatable water quality[3] – water users must be strongly encourage to avoid and prevent all anthropogenic[6] nutrient-loading[81] of receiving water resources, whenever possible. This will be effected by pursuing the BPEO[32].

Striving for a *"zero effluent"* state, in the case of effluent producing water users, should always be co-considered with the need to reconcile downstream water demand with water supply.

Pollution avoidance and prevention, in particular, applies to controlling the handling and prohibition of discharges or disposal of hazardous substances. Toxicity, persistence, capacity for bioaccumulation and emerging pollutants, such as those that can cause endocrine disruption, present a major threat in receiving water resources. Where these hazardous substances are involved, both the differentiated and the RWQOs approaches do not readily apply, because of the fact that very little to no allocatable water quality exists and due to the difficulties associated with determining appropriate RQOs for hazardous pollutants. In the case of hazardous substances, all decisions must be based on the precautionary principle.

Minimisation of anthropogenic eutrophication

It is acknowledged that, in many instances, some degradation of water quality in receiving water resources is inevitable, and is sometimes necessary to permit much needed socio-economic development. Irrespective of the amount of allocatable water quality[3] – minimisation of anthropogenic

[30] Refer to **POLICY STATEMENT 9**: The application of the Best Practicable Environmental Option.

[31] Refer to **POLICY STATEMENT 4**: The application of the precautionary principle.

[32] Refer to **POLICY STATEMENT 9**: The application of the Best Practicable Environmental Option.

nutrient-loading and water conservation and demand management, by pursuing the BPEO, will be encouraged at all times.

In the case of point sources, such as waste discharges, the precautionary approach will be applied by enforcing national minimum norms & standards, such as uniform Waste Discharge Standards (WDSs)[33], by default, should they exist. These norms and standards can be made stricter or relaxed in accordance with the differentiated and RWQOs approaches. When diffuse pollution sources are persistently contributing towards excessive nutrient enrichment[79] in receiving water resources, the DWS will approach the responsible authority, examine the causes of the problem and identify appropriate interventions to correct the problem and minimise anthropogenic eutrophication.

Remediation of residual anthropogenic eutrophication impacts and their causes

In cases where anthropogenic nutrient-loading has occurred and has caused unacceptable residual impacts, the cause(s) of such impact(s) and/ or the effected water resource(s) must be remediated to a near-natural, or an agreed state, especially in catchments with existing water quality stress, and where remediation is considered necessary, practical and equitable. It is recognised that remediation can be extremely expensive and may sometimes be totally impractical, for example in the case of some aquifers. This is regarded as a strong motivation for avoiding the need for remediation in the first place, by applying pollution avoidance and prevention and waste minimisation.

The polluters-pay principle will be applied to all remediation. Where polluters cannot be held accountable, the cost of remediation has to be borne by the taxpayer.

Offsetting to address anthropogenic eutrophication elsewhere

In special cases – offsetting[41] must be considered to limit, and progressively reverse, the unacceptable effects of anthropogenic eutrophication through counterbalancing the effects of anthropogenic eutrophication on water resources, that remain after every effort has been made to avoid and prevent, minimise and then remediate the causes/ effects, through avoiding and preventing, minimising and then remediating such causes/ effects, elsewhere. Offsetting includes the process of quantifying causes/ effects in order to draw comparisons with potential offsets and to ensure that a net gain of allocatable water quality[3] is achieved. The responsible authority must keep a publicly accessible register of all offsets to facilitate compliance monitoring. The water quality allocation plan constitute a key tool for the implementation of nutrient-loading off-sets in South Africa[34]. The umbrella Environmental Offset Policy [DEFF, 2018] requires the DWS to compile and publish specific sector offset guidelines for wetlands and water quality to enable the rolling out of offsetting for eutrophication management.

Policy status

The first version of policy that addressed hierarchal decision-making to mitigate environmental degradation, in South Africa, was pioneered for water pollution[35]. Over time, this policy position had been adopted as a general requirement for sustainable development, and has been

33 Currently the General and Special Standards and the Special Standards for phosphate [GN R.991, 1984].

34 Refer to **Section 3.1.2.4.3, Part 3:** Reconciliation and allocation of water quality.

35 Refer to IWQM Policy Statement B.2-1: The hierarchy of pollution management decision-making, [DWS, 2017b].

incorporated in South Africa's environmental legislation to limit degradation of aquatic ecosystems and biological diversity; pollution and environmental degradation; the disturbance of landscapes and natural heritage sites; waste; and impacts on people's environmental rights. In recent developments, this policy on hierarchal decision-making to mitigate environmental degradation had been extended to include off-setting as an accepted concept and consideration for environmental preservation and management. The current version of the mitigation hierarchy for decision-making on eutrophication includes these requirements.

POLICY STATEMENT 3

3.3 The differentiated approach for the control of excessive nutrient-loading

Premise

A one-fits-all approach ignores local differential requirements for either stricter levels of protection, or more lenient approaches that are beneficial to social development and economic growth.

Differentiated approach

The differentiated approach ensures that catchment-specific conditions are considered when controlling sources of water pollution. Effect must be given to any water resource Management Class(es) (and RQOs/ Reserves), in order to protect significant water resources against point and diffuse sources of, *inter alia*, anthropogenic nutrient-loading, at a cost acceptable to society.

In cases where a particular impact is unavoidable or cannot be prevented in catchments with no water quality stress, even if considerable allocatable water quality exists, the precautionary principle [36] will be applied by enforcing, particularly in respect of point wastewater discharges, minimum norms & standards, such as uniform Waste Discharge Standards (WDSs)[37].

In unstressed catchments, these norms and standards may be relaxed under special circumstances, but only if the water resource Management Class(es) (and RQOs/ Reserves) will be maintained, also acknowledging that the solution to pollution is never to relax applicable norms and standards for compliance sake! Exemptions from compliance with the WDSs will be considered only as a last resort on a temporary basis and only if receiving surface water resources has enough dilution capacity to accommodate additional waste loading without affecting its fitness-for-use. Relaxations would have to be justified on the basis of technological, economic and socio-political considerations.

In stressed catchments, or catchments where the application of minimum norms & standards are insufficient to maintain the water resource Management Class(es) (and RQOs/ Reserves), stricter norms & standards, particularly in respect of point wastewater discharges, must be considered. In special cases it may be necessary to impose additional regulatory measures and/or to prohibit unsustainable practices, in order to comply with the water resource Management Class(es) (and RQOs/ Reserves).

[36] Refer to **POLICY STATEMENT 4**: The application of the precautionary principle.

[37] Currently the General and Special Standards and the Special Standards for phosphate [GN R.991, 1984].

Stricter or more lenient WDSs will be site-specific and must be based on the results of waste load allocation investigations, in accordance with the RWQOs[38] approach. In cases where the water resource Management Class(es) (and RQOs/ Reserves) are too lenient, too strict, or require adjustment, reclassification and/ or the re-determination of RQOs/ Reserves may be considered[39].

Groundwater

The South African situation, of widespread and highly localised groundwater occurrence and use, makes it physically and economically impossible to protect all groundwater resources to the same degree. Neither does the IWQM Policy aim to prevent impacts on water resources at all costs, since such an approach will deny much-needed social development and economic growth.

For effective and focused intervention, a differentiated approach to groundwater protection is necessary, based on the vulnerability, and the local and regional importance of aquifers. Importance will be based on the potential yield, as well as on the level to which communities depend on the aquifer. Aquifers that represent the sole source of water for communities will be afforded special status, irrespective of the potential yield and will enjoy the highest level of protection [DWAF, 2000].

Policy status

The discriminatory application of environmental measures to suit local or regional requirements for environmental preservation and protection is not a new policy concept. This policy position has been included because of its importance to eutrophication management and because it should be implemented in conjunction with the mitigation hierarchy for decision-making on eutrophication. This policy statement was derived from existing policy[40].

POLICY STATEMENT 4

3.4 The application of the precautionary principle

Premise

The precautionary principle applies when there is a lack of scientific certainty regarding impacts, or when there is an unacceptable risk to human health or ecological integrity.

Precautionary principle

In an eutrophication management context, the precautionary principle applies specifically-

- when WDSs for the management and control of point wastewater discharges are being determined in the absence of sufficient scientific certainty linked to the maintenance of the water resource Management Class(es) (and RQOs/ Reserves). A lack of scientific certainty, specifically, exists in cases where catchment specific water quality load-based

[38] Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives approach applied to eutrophication management.

[39] The NWA (36:1998), at the moment, does not make explicit provision for the reclassification of water resources or the re-determination of RQOs/ Reserves and a legislative amendment will be required. Refer to **ANNEXURE G** for a list of all recommended legislative amendments.

[40] Refer to IWQM Policy Statement B.2-4: Differentiated water use authorisations, [DWS, 2017b].

information is not readily available to inform and support the determination of *"end-of-pipe"* WDSs;

- when best practices and interventions for the management and control of diffuse sources of impacts on water resources are being determined in the absence of sufficient scientific certainty linked to the maintenance of the water resource Management Class(es) (and RQOs/ Reserves). A lack of scientific certainty, specifically, exists in cases where catchment specific water quality load-based information is not readily available to support the determination of appropriate interventions to address the effects associated with diffuse sources of anthropogenic[6] nutrient-loading[81];
- to all groundwater, assumed to be vulnerable to damage unless it can be shown otherwise;
- to the prohibiting hazardous substances; and
- when water resource and catchment management decisions (with an unacceptable risk profile) must be made in the absence of sufficient scientific certainty.

Under such circumstances, application of the precautionary principle ensures that risk-averse and conservative decisions are made to minimise risks, in support of ecologically sustainable development.

Policy status

Policy on the application of a risk-averse and cautious approach, which takes into account the limits of current knowledge about the consequences of management decisions and actions, has been included because of its importance to eutrophication management and because of the important role that this principle plays in many other pertinent eutrophication management policy statements. This policy statement was derived from existing policy[41].

POLICY STATEMENT 5

3.5 The Receiving Water Quality Objectives approach applied to eutrophication management

Premise

Upstream sources of impacts, occurring as either point or diffuse sources of anthropogenic nutrient-loading, must be considered on a cumulative basis and must be controlled such that receiving water resources remain fit-for-use and that the water resource Management Class(es) (and RQOs/ Reserves), as determined for all significant water resources, are maintained. Nutrient-load investigations must be carried out and used to integrate receiving water resources requirements with WDSs and to inform fitting SDCs.

Assimilative capacity

The term *"assimilative capacity"* refers to the capacity of a water resource to assimilate disposed waste, through processes such as dilution, dispersion, and chemical and biological degradation, without water quality changing to the extent that fitness-for-use or ecosystem health is adversely impaired [DWAF, 1995]. Importantly, the assimilative capacity of a water resource depends on many factors – include chemical processes (*e.g.* adsorption),

41 Refer to IWQM Policy Statement B.1-4: Targeted, risk-based approaches, [DWS, 2017b].

physical processes (*e.g.* aeration and sedimentation) and biological processes (*e.g.* uptake by plants and micro-organisms). These processes can vary considerably in terms of their temporal extent. *"Assimilation"* can occur by processes such as dilution, adsorption, degradation or metabolism to other (either less or more harmful) products, physical removal (*e.g.* via volatilisation) and biological absorption and transformation (*e.g.* bioaccumulation) [Roux , et al., 1999].

Groundwater

Groundwater protection will be based on the precautionary approach[42]. All groundwater will, therefore, be assumed to not have any assimilative capacity and to be vulnerable to damage unless it can be shown otherwise. This approach to the protection of groundwater will be implemented for all source, resource and remediation directed measures and controls [DWAF, 2000].

Dilution capacity

The accurate quantification of assimilative capacity in a way that allows it to be used as a useful management instrument is an extremely complicated process. While the existence of the general phenomenon of assimilative capacity is acknowledged, it is Departmental policy to use this as a routine management instrument only in the particular context of dilution capacity. This will specifically be related to the concept of *"allocatable water quality"*[3] (**FIGURE 29**).

Allocatable water quality

Understanding the basic concept of allocatable water quality is complicated by the many water quality attributes that may be involved. In general, each type of user in a catchment may require each of a number of attributes to fall within some pre-determined range for that water to be considered *"fit-for-use"*. These attributes may vary from concentrations or loads of chemical substances, to biological responses (such as toxicity), and measures of physical pollution.

For water to be judged fit-for-use for a number of different water users in the same catchment, the water quality needs to satisfy the most demanding of those water users.

Just as a quantity of water can be *"used"*, so can water quality. Typically, this will be quantified in terms of individual water quality attributes. This is the basis for the concept of *"allocatable water quality"*, which can be defined from two points of view:

- First, it can be regarded as that water quality, if any, that remains allocatable (available) to uses other than the strategic national priority uses (Reserve, international obligations, etc.) and current ELUs; and
- Secondly, it can also be more formally regarded as the maximum worsening change in any water quality attribute away from its present value, which will still maintain it within a pre-determined range that reflects the desired future state, typically defined by RQOs. If the present state is outside of the pre-determined range, the allocatable water quality is zero.

42 Refer to **POLICY STATEMENT 4**: The application of the precautionary principle.

A water resource will be considered *"stressed"* in respect of a water quality attribute if, for that attribute, there is no allocatable water quality [DWAF, 2006b].

The Department is under no obligation to fully allocate all the allocatable water quality that may exist in any particular water resource. In fact, care must be taken to implement the RWQOs approach in conjunction with the mitigation hierarchy for decision-making[43] – this being necessary to prevent water resources from deteriorating to the point where all water resources eventually become only marginally fit-for-use.

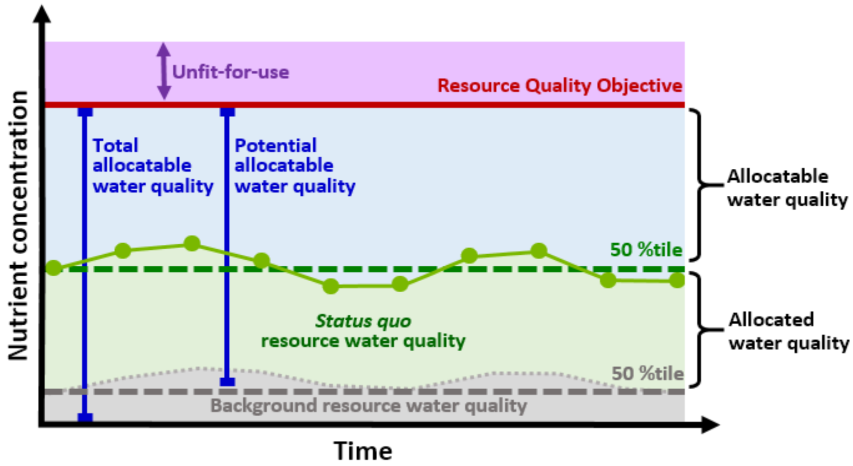

FIGURE 29: Simple conceptual illustration of allocatable water quality for an unstressed water resource.

Policy status

The Receiving Water Quality Objectives approach exists since 1991 [DWAF, 1991]. The explicit expression of this approach through source directed measures and controls, however, remains to be fully implemented. The application of appropriate source directed measures and controls in eutrophication management is essential, justifying the inclusion of the particular policy statement as part of pertinent eutrophication policy. This policy statement was derived from existing policy[44].

POLICY STATEMENT 6

3.6 A life cycle view on nutrient-loading

Premise

A life cycle view (**FIGURE 30**) on the origin and fate of nutrients has become inevitable. Life Cycle Assessments (LCA)[61] of many household products has demonstrated that the impact of detergent phosphorus on WWTWs' phosphate loading varies significantly between facilities, depending on the contribution made by industrial sources in the facility's catchment, but may be up to 50% Soluble Reactive Phosphorus (SRP) and 32% Total Phosphorus (TP) in WWTWs treating predominantly residential wastewater [Quayle, et al., 2010; Pillay & Buckley, 2001].

43 Refer to **POLICY STATEMENT 2**: The mitigation hierarchy for decision-making on eutrophication.

44 Refer to IWQM Policy Statement B.2-1: The hierarchy of pollution management decision-making, [DWS, 2017b], which mentions the Receiving Water Quality Objectives approach.

Life Cycle Assessment

LCA provides an extension of the notion to *"treat causes, rather than their symptoms"*, which is based on the general observation that such an approach is typically the most cost effective and just option. Manufacturers of products that contribute towards excessive nutrient-loading and anthropogenic eutrophication can be compared to dischargers of effluent – in this case *"discharging"* their products through their consumers to receiving water resources. The LCA approach to understand and manage the origin and fate of nutrients in household products requires further investigation in collaboration with industry. The production of nutrient-free or low nutrient content products can be enforced by regulation or can be introduced on a voluntary basis by *inter alia* utilising eco-labelling[45] and public awareness schemes and/ or through encouraging the application of the ISO 14040 series of standards [ISO, 2006], which provide a standards for quantitative assessment methodologies for LCA, to promote the production and use of water resource-friendly products. Most food stuff will probably be excluded from such a nutrient-limiting drive.

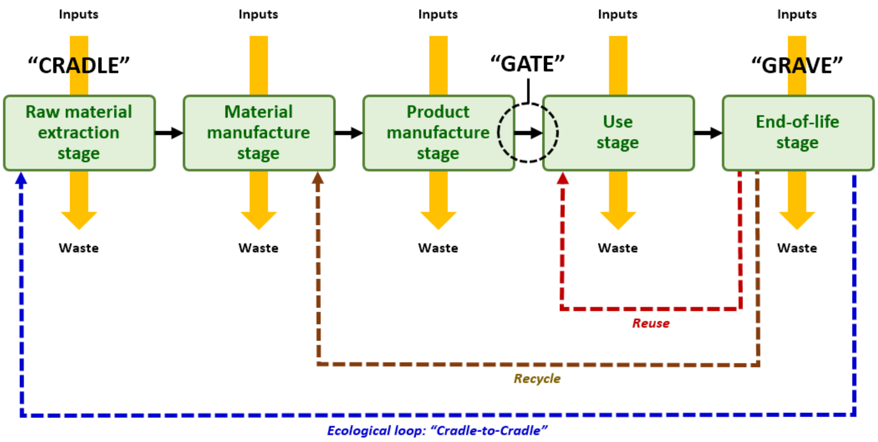

FIGURE 30: An illustration of the Life Cycle Assessment stages.

It will be expected of producers of such household products, in consultation with responsible authorities, to-

- compile inventories of relevant nutrient inputs in production processes and associated environmental emissions;
- evaluate potential impacts on water resources, associated with the identified nutrient inputs and emissions;
- interpret the results to enable informed decision-making; and
- give effect to the mitigation hierarchy for decision-making on eutrophication[46], by limiting the amount of nutrients being passed on through the LCA *"gate"* (**FIGURE 30**).

Policy status

Whereas LCA, as an instrument of environmental analysis, has been in existence for some time now, the inclusion of a policy position to maintain a life cycle view on nutrient-loading, is new. Further investigation and the implementation of this approach, will testify to the feasibility of potentially

[45] Refer to **POLICY STATEMENT 7**: Incentive-based regulation.

[46] Refer to **POLICY STATEMENT 2**: The mitigation hierarchy for decision-making on eutrophication.

extending this approach, in future, to other pollutants. This is a new policy statement.

POLICY STATEMENT 7

3.7 Incentive-based regulation

Premise

Albeit that incentive-based water regulation can take several forms, examples of this type of regulation can generally be arranged into two different categories, *viz.* economic; and non-economic, incentive-based regulation.

Economic water incentives are based on the user-pays[119] and/ or polluter-pays[93] principles and rely on market forces and changes in relative prices to modify the behaviour of water users and polluters in ways that support water resource protection or improvement, whereas non-economic water incentives are generally based on the aspiration to receive a non-monetary reward, such as positive recognition or a boosted public image.

Incentive-based regulation to limit anthropogenic eutrophication

Examples of incentive-based regulation are listed in **TABLE 11**. These options for incentive-based regulation must be considered and utilised in eutrophication management to facilitate the mitigation hierarchy for decision-making on eutrophication[47].

TABLE 11: Examples of incentive-based regulation.

ECONOMIC INCENTIVE-BASED REGULATION	NON-ECONOMIC INCENTIVE-BASED REGULATION
▶ Waste Discharge Charge System; and ▶ Administrative penalties.	▶ Certification schemes, such as Green Drop certification; ▶ Water Polluter Register; ▶ Management-by-shame; and ▶ Eco-labelling.

Any, or any combination, of the management instruments for environmental compliance[48] can be utilised to promote incentive-based regulation of anthropogenic eutrophication.

Economic incentive-based regulation: User-pays principle

The user-pays principle is a pricing approach based on the idea that the most efficient allocation of resources occurs when consumers pay the full cost, or a part thereof, of the goods that they consume. To solve anthropogenic eutrophication and development challenges, benefits from investments must be maximised, and economic incentives must be put in place that ensure lasting systemic change and reduce excessive nutrient-loading. The user-pays principle must be employed to incentivise the reuse and recycling of wastewater that contributes to excessive nutrient-loading and

[47] Refer to **POLICY STATEMENT 2**: The mitigation hierarchy for decision-making on eutrophication.

[48] Refer to **POLICY STATEMENT 1**: Application of management instruments for environmental compliance in eutrophication management.

anthropogenic eutrophication. The reconciliation of water supply and demand must be considered in all instances.

Economic incentive-based regulation: Polluter-pays principle

The polluter pays principle seeks to reverse externalised pollution costs and to achieve accountability by ensuring that such pollution costs are internalised and carried by the polluter, with due regard to public interest and without unduly distorting trade and investment. To solve anthropogenic eutrophication and development challenges, benefits from investments must be maximised, and economic incentives must be put in place that ensure lasting systemic change and reduce excessive nutrient-loading. The polluter-pays principle must be employed to limit anthropogenic nutrient-loading.

Non-economic incentive-based regulation

Water users, where feasible and desirable, must be incentivised with non-economic regulation to limit anthropogenic nutrient-loading. In this instance certification schemes, such as Green Drop Certification, has a most important role to play, not only to incentivise excellence, but also to promote transparency[49] and cooperative management[50].

Policy status

Whereas incentive-based regulation, as a concept, has been considered for some time, with one or two examples of practical implementation, *e.g.* the Green Drop System (GDS) and the development of the WDCS, to testify to this fact, little success in implementing or continued application of this approach had been achieved. As incentive-based regulation, potentially, can provide significant benefit to eutrophication management, and in support of similar requirements in the IWQM Policy yet to be implemented, it was opted to include the particular policy statement as part of pertinent eutrophication policy. This policy statement was derived from existing policy[51].

POLICY STATEMENT 8

3.8 Nature-based solutions

Premise

Ecological infrastructure is the nature-based equivalent of built or hard infrastructure and provides renewable (**FIGURE 31**) and non-renewable services, or *"nature-based solutions"* [Costanza, et al., 1997] to South Africans, which fall into one of the following four broad categories [WRC, 2014]:

- **Supporting services,** like nutrient dispersal and cycling, seed dispersal and primary production;
- **Provisioning services**, like food (*e.g.* fresh-water, fish and game), crops, wild foods, spices, water, minerals, medicinal plants, pharmaceuticals, biochemicals, industrial products, energy (hydropower, biomass fuels);
- **Regulating services**, like carbon sequestration and climate regulation, waste decomposition and detoxification, purification of water and air, crop pollination, pest and disease control; and

49 Refer to **POLICY STATEMENT 13**: Information management.

50 Refer to **POLICY STATEMENT 19**: Cooperative management.

51 Refer to IWQM Policy Statements B.2-7: Administrative penalties; B.2.8: Alternative instruments to incentivise responsible behaviour; and C.2-5: Implementation of the WDSC, [DWS, 2017b].

- **Cultural services**, like cultural, intellectual and spiritual inspiration, recreational experiences (including ecotourism) and scientific discovery.

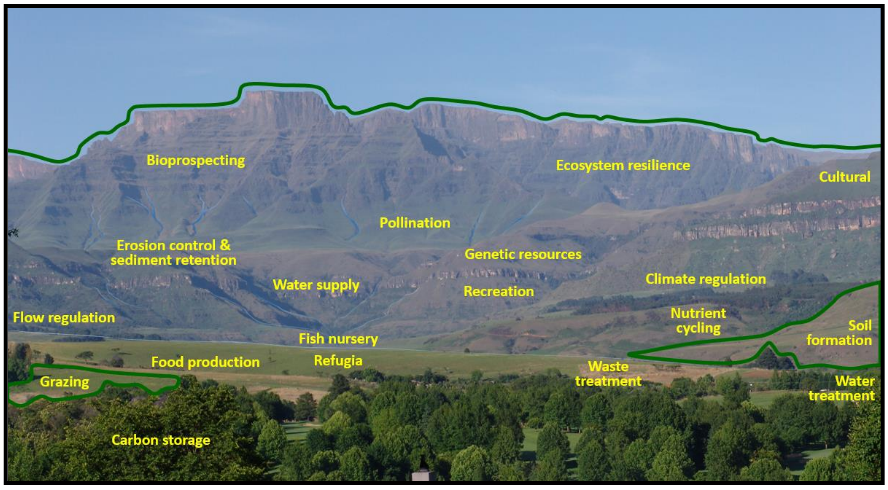

FIGURE 31: Integrated ecosystem services. **PHOTO 3:** J.J. van Wyk ©

Catchment services and water security

In an eutrophication context, the emphasis is on the ecological infrastructure that underpins water-related ecosystem services or solutions – colloquially known as *"catchment services"*. In essence, ecological infrastructure that supports healthy catchments does much the same work as water treatment plants and other built water quality infrastructure, but without the expensive equipment and associated operating costs, and with added benefits like protection of wildlife habitats and carbon sequestration [WRC, 2014]. Additionally, maximising ecological infrastructure services and water security supports South Africa's development objectives of poverty alleviation, rural development and job creation [NPC, 2012].

Ecological infrastructure associated with high yield water source areas

Of particular importance, is the protection of high-yield water source areas[52], which are those areas that supply a disproportionate large amount of mean annual runoff to the geographical region of interest [le Maitre, et al., 2018; Nel, et al., 2013; Colvin, et al., 2013]. These areas are not only suppliers of significant dilution capacity to receiving water resources, but are also often associated with wetland-areas that provide valuable water quality improvement functions.

Ramsar Convention

South Africa, as a signatory of the Ramsar Convention on wetlands of international importance, must ensure that designated wetlands are conserved and utilised sustainably. Anthropogenic eutrophication, posing a major threat to wetlands generally, must be limited and managed, especially in the case of Ramsar wetlands, to preserve rare or unique wetland types; and to conserve biological diversity, including water birds, fish, and other taxa.

[52] The NWA (36:1998) allows for only the prohibition of activities in high yield water source areas. A legislative amendment is necessary to allow for the declaration of high yield water source area as protected areas. Refer to **ANNEXURE G** for a list of all recommended legislative amendments.

National Freshwater Ecosystem Priority Areas

Responding to the high levels of threat prevalent in river, wetland and estuary ecosystems of South Africa – Freshwater Ecosystem Priority Areas (FEPAs) were identified to meet national biodiversity goals for freshwater ecosystems and to develop a basis for enabling effective implementation of measures to protect FEPAs. These FEPAs, therefore, provides strategic spatial priorities for conserving the country's freshwater ecosystems and supporting sustainable use of water resources through the management of eutrophication and other regulatory means.

Functioning ecological infrastructure

Decision-making in eutrophication management must support the maintenance of functioning ecological infrastructure, in particular ecological infrastructure in designated special areas, such as high yield water source areas, Ramsar Wetlands and FEPAs, and, where necessary, the restoration of degraded ecological infrastructure. Ecological infrastructure must be integrated into all land use development and water resource planning and management efforts, including the national planning and management scale. The private sector has a significant role to play in investing in ecological infrastructure as a means of managing risk; as a licence to operate; and as a custodian of ecological infrastructure.

Policy status

The utilisation of ecological infrastructure to provide nature-based solutions to eutrophication-related challenges, as a formal policy position, is new. Policy on the protection of designated areas[53], however, exists.

POLICY STATEMENT 9

3.9 The application of the Best Practicable Environmental Option

Premise

In any project or development, several options are usually available to address eutrophication-related challenges. The recommendation for the desired option must be based of scientific defensible evidence.

Eutrophication management options and identification of the Best Practicable Environmental Option

All feasible eutrophication management options must be identified and appraised in order to identify the Best Practicable Environmental Option (BPEO). The BPEO is the option that provides the most benefit or causes the least damage to the environment as a whole, at a cost acceptable to society, in the short-term, as well as in the long-term [NEMA, 1998, S.2.(4)(b)].

The appraisal of options must be done, within the context of the mitigation hierarchy for decision-making on eutrophication[54], by considering all relevant ecological, social and economic implications. These implications can be compared and evaluated by utilising optioneering tools, such as Cost-Benefit Analysis (CBA)[24], Life Cycle Assessment (LCA)[61], Strategic Environmental Assessment (SEA)[113], Environmental Impact Assessment (EIA)[41], Environmental Risk Assessment (ERA)[44], Social Impact Assessment (SIA)[112] and many more! Optioneering[85] studies should be polluter-pays[93] biased and must, additionally to the short-term planning horizon, also consider long-term residual impacts. Long-term costs should not exceed

53 Refer to IWQM Policy Statement B.2-5: Instruments for the protection of designated areas, [DWS, 2017b].

54 Refer to **POLICY STATEMENT 2**: The mitigation hierarchy for decision-making on eutrophication.

shorter-term benefit. Solutions with unwanted unintended consequences, such as substituting point sources for diffuse sources of unabated impact; or the evaporation of water containing waste must, be avoided. Options with fatal flaws may not be implemented.

All feasible project alternatives, such as project desirability, necessity, short- and long-term feasibility, location, scale, layout, technology and phasing must be considered.

BPEO appraisal

BPEO appraisal generally includes the following generic key stages, *viz.*:

- Objectives definition – including the identification of all relevant Management Class(es) (and RQOs/ Reserves) and/ or any RWQOs/ WQPL that may exist;
- Options generation;
- Options analysis;
- Documentation of the results of the options analysis;
- Authorities consultation;
- BPEO selection;
- Authorities sanction and/ or authorisation;
- BPEO implementation; and
- Monitoring and review.

Best management practice

Additionally, best management practice options must always be considered in the context of the mitigation hierarchy for decision-making on eutrophication[55] and from a catchment management perspective[56], and should, amongst others and where appropriate, include:

- The application of best available technology;
- Cleaner technology and cleaner production;
- The conversion of environmental problems into socio-economic and developmental solutions;
- Waste reduction, recycling and reuse; and
- The use of buffer zones.

Policy status

Although BPEO is mentioned in other water quality management policy statements[57], discrete water quality management policy requiring the application of the BPEO has not been published. Suitable solutions, such as addressing challenges in connection with untreated sewage spills, are vital, and must be identified and implemented. This is a new policy statement.

POLICY STATEMENT 10

3.10 Holistic eutrophication management

Premise

Effective water quality management, specifically the management of eutrophication, is not possible if being conducted on an *ad hoc* basis!

55 Refer to **POLICY STATEMENT 2**: The mitigation hierarchy for decision-making on eutrophication.

56 Refer to **POLICY STATEMENT 10**: Holistic eutrophication management.

57 Refer to IWQM Policy Statement B.2-6: Compliance monitoring and enforcement, [DWS, 2017b].

Multiple point and diffuse sources of anthropogenic nutrient-loading, potentially affecting a multitude of receiving water users and aquatic ecosystems in different ways, in any given catchment, can only be controlled and managed effectively, if such control and management efforts are well planned, coordinated and integrated from the catchment basis upward to the national strategic scale, and also from the catchment basis downward to the source-specific operational scale, and *vice versa*.

Holistic catchment eutrophication management thinking deals with wholes rather than parts

Different land and water use activities occur in sub-catchments, which are nested within larger catchments, which, in some instances, may also be linked to neighbouring catchment areas via inter-basin transfers. Water resources, furthermore, are not confined to administrative areas and are often transecting, or shared as, local, provincial, national and, occasionally, as international boundaries. Additionally, water resources that are fit-for-use are an essential requirement of socio-economic advancement in South Africa and ecological considerations need to be balanced against the needs for social development and economic growth at the various geographical and political scales mentioned. The entire water value chain – from resource to source to resource to sea needs to be considered collectively. The character of receiving water resources testifies to the nature of the upstream catchment area and its associated land and water use activities. Regulatory responsibilities to control eutrophication-related impacts are shared amongst different spheres of government and between government departments. Eutrophication management, thus, is interrelated, and the focus of management varies at different geographical scales (**FIGURE 32**) – necessitating that strategic considerations inform local action.

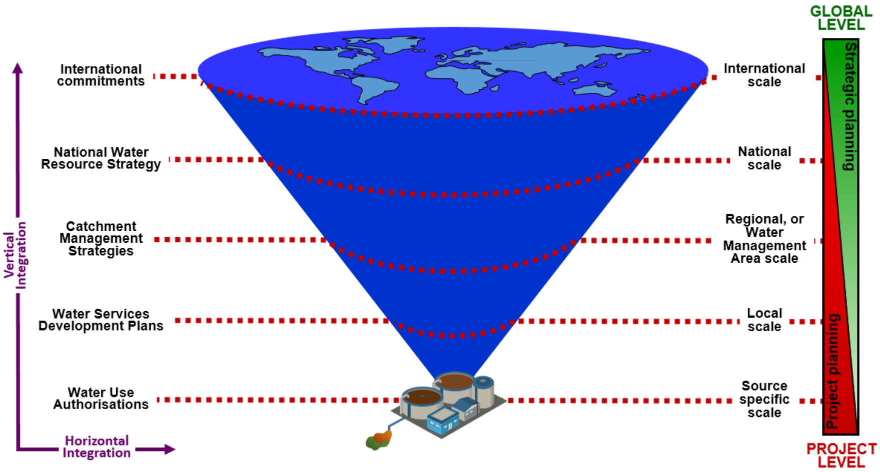

FIGURE 32: Geographical scales of eutrophication management in the context of integrated water resource management.

***"Horizontal"* and *"vertical"* integration**

Whereas it is vital that *"vertical"* integration across the different scales of eutrophication management takes place, it is equally important that *"horizontal"* integration is also achieved. In the context of managing eutrophication, this, for instance, implies that any given Water Use Authorisation or Water Services Development Plan (WSDP) or Catchment Management Strategy (CMS), should not *"vertically"* contradict the National Water Resource Strategy (NWRS), neither should there be *"horizontal"* contradiction at any scale of management, for instance, incompatible authorisations, whether it be Water Use Authorisations, Environmental

Management Programme Reports(EMPR), waste management licences, or any other.

Tools for holistic eutrophication management

Various mechanisms exist and must be employed, in concert, to ensure that *"bigger-picture"* management of eutrophication transpires into focused local action. These mechanisms include:

- Water management strategies and services plans, supported by integrated water resource and services planning and stipulating frameworks for eutrophication management at the local, catchment and Water Management Area (WMA), national and trans-boundary scales, as may be relevant, must be established and implemented;
- Appropriate statutory Resource Directed Measures (RDMs), *i.e.* water resource Management Class(es) (and RQOs/ Reserves), and any other requirements for complying with the RQOs, such as RWQOs/ WQPLs, must be determined, planned and operationalised, in accordance with the Receiving Water Quality Objectives approach[58];
- All the eutrophication management instruments[59] must be applied together to ensure that impacts on the water resources remain within acceptable levels;
- Appropriate water resource and services data must be collected[60] and management information generated[61] to yield water quality intelligence necessary to facilitate informed decision-making[62] and eutrophication management; and
- Water management and services institutions must be established and supported to devolve eutrophication management to the appropriate levels, so as to enable everyone to participate[63] and to enrich management efforts with local stakeholder knowledge and insights to achieve strategic imperatives.

Policy status

There are many sides to eutrophication that makes it a prerequisite to view and address matters holistically. For this reason policy on holistic eutrophication management was included. This is a new policy statement.

POLICY STATEMENT 11

3.11 Eutrophication management responsibility and accountability

Premise

Escalating anthropogenic eutrophication and a lack of ownership by many in positions of influence, emphasise a dire need for taking responsibility and for being accountable for actions taken, or the lack thereof.

Duty of care

There is a duty of care on every water user who causes, has caused or may cause significant pollution or degradation of water resources to take reasonable measures to avoid and prevent such pollution or degradation

58 Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives approach applied to eutrophication management.
59 Refer to **POLICY STATEMENT 1**: Application of management instruments.
60 Refer to **POLICY STATEMENT 12**: Monitoring.
61 Refer to **POLICY STATEMENT 13**: Information management.
62 Refer to **POLICY STATEMENT 14**: Water resource assessment and planning to inform decision-making.
63 Refer to **POLICY STATEMENT 19**: Cooperative management.

from occurring, continuing or recurring, or, in so far as such harm to water resources is authorised by law or cannot reasonably be avoided or stopped, to minimise and rectify such pollution or degradation of water resources [NEMA, 1998, S.28(1)].

Responsibility

EVERYBODY IS RESPONSIBLE!

Furthermore, every water user has the ongoing and general *"responsibility"* to act lawfully, including to give effect to the duty of care, as paraphrased above for water resources, in this case to avoid and prevent or minimise anthropogenic eutrophication. Unlawful conduct, violating this ongoing and general *"responsibility"*, would include water use that is not permissible under the NWA (36:1998), or causing water pollution, such as diffuse wash-off from land that causes, has caused or may cause excessive primary production in receiving water resources.

Accountability

ACCOUNTABILITY IS ASSIGNED!

In contrast to *"responsibility"*, *"accountability"* is assigned, for instance, by mandate in terms of the Constitution (108:1996) and other legislation, or by water use authorisation, preferably to a single party, and for a specific activity or assignment. *"Accountability"* is about a duty to give account of (report on) the state of affairs or outcomes related to that particular activity or assignment.

In cases where the discharge of water containing waste is authorised, or where a municipality (Water Services Authority), for instance, had been mandated with the provision of water services, or both, the accountability accompanying the particular mandate or water use entitlement cannot be readily passed on to a third party, unless provided for by law. Neither does actions, such as appealing for support of any kind, for instance by a municipality, provide impunity from obeying the law.

Liable parties and liability

There is a duty on the following parties to take all reasonable measures to prevent anthropogenic eutrophication in a water resource from occurring, continuing or recurring, if an activity or process is or was performed or undertaken on land, or any other situation exists on land which causes, has caused or is likely to cause excessive nutrient-loading of a water resource [NWA, 1998, S.19]:

- The owner of the land;
- A person in control of the land; or
- A person who occupies or uses the land.

The person who has to undertake the measures is therefore not necessarily the person who is or was responsible for the activity, process or situation. The activity or process could even have taken place before the person concerned became the owner of the land or in control of the land or occupied or used the land. Further, the water resource polluted or that could be polluted need not to be on the land concerned.

The National Environmental Laws Amendment Act, 2009 (Act No. 14 of 2009) strengthened retrospective liability by explicitly stating that the duty of care also applies to significant pollution or degradation that–

- occurred before the commencement on the NEMA (107:1998) in 1998;
- arises or is likely to arise at a different time from the actual activity that caused the contamination; or
- arises through an act or activity of a person that results in a change to pre-existing contamination.

In the event of an unlawful act or where the duty of care, *viz.* to avoid and prevent or minimise anthropogenic eutrophication, is not satisfied, such a violation is likely to lead to some sort of legal action for relief. In such a scenario, the party(ies) may be legally liable and potentially guilty of an offence[64].

Policy status

The perceived lack of responsibility and accountability is regarded to be a major part of current challenges in connection with sub-standard effluents being released and contributing towards eutrophying water resources. For this reason policy on eutrophication management responsibility and accountability was included. This is a new policy statement.

POLICY STATEMENT 12

3.12 Monitoring

Premise

A base of appropriate data and information is a vital element of effective water quality planning and management, in this instance, specifically with respect to eutrophication (**FIGURE 33**). Such data and information may relate to water quality, quantity and the integrity of aquatic ecosystems, or their causal relationships, which often extend into the socio-economic domain. Data and information must be gathered over a suitable time period and at the correct spatial extent.

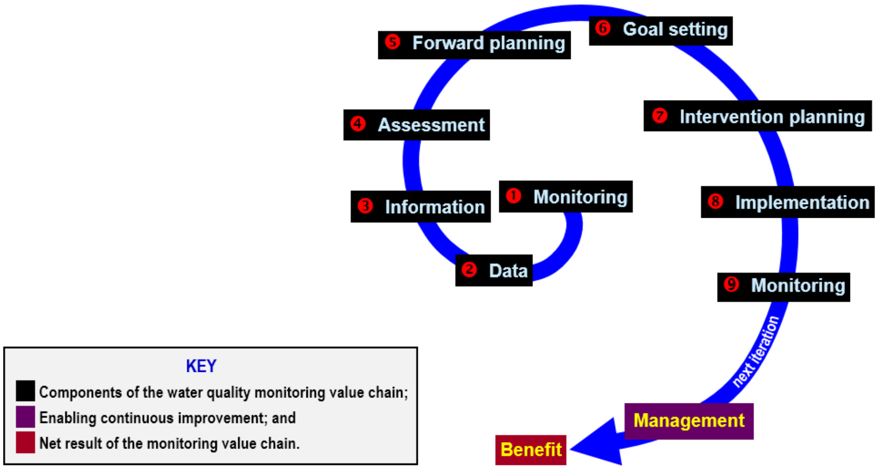

FIGURE 33: The water quality monitoring value chain.

[64] Refer to **POLICY STATEMENT 12**: Monitoring.

Purpose of eutrophication-related monitoring

Acknowledging the obligation to establish a monitoring system for water resources [NWA, 1998, Chapter 14], eutrophication-related data and information must be collected to assess-

- sources of anthropogenic eutrophication and their relative load contributions, especially in the case of point discharges – compliance with WDSs;
- the application of wastewater and waste reuse and recycling strategies;
- the status of and effects on receiving water quality, especially nutrient-loading of receiving water resources, and compliance with RDMs and RWQOs/ WQPLs;
- the integrity of aquatic ecosystems, as an indicator of system health;
- the efficacy of remediation projects;
- whether offset initiatives are yielding the agreed offset improvement impacts; and
- causal chains and linkages with the socio-economic domain, and root-causes of failure.

Additionally, eutrophication-related monitoring must-

- contribute meaningfully to efforts to facilitate ecologically sustainable development;
- reflect the ecologically interdependent nature of water resources, including the dependence on water quantity, whenever appropriate; and
- become an essential enabling component of adaptive and integrated water quality management.

Temporal extent

Sampling frequencies at monitoring stations where water quality varies considerably must be higher, than at monitoring stations where variation remains relatively constant. An interval of one month between the collection of individual samples at a monitoring station is generally acceptable for characterising water quality over long time periods, whereas, for control purposes, shorter frequency sampling is necessary. If significant differences are suspected or detected, samples may have to be collected daily or on a continuous basis.

The value of sustainable, long-term monitoring and the availability of suitable historic data and information should not be underestimated and care must be taken to continue with such data gathering exercises in the interest of continued water security.

Spatial extent

Eutrophication monitoring must be executed at appropriate spatial scales, as may be necessary, including:

- National water resource status and trends monitoring, which provides a higher-level integrated picture of overall national effectiveness;
- Regional water resource performance monitoring, which compares actual resource water quality with pre-determined RDMs (such as RQOs) and or RWQOs/ WQPLs, providing information at the spatial and temporal scale for which such objectives have been defined; and
- Source compliance monitoring, which provides local site-specific information that is required to determine the effectiveness of source directed measures and controls.

Compliance monitoring and enforcement

A significant challenge in the management of eutrophication is weakness in enforcement of legislation and authorisation conditions under the NWA (36:1998), resulting in the externalisation of costs to communities and society. The degree to which individual water users are remaining within (*i.e.* complying with) the conditions, as defined in their water use authorisations (*e.g.* licences), must be measured, assessed and reported on regularly. Capacity for controlling discharges of water containing waste must be enhanced. Stringent action must be taken against the unlawful discharge of water containing waste and the unlawful disposal of waste, and to ensure compliance with authorisation conditions through combined actions, by DWS and DEFF in particular. In this regard, the exchange of information, where necessary, will be facilitated and the use of combined compliance drives will be utilised. Environmental compliance[23] and enforcement[39] capacity must be strengthened through the appointment and capacitation of Environmental Management Inspectors (EMIs), and a policy of zero tolerance towards non-compliance, specifically excessive nutrient-loading, must be applied.

Policy status

Due to the crucial role of data and information in eutrophication management, a policy statement on monitoring was included, as part of the pertinent policy on eutrophication management. This policy statement was derived from existing policy[65].

POLICY STATEMENT 13

3.13 Information management

Premise

The collection of data and the interpretation of trophic status information are critical to all aspects of eutrophication management. Without accurate information, the correct picture of the eutrophication challenges cannot be determined and strategy formulation and implementation could be compromised. Data and information management systems are prerequisites for the assessment of eutrophication, the magnitude of the problems and challenges.

Gathering of data and information

Data management systems must be appropriately cost-effective and able to adequately meet all of the requirements of national and other regional eutrophication monitoring programmes. The ultimate goal is to provide information needed for planning purposes, decision-making, operational and strategic water resources management and the establishment of relevant infrastructure, at the local, regional and national scales.

Access to information

Acknowledging the obligation to provide access to information held by the State [Access to Information Act, 2000 (Act No. 2 of 2000)], data collected in national and other regional eutrophication monitoring programmes, for which the DWS, catchment management agencies or other government institutions have responsibility, will be made available upon a reasonable

65 Refer to IWQM Policy Statements B.2-6: Compliance monitoring and enforcement; and D.1-1: Strengthening of national water quality monitoring networks, [DWS, 2017b].

request for access. Reasonable charges for the provision of such data may be imposed.

Information management cooperation and efficiency

The accepted corporate data and information management systems must be used for all management-related data and information, associated with monitoring programmes for eutrophication. The harmonisation of monitoring systems across trans-boundary, national, WMA, local and the water use specific scales, in the interest of improved eutrophication management, must be investigated and supported. Collaboration with local government, specifically, on eutrophication data and information handling and management, should be strengthened and improved.

Policy status

Due to the need to generate appropriate information and due to the importance of such information to eutrophication management, a policy statement on information management was included, as part of the pertinent policy on eutrophication management. This policy statement was derived from existing policy[66].

POLICY STATEMENT 14

3.14 Water resource assessment and planning to inform decision-making

Premise

The complexities and uncertainties associated with water resource management, specifically the management of eutrophication, and the need for a sound understanding of catchment processes and issues, must be addressed.

Holistic catchment context

It is crucial to improve one's understanding, by striving for a holistic comprehension[67] of all catchment processes and issues, based on adequate and objective observations for as far as this is possible. This should occur before catchment management decisions are taken that are intended to improve the current state of water resources [DWAF, 2006b].

Informed decision-making

Apart from the option to address some eutrophication knowledge gaps through theoretical or applied research[68], water resource planning, preceded by an appropriate situation assessment, must be promoted. An assessment of the relevant issues within the geographical area in question, mostly at the level of the catchment, must inform planning activities. Data and information from monitoring[69], assessment thereof within a catchment or water resource system context and value added through water resource planning must inform water resource management and remediation activities, and thereby enrich decision-making. In the absence of suitable management knowledge, and when an unacceptable level of risk exists, the precautionary principle[70] must be applied to catchment and water resource management decision-making. Appropriate water resource assessment and

[66] Refer to IWQM Policy Statement D.1-2: Strengthening and improvement of information management systems, [DWS, 2017b].

[67] Refer to **POLICY STATEMENT 10**: Holistic eutrophication management.

[68] Refer to **POLICY STATEMENT 16**: Promotion of eutrophication-related research.

[69] Refer to **POLICY STATEMENT 12**: Monitoring.

[70] Refer to **POLICY STATEMENT 4**: The application of the precautionary principle.

planning provide the bases for sound eutrophication management and continuous improvement.

Policy status

Eutrophication management measures should, ideally, be informed by appropriate water resource assessment and planning, motivating the inclusion of policy on water resource assessment and planning to inform decision-making, as part of the pertinent policy on eutrophication management. This policy statement was derived from existing policy[71].

POLICY STATEMENT 15

3.15 Resourcing of eutrophication management

Premise

The establishment of eutrophication management strategy constitutes an initial and important step to improve the trophic state of many water resources. An even more important step in this eutrophication management process, is the need for empowering role-players to participate, *inter alia*, in the implementation of essential eutrophication management measures.

Budget, human capital and equipment

It is the constitutional duty of all spheres of government to protect the quality of South Africa's water resources. This principle is supported by the constitutional imperative for co-operative government.

A sufficient number of capable public and/ or private sector employees must be appointed or assigned with eutrophication management duties, as necessary. Sufficient budget must be allocated and the necessary equipment procured to effectively fulfil the duties assigned to personnel with eutrophication management responsibilities.

Policy status

Good intentions without the necessary resources will achieve little, motivating the inclusion of policy on the resourcing of eutrophication management, as part of the pertinent policy on eutrophication management. This is a new policy statement.

POLICY STATEMENT 16

3.16 Promotion of eutrophication-related research

Premise

The eutrophication managed context is continually changing, not least, due to a growing demand for more advanced and effective, yet more affordable technology, the ever increasing pressures associated with development, causing escalating nutrient enrichment[79] in receiving water resources and the potential future impacts of climate change. With the growing suite of emergent water quality issues, as well as the need for innovation in resolving more pervasive issues, ongoing Research and Development (R&D) has become critical.

National water quality research and development plan

The DWS and the WRC will play a key role in developing a national water quality R&D plan that aligns applied research priorities throughout the water value chain to ensure that water R&D directly contributes to the resolution

[71] Refer to IWQM Policy Statements B.1-2: Strengthening of integrated water resource planning at all scales; and B.1-3: Development of integrated planning approaches at the catchment scale, [DWS, 2017b].

of water sector challenges, specifically eutrophication-related challenges, and addresses emergent areas like the growing need for the implementation of water reuse and recycling strategies. The role of South Africa's academic institutions, and independent research organisations, will be critical in the development and roll-out of this plan.

Transfer of new and applied technologies

The DWS and the WRC, together with other sector organisations, academic institutions and others, will promote innovation and knowledge sharing to support new and appropriate technology uptake. There will be a specific focus on supporting municipalities to use appropriate and new technology and designing, developing and marketing new technology and approaches in partnerships with the private sector, civil society and the research community. In this regard, the WRC and the Department of Science and Innovation (DSI) will continue to develop and enhance the impact of the Water Technologies Demonstration Programme. This programme aims to pull together the applied R&D and commercialisation stages of the water innovation continuum, and to bridge the gap between water research and the market in order to achieve a connected water innovation system that delivers socio-economic benefits for South Africa.

Policy status

Applied research is vital to the renewal and improvement of eutrophication-related knowledge, motivating the inclusion of policy on eutrophication-related research, as part of the pertinent policy on eutrophication management. This policy statement was derived from existing policy[72].

POLICY STATEMENT 17

3.17 Transparency

Premise

Eutrophication management decisions must be taken in an open and transparent manner, and access to information[73] must be provided in accordance with the law [NEMA, 1998, S.2].

Communication

Communication channels, where necessary, must be established to inform and persuade, to build relationships, and to encourage open dialogue, in the public interest, on eutrophication management related topics.

Policy status

In line with the democratic values enshrined in our Constitution, people, as citizens, must be able to participate actively in civic life. This requirement, amongst others, rely on the availability of information. The role, and potential future roles, to be played by civil society and others with respect to eutrophication is reliant on openness and transparency[74]. For this reason, policy on transparency was included as part of the pertinent policy on eutrophication management. This policy statement was derived from existing policy[75].

[72] Refer to IWQM Policy Statement D.1-5: Availability of water quality data to the public, [DWS, 2017b].
[73] Refer to **POLICY STATEMENT 13**: Information management.
[74] Refer to IWQM Policy Statements D.2-1 and D.2-2: Research and innovation, [DWS, 2017b].
[75] Refer to IWQM Policy Statements D.2-1 and D.2-2: Research and innovation, [DWS, 2017b].

POLICY STATEMENT 18

3.18 Increased capacity

Premise

The existence of a highly trained and competent cohort of role-players across the water sector, particularly in government departments and institutions, is essential for the management of eutrophication. There is indeed existent capacity, but this is stretched, and more needs to be done to establish the necessary role-player compliments with the necessary skills to manage eutrophication.

Community wellbeing and empowerment

Community wellbeing and empowerment must be promoted *inter alia* through the raising of environmental awareness, community-based science, the sharing of knowledge and experience, and other means.

Awareness creation campaigns in schools and in public spaces, and through community outreach programmes, must be lodged to raising general eutrophication management awareness. This will be supported by broader awareness campaigns to encourage societal action towards an improved trophic state of water resources. Public awareness can help by changing people's perception and attitudes about eutrophication, and the importance of protecting water resources and aquatic ecosystem.

Education and training

Education and training programmes must be developed and rolled-out at schools, universities and at the work place to build environmental and water management knowledge and capacity. Schools and universities programmes must build the capacity of young people prior to them entering the labour market, whereas work place programmes must sufficiently capacitate all who play roles in eutrophication management.

Capacity building programme to develop sector capacity

The DWS will develop and drive capacity building programmes to develop sector capacity [DWS, 2017b] and will-

- continue to provide bursaries for students to study water quality related subjects at universities in order to provide a pool of qualified recruits to the State;
- lead the development of appropriate on-the-job and technical training programmes for officials from all relevant state institutions to improve the capacity of government to adequately manage water quality and to address the eutrophication challenges of the future;
- in close cooperation with other government departments, continue to strengthen the capacity across the sector with regards to regulating activities that impact upon eutrophication management. This will include interventions to strengthen inter-departmental capacity to ensure, and to enforce compliance with regulations and other legislative prescripts;
- in partnership with CMAs, strengthen the capacity of CMFs to provide local capacity for water quality management, particularly eutrophication management; and
- in partnership with DEFF, also make training available to civil society organisations, active in the water sector, to enable their informed participation in integrated water quality management processes, particularly in eutrophication management.

Professionalization of staff in key positions in local government

DWS, in collaboration with the Department of Cooperative Governance and Traditional Affairs (COGTA), will develop the necessary regulations to ensure the professionalization of key water services positions in Water Services Authorities to ensure that the staff responsible for the management of water and wastewater systems at municipal level have the necessary training and competencies.

Policy status

Suitably capacity is a vital component of rolling-out eutrophication management, motivating the inclusion of policy on capacity building, as part of the pertinent policy on eutrophication management. This policy statement was derived from existing policy[76].

POLICY STATEMENT 19

3.19 Cooperative management

Premise

Effective eutrophication management is hampered by poor co-ordination, inadequate or incomplete institutional arrangements, siloed planning and conflicting approaches between basin states, the various South African government departments, spheres of government and sectors, and often also inadequate participation by, and with the private sector and civil society.

Trans-boundary cooperation and water diplomacy

Desirous of developing close co-operation for the judicious, sustainable and co-ordinated utilisation of the resources of the shared watercourses in the Southern African Development Community (SADC) Region, parties, including South Africa, in 2000 agreed to the revised SADC Protocol on Shared Watercourses. In terms of this Protocol [SADC, 2000], parties will foster closer cooperation to, *inter alia*,

- promote and facilitate the establishment of shared watercourse agreements and Shared Watercourse Institutions for the management of shared watercourses; and
- advance the sustainable, equitable and reasonable utilisation of the shared watercourses;
- promote a co-ordinated and integrated environmentally sound development and management of shared watercourses;
- promote the harmonisation and monitoring of legislation and policies for planning, development, conservation, protection of shared watercourses, and allocation of the resources thereof; and
- promote research and technology development, information exchange, capacity building, and the application of appropriate technologies in shared watercourses management.

Government-wide eutrophication management

It is the constitutional duty of all spheres of government to protect the quality of South Africa's water resources. This principle is supported by the constitutional imperative for co-operative government. Actual or potential conflicts of interest between organs of state should be resolved through the applicable conflict resolution procedures [NEMA, 1998, S.2].

76 Refer to IWQM Policy Statements D.3-1 and D.3-2: Capacity building and training, [DWS, 2017b].

Civil society and corporate business partnerships

The private sector and civil society have a crucial role to play in minimising its impacts on water resources. Water forums have been created to address water challenges, align plans and strengthen collaboration. Effective stewardships and partnerships will be built to deal with eutrophication challenges in specific priority areas, and platforms like CMFs will be used to ensure stakeholder engagement and collaboration. A strategic management approach to the eutrophication challenges requires that the DWS will need to forge highly focused, fit-for-purpose, civil society and corporate business partnerships that are relevant to the eutrophication challenge. The partnership approach dictates that polluters take cradle-to-grave [77] responsibility for their products and improve self-regulatory processes to reduce the regulatory burden on the state[78] [DWS, 2017b].

Stakeholder consultation

The objective is to obtain public feedback on analysis, alternatives and/or decisions. It involves acknowledging concerns and providing feedback on how stakeholder input has influenced decision-making. Decisions must take into account the interests, needs and values of all interested and affected parties, and this includes recognizing all forms of knowledge, Including traditional and ordinary knowledge [NEMA, 1998, S.2].

Harmonisation of policy, strategy and legislation

DWS will lead a collaborative process to ensure alignment and inter-departmental harmonisation of policies, legislation, regulation, integrated planning, compliance monitoring and enforcement [NEMA, 1998, S.2].

Policy status

One of the most noticeable difference between the 1991 and 2017 policies for water quality management, is the leap taken towards the integration of water quality management efforts by recognising the roles of public and private sector, and civil society roll-players. This approach is also being applied to eutrophication management, motivating the inclusion of policy on cooperative management, as part of the pertinent policy on eutrophication management. This policy statement was derived from existing policy[79].

CHAPTER 4: CONCLUSION

Outstanding text.

To be added when the Executive Summary is finalised.

[77] Refer to **POLICY STATEMENT 6**: A life cycle view on nutrient-loading.

[78] Refer to **POLICY STATEMENT 1**: Application of management instruments for environmental compliance in eutrophication management.

[79] Refer to IWQM Policy Statements A.1-1 to A.1-6 and A.2-1 to A.2-3: Inclusive approach to IWQM, [DWS, 2017b].

PART 3: EUTROPHICATION MANAGEMENT STRATEGY FOR SOUTH AFRICA

PHOTO 4: ***"EVERYBODY LIVES DOWNSTREAM!"*** © J.J. VAN WYK

CHAPTER 1: INTRODUCTION

In general terms, *"strategy"* maps out overarching approaches for implementation that are aimed at realising strategic imperatives - including implementing the strategic thrust of policy. This part of the document, accordingly, prescribes such overarching approaches for eutrophication management in South Africa, which, collectively, must ensure management efficacy geared towards protecting aquatic ecosystems and securing water resources that are fit-for-use!

The two-pronged approach opted for in this document, namely to separately define policy and strategy, makes the development of powerful and succinct strategy possible. Formulating eutrophication management strategy in this way, averts the need for strenuous repetition of eutrophication management policy imperatives and philosophies. Eloquent referencing to pertinent eutrophication management policies can simply be included, where necessary, in individual strategies. Strategy formulation, *inter alia*, specifying authority (*"who?"*), prescribed approach and action (*"how and what?"*), and spatial (*"where?"*) and temporal (*"when?"*) scales of implementation, must aim to give effect to the eutrophication management goal, objectives and policy imperatives elaborated under Part 2.

Efforts, in South Africa, to manage eutrophication are reliant on the adoption and execution of three types of interrelated and mutually supportive strategies (**FIGURE 34**), *viz.*:

- Core strategies;
- Operational strategies; and
- Supporting strategies, for eutrophication management.

These three inter-related and mutually supportive strategies, collectively, are directed towards the realisation of the national eutrophication management goal and the associated objectives[80], as shown in **FIGURE 34**.

[80] Refer to **Chapter 2** of **Part 2** for the visionary perspective.

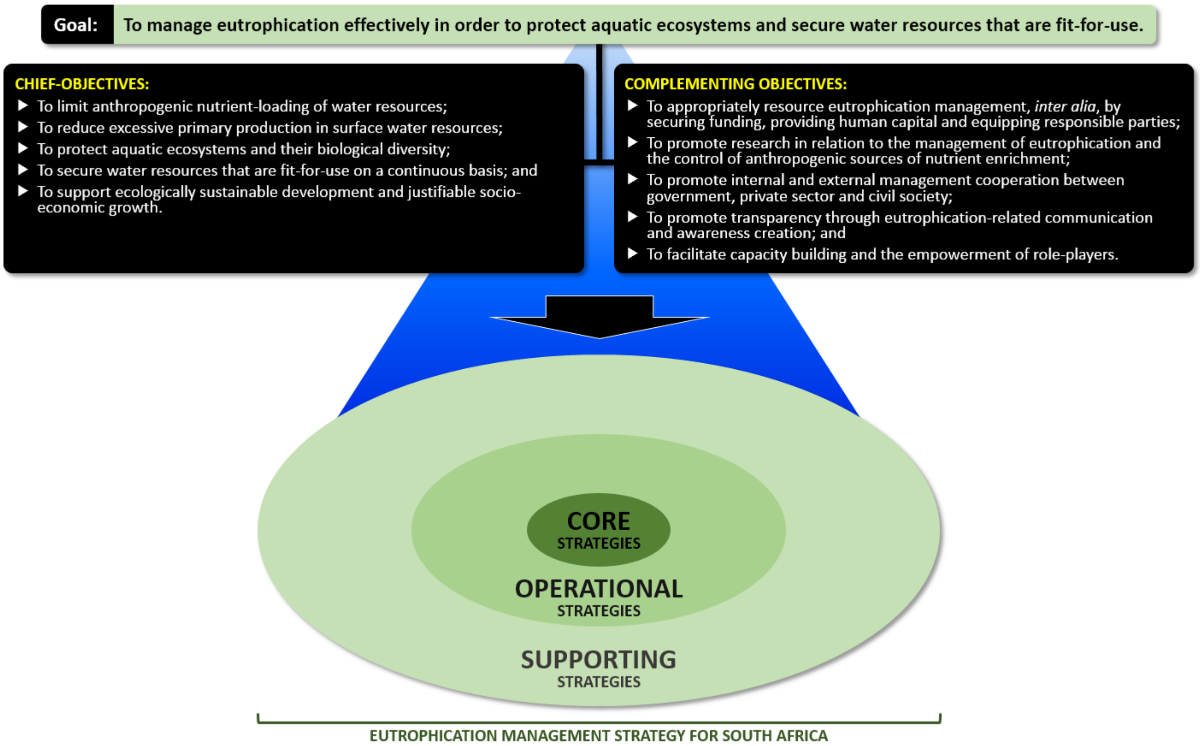

FIGURE 34: Outline of the Eutrophication Management Strategy.

These three types of overarching eutrophication management strategies are outlined next, under Chapters 2, 3 and 4, respectively. Sectoral mandates and governance responsibilities are summarised under Chapter 5.

Some of the eutrophication management strategies, or elements thereof, that are discussed next, are unique to eutrophication management, whereas others focus of the roles of eutrophication within broader IWQM. This approach that had been adopted to establish a coherent framework for eutrophication management in South Africa.

CHAPTER 2: CORE STRATEGIES

The strategies, that are core to giving effect to the ambitions of the eutrophication management goal and policy, are founded on the following two very important requirements:

(1) The establishment and strengthening of key aspects that underpin sustainable land and water use:

Sustainable land, and consumptive and non-consumptive water use is recognised as crucial requirements of water resource management. Core strategies that address specific source directed measures and controls, giving practical effect to the attainment of sustainable land and water use, is essential. These measures and controls are interrelated and have a bearing throughout the eutrophication management policy (**Part 2**), and the related execution of the integrated water quality management function.

(2) Maintenance and improvement of the quality of the country's water resources:

Intensifying land use and increasing competition for the use of the country's limited water resources place stress on water resources. This reduces the ability of water resources to support consumptive and non-consumptive water uses, and threatens water supply security! Sustained fitness-for-use of water resources is recognised as the ultimate aim of integrated water quality management. Core strategies that address the elevated trophic status, caused by excessive nutrient-loading, of many receiving water resources, is required.

The core strategies for eutrophication management are devised within an adopted management framework, comprising of **Source Directed**, **Resource Directed** and **Remediation Directed Management** (**FIGURE 35**). Whereas Source Directed and Resource Directed Management employs measures and controls proactively, Remediation Directed Management, by its very nature, employs measures and controls reactively to address residual impacts. Notably, such remedial actions can be focused on the remediation of both the causes (sources of impacts), as well as the effects (impacted water resources) of excessive nutrient-loading and anthropogenic eutrophication.

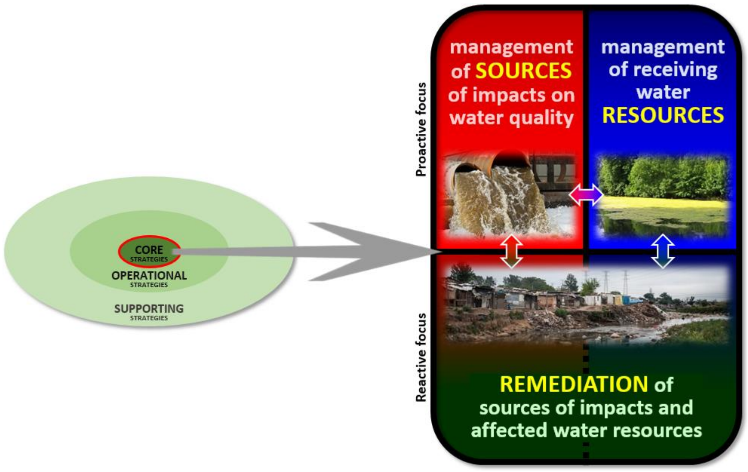

FIGURE 35: Core strategies for eutrophication management.

The core strategies for eutrophication management are interrelated and fragmented implementation will hamper efforts to manage eutrophication effectively, and, thus, to protect aquatic ecosystems and to secure water resources that are fit-for-use. Effective implementation of these core strategies must be pursued and fragmented implementation must be avoided!

Each of the three core strategies are discussed next:

2.1 Source Directed Management

2.1.1 Authority

From an eutrophication management perspective, source directed measures and controls must be imposed on land and water use to protect aquatic ecosystems and receiving water users[129] against impacts caused by excessive nutrient-loading and anthropogenic eutrophication. Since these source directed measures and controls are not necessarily all captured within water legislation and policy, and since land use managed often is the responsibility of authorities other than the DWS, the roles of other government departments in the management of sources of anthropogenic eutrophication have to be acknowledged, in line with the policy on cooperative management[81].

The relevant competencies (sectors), which deal with environmental media, such as air, land, water or any aspects thereof, and which may contribute towards anthropogenic eutrophication, include: ♦ agriculture; ♦ water and sanitation; ♦ environment; and ♦ mining. Sectoral mandates are summarised in Chapter 5, Part 3.

[81] Refer to **POLICY STATEMENT 19**: Cooperative management.

2.1.2 Prescribed approach

Source directed management involves the application of regulatory, and other measures and controls, which are imposed on land and water use activities to achieve designated levels of water resource protection.

It is endeavoured to control the causes of anthropogenic eutrophication at the sources of impact[82], by employing management instruments, such as emission standards[83], conditional authorisations[84], pollution management regulations made in terms of enabling legislation and others, in accordance with the policy on the application of management instruments[85]. Source Directed Management focusses mostly on regulatory approaches, but must, where appropriate, also include other management instruments that facilitate pollution avoidance, prevention, and minimisation, as required by policy[86]. Additionally, incentivised regulation forms an important part of Source Directed Management and must be fully explored, developed and rolled-out, as per the policy on incentive-based regulation[87].

Source Directed Management is operationalised through several operational strategies, as elaborated in Chapter 3 of Part 3, which can be shared between any of the core strategies, such as water quality monitoring, or which can be unique to Source Directed Management, such as the regulation of land and water use.

Although Source Directed and Resource Directed Management are at different ends of the spectrum of eutrophication management focus, source directed measures and controls are driven by the RDMs in place, in particular RQOs and their supporting RWQOs/ WQPLs. RDMs designate levels of protection to significant water resources and are addressed under the second core strategy, dealing with Resource Directed Management (**Section 2.2**, **Part 3**).

2.1.3 Spatial scale of implementation

Source directed measures and controls can be categorised in terms of scales of geographical focus, as follows:

- Best management practices, and other measures or controls, which apply to land and water use, nationally, or that apply to a specific land or water use type or category;
- Catchment or regional interventions, and other measures or controls, which are required by regional or catchment management strategies and/ or regional or catchment-level water quality planning; and
- Source-specific interventions associated with any land and water use authorisation process, and other measures or controls, which apply to specific activities or sources of pollution.

Source directed measures and controls, thus, can be uniform and can apply nationally, regionally, or on a catchment basis, can discriminate according to land, water use or activity types or other forms of categorisation, or can be source-specific. Importantly, source directed measures and controls, whether uniform or source-specific, are always implemented by land and water use activities, in line with policy[88], at the sources of impact to avoid, prevent or minimise water pollution.

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82 Refer to **POLICY STATEMENT 6:** A life cycle view on nutrient-loading.

83 Can relate to WDSs or Ambient Air Quality and Emission Standards.

84 Includes any environmental authorisation, including water use authorisations, such as a water use licence.

85 Refer to **POLICY STATEMENT 1:** Application of management instruments for environmental compliance in eutrophication management.

86 Refer to **POLICY STATEMENT 2:** The mitigation hierarchy for decision-making on eutrophication.

87 Refer to **POLICY STATEMENT 7:** Incentive-based regulation.

88 Refer to **POLICY STATEMENT 2:** The mitigation hierarchy for decision-making on eutrophication.

2.1.4 Temporal scale of implementation

The development and implementation of best management practice measures, appropriate to South Africa, are generally time consuming. An adequate portfolio of best management practice measures could, therefore, be some time away and, in its absence, existing measures and controls must continue to be employed. These measures and controls relate primarily to emission standards and conditional authorisations to avoid, prevent and minimise adverse water pollution effects of land and water use[89]. Attention must be devoted to operationalise the Receiving Water Quality Objectives approach[90].

Prioritisation of not only the development and implementation, but also the revision of source directed measures and controls, will be mostly dictated by signals arising from the implementation of catchment management strategies and/ or overall long-term water quality planning. Current and additional source directed measures and controls must be considered and developed, or, where necessary, refined and improved for implementation (**TABLE 12**).

TABLE 12: Actions to strengthen the source directed management of eutrophication.

	SHORT-TERM
1.	The gazetting of mandatory Waste Discharge Standards (WDSs), specifically the potential revision of the nutrient standards;
2.	Develop and implement (an) approach(s) to ensure that the conditions in water use authorisations, including those that specify WDSs, ensure compliance to RDMs;
3.	Develop and gazette regulations to compel water users to register and upload waste discharge water quality and quantity data, including eutrophication-related data and information, on the Integrated Regulatory Information System (IRiS) or alternative systems;
4.	Evaluate and/ or develop model By-laws, in support of Local Government, to limit excessive nutrient-loading and to protect raw water quality;
5.	Address shortcomings with respect to the authorisation conditions of some ELUs that cause, or may potentially cause, excessive nutrient-loading;
6.	Cleaner production and technologies;
7.	Hazardous substance elimination and priority substance identification (including a priority list of unacceptable chemical compounds/ constituents);
8.	Stormwater quality measures and controls;
9.	Measures and controls for diffuse pollution;
10.	The evaporation of, and irrigation with water containing waste;
11.	Waste discharge charges for nutrient-loading; and
12.	Sectoral standards of best management practices and continuous improvement.
	LONGER-TERM
13.	Develop and gazetting of regulations for other impacting sectors (*e.g.* feedlots, industries, etc.);
14.	Develop and implement a protocol to differentiate between water users in terms of risk;
15.	Develop and implement a protocol for an integrated licencing processes to streamline authorisations, including CMA engagement;
16.	
18.	

[89] Refer to **POLICY STATEMENT 2:** The mitigation hierarchy for decision-making on eutrophication.

[90] Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives approach applied to eutrophication management.

2.2 Resource Directed Management

2.2.1 Authority

The DWS is mandated with the management of the country's water resources [NWA, 1998, S.3] and the Minister of Human Settlements, Water and Sanitation, through the Director-General, any organ of state or any water management institution, when exercising powers or performing duties under the NWA (36:1998), must give effect to RDMs, determined for significant water resources [NWA, 1998, S.15].

Albeit that the national government, through the DWS, is the trustee of the nation's water resources, there is a strong link that must exist between RDMs and source and remediation directed management of eutrophication, and other authorities[91] that play roles in land and water use management for the purpose of water resource protection and, thus, to give effect to RDMs, must be acknowledged.

Sectoral mandates are summarised in Chapter 5, Part 3.

2.2.2 Prescribed approach

Resource directed management of anthropogenic eutrophication, inherently, has a catchment and water resources outlook on water quality management[92]. The ultimate purpose of Resource Directed Management is to ensure continued fitness-for-use of the country's water resources[128], which are being used by five groups of recognised water users; these being:

- Agriculture;
- Domestic;
- Industry;
- Recreation; and also
- Aquatic ecosystems.

In order to realise this *"ultimate purpose"* - a sound understanding[93], *inter alia,* of the nature of, and the relationships between water resources and their quality; current and future water users and their water requirements; current and expected pressures on resource quality; the intrinsic social and economic dynamics; availability of allocatable water quality[94], desired levels of water resource protection and the potential for additional ecologically sustainable development, if any, in catchments is essential. This information is utilised to plan ahead, to determine management objectives[95] and to establish strategies and plans that frame desired eutrophication management approaches for implementation over time. The eutrophication management strategies and plans, amongst others, must also be utilised for the purpose of monitoring and evaluating implementation progress.

Resource Directed Management have to direct both the source and remediation directed management of eutrophication in catchments, as follows:

- RDMs must influence Source Directed Management, and any WDSs, that are applied to upstream water uses in order to protect downstream aquatic ecosystems and water users, and to ensure fitness-for-use of receiving water resources; and
- RDMs must influence Remediation Directed Management, such that-

[91] Refer to **POLICY STATEMENT 19**: Cooperative management.

[92] Refer to **POLICY STATEMENT 10**: Holistic eutrophication management.

[93] Refer to **POLICY STATEMENT 14**: Water resource assessment and planning to inform decision-making.

[94] Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives approach applied to eutrophication management.

[95] Management objectives include the water resource Management Class, RQOs, Reserves, and supporting RWQOs or WQPLs.

- upstream residual sources of excessive nutrient-loading, such as degraded land, are ameliorated to protect downstream aquatic ecosystems and water users, and to ensure fitness-for-use of receiving water resources; and
- degraded or impaired receiving water resources and associated aquatic ecosystems are ameliorated to meet the applicable RDMs, specifically the Reserve, if determined and any other environmental requirements that may exist.

It, therefore, is vital that all three core strategies for eutrophication management must be harmonised and that RDMs must integrate with the relevant source and remediation directed measures and controls!

Resource Directed Management is operationalised through several operational strategies, as elaborated in Chapter 3, Part 3, which can be shared between any of the core strategies, such as water quality monitoring, or which can be unique to Resource Directed Management, such as the determination of statutory Resource Directed Measures (RDMs).

2.2.3 Spatial scale of implementation

Whereas the resource directed management of eutrophication has a catchment and receiving water resource focus, it is also of national interest.

From a catchment and receiving water resource perspective – consideration must be given to all relevant catchment attributes when conducting forward planning, determining management objectives, including RDMs for significant water resources, and establishing eutrophication management strategies and plans for implementation. Additionally to the *"inward"* catchment focus on receiving water resources, it is also important to consider possible linkages that may exist between catchments. Such linkages, for example, may include inter-basin or return-flow transfers between catchments that potentially affect the trophic status of receiving water resources. Although not explicitly mentioned above, groundwater and its influences on surface water resources, and *vice versa,* must also be considered in the resource directed Management of eutrophication. Hydrological regions and catchment areas often don't correspond, and in some cases links different catchments by providing potential pollution pathways. Note should be taken that groundwater resources have little to no assimilative capacity – an important considering when linking appropriate source directed measures and controls.

Within the national dimension, national decision-makers will have to be made aware that anthropogenic eutrophication and hypertrophic conditions that exist, or that are emerging, in many of our impoundments, are not externalities and that it cannot continue to be accommodated as an add-on to conventional strategy and/or policy development processes having the potential to affect water resources. Development and related policy implementation must be aligned with the requirement of maintaining the productivity and viability of the country's water resources and associated ecological infrastructure. Hence, it must be endeavoured to elevate eutrophication management and water resource protection to the same level and consideration as Government's other national priorities, such as economic growth, poverty eradication, rural development, etc. This effort will also involve demonstrating that water resource management must be integrated into the national economy, recognising the vital role of water for the satisfaction of basic human needs, provision of food and food security, poverty alleviation and ecosystem maintenance.

2.2.4 Temporal scale of implementation

The DWS has made good progress with the determination of RDMs nationally, starting with priority WMAs first. Additionally, RWQOs/ WQPLs, in support of Resource Directed Management, are also becoming available in many sub-catchments. It is now vital that the Receiving Water Quality Objectives approach must be operationalised[96] to improve the trophic status of many eutrophic water resources, through the application of appropriate source directed measures and controls.

A number of specific actions have already been identified to spearhead the improvement of resource qualities, including the effects of excessive nutrient-loading. These actions are listed in **TABLE 13**.

TABLE 13: Actions to strengthen the resource directed management of eutrophication.

	SHORT-TERM
1.	Determine RDMs, *i.e.* classification, RQOs and the Reserve for outstanding significant water resources;
2.	Determine RWQOs/ WQPLs, based on the South African Water Quality Guidelines [DWAF, 1996], in support of RQOs;
3.	Undertake routine national eutrophication monitoring, considering the recommendations of the Review of the South African Water Resource Monitoring Network;
4.	Realign/ establish regional water quality monitoring programmes in cooperation with all relevant role-players and undertake routine regional eutrophication monitoring;
5.	Development and implement a programme to create and support citizen-based eutrophication monitoring programmes;
6.	Improve the effectiveness and efficiency of the water quality data management system(s) through the implementation of the findings of the Data Acquisition and Management (DAM) Strategy;
7.	Harmonise the systems and approaches being used across sector Departments and catchments for resource water quality data and information management;
8.	Compile annual national eutrophication status report(s);
9.	Compile annual catchment resource water quality status report(s);
10.	Operationalise the Receiving Water Quality Objectives approach and achieve compliance to the requirements of RQOs (for water quality) and supporting RWQOs/ WQPLs;
11.	Co-operative governance which will be refined and implemented as part of the operational execution of the IWQM Policy and Strategy [DWS, 2017b; DWS, 2017d];
12.	SDG 6.3.2D reporting on the status of South Africa's water resources that will provide a national picture of the fitness-for-use of such water resources; and
13.	Other?
	LONGER-TERM
17.	Finalise NPS Strategy;
18.	Develop and implement sector specific action plans to reduce non-point source pollution (in support of the NPS Strategy);
19.	

2.3 Remediation Directed Management

2.3.1 Authority

Remedial action, relevant to the management of eutrophication, focusses on residual pollution sources causing excessive nutrient-loading of water resources, and degraded, impaired and contaminated land areas and water resources. Remedial action is generally subject to an array of regulatory requirements, and may also be based on assessments of human health and ecological risks where no legislative standards

[96] Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives approach applied to eutrophication management.

exist, or where standards are advisory. Remedial action can be required by many role-player authorities[97], in addition to the DWS. Relevant competencies (sectors) where requirements for remediation to protect water resources and aquatic ecosystems may exist, include: agriculture; water and sanitation; environment; and mining. Sectoral mandates are summarised in Chapter 5, Part 3.

2.3.2 Prescribed approach

Remediation directed eutrophication management relates to those measures and controls that must be adopted and enforced to effect-

- amelioration of residual sources of excessive nutrient-loading, such as land areas that are contaminated, to meet statutory RDMs, specifically RQOs determined for receiving water resources if available; as well as the
- amelioration of degraded or impaired receiving water resources and associated aquatic ecosystems to meet the applicable statutory RDMs, specifically the Reserve if available, and any other environmental requirements that may exist.

To date, and in the absence of a dedicated remediation strategy to guide the removal of contaminants from, amongst others, soil, surface water, groundwater and sediment that may exacerbate eutrophic conditions in receiving water resources, regulatory instruments (not necessarily developed to address remediation) are being applied to manage situations requiring remediation. This resulted in inadequate and/ or inconsistent handling of legacy water pollution problems. More emphasis on Remediation Directed Management should elevate regulatory capabilities to levels equivalent to those related to the source and resource directed management of eutrophication. An amendment of the NWA (36:1998) to enforce financial provisioning to address *post facto* remedial activities must be considered[98].

Legacy stores of phosphorus (P) and nitrogen (N) in catchments may be sufficient to sustain algal blooms and hypertrophic conditions in water resources for decades to come and more innovation is needed to drawdown and recover these nutrients. Agriculture's impact on eutrophication risk may be overestimated in many catchments, and more accurate accounting of sources, their bio-availabilities and lag times are needed to direct proportioned mitigation efforts more effectively [Withers, et al., 2014]. All sectors of society must clearly use P and N more efficiently to develop long-term sustainable solutions to this complex issue and nutrient reduction strategies should take account of the whole catchment-to-coast continuum. However, the right balance of local interventions (including additional biophysical controls) will need to be highly site specific and better informed by research[99] that unravels the linkages between sustainable practices, patterns of nutrient delivery, biological response and recovery trajectories in different types of waterbodies.

In keeping with the thrust to use water resources sustainably, to protect water resources and to ensure fitness-for-use of receiving water resources, residual pollution sources causing excessive nutrient-loading, and impaired and degraded water resources and associated aquatic ecosystems must be ameliorated or replaced at a rate that at least matches the rate of contamination, degradation and destruction.

As a rule, the polluter-pays-principle[100] will be applied to the cleaning-up of legacy pollution cases. Financing and implementing remediation in those cases deemed to be the State's responsibility will continue. Remediation will be implemented on a case-by-case basis, depending on the relative risk levels[101] and priorities assigned to them. In cases where remedial action is associated with existing land or water

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97 Refer to **POLICY STATEMENT 19**: Cooperative management.

98 Refer to **ANNEXURE G** for a list of all recommended legislative amendments.

99 Refer to **Section 4.3:** Research & technology development.

100 Refer to **POLICY STATEMENT 7**: Incentive-based regulation.

101 Refer to **Section 3.2.2.2.12:** Differentiated water use management based on risk.

use activities, care must be taken to ensure that appropriate source directed measures and controls are in place prior to any remediation being undertaken.

2.3.3 Spatial scale of implementation

Remediation directed measures and controls for the management of eutrophication are applied locally to specific legacy sources of excessive nutrient-loading, or to specific impaired or degraded surface and/ or groundwater resources and associated aquatic ecosystems. In the case of multiple sources and/ or resources that require remediation, such remedial action could assume a regional or a catchment character. Therefore, remediation will not only be promoted on a facility or site level, but also at a broader operational level by actively supporting remediation research as well as incorporating it in regional planning.

2.3.4 Temporal scale of implementation

In the absence of a remediation strategy to guide the remediation directed management of eutrophication, available regulatory instruments to handle situations requiring remediation will be applied. A Remediation Working Group should be established to guide remedial activities and to initiate the development of the necessary tools. **TABLE 14** provides a list of actions necessary to provide momentum to the roll-out of the remediation directed management of eutrophication.

TABLE 14: Actions to strengthen the remediation directed management of eutrophication.

	SHORT-TERM
1.	A remediation strategy to address residual sources causing excessive nutrient-loading, and impaired, degraded and contaminated land areas and water resources must be developed;
2.	Implementation of financial provision in conjunction with the WDCS to cover the cost of remedial action is currently being contemplated and should form part of the remediation strategy investigation;
3.	Clean-up levels and targets, in addition to any RDMs, and in support of Resource Directed Management, must be developed to address residual pollution sources, and impaired, degraded and contaminated land areas and water resources;
4.	Risk-based remediation approaches and measures must be developed to prioritise remediation activities; and
5.	Rule-based best management practice measures could be appropriate and/ or a requirement in some remediation cases.
6.	Other?
	LONGER-TERM
10.	The development of an implement programme to remediate and manage resource water quality in priority catchments, in accordance with relevant catchment water quality management plans and strategies (utilising revenue from the WDCS);
11.	
13.	

CHAPTER 3: OPERATIONAL STRATEGIES

The operational eutrophication management strategies have a dual purpose, namely to-

- **complement the core strategies for eutrophication management**, by providing additional resolution on key stages within the water quality management framework, specifically in relation to eutrophication; and

- **provide further operational guidance to eutrophication management** in South Africa.

Since these operational strategies for eutrophication management cannot necessarily be arranged in a tiered and hierarchical fashion under specific core strategies, and since many of the operational strategies are common to more than one core strategy, the operational strategies for eutrophication management in South Africa are structured within an excepted international framework for management systems, known as the Shewhart-Deming or PDCA Cycle [Moen & Norman, 2009]. *"P-D-C-A"* stands for *"**P**lan – **D**o – **C**heck – **A**ct"*, and represents a generic management framework, with *"learn by doing"*, or continuous management improvement, as a key characteristic.

The PDCA Cycle is handy for describing the nature of water quality management [Van Wyk, et al., 2003]. The operational strategies for eutrophication management represent an important facet of integrated water quality management. For easy reference purposes, all the operational strategies are presented within the context of the PDCA Cycle (**FIGURE 36**) to render a framework for the operational management of eutrophication. Though it is acknowledged that each of the operational strategies, within this framework for the operational management of eutrophication, can individually also be presented in a *"Plan – Do – Check – Act"* fashion, *e.g. "Domestic status and trends monitoring and reporting"*, for instance, is also planned, rolled-out, verified for efficacy and improved, if necessary, the focus here is on the **MANAGEMENT OF EUTROPHICATION** and not the individual operational strategies.

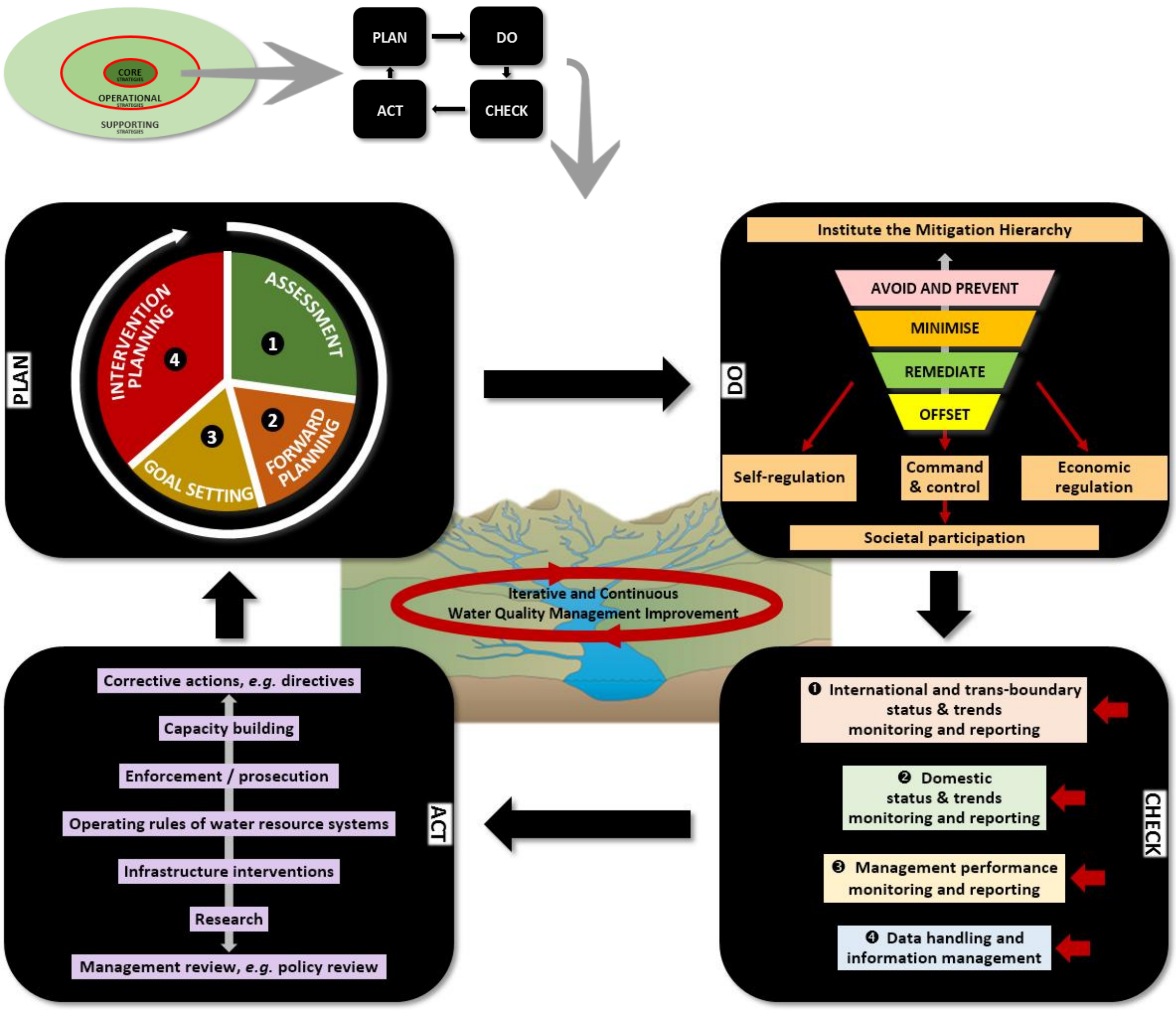

FIGURE 36: Framework with operational strategies for the management of eutrophication.

3.1 The *"plan"* stage

Altogether the *"plan"* stage, in the eutrophication management framework, must assist–

- to consult and learn from stakeholders and to establish common ground and buy-in;
- to gather a suitable base of catchment information that will support the management of eutrophication;
- to limit uncertainties and to generate essential eutrophication management intelligence to promote high confidence and informed decision-making;
- to proactively identify stumbling blocks, and to maximise strengths and utilise opportunities;
- to make informed predictions of what can be expected in future, in order to be ready;
- to identify desired and clear end-points, and to understand what needs to be done to realise the desired effects;
- to coordinate efforts, if necessary across sectors, and to avoid *ad-hoc* actions and responses where one have to attend to successive crises in the absence of clear and holistic eutrophication plans or goals;
- to promote responsibility and accountability;
- to assist the structured allocation of scarce resources – *i.e.* financial and human capital, time, information, equipment, etc. – to implement strategies and plans, and to achieve goals; and
- to assess and evaluate implementation progress regularly and effectively in support of adaptive management.

A simplified schematic of the water quality planning cycle is depicted in **FIGURE 37**. Although the chronology of individual components in the Water Quality Planning Cycle is illustrated, the linkages that exist between these components, are not! Iterative linkages exist between the individual components and are elaborated in Section 3.1.2, Part 3 below. Connections between the individual components are indicated through the inclusion of footnotes with cross-reference to such other components.

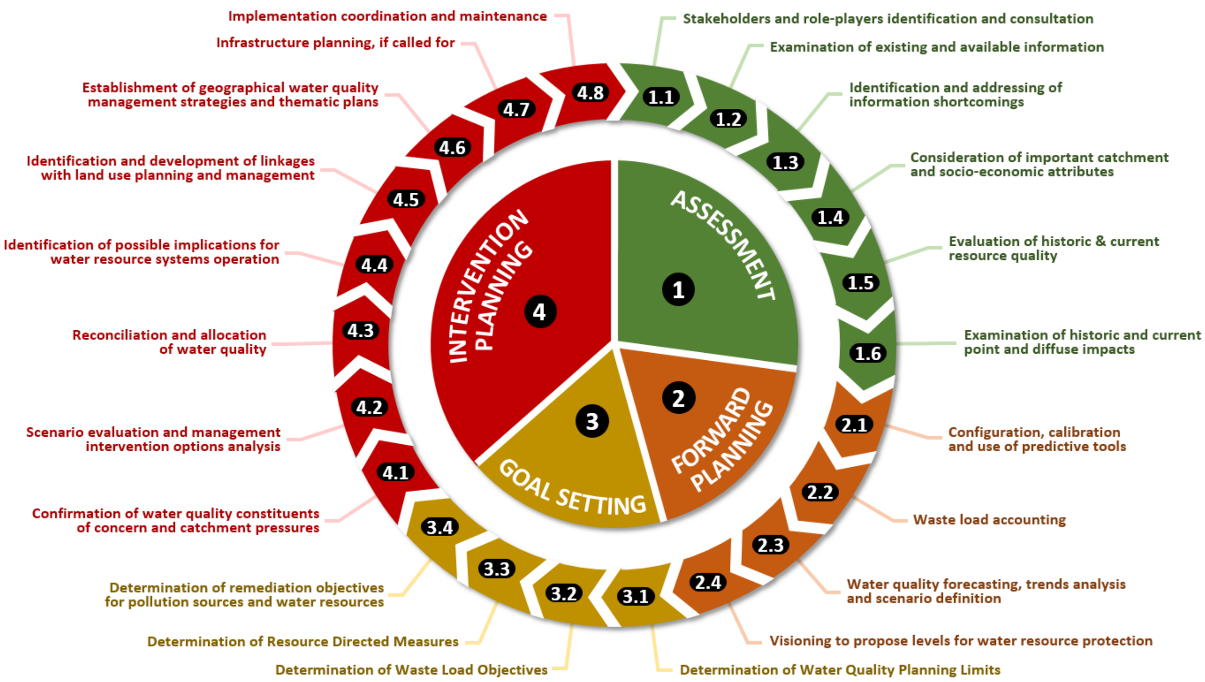

FIGURE 37: The Water Quality Planning Cycle.

The *"plan"* stage, in the eutrophication management framework, comprises of four linked operational strategies [adapted from DWAF, 2003a]. These operational strategies and their purpose and composition are summarised in tabular form in **TABLE 15.**

TABLE 15: The operational strategies in the *"plan"* stage of the eutrophication management framework, and their composition.

OPERATIONAL STRATEGIES AND PURPOSE		KEY COMPONENT(S)
1. Assessment	*To describe and understand the catchment, or geographical area, under investigation.*	Stakeholders and role-player identification and consultation;
		Examination of existing and available information;
		Identification and addressing of information shortcomings;
		Consideration of important catchment and socio-economic attributes;
		Evaluation of the historic and current resource quality; and
		Examination of historic and current point and diffuse impacts.
2. Forward planning	*To support decision making by adding value to the assessment.*	Configuration, calibration and use of predictive tools;
		Waste load accounting;
		Water quality forecasting, trends analysis and scenario definition;
		Visioning to propose levels for water resource protection.
3. Goal setting	*To define desired outcomes, based on information from the assessment and forward planning.*	Determination of Resource Water Quality Objectives or Water Quality Planning Limits;
		Determination of Waste Load Objectives
		Determination of statutory Resource Directed Measures; and
		Determination of remediation objectives for pollution sources and water resources.
4. Intervention planning	*To devise detailed approaches to realise the desired outcomes.*	Confirmation of the water quality constituents of concern and catchment pressures;
		Scenario evaluation and management intervention options analysis;
		Reconciliation and allocation of water quality;
		Identification of possible implications for water resource systems operation;
		Identification and development of linkages with land use planning and management;
		Establishment of geographical water quality management strategies and thematic plans;
		Infrastructure planning, if called for; and
		Implementation coordination and maintenance.

3.1.1 Authority

There are a number of roll-player authorities, in addition to the DWS, who play roles during the *"plan"* stage of eutrophication management[102], and whose actions may, to a greater or to a lesser extent, influence or affect the trophic status of receiving water resources. Especially authorities outside the water sector who deal with the management of land uses and development planning should be cognisant of the implications of their actions for eutrophication. Competencies (sectors), such as agriculture; water

[102] Refer to **POLICY STATEMENT 19**: Cooperative management.

and sanitation; ♦ environment; and ♦ mining are relevant. Sectoral mandates are summarised in Chapter 5, Part 3.

3.1.2 Prescribed approaches

3.1.2.1 Assessment

"If you can't explain it simply, you don't understand it well enough!" Author: Albert Einstein

The complexities and uncertainties associated with land use and water resource management, specifically the management of eutrophication, and the need for a sound understanding of processes and issues, require thorough appraisal and development of knowledge systems that must serve as a basis for informing water resource goal setting, planning, management and remediation.

A catchment assessment study[103] is the process of collating, processing and interpreting data and information about water-related conditions, issues and developments within a catchment context. The catchment assessment, must provide a statement on the historic and present status of the catchment in question, and as such, includes data and information that are required for informed eutrophication planning and management. The nature of the catchment assessment study [adapted from DWAF, 2003a] is discussed next:

3.1.2.1.1 Stakeholders and role-player identification and consultation

An identification of catchment stakeholders and role-players, relevant institutional arrangements and linkages to assist with consultative processes[104], information gathering and management participation[105], must be undertaken.

Knowledge about interested individuals and institutions, who have a stake in eutrophication management issues, for whatever reason, will ensure that such parties are recognised and given an opportunity to make inputs. Local and available expert knowledge on eutrophication should be utilised to complement and augment existing sources of available information, knowledge and expertise, as may be necessary[106].

Furthermore, the trophic status of receiving water resources is closely linked to land use and other physical developments that may cause excessive nutrient-loading during the terrestrial phase of the hydrological cycle. Control over many of these land uses and physical developments, however, lies outside the statutory domain of the NWA (36:1998), and other laws and authorities, other than the DWS or Water Management Institutions, have jurisdiction over many of these activities that might somehow cause anthropogenic eutrophication. Against this fragmented background, and in the interest of management cooperation, it is imperative that the relevant institutional arrangements and linkages must be understood and suitably mobilised in support of the eutrophication management goal, objectives and policy imperatives.

3.1.2.1.2 Examination of existing and available information

No catchment is a clean slate in terms of information or knowledge about it. Some experienced-based understanding of the functioning of at least some parts of a catchment is usually present among some longstanding catchment inhabitants, as well as among government officials or professionals active in water-related matters within that catchment[107]. Similarly, the existence of water-related issues and problems is often common knowledge and/ or particular water-related studies have historically been

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103 Refer to **POLICY STATEMENT 14**: Water resource assessment and planning to inform decision-making.

104 Refer to **POLICY STATEMENT 17**: Transparency.

105 Refer to **POLICY STATEMENT 19**: Cooperative management.

106 Refer to **POLICY STATEMENT 4**: The application of the precautionary principle.

107 Refer to **Section 3.1.2.1.1**: Stakeholders and role-player identification and consultation.

conducted in the catchment(s) under consideration[108]. Relevant sources of existing information must be identified, acquired and considered in order to prevent undue duplication of effort and to utilise scarce government resources effectively.

Explicit attention must also be given to examine the following existing and available information:

- Existing resource objectives, if any, notably the water resource Management Class(es) (and RQOs/ Reserves) and/ or supporting RWQOs/ WQPLs and/ or remediation objectives, must be identified for further consideration during goal setting[109];
- Existing water management strategies and plans, such as the NWRS and the NW&S MP, must be sourced for further consideration during geographical water quality management strategies and thematic plans establishment[110];
- Other strategies, plans or alike that may have relevance, or that may affect eutrophication management in the catchment in question, such as provincial growth strategies, Integrated Development Plans (IDPs), Water Services Development Plans (WSDPs), Environmental Management Frameworks (EMFs), etc. must be sourced for further consideration during the identification and development of linkages with land use management[111]; and
- Relevant trans-boundary requirements or obligations, if any, must be identified and examined.

3.1.2.1.3 Identification and addressing of information shortcomings

Additional field surveys and investigations, if necessary, must be considered as a means of addressing eutrophication-related information shortcomings. This includes undertaking additional *"snapshot"* sampling drives[112] to support catchment assessment. The application of technology tools, such as remote sensing to assess the effects of eutrophication [Matthews & Bernard, 2015], can be considered during the evaluation of the historic and current resource quality[113] to augment eutrophication monitoring data and information availability. Additionally, modelling and data gap infilling to produce extrapolated data and information, albeit not at the same confidence level as actual data, can be considered during the calibration and use of predictive tools[114].

Sufficient and appropriate data are indispensable to meaningful forward planning, goal setting and intervention planning. Insufficient data and information reduce confidence in planning recommendations and effective monitoring and data handling[115] is essential to the effective management of eutrophication!

3.1.2.1.4 Consideration of important catchment and socio-economic attributes

Consideration must be given to all relevant natural and anthropogenic attributes, their linkages and concomitant socio-economic characteristics in the catchment in question. These may relate to any of the following:

- **Natural attributes**, such as geology, soil types, rainfall, evaporation, aquifer boundaries and characteristics, vegetation, and sediment production potential;
- **River system details**, such as main stem and tributary channels (*i.e.* the primary, secondary, tertiary, quaternary and/ or quinary drainage region[97] levels, as may be necessary), wetlands, estuaries and sub-catchment boundaries;

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[108] Refer to **Section 3.1.2.4.1**: Confirmation of the water quality constituents of concern and catchment pressures.

[109] Refer to **Section 3.1.2.3**: Goal setting.

[110] Refer to **Section 3.1.2.4.6**: Establishment of geographical water quality management strategies and thematic plans.

[111] Refer to **Section 3.1.2.4.4**: Identification and development of linkages with land use planning and management.

[112] Refers to once-off sampling run(s), *e.g.* once under low-flow and once under high-flow conditions to augment currently available data and information.

[113] Refer to **Section 3.1.2.1.5**: Evaluation of the historic and current resource quality.

[114] Refer to **Section 3.1.2.2.1**: Configuration, calibration and use of predictive tools.

[115] Refer to **Section 3.3.2.4**: Data .

- **Monitoring locations and type**, such as surface or groundwater stations, effluent stations, flow gauging stations, rainfall stations, evaporation stations and weather stations[116];
- **Infrastructure locations and dimensions**, such as storage dams, balancing reservoirs, irrigation schemes, water transfer schemes, water and WWTWs, major roads, and railway lines;
- **Areas and ecological infrastructure that must be protected,** such as nature reserves, indigenous veld and forests, National Freshwater Ecosystem Priority Areas (NFEPA), high yield water source areas[117], Ramsar wetlands, buffer areas and others;
- **Demographic distribution in the catchment**, such as urban and rural settings;
- **Land use**, such as different categories of human settlements, commercial and industrial areas, different categories of irrigation activities, commercial and other plantations, dryland agriculture, mining activities, and waste disposal sites[118];
- **Water uses** must be identified, *inter alia*, by utilising data and information stored in WARMS, or by undertaking V&V studies for waste and water containing waste related water uses[119];
- **Socio-economic profiles**, such as the types and extent of economic outputs per management unit, in terms of absolute values, as well as proportion of Gross Domestic Product (GDP), Gross National Product (GNP) and per capita. An understanding, specifically of the social and economic dynamics at play, is used in optioneering studies, such as Cost-Benefit Analyses being applied in scenario evaluation[120];
- **Areas, jurisdictions and boundaries**, such as WMAs, CMAs and other Water Management Institutions; municipal areas and Water Services Institutions, etc. and also others relating to the municipal, provincial, national and trans-boundary scales[121];

3.1.2.1.5 Evaluation of the historic and current resource quality

An evaluation of the historic and *status quo* resource qualities, *i.e.* water quality, quantity and the integrity of aquatic ecosystems, is necessary to support informed eutrophication management decision-making, in specific catchments. Suitable resource quality data and information must be obtained from credible sources and analysed to describe-

- the aquatic ecosystem health, water quality and flow, in the catchment, at an overview level;
- any residual effects on water resources and associated aquatic ecosystems, which have resulted from historic nutrient-loading;
- any prominent spatial trends that can be observed; and
- any temporal trends of concern.

Prior to goal setting[122], the South African Water Quality Guidelines must be utilised as benchmark when evaluating historic and current water quality data and information. The information must be utilised to develop a preliminary understanding of the problem constituents and fitness-for-use by individual water user groups.

3.1.2.1.6 Examination of historic and current point and diffuse impacts

Unlike diffuse sources of excessive nutrient-loading, point sources of nutrient pollution are, in principle, relatively easily quantifiable. Discharge authorisation conditions usually require regular effluent sampling and flow rate monitoring. Unfortunately, unlicensed discharging, or periodic dumping of effluents by authorised dischargers in excess of prescribed conditions, does occur. Point source assessment, therefore,

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[116] Refer to **Section 3.1.2.1.5**: Evaluation of the historic and current resource quality.
[117] Refer to **Section 3.1.2.2.4**: Visioning to propose levels for water resource protection.
[118] Refer to **Section 3.1.2.1.6**: Examination of historic and current point and diffuse impacts.
[119] Refer to **Section 3.1.2.1.6**: Examination of historic and current point and diffuse impacts.
[120] Refer to **Section 3.1.2.4.2**: Scenario evaluation and management intervention options analysis.
[121] Refer to **Section 3.1.2.1.1**: Stakeholders and role-player identification and consultation.
[122] Refer to **Section 3.1.2.3**: Goal setting.

does not only comprise the processing of available effluent stream records, but may also include scrutiny of streamflow water quality records[123] to identify unknown contaminant loadings, which may signify unauthorised and unlawful discharges. In many instances, it may even be required to initiate the necessary Validation and Verification (V&V) studies to identify and confirm all waste and water containing waste related water uses within the catchment(s) in question.

Diffuse sources of nutrient-loading represent land use types, areas and activities that result in the mobilisation and discharge of such contaminants in any manner other than through a discrete or discernible conveyance. Diffuse source nutrient-loading of surface waters in South Africa is largely caused by rainfall and the associated surface runoff or groundwater discharge. Diffuse nutrient sources may be intermittent, contributing to contamination of water resources over a widespread area, such as storm wash-off and drainage from urban or agricultural areas. Alternatively, they may be concentrated, associated with localized high activity areas, such as mines, feedlots, landfills and industrial sites. Although diffuse source impacts of surface wash-off are relatively immediate, the diffuse source impact of groundwater discharge is often delayed, due to the time taken for contaminants to mobilise and move through the soil matrix into receiving surface water resources.

Whereas the identification and quantification of diffuse nutrient pollution sources may also include the scrutiny of streamflow water quality records[124] to identify unknown contaminant loadings, which may signify the presence of diffuse nutrient impacts, diffuse sources quantification mostly occurs via the calibration and use of predictive tools[125] and confirmation through waste load accounting[126].

The following point and diffuse source information must be collected or generated:

- A summary table containing general point and diffuse impact information, such as locations, names and types, primary activities involved, identity, position and contact details of accountable persons, etc.;
- A database of annual and/ or monthly historical time series of waste and water containing waste related disposal or discharge volumes and nutrient-related constituent concentrations;
- A database of raw information on waste and water containing waste related disposal or discharge volumes and sample analyses;
- A database of annual and/ or monthly historical time series of diffuse waste loads, associated with waste and water containing waste related water uses. The quantification of the diffuse nutrient impacts can be derived through the calibration and use of predictive tools[127] and waste load accounting[128]; and
- A database of legacy point and diffuse nutrient sources.

3.1.2.2 Forward planning

"Planning is bringing the future into the present so that you can do something about it now" Author: Alan Lakein

Forward planning[129] utilises the data and information that are produced during the assessment to identify possible permutations of alternative future realities and to evaluate likely outcomes. Forward planning must provide statements on the expected and recommended future statuses of the catchment in question, and as such includes the following [adapted from DWAF, 2003a]:

[123] Refer to **Section 3.1.2.1.5**: Evaluation of the historic and current resource quality.
[124] Refer to **Section 3.1.2.1.5**: Evaluation of the historic and current resource quality.
[125] Refer to **Section 3.1.2.2.1**: Configuration, calibration and use of predictive tools.
[126] Refer to **Section 3.1.2.2.2**: Waste load accounting.
[127] Refer to **Section 3.1.2.2.1**: Configuration, calibration and use of predictive tools.
[128] Refer to **Section 3.1.2.2.2**: Waste load accounting.
[129] Refer to **POLICY STATEMENT 14**: Water resource assessment and planning to inform decision-making.

3.1.2.2.1 Configuration, calibration and use of predictive tools

The configuration and calibration of water quality predictive tools require land and water use information as essential inputs[130]. Not only current day information, but also historical land and water use trends, with reasonably reliable records of both point and diffuse nutrient sources and their constituent loadings, are required for proper calibration of such predictive tools over a representatively long time period. Application of predictive tools play a significant role in water quality focused forward planning, as typified below:

- Sound management decisions may rely on the ability to predict the outcomes of streamflow and water quality along different river reaches and for different scenarios[131] of land and water use in the catchment. Various predictive approaches are available to address eutrophication-focused management questions, ranging from process-based catchment models, through to rule-based methods, to simple regression-based formulas;
- Similarly, models are also available for the prediction of the outcomes of different ways of operating an existing or planned river-reservoir system over an extended time period[132];
- Once the contributions of point sources of nutrient-loading on streamflow and groundwater are quantified, the remaining causes of excessive nutrient-loading evident from the applicable monitoring data, must be of a diffuse nature[133]. For their quantification, contributions by diffuse nutrient sources have to be estimated, as, by their very nature, diffuse nutrient source contributions cannot be measured directly. In effect, therefore, a significant component of modelling support required during eutrophication-focused forward planning, relates to non-point source impacts; and
- The high variability of rainfall and streamflow from year to year in South Africa dictates that, for sound management decisions, surface water availability and water quality patterns should be assessed via long-term characteristics, so that the inherent variability is adequately recognised. Unfortunately, the reality of water quality databases is that they are limited in duration and spatial representativeness, and often comprise only intermittent samples. Mathematical predictive tools provide a way around this dilemma. Catchment modelling, driven by long sequences of rainfall, provides a useful approach to extend or infill streamflow and surface water quality time series synthetically[134], with the intention of capturing temporal and spatial variability better than the data do. Alternatively, simple empirical predictive tools, driven by the statistics of long sequences of streamflow, or based on heuristic interpretations of land uses, may be used for estimation of long-term statistics of particular eutrophication-related constituents of concern[135]; and
- RWQOs/ WQPLs and RDMs represent an economic balance between water user and ecological water quality requirements on the one hand, and the costs of mitigation measures to achieve the RWQOs/ WQPLs and RDMs on the other. Future scenarios[136] are typically compared on a cost-benefit basis by utilising predictive tools to compare the economic dis-benefit due to the water quality received by water users and the cost of a particular management option.

3.1.2.2.2 Waste load accounting

Nutrient-load accounting must be utilised to balance input and output constituent specific loads, and to develop nutrient-load budgets, for the sub-catchments and catchment(s) in question.

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[130] Refer to **Section 3.1.2.1.4**: Consideration of important catchment and socio-economic attributes.
[131] Refer to **Section 3.1.2.2.3**: Water quality forecasting, trends analysis and scenario definition.
[132] Refer to **Section 3.1.2.4.5**: Identification of possible implications for water resource systems operation.
[133] Refer to **Section 3.1.2.2.2**: Waste load accounting.
[134] Refer to **Section 3.1.2.1.3**: Identification and addressing of information shortcomings.
[135] Refer to **Section 3.1.2.1.5**: Evaluation of the historic and current resource quality.
[136] Refer to **Section 3.1.2.4.2**: Scenario evaluation and management intervention options analysis.

Point source nutrient loads and diffuse sources of nutrients that are collected and discharged as nutrient-loads through a discrete or discernible conveyance, such as in the case of many irrigation and urban stormwater return-flows, are relatively easily quantifiable. The remaining portion of diffuse nutrient contributions cannot be measured directly, and the application of predictive tools[137] are often required. The effects of any legacy point and diffuse sources of nutrient pollution must be included in the nutrient-load budget of catchments.

The resulting nutrient load accounts set up for the sub-catchments and catchment(s) in question, will serve as basis for the reconciliation and allocation of water quality[138], once the necessary in-water resource water quality objectives, and associated Nutrient Load Objectives (NLO)[139] have been determined.

3.1.2.2.3 Water quality forecasting, trends analysis and scenario definition

Water quality forecasting and trend analysis must be undertaken to predict expected future eutrophication-related pressures on resource quality. Spatial and temporal nutrient constituent concentration and nutrient-load distributions must be interrogated to proactively identify areas of concern. Care must be taken to utilise time series data over a suitable period, preferably longer than five years, especially if significant seasonality is present. Seasonality occurs when one part of the year tends to produce consistently higher or lower values than other parts of the year. Water quality foresight is to be supported through nutrient modelling [140] and the evaluation of eutrophication management and developmental scenarios.

Scenarios definition and construction must yield a list of all possible eutrophication management and developmental scenarios. A preliminary screening must be undertaken to eliminate non-feasible scenarios with fatal flaws. Scenarios definition includes considering reuse and recycling of nutrient rich waste and water containing waste return-flow options, as a means to address eutrophication concerns. The identified scenarios can only be evaluated subsequent to goal setting, since scenario evaluation and management options analysis[141] are closely related, and are dependent on the management objectives that are derived through goal setting[142].

3.1.2.2.4 Visioning to propose levels for water resource protection

Visioning, by its nature, is both forward looking and aspirational, and provides the bridge between forward planning and goal setting. In the absence of water resource classification, visioning is necessary to fix the desired levels of water resource protection, which informs the determination of RWQOs or WQPLs[143], and RQOs. The vision, additionally, proposes the direction of change from the *status quo* that is necessary, or that can be allowed, if justified. During the classification of water resources, visioning is inherently part of the classification process[144] and is not done as an *ad hoc* exercise.

Water use needs, water user requirements and the quality of water resources are dynamic over space and time. Visioning provides the mechanism within which this dynamic variability can be aligned towards an agreed sustainable future in a catchment context (**FIGURE 38**) [DWAF, 2006c].

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[137] Refer to **Section 3.1.2.2.1**: Configuration, calibration and use of predictive tools.

[138] Refer to **Section 3.1.2.4.3**: Reconciliation and allocation of water quality.

[139] Refer to **Section 3.1.2.3**: Goal setting.

[140] Refer to **Section 3.1.2.2.1**: Configuration, calibration and use of predictive tools.

[141] Refer to **Section 3.1.2.4.2**: Scenario evaluation and management intervention options analysis.

[142] Refer to **Section 3.1.2.3**: Goal setting.

[143] The narrative descriptions commonly used to express judgements about the fitness of water resources for use are: *"ideal"*; *"acceptable"*; *"tolerable"*; and *"unacceptable"*. Visioning must relate the need to protect water resources to any of the first three levels, *i.e.* *"ideal"*; *"acceptable"*; or *"tolerable"*. *"Unacceptable"* water quality does not support ecologically sustainable development and is not an option.

[144] Refer to **Section 3.1.2.3.3**: Determination of statutory Resource Directed Measures.

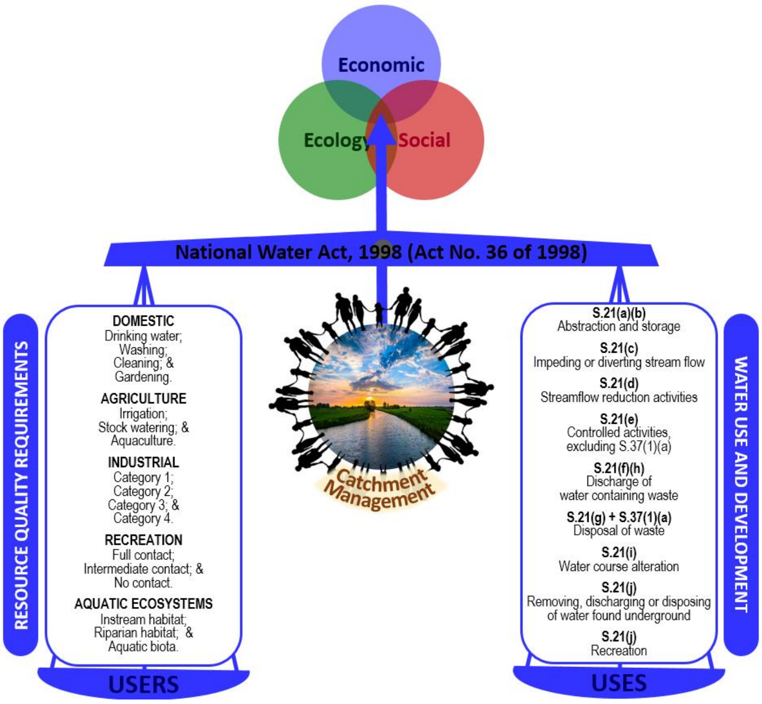

FIGURE 38: Balancing water resource protection with water resource use and development [Van Wyk, et al., 2003].

The catchment vision both considers the current trophic status of water resources, and the potential for improved trophic conditions. This might result in an idealistic vision of the desired trophic status, which would have to be balanced with the concomitant impacts of land use activities on anthropogenic eutrophication. Almost all water use activities generate either point or diffuse source pollution – *i.e.* one may not insist on ideal water quality, when one's own activity contributes to the deterioration in water quality. This, therefore, leads to both the acceptance of the need to use the water resource to dispose of waste or to discharge water containing waste (including its diffuse source forms), and to the formulation of more realistic water quality requirements.

3.1.2.3 Goal setting

"There is no achievement without goals." Author: Robert J. McKain

Goals are inherent building blocks of any management process! This statement is equally valid for the management of eutrophication. The goals in the eutrophication management framework direct the eutrophication management actions and efforts (during the *"Do"* stage), and also serve as benchmark for the measuring of implementation progress and success (during the *"check"* stage), and the potential prompting of corrective steps (during the *"act"* stage), should goals not be met.

These goals, generally, comprise of:

- RWQOs or WQPLs[145];
- Waste load objectives;
- Gazetted RDMs, *i.e.* water resource Management Class(es) (and RQOs/ Reserves);
- Remediation objectives; and
- Any other supporting management goals.

[145] Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives approach applied to eutrophication management.

There is no ideal sequence for setting-up these goals and any of these goals can be set-up first. The gazetted goals, *i.e.* the water resource Management Class(es) (and RQOs/ Reserves), set the tone and the other goals must support any of the gazetted goals. In cases where RDMs have not yet been determined and gazetted, but some, or all of the other goals have, such other goals will serve as input to the determination of RDMs when commissioned. Collectively, when referring to the water quality components of RQOs and to either the RWQOs or WQPLs, reference is sometimes made to *"in-water resource water quality objective"*, or *"in-stream water quality objective"* for surface water and *"in-aquifer water quality objectives"* for groundwater.

3.1.2.3.1 Determination of Resource Water Quality Objectives or Water Quality Planning Limits

The CMA, or in the absence of the CMA, the proto-CMA, may determine "*Resource Water Quality Objectives*" (RWQOs), and the DWS *"Water Quality Planning Limits"* (WQPLs). The RWQOs and WQPLs are similar in nature. Both are narrative or quantitative objectives that are determined – either in-stream or in-aquifer – within discrete management units. The management units are sub-catchments areas that are delineated taking into account relevant catchment and socio-economic attributes[146]. These objectives may be set at a greater spatial resolution (*i.e.* closer together) and/ or temporal resolution (*i.e.* more frequently monitored) than the RQOs (preliminary or otherwise), to which they must be linked, if such RQOs are available and gazetted.

Catchment eutrophication management is a highly complex task. The trophic status, water quantity and aquatic ecosystem components of water resources are all interdependent and linked by a complex set of biological, physical and chemical relationships. Water quality changes continuously as water that contains waste is added to surface water resources, which is then further modified as such water flows downstream to meet estuaries, which, in turn, are also influenced by ocean tides. The trophic status of surface water resources may also be affected by abstractions, which decrease the capacity of the water resource, both the river and its estuary, to assimilate nutrients. Water in rivers may be impounded, which then realises a whole new set of biological, physical and chemical interactions, while groundwater, or water in tidal estuaries, may be subjected to an altogether different set of biological, physical and chemical interactions.

The formulation of viable RWQOs or WQPLs is perhaps one of the most important steps in the eutrophication management framework. RWQOs and WQPLs that have the support of the stakeholders will secure their participation in the ongoing eutrophication management process. It also sets the goals that drive the technical process of formulating Nutrient Load Objectives, the allocation of water quality[147], and geographical strategies and thematic plans[148]. It, therefore, is critical to ensure that this process produces viable in-stream and in-aquafer objectives that stakeholders can support.

The formulation of the RWQOs or WQPLs should be supported by an assessment of the major point and diffuse sources of pollution in the catchment[149]. However, there will be some degree of iteration between these assessments and the formulation of the RWQOs/ WQPLs. For example, initial water quality assessments would be based on the South African Water Quality Guidelines[150], but the final water quality assessments must be based on the RWQOs/ WQPLs once these have been established[151]. Similarly, initial assessments of the sources of pollution would be broad-brush assessments of all potential sources, but once the RWQOs/ WQPLs have been established, final pollution source assessments would be based on the critical pollution sources[152]. The catchment assessment should, therefore, run in parallel with the process of formulating the RWQOs/ WQPLs.

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[146] Refer to **Section 3.1.2.1.4**: Consideration of important catchment and socio-economic attributes.

[147] Refer to **Section 3.1.2.4.1**: Confirmation of the water quality constituents of concern and catchment pressures.

[148] Refer to **Section 3.1.2.4.6**: Establishment of geographical water quality management strategies and thematic plans.

[149] Refer to **Section 3.1.2.1.6**: Examination of historic and current point and diffuse impacts.

[150] Refer to **Section 3.1.2.1.5**: Evaluation of the historic and current resource quality.

[151] Refer to **Section 3.1.2.4.1**: Confirmation of the water quality constituents of concern and catchment pressures.

[152] Refer to **Section 3.1.2.1.6**: Examination of historic and current point and diffuse impacts.

In the case of surface water resources, RWQOs and WQPLs affect both the upstream water uses and the downstream water users (**FIGURE 39**). In determining these objectives, the DWS or CMA strives to achieve a balance between protecting the water resource for the downstream users and allowing use and development of the water resource upstream of that objective point. For the downstream water users, the focus is on protecting the water quality in order to ensure a healthy functional aquatic ecosystem, while also meeting the fitness-for-use requirements of the five recognised water user groups[129] downstream of that point. However, the selected RWQO/ WQPL might also restrict the type and extent of water use upstream of that point. Water uses are addressed in Section 3.2.2.2.3 and includes uses such as the discharge of water containing waste (using some of the allocatable water quality) or taking water from a water resource (using some of the dilution capacity) [DWAF, 2006d]. The purpose of the RWQOs/ WQPLs, thus, are to provide greater detail upon which to base the management of water quality, including eutrophication, that is aimed at achieving and sustaining compliance with RQOs, if determined and gazetted [DWAF, 2006b].

When determining RWQOs/ WQPLs, the following is implied:

- In the absence of a high confidence determination of RWQOs/ WQPLs and proper motivation, deterioration in water quality may not be accepted from the present state;
- In areas of deteriorated water quality, the quality should be improved from an Ecological Category of *"E/F"* to an ecological category of *"D"* and a management class of "Heavily used" (as a minimum);
- RWQOs should be determined to (as a minimum) meet the Ecological and Basic Human Needs Reserve (or better); and

The default rule for the other water users is that the minimum desired category should be *"Tolerable"*.

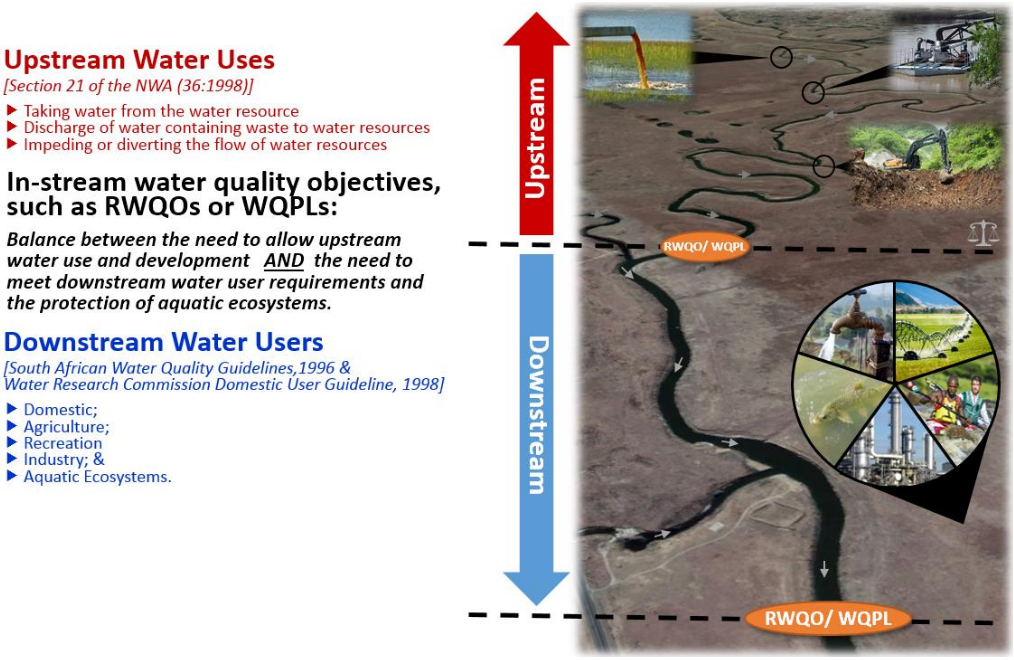

FIGURE 39: In-stream water quality objectives and sustainable development.

3.1.2.3.2 Determination of Waste Load Objectives

Waste Load Objectives (WLOs) refer to load targets that are determined for any water quality constituent of concern. For the purpose of this strategy, reference will be made to Nutrient Load Objectives (NLOs) that represent load targets for any phosphorus or nitrogen compounds of concern[153]. NLOs are determined

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[153] Refer to **Section 3.1.2.4.1**: Confirmation of the water quality constituents of concern and catchment pressures.

by balancing nutrient load targets with the technical, economic and administrative practicalities of achieving these targets. As such, the WLO constitutes an extension of the in-stream water quality objective (*i.e.* RWQOs, WQPLs and/ or RQOs)[154] within that management unit (**FIGURE 40**), and forms a link with the allocation of water quality[155], and the establishment of the geographical water quality management strategies and thematic plans[156]. WLOs are not source- or sector-specific, but are determined by the DWS, or the CMA, on a geographical sub-catchment basis (*e.g.* a phosphorus load reduction target for the catchment of an eutrophic impoundment), up to the WMA level, in the case of neighbouring WMAs that share water resources. WLOs must aim to phase-in giving effect to the designated in-stream water quality objectives within a five year timeframe.

NLOs outline incremental nutrient load targets predominantly for surface water resources in any geographical area, usually in sub-catchments up to WMA level, at the sites where in-stream water quality objectives have been determined. WLOs, as a rule, are not determined for groundwater, because of the application of the precautionary principle to groundwater protection[157]. NLOs outline what needs to be done to realise in-stream water quality objectives, but not who or how this must be done. The latter aspects are addressed through the allocation of water quality [158] and the establishment and implementation of the geographical water quality management strategies and thematic plans[159]. The nutrient-load objectives, therefore, specify incremental nutrient-load reductions (in stressed sub-catchments), or potential for increases (in unstressed sub-catchments), required to realise water user and use needs. NLOs may also indicate that total incremental nutrient loads should be maintained in the face of increasing development in the catchment[160].

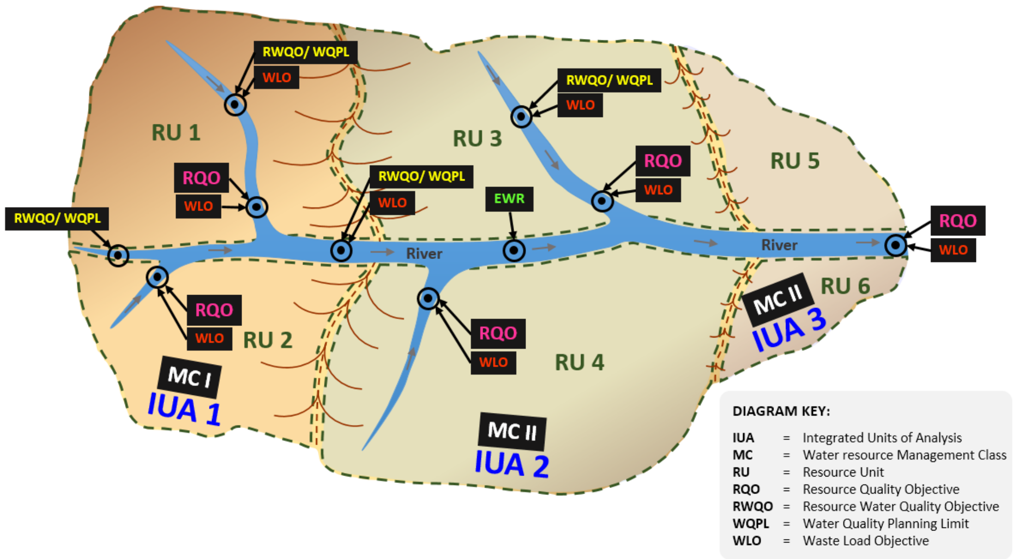

FIGURE 40: In-water resource water quality objectives and Waste Load Objectives.

In addition, the process of determining NLOs need not be based on quantifiable cause-effect relationships. NLOs can be based on simple heuristic understandings of the likely effects and feasibility of specific nutrient load reductions (or increases), or on previous modelling studies[161] of the likely effects of given changes in

[154] Refer to **Section 3.1.2.3**: Goal setting.
[155] Refer to **Section 3.1.2.4.3**: Reconciliation and allocation of water quality.
[156] Refer to **Section 3.1.2.4.6**: Establishment of geographical water quality management strategies and thematic plans.
[157] Refer to **POLICY STATEMENT 4**: The application of the precautionary principle.
[158] Refer to **Section 3.1.2.4.3**: Reconciliation and allocation of water quality.
[159] Refer to **Section 3.1.2.4.6**: Establishment of geographical water quality management strategies and thematic plans.
[160] Refer to **Section 3.1.2.2.3**: Water quality forecasting, trends analysis and scenario definition.
[161] Refer to **Section 3.1.2.1.2**: Examination of existing and available information.

nutrient loading. The difference between the current state, and the in-stream water quality objective and NLO indicates the overall reduction or increase in nutrient concentrations and loads that should be considered.

In stressed catchments, in-stream water quality objectives will differ significantly from the current state, and considerable load reductions may be required to realise the relevant in-stream water quality objectives. Many of the water resources in these catchments are also likely to have a lower water resource MC, and hence less stringent source-directed measures and controls. It is, therefore, possible that additional catchment-specific standards and management practices will be required to meet relevant in-stream water quality objectives. In these cases, the economic and technical feasibility of NLOs will have to be carefully weighed against the likely impacts of nutrient load reduction. The management emphasis will be on assessing the overall nutrient load reductions required to give effect to any in-stream water quality objectives. This may require detailed assessments of the likely effects of nutrient load reductions on the downstream tropic status of surface water resources.

In threatened catchments, NLOs are likely to specify that there should be no overall increase in nutrient-loading. This need not prevent further development of the catchment, but rather indicates that development in the catchment has to be balanced by reductions in nutrient-loading elsewhere in the catchment. The management emphasis in these cases will, therefore, be on allocating nutrient loads to different sectors according to a water quality allocation schedule[162].

In unstressed catchments, NLOs will specify the potential increases in nutrient-loading that may be accommodated without threatening the relevant in-stream water quality objectives. However, this is not a free licence to increase nutrient-loading, and proposed increases in nutrient-loading should only be considered if there are clear social and economic benefits to the catchment as a whole, while also considering the natural growth in the catchment, as well as any proposed developments that may occur in future[163].

3.1.2.3.3 Determination of statutory Resource Directed Measures

On September 2010, in support of Chapter 3 of the NWA (36:1998) which stipulates the requirement for adequate protection and effective management of water resources, the DWS promulgated regulations prescribing a Water Resources Classification System (WRCS). The WRCS provides an outline for the determination of RDMs. These measures are aimed at maintaining the desired state of water resources, by setting, over a period of time,

- the water resource Management Class (MC) in Integrated Units of Analysis (IUAs);
- the Reserve; and
- the RQOs for each significant water resource in Resource Units (RUs).

The classifying of water resources take into account the social, economic and ecological landscape in a catchment in order to assess the costs and benefits associated with use and development *versus* protection of a water resource. As such, the classification process is not carried out in isolation, but is integrated within the overall planning for water resource protection, development and use. The purpose of the water resource MC is to stipulate desired levels of protection in terms of *Class I* (minimally used), *Class II* (moderately used), or *Class III* (heavily used); to ensure long-term sustainable water resource use; to provide regulatory certainty and a framework within which other goals (*i.e.* RQOs and the Reserve) can be determined; and to*, inter alia*, allow for the measurement of regulatory performance and compliance.

Section 3, NWA (36:1998) requires that the Reserve be determined for water resources, *i.e.* the quantity, quality and reliability of water needed to sustain both *basic human needs* (Basic Human Needs Reserve) and *aquatic ecosystems* (Ecological Reserve), so as to meet the requirements for economic development

162 Refer to **Section 3.1.2.4.3**: Reconciliation and allocation of water quality.

163 Refer to **Section 3.1.2.2.3**: Water quality forecasting, trends analysis and scenario definition.

without seriously impacting on the long-term integrity of ecosystems. It, therefore, is imperative that the Reserve must be determined and that the requirements be met, before other economic activities can be satisfied, as it is the only right to water according to the applicable water legislation.

The Ecological Reserve, also referred to as the Ecological Water Requirements (EWR), directly relates to eutrophication (**FIGURE 41**). It is defined as the quantity and quality of water necessary to protect aquatic ecosystems and to secure ecologically sustainable development and use of the relevant water resource. Water flow, water quality and geomorphology are the main drivers of EWRs and the habitat (vegetation) and biota (fauna) being the responses. The implementation of the Ecological Reserve consists of both the physical implementation of the flow requirements, as well as the monitoring and management of water quality, habitat and biota. Eutrophication is one of the prevalent water quality issues in South Africa, and effective eutrophication management is required to meet the Reserve.

RQOs[102] are *"clear goals relating to the quality of the relevant water resources"*. RQOs are both descriptive statements and attendant numerical values for a range of water resources throughout WMAs, *i.e.* narrative and qualitative statements that describe the overall objectives for the resource unit [DWAF, 2006b]. They define goals to protect water resources and ensure alignment to MC of the water resource. In determining the RQOs, it is important to recognise that different water resources will require different levels of protection.

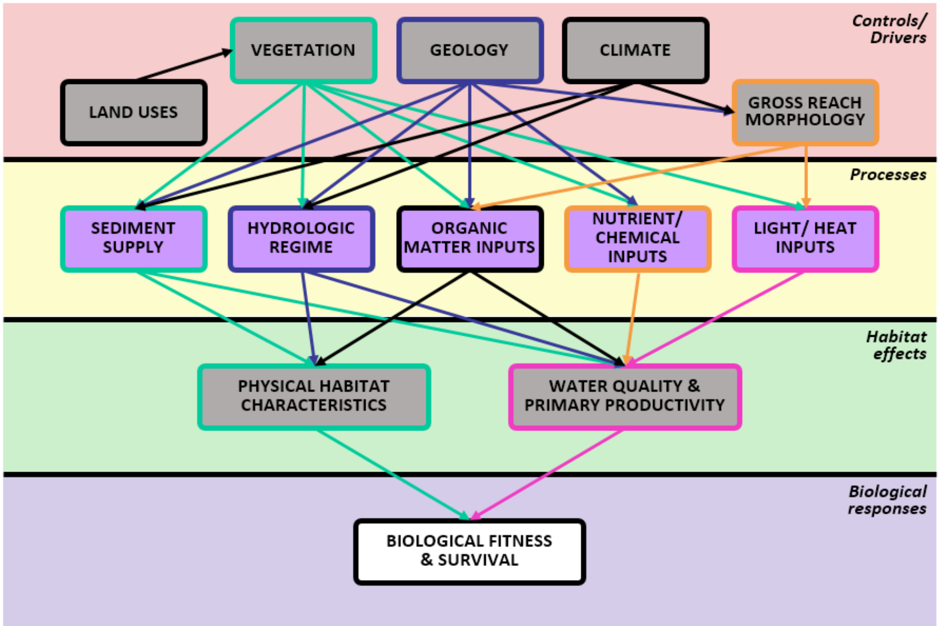

FIGURE 41: The Ecological Water Requirements components of the Reserve [Beechie & Bolton, 1999]. *(Black boxes indicate controls not affected by land use)*

Since the inception of the WRCS in September 2010, DWS has conducted Reserve, Classification and RQO studies across the country. Water resource Management Class(es) (and RQOs/ Reserves) have been gazetted for various WMAs such as Olifants-Doorn, Vaal, Crocodile-West Marico, Mvoti to Umzimkulu, Berg, Mokolo and Matlabas, Mzimvubu, Breede-Gouritz and Inkomati-Letaba. In order to give effect to the Eutrophication Management Strategy, the implementation of these RDMs have to be realised.

3.1.2.3.4 Determination of remediation objectives for pollution sources and water resources

The presence of legacy point and diffuse nutrient sources[164], and residual impacts on water resources and associated aquatic ecosystems, which resulted from historic anthropogenic eutrophication[165] have been identified and assessed during the catchment assessment. The quantification of legacy point and diffuse nutrient-loads have been undertaken as part of the waste load accounting[166], which, together with information, as generated through the allocation of water quality[167], must inform the determination of remediation objectives for such legacy point and diffuse nutrient sources. Remediation objectives for residual impacts on water resources and associated aquatic ecosystems must be informed by the Reserve, if available[168]. The remediation objectives must be used to shape the establishment of geographical water quality management strategies and thematic plans[169].

3.1.2.4 Intervention planning

"A goal without a plan is just a wish!" Author: Antoine de Saint-Exupéry

The end-purpose of eutrophication-focused intervention planning[170] is to map-out desired ways forward, in the form of geographic water quality strategies and/ or thematic plans. These strategies and plans specify implementation details for water quality management, including different types of interventions to address eutrophication challenges, and can also be utilised to track implementation progress. Intervention planning, generally, includes the following steps [adapted from DWAF, 2003b]:

3.1.2.4.1 Confirmation of the water quality constituents of concern and catchment pressures

Historic and *status quo* concentration[171] and waste load[172] information, together with water quality intelligence gained through water quality forecasting[173], must be compared to relevant in-resource water quality objectives and WLOs[174] to confirm all water quality constituents of concern and to select indicators for monitoring[175]. Additional and follow-up assessments over a period of time may be required to evaluate potential emerging pollutants. Spatial and temporal water quality and load profiles must be produced for all relevant Management Units and explained by indicating likely point and diffuse causes. These pressures must be ranked according to their observed and projected impacts to facilitate scenario evaluation and to guide the prioritisation of interventions and management options analysis[176].

3.1.2.4.2 Scenario evaluation and management intervention options analysis

Sound eutrophication management decisions often rely on the ability to predict outcomes of streamflow and nutrient-loading along different river reaches, and for different scenarios of land and water use in the catchment. Various predictive approaches are available for the evaluation of eutrophication management

[164] Refer to **Section 3.1.2.1.6**: Examination of historic and current point and diffuse impacts.
[165] Refer to **Section 3.1.2.1.5**: Evaluation of the historic and current resource quality.
[166] Refer to **Section 3.1.2.2.2**: Waste load accounting.
[167] Refer to **Section 3.1.2.4.3**: Reconciliation and allocation of water quality.
[168] Refer to **Section 3.1.2.3.3**: Determination of statutory Resource Directed Measures.
[169] Refer to **Section 3.1.2.4.6**: Establishment of geographical water quality management strategies and thematic plans.
[170] Refer to **POLICY STATEMENT 14**: Water resource assessment and planning to inform decision-making.
[171] Refer to **Section 3.1.2.1.5**: Evaluation of the historic and current resource quality.
[172] Refer to **Section 3.1.2.2.2**: Waste load accounting.
[173] Refer to **Section 3.1.2.2.3**: Water quality forecasting, trends analysis and scenario definition.
[174] Refer to **Section 3.1.2.3**: Goal setting.
[175] Refer to **Section 3.3**: The *"check"* stage.
[176] Refer to **Section 3.1.2.4.2**: Scenario evaluation and management intervention options analysis.

scenarios, ranging from process-based catchment models, to rule-based methods, through to simple regression-based formulas.

The information *"mosaic"*, created through the catchment assessment, and the value added through forward planning and management goal setting, allows for a management-oriented analysis of potential future water quality trends in space and time. It should be borne in mind that, like all projections, various degrees of uncertainty would be present in the prediction of nutrient-loading and the associated effects on trophic conditions and that a wide range of sensitivity analyses of the predictions in response to variations of controlling variables should form a standard part of the scenario evaluation.

Feasible scenarios[177] must paired with potential management and interventions options, and screened by applying pre-defined criteria. This is done in order to ensure that the evaluations are comparable, and to make the ranking of scenarios and eutrophication management options, in sequence of feasibility, possible. Scenarios and management options screening criteria could include:

- Economic considerations;
- Socio-political considerations;
- Ecological considerations;
- Recreational and/ or eco-tourism aspects;
- Legal considerations;
- Technical viability (physical and operational); and
- Statutory and institutional responsibilities, including co-operative arrangements.

Optioneering is mostly done through cost-benefit analysis.

3.1.2.4.3 Reconciliation and allocation of water quality

The current excessive nutrient-loading trajectories, observed in many of our water resources, are exceeding the ability of such water resources to assimilate nutrients without compromising fitness-for-use. In order to arrest this deteriorating trend, it has become critical that demands for allocatable water quality[3] must be balanced with availability[178]. The mechanism that is used to unpack the demands for water quality and to reconcile water quality, is the allocation of water quality through a *"water quality allocation schedule"* that forms the foundation of the *"water quality allocation plan"*.

The *"water quality allocation plan"* is aligned with the Water Allocation Plan required, as part of Catchment Management Strategies (CMS) [NWA, 1998, S.9(e)]. In the context of eutrophication management, the water quality allocation plan, through the water quality allocation schedule, must allocate the available incremental nutrient load, defined by the NLOs, to different water user sectors on a template of *"Management Units"*[65]. The water quality allocation plan, further, must specify and link to the necessary source or remediation directed measures and controls, which must be adopted for each sector, and which must address both point and diffuse nutrient sources, in order to achieve the desired nutrient-loading.

This approach, therefore, allocates nutrient load targets, through the NLOs, to parts of catchments. These incremental sub-catchment NLOs are then re-allocated to specific sectors or sources within the water quality allocation plan. As the water quality allocation plans are developed in close co-operation with stakeholders from the relevant sources and sectors, this process forces stakeholders to think within the wider catchment perspective when allocating load targets for specific sectors or sources.

The water quality allocation plan may relate to point and diffuse source impacts, and in-stream management, including suitable reservoir release operating rules[179], in-stream rehabilitation[180] and

[177] Refer to **Section 3.1.2.2.3**: Water quality forecasting, trends analysis and scenario definition.

[178] Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives approach applied to eutrophication management.

[179] Refer to **Section 3.1.2.4.5**: Identification of possible implications for water resource systems operation.

[180] Refer to **Section 3.4.2.1**: Retrospective action.

ecological water requirements[181]. The water quality allocation plan, further, plays an important role in nutrient-loading off-setts[182]. The water quality allocation plan has a central relationship with, and forms an important part of the geographical water quality management strategies and thematic plans that must be established[183], and provides an indication of the potential for additional ecologically sustainable development, if any, to support further socio-economic development.

3.1.2.4.4 Identification and development of linkages with land use planning and management

Catchment eutrophication management is part of a wider planning and development environment, which is affected by the fragmentation that characterises South Africa's water, land-use, and environmental legislation and administration. Whereas the institutional linkages that are required to counter this fragmentation must be addressed during the catchment assessment study[184], it is equally important to focus on the fragmented statutory arrangements for spatial, land-use and infrastructural development planning that potentially affect anthropogenic eutrophication. Any potential synergy with national, provincial, regional and local planning processes to limit the effects of anthropogenic eutrophication must be identified and developed, through cooperative governance and consultation[185]. The projected growing nutrient-loading trends due to population growth and potential physical developments in the catchment must be identified, and development planning and land use management must be influenced, in the interest of water security. The identification and development of linkages with land use planning and management must be transferred to the establishment and implementation of the geographical water quality management strategies and thematic plans[186].

3.1.2.4.5 Identification of possible implications for water resource systems operation

The DWS is responsible for the development and maintenance of water resource system operating rules for reservoirs and systems of interlinked reservoirs on large schemes, which support major economic zones, as well as for smaller reservoirs and systems, supplying water to towns and rural areas. These operating rules are often based on complex decision support systems, which include stochastic simulation models that carry out monthly simulations and that advise users of the risk of entering a restriction zone in future so that informed decisions can be made. Such operating rules, for instance, address the transfer of water between water resources, the conjunctive use of surface and groundwater, or the use of desalination plants during periods of drought.

The regulation of developed surface water resources has the potential to either adversely affect, or to improve aquatic ecosystem health. Flow manipulation has proved to be a most promising intervention to combat eutrophication in developed river systems, because of addressing the key drivers of algal blooms, *viz.* residence time and stratification [Davis & Koop, 2006; Davis & Koop, 2001]. Much greater attention must be given to flow management as a means of reducing primary production levels and mimicking natural flow situations[187] in downstream water resources, particularly in the case of highly regulated river systems.

3.1.2.4.6 Establishment of geographical water quality management strategies and thematic plans

Geographical water quality management strategy assembles the elements of integrated water quality management, including to suitably address any relevant eutrophication challenges and priorities, at the level of sub-catchments (Management Units) and/ or WMA-wide. The geographical water quality

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181 Refer to **Section 3.1.2.3**: Goal setting.

182 Refer to **POLICY STATEMENT 2**: The mitigation hierarchy for decision-making on eutrophication.

183 Refer to **Section 3.1.2.4.6**: Establishment of geographical water quality management strategies and thematic plans.

184 Refer to **Section 3.1.2.1.1**: Stakeholders and role-player identification and consultation.

185 Refer to **POLICY STATEMENT 19**: Cooperative management.

186 Refer to **Section 3.1.2.4.6**: Establishment of geographical water quality management strategies and thematic plans.

187 Refer to the Reserve, as per **Section 3.1.2.3.3**.

management strategy and/ or sub-strategies are supported by the establishment of any number of water quality management plans required to address particular water quality management related themes, such as the combating and management of eutrophication and the allocation of water quality. Collectively the geographical water quality management strategies and thematic plans must ensure that the vision[188] and relevant management goals[189] are operationalised through the implantation and tracking[190] of the selected management intervention options[191]. These intervention options may include a variety of source[192] and remediation[193] directed, and cooperative land use development and management[194] measures and controls, water resource systems operating rules[195], and the roll-out of infrastructure solutions[196] to limit excessive primary production in water resources. In the case of fully operational CMAs, the geographical water quality management strategies and thematic plans, described here, will form part of their Catchment Management Strategies (CMSs) and supporting documentation.

3.1.2.4.7 Infrastructure planning

Even though nature-bases solutions are preferred[197], build or hard infrastructure must often be employed to address point and diffuse nutrient challenges. In many cases, intervention options analysis[198] may prefer the establishment of build or hard infrastructure to address eutrophication-related challenges. The absence of necessary infrastructure solutions to deal with waste and wastewater with a high nutrient or organic character, is likely to contribute to accelerated anthropogenic eutrophication. Infrastructure to address nutrient pollution causes and effects, include waste, wastewater and water treatment, waste disposal and pollution control facilities; networks of water reticulation, reservoirs and pumping systems; stormwater control infrastructure; and much more! These infrastructure solutions are utilised by the three spheres of government and by private sector to prevent, manage and/ or treat nutrient rich pollution-related causes and effects. Government funded infrastructure planning investigations must be conducted in an incremental manner to limit spending on non-feasible projects. To achieve this, planning investigations are usually conducted at three levels to ensure that non-viable projects are identified early on. These planning investigation levels are:

- **Reconnaissance:**

The main objective of this level of investigation is to determine, at the lowest investigation cost, whether the proposed infrastructure project indeed has development potential;

- **Pre-feasibility:**

The main objective of this level of investigation is to compare one project with another in order to select the most feasible project for further investigation at feasibility level. Comparisons are not only made on economic grounds, but also on environmental grounds and

- **Feasibility:**

The main objective of this level of investigation is to demonstrate technical feasibility and economic viability. The feasibility study, therefore, is conducted at a high level of detail. The feasibility report would

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[188] Refer to **Section 3.1.2.2.4**: Visioning to propose levels for water resource protection.
[189] Refer to **Section 3.1.2.3**: Goal setting.
[190] Refer to **Section 3.1.2.4.8**: Implementation coordination and maintenance.
[191] Refer to **Section 3.1.2.4.2**: Scenario evaluation and management intervention options analysis.
[192] Refer to **Section 2.1**: Source Directed Management.
[193] Refer to **Section 2.3**: Remediation Directed Management.
[194] Refer to **Section 3.1.2.4.4**: Identification and development of linkages with land use planning and management.
[195] Refer to **Section 3.1.2.4.5**: Identification of possible implications for water resource systems operation.
[196] Refer to **Section 3.1.2.4.7**: Infrastructure planning.
[197] Refer to **POLICY STATEMENT 8**: Nature-based solutions.
[198] Refer to **Section 3.1.2.4.2**: Scenario evaluation and management intervention options analysis.

also be used for Environmental Impact Assessment (EIA) purposes. The feasibility report are the primary source document to be used during detailed design.

3.1.2.4.8 Implementation coordination and maintenance

The implementation and maintenance of the geographical water quality management strategies, and associated thematic plans (or the CMS - in the case of operational CMAs), specifically with respect to the management of eutrophication, is vital to limit excessive nutrient-loading and to improving the trophic status of many water resources. The establishment of a Strategy Steering Committee (SSC) to oversee implementation and maintenance must be considered. The SSC will have to meet regularly enough to effectively track strategy roll-out and updating. The SSC will have to comprise of relevant authorities, key land and water user sectors, key stakeholders, and selected experts.

3.1.3 Spatial scale of implementation

Assessments[199] can be conducted on an *ad hoc* basis or regularly, and for different geographical scales, ranging from the trans-boundary scale to a national, regional, catchment or sub-catchment scale to a local scale.

Any of the operational strategies, being part of the *"plan"* stage in the eutrophication management framework, can be conducted for different geographical scales, ranging from the trans-boundary scale to a national, regional, catchment or sub-catchment scale to a local scale.

Assessments, forward planning, goal setting and intervention planning must take place at spatial scales that appropriately balances–

- the complexities of the area in question;
- environmental integration; and
- the need to devolve water quality management to the lowest practical and appropriate level.

3.1.4 Temporal scale of implementation

The operational strategies, being part of the *"plan"* stage in the eutrophication management framework, can be conducted on an *ad hoc* basis or regularly, depending on the purpose. **TABLE 16** gives a summary of potential outstanding actions:

TABLE 16: Actions to strengthen the *"plan"* stage of the eutrophication management framework.

	SHORT-TERM
1.	TSI monitoring
2.	Alert levels
3.	
4.	
5.	
	LONGER-TERM
6.	
7.	

[199] Refer to **POLICY STATEMENT 14**: Water resource assessment and planning to inform decision-making.

3.2 The *“do”* stage

A “plan” stage without a “do” stage is as meaningless as a “do” stage without a “plan” stage. These two stages in the eutrophication management framework are interdependant and must exist, side-by-side!

The *“do”* stage in the eutrophication management framework is about implementation, which must turn eutrophication management strategy into *“actions”* and *“results”*, in order to accomplish the eutrophication management goal, objectives and associated policy imperatives.

Altogether the *“do”* stage, in the eutrophication management framework, must–

- give effect to the goals that were determined[200], and the water quality management strategies and thematic plans that were established, during the *“plan* stage in the eutrophication management framework for the management of eutrophication on a catchment-basis;
- protect the aquatic ecosystem and other water users by ensuring fitness-for-use of water ending-up in receiving water resources[201];
- be rolled-out in a cooperative manner[202], collaborating, specifically, with other regulators;
- address eutrophication challenges in a holistic[203] and *“cradle-to-grave"* fashion by addressing pollution as close as possible to its source or origin[204];
- make suitable use of the management instruments for environmental compliance[205];
- facilitate pollution avoidance, prevention and minimisation[206]; and
- promote the application of nature-based solutions[207] and the implementation of the BPEO[208], as may be appropriate.

The *“do”* stage, in the eutrophication management framework, focuses on three linked operational strategies (**FIGURE 42**).

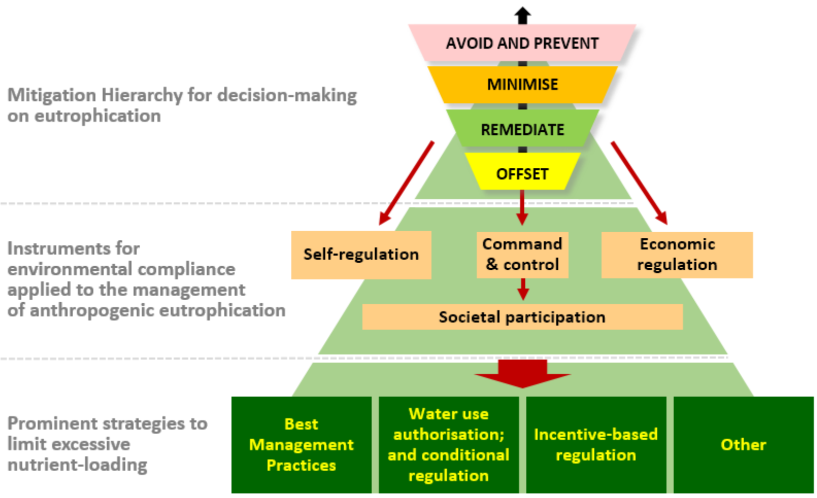

FIGURE 42: Limiting nutrient-loading through best management practices; water use authorisation and conditional regulation; and incentive-based regulation.

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200 Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives approach applied to eutrophication management.
201 Refer to **POLICY STATEMENT 3**: The differentiated approach for the control of excessive nutrient-loading.
202 Refer to **POLICY STATEMENT 19:** Cooperative management.
203 Refer to **POLICY STATEMENT 10**: Holistic eutrophication management.
204 Refer to **POLICY STATEMENT 6**: A life cycle view on nutrient-loading.
205 Refer to **POLICY STATEMENT 1**: Application of management instruments for environmental compliance in eutrophication management.
206 Refer to **POLICY STATEMENT 2**: The mitigation hierarchy for decision-making on eutrophication.
207 Refer to **POLICY STATEMENT 8**: Nature-based solutions.
208 Refer to **POLICY STATEMENT 9**: The application of the Best Practicable Environmental Option.

These three operational strategies and their purpose and composition are summarised in **TABLE 17**:

TABLE 17: The operational strategies, in the *"do"* stage of the eutrophication management framework, and their composition.

OPERATIONAL STRATEGIES AND PURPOSE		KEY COMPONENT(S)
1. **Best management practice**	*To apply management practices that limit excessive nutrient-loading.*	Best available technology;
		Cleaner technology and cleaner production
		Conversion of environmental problems into socio-economic and developmental solutions;
		Waste reduction, recycling and reuse;
		The use of buffer zones.
2. **Water use authorisation and conditional regulation**	*To enforce conditional authorisations and other regulatory requirements that limit excessive nutrient-loading.*	National Water Pollutant Register
		Waste Discharge Standards (WDSs);
		Water use;
		Registration of water use;
		Lawful water use;
		Schedule 1 water use;
		General Authorisations;
		Existing Lawful water Use (ELU);
		Water use licensing;
		Alternative authorisations; and
		Diffuse pollution sources.
		Differentiated water use management based on risk
3. **Incentive-based regulation**	*To incentivise responsible behaviour that limits excessive nutrient-loading.*	Waste Discharge Charge System (WDCS);
		Certification Schemes;
		Water Polluter Register; and
		Eco-labelling.

3.2.1 Authority

There are a number of authorities involved in the authorisation of activities that may cause excessive nutrient-loading. The DWS and Catchment Management Agencies (CMAs), may issue General Authorisations (GAs) and licenses to authorise water use, whereas other authorities are responsible for the authorisation of several types of land use activities, or aspects thereof, which may contribute towards anthropogenic eutrophication. In addition to the siloed approach to environmental authorisations, often raised as a hindrance to economic development, fragmented authorisation processes often also burden achieving government goals, such as the goal for eutrophication management, when the other environmental authorisations are administered by authorities with non-water resource related mandates. Additionally to the establishment of the one environmental system, which is supported[209], regulatory cooperation between authorities, with respect to the management of anthropogenic eutrophication, must

[209] Refer to **POLICY STATEMENT 1**: Application of management instruments for environmental compliance in eutrophication management.

be improved[210]. Competencies (sectors), which are relevant here, include agriculture; water and sanitation; environment; and mining. Sectoral mandates are summarised in Chapter 5, Part 3.

3.2.2 Prescribed approaches

3.2.2.1 Best management practice

Best management practices (BMPs), in the context of eutrophication management, are practices or methods that have been devised to be the most effective and practical means of limiting point and diffuse sources of excessive nutrient-loading, and to help achieve the eutrophication management goal, objectives and policy imperatives. The BMPs can have a catchment and water resource focus, or can apply to sources of anthropogenic eutrophication. The list of important BMPs and concomitant descriptions, referenced below, by no means constitutes an exhaustive list. A portfolio of BMPs, therefore, have to be identified and BPGs developed over time to provide sectoral standards for BMPs and a comprehensive series of BPGs. One should be able to apply such BPGs to land and water use activities through cooperative management[211], also considering making some of these BMPs, where appropriate, compulsory in future[212]. The BPGs for eutrophication management must be set up such that they promote the mitigation hierarchy for decision-making on eutrophication[213]. The categories (1) pollution avoidance and prevention; (2) minimisation; and then (3) remediation; and, finally, (4) offsetting should be utilised to structure eutrophication management BPG development per category. Some BMPs for eutrophication management are briefly elaborated, next:

3.2.2.1.1 Best available technology

Wastewater treatment technologies are generally proven for South African conditions and a local knowledge base exists to plan, design, construct, operate and maintain a wide range of treatment technologies and WWTWs. BMPs with guidelines for smaller and conventional treatment technologies and/ or WWTWs must be considered and, if merited, developed. Some of the more sophisticated technologies such as advanced oxidation, membrane desalination, *etc.* have been applied to a limited number of local projects. The South African water and waste disposal industry will need to grow capacity to confidently implement and maintain some of the more advanced wastewater treatment technologies. BMPs with guidelines for these treatment technologies and/ or WWTWs should be considered and, if merited, developed.

3.2.2.1.2 Cleaner technology and cleaner production

Cleaner production emerged as an industry initiative that is intended to minimize waste and emissions, and to maximize product output and profitability. By analysing the flow of materials and energy in industrial production processes, options to minimize waste and emissions can be identified and industry source reduction strategies can be established. Improvements of organisation and technology help to suggest better choices in the utilisation of materials and energy, to avoid waste, wastewater generation, gaseous emissions, waste heat and noise, as well as more efficient resource use, increased business profitability and competitiveness, and increased production process efficiency. Cleaner production is applicable to all businesses, regardless of size or type. In addition to the BPGs for wastewater treatment

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[210] Refer to **POLICY STATEMENT 19**: Cooperative management.

[211] Refer to **POLICY STATEMENT 19**: Cooperative management.

[212] Refer to S. 26(1)(i), NWA (36:1998): *"The Minister may make regulations prescribing the outcome or effect which must be achieved through management practices for the treatment of waste, or any class of waste, before it is discharged or deposited into or allowed to enter a water resource."*, and **ANNEXURE E** for other regulations.

[213] Refer to **POLICY STATEMENT 2**: The mitigation hierarchy for decision-making on eutrophication.

and handling, BMPs with guidelines for cleaner production and cleaner technology should also be considered and, if merited, developed.

3.2.2.1.3 Conversion of environmental problems into socio-economic and developmental solutions

- In situations where pollution problems exist, an attempt must be made to exploit opportunities and to convert problems into solutions. Such opportunities may, amongst others, include recognising-
  - the nature of water scarcity in South Africa and moving to waterless sanitation options for all South Africans; and
  - the nature of human excreta (faeces and urine) as a resource to be utilised, particularly for fertiliser products, but also for the reclamation of important elements, such as phosphorus, which is a critical and a globally limited resource, essential for crop production.

Opportunities to convert problems into solutions must be identified and, if merited, established through research, development and wider implementation and roll-out. BMPs with guidelines must be considered to give further impetus to the conversion of specific problems into solutions.

3.2.2.1.4 Waste reduction, recycling and reuse

The discharge and disposal of waste and wastewater, including the evaporation of, and the non-beneficial irrigation with water containing waste, is a last resort. The recycling and reuse of wastewater, if possible and desirable, is preferred compared to the use of potable water. Reuse and recycling strategies are of particular importance in the context of urban areas where significant volumes of wastewater are constantly being produced and discharged, after treatment, by municipal WWTWs. Potential municipal water reuse options include the irrigation of public open spaces (*e.g.* parks), sports fields (*e.g.* municipal, school and club facilities and golf courses), and cooling (related to industry and power generation), as well as firefighting, toilet flushing, cooling systems, street cleaning, dust control and a variety of other applications which do not require potable water [DWA, 2011]. Reuse strategies must be cognisant of any water budget requirements that may apply. BMPs with guidelines must be identified and, if merited, developed to give further impetus to pollution minimisation.

3.2.2.1.5 The use of buffer zones

The use of buffer zones hold great promise and must be used to, *inter alia,* assist with sediment; nutrient and toxins removal; the maintenance of channel stability; flood attenuation; improved groundwater recharge; provision of habitat for wildlife; the screening of adjacent disturbances; habitat connectivity; aesthetic appeal; and the control of water temperature resulting from the vegetation alongside water resources affecting the microclimate of stream areas nearest to stream banks [Macfarlane, et al., 2009]. Existing guidelines should be considered and, if necessary, adjusted and/ or fully implemented.

3.2.2.2 Water use authorisation and conditional regulation

Command-and-control, or alternatively called *"regulation"*, is a key approach employed by government to ensure environmental compliance[214]. In the context of eutrophication management, a suite of regulatory measures should ideally have been available to address different types and combinations of point and diffuse sources of excessive nutrient-loading on a catchment-by-catchment basis. This, however, is not the case, and current regulatory measures mostly focus on point sources of pollution. These source directed measures and controls, are elaborated below:

3.2.2.2.1 National Water Pollutant Register

Everything that happens in a catchment reflects in the quality of water resources that flow through, or that occur within it, because the results of human activity and lifestyle ultimately end up in water resources

[214] Refer to **POLICY STATEMENT 1**: Application of management instruments for environmental compliance in eutrophication management.

through runoff and point impacts. Anthropogenic eutrophication is the result of nutrients that are being introduced into water resources by catchment activities. Factors, such as increasing industrialization, urbanization, intensive farming practices and climate change, all have an impact on the potentially changing character of water pollution (**FIGURE 43**). Many emerging pollutants potentially contain different amounts of phosphorus and nitrogen. To stay abreast and to focus management action, the potentially changing character of pollution must be continuously evaluated[215].

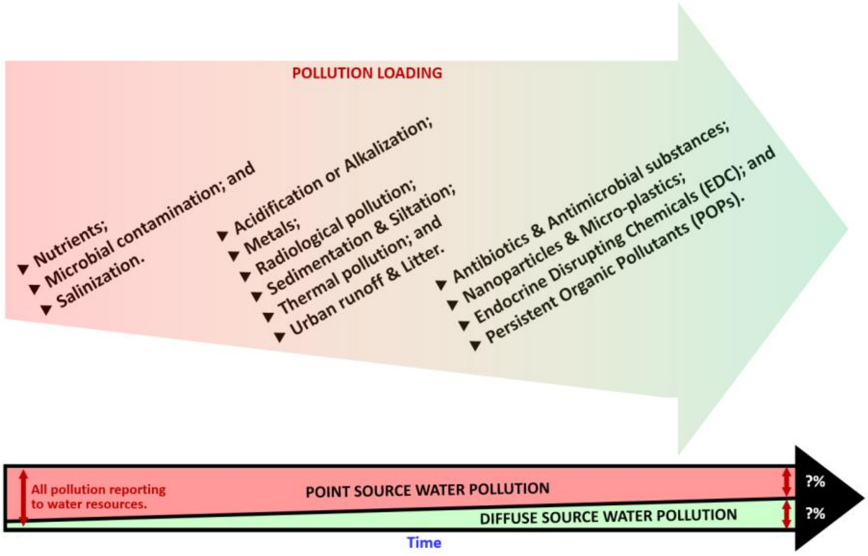

FIGURE 43: Changing character of water pollution and the introduction of emerging pollutants.

The development of a National Water Pollutant Register, in conjunction with the development of WDSs (**Section 3.2.2.2.2**) and other emission standards, such as ambient air quality and emission standards, must be considered. Such a register will provide structure to pollution control and integrated water quality management in a changing environment, and can be utilised to identify categories of pollutants or substances that have to be dealt with in particular ways. The following substance list categories are proposed:

- **A list of a national priority substances**, which pose a national threat to receiving water users and aquatic ecosystems, and for which WDSs and, if necessary, other emission standards, such as national ambient air quality and emission standards, have to be determined to reduced or eliminated such substances in surface or groundwater, or in marine waters. The list of national priority substances must be periodically reviewed, *e.g.* five yearly;
- **A list of WMA or sub-catchment specific priority substances**, which pose a local or regional threat to receiving water users and aquatic ecosystems only, and for which WDSs and, if necessary, other emission standards, such as provincial or local ambient air quality and emission standards, have to be determined to reduced or eliminated such substances in surface or groundwater. The list of WMA or sub-catchment priority substances must be periodically reviewed, *e.g.* five yearly, in collaboration with CMAs;
- **A *"watch list"* containing new or emerging substances** for which no WDSs are available, or for which little information is available, that should be monitored for the purpose of risk determination and to determine WDSs and/ or other emission standards, as may be necessary. The *"watch list"* containing new and emerging substances must be periodically reviewed, *e.g.* five yearly and can be used, *inter alia*, to influence research and technology development priorities[216], etc.; and

[215] Refer to **POLICY STATEMENT 14**: Water resource assessment and planning to inform decision-making.
[216] Refer to **Section 4.3**: Research & technology development.

- **A list of priority hazardous substances** for which water resources has no assimilative capacity due to their persistency, liability to bio-accumulate and toxicity, or other equivalent concerns, and that need to be eliminated from water resources[217]. The list of priority hazardous substances must be periodically reviewed, *e.g.* five yearly.

It is possible for hazardous substance to also appear on the lists of either national, or WMA or sub-catchment priority substances. When more information becomes available, substances can be transferred from the *"watch list"* to any of the other three lists or they can be dropped. It may be considered to establish a list of non-priority substances for record purposes.

3.2.2.2.2 Waste Discharge Standards (WDSs)

The *General and Special Standards for the purification of Wastewater or Effluent*, dating back to 1984 [GN R.991, 1984], is overdue for revision – especially the Special Standard for phosphorus of 1mg/ℓ orthophosphate. Section 15 of the NWA (36:1998) compels the Minister of Human Settlements, Water and Sanitation, the Director-General, organs of state and any water management institution, when exercising powers or performing duties under the NWA (36:1998), **to give effect to any determination of a water resource MC and RQOs**, and any other requirements for complying with the RQOs[218].

Ideally, WDSs must be determined for every point discharge (**FIGURE 44**) to ensure that compliance to such WDSs will give effect to the relevant RDMs and to ensure fitness-for-use. In this way, source directed measures and controls to be applied to point discharges can be custom-fitted and directly linked with relevant receiving water resources requirements, *i.e.* the *"RQOs and any other requirements for complying with the RQOs"*. Although, doable, such an arrangement will certainly not be practical, under current circumstances, and is probably not desirable.

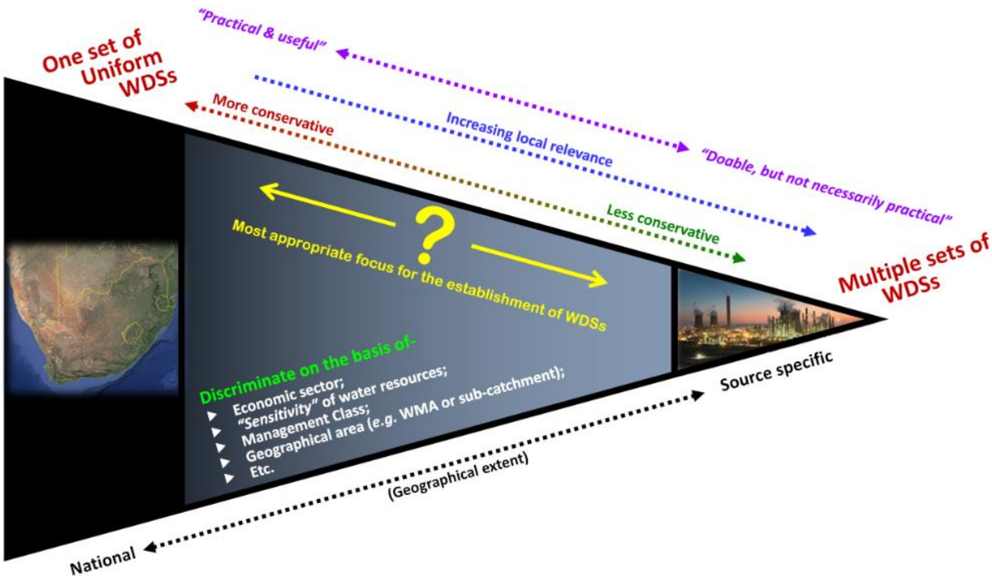

FIGURE 44: The establishment of uniform Waste Discharge Standards to support water use authorisation.

For this reason, it is important that a set, or sets, of appropriate uniform WDSs must be developed, in support of Source Directed Management. Uniform WDSs are essential and are useful, because they-

- can be utilised as benchmarks during the authorisation of waste and water containing waste related water use;

[217] Refer to **POLICY STATEMENT 4**: The application of the precautionary principle.

[218] Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives approach applied to eutrophication management.

- provide a practical, albeit conservative, way to give effect to RDMs;
- complement the mitigation hierarchy for decision-making on eutrophication[219] and because they can be used to promote precaution[220] in cases of uncertainty;
- can be referenced in waste and water containing waste related water use authorisations, potentially allowing for periodic updating of the said uniform WDSs without necessarily having to amend the water use authorisations in question; and
- can be administered and maintained effectively through the publication in regulations[221].

Factors that must be considered when uniform WDSs are being developed for typical water resource use scenarios, include:

- The size of the discharge;
- The size of the river;
- The water quality of the effluent;
- The catchment background water quality;
- Water quality of the receiving surface water resource(s);
- The mixing ratio;
- The effects of seasonality;
- Recognised receiving water users that must be protected;
- Ecological importance and sensitivity;
- The required levels of protection;
- The capability of treatment technologies (BPEO)[222];
- The history and nature of activities;
- Potential cumulative effects; and
- The associated socio-economic consequences.

Additionally to the need to revise and update the uniform WDSs, WDSs can also be determined on an *ad hoc* basis for inclusion in water use authorisations on a case-by-case basis. This may be necessary in the absence of suitable uniform WDSs, or when there is a justified need for deviation, once they are determined, from the uniform WDSs, such as to enforce stricter or more lenient WDSs in accordance with the differentiated approach[223]. Whether enforcing WDSs that were determined on an *ad hoc* basis, or that were derived from any uniform WDSs, it is vital that the Receiving Water Quality Objectives approach[224] must be operationalised, either, locally, for the water resource in question or, regionally, for a water resource system type! The further the WDSs applicability moves away from a particular water use, the more conservative such WDSs will have to be in order to ensure that effect is given to RDMs.

3.2.2.2.3 Water use

Section 21 of the NWA (36:1998) collectively defines 11 consumptive and non-consumptive water uses (**TABLE 18**), which may have a profound or more subtle effect on eutrophication:

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219 Refer to **POLICY STATEMENT 2**: The mitigation hierarchy for decision-making on eutrophication.

220 Refer to **POLICY STATEMENT 4**: The application of the precautionary principle.

221 Refer to S. 26(1)(h), NWA (36:1998): *"The Minister may make regulations prescribing waste standards which specify the quantity, quality and temperature of waste which may be discharged or deposited into or allowed to enter a water resource."*, and **ANNEXURE E** for other regulations.

222 Refer to **POLICY STATEMENT 9**: The application of the Best Practicable Environmental Option.

223 Refer to **POLICY STATEMENT 3**: The differentiated approach for the control of excessive nutrient-loading.

224 Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives approach applied to eutrophication management.

TABLE 18: Water uses and their potential effect on eutrophication.

FOR THE PURPOSES OF THE (NWA 36:1998), WATER USE INCLUDES –		DIRECT RELEVANCE	NOTES
S.21(a)	taking water from a water resource;	✗	These water uses can affects the dilution capacity of receiving water resources, which may have an indirect effect on eutrophication.
S.21(b)	storing water;	✗	
S.21(c)	impeding or diverting the flow of water in a watercourse;	✗	
S.21(d)	engaging in a stream flow reduction activity;	✗	
S.21(e)	**engaging in a controlled activity;**	✓	The irrigation of any land with waste or water containing waste, generated through any industrial activity or by a waterwork, has the potential to generate excessive diffuse nutrient pollution of surface and groundwater resources.
S.21(f)	**discharging waste or water containing waste into a water resource through a pipe, canal, sewer, sea outfall or other conduit;**	✓	The discharge of water containing waste, such as sewage or industrial effluent, has the potential to promote excessive nutrient-loading, and to cause anthropogenic eutrophication.
S.21(g)	**disposing of waste in a manner which may detrimentally impact on a water resource;**	✓	Waste disposal activities has the potential to generate excessive diffuse nutrient pollution of surface and groundwater resources.
S.21(h)	**disposing in any manner of water which contains waste from, or which has been heated in, any industrial or power generation process;**	✓	Sea-outfalls has the potential to promote anthropogenic eutrophication of the marine waters.
S.21(i)	altering the bed, banks, course or characteristics of a watercourse;	✗	The alteration of aquatic ecosystems can indirectly affect eutrophication.
S.21(j)	**removing, discharging or disposing of water found underground if it is necessary for the efficient continuation of an activity or for the safety of people; and**	✓	Mine water handling, including the discharge of mine water containing waste to water resources[225], has the potential to generate excessive point and diffuse nutrient pollution of surface and groundwater resources.
S.21(k)	using water for recreational purposes.	✗	Recreational water use does not have a direct relationship with eutrophication, other that it being detrimentally affected by it.

TABLE 18 shows that all waste and water containing waste related water uses, potentially, have a direct effect on the nutrient-loading of water resources.

A person who uses water, specifically discharges or disposes waste or water containing waste, as contemplated in Sections 21(e), (f), (g), (h) and (j)–

- must use the water subject to the conditions specified in the relevant water use authorisation;
- is subject to any limitation, restriction or prohibition, in terms of the NWA (36:1998), or any other applicable law;

[225] The pumping of mine water from underground in order to safely and efficiently continue with mining activities constitutes a S.21(j) water use. However, when the pumped underground mine drainage is treated and/ or discharged, the latter action constitutes a S.21(f) water use. Irrigation of mine drainage constitute a S.21(e) water use and the disposal of mine residue constitute a S.21(g) water use. All of these water use examples may promote excessive nutrient-loading.

- must comply with any applicable WDSs or BMPs prescribed under the NWA (36:1998)[226], unless the conditions of the relevant water use authorisation provide otherwise;
- may not waste that water; and
- must return any seepage, runoff or water containing waste, which emanates from that use, to the water resource from which the water was taken, unless the DWS, or a CMA directs otherwise, or the relevant water use authorisation provides otherwise.

3.2.2.2.4 Registration of water use

Any person who uses water in terms of Section 21 of the NWA (36:1998) must register[227] such water use, except-

- any water use listed in Schedule 1 of the NWA (36:1998);
- where registration is not required in terms of a GA; and
- a person who obtains water from a bulk water supplier, a Water Management Institution, or from a communal scheme.

Registration of a water use is not an entitlement to use water and must not be confused with a water use authorisation. A person who no longer wishes to continue with his or her registered water use must apply to the responsible authority for the deregistration of that water use.

Water use registration information is important to eutrophication management, because–

- It serves as official notifying of lawful waste and water containing waste related water uses;
- It serves as basis for water quality planning and management; and
- It potentially supports the determination of allocated and allocatable water quality.

Verification and Validation (V&V) of waste and water containing waste related water uses should be prioritised to ensure proper registration of such water uses and to determine the extent of lawfulness.

3.2.2.2.5 Lawful water use

Water uses are only permissible, in terms of the NWA (36:1998), if any of the following five entitlements are in place, *i.e.* if a water uses is (**FIGURE 45**)-

- listed in Schedule 1 of the NWA (36:1998);
- generally authorised;
- An Existing Lawful water Use (ELU)[48];
- authorised under an alternative authorisation, if dispensing with the requirement for a licence; or
- licenced.

226 Refer to Section 26(1)(h) and (i) of the NWA (36:1998).

227 Section 26(1)(c) of the NWA (36:1998) allows for registration of all water uses, including ELU in terms of Section 34(2). Section 29(1)(b)(vi) also states that in the case of a GA, the responsible authority may attach a condition requiring the registration of such water use.

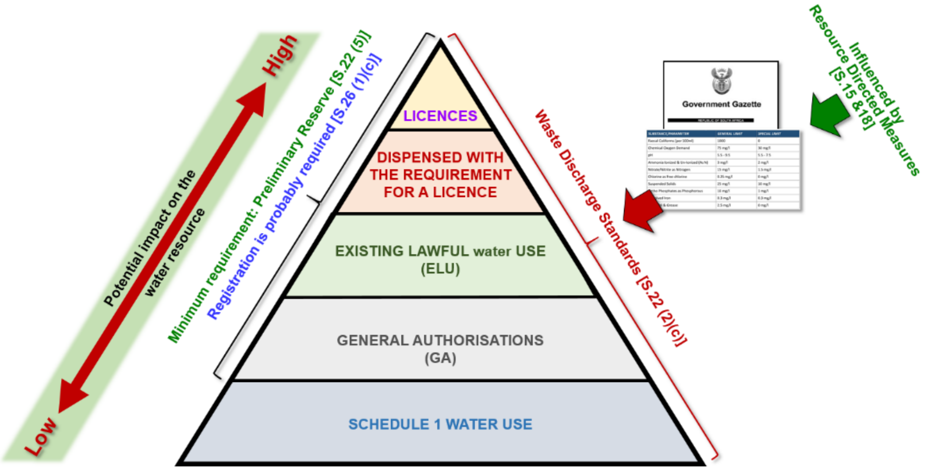

FIGURE 45: Illustration of permissible water use, with references to sections in the NWA (36:1998).

The terms of such entitlements are typically set out in the form of conditions in authorisations or approvals. In the case of the waste and water containing waste related water uses, as highlighted in **TABLE 18**, the conditions set out in the required authorisations or approvals can be utilised to control and manage anthropogenic eutrophication, while at the same time also supporting the need for socio-economic development. These conditions in the waste and water containing waste related authorisations or approvals often also specify WDSs (**Section 3.2.2.2.2**, **Part 3**). A lawful water use, therefore, is a water use that is both permissible, in terms of the NWA (36:1998), and that are compliant with the applicable conditions, including the stipulated WDSs, contained in the water use authorisation or approval in question (**FIGURE 46**).

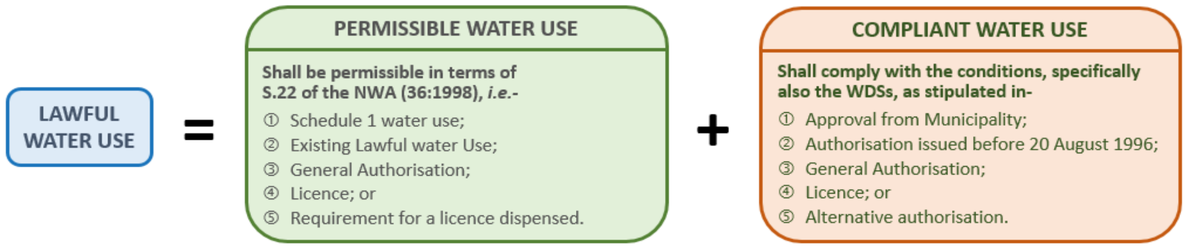

FIGURE 46: Illustration of lawful water use.

The purpose of water use authorisations [adapted from DWAF, 2006a] is to-

- ensure that water is used for the authorised purpose(s) only; and
- enable the DWS to give effect to receiving water resource requirements, such as RQOs, and hence to contribute towards ecologically sustainable development.

Compliance monitoring (**Section 3.3.2.2.1**) and enforcement (**Section 3.4.2.2**) play a vital role in the implementation of WDSs and constitute an essential aspect of eutrophication management!

3.2.2.2.6 Schedule 1 water use

The purpose of Schedule 1 water use is to allow small impact water uses to continue without adding to the administrative burden of the licensing process. Schedule 1 water use entitles a person to use water for reasonable domestic use, and not for commercial purpose. Schedule 1 water use, *inter alia*, includes the discharge of-

- waste or water containing waste; or
- runoff water, including stormwater from any residential, recreational, commercial or industrial site,

into a canal, sea outfall or other conduit controlled by a third party authorised to undertake the purification, treatment and/ or disposal of waste or water containing waste, subject to the approval of the third party controlling the canal, sea outfall or other conduit.

Cumulatively, industrial and commercial waste, water containing waste and runoff water has the potential to detrimentally affect the functioning and performance of WWTWs. A better understanding of the water quality character of these Schedule 1 water uses and their influence on municipal wastewater handling, is necessary in order to obtain an improved national understanding of the poor performance records of many municipal WWTWs.

It is foreseen that such an improved national understanding will be beneficial to eutrophication management in South Africa and that additional water quality management intelligence can be generated, such as:

- Information about the character of wastewater and stormwater streams received from commercial and industrial activities, and the effects thereof on municipal WWTWs;
- Information on source directed controls and measures, if any, being applied within the municipal water management environment, including the employment of municipal WDSs, the issuing of conditional approvals and the use of bylaws;
- Compliance information in connection with wastewater and stormwater treatment, if any, by commercial and industrial activities that discharge to municipal sewer network systems; and
- Information on wastewater and stormwater reuse and recycling to promote water conservation and water demand management.

Such additional water quality management intelligence can be utilised to, *inter alia*, inform:

- Research relating to the handling of waste, water containing waste and stormwater by the commercial and industrial activities, and by municipalities; and
- Research and development to improve treatment technologies and application.

3.2.2.2.7 General Authorisations

The purpose of generally authorised water use[228] is to allow relatively low impact water uses to continue and to ease the administrative burden of the licensing process. GAs allow water users to use water without a licence, provided that such water use are exercised within the conditions set out in the relevant GA. GAs for waste and water containing waste related water uses, *i.e.* for the Section 21 (e), (f), (g), (h) and (j) water uses, are available. GAs are not necessarily applicable to the whole country and may only be applicable to specific rivers or catchments. GAs are generally reviewed every five years. It is critical that the cumulative effects of generally authorised water uses must not result in the violation of the relevant RDMs and that effect is given to the Receiving Water Quality Objectives approach[229].

The water use and water resource data and information required by GAs, are vital! For this information to be useful, the provision of relevant water quality and volumetric data must be called for and accepted through a public *e*-portal into database(s) that allow for central interrogation in an information management system, such as a potential IRiS-WMS combination. In this way, a better handle on the cumulative impacts of generally authorised water uses and other water uses, and their collective relationship with RDMs, within the context of the catchment, can be obtained. Once uniform WDSs have been developed, the wastewater limit values in GAs should be substituted with the updated WDSs or references to the uniform WDSs should be included.

[228] Refer to Section 39 of the NWA (36:1998).

[229] Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives approach applied to eutrophication management.

3.2.2.2.8 Existing Lawful water Use (ELU)

Section 32 of NWA (36:1998) identifies water uses that were authorised under legislation, which was in force immediately before the date of commencement of the NWA (36:1998), as Existing Lawful water Use (ELU)[48]. This is subject to the requirement that such water uses took place at any time during the two years prior to the date of commencement of the NWA (36:1998), *viz.* 1 October 1998. The purpose of ELU is to enable existing economic activities, based on the use of water, to continue until such time as compulsory licensing is called for in a particular area.

It is highly likely that ELUs with a potential to cause excessive nutrient-loading, such as those water uses associated with some municipal, industrial or agricultural activities, still exist today. It is also likely that the conditions that were formulated at the time of authorising those water uses, in many cases several years ago, are now out-dated or inadequate. The extent of the compounded nutrient-loading effect on water resources, as a result of possible out-dated and inadequate ELU authorisation conditions is unknown. In order to ascertain whether this observation, indeed, poses an obstacle to giving effect to RDMs, it would be required to commission the necessary Validation and Verification (V&V) studies of all waste and water containing waste related water uses, *i.e.* those highlighted in **TABLE 18**, to update the Water use Authorisation and Registration Management System (WARMS) and to assess the effects of such water uses on RDMs. This will allow the DWS to commission compulsory licensing campaigns, where necessary, to replace all heritage authorisations with licences. In the interim, and prior to the extent of the potential problem, and/ or the outcomes of any V&V studies becoming known and the conclusion of any compulsory licensing campaigns, the DWS may wish to improve the regulation of ELUs by means of a regulation published under Section 26 of the NWA (36:1998)[230].

3.2.2.2.9 Water use licensing

Water users must apply for water use licenses for any new water use that is not listed under Schedule 1 of the NWA (36:1998) or that is not covered by a GA. The purpose of licensing is to control water uses that exceed the limits outlined in Schedule 1 of then NWA (36:1998) and those allowed under GAs.

Effective licensing administration is of utmost importance to eutrophication management, as is knowledge of waste and water containing waste related water uses that are not permissible under the NWA (36:1998). Licensing, currently, is the single most important instrument in the DWS's arsenal to control and manage waste and water containing waste related water uses with an adverse impact potential. Unlawful water use poses a threat to ecologically sustainable development and to the country!

Water use licences give existing or new water users formal authorisation to use water for productive and beneficial purposes, and specify the conditions, including WDSs, under which the water can be used. It is critical that the cumulative effects of all authorised water uses must not result in the violation of relevant RDMs and effect must be given to the Receiving Water Quality Objectives approach[231] .

The NWA (36:1998) makes provision for two types of applications for water use licences, *viz.* individual and compulsory applications.

Compulsory licensing will prioritise areas with water shortages (where current or future water demand exceeds water supply) or where pollution is severe (stressed catchments). The compulsory licensing process may be utilised to–

- achieve a fair allocation of water from stressed water resources;
- achieve equity in water allocation through the Water Allocation Reform (WAR) programme;
- promote beneficial use of water in the public interest;
- facilitate water use efficiency; and

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230 Refer to S. 26(1)(a), NWA (36:1998): *"The Minister may make regulations limiting or restricting the purpose, manner or extent of water use."*, and **ANNEXURE E** for other regulations.

231 Refer to **POLICY STATEMENT 5**: The Receiving Water Quality Objectives approach applied to eutrophication management.

- protect water resource quality.

It is important that users register their existing use so that their existing use is taken into account during compulsory licensing. Catchments that are severely impacted by excessive nutrient-loading, or where licence conditions, specifically the WDSs, do not fully implement the Receiving Water Quality Objectives approach and where effect is not given to RDMs, must be identified. These areas or river systems can be prioritised for compulsory licensing.

The water use and water resource data and information required by licenses, are vital! For this information to be useful, the provision of relevant water quality and volumetric data must be called for and accepted through a public *e*-portal into database(s) that allow for central interrogation in an information management system, such as a potential IRiS-WMS combination. In this way, a better handle on the cumulative impacts of licenced water uses and other water uses, and their collective relationship with RDMs, within the context of the catchment, can be obtained.

A licence may be issued for a maximum of 40 years[232] and licence conditions may be reviewed at a review period listed in the licence, which may be any period not exceeding five years[233]. The responsible authority may amend any condition of a licence by agreement with the licensee[234].

3.2.2.2.10 Alternative authorisations

The DWS, or a CMA may dispense with the requirement for a water use licence if satisfied that the purpose of the NWA (36:1998) will be met by the granting of a licence, permit or other authorisation under any other law. In the interests of cooperative management, the DWS, or a CMA, may promote arrangements with other organs of state to combine authorisation requirements into a single authorisation requirement.

Alternative authorisations, which may have a bearing on eutrophication management, include the regulation of land use activities and the control of development activities through regulations, Environmental Management Programme Reports (EMPRs) for mining, Environmental Impact Assessments (EIAs), atmospheric emission licences, waste management licences, coastal waters discharge permits, prohibitions on certain activities, in line with the National Freshwater Ecosystem Priority Areas (NFEPAs), setting of product or technical production standards, and setting of performance standards. Synergy between alternative authorisations, including the examples listed above must be explored, in the interest of management cooperation[235] and efficient eutrophication management.

3.2.2.2.11 Diffuse pollution sources

In comparison to point source pollution, diffuse source pollution and their impacts on human and ecosystem health largely remain under-reported and under-regulated. This is because diffuse pollution sources are challenging to monitor and regulate due to [OECD, 2017]–

- their high variability, spatially and temporally, making attribution of sources of pollution complex;
- the high transaction costs associated with dealing with large numbers of heterogeneous polluters (*e.g.* agriculture, formal and informal settlements, industry, etc.); and
- because diffuse source pollution control may require co-operation and agreement within catchments, and across sub-national jurisdictions and even in different co-basin states.

It is necessary, and more effective, to utilise combinations of the different management instruments for environmental compliance[236], *i.e.* the command-and-control, economic, self-regulatory and societal participation instruments, to improve pollution control, and to manage diffuse nutrient-loading of water

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232 Refer to Section 28(1)(e), NWA (36:1998).

233 Refer to Section 28(1)(f), NWA (36:1998).

234 Refer to Section 52(4), NWA (36:1998).

235 Refer to **POLICY STATEMENT 19:** Cooperative management.

236 Refer to **POLICY STATEMENT 1**: Application of management instruments for environmental compliance in eutrophication management.

resources and ultimately anthropogenic eutrophication. Some instruments that may potentially be employed to manage anthropogenic eutrophication from a diffuse origin are listed in **TABLE 19**. These instruments must be investigated, further developed and rolled-out for eutrophication management, as part of a diffuse source or non-point source (NPS) strategy.

The fact that the control and management of diffuse sources of pollution is broader than only the management of eutrophication, necessitates the establishment of a diffuse source or non-point source (NPS) strategy for South Africa that addresses the full spectrum of diffuse pollution challenges. Such a strategy may include the identification of P and N vulnerable zones to protect surface and groundwater resources in particular areas and to enforce stricter or special source directed measures and controls. Within these zones, for instance, specific fertiliser, manure, crop and livestock farming practices could be made mandatory. Legislative amendments may be required and need to be investigated, as part of the development of a NPS Strategy for South Africa[237].

TABLE 19: Management instruments to address excessive diffuse nutrient-loading of water resources.

Command and control management instruments:	**Societal participation management instruments:**
▶ The use of WDSs to control the discharge of collected diffuse polluted return-flow water, *e.g.* irrigation return-flows and stormwater; ▶ The use of WDSs to control modelled diffuse water quality outputs; ▶ Conditional water use authorisations to control the discharge of collected diffuse polluted return-flow water, *e.g.* irrigation return-flows and stormwater; ▶ Mandatory BMPs[238], including the introduction and maintenance of buffer areas; ▶ Mandatory diffuse source pollution management plans, *e.g.* irrigation management plans, etc.; ▶ Load allocations to diffuse nutrient contributors;	▶ Information and awareness campaigns; ▶ Farm advisory and extension services for improved farming techniques (to minimise negative impacts on water quality and to protect agricultural resources); ▶ *"Management-by-shame"* as a tool, is also often employed by catchment forums, which enjoy diverse representation of forum members with many different interest, views and objectives that require balancing; ▶ Best environmental practices (or good management practices); and ▶ Environmental labelling – products that meet certain environmental standards can be marketed and sold at a premium and/ or subsidised.
Economic management instruments:	**Self-regulatory management instruments:**
▶ Pollution taxes (on inputs), *e.g.* additional tax on herbicides and pesticides*; ▶ WDCS (on outputs); ▶ Replace synthetic fertilisers with organic fertilisers, thereby promoting recycling and reuse of waste; ▶ Government capital funding to upgrade and maintain wastewater sludge infrastructure and waste disposal; and ▶ Payment for ecological infrastructure services.	▶ Contracts/ bonds (*e.g.* land retirement contracts); and ▶ Voluntary standards and management systems.

* May require a legislative amendment[239].

[237] Refer to **ANNEXURE G** for a list of all recommended legislative amendments.

[238] Refer to Refer to S. 26(1)(i), NWA (36:1998): *"The Minister may make regulations prescribing the outcome or effect which must be achieved through **management practices** for the treatment of waste, or any class of waste, before it is discharged or deposited into or allowed to enter a water resource"*, and **ANNEXURE E** for other regulations.

[239] Refer to **ANNEXURE G** for a list of all recommended legislative amendments.

3.2.2.2.12 Differentiated water use management based on risk

In order to use the limited government human and financial resources judiciously and to achieve the greatest impact, a targeted risk-based approach must be adopted to control and manage water use. Under this approach, the potential significance of the impact of water pollution will inform the level of response or intervention from the state. Thus, areas of particular sensitivity will receive heightened attention, as will activities from which the pollution potential is of a particularly hazardous nature and areas where pollution is already extremely high. Such a targeted risk-based approach should–

- be used for the categorisation of water polluters, based on risk[240], to strengthen differentiated control and management in support of ecologically sustainable development;
- be used to revise the administrative fees for water use authorisation applications;
- inform the water use authorisation process; and
- inform financial provisioning, potentially, to be extended beyond mining to other high risk water users to address *post facto* remedial actions that may be requirements.

3.2.2.3 Incentive-based regulation

3.2.2.3.1 Waste Discharge Charge System (WDCS)

The Waste Discharge Charge System (WDCS) is being developed to promote waste reduction and water conservation. It forms part of the Pricing Strategy, established under the NWA (36:1998). The WDCS is based on the polluter-pays principle and aims to–

- promote the efficient use of water resources and ecologically sustainable development;
- promote the internalisation of environmental costs by impactors;
- create financial incentives to promote the reduction, recycling and reuse of waste and water containing waste, and to use water resources in an optimal manner; and
- recover costs associated with the mitigating of resource quality impacts caused by waste and water containing waste related water uses.

Differential rates for discharges can be employed by the WDCS to also address discharges that contribute to excessive nutrient-loading, taking into account–

- the characteristics of the particular waste discharged;
- the load and concentration of any substance being discharged;
- the nature and extent of the impact on a water resource caused by the waste discharged;
- the extent of the permitted deviation from prescribed WDSs or management practices; and
- the required extent and nature of monitoring the water use.

The WDSC must be implemented in catchments or in sub-catchments, as may be appropriate, irrespective of whether the relevant water resource Management Class(es) (and RQOs/ Reserves) is/ are being met or not, as per the waste mitigation hierarchy requirements of Section 2(4) of NEMA (107:1998)[241].

The WDCS must be piloted and implemented to reduce anthropogenic eutrophication[242].

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[240] An amendment of the NWA (36:1998) is required to allow for the categorisation of polluting industries, based on risk. Refer to **ANNEXURE G** for a list of all recommended legislative amendments.

[241] Refer to **POLICY STATEMENT 2**: The mitigation hierarchy for decision-making on eutrophication.

[242] In order for the Waste Discharge Levy to be introduced, an amendment to the NWA (36:1998) is required to give the Minister permission to promulgate a Money Bill. Refer to **ANNEXURE G** for a list of all recommended legislative amendments.

3.2.2.3.2 Certification Schemes

Non-economic incentive based regulatory approaches, specifically the utilisation of certification schemes, have gained significant momentum in South Africa [DWS, 2014], and currently include the–

- Blue Drop Certification Programme for drinking water quality management regulation;
- No Drop Certification Programme for water use efficiency and water loss management; and
- Green Drop Certification Programme for wastewater quality management regulation.

The Green Drop process measures and compares the results of the performance of water service authorities and their providers via a standardised scorecard, and subsequently rewards (or penalises) the municipality upon evidence of their excellence (or failures) according to the minimum standards or requirements that has been defined. Awareness of this performance is obtained by pressure from customers, the media, political classes and Non-Governmental Organisations (NGOs). The Programme revolves around the identification of mediocre performing municipalities which consequently correct identified shortcomings, as well as the introduction of competitiveness amongst the municipalities and using benchmarking in a market where competition is difficult to implement. The Green Drop System (GDS) must urgently be strengthened, expanded and implemented on a sustainable basis.

3.2.2.3.3 Water Polluter Register

A Water Polluter Register (or Water User Register), extending reporting to beyond municipalities and to incentivize polluters to reduce their pollution must be investigated and potentially implemented. In the Water Polluter Register, parties that are meeting BMP standards will be recognised, as will non-compliance by polluting parties. This will require an amendment of the NWA (36:1998)[243].

3.2.2.3.4 Eco-labelling

Eco-labelling can be considered as an extension of conventional marketing practices – a profit-driven response by industry to the commercial pressures of green consumer-consciousness. OECD, 1991 interprets the goals of environmental labelling as follows:

- Improving the sales or image of a labelled product;
- Raising the awareness of consumers;
- Providing accurate information;
- Directing manufacturers to account for the environmental impact of their products; and
- Protecting the environment.

The merits of adopting an eco-labelling scheme for problem nutrients must be investigated and potentially implemented, acknowledging the ambitions of eutrophication management policy[244].

This will require an amendment of the NWA (36:1998)[245].

3.2.3 Spatial scale of implementation

The operational strategies in the *"do"* stage of the eutrophication management framework focus on Source Directed Management, addressing the sources of impacts at a source specific scale through source directed measures and controls. These source directed measures and controls are mostly established and enforced by relevant authorities, but private sector, through self-regulation and voluntary initiatives, and civil society, through management participation and often acting as *"watchdogs"*, also play important roles.

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[243] Refer to **ANNEXURE G** for a list of all recommended legislative amendments.

[244] Refer to **POLICY STATEMENT 6**: A life cycle view on nutrient-loading.

[245] Refer to **ANNEXURE G** for a list of all recommended legislative amendments.

3.2.4 Temporal scale of implementation

The operational strategies, being part of the *"do"* stage in the eutrophication management framework, can be conducted on an *ad hoc* basis or regularly, depending on the purpose. **TABLE 20** gives a summary of potential outstanding actions:

TABLE 20: Actions to strengthen the *"do"* stage of the eutrophication management framework.

	SHORT-TERM
1.	V&V including volumes discharged
	The DWS will be responsible for the national assessment of water quality based on this data and will report annually to Parliament on the state of water quality in the country, including the performance of local government management of waste water through the Green Drop reports. To achieve this, DWS with strengthen its role in the monitoring and evaluation of performance by local government.
2.	Law review to enforce monitoring within the municipal water value chain
3.	BPGs for pollution avoidance and prevention, minimisation, remediation and offsetting
4.	By-laws
5.	
	LONGER-TERM
6.	
8.	

3.3 The *"check"* stage

Altogether the *"check"* stage, in the eutrophication management framework, must–

- support trans-boundary and international monitoring campaigns;
- generate national and regional intelligence on nutrient-loading and the trophic status of receiving water resources;
- monitor compliance of land and water use activities to any applicable regulatory requirements that support the limiting of anthropogenic eutrophication;
- evaluate the implementation and effectiveness of management interventions, which aims to limit nutrient loading and anthropogenic eutrophication; and
- establish suitable information management systems to enable and improve data handling and the generation of eutrophication-related management information.

The *"check"* stage, in the eutrophication management framework, focuses on four operational strategies, depicted in **FIGURE 47**.

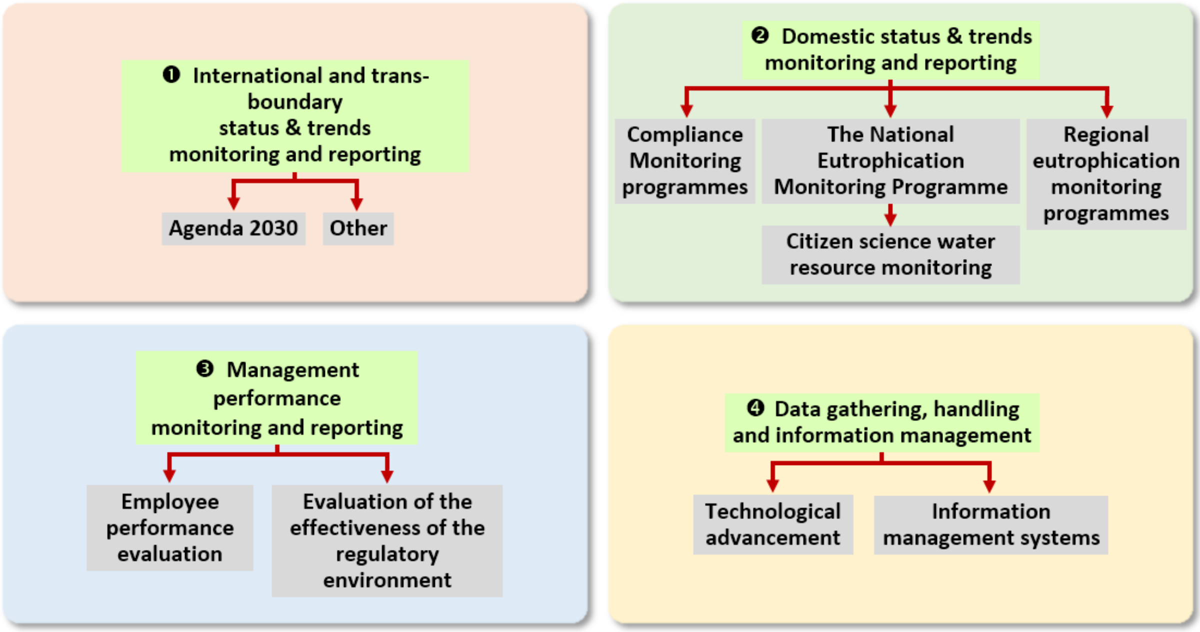

FIGURE 47: Conceptual outline of the *"check"* stage in the eutrophication management framework.

These four operational strategies and their purpose and composition are summarised in **TABLE 21**:

TABLE 21: The operational strategies, in the *"check"* stage of the eutrophication management framework, and their composition.

OPERATIONAL STRATEGIES AND PURPOSE		KEY COMPONENT(S)
1. International and trans-boundary status and trends monitoring and reporting	*To support transboundary and international eutrophication management related monitoring programmes*	Agenda 2030 and potential similar future programmes; and
		Other international and trans-boundary eutrophication-related monitoring programmes.
2. Domestic status and trends monitoring and reporting	*To monitor land and water use compliance to eutrophication management related regulatory requirements, and to track the national and regional trophic statuses of water resources.*	Compliance monitoring programmes;
		The National Eutrophication Monitoring Programme; and
		Regional eutrophication monitoring programmes.
		Citizen science water resource monitoring
3. Management performance monitoring and reporting	*To track the implementation and effectiveness of eutrophication management measures.*	Employee performance evaluation; and
		Evaluation of the effectiveness of the regulatory environment.
4. Data acquisition and information management	*To ensure access to eutrophication-related data and information.*	Technological advancement
		Information management systems.

3.3.1 Authority

It is vital that the causes of anthropogenic eutrophication and the effects of excessive nutrient loading on water resources, and on social and economic development, must be monitored by relevant authorities to gauge the effectiveness of regulatory approaches, and to identify potential management shortcomings and possible improvement. Competencies (sectors), which are relevant here, include agriculture; water and sanitation; environment; and mining. Sectoral mandates are summarised in Chapter 5, Part 3.

3.3.2 Prescribed approaches

"You can't manage what you don't measure!" Author: Peter Drucker

3.3.2.1 International and trans-boundary status and trends monitoring and reporting

3.3.2.1.1 Agenda 2030 and potential similar future programmes

Agenda 2030 calls for the regular monitoring of a series of indicators (**FIGURE 48**) and for the reporting on a three yearly basis to the United Nations (UN) on the sustainability of water resource use in countries. SDG Target Indicator 6.3.2 constitutes the ultimate indicator to demonstrate and track the fitness-for-use of countries' water resources, specifically also including requirements to report on the nitrate-nitrite (NO_3-NO_2) and orthophosphate (PO_4) status and trends observed in receiving water resources. Agenda 2030 also calls for the regular compliance monitoring and reporting to the UN on a number of point and diffuse sources (through the additional indicators) of water pollution that potentially contribute towards anthropogenic eutrophication. These monitoring and reporting approaches should be internalised and expanded to improve South Africa's domestic monitoring programmes[246], in support of effective eutrophication planning, regulation and management.

Reporting to the UN on these aspects must not be viewed as additional requirements, but should be integrated into the day-to-day agenda to manage eutrophication and to generate suitable water quality intelligence to promote effective water quality management and water security. Similar to the SDGs constituting a country programme, eutrophication management must also become part of the country approach aiming to facilitate ecologically sustainable development.

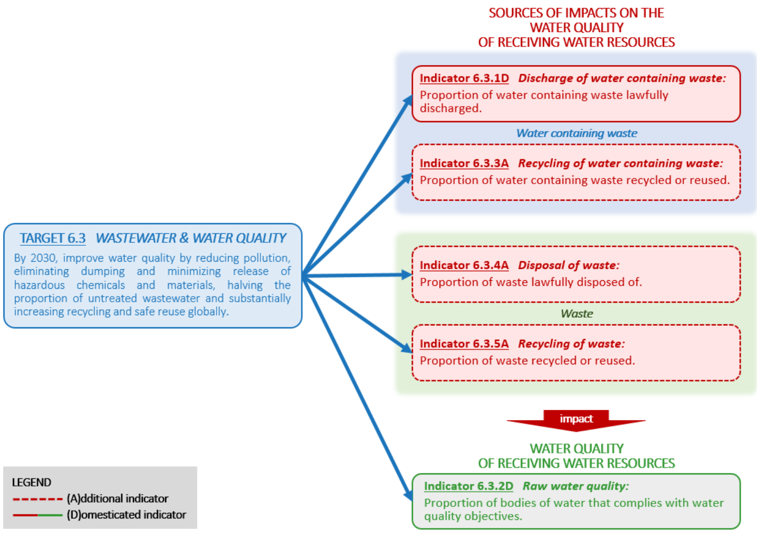

FIGURE 48: Relationship between SDG Target 6.3 and its indicators [Van Wyk, et al., 2020].

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[246] Refer to **Section 3.3.2.2:** Domestic status and trends monitoring and reporting.

3.3.2.1.2 Other international and trans-boundary eutrophication-related monitoring programmes

International and trans-boundary water resource quality status and trend monitoring programmes focus on shared drainage regions, and drainage regions or ecological infrastructure of international significance. These programmes mostly aim to address matters of global relevance; or to deal with matters of common interest in order to promote healthy relations and sustainable water resource use and development through collaboration and water diplomacy.

The GEMS/Water Programme is a good example of such an international monitoring programme. The GEMS/Water Programme was established in 1978 as an interagency programme under the auspices of the United Nations to collect world-wide water quality data for assessments of status and trends in global inland water quality. In 2003, South Africa joined in the GEMS/Water Programme – being an active participant ever since [Van Niekerk, 2004]. **FIGURE 49** provides an international profile, which emanated from this programme, of phosphorus loading of major lakes. Today, the GEMS/Water Programme is operating in more than 124 countries around the world and is providing water quality data to a central database known as GEMStat.

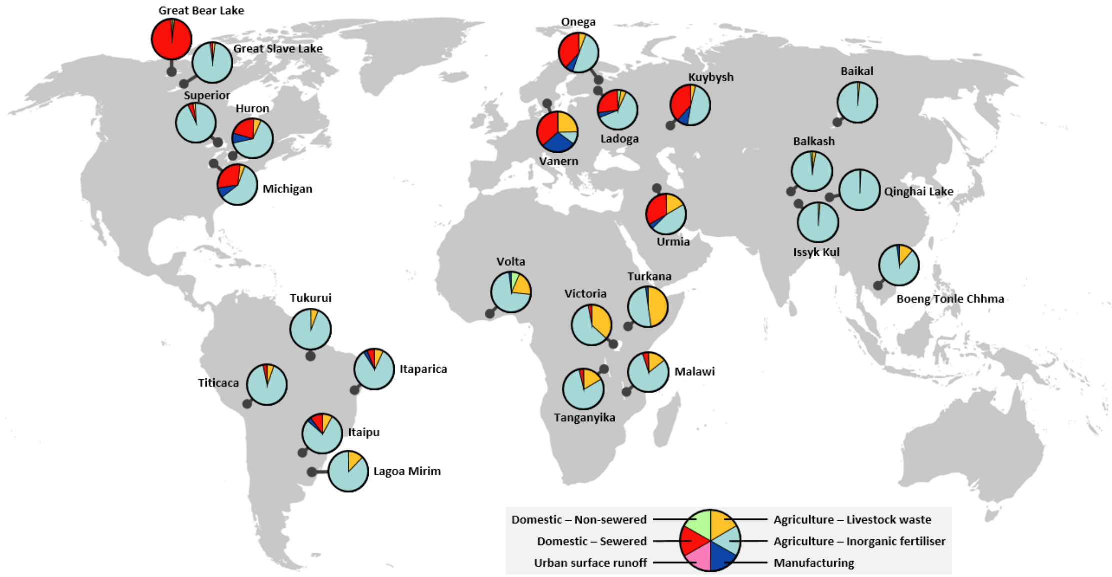

FIGURE 49: Sources of anthropogenic total phosphorus loadings to major lakes, shown as average percentage contributions to annual loading between 2008 and 2010 [UNEP, 2016].

Another example of international collaboration relates to the Ramsar Convention on Wetlands of International Importance where South Africa joined more than 170 other countries in the management of identified significant wetlands. On 21 December 1975, South Africa became a signatory to the Ramsar Convention[247], and consequently needs to regularly report on the status of the 27 South African sites currently designated as Ramsar Wetlands. Of the two South African sites currently listed on the Montreux Record of Ramsar Wetlands – *i.e.* sites *"where changes in ecological character have occurred, are occurring, or are likely to occur as a result of development, pollution or other anthropogenic interference"* – at least one, namely the Blesbokspruit Wetland, is being affected by excessive nutrient (and hydraulic) overloading [Ramsar, 2021].

Additionally, South Africa shares three river basins with sovereign neighbouring countries in the SADC Region (**TABLE 22**):

[247] Refer to **POLICY STATEMENT 8**: Nature-based solutions.

TABLE 22: Shared river basins and water course institutions.

SHARED BASIN	COUNTRIES	SHARED WATER COURSE INSTITUTIONS	AGREEMENT
Inco-Maputo	▶ Eswatini; ▶ Mozambique; and ▶ South Africa.	Tripartite Permanent Technical Committee between the Republic of Mozambique, the Republic of South Africa and the Kingdom of Swaziland (TPTC)	Tripartite Interim Agreement between the Republic of Mozambique and the Republic of South Africa and the Kingdom of Swaziland for co-operation on the protection and sustainable utilisation of the water resources of the Incomati and Maputo Watercourses (2002)
Orange Senqu	▶ Botswana; ▶ Namibia; ▶ Lesotho; and ▶ South Africa.	Orange-Senqu River Commission (ORASECOM)	Revised Agreement between the governments of the Republic of Botswana, the Kingdom of Lesotho, the Republic of Namibia, and the Republic of South Africa on the establishment of the Orange-Senqu Watercourse Commission (2019)
Limpopo	▶ Botswana; ▶ Mozambique; ▶ South Africa; and ▶ Zimbabwe.	Limpopo Watercourse Commission (LIMCOM)	Agreement between the Republic of Botswana, the Republic of Mozambique, the Republic of South Africa and the Republic of Zimbabwe on the establishment of the Limpopo Watercourse Commission (2003)

Of the three shared water course institutions listed above, ORASECOM, in 2000, was the first to be established and to be fully operational. ORASECOM, in 2010, commissioned the first of its joint basin surveys – to be repeated five yearly. The most recent Survey revealed that eutrophic conditions, pertaining to the Orange-Vaal River System, are mostly associated with urban centres, including also downstream of the city of Maseru, Lesotho [Ross-Gillespie, et al., 2015], underscoring the importance for transboundary collaboration[248] on aspects relating to eutrophication monitoring, reporting and management. The remaining three water course institutions have not yet commissioned joint water resource quality surveys.

3.3.2.2 Domestic status and trends monitoring and reporting

Domestic status and trends monitoring, specifically with respect to eutrophication management, should remain focused, cost-effective and sustainable, and must ensure that [DWAF, 2006b, p. 53]–

- monitoring programmes have well-defined objectives;
- the monitoring designs provide the maximum amount of demonstrably useful information at minimum cost;
- data assessments and reports support informed decision-making;
- no duplication of effort occurs at any stage of implementation; and
- partnerships should be created with appropriate stakeholders who will share costs and benefits.

Acknowledging the limitations that may exist with respect to financial and other resources, it is essential that suitable and quality verified resource quality data and information must be collected on an uninterrupted basis to support high confidence water resource planning, informed decision-making and efficient eutrophication management. Water quality, quantity and the aquatic ecosystems are interconnected and the following eutrophication-related data and information (**TABLE 23**), depending on whether causes or effects are being monitored, are regarded as useful and necessary:

[248] Refer to **POLICY STATEMENT 19**: Cooperative management.

TABLE 23: Eutrophication-related variables.	
MONITORING TYPE	**PARAMETER**
	Drivers/ stressors
Physico-chemical monitoring	Typically inorganic variables, but also organic and inorganic toxicants, including temperature, pH, turbidity, Secchi disk depth, DO, BOD, COD and nutrients.
Microbial monitoring	Typically faecal microorganisms, such as *Escherichia coli*, that are also often associated with poorly operated WWTWs.
Volumetric monitoring	Typically stream flow or effluent discharge volumes.
	Responses
Eutrophication monitoring	Use trophic status indices as an indication of the trophic conditions of surface water resources.
Biomonitoring	Use bio-indicators, such as invertebrates and fish, to assess aquatic ecosystem health.
Toxicity monitoring	Such as neuro and hepatotoxins released from some algal species, which can kill animals and pose a threat to human health.

Unnecessary duplication of monitoring must be avoided and monitoring efforts must be harmonised and integrated, where possible and desirable – especially across the various spheres of government, with other existing monitoring programmes. Monitoring programmes must be appropriately resourced and strengthened to support the heightened efforts to clamp down on anthropogenic eutrophication and excessive nutrient-loading. Eutrophication-related information requirements can vary considerably and depend on, among other factors, the spatial scale of interest (**FIGURE 50**).

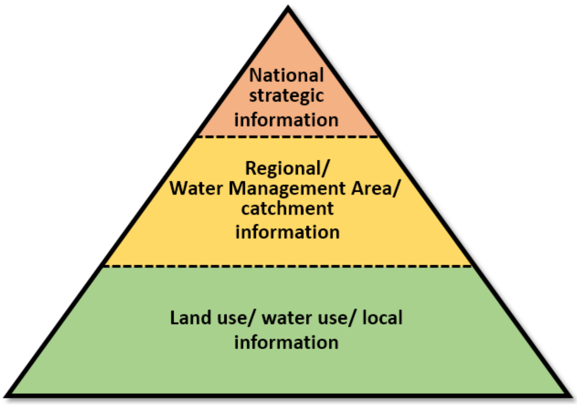

FIGURE 50: Hierarchy of information requirements for eutrophication management [adapted from DWAF, 2006e, p.9].

The following programmes for domestic status and trends monitoring must be maintained:

- Compliance monitoring;
- National eutrophication monitoring; and
- Regional eutrophication monitoring.

These programmes are presented next:

3.3.2.2.1 Compliance monitoring programmes

The **purpose of compliance monitoring** is to measure, assess and report on a regular basis the degree to which–

- municipalities comply with the requirements of certification schemes, such as the Green Drop System;
- individual land and water uses comply with relevant regulatory requirements, such as the WDSs stipulated in the water use authorisations, or conditions stipulated in alternative authorisation; and

- individual land and water uses impact on the local water resource quality.

The primary users and use of this type of information, and their responsibilities are summarised in **TABLE 24**:

TABLE 24: Compliance monitoring information – key users, use and management responsibilities.

KEY USER	USE OF INFORMATION	MANAGEMENT RESPONSIBILITY
Land or water user	The information will indicate to land and water users the extent to which adequate measures have been taken to limit and control likely impacts on the quality of the local water resource. Non-compliance can indicate the need for pro-active corrective actions such land and water users.	The primary responsibility for regulatory compliance resides with the individuals or organisations whose water or land use is being monitored. Water use licence conditions typically stipulate upstream and downstream monitoring, and monitoring of any discharge of water containing waste.
Relevant authority	The information will indicate whether or not land and water users are complying with regulatory conditions, such as those contained in water use licences. Non-compliance may lead to a number of possible actions in order to ensure regulatory compliance.	Relevant authorities have the responsibility to audit the results by performing their own sampling and analysis.

Catchment compliance monitoring (**FIGURE 51**) typically includes-

- monitoring upstream and downstream of point and diffuse sources of impact (*"Level 3"*); and
- monitoring of discharges of water containing waste for compliance with authorisation conditions purposes (*"Level 4"*).

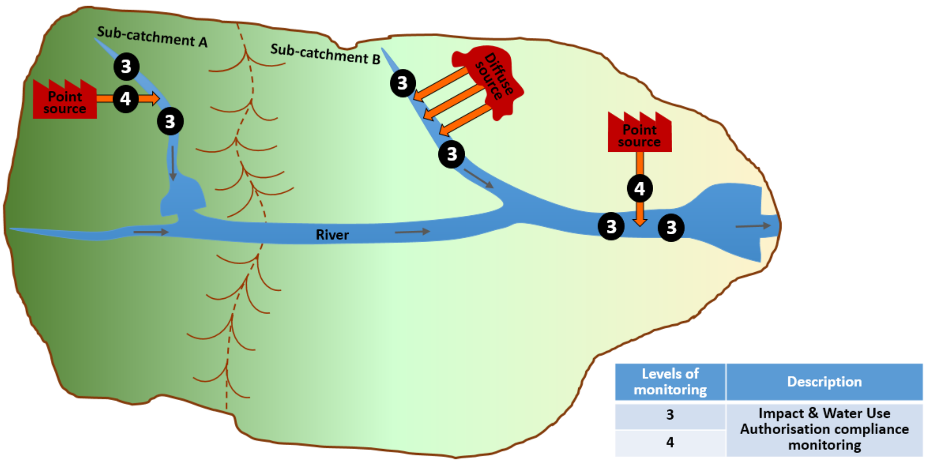

FIGURE 51: Illustration of compliance monitoring levels.

In the interim, the General and Special Standards for the purification of Wastewater or Effluent can be used to assess most effluent data [GN R.991, 1984]. The South African Water Quality Guidelines (among others) can be used to assess water resources [DWAF, 1996]. Where RQOs and RWQOs/ WQPLs are determined, these should be sensibly back-calculated to WDSs to assess effluent data.

Municipalities receive Green Drop status when they achieve scores of 90% or higher, against stringent Green drop assessment requirements. Green Drop scores are given per individual wastewater system within the municipal area for the following:

- Process control, maintenance and management skills;
- Wastewater quality monitoring;
- Credibility of wastewater sampling and analysis;
- Submission of wastewater quality results;

- Wastewater quality compliance;
- Management of wastewater quality failures;
- Storm-water and water demand management;
- By-laws;
- Capacity and facility to reticulate and treat wastewater;
- Publication of wastewater quality performance; and
- Wastewater asset management.

Data will be converted into information and regularly (quarterly or longer) published in compliance monitoring reports that explicitly also address eutrophication management related compliance.

3.3.2.2.2 The National Eutrophication Monitoring Programme

A **national eutrophication status and trends monitoring programme is necessary** to measure, assess and report on the current status and temporal trends of nutrient-loading and other selected indicators of anthropogenic eutrophication in South African water resources, in a manner that will support national strategic management decisions (**FIGURE 52**) in the context of fitness-for-use of water resources and aquatic ecosystem integrity.

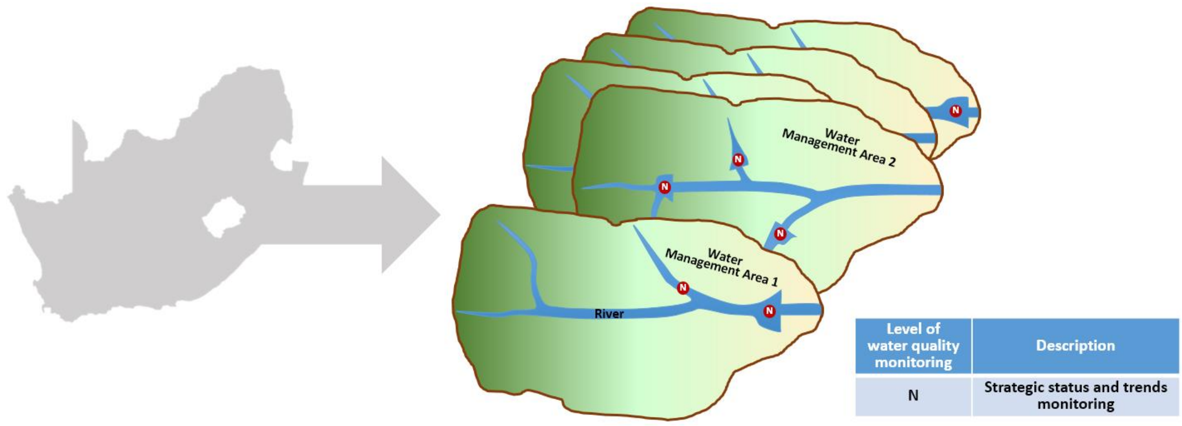

FIGURE 52: Illustration of national status and trend monitoring.

The following strategic responsibilities, that specifically motivate the need for a national eutrophication monitoring perspective, is acknowledged:

- The need to monitor the overall national effectiveness of eutrophication management related policies and strategies, which themselves are usually regionally focussed;
- The need to honour international obligations and participation in appropriate global and trans-boundary initiatives;
- Keeping abreast of international trends in emerging problems; and
- In the current interim transitional phase, the creation of monitoring capacity upon which further region-specific capacity creation can be based, for example as CMAs become operational.

The DWS is the custodian of the National Eutrophication Monitoring Programme (NEMP) (**ANNEXURE F**), which aims to establish [DWAF, 2002] –

- the trophic status, with respect to key reservoirs;
- an early warning system, with respect to wastewater treatment;
- an early warning system, with respect to algal blooms;
- an early warning system, with respect to the presence of invasive macrophytes;
- an early warning system, with respect to potential longer term impacts; and
- strategic nutrient balances.

Data will be converted into information and regularly (annually or longer) published as eutrophication management related status and trends reports, such as Status of the Water Resources Reports and Water Quality Planning-level Review Reports.

3.3.2.2.3 Regional eutrophication monitoring programmes

The **purpose of regional eutrophication monitoring** is to measure, assess and report, on a regular basis, the status and trends relating to excessive nutrient-loading and anthropogenic eutrophication in major water resources, in a manner that will support strategic eutrophication management decisions in Water Management Areas (WMAs) in the context of fitness-for-use of water resources and aquatic ecosystem integrity.

Whereas the DWS takes primary responsibility for all national water quality and related monitoring programmes, as well as for regional water quality monitoring programmes, through the proto-CMAs in the absence of CMAs, the delegation of the responsibility for the implementation, and the associated data management, of regional monitoring programmes to CMAs will occur as and when the CMAs are fully operational and adequately capacitated.

The selection of regional monitoring sites for nutrient-loading and eutrophication-related monitoring, *inter alia*, depends on the availability of in-water resource water quality objectives[58]. In the interim, monitoring sites should be chosen along main watercourses and major tributaries that can be regarded as strategically representative of those water resources (**FIGURE 53**). When RQOs or RWQOs/ WQPLs exist[249], such in-water resource water quality objectives will typically define where compliance is required. Should these sites be of a sufficiently important strategic nature, they must be used. It should also be considered to augment the sites that may exist for the National Eutrophication Monitoring Programme to provide a resolution that is more suitable for the WMA and sub-catchments (**FIGURE 53**). Compatible flow measurement is necessary to assess compliance to NLOs[250].

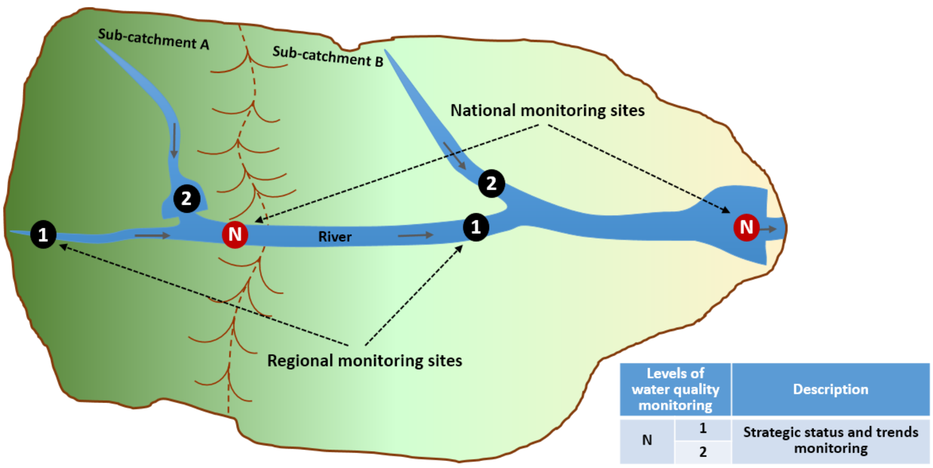

FIGURE 53: Augmenting national monitoring to obtain a regional profile [DWAF, 2006e].

Whereas the *"Level N"* monitoring sites form part of the national eutrophication monitoring network, the *"Levels 1 to 4"* monitoring sites refer to regional water resource quality monitoring [DWS, 2017e] that is geared towards providing regional eutrophication management-related intelligence that is necessary for integrated water quality management at the scale of the WMA and sub-catchments (**FIGURE 53**):

249 Refer to **Section 3.1.2.3**: Goal setting.

250 Refer to **Section 3.1.2.3.2**: Determination of Waste Load Objectives.

- **Impact & Water Use Authorisation compliance monitoring:** This typically entails upstream and downstream monitoring of sources of impact (*"Level 3"*), and monitoring of effluent discharges to monitor compliance with authorisation conditions relating to *"end-of-pipe"* WDSs (*"Level 4"*);
- **Strategic status and trends monitoring:** This can include major watercourses (*"Level 1"*) and key tributaries of those watercourses (*"Level 2"*). This kind of monitoring is conceptually aligned with the objectives of the existing national water quality monitoring programme. However, on a regional and local scale this should ultimately be aligned with the water resource Management Class, in-water resource water quality objectives[58] and Nutrient Load Objectives (NLOs); and
- **Reserve monitoring:** This monitors whether or not water quality meets the requirements of the Reserve.

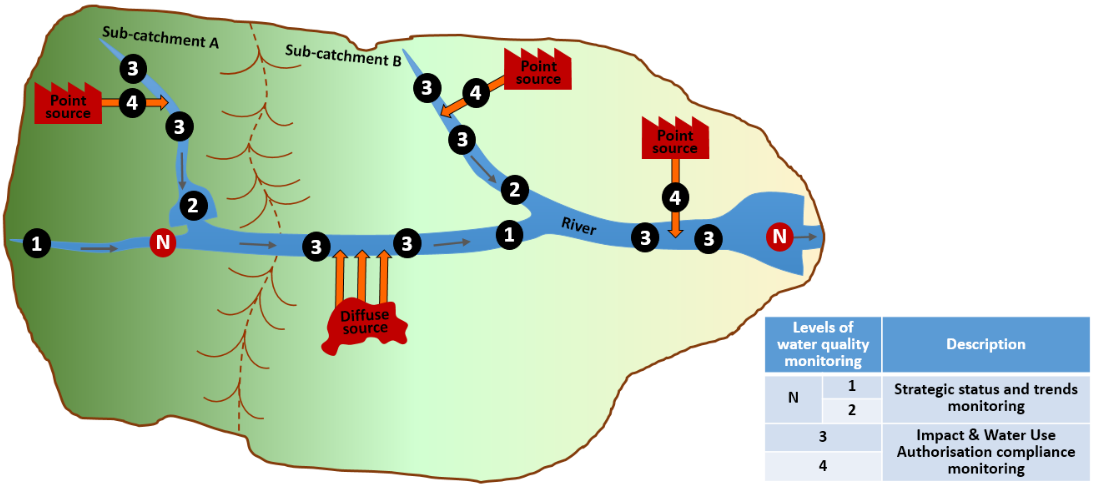

FIGURE 54: Illustration of compliance, and national and regional monitoring.

Data will be converted into information and regularly (monthly or longer) published as eutrophication management related status and trends reports, such as WMA Water Quality Status Reports.

3.3.2.2.4 Citizen science water resource monitoring

"Citizen Science" is scientific research conducted, in whole or in part, by amateur or nonprofessional scientists, often by crowd sourcing and crowd funding. Formally, citizen science has been defined as *"the systematic collection and analysis of data; development of technology; testing of natural phenomena; and the dissemination of these activities by researchers on primarily a vocational basis"*. Citizen science is sometimes also called *"public participation in scientific research"* [Graham & Taylor, 2018].

As a concept, citizen science is growing in popularity and interest in many scientific and social circles. Various water resource monitoring tools exist (**TABLE 25**), which can improve catchment management, particularly with respect to the ability of citizens to improve their understanding, both from the bottom-up (citizens' understanding of catchment issues and societies impacts on water resources), but also from the top-down (authorities' understanding where there are key resource issues and problems).

TABLE 25: The Water Research Commission citizen science toolkit [Graham & Taylor, 2018].

AVAILABLE TOOLS	SUITABILITY TO MONITOR ASPECTS OF EUTROPHICATION
1. Aquatic biomonitoring tool (miniSASS)	A low technology, scientifically reliable and inexpensive participatory tool which can be used by anyone to monitor the health of a river.

AVAILABLE TOOLS	SUITABILITY TO MONITOR ASPECTS OF EUTROPHICATION
2. The Riparian Health Audit;	The Riparian Health Audit is based on the scientific *"Index for Habitat Integrity"* (IHI) method. Users assess a riparian reach by determining its natural condition, identifying the extent of impacts in the reach and then rating the principle impacts, if any, that alter the ecological health of the riparian reach being assessed.
3. The Water Clarity Tube;	Suspended solids affects water clarity and comprises several types of material, including soil particles, planktonic organisms and organic matter.
4. The Transparent Velocity Head Rod;	A very simple tool to measure the velocity and discharge of a stream or river.
5. The Wetland assessment tool;	A method for assessing wetland ecological condition based on land-cover type.
6. The Estuary tool;	Assists with the monitoring and management of an estuary on a routine and structured basis.
7. The Spring tool;	The Spring Health Index tool leads the citizen scientists through a number of steps to determine the current ecological condition of the spring, starting with determining the location and type of spring, investigating the surrounding land cover and use and the geomorphology of the area. The ecological condition is calculated as the percentage of change that has occurred to the spring system, compared to its natural (original) condition, giving a description of the current conditions of the spring.
8. Rain Gauge;	Capturing of rainfall data.
9. Weather monitoring tools; and	Capturing wind speed and direction, as well as temperature.

3.3.2.3 Management performance monitoring and reporting

Achieving sound monitoring and reporting in relation to the indicators of eutrophication, as outlined above, is by far the most pressing need, whether it be for compliance monitoring purposes, for national or regional water resource quality monitoring purposes, for citizen science water resource monitoring purposes, or in support of international and trans-boundary monitoring programmes. This view, however, need to be expanded to a more ambitious perspectives on monitoring to better understand the eutrophication causal chain. The paradigm introduced next will assist in understanding and presenting on the results obtained by domestic, and international and trans-boundary monitoring and reporting.

3.3.2.3.1 Employee performance evaluation

Employee performance in most organisations is managed, regularly evaluated and, in most instances, annually reported through the application of performance management and development systems, which are generally linked to such organisations' business plans, or alike.

This is also the case in the civil service. In order to achieve individual excellence and achievement, employee performance management, in government [DPSA, 2007], strives to–

- establish a performance and a learning culture in the Public Service;
- improve service delivery;
- ensure that all jobholders know and understand what is expected of them;
- promote interaction on performance between jobholders and their supervisors;
- identify, manage and promote jobholders' development needs;
- evaluate performance fairly and objectively;
- recognise categories of performance that are fully effective and better; and
- manage categories of performance that are not fully effective and lower.

The inclusion of tangible performance criteria in the performance agreements of relevant employees, especially in the case of civil servants, that hold responsibilities that may relate to the management of any causes or effects of excessive nutrient loading, must be considered for annual evaluation. Such eutrophication management related performance criteria may relate to any, or any variation, of the following:

- Internal audit outcomes linked to the environmental compliance performance of industry;
- Proportion of water containing waste recycled or reused in a particular geographical area or by a particular industry;
- Proportion of effluent discharges in a particular geographical area that is appropriately authorised;
- Proportion of water containing waste in a particular geographical area that is lawfully discharged;
- Proportion of waste lawfully disposed of;
- Proportion of waste recycled or reused; and
- Proportion of bodies of water in a particular geographical area that complies with specified in-water resource water quality objectives.

3.3.2.3.2 Evaluation of the effectiveness of the regulatory environment

This type of broader evaluation applies to (1) the general ***"policy, strategy and law environment"***; as well as (2) specific ***"interventions"***, which collectively influence regulatory effectiveness.

Policy drives strategy and legislation. Evidence is critical in the entire policy cycle – from diagnosis of a problem or opportunity – to monitoring and evaluation – and back to policy development or review [Presidency, 2020]. Evidence based monitoring separates facts from opinions. Performance information on programmes that are designed to implement policy should determine whether to continue with that policy, as an option, or to establish ways in which it can be modified.

Government's Socio-Economic Impact Assessment System (SEIAS) can be used to assess and monitor the social and economic impact of eutrophication management related policies, legislation, and other general regulatory arrangements. The SEIAS is aimed at improving the regulatory environment, by *inter alia* analysing risks and proposing ways to mitigate them. Additionally, the DPSIR framework[251], as undertaken and reported under **Section 1.2, Part 1**, can be utilised to evaluate social and economic activities (the driving forces) that exert pressures on ecosystems and that change the state of those ecosystems, which, again, may lead to various impacts, resulting in responses from society that ultimately aim to mitigate those impacts by directly addressing the driving forces, pressures, the state, or impacts.

Effective monitoring and evaluation, with respect to the ***"policy, strategy and law environment"***, requires [Presidency, 2020, p. 15]:

- **Relevance:** The evaluation should be cognisant of the purpose, namely to suitably address the causes and effects of excessive nutrient-loading;
- **Significance:** It must make a difference to the current trophic status being experienced in problem water resources;
- **Originality:** It must generate new information that was not available before the evaluation was undertaken;
- **Legitimacy:** It must enjoy the support of relevant stakeholders;
- **Reliability:** The data-collection process must be stable and exist across time and space to ensure the accuracy of the data;
- **Validity:** The findings and conclusions of the evaluation must have effective causal linkages with the descriptive, factual component of the evaluation. Evaluation techniques and indicators must clearly and directly measure the performance intended to be measured;
- **Objectivity:** The evaluation should be undertaken in an impartial and unbiased way and any value or normative judgments should be minimised and openly declared; and

[251] The River Health Programme uses the DPSIR framework.

- **Timeliness:** The evaluation findings should be based on recent performance and should be available in time to influence future intervention decisions.

Specific interventions, to address issues of anthropogenic eutrophication in catchments and water resources, are most efficiently implemented when executed based on appropriate water resource planning. Coherent implementation of these measures requires roll-out in accordance with the geographical water quality management strategies and thematic plans[252] applicable to those catchments and water resources. In this instance, utilising strategy steering committees presents an effective mechanism to coordinate and maintain implementation. The objectives of such committees, which can be utilised to implement interventions to address catchment-specific eutrophication challenges, include the following:

- To identify and highlight water quality issues of concern, including eutrophication, in relation to the mandate and responsibility of each of the committee members;
- To facilitate coordination between the various components within the DWS (Head and Regional Offices), CMAs and other relevant authorities, with the aim of giving effect to the relevant geographical strategies and thematic plans;
- To promote coordination and integration of water quality management related actions throughout all relevant sub catchments;
- To ensure the implementation, and where appropriate the updating, of the relevant geographical strategies and thematic plans; and
- To ensure accurate and efficient feedback with regard to the implementation of the abovementioned actions to the SSC and/ or any other relevant structures.

3.3.2.4 Data acquisition and information management

3.3.2.4.1 Technological advancement

The world is moving toward the fourth industrial revolution, in which mobile communications, social media and sensors are blurring the boundaries between people, the internet and the physical world. Ways to work smarter – not harder – should be explored! Careful planning often converts short-term cost into long-term benefit. Improvements to information management should be carefully considered with the objective to improve management efforts and to ultimately improve South Africa's raw water quality.

Further research on data streams that can feed eutrophication data base *e.g.* in integration of earth observation into eutrophication monitoring (EONEMP), making use of satellite earth observation (remote sensing) for the monitoring of cyanobacterial blooms and eutrophication in South Africa's large- and medium-sized fresh water bodies should be supported. The inherent limitations of the various systems *e.g.* EONEMP inability to provide information on nutrient concentrations should be considered. Other technological advancement that can be considered include, real time monitoring, the use of drones, etc.

3.3.2.4.2 Information management systems

Primary data capturing can potentially occur in any of at least two conceivable ways, namely:

- The capture of results in the laboratory; or
- The capture of laboratory results by the data owner on a centralised database.

In either case, the probability of human error must be minimised. Clear and robust protocols must exist to ensure that the data, once captured on a centralised database, are stored in such a way that would facilitate subsequent efficient access and processing. All data must be stored so they can be made available-

[252] Refer to **Section 3.1.2.4.6**: Establishment of geographical water quality management strategies and thematic plans.

- when a reasonable request for data is received from any stakeholder or interested party. Data should be provided, at reasonable charge if necessary, in line with the Access to Information Act, 2000 (Act No. 2 of 2000) and the NWA (36:1998); and
- to report on eutrophication related matters, as part of formal and regular information dissemination mechanisms.

TABLE 26 lists various corporate information management systems utilised by the Department.

TABLE 26: Departmental information management systems.

INFORMATION MANAGEMENT SYSTEM	APPLICATION
Electronic Water Use license Application and Authorisation System (EWULAAS)	?
Green Drop System (GDS)	?
Hydrological Data System (HYDSTRA)	?
Integrated Regulatory information System (IRiS)	?
National Integrated Water Information System (NIWIS)	?
Water Authorisation, Registration and Management System (WARMS)	?
Water Management System (WMS)	?

According to the Department's Data Management Strategy, the four main pillars for efficient and effective data acquisition and management, namely–

- data governance;
- data life cycle management;
- data management systems; and
- alignment between stakeholders in the water and sanitation sectors;

must be enhanced to improve the authoritativeness, availability, accessibility, timeliness and security of data [DWS, 2020].

3.3.3 Spatial scale of implementation

The operational strategies in the *"check"* stage of the eutrophication management framework address the full continuum of geographical scales, ranging from the international and trans-boundary level, to the national level, to the regional level, to the land and water use activity specific levels. Additionally, the *"check"* stage also contain strategies that extends monitoring and evaluation to the performance of employees; the implementation of catchment and water resource specific interventions in the context of water resource systems or catchments; and, ultimately, to the effectiveness of the broader policy, strategy and law environment.

3.3.4 Temporal scale of implementation

The operational strategies, being part of the *"check"* stage in the eutrophication management framework, must, depending on purpose, mostly be attended to on a constant basis. **TABLE 27** gives a summary of potential outstanding actions:

TABLE 27: Actions to strengthen the *"check"* stage of the eutrophication management framework.

	SHORT-TERM
1.	Learn from the SDG Programme and expand South Africa's domestic monitoring programmes in support of effective eutrophication planning, regulation and management.
2.	
3.	
4.	
5.	
	LONGER-TERM
6.	
7.	
8.	
9.	
10.	

3.4 The *"act"* stage

The "*act*" stage, of the eutrophication management framework, comprises of four linked operational strategies. These operational strategies and their purpose and composition are summarised in **TABLE 28**:

TABLE 28: The operational strategies, in the *"act"* stage of the eutrophication management framework, and their composition.

OPERATIONAL STRATEGIES AND PURPOSE		KEY COMPONENT(S)
1. Retrospective action		Duty of care
		Water resource remediation
		Biological manipulation
2. Enforcement		Administrative penalties
		Prosecution
3. Management review		Revision of policy and strategy
4. Continuous improvement		

3.4.1 Authority

3.4.2 Prescribed approaches

The rating of water resources according to a Trophic State Index (TSI) for the classification of water bodies according to the amount of biological productivity they sustain can, on a regular basis, be utilised, together with nutrient-loading and other eutrophication-related information, to inform eutrophication management and to gauge management performance. Consideration must also be given to include TSI information in the water resource Management Class(es) (and RQOs/ Reserves) to firmly link resource requirements with SDCs, and in regional water quality monitoring programmes.

Additionally, consideration must be given to the development of formal alert levels for problem water resources, as part of an early warning system that, amongst others, utilises trophic status assessment information. Such a system should be used to warn water users, in particular recreational water users, of potential water quality, health and safety concerns. Consideration must be given to the fact that anthropogenic eutrophication are often also associated with other water pollution concerns, such as microbial water pollution. In this way, members of the public can be made aware of potential hazardous conditions, as may be linked to the trophic status of a particular problem water resource.

3.4.2.1 Retrospective action

3.4.2.1.1 Duty of care

3.4.2.1.2 Water resource remediation

3.4.2.1.3 Alien vegetation

3.4.2.1.4 Biological manipulation

This technique targets food-chain functioning and involves the use or harvesting of non-desirable organisms to eventually control algal growth or other components of the food chain that may cause eutrophication-related problems. The main aim is to control certain key species at critical points in the food web, *e.g.* fish species that prey on zooplankton to an extent that may alter the normal functioning of the ecosystem [Van Ginkel, 2011]. BMP with guidelines should be considered and, if merited, developed.

3.4.2.2 Enforcement

Non-compliance penalties – nonrenewal of resource permits or greater restriction on current permits

Non-compliance fines

3.4.2.2.1 Administrative penalties

The current penalties for non-compliance are not effectively implemented, but also not sufficiently priced to change behaviour and must be reviewed. A system of effective administrative penalties for water pollution offences, in addition to the current criminal prosecution route, must be adopted. DWS will work in coordination with DEFF to create the relevant legislative framework and regulatory authority to impose administrative penalties that reflect the cost of water quality violations to society. This intervention will enable the State to achieve greater compliance with water quality regulations amongst waste dischargers.

This will require an amendment of the NWA (36:1998)[253]. In line with the inter-departmental approach to IWQM, this regulatory authority could serve both DWS and DEFF in relation to administrative penalties for water and environmental non-compliance. Certain activities that result in water pollution, however, will still follow the criminal prosecution route, such as acts of vandalism. DWS will work with DEA on the training of inspectors, and in enforcement of legislation [DWS, 2017b, p. 49].

3.4.2.2.2 Prosecution

3.4.2.3 Management review

3.4.2.3.1 Revision of policy and strategy

3.4.2.4 Continuous improvement

3.4.3 Spatial scale of implementation

3.4.4 Temporal scale of implementation

TABLE 29: Actions to strengthen the *"act"* stage of the eutrophication management framework.

SHORT-TERM	
1.	
2.	
3.	
4.	
5.	
LONGER-TERM	
6.	
7.	
8.	
9.	
10.	

[253] Refer to **ANNEXURE G** for a list of all recommended legislative amendments.

Consideration must be given to the development of alert levels for problem water resources, as part of an early warning system that, amongst others, utilises trophic status assessment information. Such a system should be used to warn water users, in particular recreational water users, of potential water quality, health and safety concerns. Consideration must be given to the fact that anthropogenic eutrophication are often also associated with other water pollution water concerns, such as microbial water pollution. In this way, members of the public can be made aware of potential hazardous conditions, as may be linked to the trophic status of a particular problem water resource.

CHAPTER 4: SUPPORTING STRATEGIES

4.1 Building of technical capacity

4.1.1 Authority

4.1.2 Prescribed approach

4.1.3 Spatial scale of implementation

4.1.4 Temporal scale of implementation

4.2 Resourcing

4.2.1 Authority

4.2.2 Prescribed approach

4.2.3 Spatial scale of implementation

4.2.4 Temporal scale of implementation

Adequately funded: Policy is a course of action and must be adequately funded- otherwise it will be a good policy that is shelved and gathers dust. It has to be costed prior to approval, consulted on with stakeholders, while the SEIAS should assist in minimising costs through innovation and establishing partnerships [Presidency, 2020].

Temporal scale of implementation

The Department of Water and Sanitation is in the process of developing a Waste Discharge Charge System (WDCS) to promote waste reduction and water conservation. It forms part of the Pricing Strategy and is being established under the National Water Act, 1998 (Act 36 of 1998).

The WDCS is based on the polluter-pays principle and aims to:

(3) Promote the sustainable development and efficient use of water resources;
(4) Promote the internalisation of environmental costs by impactors;
(5) Create financial incentives for dischargers to reduce waste and use water resources in a more optimal way; and
(6) Recover the costs of mitigating the impacts of waste discharge on water quality.

The WDCS will also encourage the water users to change their behaviour by encouraging them to meet the required standard before discharging into the water resources. This is a tool that will be used in future to support existing water quality management initiatives, and rehabilitation of polluted water resources.

4.3 Research & technology development

4.3.1 Authority

4.3.2 Prescribed approach

4.3.3 Spatial scale of implementation

4.3.4 Temporal scale of implementation

4.4 Collaboration and management participation

4.4.1 Authority

4.4.2 Prescribed approach

4.4.3 Spatial scale of implementation

4.4.4 Temporal scale of implementation

CHAPTER 5: GOVERNANCE

5.1 Mandates

Requires effective and well-functioning government institutions: Policy-making and implementation require institutions that are effective, innovative and have a strong culture of performance.

TABLE 30: Competencies, relevant authorities and roles in eutrophication management.

COMPETENCIES	RELEVANT AUTHORITIES	ROLES IN EUTROPHICATION MANAGEMENT

Biological solutions - Food web manipulation (Responsibility Infrastructure Branch – Part 3 and next report on Putting strategy into practice)

5.2 Improved cooperation and coordination

5.2.1 Internal strengthening

Efforts will be undertaken to strengthen the water quality management function, specifically eutrophication management, within the DWS. This will include organisational aspects, as well as those of systems and resources. In so doing, a national champion will be identified, and this person will have the responsibility to pull together the internal DWS functioning, as well as act as the anchor for facilitating the inter-governmental approach to eutrophication management.

5.2.2 Water management institutions

In line with the principles of subsidiarity, the management of eutrophication is best performed at a local and catchment scale. In this regard, the Catchment Management Agencies (CMAs) will utilise Catchment Management Forums (CMFs) and Catchment Committees, and will collaborate with Water User Associations (WUAs) to support participatory eutrophication management. The DWS and CMAs will provide the necessary national strategic guidance, oversight and leadership on transboundary eutrophication-related matters, collaborating with bodies concerned with international water management, as may be necessary.

5.2.3 Annual reporting

All relevant departments and government agencies will be held accountable for their actions in relation to this Policy, and DWS will report annually, in its annual report, on the effective implementation of the government-wide approach towards IWQM, specifically eutrophication management.

5.2.4 Water stewardship

DWS will actively promote the concept of water stewardship and encourage private enterprise to look beyond the factory fence to support eutrophication management at the local and catchment scale in line with the International Alliance for Water Stewardship Standard which is designed to achieve four water stewardship outcomes: (1) good water governance, (2) sustainable water balance, (3) good water quality status and (4) healthy status of important water-related areas.

5.2.5 Partnerships with civil society

In managing water quality, it is crucially important that government forges strong partnerships with civil society, which has an important role to play both in compliance monitoring and enforcement and as partners in pollution prevention and rehabilitation programmes. At the national and catchment scale, Government/CMAs will work closely with civil society organisations to build programmes of citizen-based monitoring, and education and awareness programmes to reduce pollution of water resources.

Active CMFs and catchment committees will be established and used as appropriate. These must be supported Government/CMAs to ensure an on-going platform for participation in eutrophication management by civil society, together with other stakeholders. These will provide an important conduit for Civil Society to raise issues and engage in debate with Government and Private Sector actors.

CHAPTER 6: CONCLUSION

Outstanding text.

To be added when the Executive Summary is finalised.

Focus of Core strategies is linkages between source-resource-remediation.
Focus of Operational strategies is management
Focus of Support strategies is support.
The outlines of these strategies overlap….

None of the three strategies are mutually exclusive. There is a need to highlight the core business through core strategies, or to highlight those strategies that support or to discern those operational approaches that constitute eutrophication management through the highlighting of operational strategies.

PART 4: THE WAY FORWARD

PHOTO 5: *"ACTION IS THE KEY TO SUCCESS!"* © P. VENTER

CHAPTER 1: INTRODUCTION

CHAPTER 2: IMPLEMENTATION

CHAPTER 3: CONCLUSION

Outstanding text.

To be added when the Executive Summary is finalised.

PART 5: BIBLIOGRAPHY

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ANNEXURE A

Human health, and other effects of water resources that are unfit-for-use, with respect to some eutrophication-related water quality parameters.

ANNEXURE A

Human health, and other effects of water resources that are unfit-for-use, with respect to some eutrophication-related water quality parameters.
[Scherman, 2008; DWAF, 1996]

ALPHABETICALLY ARRANGED PARAMETERS	APPLICABLE CONCENTRATION RANGES	EXPECTED EFFECT CAUSED BY WATER RESOURCES WITH WATER QUALITY IN THE UNACCEPTABLE CONCENTRATION RANGE	RECEIVING WATER USER
Algae *[free floating green algae]*	***Aesthetics:*** I: <=15 µg Chl-α/ℓ A: >15 to <=8 µg Chl-α/ℓ T: >8 to <=30 µg Chl-α/ℓ U: >30 µg Chl-α/ℓ	Severe nuisance conditions may be encountered. Aesthetically unacceptable surface algal scums evident for much of the time. The composition and health of the fish population may be affected, depending on species. Rotting algae may cause severe odour problems. No health effects expected.	Recreation : Full-contact
	Aesthetics: I: <=20 µg Chl-α/ℓ A: >20 to <=25 µg Chl-α/ℓ T: >25 to <=30 µg Chl-α/ℓ U: >30 µg Chl-α/ℓ	Severe nuisance algal blooms (scums) as well as other symptoms of eutrophication. Rotting algae may cause severe odour problems. No health effects expected.	Recreation: Non-contact
Algae *[blue-green algae]*	***Human health:*** I: <=50 colonies/mℓ A: >50 to <=14 000 colonies/mℓ T: >14 000 to <=42 000 colonies/mℓ U: >42 000 colonies/mℓ	Significant risk of acute and chronic effects associated with the ingestion of the algae.	Domestic
	Human health: I: <=6 blue-green algae units* A: - T: - U: >6 blue-green algae units	Blue-green algae present in significant numbers and scum formation likely. Recreational users should increase their vigilance for algal scums and avoid all contact with scums. Notices warning users to avoid algal scums should be posted. Health effects likely with accidental ingestion of the scums and skin irritations likely with contact with the scums.	Recreation: Full-contact

ALPHABETICALLY ARRANGED PARAMETERS	APPLICABLE CONCENTRATION RANGES	EXPECTED EFFECT CAUSED BY WATER RESOURCES WITH WATER QUALITY IN THE UNACCEPTABLE CONCENTRATION RANGE	RECEIVING WATER USER
	Health of livestock: I: <=12 colonies/mℓ; and <=2 000 Microcystis colonies/ mℓ A: - T: >12 colonies/mℓ; and <=2 000 Microcystis colonies/ mℓ U: >12 colonies /mℓ; and >2 000 Microcystis colonies/ mℓ	High risk of acute toxic effects. Do not allow livestock to drink from or have contact with the scum.	Agriculture: Livestock watering
Algae *[chlorophyll-α]*	***Aesthetics:*** I: <=1 µg Chl-α/ℓ A: >1 to <=15 µg Chl-α/ℓ T: >15 to <=100 µg Chl-α/ℓ U: >100 µg Chl-α/ℓ	Water has a distinct murky appearance, becoming increasingly green in colour. Significant taste and odour problems. Secondary growth of bacteria in the distribution system.	Domestic
Algae *[microcystins (hepatotoxins produced by algae)]*	***Human health:*** I: <=0.8 µg/ℓ A: >0.8 to <=0.9 µg/ℓ T: >0.9 to <=1 µg/ℓ U: >1 µg/ℓ	Possible acute hepatotoxic effects.	Domestic
Ammonia *[NH_3]*	***Human health & Aesthetics:*** I: <=1.0 mg N/ℓ (pH>8) A: >1.0 to <=2.0 mg N/ℓ (pH>8) T: >2.0 to <=10.0 mg N/ℓ (pH>8) U: >10.0 mg N/ℓ (pH>8)	Unacceptable in domestic water. Danger of formation of nitrite. Likelihood of fish deaths in aquaria. Chlorination is severely compromised.	Domestic

ALPHABETICALLY ARRANGED PARAMETERS	APPLICABLE CONCENTRATION RANGES	EXPECTED EFFECT CAUSED BY WATER RESOURCES WITH WATER QUALITY IN THE UNACCEPTABLE CONCENTRATION RANGE	RECEIVING WATER USER
	Aquatic ecosystem health: I: <=15.0 µg N/ℓ (pH>8) A: >15.0 to <=72.5 µg N /ℓ (pH>8) T: >72.5 to <=100 µg N /ℓ (pH>8) U: >100 µg N /ℓ (pH>8)	The toxicity of ammonia and ammonium salts to aquatic organisms is directly related to the amount of free ammonia in solution. At low to medium pH values, the ammonium ion dominates, but as pH increases ammonia is formed, the latter being considerably more toxic to aquatic organisms. Un-ionized ammonia affects the respiratory systems of many animals, either by inhibiting cellular metabolism or by decreasing oxygen permeability of cell membranes. Acute toxicity to fish may cause a loss of equilibrium, hyper-excitability, an increased breathing rate, an increased cardiac output and oxygen intake, and in extreme cases convulsions, coma and death. Chronic effects include a reduction in hatching success, reduction in growth rate and morphological development, and pathological changes in tissue of gills, liver and kidneys.	Aquatic ecosystem
Clarity	***Human health & Aesthetics:*** I: >=3.0 m (Secchi depth) A: <3.0 to >=1.5 m (Secchi depth) T: <1.5 to >=1.0 m (Secchi depth) U: <1.0 m (Secchi depth)	Unsuitable for swimming. However, if lack of clarity (or turbidity) is the only consideration preventing the use of a water body for swimming, then it may be allowed, provided all subsurface, potential hazards are removed and signs indicating water depth are clearly posted. Risk of disease transmission by organisms associated with particulate matter increases but this cannot solely be determined on the basis of clarity measurements. May be some depreciation in aesthetic quality and enjoyment of the water body.	Recreation: Full-contact
Dissolved Oxygen *[DO]*	***Aquatic ecosystem health:*** I: >=80% A: <80% to 70% T: <70% to 60% U: <60% *(7 day mean)*;and <40% *(1 day minimum)*	The 7-day mean minimum and the 1-day minimum should apply together. Violation of these minimum values is likely to cause acute toxic effects on aquatic biota.	Aquatic ecosystem
Dissolved Organic Carbon *[DOC]*	***Human health:*** I: <=5 mg C/ℓ A: >5 to <=10 mg C/ℓ T: >10 to <=20 mg C/ℓ U: >20 mg C/ℓ	Aesthetic effects (taste, odour, colour) and formation of trihalomethanes (THMs) during chlorination. Marked health effects, depending on the composition of the DOC.	Domestic
Nitrate/Nitrite *[NO_2^-/NO_3^-]*	***Human health:*** I: <=6 mg N/ℓ A: >6 to <=10 mg N/ℓ T: >10 to <=20 mg N/ℓ U: >20 mg N/ℓ	Upon absorption, nitrite combines with the oxygen-carrying red blood pigment, haemoglobin, to form methaemoglobin, which is incapable of carrying oxygen. This condition is termed methaemoglobinaemia. The reaction of nitrite with haemoglobin can be particularly hazardous in infants under three months of age and is compounded when the intake of Vitamin C is inadequate. Occurrence of mucous membrane irritation in adults.	Domestic

ALPHABETICALLY ARRANGED PARAMETERS	APPLICABLE CONCENTRATION RANGES	EXPECTED EFFECT CAUSED BY WATER RESOURCES WITH WATER QUALITY IN THE UNACCEPTABLE CONCENTRATION RANGE	RECEIVING WATER USER
	Health of livestock: I: <=100 mg N/ℓ A: >100 to <=200 mg N/ℓ T: >200 to <=400 mg N/ℓ U: >400 mg N/ℓ	Adverse chronic effects, such as restlessness, frequent urination, dyspnoea, cyanosis associated with methaemoglobinemia and decreased feed and water intake associated with adverse palatability effects may occur, but can be tolerated if- ▶ feed concentration is normal; ▶ there is adequate carbohydrate intake; and ▶ exposure is short term. Acute effects such, as severe gastroenteritis in non-ruminants and acute methaemoglobinemia in ruminants (severe dyspnoea and cyanosis) may occur. May be tolerated under certain conditions, depending on site-specific factors such as nutritional carbohydrate levels, TDS and sulphate concentrations in the water, and the type of micro-organisms present in the rumen.	**Agriculture: Livestock watering**
Nitrogen (inorganic) *[TIN]*	***Crop yield & Groundwater:*** I: <=0.5 mg total N/ℓ A: >0.5 to <=5 mg total N/ℓ T: >5 to <=30 mg total N/ℓ U: >30 mg total N/ℓ	Most crops are affected. A limited range of crops can utilise the nitrogen applied. Severe restrictions are placed on the utilisation of these waters. Increasingly serious likelihood of ground water contamination.	**Agriculture: Irrigation**
	Irrigation equipment: I: <=0.5 mg total N/ℓ A: >0.5 to <=2.5 mg total N/ℓ T: >2.5 to <=10 mg total N/ℓ U: >10 mg total N/ℓ	Hypertrophic conditions. Almost continuous growth of nuisance plants and blue-green algal blooms in irrigation structures in the absence of other growth-limiting factors.	**Agriculture: Irrigation**

ALPHABETICALLY ARRANGED PARAMETERS	APPLICABLE CONCENTRATION RANGES	EXPECTED EFFECT CAUSED BY WATER RESOURCES WITH WATER QUALITY IN THE UNACCEPTABLE CONCENTRATION RANGE	RECEIVING WATER USER
	Aquatic ecosystem health: I: <=0.25 mg total N/ℓ A: >0.25 to <=1.00 mg total N/ℓ T: >1.00 to <=4 mg total N/ℓ U: >4 mg total N/ℓ ▶ *Inorganic nitrogen concentrations should not be changed by more than 15 % from that of the waterbody under local unimpacted conditions at any time of the year; and* ▶ *The trophic status of the water body should not increase above its present level, though a decrease in trophic status is permissible; and* ▶ *The amplitude and frequency of natural cycles in inorganic nitrogen concentrations should not be changed.*	Hypertrophic conditions; usually very low levels of species diversity; usually very highly productive systems; nuisance growth of aquatic plants and blooms of blue-green algae, often including species which are toxic to man, livestock and wildlife.	Aquatic ecosystem
Odour	***Aesthetics:*** I: <=1 TON A: >1 to <=5 TON T: >5 to <=10 TON U: >10 TON	The odour of water becomes stronger and increasingly objectionable	Domestic
Orthophosphate (soluble) *[PO_4]*	***Aquatic ecosystem health:*** I: <=0.01 mg P/ℓ A: >0.01 to <=0.03 mg P/ℓ T: >0.03 to <=0.13 mg P/ℓ U: >0.13 mg P/ℓ	Hypertrophic conditions; usually very low levels of species diversity; usually very highly productive systems; nuisance growth of aquatic plants and blooms of blue-green algae, often including species which are toxic to man, livestock and wildlife.	Aquatic ecosystem

ALPHABETICALLY ARRANGED PARAMETERS	APPLICABLE CONCENTRATION RANGES	EXPECTED EFFECT CAUSED BY WATER RESOURCES WITH WATER QUALITY IN THE UNACCEPTABLE CONCENTRATION RANGE	RECEIVING WATER USER
Phosphorus (inorganic) *[TP]*	***Aquatic ecosystems:*** I: <=5 µg total P/ℓ A: >5 to <=25 µg total P/ℓ T: >25 to <=250 µg total P/ℓ U: >250 µg total P/ℓ ▶ *Inorganic phosphorus concentrations should not be changed by >15 % from that of the waterbody under local, unimpacted conditions at any time of the year; and* ▶ *The trophic status of the water body should not increase above its present level, though a decrease in trophic status is permissible; and* ▶ *The amplitude and frequency of natural cycles in inorganic phosphorus concentrations should not be changed.*	Hypertrophic conditions; usually very low levels of species diversity; usually very highly productive systems; nuisance growth of aquatic plants and blooms of blue-green algae, often including species which are toxic to man, livestock and wildlife.	Aquatic ecosystem
Turbidity	***Human health & Aesthetics:*** I: <=1 NTU A: >1 to <=5 NTU T: >5 to <=10 NTU U: >10 NTU	Severe aesthetic effects (appearance, taste and odour). Water carries an associated risk of disease due to infectious disease agents and chemicals adsorbed onto particulate matter. A chance of disease transmission at epidemic level exists at high turbidity.	Domestic
Nuisance water plants	***Swimming:***	The growth of aquatic vascular plants in water bodies used for full-contact recreation should be limited to ensure that entanglement of swimmers does not occur and that plants do not obscure visibility. Excessive plant growth should not occur in full-contact recreational areas. The presence of floating masses of detached plants which may obstruct water users are aesthetically objectionable and provide a habitat for the growth of nuisance and vector organisms (for example insects, fungi and bacteria) and should be limited as far as possible.	Recreation: Full-contact

ALPHABETICALLY ARRANGED PARAMETERS	APPLICABLE CONCENTRATION RANGES	EXPECTED EFFECT CAUSED BY WATER RESOURCES WITH WATER QUALITY IN THE UNACCEPTABLE CONCENTRATION RANGE	RECEIVING WATER USER
	Intermediate contact recreation:	Since activities involving intermediate-contact recreation may include occasional full-body immersion, the criteria given above should be used and the extent of contact should be taken into account. Where water contact is slight or infrequent, the criteria may be applied less stringently. Plant growth should also be limited to prevent possible entanglement of boats, waterskiers and boardsailors.	**Recreation: Intermediate-contact**
	No contact recreation:	Aquatic plant growth should not detract from the aesthetic aspects of water bodies used for non-contact recreation. Hence, water should not be completely covered, plant growth should not be unsightly or cause unpleasant odours, and there should be no adverse effects on other aquatic organisms.	**Recreation: Non-contact**

*** Key:**

- **I**=Ideal; **A**=Acceptable; **T**=Tolerable; and **U**=Unacceptable; and
- *"Blue-green algae units"* refers to the number of blue-green units (colonies and filaments) counted in a two-minute scan of 0.5 mℓ of water at x200 magnification.

ANNEXURE B

Supporting National Environmental Management Principles.

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Supporting National Environmental Management Principles.

NEMA (107:1998) sets out the following national environmental management principles, which also have relevance to eutrophication management:

- **Environmental management must be integrated**, acknowledging that all elements of the environment are linked and interrelated, and it must take into account the effects of decisions on all aspects of the environment and all people in the environment by pursuing the selection of the **best practicable environmental option**;
- **Environmental justice must be pursued** so that adverse environmental impacts shall not be distributed in such a manner as to unfairly discriminate against any person, particularly vulnerable and disadvantaged persons;
- **Equitable access to environmental resources**, benefits and services to meet basic human needs and ensure human well-being must be pursued and special measures may be taken to ensure access thereto by categories of persons disadvantaged by unfair discrimination;
- Responsibility for the environmental health and safety consequences of a policy, programme, project, product, process, service or activity **exists throughout its life cycle**;
- The **participation of all interested and affected parties** in environmental governance must be promoted, and all people must have the opportunity to develop the understanding, skills and capacity necessary for achieving equitable and effective participation, and participation by vulnerable and disadvantaged persons must be ensured;
- Decisions must take into account the interests, needs and values of all interested and affected parties, and this includes **recognizing all forms of knowledge**, including traditional and ordinary knowledge;
- Community wellbeing and empowerment must be promoted through **environmental education, the raising of environmental awareness**, the sharing of knowledge and experience and other appropriate means;
- The **social, economic and environmental impacts** of activities, including disadvantages and benefits, must be considered, assessed and evaluated and decisions must be appropriate in the light of such consideration and assessment;
- The **right of workers to refuse work that is harmful** to human health or the environment and to be informed of dangers must be respected and protected;
- Decisions must be taken in an **open and transparent** manner, and access to information must be provided in accordance with the law;
- There must be **intergovernmental co-ordination and harmonisation** of policies, legislation and actions relating to the environment;
- Actual or potential **conflicts of interest between organs of state** should be resolved through conflict resolution procedures;
- **Global and international responsibilities** relating to the environment must be discharged in the national interest;
- The environment is held in **public trust** for the people, the beneficial use of environmental resources must serve the public interest and the environment must be protected as the people's common heritage;
- The **costs of remedying pollution**, environmental degradation and consequent adverse health effects and of preventing, controlling or minimising further pollution, environmental damage or adverse health effects must be paid for by those responsible for harming the environment;
- The **vital role of women and youth** in environmental management and development must be recognised and their full participation therein must be promoted; and

- **Sensitive, vulnerable, highly dynamic or stressed ecosystems**, such as coastal shores, estuaries, wetlands and similar systems require specific attention in management and planning procedures, especially where they are subject to significant human resource usage and development pressure.

ANNEXURE C

The 28 Fundamental Principles and Objectives for a New Water Law in South Africa (1996), from eutrophication management perspective.

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The 28 Fundamental Principles and Objectives for a New Water Law in South Africa (1996), from eutrophication management perspective.

Water law in South Africa is based on 28 fundamental principles and objectives, as approved by Cabinet in November, 1996 [Stein, 2002]. Eutrophication management policy and strategy, broadly, should conform to these fundamental principles and objectives, especially the 13 principles and objectives that are of foremost relevance to eutrophication management, as summarised below:

LIST OF 13 PRINCIPLES AND OBJECTIVES MOST RELEVANT TO EUTROPHICATION MANAGEMENT:
The water cycle
Principle 5: In a relatively arid country such as South Africa, it is necessary to recognise the **unity of the water cycle** and the interdependence of its elements, where evaporation, clouds and rainfall are linked to groundwater, rivers, lakes, wetlands and the sea, and where the **basic hydrological unit is the catchment**.
Water resource management priorities
Principle 7: **The objective of managing the quantity, quality and reliability** of the Nation's water resources is to achieve optimum, long term, environmentally sustainable social and economic benefit for society from their use.
Principle 9: The quantity, quality and reliability of water required to maintain the **ecological functions on which humans depend** shall be reserved so that the human use of water does not individually or cumulatively compromise the long term sustainability of aquatic and associated ecosystems.
Principle 13: As custodian of the Nation's water resources, the National Government shall ensure that the development, apportionment, management and use of those resources is carried out using the criteria of **public interest, sustainability, equity and efficiency** of use in a manner which reflects its public trust obligations and the value of water to society, while ensuring that basic domestic needs, the requirements of the environment and **international obligations** are met.
Principle 14: Water resources shall be developed, apportioned and managed in such a manner as to enable all user sectors to gain equitable access to the desired quantity, quality and reliability of water. **Conservation** and other measures to manage demand shall be actively promoted as a preferred option to achieve these objectives
Principle 15: **Water quality and quantity are interdependent** and shall be managed in an integrated manner, which is consistent with broader environmental management approaches.
Principle 16: Water quality management options shall include the use of **economic incentives and penalties to reduce pollution**; and the possibility of irretrievable environmental degradation as a result of pollution shall be prevented.
Principle 18: Since many land uses have a significant impact upon the water cycle, the regulation of land use shall, where appropriate, be used as an instrument to manage water resources within the **broader integrated framework of land use management**.
Principle 19: Any **authorisation to use** water shall be given in a timely fashion and in a manner which is clear, secure and predictable in respect of the assurance of availability, extent and duration of use. The purpose for which the water may be used shall not arbitrarily be restricted.
Principle 21: The development and management of water resources shall be carried out in a manner which limits to an acceptable minimum the **danger to life and property due to natural or manmade disasters**.

LIST OF 13 PRINCIPLES AND OBJECTIVES MOST RELEVANT TO EUTROPHICATION MANAGEMENT:
Water institutions
Principle 23: Responsibility for the development, apportionment and management of available water resources shall, where possible and appropriate, be delegated to a catchment or regional level in such a manner as to **enable interested parties to participate**.
Water services
Principle 25: The right of all citizens to have access to **basic water services** (the provision of potable water supply and the removal and disposal of human excreta and waste water) necessary to afford them a healthy environment on an equitable and economically and environmentally sustainable basis shall be supported.
Principle 27: While the provision of water services is an activity distinct from the development and management of water resources, **water services shall be provided in a manner consistent with the goals of water resource management**.

ANNEXURE D

The role of the National Water Act, 1998 (Act No. 36 of 1998) and the Water Services Act, 1997 (Act No. 108 of 1997) in eutrophication management.

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The role of the National Water Act, 1998 (Act No. 36 of 1998) and the Water Services Act, 1997 (Act No. 108 of 1997) in eutrophication management.

NATIONAL WATER ACT, 1998 (ACT NO. 36 OF 1998):

Although no mention is made of nutrient enrichment in the NWA (36:1998), there are several features to the Acts that merit the inclusion of eutrophication considerations. These include:

- **The National Water Resource Strategy:** The NWA (36:1998) requires the progressive development, after consultation with society at large, of a National Water Resource Strategy (NWRS). The NWRS provides the framework for the integrated water resource management for the country as a whole. It also provides the framework within which water will be managed at regional or catchment level, in defined Water Management Areas (WMAs). The NWRS, which must be formally reviewed in five yearly cycles, is binding on all authorities and institutions exercising powers or performing duties under the Act. Nutrient management considerations should form part of the NWRS.
- **Catchment Management Strategies:** The NWA (36:1998) devolves responsibility to Catchment Management Agencies (CMAs) to progressively develop Catchment Management Strategies (CMSs) for the water resources within their jurisdiction. All CMSs must be in harmony with the NWRS and set principles for allocating water to existing and prospective users, taking into account all matters relevant to integrated water resource management in a particular WMA. Nutrient management strategies should form part of all CMSs.
- **A national Classification System:** The NWA (36:1998) calls for the development of a system to classify the nation's water resources and, thus, requires guidelines and procedures for determining different classes of water resources. The system for classifying water resources may establish guidelines and procedures for determining different classes of water resources; establish procedures for determining the Reserve; establish procedures which are designed to satisfy the water quality requirements of water users, as far as is reasonably possible, without significantly altering the natural water quality characteristics of the resource; set out water uses for instream or land-based activities which activities must be regulated or prohibited in order to protect the water resource; and provide for such other matters relating to integrated water resource management. Government is required to classify all, or part of, water resources considered to be significant. Once a class has been determined, it is binding on all authorities and institutions, when exercising any power or performing any duty under the Act. Since anthropogenic eutrophication is an impediment to achieving the class, due consideration should be given to nutrient enrichment and the trophic status of specific waterbody types (*e.g.* rivers, wetlands, reservoirs, lakes and estuaries).
- **The Reserve:** This is a volume of water that needs to be maintained for two purposes. The basic human needs reserve provides for the essential needs of individuals served by the water resource in question and includes water for drinking, for food preparation and for personal hygiene. The ecological reserve relates to the water required to protect the aquatic ecosystems of the water resource. The Reserve refers to both the quantity and quality of the water in the resource, and will vary depending on the class of the water resource. Government is required to determine the Reserve for all or part of any significant water resource. Once the Reserve has been determined for a water resource it is binding on all authorities and institutions, when exercising any power or performing any duty under the Act. Eutrophication issues should form a strong consideration on the assessment of the Reserve.

- **Resource Quality Objectives:** Government is required to determine Resource Quality Objectives[102] (RQOs) for all, or part of, water resources considered to be significant. The RQOs will vary depending on the class of the water resource. The purpose of RQOs is to establish clear goals relating to the quality of the relevant water resources. Once RQOs have been determined they are binding on all authorities and institutions, when exercising any power or performing any duty under the Act. RQOs should give due consideration to nutrient enrichment and the trophic status of specific water body types (*e.g.* rivers, wetlands, reservoirs, lakes and estuaries).
- **Pollution prevention:** The NWA (36:1998) deals with pollution prevention, and in particular the situation where pollution of a water resource occurs or might occur as a result of activities on land. The person who owns, controls, occupies or uses the land in question is responsible for taking measures to prevent pollution of water resources. If these measures are not taken, the CMA concerned may itself do whatever is necessary to prevent the pollution or to remedy its effects, and to recover all reasonable costs from the persons responsible for the pollution. Anthropogenic eutrophication, amongst others, is the result of nutrient pollution, and its management should be incorporated into pollution control considerations.
- **Water use authorisation:** The NWA (36:1998) requires all water uses to be permissible and to comply with the conditions of the entitlement, including any Waste Discharge Standards (WDSs) that may relate to the combating of eutrophication, specified in Municipal Approvals, if relevant; or an Authorisation issued prior to 20 August 1996 to an ELU; or the applicable General Authorisation; or the water use Licence in question; or an alternative authorisation, if dispensing with the requirement for a licence to be issued under the NWA (36:1998). Additionally the Act also enables the publication of a number of water quality management related regulations, which includes prescribing WDSs.
- **Regulations:** As enabling legislation, the NWA (36:1998) supports the development and publication of a variety of regulations, which deals with a range of aspects that may or should be related to the management of eutrophication (**ANNEXURE E**). These include prescribing the extent of water use; the monitoring, measurement and recording of water use; various requirements in relation to waterworks; regulation or prohibiting activities in order to protect water resources; waste standards; management practices; procedures for the allocation of water by means of public tender; and procedures, and the contents, of assessments of the likely effect of proposed licences on resource quality.
- **Water pricing:** The NWA (36:1998) acknowledges the polluters-pay principle and, through the application of a system of waste discharge charges, including charging for nutrients, aims to-
  - promote the ecologically sustainable development and efficient use of water resources;
  - promote the internalisation of environmental externalities by impactors;
  - create financial incentives for dischargers to reduce waste and use water resources in a more optimal way; and
  - recover the costs of mitigating the impacts of waste discharges on water quality.
- **Water resource information management systems:** The NWA (36:1998) requires government to establish national information systems on the quantity and quality of all water resources. Eutrophication management issues and indicators should be included on any such developed information system(s) at both national and WMA (or sub-catchment) levels.

WATER SERVICES ACT, 1997 (ACT NO. 108 OF 1997)

Overlap between the WSA (108:1997) and the NWA (36:1998) exists to some extent, principally to ensure seamless integration, albeit that cooperative governance challenges frequently exist. Although mention of nutrient enrichment is not made in the WSA (108:1997) either, there are also several features to the WSA (108:1997) that merit the inclusion of eutrophication considerations.

- **National norms and standards:** The WSA (108:1997) enables the Minister of Human Settlements, Water and Sanitation to prescribe national standards, *inter alia,* relating to-
  - the provision of water services;
  - the quality of water discharged into any water services or water resource system;
  - the effective and sustainable use of water resources for water services;
  - the nature, operation, sustainability, operational efficiency and economic viability of water services; and
  - requirements for persons who install and operate water services works.
- **Water Services Development Plans:** The WSA (108:1997) compels WSAs to, as part of the process of preparing Integrated Development Plans (IDPs), develop Water Services Development Plans (WSDPs) for the water resources and services within their area. The contents of the WSDP*, inter alia,* relates to existing and expected future industrial effluent disposal; water sources to be used and the quantity of water to be discharged into each source; and the estimated capital and operating costs associated with the operation, maintenance, repair and replacement of existing and future infrastructure. Poorly operated and maintained WWTWs are sources of excessive nutrient enrichment. Nutrient management strategies should form part of all WSDPs.
- **Municipal approvals:** In terms of the WSA (108:1997), no person may dispose of industrial effluent in any manner other than that approved by the Water Services Provider (WSPs), nominated by the WSA having jurisdiction in the area in question. Additionally the Act also enables the publication of compulsory national standards, *inter alia*, relating to– the quality of any wastewater being discharged into any water services or water resource system; and the effective and sustainable use of water resources for water services. Anthropogenic eutrophication, amongst others, is the result of nutrient pollution, and its management should be incorporated into pollution control considerations.
- **Water services information management systems:** The WSA (108:1997) requires government to establish national information systems on water services. Eutrophication management issues and indicators should be included on any such developed information system(s).

ANNEXURE E

Existing provisions in the National Water Act, 1998 (Act No. 36 of 1998) for the making of regulations, which can be employed to enhance the control and management of anthropogenic eutrophication.

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Existing provisions in the National Water Act, 1998 (Act No. 36 of 1998) for the making of regulations, which can be employed to enhance the control and management of anthropogenic eutrophication.

Regulations that are made under Section 26 of the NWA (36:1998) may-

- differentiate between different water resources and/ or different water resource MCs;
- differentiate between different geographical areas; and
- create offences and prescribe penalties.

When making regulations, the following must be considered:

- to promote the economic and sustainable use of water;
- to conserve and protect water resources or, instream and riparian habitats;
- to prevent wasteful water use;
- to facilitate the management of water use and waterworks;
- to facilitate the monitoring of water use and water resources; and
- to facilitate the imposition and recovery of charges.

The following table lists those regulations under Section 26, NWA (36:1998) that may relate more directly to eutrophication management and that could, or should, be employed to enhance the control and management of anthropogenic eutrophication:

Relevant Section 26(1) regulations, as per the National Water Act, 1998 (Act No. 36 of the 1998):

S. 26(1)	The Minister may make regulations-	Potential application in eutrophication management
(a)	*"**limiting or restricting** the purpose, manner or extent of **water use**"*;	▶ **To regulate particular water uses, with respect to purpose, manner of use and extent.** ▶ This provision can be utilised to apply specific measures, with respect to how waste or water containing waste is disposed of, or discharged, to categories of such water use or risk. It may be possible to apply this provision to improve the regulation of ELUs, as an alternative to compulsory licensing. ▶ No such regulations have been published. Please verify!
(d)	*"prescribing the **outcome or effect which must be achieved** by the installation and operation of any **waterwork**"*;	▶ **To prescribe performance criteria for any waterwork, including a government waterwork.** ▶ This provision can be utilised to prescribe performance targets for any borehole, structure, earthwork or equipment installed or used for or in connection with water use. These performance targets can be selected and formulated to benefit eutrophication management, i.e. to reduce or control the trophic status of selected receiving reservoirs and/ or other water resources. ▶ No such regulations have been published. Please verify!

S. 26(1)	The Minister may make regulations-	Potential application in eutrophication management
(e)	*"regulating the design,* ***construction****, installation, operation and maintenance of any* ***waterwork****, where it is necessary or desirable to monitor any water use or to protect a water resource"*;	▶ **To prescribe minimum requirements for the establishment, operation and maintenance of any waterwork, including a government waterwork.** ▶ This provision can be utilised to prescribe minimum requirements for the establishment, operation and maintenance of any borehole, structure, earthwork or equipment installed or used for or in connection with water use. These minimum requirements can be selected and formulated to benefit eutrophication management, i.e. to reduce or control the trophic status of selected receiving reservoirs and/ or other water resources. ▶ No such regulations have been published.
(f)	*"requiring* ***qualifications*** *for and registration of persons authorised to design, construct, install, operate and maintain any* ***waterwork****, in order to protect the public and to safeguard human life and property"*;	▶ **To prescribe minimum qualifications for persons, in connection with the establishment, operation and maintenance of any waterwork, including a government waterwork.** ▶ This provision can be utilised to prescribe minimum qualifications for persons, in connection with the establishment, operation and maintenance of any borehole, structure, earthwork or equipment installed or used for or in connection with water use. These qualifications can be selected and formulated to benefit eutrophication management, i.e. to reduce or control the trophic status of selected receiving reservoirs and/ or other water resources. ▶ A relate regulation had been published under the WSA (108:1997) [GN R.813, 2013].
(g)	***"regulating or prohibiting*** *any* ***activity*** *in order to protect a water resource or instream or riparian habitat"*;	▶ **To regulate or prohibit land and/ or water use activities in order to protect resource quality and to give effect to RDMs.** ▶ This provision can be utilised to regulate (see S.26(1)(a) above) and/ or to prohibit activities that cause excessive nutrient-loading in sensitive or stressed areas. ▶ No such regulations have been published.
(h) ***	*"prescribing* ***waste standards*** *which specify the quantity, quality and temperature of waste which may be discharged or deposited into or allowed to enter a water resource"*;	▶ **To prescribe uniform WDSs, which specify nutrient loads and/ or concentrations in waste disposed of and water containing waste discharged to surface water resources.** ▶ This provision can be utilised to prescribe updated uniform WDSs for nutrients, which *inter alia* give effect to RDMs. ▶ Although draft regulations have been prepared, no such regulations have been finalised and published.
(i) ***	*"prescribing the outcome or effect which must be achieved through* ***management practices*** *for the treatment of waste, or any class of waste, before it is discharged or deposited into or allowed to enter a water resource"*;	▶ **To prescribe BMPs, BPGs, or portions thereof, which stipulate intermediate and/ or end-results that must be achieved before waste is disposed of, or before water containing waste is discharged, or before point and/ or diffuse sources of pollution are allowed to enter water resources.** ▶ This provision can be utilised to prescribe eutrophication management practices. ▶ No such regulations have been published.

S. 26(1)	The Minister may make regulations-	Potential application in eutrophication management
(j) ***	*"requiring that **waste discharged or deposited** into or allowed to enter a water resource be **monitored** and analysed, and prescribing methods for such monitoring and analysis"*;	▶ **To require monitoring, and to prescribe methods for monitoring and analysis, of waste being disposed of, or water containing waste being discharged into, or allowed to entering, water resources.** ▶ This provision can be utilised to compel water users, who contribute to excessive nutrient-loading, to monitor the quality of their waste and/ or water containing waste, and to regularly enter such data into a common information management system, such as IRiS. The availability of such *e*-data will make it possible to easily analyse information that can help with the management of eutrophication. ▶ No such regulations have been published.
(n)	*"prescribing procedures for the **allocation of water** by means of public tender or auction"*; and	▶ **To prescribe methodologies for the allocation of water quality on the open market.** ▶ This provision can be utilised to allocate available water quality for nutrients on the open market. ▶ No such regulations have been published for water quality.
(o)	*"prescribing– (i) procedures for obtaining; and (ii) the required contents of, **assessments** of the likely **effect which any proposed licence may have** on the quality of the water resource in question"*.	▶ **To prescribe assessment methodologies that must be followed by proponents who are applying for water use authorisations in order to quantify the expected impacts on resource quality.** ▶ This provision can be utilised to compel water users to investigate and report on the potential effects, associated with the disposal of waste and/ or discharge of water containing waste, as proposed. This many include an assessment of available water quality, nutrient-loading and whether effect will be given to RDM and/ or RWQOs/ WQPLs. ▶ No such regulations have been published.

*** **Regulations may contain general provisions applicable to all waste; and/ or specific provisions applicable to waste with specific characteristics.**

ANNEXURE F

Short summary of the purpose and nature of the National Eutrophication Monitoring Programme (NEMP).

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Short summary of the purpose and nature of the National Eutrophication Monitoring Programme (NEMP).

Eutrophication monitoring in South Africa commenced in the early 1970's, where it was being done as *ad hoc* monitoring surveys and research projects supported by the Water Research commission (WRC) up to about 1985 [Toerien, et al., 1975]. In 1985 the Department of Water Affairs (DWA) initiated the first eutrophication-focused monitoring programme, the Trophic Status Project (TSP), which covered the 7 sensitive catchments mentioned in GN R.1567 (1980) and GN R.991 (1984), respectively. The TSP laid a solid foundation for the current National Eutrophication Monitoring Programme (NEMP), in that it highlighted the extent of the problem at a national scale and provided a database that was to be used for the design of the NEMP [DWAF, 2002].

After the implementation of the National Eutrophication Monitoring Programme (NEMP) in 2002, the Department also began regularly releasing data maps indicating the extent of eutrophication thereby improving the knowledge about eutrophication in South Africa for an increasing number of sites.

The national objectives of the NEMP are to measure, assess and report regularly on-

- the current trophic status of South Africa's water resources;
- the nature of current eutrophication problems experienced in South Africa; and
- the potential for future changes in trophic status in South Africa's impoundments and rivers in a manner that will support strategic decisions in respect of their national management, be mindful of financial and capacity constraints, yet, be soundly scientific.

At the regional and local level, NEMP objective extend further to:

- Provide an early warning system for specific eutrophication-related problems;
- Assistance with the establishment of nutrient balance by identifying the local source of the problem; and
- Provide data that permits regional and national monitoring objectives to be achieved through local intervention.

The determinants that are measured as part of the NEMP, include chlorophyll-α, algae species, macro chemical variables such as Total Suspended Solids (TSS), ammonium (NH_4), nitrate and nitrite (NO_3 + NO_2), orthophosphate (PO_4-P), sulphate (SO_4), silica (Si), Total Alkalinity (TAL), Kjeldahl Nitrogen (KN), Total Phosphorus (TP), Electrical Conductivity (EC), pH, Temperature and Secchi disc depth. Visual monitoring of the algae blooms and macrophytes is also undertaken at the impoundments. The concentrations of selected inorganic attributes such as sodium, chloride, magnesium, potassium and sulphate are also included.

NEMP samples are to be collected fortnightly or monthly at the dams, lakes and rivers. The water body is then assigned a trophic status as a description of the quality for the purposes of describing the stage at which the eutrophication process is at.

Until recently, there were over 380 registered sites and 90 of these being river sites. In 2021, the NEMP monitored 24 dams and 9 rivers (dam inlets) - this being due to various challenges including the 2018 financial crisis, limited laboratory capacity and lack of samplers to assist with implementation.

ANNEXURE G

Potential legislative amendments, necessary to improve eutrophication management.

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Potential legislative amendments, necessary to improve eutrophication management.

The following potential legislative amendments and reviews are proposed in this document. These changes are regarded as necessary to address anomalies or shortcomings, or to improve and strengthen certain statutory provisions:

RECOMMENDED LEGISLATIVE AMENDMENT	NOTES	REFERENCE *(page #)*
1. Amendment to allow reclassification of the water resource Management Class.	If the receiving water resource does not have enough allocable water quality to assimilate waste without exceeding the RQOs, and if there are major socio-economic drivers behind a proposed new waste discharge, there may be a case to be made for reclassification of a water resource. In this case, it needs to be investigated whether a lower water resource Management Class, that might allow for socio-economic development opportunities to be implemented, may be more appropriate. In such a case, the full procedures required under the legislation for the determination of a water resource Management Class, RQOs and Reserve, including stakeholder consultation, will be applied. The converse is also true, that is, if the water resource Management Class is found to be inadequate for any reason, a higher Management Class might be applied, after appropriate investigation and consultation.	60
2. Amendment to allow for the declaration of protected water source areas	Currently, the NWA (36:1998) allows for only the prohibition of activities in a water source area. A legislative amendment would allow the Minister of DWS to declare high yield water source area as protected. This would ensure that certain areas receive full protection. This may be required for an area to recover and rehabilitate itself, or simply, it may be required for ecological protection.	67
3. Amendment to extend the financial provisioning clause to all high-risk polluting sectors	The financial provisioning for site rehabilitation should extend to all industries that are deemed *"high-risk"* polluters, so that provision is made whilst the industry is operational to avoid post facto actions, with the State carrying the risk.	91
4. Amendments as part of the development of a Non-Point Source (NPS) Strategy	Legislative amendments may be required and need to be investigated, as part of the development of a NPS Strategy for South Africa. These may relate to amendments of the definition of water use, the authorisation process; monitoring requirements; and the addition of provisions to allow for the identification of P and N vulnerable zones; and provisions requiring several diffuse source related interventions.	125
5. Amendments to allow for pollution taxes	The ambitions of the WDCS will be extended by the introduction of pollution taxes on *"input products"*, such as on herbicides and pesticides in line with **POLICY STATEMENT 6**: A life cycle view on nutrient-loading.	126
6. Amendment to allow for the categorisation of polluting industries, based on risk	There are limited human and financial resources available within government. In order to use these resources most effectively and to achieve the greatest impact, a targeted risk-based approach should be adopted. Under this approach, the potential significance of the impact of water pollution must inform the level of response or intervention from the state. Thus, areas of particular sensitivity will receive heightened attention, as will activities from which the pollution potential is of a particularly hazardous nature and areas where pollution is already extremely high.	127

RECOMMENDED LEGISLATIVE AMENDMENT	NOTES	REFERENCE *(page #)*
7. Amendment to allow for the publication of a Water Polluter Register	The publication of information is a useful tool towards incentivising responsible behaviour. In the South African context, the Green Drop certification system for municipalities has proved the regulatory value of the reporting and disclosure of information. A Water Polluter Register should be introduced to extend this reporting beyond municipalities to incentivize polluters to reduce their pollution. In this register, enterprises that are meeting best practice standards should be recognised, as should non-compliance by enterprises.	128
8. Amendment to allow for the promulgation of a Money Bill for the Waste Discharge Levy	The WDCS is based on the polluter-pays principle and aims to promote the sustainable development and efficient use of water resources; internalise the environmental and social costs of using water; create financial incentives for water users to reduce waste and use water resources more optimally, and recover costs associated with impacts of waste discharges. It consists of two charges: a Waste Discharge Levy and a Waste Mitigation Charge. The Waste Mitigation Charge, provided for by the NWA (36:1998), is intended to cover the quantifiable administrative costs of implementing measures to mitigate the negative impacts of waste related discharges. The Waste Discharge Levy provides a disincentive to the discharge of wastewater and will be based on the rate of water utilisation as a means of disposing of waste. In order for the Waste Discharge Levy to be introduced, an amendment to the NWA (36:1998) is required to give the Minister permission to promulgate a Money Bill.	127
9. Amendments to allow for eco-labelling	The introduction of an eco-labelling scheme that acknowledges the water pollution related life cycle of goods and products will stimulate innovation as more sustainable products are invented; develop markets that cater to evolving consumer interests; create opportunities for education; create new value chains by establishing new networks of production; monitor water resource claims; influence consumer behaviour towards more water resource friendly products; promote economic efficiency in response to predefined standards; muster economic support for sustainability; and reallocate the costs of improving the trophic status of receiving water resources.	128
10. Amendment to allow for administrative penalties	Currently South Africa relies on criminal prosecution for addressing water quality violations, but such processes are slow and difficult, particularly in an overburdened criminal justice system. Criminal prosecution is dependent on evidence that proves the case beyond reasonable doubt, and the support of the South African Police Service and National Prosecuting Authority. Many of the players in the criminal justice system do not fully understand water legislation or the seriousness of environmental crimes, with the result that such violations do not draw serious penalties. This is a common problem in many countries, and as a result, many countries are moving towards administrative or civil penalty systems for environmental violations, with a criminal enforcement option retained for the worst environmental crimes. Certain activities that result in water pollution will still follow the criminal prosecution route, such as acts of vandalism.	144

ANNEXURE H

Summary table: Eutrophication management policy.

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STATEMENT #	POLICY STATEMENT
Policy statements in support of the Chief Policy Objectives	
POLICY STATEMENT 1	Application of management instruments for environmental compliance in eutrophication management
POLICY STATEMENT 2	The mitigation hierarchy for decision-making on eutrophication
POLICY STATEMENT 3	The differentiated approach for the control of excessive nutrient-loading
POLICY STATEMENT 4	The application of the precautionary principle
POLICY STATEMENT 5	The Receiving Water Quality Objectives approach applied to eutrophication management
POLICY STATEMENT 6	A life cycle view on nutrient-loading
POLICY STATEMENT 7	Incentive-based regulation
POLICY STATEMENT 8	Nature-based solutions
POLICY STATEMENT 9	The application of the Best Practicable Environmental Option
POLICY STATEMENT 10	Holistic eutrophication management
POLICY STATEMENT 11	Eutrophication management responsibility and accountability
POLICY STATEMENT 12	Monitoring
POLICY STATEMENT 13	Information management
POLICY STATEMENT 14	Water resource assessment and planning to inform decision-making
Policy statements in support of the Complementing Policy Objectives	
POLICY STATEMENT 15	Resourcing of eutrophication management
POLICY STATEMENT 16	Promotion of eutrophication-related research
POLICY STATEMENT 17	Transparency
POLICY STATEMENT 18	Increased capacity
POLICY STATEMENT 19	Cooperative management

ANNEXURE I

Summary table: Eutrophication management strategy.

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