A CONCEPTUAL FRAMEWORK FOR THE COSTING OF DETERIORATING WATER QUALITY AND IDENTIFYING MECHANISMS TO BETTER FUND WATER QUALITY MANAGEMENT

Report to the

Water Research Commission

by

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EXECUTIVE SUMMARY

BACKGROUND

In 2019, the Institute of Natural Resources (INR) was awarded a research project through a Water Research Commission (WRC) solicited call entitled: "CONCEPT NOTE 10: A Research Framework to accurately determine the financial impact of deteriorating water quality and identify mechanisms to better fund water quality management". This report is the final deliverable in the associated project entitled "A Conceptual Framework for the Costing of Deteriorating Water Quality and Identifying Mechanisms to Better Fund Water Quality Management". The aim of the project was to develop a holistic, but conceptual water-quality costing-framework as a tool to give focus and support to assessing the various costs of deteriorating water quality.

METHODOLOGY

A review of relevant literature was conducted, documented and submitted as Deliverable 2, which provided an understanding of a wide variety of water quality issues, related costs and costing models. The literature review formed a foundational understanding upon which the draft conceptual framework was built. This research was then supplemented by information regarding the costs associated with a recent major pollution event in the uMsunduzi River. The information was gathered through interviews with affected parties. The draft framework was then presented to a variety of water sector professionals, governance officials and researchers in a workshop setting where it was validated and amended. Final changes to the draft Water Quality Costing Conceptual Framework were then made to incorporate comments made during the final project steering committee meeting.

RESULTS AND DISCUSSION

The result of this project was the development of a conceptual framework that sets out the landscape of potential costs of deteriorating water quality and costing approaches. The framework guides the user to identify potential costs for a particular context. This information can be used towards identifying suitable water resource management actions and potential economic policy instruments to incentivise and / or fund these actions.

A water quality analysis / assessment tool was developed to be used to support the framework user in understanding the potential impacts of different pollutants. The tool links exceedances of established thresholds in water quality properties with potential consequences and so assists the user in understanding the specific impacts relating to particular pollutants

CONCLUSIONS

This deliverable, the final in the project, provides an overview of the work undertaken during this small research project to develop a conceptual research framework for the costing of deteriorating water quality towards identifying instruments to better fund water quality management. The key outcome of this project is the framework itself. The framework is intended to serve as a starting point towards implementation and further development into a comprehensive water quality costing model.

The project highlights several key points:

- Water quality is an 'umbrella' term for the physical, chemical, biological and aesthetic properties of water; these properties determine its fitness for a variety of uses and for protecting the health and integrity of aquatic ecosystems.

- There are a range of uses and users of water, and therefore, a range of impacts of deteriorating water quality.
- Not all of these impacts are immediately obvious and not all are easily translated into financial costs.
- Opportunity costs relate primarily to the loss of opportunity to use the water for a specific activity due to water quality being below required level, for example, the inability of water to be used for irrigation due to high bacterial loads or high salt or metal concentrations, or the lost opportunity to swim or fish in the river.
- The financial costs of deteriorating water quality are related to the intended use of the water, the user and the extent of the deterioration.
- The financial costs of deteriorating water quality are linked to both the consequences of using water that is no longer fit for its purpose (the damages resulting from the use of poor quality water), the costs of responding to water pollution and efforts to reduce or prevent water pollution.
- A better understanding of the drivers of pollution and the resulting costs and those affected can help in identifying relevant economic instruments and financing mechanisms to support water resource management. Future research and pilot applications are needed to determine which of the range of potential instruments are more suitable for the South African context and under which conditions.

RECOMMENDATIONS

It is recommended that future studies:

- **Expand on the costs of poor water quality on various sectors**, as outlined in the literature review including impacts of deteriorating water quality on power generation.
- **Investigate further the specific effects of deteriorating water quality on several sectors** as there remains uncertainty regarding impacts on recreation and tourism and on the livelihoods of those living and working by river systems, particularly from a South African perspective.
- **Conduct a larger research project aimed at quantifying the costs of deteriorating water quality**, incorporating a comprehensive review of case studies to validate the conceptual framework.
- **Develop the conceptual framework into a functional financial costing model**. Stakeholder input at the workshop pointed to the need for such a model to support a range of regulatory and enforcement activities.

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Research Manager	**Affiliation**
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ACRONYMS & ABBREVIATIONS

DUCT	Duzi-uMgeni Conservation Trust
DWAF	Department of Water Affairs
DWS	Department of Water and Sanitation
INR	Institute of Natural Resources
KZN	KwaZulu-Natal
NWA	National Water Act
WRC	Water Research Commission
WQ	Water Quality
WTW	Water Treatment Works
WWTW	Wastewater Treatment Works

CHAPTER 1: BACKGROUND

1.1 INTRODUCTION

In 2019, the Institute of Natural Resources (INR) was awarded a research project through a Water Research Commission (WRC) solicited call entitled: "CONCEPT NOTE 10: A Research Framework to accurately determine the financial impact of deteriorating water quality and identify mechanisms to better fund water quality management".

This report is the final deliverable in the associated project entitled, "A Conceptual Framework for the Costing of Deteriorating Water Quality and Identifying Mechanisms to Better Fund Water Quality Management". The study aimed to develop a holistic but conceptual water-quality costing-framework as a tool to give focus and support to assessing the various costs of deteriorating water quality. While it was identified by stakeholders as an important need[1], it was not in the scope of this project to develop this framework into a quantitative water-quality costing-model which supports water quality management and decision making.

The framework organises and communicates the multiple cost categories associated with deteriorating water quality. It guides the user to (i) draw out the specific water quality issues, water uses and resulting cost implications specific to their context, (ii) gather evidence appropriate to demonstrating and quantifying the costs, (iii) apply suitable cost assessment methods and (iv) synthesise and interpret the results to inform a financing and resource mobilisation strategy for managing water quality. Given the complex nature of deteriorating water quality, it is likely that multiple, context-specific strategies will be required.

The conceptual framework was initially developed based on a thorough review of a variety of literature which provided a foundational understanding of water quality issues and related costs. This research was then supplemented by information regarding the costs associated with a recent major pollution event in the uMsunduzi River. Such information was gathered through interviews with affected parties. The draft framework was then presented to a variety of water sector professionals, governance officials and researchers in a workshop setting where it was validated and amendments were made.

The detailed findings of the literature review (Deliverable 2) and the development of the framework (Deliverable 4) are reported in separate project reports, but for the sake of completeness, are briefly summarised below.

[1] Given the complex nature of water quality and the challenges in holistically identifying all of the costs related to its deterioration, an in-depth costing model is required for users in decision-making.

1.2 PROJECT AIM

The aim of the project was to develop a holistic, but conceptual water-quality costing-framework as a tool to give focus and support to assessing the various costs of deteriorating water quality. The framework should organise and communicate the multiple cost categories and elements associated with declining water quality, identify methods for estimating/assessing different costs and map out the actions required.

The framework is intended to guide the user to (i) draw out the specific water quality issues, water uses and resulting cost implications, (ii) gather evidence appropriate to demonstrating and quantifying the costs, (iii) apply suitable cost assessment methods and (iv) synthesise and interpret the results to inform a financing and resource mobilisation strategy for managing water quality.

1.3 SCOPE AND LIMITATIONS

1.3.1 Scope

The scope of this project was limited to the development of a conceptual framework to cost deteriorating water quality. The development of a costing model for deteriorating water quality was outside the scope of this project.

This project was designed to be carried out using a desktop approach, assisted by meetings with the project steering committee and a workshop. It was not in the scope of this project to conduct an extensive case study to validate the framework.

1.3.2 Limitations

The framework cannot provide a financial cost to deteriorating water quality. It is to be used to gain an understanding of the cost categories as a result of deteriorating water quality. Additionally, the framework is not intended to be exhaustive on identification of costs of deteriorating water quality. It is dependent on the user's context and objectives to populate a comprehensive list of cost categories.

1.4 SUMMARY OF WORK TO DATE

Table 1 summarises the due dates and the deliverables submitted in this project.

Table 1: Deliverables and due dates

No.	Deliverable	Status	Due date
1	Advance Payment	Complete	01/03/2019
2	Situational Assessment	Complete	28/07/2019
3	Stakeholder Workshop	Complete	12/02/2020

4	Draft Water Quality Costing Framework	Complete	15/05/2020
5	Popular Press Article	Complete	30/06/2020
6	Final Report	Complete	31/08/2020

CHAPTER 2: SITUATIONAL ASSESSMENT

2.1 LEGISLATIVE CONTEXT

There are many pieces of legislation which are potentially relevant to this project, not all of which can be summarised here. It is, however, important to consider the focus given to water quality in South Africa's fundamental legislation as it provides the broad legislative context for this project.

The Constitution of South Africa (Act 108 of 1996) (CSA) places a high level of importance on environmental matters and water features prominently. It states that:

- *Everyone has the right to have access to sufficient food and water;*[2]
- *Everyone has the right to an environment that is not harmful to their health or well-being;*[3]
- *Everyone has the right to have the environment protected, for the benefit of present and future generations through reasonable legislative and other measures that-*

  (i) prevent pollution and ecological degradation;
  (ii) promote conservation; and
  (iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.[4]

The Constitution then also places the onus on the state to secure these rights in section 27(2) which requires the State to take reasonable legislative and other measures, within its available resources, to achieve the progressive realisation of the right. As a step towards this, the National Water Act (Act 36 of 1998**)** (NWA) was promulgated in 1998.

The NWA is the principle regulatory tool governing the state of water resources and it stipulates a compulsory water allocation of both quantity and quality to meet the basic drinking, cooking and sanitary needs of all South Africans (Worldwatch Institute, 2006), termed the basic human needs reserve. An old school of thought held that water is only valuable when it is extracted from the natural environment and utilised on a farm, factory or in a home. This point of view has evolved to place value on water left in place as part of the ecosystem (Postel, 2008). The NWA therefore also stipulates a quality and quantity allocation of water to support ecosystem functions so as to secure the valuable services they provide to South Africans (Worldwatch Institute, 2006), termed the ecological reserve.

[2] CSA Section 27(1)(b)

[3] CSA Section 24(a)

[4] CSA Section 24(b)

The National Water Act defines water use as including a range of activities[5]. Of particular relevance to this project is the fact that several of these use definitions relate to the pollution of a water resource including:

> *(f) discharging waste or water containing waste into a water resource through a pipe, canal, sewer, sea outfall or other conduit;*
> *(g) disposing of waste in a manner which may detrimentally impact on a water resource;*
> *(h) disposing in any manner of water which contains waste from, or which has been heated in, any industrial or power generation process;*
> *(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;*

The NWA also provides for the classification of all significant water resources[6] and the establishment of Resource Quality Objectives (RQOs)[7]. The classification of water resources is a critical element of the NWA in that it provides for the use, development, conservation, management and control of all water resources. It aims to achieve the balance between the use and protection of a resource. Importantly in the context of this project, the RQOS[8] should relate to:

> *(d) the presence and concentration of particular substances in the water;*
> *(e) the characteristics and quality of the water resource and the instream and riparian habitat;*
> *(f) the characteristics and distribution of aquatic biota;*
> *(g) the regulation or prohibition of instream or land-based activities which may affect the quantity of water in or quality of the water resource;*

The NWA also provides for the establishment of a national water pricing strategy for charges for any water use[9]. This may contain a strategy for setting water use charges:

(a) for funding water resource management (including monitoring, controlling and protecting water resources);
(b) for funding water resource development and use of waterworks; and
(c) for achieving the equitable and efficient allocation of water.

This strategy is important in determining the total cost of water which is discussed further in Section 2.3.

2.2 WHAT IS WATER QUALITY

The National Water Act definition of water resource quality[10] is given as, *the quality of all the aspects of a water resource including -*

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[5] NWA Section 21

[6] NWA Sections 12 and 13

[7] NWA sections 13 and 14

[8] NWA section 13(3)

[9] NWA Section 56

a) *the quantity, pattern, timing, water level and assurance of instream flow;*
b) *the water quality, including the physical, chemical and biological characteristics of the water;*
c) *the character and condition of the instream and riparian habitat; and*
d) *the characteristics, condition and distribution of the aquatic biota;*"

Importantly from the perspective of this project, this definition includes a description of water quality as including "the physical, chemical and biological characteristics of the water"[11]. This component is the focus of this project.

Water of acceptable quality is vital to maintain all forms of life and for the improvement of the quality of life. Acceptable water quality is, however, not an absolute term and is relative to the requirements of its intended purposes. The availability of water for various uses is directly related to the management of water quality, quantity and the elimination of diseases (Dennis et al., 2002). The pollution of water resources is therefore a critical determinant in the use value of water. The relationship between required quality and pollution is then also foundational in understanding the costs of deteriorating water quality.

There are several components that make up the physical and chemical characteristics of water that are commonly influenced by human activities, including, but not limited to:

- Temperature,
- Clarity, Turbidity and Total Suspended Solids (TSS),
- pH and Alkalinity
- Electrical Conductivity (EC) and Total Dissolved Solids,
- Organic and Nutrient content
- Xenobiotic components including a wide range of emerging pollutants (e.g. microplastics and pharmaceuticals)

These factors, their sources and impacts are discussed in more detail in Deliverable 2.

2.3 TOTAL COST OF WATER

Water can be seen as an economic good for which there is no substitute. Therefore its allocation and price should not be determined by the market. Water should have a price that achieves two objectives, namely recovering the cost of providing the particular water service and giving a clear signal to the users that water is indeed a scarce good that should be used wisely (Van der Zaag and Savenije, 2006).

The total cost of potable piped water can be divided into two categories. The first is the "use cost" which includes the costs of treatment, storage and distribution of piped water. The second, less obvious, cost is

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[10] NWA Section 1 (1) (xix)

[11] NWA Section 1 (1)(xix)(b)

the "opportunity cost" incurred when one user uses water and, therefore, affects the use of the resource by another user (Briscoe, 1996). The opportunity cost of water can also be extended to the alternative uses forgone due to lowered water quality, particularly in the context of instream uses (Turner et al., 2004). In effect, water (the resource) is 'used' as a sink or conveyance system for wastes and forgoing alternative uses, the water becomes unfit for alternative purposes.

The protection and management of water resources comes at a cost which is ideally recovered from the water users by means of water use charges. The costs involved in supplying raw water in South Africa are outlined in the Pricing Strategy which was developed in terms of Section 56 of the NWA (Department of Water and Sanitation, 2015). It is aligned with the National Water Resources Strategy, where the goal is that water be efficiently and effectively managed for equitable and sustainable growth and development. The pricing strategy contains discussions on water use categories, categories of charges and implementation of the pricing strategy (Department of Water and Sanitation, 2015).

However, (current) water pricing tariffs do not reflect the real value of water and it can be expected that the cost of water services will rise when water resources become limited and/or water quality deteriorates (Water Services, 2016).

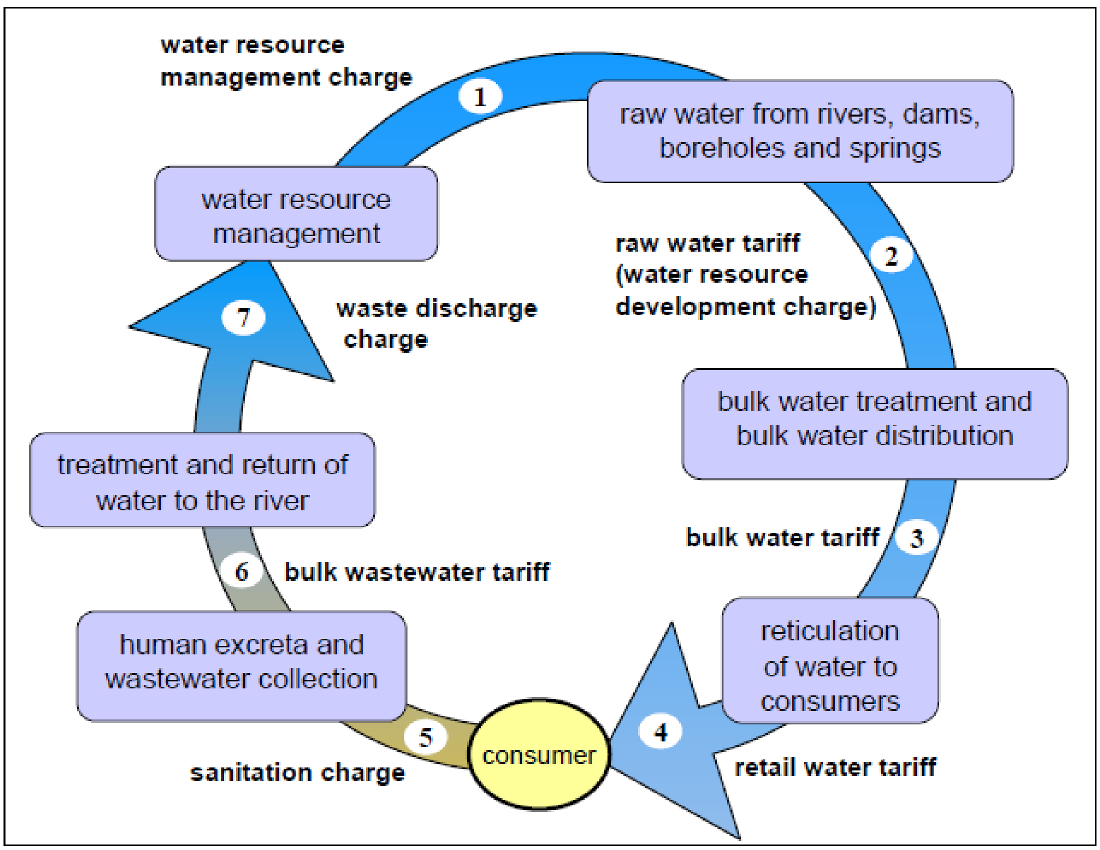

Figure 1: Water cost and pricing chain (Department of Water and Sanitation, 2015)

2.4 REVIEW OF WATER QUALITY COSTING FRAMEWORKS

From a review of the literature, there appears to be a paucity of holistic costing frameworks for deteriorating water quality that encompass a broad range of costs. There are, however, several conceptual frameworks that assess individual aspects of the costs of deteriorating water quality. This section provides an overview of some appropriate conceptual frameworks for valuing water resources and the impact of deteriorating water quality on several aspects.

Numerous conceptual frameworks have been developed to measure the impact of deteriorating water quality on property prices. Leggett and Bockstael (2000) outlined a framework that uses willingness to pay methods to illustrate the impact of faecal coliform contamination on waterfront property prices. Bockstael et al., (1987) described and compared three methods for evaluating the impacts of deteriorating water quality on property value, namely: systems of demands, discrete choice models and the hedonic travel cost approach. The three methods all have their strengths and weaknesses and all three have their uses in particular situations (Bockstael et al., 1987).

Pretty et al. (2002 & 2003) developed a framework of cost categories for costs associated with eutrophication derived from the pressure-state-response framework, where the pressures driving eutrophication arise from point and diffuse sources of nutrients. Diffuse sources of nutrients include agriculture, aquaculture, the transport sector, rural septic tanks and natural sources whereas point sources include sewage treatment and industrial effluents (Pretty et al., 2003). They distinguish between two types of costs: damage costs arising from the use of water of a reduced quality (i.e. not fit for purpose) and policy costs incurred in responding to eutrophication damage plus the costs of changing practices to meet legal requirements. Policy response costs are a measure of how much is being spent to address eutrophication (to avoid damage) and thus cannot be added to damage costs (Pretty et al., 2003).

2.5 POLICY INSTRUMENTS

Economic policy instruments can be used to generate revenue to fund improved water quality management. An economic policy instrument is one of three main types of governing tools, along with regulatory instruments and suasion instruments, used in environmental management towards achieving policy goals (Maila et al., 2018).

Generally, economic instruments aim to achieve two puposes: to achieve policy objectives and to earn revenue, known as the 'double-dividend'. Economic instruments intend to influence or change behaviour using economic incentives or disincentives (Maila et al., 2018). Regulatory instruments, such as laws of a rationing and perscriptive nature, are the most common environmental policy instruments. Suasion instruments are ethical or discretionary instruments that aim to influence or change behavior using verbal or rhetorical techniques, as opposed to force.

It is through economic policy instruments that the government generates catchment management funds by charging user fees for water use and fines for misuse. However, there are several additional types of economic instruments that can be considered in the field of water management and policy. Box 1 summarises the main economic instruments suggested for water management (reproduced from Mattheiß et al., 2009). The relevance of each of these in the context of mobilising financing for water quality management will depend on the context of the key water quality issues, the source/driver of the issues, the affected parties and the present regulatory context (legislation and implementation capacity).

Table 2: Overview of common economic instruments in the water sector (Mattheiß et al., 2009)

Type of Instrument		Function / main purpose	Examples	Policy Issues
Taxes and charges	Water tariffs	To collect financial resources for the functioning of a given water service	Tariffs for drinking water and sewage, tariffs for irrigation water	Does not account for environmental impacts resulting from the use of the service, social issues
	Environmental tax	To internalise negative environmental impacts and influence behaviour, to collect financial resources for the central budget	Tax on pollution discharge or abstraction, tax on polluting input (e.g. tax on pesticide use)	Tax levels are often too low to provide incentives effectively, thus limiting their role to revenue collection
	Environmental charge	To internalise negative environmental impacts and influence behaviour, to collect financial resources that are allocated to support environmentally friendly practices and projects	Charge on pollution discharge or abstraction, charge on polluting input (e.g. charge on pesticide use)	Charge levels are often too low to provide incentives effectively, thus limiting their role to revenue collection
Subsidies	Subsidies on products	To increase the attractiveness of "green" products and production factors that have limited negative environmental impact/footprint	Subsidies for biological agricultural products	Possible negative side effects in other markets (additional policy failure)
	Subsidies on practices	To promote the application of practices and production processes that limit negative impacts on water resources or produce positive environmental externalities	Subsidies for agri- environment measures in the field of agriculture	Level of subsidy to ensure attractiveness by private operators, indirect economic implications
Market for environmental goods	Tradable permit for pollution	To ensure an optimum allocation of pollution among sectors	Market for pollution permits among polluters of a given river basin	Definition of permits, initial allocation of permits
	Tradable permit for abstraction	To ensure an optimum allocation of water quantity among sectors (including the natural environment)	Informal water markets in irrigation schemes; temporary/permanent transfers of water from agriculture to urban areas	Definition of permits, initial allocation of permits, how to account for environmental externalities from reallocation
	Compensation mechanisms	To establish mechanisms where environmental degradation leads to financial payment that is allocated to alternative actions to compensate for the degradation	Compensation to ecological degradation in the aquatic ecosystem	To establish the equivalence between the degradation that is caused and the environmental improvement that is put in place as compensation
Voluntary agreement		To establish contractual agreement between two parties (public/private) to promote good practices that reduce pressures on water resources	Agreements between water companies and farmers to promote good agricultural practices in drinking water protection zones	Effectiveness of the agreement when financial compensation takes place, question of consistency with EU rules in terms of state/public aid

In South Africa, ‘taxes and charges’ is the primary type of economic policy instrument (EPI) applied in water resource management through the various water resources management charges applied at different stages of the water resources management cycle. However, there are several additional types of economic instruments that can be considered in the field of water management and policy. Further research is required in order to identify which of these instruments is more appropriate to the South African context.

Economic instruments operate in different ways and through different mechanisms to address the drivers of degradation (failures in markets, policies, laws, institutions and livelihoods) (Stringer et al., 2018). Many economic instruments and financing mechanisms are highly context specific (GIZ, 2018), particularly with respect to the key drivers of water pollution / degradation and the prevailing enabling environment. A better understanding of the drivers of pollution, the resulting costs and those affected can help in identifying relevant economic instruments and financing mechanisms (or appropriate combinations thereof) to address a specific issue, achieve beneficial outcomes for multiple parties and generate revenue.

Recent work in the field of economic policy instruments and innovative financing has highlighted the following as key research / action areas:

- Convening key stakeholders (including industry stakeholders and finance & insurance professionals, regulators, scientific community) to identify pollution drivers, water users / impactors, the benefits and beneficiaries of EPIs and to evaluate barriers and identify knowledge gaps;
- Translating scientific understanding into metrics of importance for key stakeholders;
- Developing solutions / approaches to overcome scaling challenges;
- Testing and evaluating the effectiveness and benefits of different instruments through detailed (feasibility level of accuracy) pilot projects that provide ‘proof of concept’; and
- Connecting multiple networks to bring lessons to the forefront and facilitate identification of the key determinants (the enabling environment) for the effective development, uptake and implementation of a particular instrument (what has / hasn’t worked and why) (WBCSD, 2017; Maila et al., 2018 (WRC project); Pringle et al., 2018 (WRC project)).

2.6 COSTS OF DETERIORATING WATER QUALITY

The ever-increasing amounts of pollution being discharged into canals, rivers, lakes and seas affect human health, environment quality and productive activities (Table 3). Polluted water exposes users to pathogens and chemical contaminants and in doing so, it increases the burden of disease on exposed populations, particularly the most vulnerable namely the poor, the undernourished and children (UNEP, 2015). Additionally, if polluted waters are used for irrigation, pathogens and chemicals can enter the food chain and have negative impacts on consumers of the polluted product, the farmers that used these waters and the surrounding populations.

Table 3: Potential negative impacts of poor water quality on human health, the environment and productive activities

Impacts on	Example of impacts
Health	• Increase in disease due to reduced drinking water quality • Increase in disease due to reduced bathing water quality • Increase in disease due to unsafe food (contaminated fish, vegetables and other farm produce) • Stress on health care system
Environment	• Reduction in biodiversity • Degraded ecosystems (e.g. eutrophication and dead zones) • Diminished recreational opportunities • Reduced ecosystem services
Productive activities	• Reduced industrial productivity • Reduced agricultural productivity • Reduced market value of harvested crops (unsafe irrigation) • Impact on tourism, or reduced willingness to pay for recreational services

Table adapted from UNEP (2015)

Most sectors make use of water and are impacted by diminishing water quality in a variety of ways. Based on a literature search and input from experts, the following categories were identified to be impacted the most by diminishing water quality in South Africa:

- Ecosystem services
- Agriculture
- Human health
- Industry
- Water supply services
- Power generation and storage
- Recreation and tourism
- Policy response
- Adaptive capacity

Costs to these categories associated with water quality were explored in more detail in the literature review (Deliverable 2).

2.7 WATER QUALITY IMPACT CASE STUDY: POLLUTION INCIDENT - BAYNESPRUIT AND UMSUNDUZI RIVERS

On 13 August 2019, an incident occurred at an edible oil manufacturing plant in Pietermaritzburg, resulting in an estimated 30 000 litres of edible oil and caustic soda spilling into the Baynespruit River and thereafter into the uMsunduzi and uMngeni Rivers (Carnie 2019). The incident was caused by the collapse of a storage tank in the factory, which caused a further two tanks to collapse and spill their contents[2]. This incident resulted in a wide variety of costs to both the manufacturer, to users of water from the rivers, and to the riverine ecosystems and their beneficiaries.

Initially, environmental spill response companies were hired to assist with the clean-up on-site and on the river downstream of the spill (Comins 2019). While a majority of the spill was recovered, it is estimated that 20 to 30 tonnes remained in the environment after the clean-up. The clean-up costs were borne by the manufacturer and are relatively easily calculated, but the impacts to the river and its users downstream are less easily identified and assessed.

The general manager of the Duzi uMgeni Conservation Trust (DUCT) said during an interview that the oil spill indirectly led to the death of two people (Brownell, 2019, pers comm). A 12-year-old boy drowned in Enkanyezeni village, while collecting dead fish from the river shortly after Umgeni Water released water from Henley Dam to flush the river (Mdletshe 2019). There are also unconfirmed reports of a 28-year-old man who drowned while trying to prevent his cattle from drinking the water. The death of a person is tragic in itself and it carries immediate financial costs such as the cost of hosting a funeral, but the associated long-term costs are potentially much greater and harder to calculate, such as the loss of earning potential in the case of an employed individual, or the loss of labour in the case of a household reliant on subsistence activities such as agriculture or fishing.

The costs to the ecosystem are also difficult to calculate. Mark Graham, the director of GroundTruth, stated during an interview that the spill led to the death of approximately 20 tonnes of freshwater fish in the 51 km of impacted river, downstream of the spill (Naidoo 2019). The primary cause of death of these fish was the clogging of their gills caused by crude soap which formed as a result of the mixing of caustic soda and oil.

The cost of the loss of these fish could theoretically be calculated using the market value of fish, but the fish in fact represent an entire ecosystem which, when in a functioning state, generates a range of benefits including the assimilation of waste. Water quality analysis results from the river after the clean-up and after the primary impacts of the spill had subsided indicated that bacteria and nutrient loads were elevated relative to before the spill. This suggested that the river's assimilative capacity had been compromised, resulting in worse than baseline[12] water quality.

[12] Baseline is considered the quality of water prior to a pollution event – see Foundational Principles in Section 9

CHAPTER 3: RESULTS

3.1 A CONCEPTUAL WATER QUALITY COSTING FRAMEWORK

A conceptual framework was developed to map out a range of costs associated with deteriorating water quality. The conceptual framework was developed out of the literature review which provided a foundational understanding and from existing economic theory. This was then refined by the project team using the inputs of water sector experts, stakeholders and users affected by pollution.

The conceptual framework, illustrated in Figure 3 and Figure 4, is to be used sequentially, starting with Assessment Context, where the user considers the scope of assessment, including spatial scale, purpose and objectives of the assessment. The Degradation Context is then researched including the nature of the water quality impacts such as the source of pollution, the nature of the pollutants and the temporal scale. The temporal scale could include chronic pollution over long periods or acute pollution events such as the uMsunduzi River pollution event assessed as a case study for this project.

The Change in Water Properties is then to be investigated including known effects of the pollutants involved. To this end, a water quality analysis / assessment tool was developed (Figure 2) to be used to support the framework user in understanding the potential impacts of different pollutants. The tool links exceedances of established thresholds in water quality properties with potential consequences and so assists the user in understanding the specific impacts relating to particular pollutants.

The Microsoft Excel-based tool requires the input of water quality data which is compared to water quality guidelines outlined by the Department of Water and Sanitation. The user is then provided with potential consequences associated with the exceedance of the guideline levels. For more information on the tool, go to the Project page on the INR website (https://www.inr.org.za/water-quality-framework/).

There was significant interest in the further development of the Water Quality Analysis Tool from the project steering committee. Suggestions included the use of the RQOs to provide a more nuanced delineation of pollutant threshold concentrations. The 1996 SA Water Quality Guidelines are seen as highly protective as they were set at a 95% protection limit. The RQOs are a more attainable and use-related set of water quality guidelines which would be worth including in the Water Quality Analysis Tool. However, the RQOs are catchment specific, thus the WQ Tool would need to be spatially intelligent to understand the specific area under consideration and to make use of the relevant limits set in the RQOs. It was also noted that the South African Water Quality Guidelines are in the process of being updated to include a risk-based approach.

Once these foundational pieces of information have been collated and understood, a range of costs can be investigated. These are predominantly divided into Damage Costs and Response Costs. Once the relevant categories of costs have been identified, appropriate valuing methods can be selected (Figure 4).

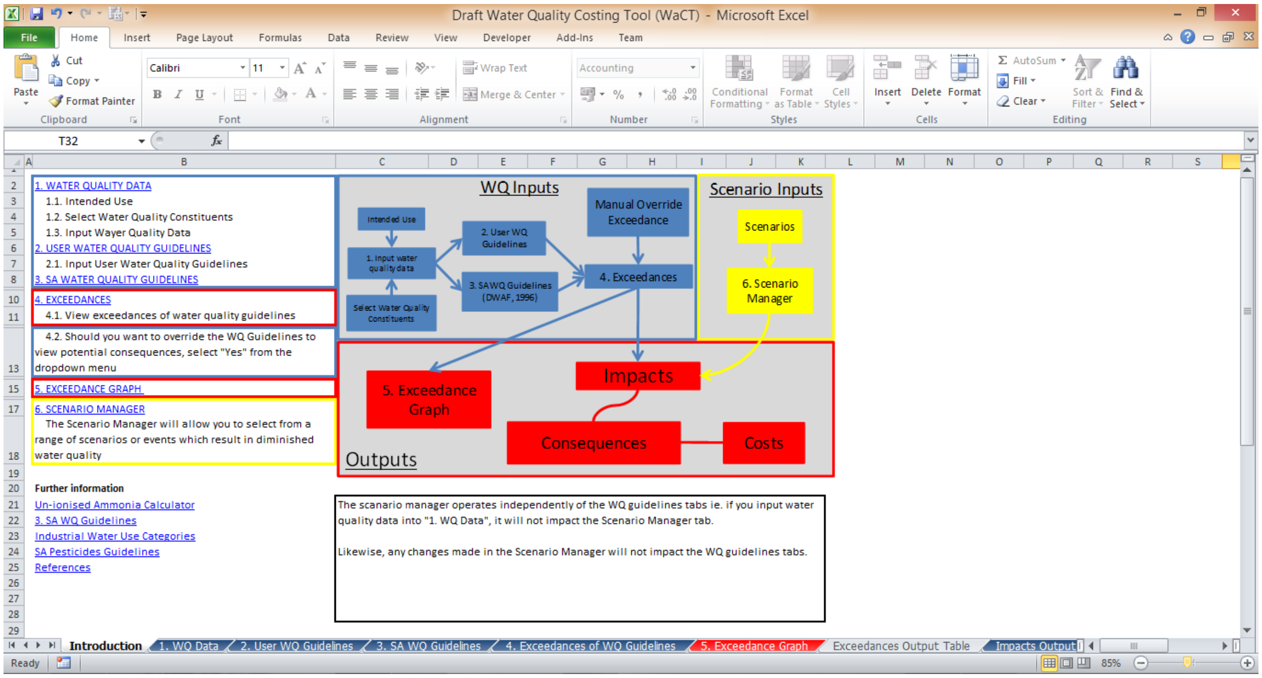

Figure 2: Excel-based water quality costing tool

3.2 KEY FOUNDATIONAL PRINCIPLES

Key foundational principles were also developed to support the use and understanding of the conceptual framework, guiding the user towards a more holistic set of cost categories for deteriorating water quality. The four key principles are:

a) Water quality describes the biological, chemical and physical characteristics of water as defined by the National Water Act.

b) Costs of deteriorating water quality are related to the intended use of the water; water 'use' includes human needs (water user requirements) and the protection of aquatic ecosystems.

c) Potential / projected climate change impacts on water supply, water quality and water uses / demands should be considered in identifying and assessing the costs of deteriorating water quality.

d) The condition of the water resource prior to the pollution discharge must be considered. In assessing the costs associated with a point source discharge incident, the condition of the site prior to the incident is the point of reference (rather than the desired state). However, the desired state and cumulative impacts need to be borne in mind in considering the overall social costs of deteriorating water quality.

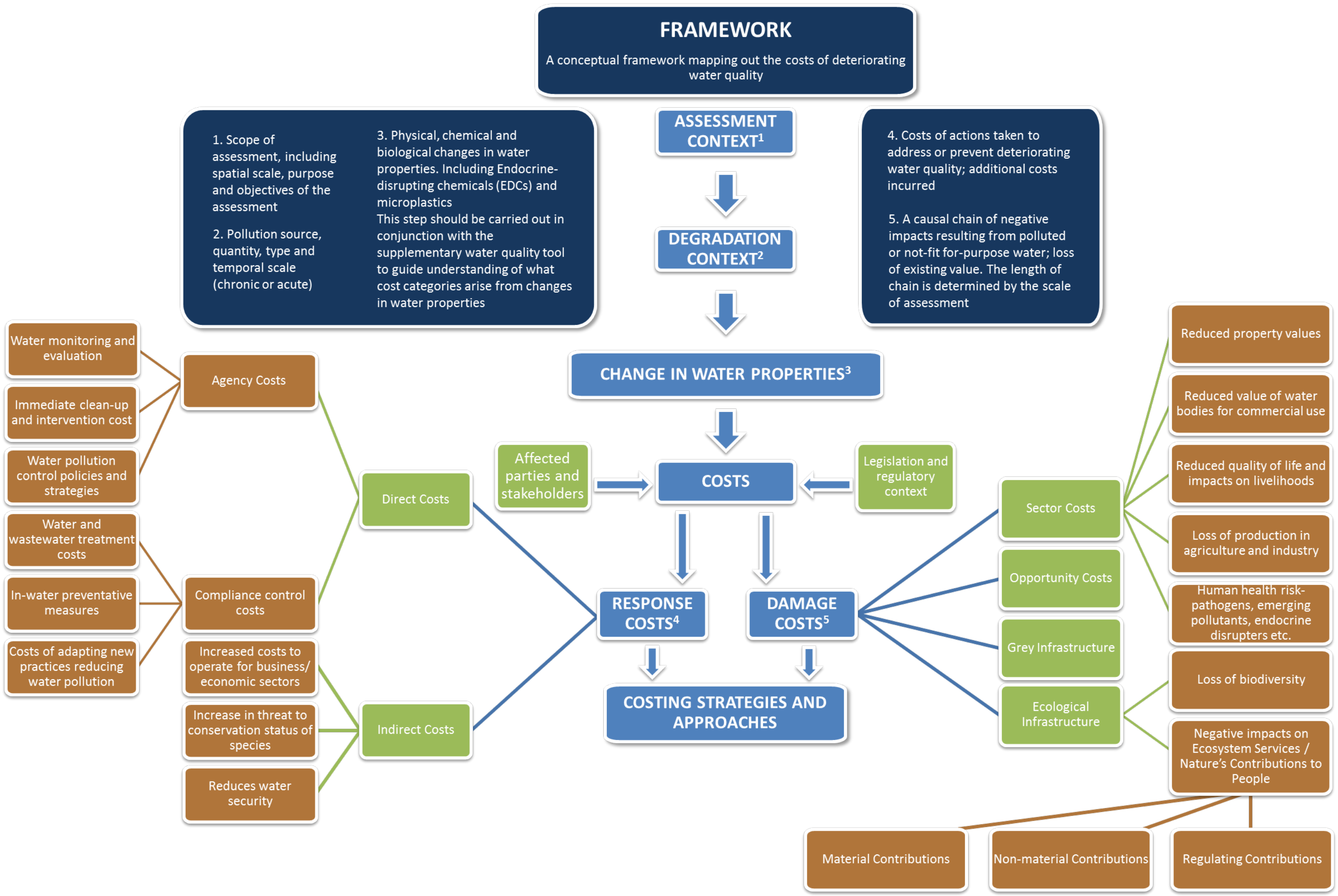

Figure 3: Conceptual framework for the costing of deteriorating water quality

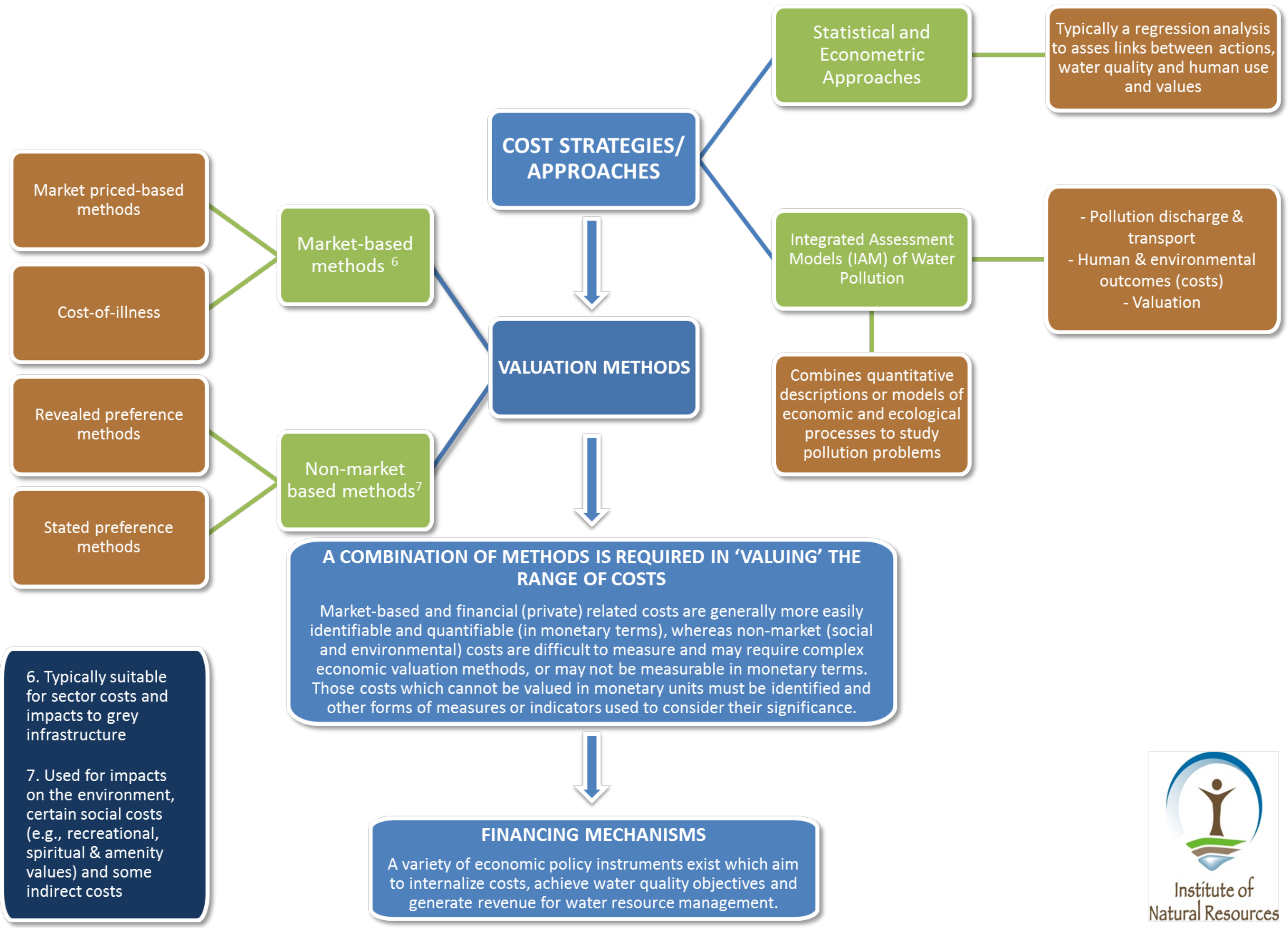

Figure 1: Conceptual framework for the costing of deteriorating water quality (continued)

3.3 REVIEW PROCESS

The literature review (Deliverable 2 of the project) and the first draft of the Water Quality Costing Framework were presented to the project steering committee (PSC) in February 2020. Feedback from the PSC meeting was used to update the literature review and the framework before these were presented at a workshop in February 2020.

The purpose of the workshop was to build on the early draft of the framework and incorporate feedback from stakeholders in attendance. The stakeholders in attendance at the workshop represented a variety of sectors affected by deteriorating water quality, including representatives from agriculture, power generation, bulk water supply, and catchment management.

The attendees were given the opportunity to provide comment on the framework using participatory workshop methods, and guided by the project team. Feedback from the workshop was positive, pointing towards the importance of the continuation of work on the framework beyond the project. Attendees expressed the need for a holistic water-quality costing-model or tool which can support management of water quality and associated decision making.

Climate change was identified as a critical component which was not explicit in the framework. Thus, it was included as a guiding principle (Key Foundational Principles). These principles guide the user to incorporate climate change impacts into their use of the framework.

CHAPTER 4: CONCLUSIONS & RECOMMENDATIONS

4.1 CONCLUSIONS

This deliverable, the final in the project, provides an overview of the work undertaken during this small research project to develop a conceptual research framework for the costing of deteriorating water quality towards identifying mechanisms to better fund water quality management. The key outcome of this project is the framework itself. The framework is intended to be a starting point towards implementation and further development into a comprehensive water-quality costing-model.

The project highlights several key points:

- Water quality is an umbrella term for the physical, chemical, biological and aesthetic properties of water; these properties determine its fitness for a variety of uses and for protecting the health and integrity of aquatic ecosystems.
- There are a range of uses and users of water, and therefore a very wide range of impacts of deteriorating water quality.
- Not all of these impacts are immediately obvious and not all are easily translated into financial costs.
- Opportunity costs relate primarily to the loss of opportunity to use the water for a specific activity due to water quality being below the required level, for example, the inability of water to be used for irrigation due to high bacterial loads or high salt or metal concentrations, or the lost opportunity to swim or fish in the river.
- The financial costs of deteriorating water quality are related to the user, the intended use of the water and the extent of the deterioration.
- The financial costs of deteriorating water quality are linked to both the consequences of using water that is no longer fit for its purpose (the damages resulting from the use of poor quality water), the costs of responding to water pollution and efforts to reduce or prevent water pollution.

4.2 RECOMMENDATIONS

It is recommended that future studies:

- **Expand on the costs of poor water quality on various sectors**, as outlined in the literature review including impacts of deteriorating water quality on power generation.
- **Investigate further the specific effects of deteriorating water quality on several sectors** as there remains uncertainty regarding impacts on recreation and tourism, and on the livelihoods of those living and working by river systems, particularly from a South African perspective.
- **Conduct a larger research project aimed at quantifying the costs of deteriorating water quality**, incorporating a comprehensive review of case studies to validate the conceptual framework.
- **Develop the conceptual framework into a functional financial costing model**. Stakeholder input at the workshop pointed to the need for such a model to support a range of regulatory and enforcement activities.

- **Gain a better understanding of the drivers of pollution, the resulting costs and the impact on those affected** as this can help in identifying relevant economic instruments and financing mechanisms to support water resource management. Future research and pilot applications are needed to determine which of the range of potential instruments are more suitable for the South African context and under which conditions.

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