Linking institutional and ecological provisions for wastewater treatment discharge in a rural municipality, Eastern Cape, South Africa

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Abstract

The Green Drop Certification Programme, launched in 2008 alongside the Blue Drop Certification Programme, aims to provide the Department of Water Affairs with a national overview of how municipalities and their individual wastewater treatment works (WWTW) are complying with licence conditions set by the National Water Act (NWA) (No. 36 of 1998; DWAF 1998) and the Water Services Act (No. 108 of 1997; DWAF 1998). By publishing the results of each municipality's performance, the programme aims to ensure continuous improvement in the wastewater treatment sector through public pressure. The programme has been identified by this project as a necessary linking tool between the NWA and the Water Services Act to ensure protection and sustainable use of South Africa's natural water resources. It does this through assisting municipalities to improve their wastewater treatment operations which in theory will lead to discharged effluent that is compliant with discharge licence conditions. These discharge licences form part of the NWA's enforcement tool of Source Directed Controls (SDC) which help a water resource meet the ecological goals set for it as part of Resource Directed Measures (RDM). The link between meeting the required SDC and achieving the RDM goals has never been empirically tested.

This project aimed to determine the present ecological condition of the Uie River, a tributary of the Sundays River which the Sundays River Valley Municipality (SRVM) discharges its domestic effluent into. It then determined whether the SRVM's WWTW was complying with the General Standard licence conditions and what the impact of the effluent on the river was through the analysis of monthly biomonitoring, water chemistry and habitat data. Lastly, the project examined the effectiveness of the Green Drop Certification Programme in bringing about change in the SRVM's wastewater treatment sector, which previously achieved a Green Drop score of 5.6%. It wanted to examine the underlying assumption that a WWTW which improves its Green Drop score will be discharging a better quality effluent that will help a water resource meets the RDM goals set for it.

The Kirkwood WWTW did not have a discharge licence at the time of assessment and was thus assessed under the General Standard licence conditions. It was found that the Kirkwood WWTW was not complying with the General Standard discharge licence conditions in the Uie River. This was having a negative impact on the river health, mainly through high concentrations of Total Inorganic Nitrogen (TIN-N), orthophosphate and turbidity. The SRVM should see an improvement in its Green Drop score for the Kirkwood WWTW.

However, the municipality showed no implementation of necessary programmes. Implementation of these programmes would help the SRVM meet the General Standard licence conditions (part of SDC) which would help the Uie River meet the RDM goals set for it.

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List of Acronyms

ASPT	Average Score per Taxon
AusRivAS	Australian River Assessment Scheme
CMA	Catchment Management Agency
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
EC	Electrical Conductivity
EWQ	Environmental Water Quality
FRAI	Fish Response Assessment Index
GAI	Geomorphology Driver Assessment Index
GD	Green Drop
GDP	Green Drop Programme
GDIP	Green Drop Improvement Programme
GSM	Gravel, Sand and Mud
HIV/AIDS	Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome
HAI	Hydrological Driver Assessment Index
IWRM	Integrated Water Resource Management

IHAS	Integrated Habitat Assessment System
KPA	Key Performance Area
MIRAI	Macroinvertebrate Health Assessment Index
NGO	Non-governmental Organizations
NTU	Nephelometric Turbidity Units
NWA	National Water Act
NWRS	National Water Resource Strategy
PAI	Physico-chemical Driver Assessment Index
PES	Present Ecological State
RDM	Resource Directed Measures
RHP	River Health Programme
RIVPACS	River Invertebrate Predicition and Classification System
RQO	Resource Quality Objective
RRU	Rapid Response Unit
SAM	Strategic Adaptive Management
SANPAD	South Africa and Netherlands Programme for Alternative Development
SASS5	South African Scoring System version 5
SDC	Source Directed Controls
SIC	Stones In Current

SOOC	Stones Out Of Current
SRVM	Sundays River Valley Municipality
TDS	Total Dissolved Solids
TIN-N	Total Inorganic Nitrogen
VEG	Vegetation
VEGRAI	Riparian Vegetation Response Assessment Index
WMA	Water Management Area
WQ	Water Quality
WRCS	Water Resource Classification System
WSA	Water Services Authority
WSP	Water Services Provider
WWTW	Wastewater Treatment Works

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Chapter 1: General introduction

1.1 Access to water and sanitation

As the global population continues to increase at exponential rates, so does the demand for secure sources of freshwater. Yet, with this increasing need for freshwater comes the increase in pollution of freshwater sources through domestic wastewater (black and grey water) as well as industrial wastewater discharge and agricultural runoff. Whitcutt et al. (2004) point out the irony of the current situation in many countries in Asia, Africa and Latin America, where the right of access to usable freshwater is being written into law while the likelihood of it being realized is fast disappearing. This is most often associated with decreasing abundance of these resources due to supply demands and pollution by wastewater.

At present more than 1 billion people across the globe lack access to safe drinking water with 2.6 billion lacking access to adequate sanitation (Watkins 2009). Water borne diseases, due to the lack of access to clean drinking water and adequate sanitation cause the mortality of around 1.8 million children each year. The United Nations Development Programme states that at the start of the 21st century, unclean water was the second biggest reason for death in children (Watkins 2009). Therefore, adequate wastewater management and treatment has the potential to assist countries in meeting three of the eight Millennium Development goals (namely goals 4, 6 and 7) (Saravanan et al. 2011):

- **Goal 4:** Reduce child mortality by two-thirds relative to 1990,
- **Goal 6:** Prevent the spread of HIV/AIDS, malaria and other disease (including water borne disease such as cholera and diarrohea),
- **Goal 7:** Ensure environmental sustainability (Sachs & McArthur 2005).

Wastewater treatment is arguably “the first barrier in a multi-barrier system of ensuring public and environmental health” (DWA 2011f) and is “the most powerful preventative medicine available to governments to reduce the rate of infectious diseases” (Saravanan et al. 2011). Every country across the globe has different ways of dealing with their wastewater, some more successfully than others as will be shown in this document.

1.2 What is wastewater?

Wastewater is defined as "a combination of the liquid or water-carried wastes removed from residence, institutions and commercial and industrial establishments, together with groundwater, surface water and stormwater may be present" (Tchobanoglous & Burton 1981). There are several main sources of water pollution:

- Sediment due to wind and water erosion of soils,
- Nutrients from fertilizers, animal wastes, and sewage-treatment plants,
- Pesticides including herbicides, insecticides, fungicides etc.,
- Salts from domestic, industrial and mining effluents as well as agricultural return flows, and
- Toxics from manufactured and refined products (Davies et al. 1998, de Clerq et al. 2010, Frost & Sullivan 2010, Huang & Xia 2001).

These forms of water pollution can enter freshwater systems through two mechanisms, i.e. point and non-point sources.

Point sources can be defined as "concentrated originating points such as pipes from industries or feedlots with specific points of discharge" (Huang & Xia 2001). These include sewage treatment works which discharge their final effluent into the environment. Point sources tend to be easier to monitor and manage than non-point sources because water quality can be sampled at the outlet, and directly upstream and downstream to quantify the effects on the water body. They also tend to have a continuous flow making temporal measurements easier to quantify. Many developed countries have established monitoring programmes around point source effluent discharge; unfortunately this is not the case in many developing countries (Watkins 2009). Point source pollutants are controlled through regulating the quality and quantity of the effluent that is discharged into the environment. A number of authors note that point source effluent can have a more acute impact on a water body than diffuse pollution (Daniel et al. 2002, Jarvie et al. 2006).

Diffuse or non-point source effluent can be defined as "highly dynamic spread pollution sources and their magnitude is closely related to meteorological factors such as precipitation" (Vink et al. 1999). Thus, diffuse sources are generally found adjacent to water bodies and enter through seepage, erosion and runoff. They tend to enter the source during or after a specific meteorological event, such as rainfall or flood. They are more difficult to monitor than point sources as the source of pollutants enter the river at a much larger scale than point-source pollutants.

Agriculture is one of the largest contributors to diffuse sources of pollution. This can be through runoff of salts (de Clerq et al. 2010, Flügel 1995), nutrients (van der Laan et al. 2012) or pesticides (Jovanovic et al. 2012). The major nutrients from agricultural runoff are nitrogen and phosphorus, which, in high concentrations, can cause algal blooms harmful to ecosystem integrity. High concentrations of nitrate (NO_3^-) can also be hazardous to children and livestock (van der Laan et al. 2012). However, for the most part, nutrients are mainly not toxic, even in high concentrations (Davies et al. 1998). Nonetheless, studies from South Africa show that although agriculture has a large impact on salinity loads in rivers, nutrient loads are most often attributed to point sources (Cullis et al. 2005). Measures used to combat agricultural runoff often target the chemicals and fertilizers utilized rather than trying to limit the concentrations which enter the river. Preventing runoff is almost impossible. Domestic wastewater is sometimes used for irrigation due to its high nutrient loads and the constant availability of supply. Contaminants found in domestic wastewater can end up in the water resource through agricultural runoff and seepage.

Wastewater, especially from point sources, which comes into contact with people or ecosystems can have adverse health impacts. This is due to combinations of pathogens, high nutrient load, heavy metals, synthetic chemicals and increased flow which alter the natural variation experienced by the system (Daniel et al. 2002). For human health, the main concerns are contact with pathogens and heavy metals. Pathogens can cause sickness such as diarrhea and even death if not treated, while heavy metals can have long term health effects through bioaccumulation in the body (Kistemann et al. 2012). In the environment, large fluxes of nutrients can cause algal blooms leading to decreases in instream dissolved oxygen, availability of sunlight and reducing species diversity. Nonetheless, because of the high nutrient loads, the utilization of wastewater can sometimes be beneficial.

1.3 Utilization of wastewater

Many developing and developed countries have identified that wastewater is sometimes a a valuable resource and not entirely a negative. Not only does the discharge of effluent return water to the water cycle and improve flow but there may be economic benefits associated with its reuse. Increasingly the recycling of wastewater is being investigated for different purposes. This has the positive effect of reducing impacts on receiving environments, reducing the demand for freshwater and reducing overall cost of potable water treatment (Jefferson et al. 2000). Recycling of wastewater treatment effluent that includes industrial waste is costly as there is often a complex ‘cocktail’ of chemical components which requires sophisticated treatment technologies. For this reason recycling industrial wastewater rather than wastewater treatment effluent is achieved mainly in developed countries.

The issues of reducing freshwater demand and reducing anthropogenic impacts on the environment are also pertinent to developing countries. A number of authors have explored the reuse of wastewater for agricultural production (Hanjra et al. 2012, Jagals & Steyn 2002, Qadir et al. 2010, Srinivasan & Reddy 2009, Snyman & van der Waals 2004). This is a more likely alternative for developing countries, including South Africa, as the capital investments are not as great as implementing a complicated collection and treatment system. The clear benefit of this is that only 15-25% of urban water-use is consumed or withdrawn, the rest returning to the hydrological cycle. Large areas of land can be irrigated using this returned wastewater. Often the wastewater receives no form of treatment with the result that it is nutrient rich. Studies showed that irrigating with wastewater can provide profitable returns compared to irrigation using non-wastewater (Wichelns & Drechsel 2011). The high nutrient loads mean that farmers do not need to rely on additional fertilizers and see increased profits. It also ensures a steady supply of water and reduces the impact of runoff on the environment (Hanjra et al. 2012). There are thus clear economic incentives for irrigating with wastewater as it reduces the amount of wastewater treatment needed and can increase crop production by reducing the need for excess fertilizers. Drechsel et al. (2006) show how only 10% of the wastewater generated in West African cities, where irrigation with wastewater is a common occurrence, is collected in reticulated waste systems and receives no form of primary or secondary treatment. China, which irrigates approximately 1.3 million hectares of land with wastewater (Saravanan et al. 2011), only treats 45% of this wastewater (Srinivasan & Reddy 2009). Therefore, there is already large scale irrigation with wastewater throughout developing countries.

Irrigating with wastewater does however have some negative impacts. Domestic water is frequently high in harmful pathogens (Drechsel et al. 2006) while “industrial wastewater often contains elevated levels of metals, metalloids, and volatile or semi-volatile compounds”

(Qadir et al. 2010). These studies found that although there are economic benefits of irrigating with wastewater due to the high nutrient loads, the health effects tend to outweigh these due to the heavy metals and pathogens, which are harmful to human and environmental health in both the short and long term. Nonetheless, the studies argue that if the wastewater receives some form of primary or secondary treatment, these negatives can be overcome. However, this requires large inputs of capital for infrastructure and institutional development.

As has already been touched on, every country approaches the treatment of wastewater and its effects on the environment in different ways. This treatment of wastewater is skewed towards the wealthier countries that have the technologies and capital to treat their effluent, while developing countries tend to utilize more of their wastewater as these technologies are not so readily available. Nonetheless it is necessary to look at the global situation in more detail.

1.4 The global wastewater situation

Globally, one of the major issues around sewage treatment is the inequality in the provision of these services. The international literature on wastewater treatment argues that most developed countries have managed to achieve the basic stages of wastewater treatment and are currently focused on aligning them to achieve national and regional standards (von Sperling et al. 2002). In contrast, developing countries are still struggling to ensure the basics of wastewater treatment are in place, while trying to meet international guidelines, ensure protection of their aquatic ecosystems and continued economic and social development. The serious global shortfall in wastewater treatment technologies is well illustrated in the literature. Within Latin America it is reported that only 14% of domestic wastewater is treated. In São Paulo state, one of Brazil’s most developed areas, only 16% of the urban sewage receives treatment, while the majority of the wastewater generated across Brazil is discharged directly into rivers with no treatment (Daniel et al. 2002). Sub-Saharan Africa sees less than 10% of wastewater receiving any form of primary treatment (Watkins 2009). China, with its rapidly expanding economy, treats a mere 20 percent of its municipal wastewater. Most towns in Pakistan, which have a wastewater disposal system, use the wastewater for irrigation (Hoek et al. 2002). In towns without a wastewater system, water for irrigation is usually abstracted from local water sources. A high proportion of these water sources are used for wastewater disposal upstream of the abstraction points. There is clearly a serious deficit in the available wastewater treatment facilities in developing countries.

Von Sperling et al. (2002) propose a list of the common problems associated with setting up and implementing wastewater treatment standards in developing countries:

- guidelines are directly taken as national standards,
- guideline values are treated as absolute values, and not as target values,
- protection measures that do not lead to immediate compliance with the standards do not obtain licensing or financing,
- standards are frequently copied from developed countries,
- developing countries sometimes attempt to reach developed countries' status too quickly,
- some standards are excessively stringent or excessively relaxed,
- there is no affordable technology to lead to compliance with standards,
- compliance with standards is at a lower level of priority compared to other basic environmental sanitation needs,
- standards are not enforced,
- discharge standards are not compatible with water quality standards,
- the number of parameters monitored are frequently inadequate (too many or too few),
- monitoring requirements are undefined or inadequate,
- the required percentage of compliance is not defined,
- low standard values are sometimes below laboratory detections limits,
- there is no institutional development which could support and regulate the implementation of standards,
- reduction of health or environmental risks due to compliance with the standards is not immediately perceived by decision-makers or the population.

It is often a combination of the above mentioned problems that prevent a developing nation from implementing an effective wastewater management programme. In some cases some of the prerequisites for setting up this programme may be in place, such as the infrastructure, yet the institutional framework is lacking. Connors' (2005) research in Delhi, India is a good example. Although Delhi has a sanitation model similar to that of a developed country with extensive sewage network infrastructure, less than a fifth of the city's waste is processed by its sewage treatment works. This is because a large proportion of the network is silted up and the WWTW only have the ability to process half of the city's waste, yet are often operating below capacity. Thus, it is necessary to examine in greater detail the different institutional controls countries use around the business of wastewater treatment.

1.5 Institutional control

Every country has its own way of regulating and enforcing the treatment and discharge of its wastewater. This is because of different socio-ecological environments thats require case specific regulations and controls (King & Pienaar 2011). As mentioned above, developed countries generally had more resources to overcome the stumbling blocks in regulation, enforcement and infrastructure development of their wastewater institutions than developing countries in general. This tends to result in a higher overall treatment capacity that produces a better quality effluent than developing countries (Xu et al. 2013). The different institutional controls surrounding wastewater treatment in developed and developing countries are discussed below.

United States of America

The United States of America's core piece of legislation that regulates wastewater discharge is the Clean Water Act of 1972 (EPA 2008). This Act "establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters" (EPA 2013). Under this Act it is unlawful to discharge into a water resource without a permit. These permits are issued by the National Pollutant Discharge Elimination System. The permits "specify discharge limits, monitoring and reporting requirements and may also require these facilities to undertake special measures to protect the environment from harmful pollutants" (EPA 2013). Hering et al. (2010) argue that there are clear parallels between the Clean Water Act (EPA 2008) and the European Union's Water Framework Directive (EP 2000). Both Acts control discharge through setting water quality standards, implementing discharge controls and minimizing anthropogenic impacts.

Europe

Wastewater treatment in Europe is regulated through the European Water Framework Directive adopted in 2000 (Hering et al. 2010). This Directive changed the way water resources in all member states are managed, putting aquatic ecology at the base of all management decisions. The Water Framework Directive has moved water governance away from political boundaries and focused them around hydrological catchment boundaries, making decisions regarding activities more catchment specific, and giving these decisions greater impact. This is similar to the way South Africa intends to manage its water resources through Catchment Management Agencies (CMAs), as defined by the National Water Act, (NWA, No 36 of 1998) (DWAF 1998). The main objectives of the EU Directive have moved away from specific pollution control to trying to ensure ecosystem integrity. It therefore moves from merely relying on data generated on selected water chemistry variables to including data generated on biotic communities.

The Water Framework Directive has a much larger scope than the USA's Clean Water Act. The signatories are countries from around Europe who desire a united goal for the way they address water, sanitation and the needs of people and the environment. The Clean Water Act is specifically focused for the United States. It is therefore a national piece of legislation which is effective in a developed country. However, both these Acts have been produced by developed countries and may not be applicable to developing countries.

Brazil

A country similar to South Africa is Brazil. Both countries are developing nations with a history of socio-economic inequalities. They are both classed as upper middle income countries with similar levels of social inequality. In 2006, 23% of South Africa's population was living below the poverty line compared to 26.8% in Brazil (World Bank 2006). South Africa's Gini coefficient[1] (63.1) in 2009 was slightly higher than Brazil's (54.7) but still shows that both countries face high levels of wealth inequality. As previously mentioned, one of the ways of alleviating the experience of poverty is ensuring access to adequate sanitation. One would thus expect that it would be the best interest of both countries to ensure adequate sanitation for its populations. However, as previously shown by Daniel et al. (2002), Brazil is far behind in ensuring adequate sanitation.

[1] "Gini index measures the extent to which the distribution of income or consumption expenditure among individuals or households within an economy deviates from a perfectly equal distribution. A Lorenz curve plots the cumulative percentages of total income received against the cumulative number of recipients, starting with the poorest individual or household. The Gini index measures the area between the Lorenz curve and a hypothetical line of absolute equality, expressed as a percentage of the maximum area under the line. Thus a Gini index of 0 represents perfect equality, while an index of 100 implies perfect inequality" (World Bank 2013).

Brazil's regulating water institution is the National Water Agency established in 2000. It is the government agency responsible for regulating the usage of water resources and all operations related to the quantity and quality of water (Oliveira et al. 2006). The National Water Agency works alongside the River Basin Committees to issue and enforce licences and associated charges for abstraction and effluent disposal. The River Basin Committees are the legal entities which deal with administrative issues surrounding water resource management. These duties include coordination, monitoring, conflict resolution and setting as well as collecting fees for water services and licenses. The business of wastewater collection and treatment is often handled by state and municipal companies under concessions from municipalities. These companies have to operate the treatment plants according to national standards which are set by the National Environmental Council. This council also decides on the intended use of a river and sets the classification for the river. It is important to note that there are two types of standards which need to be met. The first is the effluent discharge standard which determines the concentrations and quality of the effluent that is allowed to be discharged (emission standards). The second is standards for the quality of the receiving water body, depending on the desired use. Oliveira et al. (2006) say that "Brazilian legislation states clearly that, in all cases, the standards for the water body must be complied with, irrespective of the discharge concentrations". These are similar to the forms of control that are used in South Africa (DWA 2013c).

1.6 The wastewater framework of South Africa

Within South African legislation and water management there are two water acts which focus on different aspects of water use and protection: the National Water Act, (No. 36 of 1998) (NWA) (DWAF 1998) and the Water Services Act (No. 108 of 1997) (DWAF 1997). The NWA focuses on resource management while the Water Services Act focuses on water service provision of the resource. The Water Services Act establishes and clarifies the institutional arrangements for water service provision, with local government in a central role (DWAF 1997). The Water Services Act in combination with the NWA provides the necessary guidelines and goals which need to be met in order to ensure that a person's right to a safe and healthy environment is not undermined as stated in section 152 of the Constitution of South Africa (SRSA 1996).

1.6.1 The National Water Act

The NWA promotes the implementation of an Integrated Water Resource Management (IWRM) framework, which seeks to achieve a balance between resource use and resource protection in an integrated, economically and ecologically sustainable manner. The three main principles on which the NWA is based are equity, sustainability and efficiency. The NWA is an enabling piece of legislation and does not provide regulations and penalties. Instead, it relies on regulations developed in terms of the National Water Resource Strategy (NWRS) (DWA 2013c, DWAF 2004a).

Resource protection is achieved through three management processes. The resource is classified, the reserve is determined and the Resource Quality Objectives are set (DWA 2013c). The classification of a water resource describes the extent of the water use and the allocation of the amount of water that can be used from a water resource. There are a wide variety of water users within a catchment, each with their own water use requirements. The classification processes takes these into account through stakeholder engagement after which the water resource will be classified according to one of the three classes (Figure 1.1). The three classes a water resource can be classified as range from Class I (minimal use of the resource) to Class III (heavy use of the resource). Each class determines how much water can be allocated from the resource for use.

Usually in the resource protection process, the reserve determination will run concurrently with the resource classification process.To achieve a decided level of resource protection the NWA introduced the concept of the Reserve which is defined as:

> "***Reserve*** means the quantity and quality of water required:
>
> a) to satisfy basic human needs by securing a basic water supply, as prescribed under the Water Services Act, 1997 (Act No. 108 of 1997), for people who are now or who will, in the reasonably near future, be –
>   i. relying upon
>   ii. taking water from; or
>   iii. being supplied from, the relevant water resource

b) to protect aquatic ecosystems in order to secure ecologically sustainable development and use of relevant water resource" (DWAF 1998, chapter 1(1)(xviii)).

The Reserve stipulates that before any water use can take place the needs of people (for drinking, cooking and hygiene) and the environment must be met. This not only refers to quantity but also the quality and reliability of the water. The Reserve is thus comprised of the basic human needs Reserve and the ecological Reserve. Only once these needs have been met can water for other uses such as industry, agriculture, domestic use and waste disposal be allocated through water use licenses (Palmer et al. 2007).

Class I	Class II	Class III	Requires Rehabilitation	**Water Resource Classification**
Minimal Use	Moderate Use	Heavy Use		

A	**B**	**C**	**D**	**E & F**	**Ecological Reserve Categories**
Minimal	Slight	Moderate	Heavy	Unacceptable	

Figure 1.1 Diagram of a proposed system of water resource classification (Palmer et al. 2004)

The principle of sustainability is addressed by ensuring the ecological Reserve is met. Since the introduction of the NWA, the water resources of South Africa have been and continue to be categorized in terms of health and integrity. Resource categories range from an A, which stipulates a water body with minimal impact, to an F which is a water body in an unacceptable state. Water resources cannot be managed in an E or F category and remedies must be taken to raise them to at least a D category.

When a water resource is categorized, ecological parameters (both quantitative and qualitative) are determined for each class A to F (Figure 1.1). This allows for management decisions to be made as it indicates what would have to be present for the water resource to exist in each of the ecological categories (Palmer et al. 2004a). Thus, for each of these categories Resource Quality Objectives (RQOs) are set. Resource Quality Objectives set goals for the flow (quantity, pattern, timing, water level and assurance of instream flow), the water quality (chemistry, physical and biological characteristics of the water), the instream and riparian habitat (character and condition) and the aquatic biota (characteristics, condition and distribution) of a water resource (Scherman et al. 2003). All of these variables are thus interlinked and determine the 'health' of a water resource.

The Water Resource Classification System (WRCS), the Reserve and Resource Quality Objectives all work together as Resource Directed Measures (RDM) to set goals for the level of protection for a water resource. This level of protection determines for what the water resource can be used. However, merely setting the management class is not enough to ensure this balance between resource use and protection is achieved. For this, regulation is required.

Regulation is achieved through tools such as Source Directed Controls (SDCs) which govern the use of the resource. Source Directed Controls are the management actions which specify the criteria and licensing for ensuring the goals of the RDM are met (Palmer 2004a). This enforcement is needed to underpin regulatory measures. There are links between RDM and SDC such as the conditions attached to an authorization to use the water resource. These authorizations fall under section 21 of the NWA and are termed water use licenses (DWAF 1998). These stipulate the conditions which must be met in order for the water use to be legal. All of these provisions are included in the NWA.

1.6.2 The Water Services Act

The Water Services Act stipulates the way drinking water and sanitation services are to be managed and delivered by local government (DWAF 1997). It contains rules and regulations to municipalities on how they should provide water services. These rules and regulations come in the form of water use licenses, which control waste discharge and abstraction, and other regulatory mechanisms which seek to monitor and enforce the way people utilize resources. The main users of the Water Services Act are institutions, such as municipalities, who are focused on water service provision to water users.

It is important for the Water Services Act to be read in tandem with the NWA as the NWA is "the primary legal instrument relating to accessibility and provision of water services (which include drinking water and sanitation services)" (LHR Publication Series 2009). However, there is a general experience that this is rarely the case (Palmer et al. 2004a). A useful contribution to bridging this dichotomy would be a clear example of the advantage to water managers in utilizing both Acts concurrently. The main focus of this study was the sewage treatment and disposal aspect of the Water Services Act with specific focus on the controls (such as management and infrastructure) surrounding effluent discharge into a receiving water body, linked to the RDM goals of the ecosystem. The regulatory process, linking the provisions of the NWA and the Water Services Act, thus assists the assessment of wastewater treatment works within municipalities.

1.7 The Green Drop Programme

In 2008, incentive-based regulation for the water services sector was introduced through the Blue Drop and Green Drop Certification programmes (DWA 2011a). The Blue Drop focuses on potable water while the Green Drop focuses on wastewater. Most relevant to this study is the Green Drop Programme (GDP). The GDP aims to provide DWA with a national monitoring programme of the performance of individual WWTW within each municipality, and across municipalities as a whole. The programme does this through risk-based and incentive-based initiatives. Risk-based initiatives identify the WWTWs which pose the highest risk to human and environmental health while the incentive initiative is based on releasing the scores of each municipality and its individual WWTWs to the public who then hold the municipality accountable. The GDP assesses the entire process of wastewater treatment, from the consumer to the discharge into the water resource as well as the operations, maintenance and emergency response plans in between (DWA 2011e). The majority (70%) of the GDP provisions assess management and institutional capabilities of a municipality's WWTW which fall under the jurisdiction of the Water Services Act. The remaining 30% of the GDP provisions assess the quality of the effluent being discharged into the receiving water body. This 30% is therefore governed in terms of the NWA as it is aimed at ensuring the RQOs of a water body are being met (part of RDM) and controlling effluent discharge via a license (SDC). Thus the GD Programme draws from both the NWA and the WSA and promotes principles and governance structures from both, as depicted in Figure 1.2.

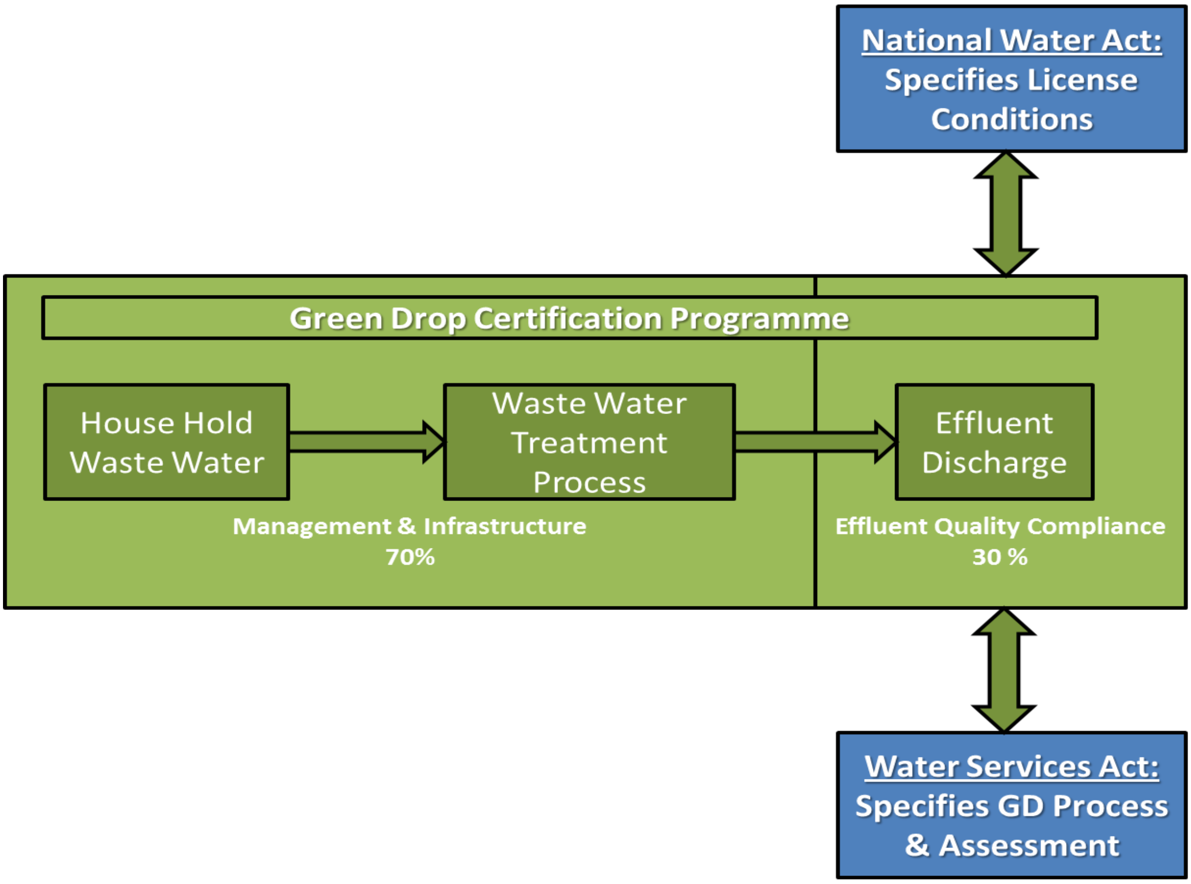

Figure 1.2 Illustration of the Gree n Drop (GD) process from user to discharge into the environment

In the above illustration, the light green boxes show which areas of the business of wastewater treatment can be grouped together. The illustration also highlights the part of the Green Drop assessments which links the NWA and the Water Services Act.

1.8 A local case study on wastewater

Since there are two major pieces of legislation (NWA and the Water Services Act), with the NWA setting the goals of the resource and the Water Services Act setting licence criteria for discharge, the motivating question for this research was "if a sewage treatment works meets its discharge license conditions (part of the SDCs covered by the NWA and the water use licenses covered by the Water Services Act), will the receiving water body meet its RDM goals?". The Sundays River Valley Municipality (SRVM) was chosen as a case study for a broader research programme *From policy to practice: enhancing implementation of water policies for sustainable development,* funded by the South African and Netherlands

Programme for Alternative Development (SANPAD). The SRVM was placed under administration by the provincial government in 2011 due to mismanagement of the municipality's finances. (Definitions of, and provisions for the placement of a municipality under administration are described in COGTA (2009)). The larger research team aimed to investigate integrated transdisciplinary approaches to addressing intractable water resource management problems (Palmer et al. submitted). The Sundays River Valley Municipality was selected because of the need for urgent turnaround strategies. Engagement in wastewater treatment and discharge management was part of this remit. This specific project was therefore initiated as part of the larger research initiative. The Sundays River is the recipient of inter-basin transfer flows from the Orange River, so the main stem of the river has far more dilution capacity than it would have had naturally. This study thus focused on the effect of wastewater discharged directly into the smaller receiving tributary – the Uie River, rather than the effect on the larger receiving system, the Sundays River.

In order to link river health and WWTW performance, compliance of the Kirkwood wastewater treatment works with its license conditions was assessed. The WWTW did not have any specific authorization, but because the plant discharges less than 2Ml of wastewater a day and deals mainly with domestic waste, the plant was assessed against the General Standard (DWAF 2004a, DWA 2011e). These conditions specify the maximum concentration for a number of determinants the WWTW is allowed to discharge into a water resource such as the Uie River. The effect of the wastewater treatment works on the Uie River was quantified through monthly biomonitoring, habitat and water quality assessments at three sites along the Uie River. In addition, Key Performance Areas (KPAs) assessed in the Green Drop Programme, were used to examine changes in the way the municipality managed the business of wastewater treatment subsequent to interventions by a number of outside role-players such as the DWA's Rapid Response Unit (RRU) (See section 4.2).

1.9 Aims, Objectives and structure of thesis

The main aims and objectives of this research project are to:

1. Undertake a partial ecological classification of the Uie River, using monthly water chemistry, macroinvertebrate and habitat data, to determine the variation from the established reference conditions between the three sites along the Uie River.

2. Evaluate the extent to which the Sundays River Valley Municipality (SRVM) is compliant with the effluent discharge license conditions set for the Kirkwood WWTW as legislated by the NWA, and required by the Water Services Act's Green Drop Programme.
3. Asses the relationship between the compliance of the WWTW final effluent and the effect on the river health in relation to the surrounding land use practices.
4. Evaluate the effectiveness of the GD certification programme in assisting municipalities to improve their wastewater treatment process by assessing the degree to which improvements took place in the GD Key Performance Areas.

The above chapter provided an introduction to wastewater and the way different countries deal with this resource. Chapter 2 provides insight into the study site through a description of the catchment, land use practices and demographic profile of the Sundays River Valley Municipality. Following this is a description of the three sites selected for water chemistry and biomonitoring sampling. Chapter 3 and four have each been set out in the style of a research paper. Chapter 3 is the ecological assessment of the Uie River and the effects of the Kirkwood WWTW on this river and focuses on answering aims 1 through 3. It provides an introduction to river health followed by the methodology used, the results found and a discussion of these results in light of the three aims. Chapter 4 provides an assessment of the Sundays River Valley Municipalities wastewater treatment business and the effectiveness of improvement strategies surrounding this. This chapter is focused on answering Aim 4. The chapter begins with an introduction to the wastewater laws within South Africa and how these brought about the implementation of the Green Drop Certification Programme as well as the situation within the municipality at the beginning of the study. Following is the methodology used to assess the municipality and the changes that took place through interventing and assisting institutions such as the provincial government, the Department of Water Affairs through Amatola Water and Rhodes University. The results of the study and a discussion of these results are presented after this. Chapter 5 ties Chapters 3 and 4 together, showing how the management strategies used by the Sundays River Valley Municipality directly influence the ecological aspects of the Uie River. This will address aim 5. Chapter 5 concludes with limitations to the study as well as recommendations.

Chapter 2: Study area

2.1 The Sundays River catchment

The study site is located in the lower Sunday's River Valley situated in the Eastern Cape, South Africa. The Sundays River originates from the Sneeuberge, which includes the Compass Berg. The river flows in a south to south-easterly direction finally flowing into the ocean at Algoa Bay through the Sundays River Estuary (33° 43' S; 25° 51' E) (Kotsedi et al. 2012). The river is 481 km in length, with a width that varies from 50 to 80 m (Wooldridge et al. 2008).

The Sundays River forms part of the Fish-Sundays transfer scheme and receives additional water via the Orange River transfer scheme (Figure 2.1). Water from the Orange River is transferred via the Orange-Fish tunnel from the Gariep Dam to the Great Fish River. Water is then diverted into the small Fish River at the Elandsdrift Weir via the Cookhouse canal and tunnel system. This water is finally diverted at the De Mistkrall Weir via the Skoenmakers Canal into Darlington Dam, formerly Lake Menz and established in 1922. The discharge from Darlington Dam is regulated, creating an unnatural flow regime for the river (Roux et al. 2002, Nel 2006). Koorhansdrift Weir is the only other major impoundment on the Sundays River which diverts some of the water into the canal system for the citrus industry around the town of Kirkwood (Wolff-Piggott et al. 1996). The remainder of the water is allowed to flow downstream towards the estuary where some of it is abstracted by farmers and a larger proportion extracted via a pipeline to meet the needs of the Nelson Mandela Metropolitan Municipality (DWA n.d).

The Sundays River Basin has a catchment area of 20 990 km^2 (Kotsedi et al. 2012). The catchment lies within a transition zone with a bimodal rainfall character. Due to this, the northern part, from the source waters to Darlington Dam, is dominated by summer rainfall where rainfall can exceed 1 000mm annually, while the lower course, from Darlington Dam to the Sundays Estuary, has two peaks in late autumn and winter with an average rainfall of 400mm per annum (Kotsedi et al. 2012). The main interest for this study was the lower part of the river which is located in the N40 Water Management Area (WMA) (DWA n.d). The study area is located in quaternary catchment N40C (Figure 2.2).

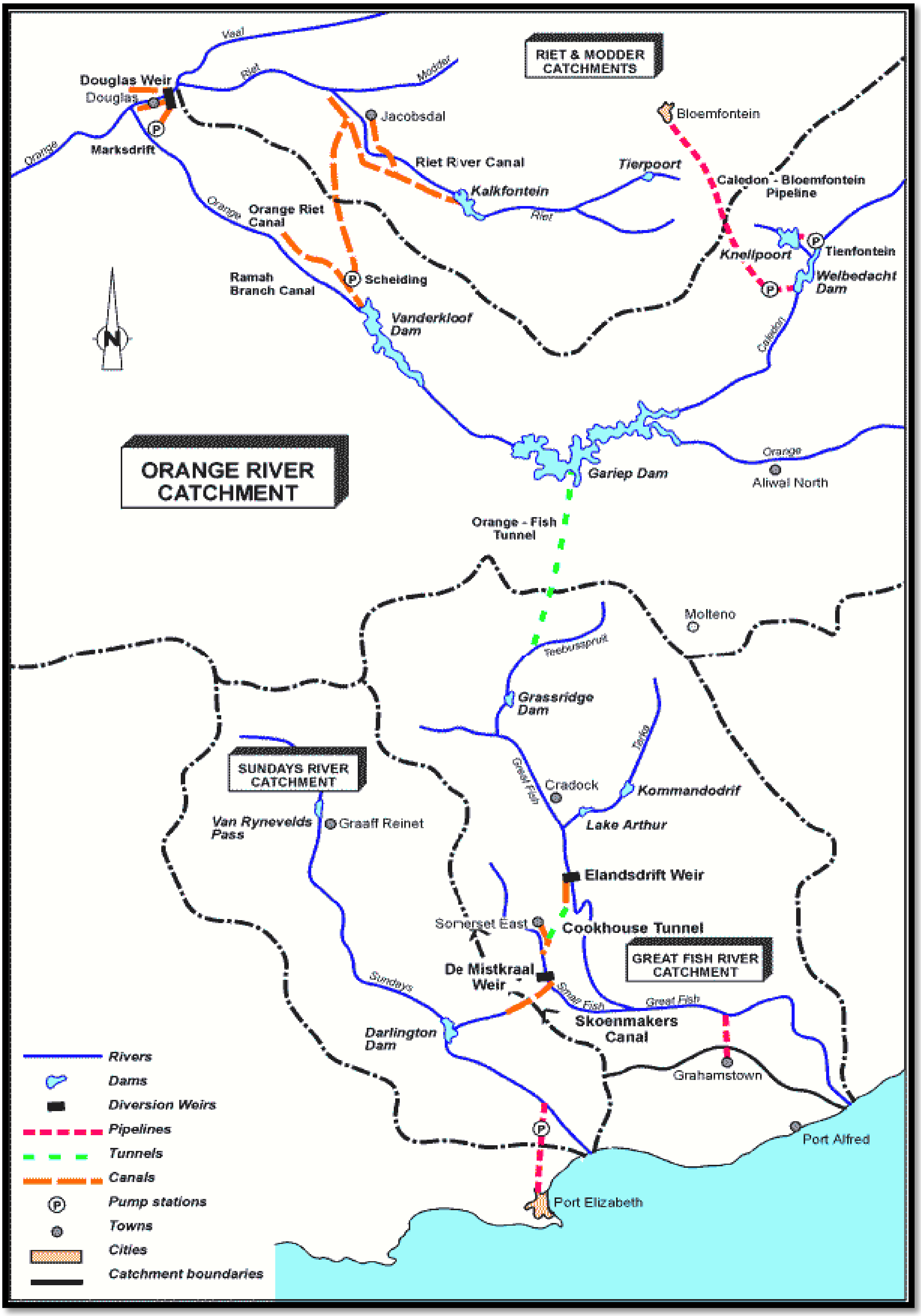

Figure 2.1 The Orange-Fish-Sundays transfer scheme (DWA no date)

The freshwater flow in the lower Sundays River is approximately 0.4 – 1 m^3/s which is relatively consistent. This is due to the inter-basin transfer from the Orange River system and agricultural return flows (Kotsedi et al. 2012). The catchment area of the Sundays River is typically semi-arid due to the low mean annual rainfall (Vromans et al. 2012). The typography of the lower catchment is typically undulating hills rising from the coastal belt. The vegetation of the area is mainly classified as Sundays Thicket which is "comprised of tall dense thicket species and a well-developed variety of lianas. This thicket vegetation type is extremely heterogeneous and contains numerous endemic species, for example *Encephalartos horridus* (the tree cycad), *Aloe bowiea* (a succulent shrub), *Ceropegia dubia* (a succulent climber) and *Haworthia arisata* (a succulent herb)" (Vromans et al. 2012).

The majority of earlier water quality work on the Sundays River found the water quality had a high amount of Total Dissolved Solids (TDS), especially in the lower reaches of the Sundays River (Forbes & Allanson 1970). A number of other authors have reported similar findings (Wolff-Piggott et al. 1996, Pedersen et al. 2007). Many of these authors allude to the quality of the river water being greatly affected by the geological nature of the catchment. The geology of the Sundays River is of marine origin, thus the base-flows naturally contain a higher amount of TDS (Forbes & Allanson 1970). The increasing areas of irrigated agriculture along the banks of the river also lead to highly saline return flows (Davies et al. 1998, Wolff-Piggott et al. 1996). A number of authors have recognised that high levels of salinity can be a limiting factor to macroinvertebrate community abundances (Kefford et al. 2005, Horrigan et al. 2005, Kefford et al. 2003, Goetsch & Palmer 1997). This is supported by Forbes and Allanson's (1970) contention that the Sundays River had comparatively fewer macroinvertebrate species than other study sites. They proposed that this was due to the high TDS levels in the river, particularly in the lower course. However, since Forbes and Allanson's work the Sundays River water has been augmented by the interbasin transfer scheme. The water from this transfer scheme has the effect of diluting the naturally saline water (Pedersen et al. 2007). Nonetheless, little work has been done on the macroinvertebrate communities since this transfer scheme became operational.

2.2 Land use

2.2.1 Agriculture

The main economic drivers of the lower Sundays River area are agriculture and tourism. Land use within the catchment is mostly agricultural, with limited industrial activity taking place in the Sundays River catchment (Kotsedi et al. 2012). The main agricultural practices are citrus cultivation around the towns of Kirkwood and Addo in the Lower Sundays River and livestock around the Alexandria area (Figure 2.2). The citrus area generates approximately 25% of South Africa's navel oranges and 50% of its lemons. A large proportion of the citrus grown is exported to the European markets. This export brings in over R1 billion in foreign currencies to South Africa (SRVM 2013).

Less than 1 % of the catchment is urban, which is mainly residential with some commercial activity. The only major town in the area is Graaff-Reinet which is located in the upper catchment. Smaller towns such as Kirkwood, Jansenville and Paterson are found in the middle to lower catchment.

2.2.2 Game parks and conservancies

The Sundays River area is fast becoming a tourist attraction due to the development of conservation and eco-tourism (SRVM 2013). There are a large number of game parks as well as the renowned Greater Addo Elephant National Park, which receives around 150 000 visitors per year, of which half are foreign visitors. The Park was established to protect the remaining elephant populations which were under serious threat due to poaching and contact with citrus farmers (SANParks 2013). Formally established in 1931, the Park had an elephant population of 16 which has since grown to over 550. The Park now "includes five of the seven biomes (areas with relatively homogenous climate and vegetation) that occur in southern Africa" (Rutherford & Westfall 1994). It thus has large ecological importance for ensuring the survival of these biomes, many of which are seriously threatened. The Park has grown in size and is currently the third largest national park in South Africa (SANParks 2013). Further plans are in place to expand the parks terrestrial borders to cover around 372 000 ha plus an additional 120 000 ha of marine reserve. At the moment, the bulk of tourist activities takes place within the main camp which has a reserve size of 13 500 ha.

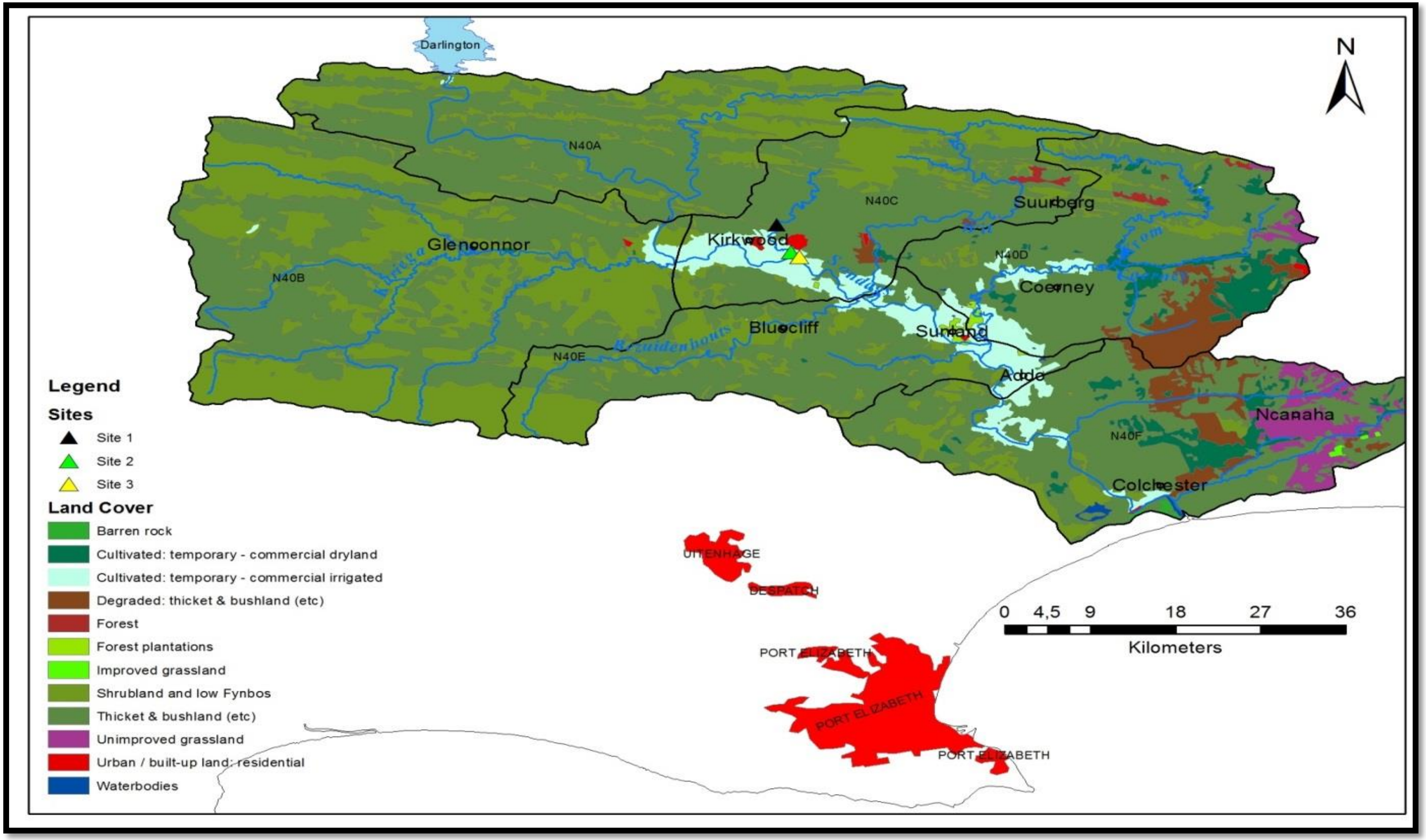

Figure 2.2 Land use map of the N40 lower Sundays River catchment. The sites at which water quality sampling took place around the town of Kirkwood are also shown on the map (Retief 2013)

2.3 The Demographic Profile of the Sundays River Valley Municipality

The local authority in the lower Sundays River Valley is the Sundays River Valley Municipality (SRVM). The SRVM's boundaries cover 3507.59km^2 (SRVM 2013) with a population of 54 504 people living in 14 749 households translating to an average household size of 3.5 people per household (StatsSA 2013). According to the 2011 South African census, 72% of the population are Black African, 21% are Coloured with the remaining 7% being made up by Indian/Asian and White (StatsSA 2013). Of the people between the ages of 15 and 64 a total of 15 751 are employed while 2 791 are unemployed giving the municipality an unemployment rate of 15.1%. Of the households with household members earning some form of income, 7 935 of these households earn incomes of less than R2 300 per month. Thus, just over half of the households in the area are living below the poverty line in South Africa. This employment rate changes during the year according to the citrus harvesting seasons which see an increase in employment rates. Agriculture is responsible for 47.7% of the employment in the area (SRVM 2013).

In terms of basic amenities, 10 713 households have access to piped water inside their yard/dwelling, 2 460 have access to piped water on a communal stand and 1 576 have no access to piped water. There are 8 747 households with flush/ceramic toilets, 3 123 with pit latrines, 1 066 with bucket toilets and 967 without toilet facilities. Thus, more than half the households in the SRVM have access to waterborne sanitation which ends up at one of the four WWTW (SRVM 2013).

2.4 River health sampling sites

To address aims 1 through 3 it was necessary to take monthly water chemistry and biomonitoring samples. This would allow for the present ecological state of the river to be determined as well as the impact of the discharging WWTW to be quantified.

The Sundays River Valley Local Municipality manages four wastewater treatment works (WWTW), i.e. Kirkwood (33°24'23.92" S; 25°28'39.30" E), Enon/Bersheba (33°24'14.79" S; 25°32'51.52" E), Addo (33°32'33.92" S; 25°42'36.75" E) and Paterson (33°26'15.22" S; 25°59'09.12" E), within their district. Of these four, Enon/Bersheba, Addo and Paterson use oxidation ponds to treat the wastewater they receive. All three discharge their final effluent into adjacent storage dams which are used for irrigation. The Kirkwood WWTW is the only activated sludge plant. It is also the only WWTW of the four that discharges its effluent into a river – the Uie River, a tributary of the Sundays River. It receives the incoming wastewater from the towns of Kirkwood and Moses Mabida.

To assess river health and the impact of the WWTW, three sampling sites were chosen along the Uie River for instream water chemistry and biomonitoring (Figure 2.3). These sites were sampled monthly from July 2012 to June 2013.

2.5 Site descriptions

2.5.1 Site 1

Site 1 was chosen as the least impacted site along the Uie River (33°22'48.25" S; 25°27'34.40" E). The site was directly downstream of the Addo Elephant Park and upstream of any residential or irrigation activity. The site therefore illustrated what the river health could be under pre-impact conditions. The site is typical of the upper reaches of many rivers. The river character is generally a slow flowing clear stream with large numbers of loose stones and rocks with some gravel, sand and mud. When sampling first started (July 2012), the site had a large amount of instream aquatic vegetation. However, after the floods of October 2012 this vegetation was washed out (Figure 2.4). At the end of sampling (June 2013), the river began drying up, and sampling in May 2013 was not possible due to no surface flow (Figure 2.5). This is not unusual for the river as it is an episodic river, mainly subterranean with water only surfacing in small patches (Roux et al. 2002).

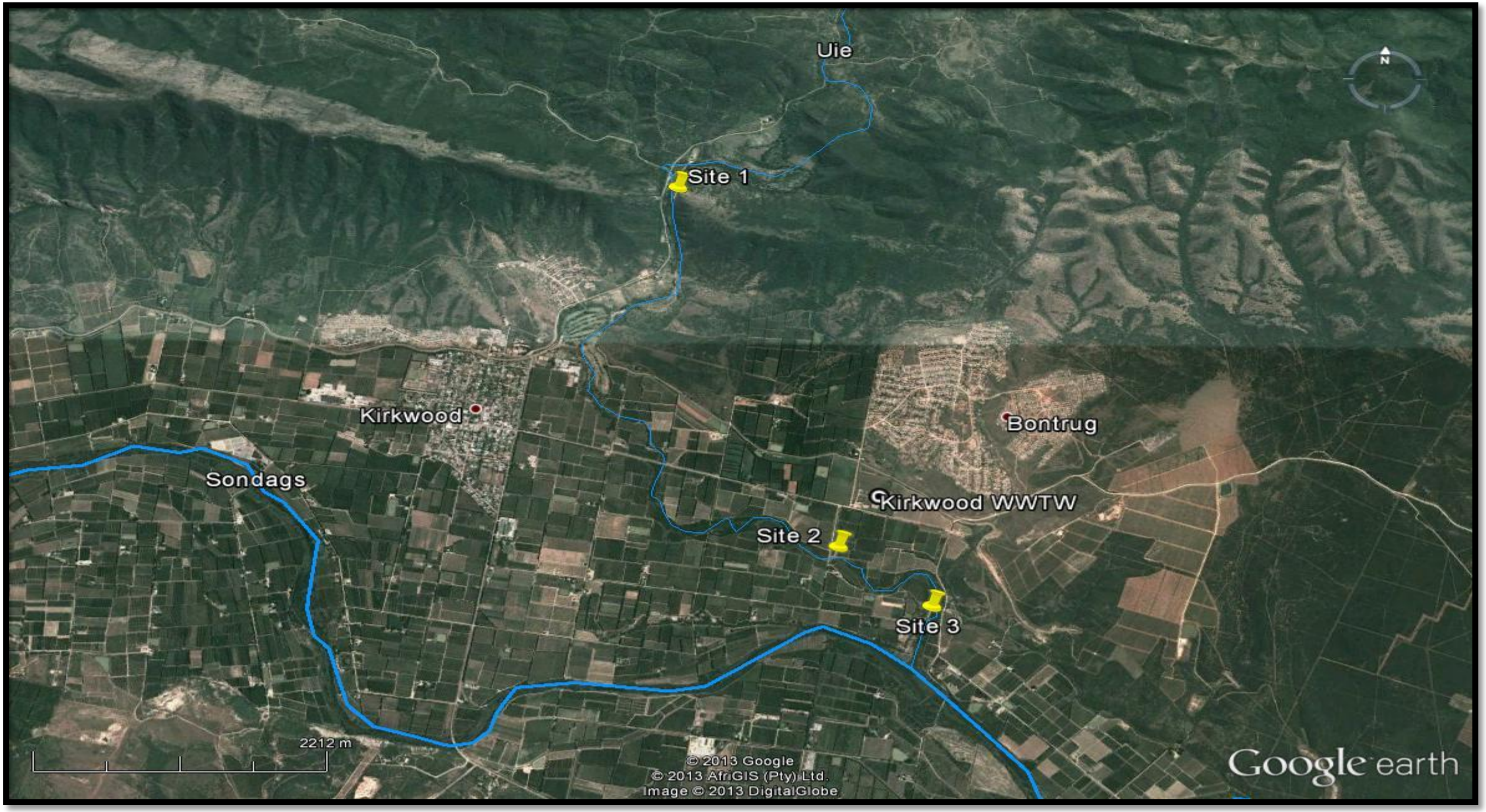

Figure 2.3 Location of water quality and biomonitoring sampling sites along the Uie River in relation to the Kirkwood WWTW and the Sundays (Sondags) River (Google Earth 2013)


Figure 2.4 Site 1 with a large amount of instream vegetation in August 2012 (left) and during the October 2012 floods, (right)

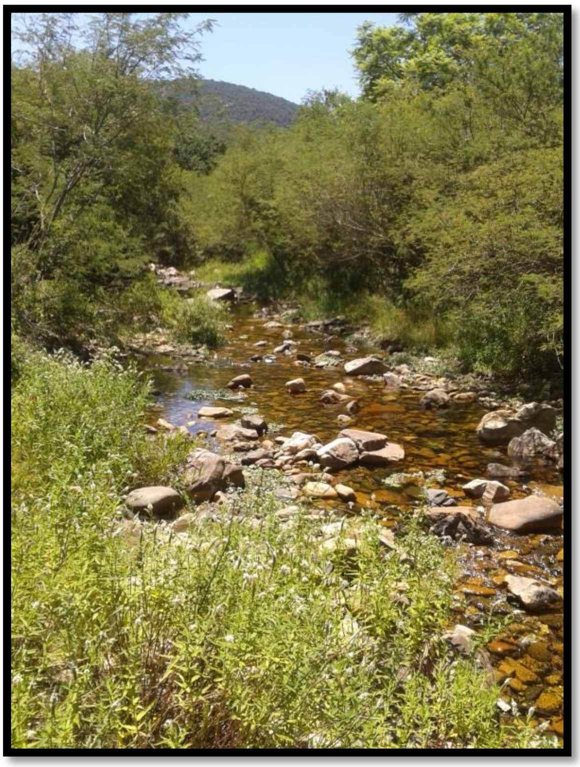
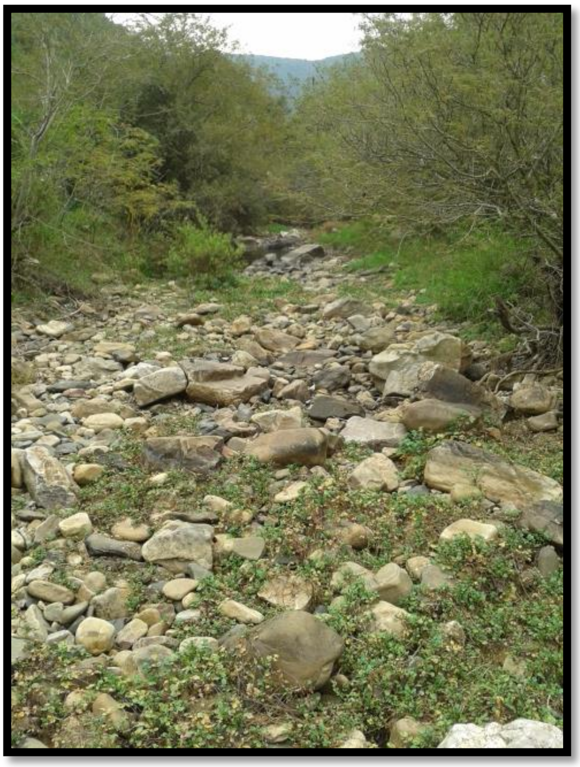

Figure 2.5 Site 1 during the February 2013 sampling trip (left) and with no flow during the May 2013 sampling trip (right)

2.5.2 Site 2

Site 2 was situated directly downstream of the effluent discharge point approximately 5.8km downstream from Site 1 (33°24'42.67" S; 25°28'25.21" E). It was selected to show the immediate impact of the sewage treatment works on the river. The land use around the site is intensive citrus agriculture. The river character consists of a faster flowing river than Site 1 and the water is more clouded with a large number of instream stones and boulders. The increased flow is most likely due to increased irrigation runoff, but also due to return flows from the wastewater treatment works which could discharge up to 2 ML of water a day (Appendix 1). No gravel, sand or mud was present at the site. There was dense marginal vegetation with little aquatic vegetation. At the start of the sampling (July 2012), the river was inundated with sludge from the sewage treatment works. The majority of this was washed out after the October 2012 floods (Figure 2.7). This sludge began settling again after the floods had subsided. Towards the end of the sampling period (June 2013) the sludge levels in the river started reaching similar levels as at the start, up to 23 centimetres deep in places (Figure 2.6). After the floods, the river was rapidly colonised by instream aquatic vegetation which began to disappear towards the end of the sampling (June 2013).

Figure 2.6 Effluent being discharged into the Uie River upstream of Site 2, Jaunary 2013 (left). Sludge build-up at the effluent discharge point, January 2013 (right)

Figure 2.7 Site 2 during October floods 2012 (left) and build up of sludge and aquatic vegetation, February 2013 (right)

2.5.3 Site 3

Site 3 was situated further down the Uie River just before the confluence of the Uie and Sundays rivers (33°25'0.86" S; 25°28'53.56" E). It was selected as a recovery site before the Uie River meets the Sundays River (Figure 2.3). Sampling took place on either side of a culvert through which the river flowed (Figure 2.8). The river was faster flowing than the other two sites most likely a result of irrigation return flows, with the water generally being clear. There was a good amount of marginal vegetation with little aquatic vegetation above the culvert but some below. The stream make up was generally smaller stones and rocks above the culvert with some gravel sand and mud below. The October 2012 floods had little impact on the site which is most likely due to the small wetland situated just above (Figure 2.9).

Figure 2.8 Site 3 upstream of culvert, November 2012 (left) and downstream of culvert, November 2012 (right)

Figure 2.9 Culvert at Site 3, September 2012 (left) and 3 during the October floods 2012, Uie River (right)

Chapter 3: An assessment of the link between wastewater compliance and river health.

3.1 Introduction

3.1.1 What is 'river health'?

Humans rely on rivers for a number of ecosystem goods and services (Costanza et al. 1997, Blignaut et al. 2013). The services can be separated into provisioning, regulatory, supporting and cultural services (MEA 2005). Examples of each of these services are given in Table 3.1. Rivers in a good condition are able to provide a wider range of good quality services than rivers in a poorer condition. Humans have an impact on rivers through alteration of "physical habitat, modifying seasonal water flow, changing the system's food base, changing interactions among stream organisms, and contaminating the water through chemicals" (Karr 1999). These impacts are mostly caused by abstraction of water, effluent disposal, runoff from surrounding land use or physical perturbations to the habitat (MEA 2005). With each impact, the services a river can provide are degraded until the service is no longer available. River systems can thus only accommodate a certain amount of perturbation before their natural functions are compromised. For managers who want to use rivers sustainably it is necessary to determine what the river can provide, how much perturbation it can process and what society wants to use the river for (Karr 1999). To achieve this, the current health status of the river must first be determined. The categorization system used by water managers in South Africa, under the National Water Act (No. 36 of 1998), inherently includes the concept of ecosystem services. Different categories are able to provide different range of ecosystem services (Palmer et al. 2004b). This should give a basis on which to select a category. However, defining river health is not an easy task.

The definition of 'river health' is still hotly debated. The main debate tends to focus around whether the term 'health' can be applied to a river and if so how it can be scientifically measured. Authors who support the term 'river health' argue that it provides an easier understanding for non-scientists as it is analogous to human health and is therefore something with which we are all familiar (Norris & Thoms 1999, Norris & Hawkins 2000, Meyer 1997, Rapport et al. 1998, Kay & Regier 2000). Rapport et al. (1998) discuss the issue of measuring river health and argue that ecosystems could be distinguished as healthy or unwell based on three approaches: (i) the absence of distress defined by measured characteristics or indicators; (ii) the ability of an ecosystem to absorb stress, and bounce back – its resilience; and (iii) the identification of risk factors such as industrial or sewage effluents (Norris & Thoms 1999). Therefore, it is argued that the benefit of using the term 'health' to describe ecosystems is that a wider audience can easily understand what is being communicated. However, there is a large body of literature that argues against using the term 'health' when referring to a river or ecological system. These arguments often relate to how ecosystem health is measured and that the idea of health, when applied to an ecosystem, is too simplistic (Karr 1999). For example, Scrimgeour & Wicklum (1996) argue that the health of a river is defined in terms of how useful it is to society which is a value laden concept, something that is not appropriate in the scientific arena. Suter (1993) argues a similar point saying that health is not an observable ecological property. Thus the term river health is contested.

Table 3.1 Types of ecosystem services provided by freshwater ecosystems and examples of the different services they provide (MEA 2005)

Type of service	Description
Provisioning Services	▪ Water (quantity and quality) for consumptive use (drinking and domestic, agricultural, and industrial use) ▪ Water for non-consumptive use (generating power and transport/ navigation) ▪ Aquatic organisms for food and medicines
Regulatory Services	▪ Maintenance of water quality (natural filtration and water treatment) ▪ Buffering of flood flows, erosion control through water/land interactions and flood control infrastructure
Supporting Services	▪ Role in nutrient cycling (maintenance of floodplain fertility), primary production ▪ Predator/prey relationships and ecosystem resilience
Cultural Services	▪ Recreation (river rafting, kayaking, hiking, and fishing as a sport) ▪ Tourism (river viewing) ▪ Existence values (personal satisfaction from free-flowing rivers)

To address this problem a number of authors use the term 'integrity' alongside or instead of 'health' (Karr 1999, Kay & Regier 2000, Townsend & Riley 1999). Integrity, as defined by Karr (1996), is "the capacity to support and maintain a balanced, integrated, adaptive biologic system having the full range of elements and processes expected in the natural habitat of a region". Other terms which are used alongside environmental health include self-organizing, resilient and productive (Karr 1999). However, these terms are not as widely understood by the non-scientific community and do not appeal to as wide an audience. Thus, the term river health and integrity are often used interchangeably. In this study, the term river health is used with an understanding of its limitations and accepting the associated implications of ecological integrity.

3.1.2 Measuring river health

There are a number of variables which can be used to measure river health. Traditionally, the main way to measure river health was through monitoring the physical and chemical attributes of water (Roux et al. 1993). However, it has been recognised that, on its own, chemical monitoring is insufficient for understanding river health. Depending on the frequency of monitoring, chemical monitoring provides a snapshot of the water quality at the point in time of monitoring. Chemical monitoring in South Africa is generally monthly, and cannot account for daily or weekly variations before becoming costly in terms of finances and time (Roux et al. 2002). In addition, chemical monitoring cannot account for many man-made perturbations such as habitat and flow alterations which impair biological health. Thus, national monitoring programmes around the world, such as the Water Framework Directive in Europe (EP 2000), the Clean Water Act in the USA (EPA 2008), the National River Health Programme in Australia (Smith et al. 1999) and the River Health Programme (RHP) in South Africa (CSIR 2008), use biological monitoring alone, or in addition to chemical monitoring to determine river health.

Biological monitoring offers a number of advantages alongside chemical monitoring (Roux et al. 2002). Aquatic biological communities are continuously exposed to a wide array of natural and man-made stressors as they live within these environments, which impact their health. While biomonitoring cannot directly identify what the stressor is, it can show the effects of a mixture of contaminants through time rather than simply measuring the effects of each individual contaminant which is costly and time consuming (Palmer et al. 2007). The structure of the communities present reflects the ecosystems' ability to tolerate these stressors – its integrity/resilience. Thus, biological communities can act as a red flag or warning for water managers as they "offer a time-integrated indication of possible unmeasured chemical conditions" (Palmer et al. 2004a).

With biomonitoring, a number of different groups of organisms can be used. These include macroinvertebrates, fish, algae, diatoms and vegetation (Roux et al. 2002). Arguably the most common organisms used for biomonitoring assessments are macroinvertebrates. Some advantages of using macroinvertebrate communities for bioassessments are that:

- they constitute an important link between energy sources and top predators;
- they are good indicators of anthropogenic pressures;
- they are widely distributed;
- they give cost efficient results;
- they have a large-scale applicability and can be used across eco-regions; and
- they are subjected to the totality of chemical and physical influences and integrate their effects over time (Alvarez-Cabria et al. 2010, Roux et al. 1999).

These advantages have led to a number of national monitoring programmes being set up around macroinvertebrates alongside water chemistry data such as the River Invertebrate Prediction Classification System (RIVPACS) in Britain (Wright et al. 1993), the Australian River Assessment Scheme (AusRivAS) in Australia and the River Health Programme (RHP) in South Africa (CSIR 2008).

Nonetheless, there are also a few negatives to selecting macroinvertebrates as a biological indicator, the most significant being that their structure and composition change seasonally and that each species has a different life cycle which will produce different data sets over time (Welch 1980). Another limitation is that stressors causing the change cannot be directly identified.

Therefore, while biological monitoring is useful as a red flag and water chemistry as a possible indicator of the stress, there needs to be a tool which provides a causal link between the two. Ecotoxicology is the third component of an approach called Environmental Water Quality (EWQ) which attempts to do this (Palmer et al. 2004, Scherman et al. 2003). Ecotoxicology is beneficial when used along water chemistry monitoring and biomonitoring as it relates biological responses (or tolerances) to physio-chemical values (Scherman et al. 2003). With the ecotoxicology tool, "selected organisms, or communities of organisms, are exposed to single substance solutions or complex mixtures, in the laboratory. The concentrations are carefully controlled and responses are reported as statistical probabilities" (Palmer et al. 2004a). Ecotoxicology therefore provides a causal link between the instream chemical concentrations and the instream biological responses being measured through biomonitoring. However, although the data generated from ecotoxicological tests is important in providing a causal link, the tests can be time consuming and expensive as they require a good scientific understanding of how to prepare and run the tests such as what and how many species to use, whether to use laboratory or field species, how they will be exposed to the chemical, what concentrations of the stressor to expose them to, how long to run the test, what the end-point will be, and how to interpret the results.

Nonetheless, biological, chemical and ecotoxicology monitoring under the EWQ approach, each have their advantages, and when used in conjunction they provide a more holistic picture of whether an ecosystem is impacted by stress and the nature of the stressor. Palmer et al. (2004a) used the following analogy of human health. When a child is sick, one of the first things parents do is take the temperature. If the child's temperature is high the parent may take them to a doctor for a further diagnosis. The thermometer therefore provides a rough index of human health – a high temperature means a person is not well. However, it cannot identify the cause of the problem. Water managers do a similar thing with rivers by using the EWQ approach (WRC 2010, Palmer et al. 2004a).

3.1.3 River health monitoring in South Africa

The National Water Act (No 36 of 1998) recognised that the water resources of South Africa were under stress and immediate action needed to be taken to protect these resources for future generations (DWAF 1998). In order to achieve this the NWA relies on two tools, namely Resource Directed Measures (RDM), which determine the Present Ecological State (PES) of the river and recommends the Ecological Category for the river to be managed, and Source Directed Controls (SDC), that is the policies and licenses that control water use (abstraction and waste discharge). First and foremost, the NWA required that the Minister of Water Affairs implement a classification system for the water resources of South Africa as soon as possible. This would allow an ecological and management classification (which stipulates quantitatively and qualitatively the different variables required for river reaches to exist in a specific ecological category and management class) to be determined for every significant water resource in the country (DWAF 1998).

The term Ecological Classification in South Africa, as defined by Kleynhans et al. (2008):

> “refers to the determination and categorisation of the Present Ecological State (PES; health or integrity) of various biophysical attributes of rivers relative the natural or close to the natural reference condition. The purpose of the EcoClassification process is to gain insights and understandings into the causes and sources of the deviation of the PES of biophysical attributes from the reference condition” [*sic*].

This EcoClassification process relies on a suite of six models to determine a final ecological condition for the river. These models are the:

- Hydrological Driver Assessment Index (HAI),
- Geomorphology Driver Assessment Index (GAI),
- Physico-chemical Driver Assessment Index (PAI),
- Fish Response Assessment Index (FRAI),
- Macro Invertebrate Response Assessment Index (MIRAI),
- Riparian Vegetation Response Assessment Index (VEGRAI).

Data for each of these models are generated by a team of experts for a specific water resource. The outputs from each model are then combined to determine the EcoStatus and PES. The macroinvertebrate and fish response indices are used to determine an instream Ecological Category (Kleynhans et al. 2008). Thus, within South Africa, the main biological indicators for determining the instream present ecological condition as well as the effects from outside influences are fish and macroinvertebrate communities.

The NWA provides for the implementation of the River Health Programme “to serve as a source of information regarding the ecological state of river ecosystems in South Africa, in order to support the rational management of these natural resources” (CSIR 2008). This programme also uses the EcoClassification process; however it “focuses primarily on biological responses as an indicator of ecosystem health, with only a general assessment of the cause-and-effect relationship between the drivers and the biological responses” (Kleynhans et al. 2008). Macroinvertebrate communities are the biological indicator of choice for a rapid assessment of a river reach in South Africa.

It is understood that simply determining the ecological category of a river is not sufficient to ensure its sustainable use. Anthropogenic impacts need to be mitigated through the implementation of SDC (DWAF 1998). The degree to which these impacts need to be mitigated depends on what category water managers want the river to exist in and what ecosystem services are desired – the ecological category decided on. Both the NWA and the Water Services Act in South Africa aim to limit anthropogenic impacts through issuing water use licenses. These licences determine the roles and responsibilities of water users whose activities may impact a water resource. For example, a wastewater treatment works (WWTW) will be issued with a water use licence which specifies quantitatively the amount and the quality of effluent that is allowed to be discharged into a water resource (DWAF 1997). To protect the resource its present condition needs defining (PES), criteria for positively changing the present state need to be set (RDM) and measures to ensure this change is met (SDC) need to be implemented.

Although the NWA, which was published more than 15 years ago, proposed the classification of all significant rivers in South Africa as soon as possible, there are a number of significant rivers and tributaries of these rivers that have not yet been classified. The Uie River, a non-perennial tributary of the Sundays River in the Eastern Cape of South Africa, is one such tributary. The main anthropogenic impacts on the tributary are runoff from surrounding citrus farming (non-point source pollution) and sewage discharge (point source pollution) from a wastewater treatment works (WWTW) managed by the Sundays River Valley Municipality (SRVM).

The question therefore arises: Is there evidence that if the WWTW discharging into the river complies with its licence conditions, the required ecological health of the receiving stream be ensured? To date no empirical data have been collected to address this question. This study aims to provide such data and this chapter focuses on providing the PES of the Uie River using macroinvertebrate and water chemistry data to illustrate variation across the three sites with regards to effluent discharge from the Kirkwood WWTW.

3.2 Methodology

Water chemistry and instream macroinvertebrate data were collected at three sites along the Uie River, a tributary of the Sundays River, on a monthly basis. While water chemistry data provide only a snapshot view of concentrations of selected physical, chemical and microbial constitutions of the water, biomonitoring data are used in addition to provide a more holistic picture of the water quality (Palmer et al. 2004b). Biomonitoring data act as a warning of disturbances to the river, while water chemistry data can indicate possible stressors, depending on the concentrations of the constituents (Palmer et al. 2004a). However, biomonitoring cannot provide a clear link to a particular stressor or the conditions under which a stressor or a mixture of stressors becomes harmful to the aquatic environment. The current study attempted to understand the possible magnitude of the impact of the sewage effluent on the river health rather than which chemical stressors had a specific effect on the river health. Thus, water chemistry analysis and biomonitoring were used to give an understanding of the present ecological condition of the river and the possible effects of a WWTW on river health using invertebrates as an indicator.

3.2.1 Water quality sampling in the Uie River

The following water quality variables were monitored monthly (July 2012 to June 2013) at the three study sites in the Uie River during biomonitoring sampling: temperature (using a mercury thermometer), pH (handheld Cyberscan pH 11), electrical conductivity (EC) (handheld Cyberscan CON 11 conductivity meter), turbidity (handheld Eutech Instruments TN_100) and dissolved oxygen (DO) (handheld Cuberscan DO 110). Portable meters were calibrated before each sampling occasion and the same meters were used throughout the study to ensure consistency.

These variables are important for a number of reasons. Aquatic organisms are very susceptible to changes in temperature. Temperature affects the rates of chemical reactions and therefore also the metabolic rates of organisms (DWAF 1996b). Sudden changes of temperature outside of the normal range can affect optimal growth, reproduction, migration and emergence (Dallas & Day 2004). Temperature also affects the DO concentrations in water. Higher temperatures lead to a decrease in DO concentrations. Dissolved oxygen is one of the most important factors for the survival of aquatic organisms as it is required for their survival and functioning. Unlike air-breathing organisms which freely have access to air, aquatic organisms are dependent on the amount of DO in the water. Therefore, DO concentrations can provide a useful measure for aquatic health (DWAF 1996b, Dallas & Day 2004). The pH of a water resource can change the availability and toxicity of constituents such as trace metals, non-metallic ions such as ammonium, and essential elements such as selenium (DWAF 1996b). Thus, pH plays an important role in the availability of nutrients necessary for aquatic organisms and the toxicity of harmful constituents. The electrical conductivity of water, often used interchangeably with total dissolved solids (TDS), is the measure of the number of charged particles (ions) in solution which is also a measure of the total quantity of salts (Dallas & Day 2004). The proportional concentrations of major ions affect the buffering capacity of water and hence the metabolism of organisms which affects the health of the ecosystem (Palmer et al. 2004c). Turbidity is the water variable most clearly visible to the casual observer. Its immediate effect is to reduce the clarity of water due to the amount of suspended solids. This impedes light penetration which can reduce the temperature, affect photosynthesis, and predator-prey relationships due to reduced visibility (Gordon et al. 2012).

In addition to the field water quality data collection, a grab sample of river water was collected before the macroinvertebrate sampling to analyse the water for the following nutrients: orthophosphate (as phosphorus, PO_4-P), nitrates (NO_3), nitrites (NO_2) and ammonia (NH_3). Total inorganic nitrogen (TIN-N) was calculated using NO_3, NO_2 and NH_4. Nitrogen (NH_4, NO_2 and NO_3) and phosphorus are major plant nutrients and are the most commonly implicated nutrients in eutrophication. While these nutrients are often not toxic unless in high concentrations, eutrophication can cause imbalances in biological communities, generally through aquatic plant growth (van Ginkel 2011).

An acid washed bottle was filled with water, marked and stored in a cooler box with ice packs in the field and later transferred to a fridge in the laboratory to slow the degradation process of the variables before analysis (Álvarez-Cabria et al. 2010, Ometo et al. 2000, Vega et al. 1998). No chemical preservation was done as analysis of the water samples was completed within the next 48 hours to limit nutrient degradation.

Ammonia was analysed using the Spectroquant 1.14752 test kit (analogous to EPA 350.1, APHA 4500-NH_3 D, and ISO 7150/1) (Merck 2013b). Phosphorous (PO_4-P) concentrations were calculated using the Spectroquant 1.14543 test kit (analogous to EPA 365.2+3, APHA 4500-P E, and DIN EN ISO 6878) (Merck 2013a). Calibration curves for ammonia and phosphorous were produced for each reagent kit used to compensate for batch differences.

Nitrites (NO_2) were analysed using the Colorimetric Method (4500-NO_2^- B) and Nitrates (NO_3) were analysed using the Ultraviolet Spectrophotometric Screening Method (4500-NO_3^- A) according to the *Standard methods for the examination of water and wastewater* (APHA 1992). Calibration curves for nitrates and nitrites were created every two months or when new solutions were prepared. The reagents were prepared and stored in Schott Duran 250ml bottles wrapped in aluminium foil and stored at 4ºC. When analyzing nitrate concentrations for Site 2 and Site 3 samples were diluted to a ratio of 1:5 with ultrapure water (Milli Q Direct 16) as NO_3 levels were below the detection limits.

It was not possible to sample at the sites during October 2012 due to flooding in the Eastern Cape. In May 2013 there was no flow at Site 1 so no sampling could take place.

3.2.2 Effluent quality data from the wastewater treatment works

In order to understand what effect the WWTW effluent was having on the river the project needed to examine the quality of the actual effluent being discharged. The Sundays River Valley Municipality (SRVM) began its compliance monitoring for both potable and wastewater in July 2012; prior to this no compliance monitoring had been done. The municipality sent its samples to an accredited laboratory, Talbot & Talbot (Port Elizabeth, South Africa) once a month. These samples were taken towards the end of every month and sent for analysis by either the Environmental Health Practitioner or a Technical Officer from the municipality. The general effluent quality limits for which the SRVM's Kirkwood wastewater works were required to test for are shown in Table 3.2.

Table 3.2 Wastewater limits applicable for discharge of wastewater into a water resource (DWAF 2004b)

Substance/Parameter	General Limit
faecal coliforms	1000 (per 100 ml)
chemical oxygen demand	75 (mg/l)
pH	5.5-9.5
ammonia	6 (mg/l)
nitrate/nitrite as nitrogen	15 (mg/l)
suspended solids	25 (mg/l)
electrical conductivity	70 ms/m above intake, max 150(mS/m)
orthophosphorous as phosphorous	10 (mg/l)

Compliance was determined by first comparing the number of compliant samples of each variable to the number of overall samples reported (DWA 2011e). Following this the percentage compliance per variable (for each of the eight variables) was determined as follows:

$$\frac{Number\ of\ compliant\ samples}{Total\ number\ of\ samples\ reported} \times 100$$

This compliance percentage was compared with the compliance percentage stated by the General Standard licence conditions to understand whether the WWTW was complying with the specific variable.

Generating the WWTW's overall compliance was done in a similar fashion. Here, the sum of the number of compliant results and the sum of the number of samples reported for the period were used in the following equation:

$$\frac{Sum\ of\ number\ of\ compliant\ samples}{Sum\ of\ total\ number\ of\ samples\ reported} \times 100$$

The final percentage therefore illustrated how the WWTW is complying overall, providing an indication of potential effect on the river (DWA 2011e).

3.2.3 Macroinvertebrate Response Assessment Index (MIRAI)

Biomonitoring was undertaken using the South African Scoring System methodology (SASS5) (Dickens & Graham 2002). The South African Scoring System is a scoring metric which determines a score for a site depending on the presence/absence of macroinvertebrate taxa and is the main tool used by the River Health Programme in South Africa (CSIR 2008). Macroinvertebrate taxa have been assigned scores according to their sensitivity to disturbances. The sampling involves collecting macroinvertebrate species from three biotopes at each site namely,

1. stones (including stones in current (SIC) and stones out of current (SOOC));
2. gravel, sand and mud (GSM); and
3. instream and riparian aquatic vegetation (Veg).

Each taxon identified is given sensitivity and abundance ratings. The scores for each taxon present are then added up to get a final score for each biotope as well as an overall SASS score for the site. This score is then divided by the number of taxa identified to give the average score per taxon (ASPT) for each site as well as each biotope. A number of studies have found that the ASPT score is less variable than SASS score and should be the common SASS index of choice in most instances (Dallas 2000, Chutter 1998).

On its own, the SASS provides limited information about the current health status of the instream macroinvertebrate communities as it is a rapid assessment. To gain a deeper understanding SASS data can be entered into the Macroinvertebrate Response Assessment Index model (MIRAI). This is a model which forms part of a larger suite of models used when conducting ecological Reserve studies. The MIRAI generates a basic instream category based on the instream macroinvertebrate assemblages. To do this MIRAI uses four different metric groups that measure the deviation of the invertebrate assemblages from the reference (expected) assemblages in terms of

i. flow modification;
ii. habitat modification;
iii. water quality modification; and
iv. system connectivity and seasonality (Thirion 2008).

Thus, MIRAI was seen as the most appropriate methodology for determining the present ecological condition of the macroinvertebrates in river and how this deviated from the reference condition due to the impact of the WWTW on the river.

For this study, data were entered for each of the MIRAI metrics. Weightings were assigned to each of the metrics depending on how much they were expected to contribute to the overall score. These weightings were derived by understanding whether and to what extent a change from the reference condition had occurred. This was measured through either an increase or a decrease in abundance and/or frequency of occurrence in the macroinvertebrate communities measured (Thirion 2008). The metric are calculated on a six point rating score as follows:

- 0 = No change from reference;
- 1 = Small change from reference;
- 2 = Moderate change from reference;
- 3 = Large change from reference;
- 4 = Serious change from reference;
- 5 = Extreme change from reference;

The combination of these metrics generated a present ecological category for macroinvertebrates at each site (Thirion 2008). A copy of the model's information sheets can be found in Appendix 2.

Part of the information required for establishing the MIRAI scores for sites is the determination of reference conditions. This can either be done using a minimally impacted site in the same Level II EcoRegion or through the use of historical data from similar sites in different rivers (Thirion 2008). In this instance it was only possible to use the historical data from similar sites as no idea reference site could be found. The only historical data that were available were from a previous study on the main stem of the Sundays River. The previous study had four sampling sites. Each site had been sampled on four occasions over two years (December 2006 to November 2008). Only two of these sites were selected as they fell within the same EcoRegion as the study sites. These were at site below the Barkley Bridge and another site on the Sunlands citrus farm. With the help of Dr Gordon who has worked in the area, collected the data and has experience with MIRAI, a reference condition for the Uie River was determined (See attached CD for copies of the reference data). This reference condition reflects what macroinvertebrates one would expect to find under natural conditions in the Uie River.

3.2.4 Integrated Habitat Assessment System (IHAS)

The physical habitat structure of a lotic ecosystem is of critical importance to the composition, diversity and abundance of resident biological communities (Ollis *et al.* 2006). The quantity and quality of this habitat greatly affects the potential of aquatic communities. This is especially true with regards to macroinvertebrate communities. Macroinvertebrate habitat diversity is considered to have the greatest impact after water quality (Chutter 1998). Thus, when conducting an assessment of the health of macroinvertebrate communities one cannot ignore the influence of the physical habitat.

For this study the Integrated Habitat Assessment System (IHAS) was selected to assess the state of the physical habitat and to what degree it was influencing macroinvertebrate health scores. This assessment system is widely used across South Africa especially when conducting macroinvertebrate bioassessments. The ultimate aim of the IHAS "is to summarise and numerically reflect the quantity, quality and diversity of biotopes available for habitation by macroinvertebrates at a sampling site" (Ollis *et al*. 2006).

The IHAS is split into two main sections: Sampling Habitat and Stream Condition/Characteristics. The Sampling Habitat is further split into three sub-sections: Stones-in-Current, Vegetation, and Other Habitat. Each of these sections has a series of questions with up to five possible answers with a numeric value assigned to each answer. The numeric values from these answers are then totalled to give a score for each sub section which are added together to give a score for Sampling Habitat and Stream Condition/Characteristics. The IHAS score is out of 100 points and is derived by adding the scores from Sampling Habitat and Stream Condition/Characteristics (McMillan 1998). Any IHAS score above 75 is regarded as a habitat in excellent condition while any score between 65 and 75 indicate adequate habitat conditions.

3.3 Results

3.3.1 Water chemistry

Figures 3.1 to 3.7 below and Appendix 3 show the ranges of instream water quality variables measured at each site from July 2012 to June 2013. The average temperatures show little variation between sites although there is a slight decrease in temperature downstream (Figure 3.1). The temperatures show an increase in summer and a decrease towards winter, which is expected. There is little variation between pH between sites, with Site 1 showing a marginally lower pH (Figure 3.2). All three sites are well within the Target Water Quality Range (TWQR) given by DWAF (DWAF 1996b). A slight spike in pH was recorded in the June 2013 sampling, possibly due to a faulty pH meter. The average DO value at Site 3 is slightly lower than the other two sites with less variation between seasons (Figure 3.3). All sites are above the TWQR for DO of 3 mg/l (DWAF 1996b).

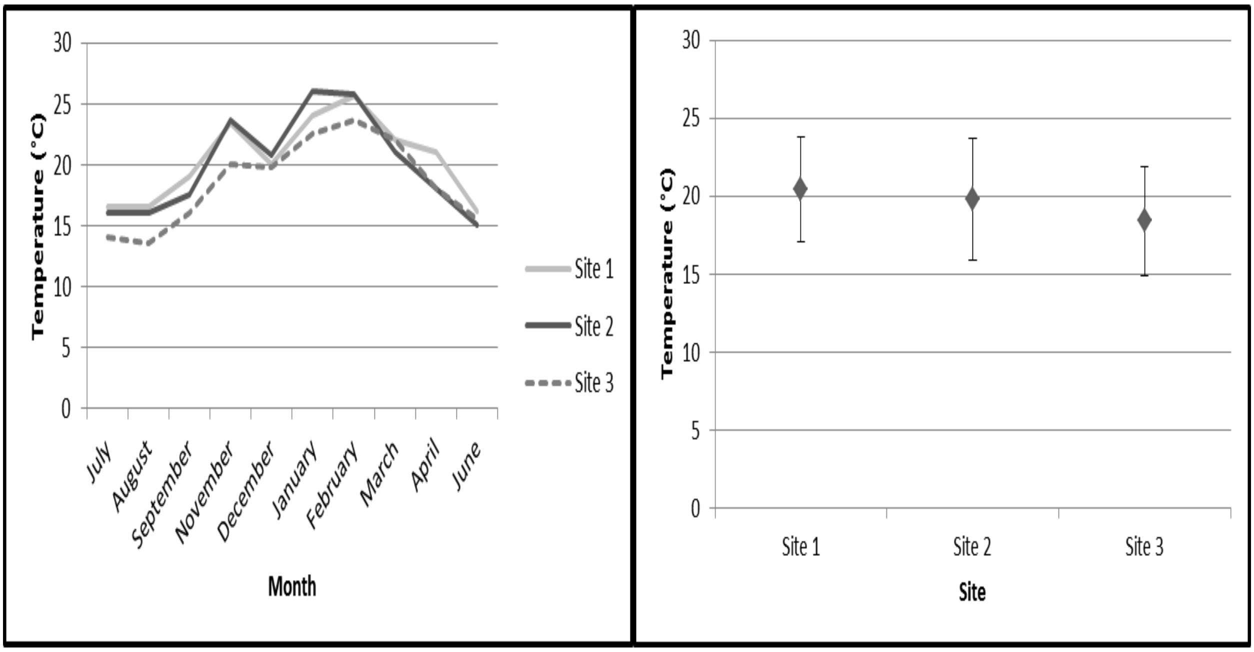

Figure 3.1 Monthly **temperature** variation (left) and average per site (right) with standard deviation over the period of July 2012 to June 2013

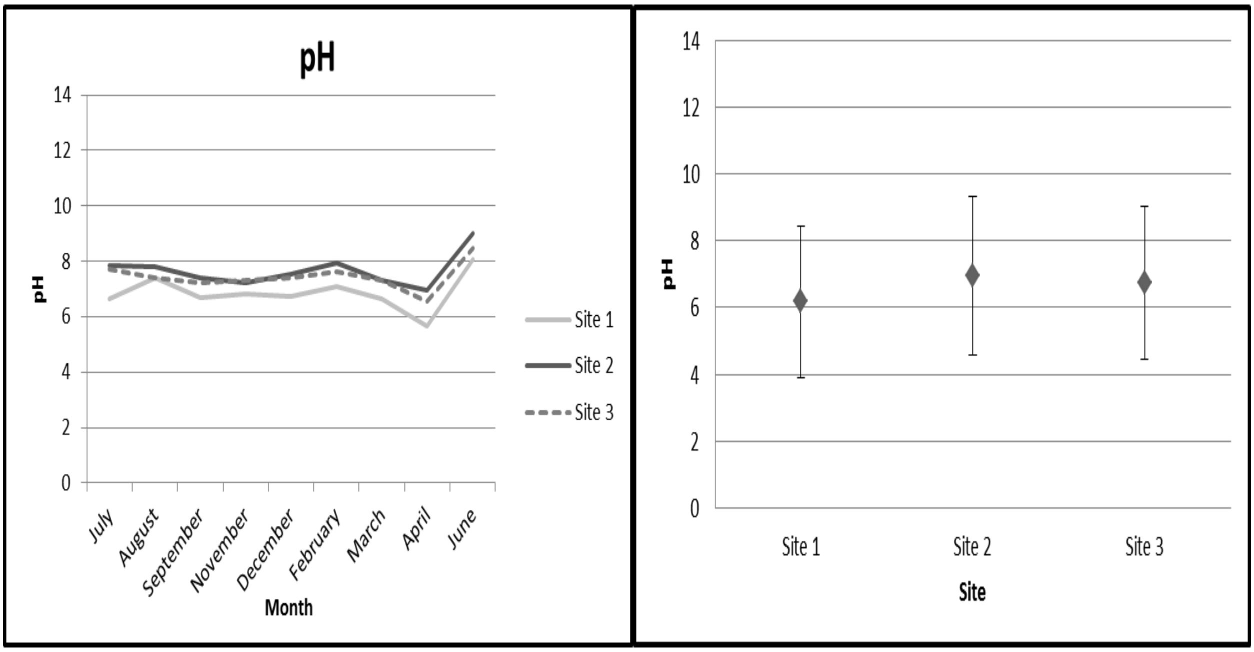

Figure 3.2 Monthly **pH** variation (left) and average per site (right) with standard deviation over the period of July 2012 to June 2013.

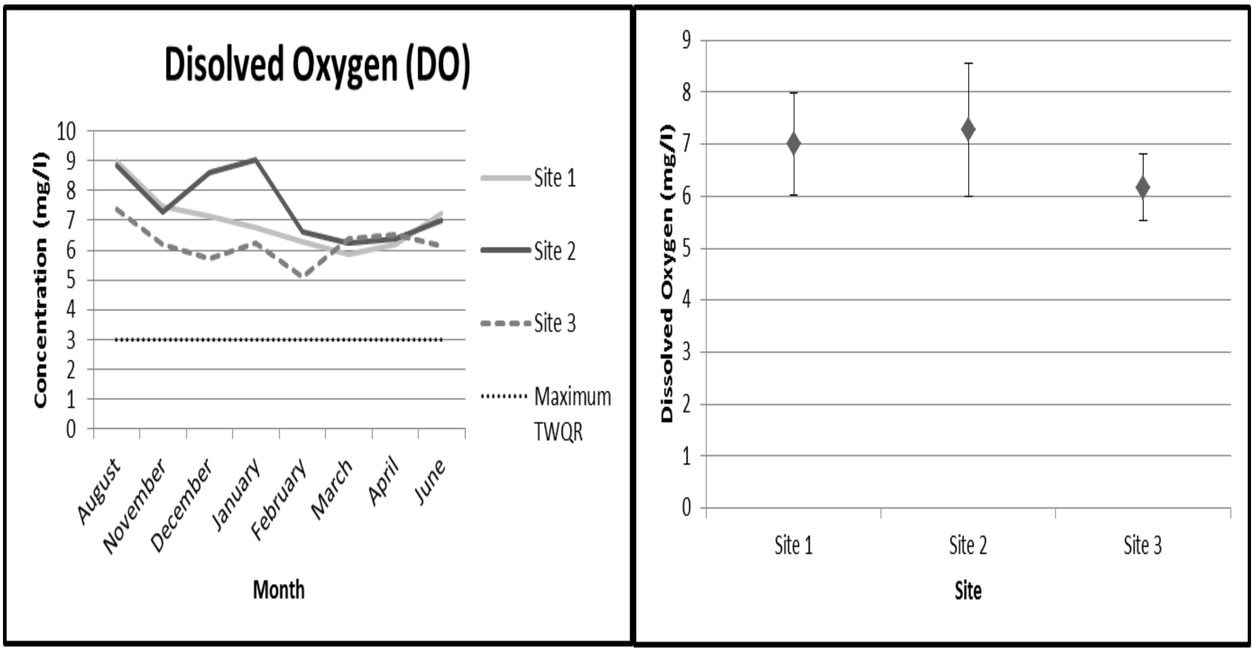

Figure 3.3 Monthly **dissolved oxygen (DO)** variation (left) and average per site (right) with standard deviation over the period of July 2012 to June 2013.

The Electrical Conductivity (EC) values for Sites 1 and 2 are relatively similar with Site 2 showing slightly higher EC values (Figure 3.4). The monthly variation in EC follows a similar trend for these two sites. The average EC values for Site 3 are higher with greater variability than the other two sites showing a steep increase from January through to June 2013. The EC values for Site 3 are all above the TWQR with Sites 1 and 2 occasionally ranging above this limit (DWAF 1996b). The average turbidity (Figure 3.5), total inorganic nitrogen (TIN-N) (Figure 3.6) and orthophosphate (Figure 3.7) concentrations show a much higher value at Site 2 compared to the values for Site 1. The average turbidity and orthophosphate concentrations at Site 3 show a decrease towards the concentrations at Site 1 while the average TIN-N values at Site 3 are slightly lower than those at Site 2. Only Site 1 is below the TWQR for TIN-N (DWAF 1996b). The nitrate (NO_3) concentrations are the main reason the TIN concentrations at the other two sites are so high. The orthophosphate levels at Sites 1 and 3 remain below the TWQR while Site 2 shows a large increase towards the end of the sampling period.

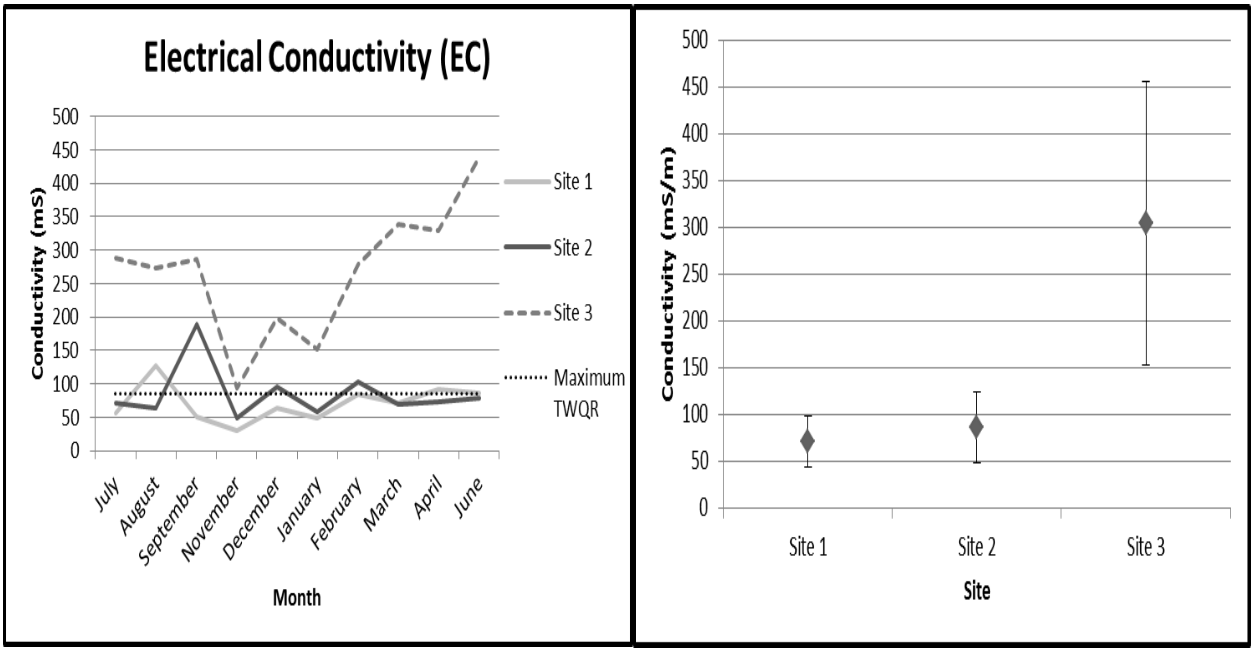

Figure 3.4 Monthly **electrical conductivity (EC)** variation (left) and average per site (right) with standard deviation over the period of July 2012 to June 2013.

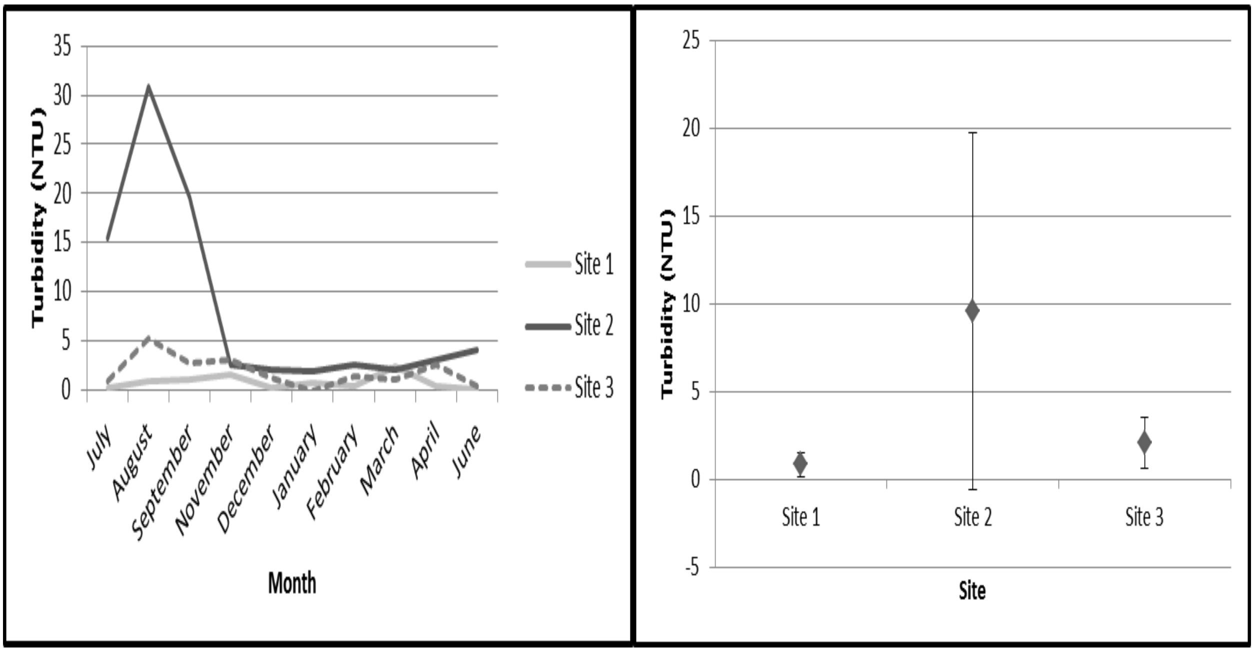

Figure 3.5 Monthly **turbidity** variation (left) and average per site (right) with standard deviation over the period of July 2012 to June 2013.

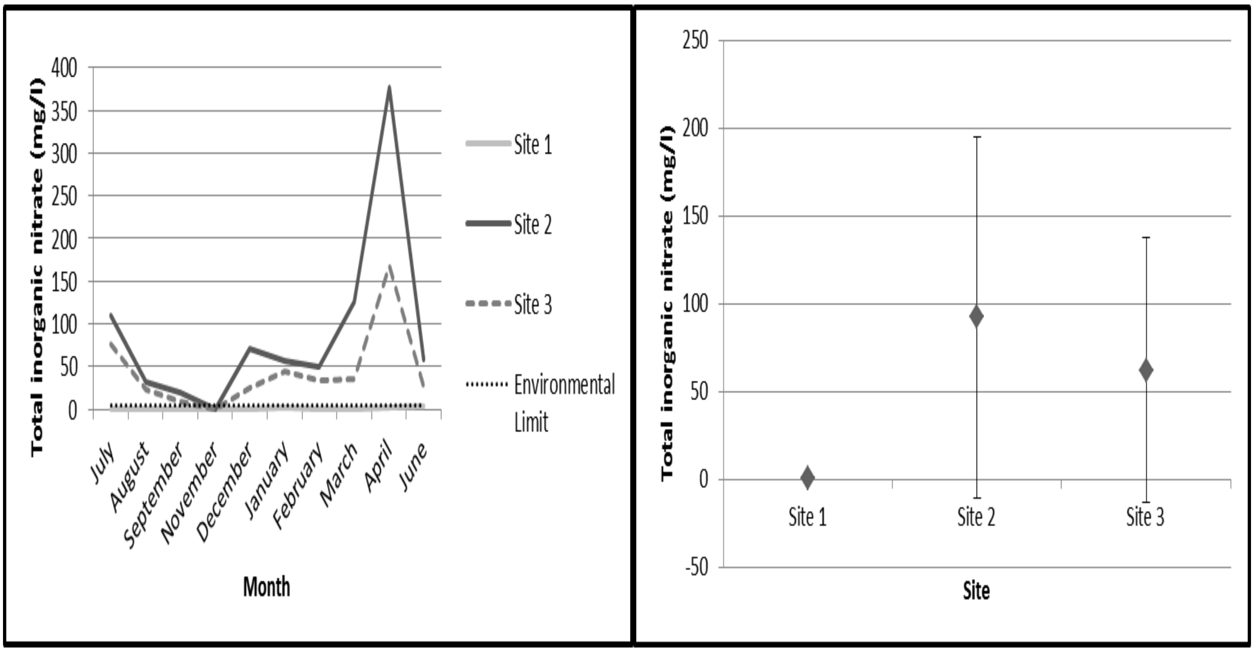

Figure 3.6 Monthly **total inorganic nitrogen (TIN-N)** variation (left) and average per site (right) with standard deviation over the period of July 2012 to June 2013.

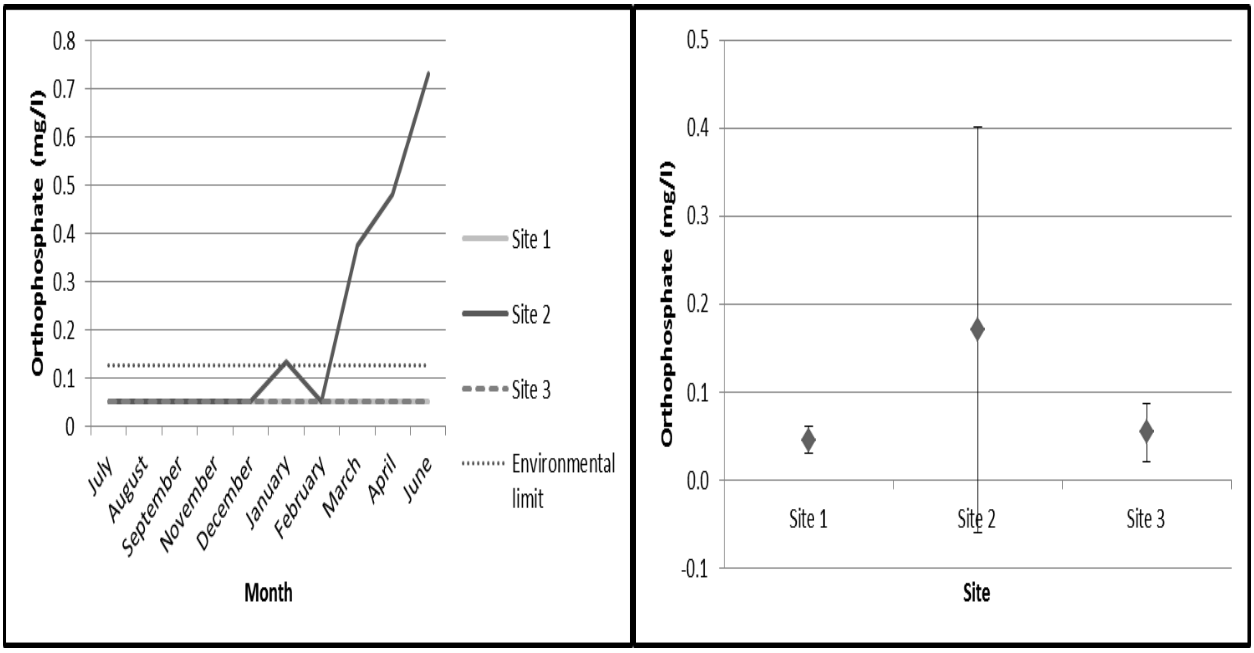

Figure 3.7 Monthly **orthophosphate (PO_4-P)** variation (left) and average per site (right) with standard deviation over the period of July 2012 to June 2013.

3.3.2 Macroinvertebrate Response Assessment Index (MIRAI)

The SASS and IHAS data collected over the assessment period (July 2012 to June 2013) for all three sites are given in Figures 3.8 to 3.11 (and Appendix 4). The SASS scores and number of taxa observed for Site 1 are higher than the scores at the other two sites with Site 2 achieving the lowest scores of the three (Figures 3.8 and 3.9 respectively). The ASPT for Sites 1 and 3 are similar while the ASPT scores for Site 2 are once again lower than the other two sites (Figure 3.10). The ASPT is considered to be the least variable of the SASS scores and thus preferred when assessing river health using invertebrates. The habitat scores (IHAS) for all three sites were variable throughout the year but the average scores for each month were generally similar with Site 3 scoring marginally higher followed closely by Site 1 and then Site 2 (Figure 3.11). This most likely means that habitat is not the main driver for the low macroinvertebrate scores at Site 2. There must be another variable causing this drop in macroinvertebrate scores.

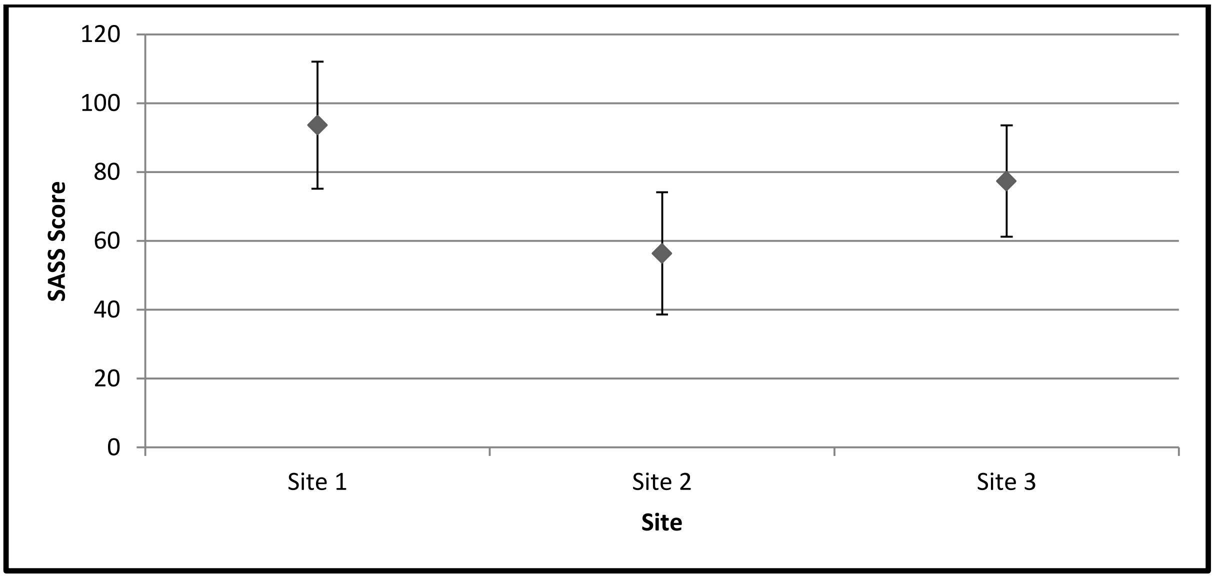

Figure 3.8 Average **South African Scoring System (SASS) score** with standard deviation for each site over the period of July 2012 to June 2013

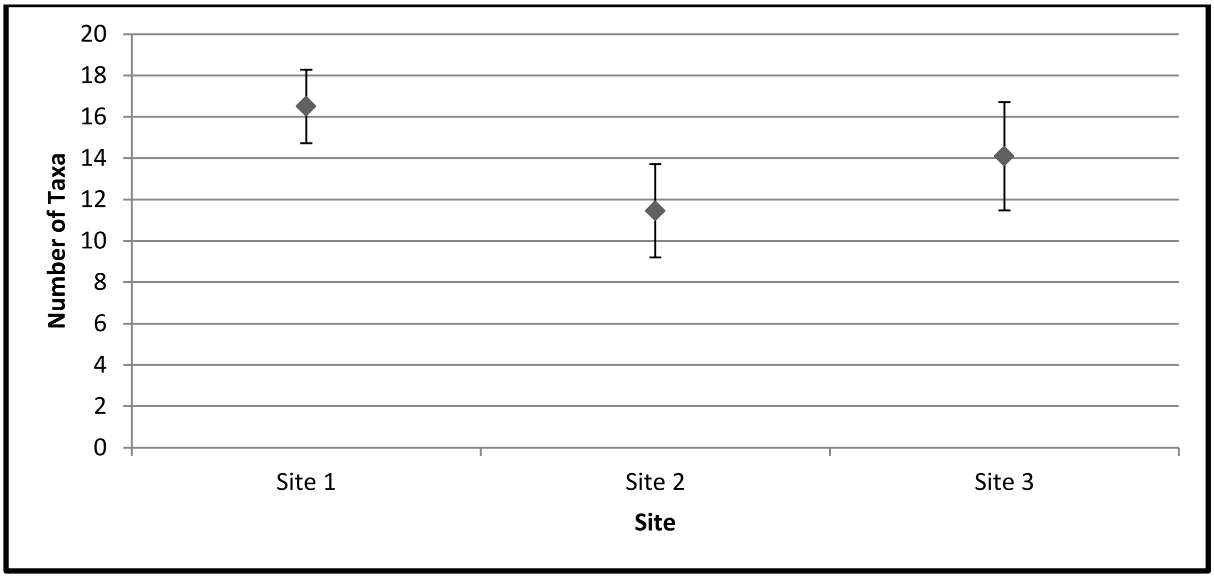

Figure 3.9 Average **Number of Taxa** present with standard deviation at each site over the period of July 2012 to June 2013

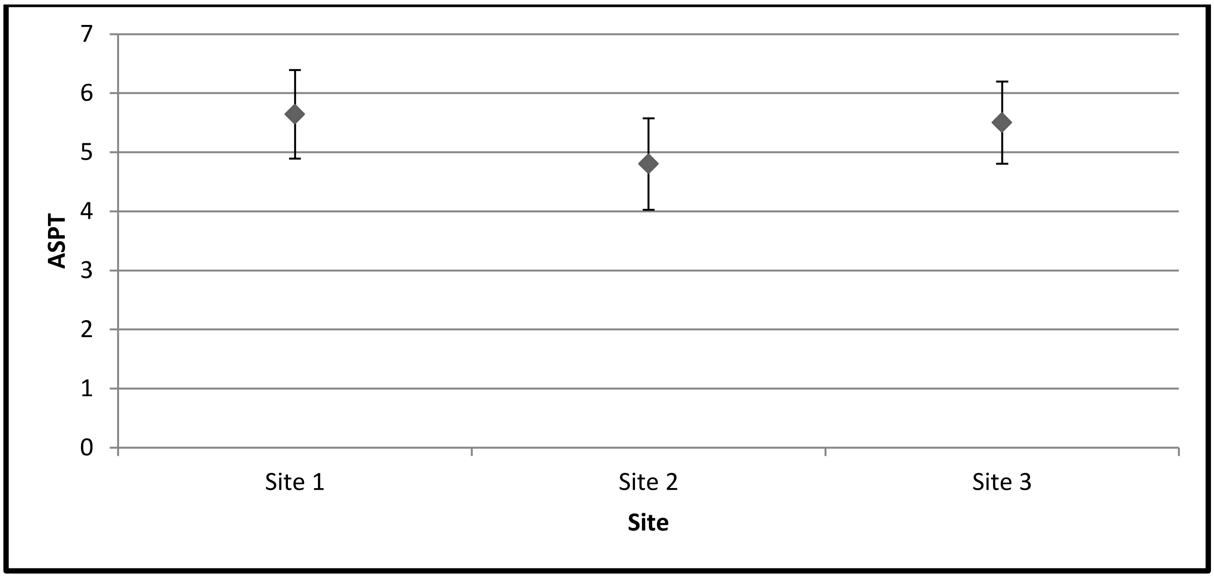

Figure 3.10 Averages of the **Average Score Per Taxa** with standard deviation for each site for the period July 2012 to June 2013

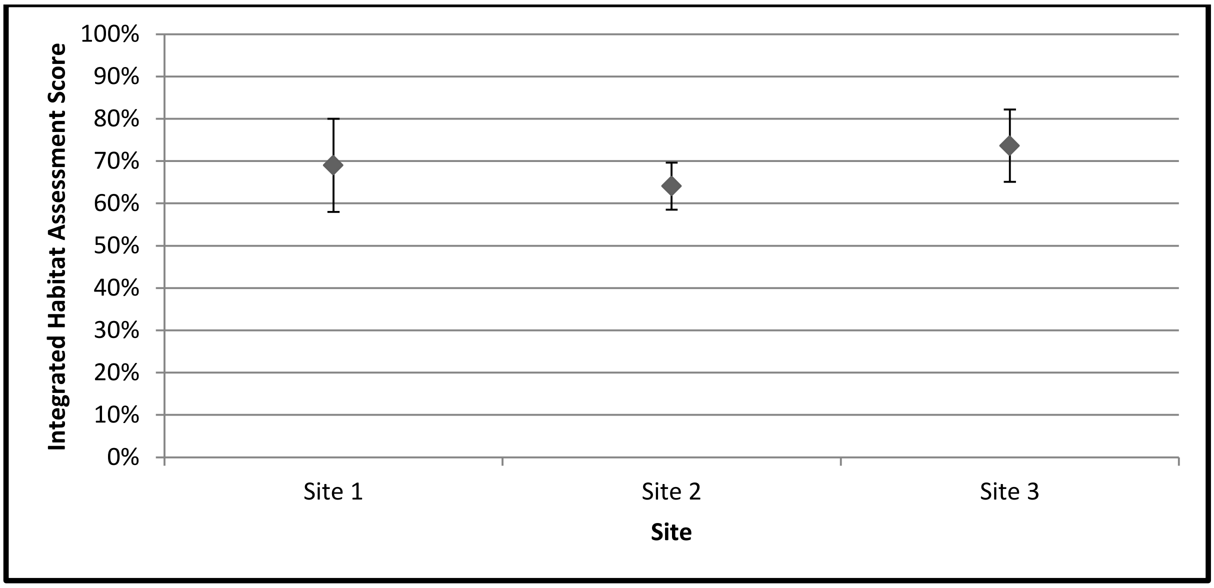

Figure 3.11 Average **IHAS** with standard deviation for each site for the period July 2012 to June 2013.

The SASS data were entered into the MIRAI model which produced a category for each site. Tables 3.3 to 3.5 below show the final MIRAI metric for each site. The tables show the score each site achieved for every metric. They also show the calculated and weighted score of each metric which is in built into the model. The rank of the metrics is input by the user and has no effect on the final score except to assist the user in deciding on the percentage weight for each metric group. The user then assigns a weighting to each metric. From this the model generates an invertebrate score which is linked to an ecological category.

Site 1 achieved a score of 80.5 which corresponds to a B category (Table 3.3). At Site 2 the ecological category score was 53.3 which corresponds to a D category (Table3.4). This decrease is most likely related to the WWTW as there are no other significant disturbances. Some recovery in the invertebrate health is evident at Site 3 which shows an improved score of 64 which is a category C (Table 3.5).

Table 3.3 Combined Macroinvertebrate Response Assessment Index (MIRAI) metric for Site 1 generated from SASS data collected over the period of July 2012 to June 2013

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC GROUP	%WEIGHT FOR METRIC GROUP	COMMENTS
		INVERTEBRATE EC: BASED ON WEIGHTS OF METRIC GROUPS					
FLOW MODIFICATION	FM	85.2	*0.345*	29.3742	1	100	
HABITAT	H	81.9	*0.276*	22.5833	2	80	
WATER QUALITY	WQ	72.5	*0.241*	17.5076	3	70	
CONNECTIVITY & SEASONALITY	CS	80.0	*0.138*	11.0345	4	40	
						290	
INVERTEBRATE EC				80.5			
INVERTEBRATE EC CATEGORY				B			
>89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F							

Table 3.4 Combined Macroinvertebrate Response Assessment Index (MIRAI) metric for Site 1 generated from SASS data collected over the period of July 2012 to June 2013

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC GROUP	%WEIGHT FOR METRIC GROUP	COMMENTS
		INVERTEBRATE EC: BASED ON WEIGHTS OF METRIC GROUPS					
FLOW MODIFICATION	FM	51.5	*0.286*	14.709	2	80	
HABITAT	H	56.4	*0.214*	12.0753	3	60	
WATER QUALITY	WQ	58.1	*0.357*	20.7563	1	100	
CONNECTIVITY & SEASONALITY	CS	40.0	*0.143*	5.71429	4	40	
						280	
INVERTEBRATE EC				53.3			
INVERTEBRATE EC CATEGORY				D			
>89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F							

Table 3.5 Combined Macroinvertebrate Response Assessment Index (MIRAI) metric for Site 1 generated from SASS data collected over the period of July 2012 to June 2013

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC GROUP	%WEIGHT FOR METRIC GROUP	COMMENTS
		INVERTEBRATE EC: BASED ON WEIGHTS OF METRIC GROUPS					
FLOW MODIFICATION	FM	70.0	*0.323*	22.5806	1	100	
HABITAT	H	55.0	*0.258*	14.1935	3	80	
WATER QUALITY	WQ	58.4	*0.290*	16.9519	2	90	
CONNECTIVITY & SEASONALITY	CS	80.0	*0.129*	10.3226	4	40	
						310	
INVERTEBRATE EC				64.0			
INVERTEBRATE EC CATEGORY				C			
>89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F							

3.3.3 Wastewater treatment works effluent compliance data

The WWTW effluent compliance data collected by the municipality contained a large number of gaps, with some months recording only a few variables while in other months no recording took place due to financial or technical difficulties. Data collected by the municipality are shown in Table 3.6 and are compared to the instream values measured over the same period at Site 2 directly downstream of the effluent discharge point, so as to discern any patterns or trends.

As Table 3.6 shows, the pH of the effluent and the river water at Site 2 are similar except for the pH value June (2013), which was most likely due to a faulty pH meter. The effluent's pH falls well within the discharge limits. The EC, ammonium (NH_4) and orthophosphate (PO_4-P) of the effluent are generally higher than that of the river water (Table 3.6). The nitrate (NO_3) concentrations in the river are higher than in the effluent.

The EC concentration of the effluent generally falls just under the discharge limit except for August 2012 (Figure 3.12). The turbidity and nitrate concentrations of the effluent are more variable, either falling just below the discharge limit or exceeding it (Figure 3.13 and 3.14 respectively). The ammonium and orthophosphate concentrations of the effluent fall well below the discharge limits (Figures 3.15 and 3.16 respectively).

Table 3.6 Wastewater treatment works **e**ffluent compliance data collected by the Sundays River Valley Municipality compared to instream water quality data collected at Site 2 from the period June 2012 to July 2013. The grey highlighted values show non-compliance with the General Standard discharge licence

	Physical properties						**Chemical properties**					
	pH		Electrical Conductivity		Turbidity		NO_3		NH_4		PO_4-P	
Month	**Effluent pH**	**River pH**	**Effluent EC**	**River EC**	**Effluent Turbidity**	**River Turbidity**	**Effluent NO3**	**River NO3**	**Effluent NH4**	**River NH4**	**Effluent PO_4-P**	**River PO_4-P**
July	7.4	7.9	141	70.8	68	15.5	18.4	109.7	0.14	0.05	0.54	0.05
August	7.6	7.8	152	63.6	20	-	-	31.3	-	0.05	0.16	0.05
September	7.5	7.4	137	188.6	72	19.6	14.1	18.8	0.16	0.05	0.18	0.05
November	7.6	7.8	145	48.8	21	2.7	-	0.5	-	0.05	0.81	0.05
December	-	7.6	-	99.5	-	2.2	-	71.1	-	0.22	-	0.05
January	7.6	-	146	58.4	11	1.9	-	55.6	0.11	0.09	2.32	0.13
February	-	7.9	-	103.9	-	2.7	-	47.7	-	0.05	-	0.05
March	-	7.3	-	68.6	-	2.1	-	120.7	-	4.24	-	0.37
April	-	7.0	-	73.7	-	3.1	-	374.2	-	2.01	-	0.48
May	-	7.3	120	100.3	16	15.0	18.7	112.5	0.14	1.97	0.37	0.03
June	7.2	9.0	106	79.1	43	4.1	22.1	54.1	0.72	2.87	3.20	0.73

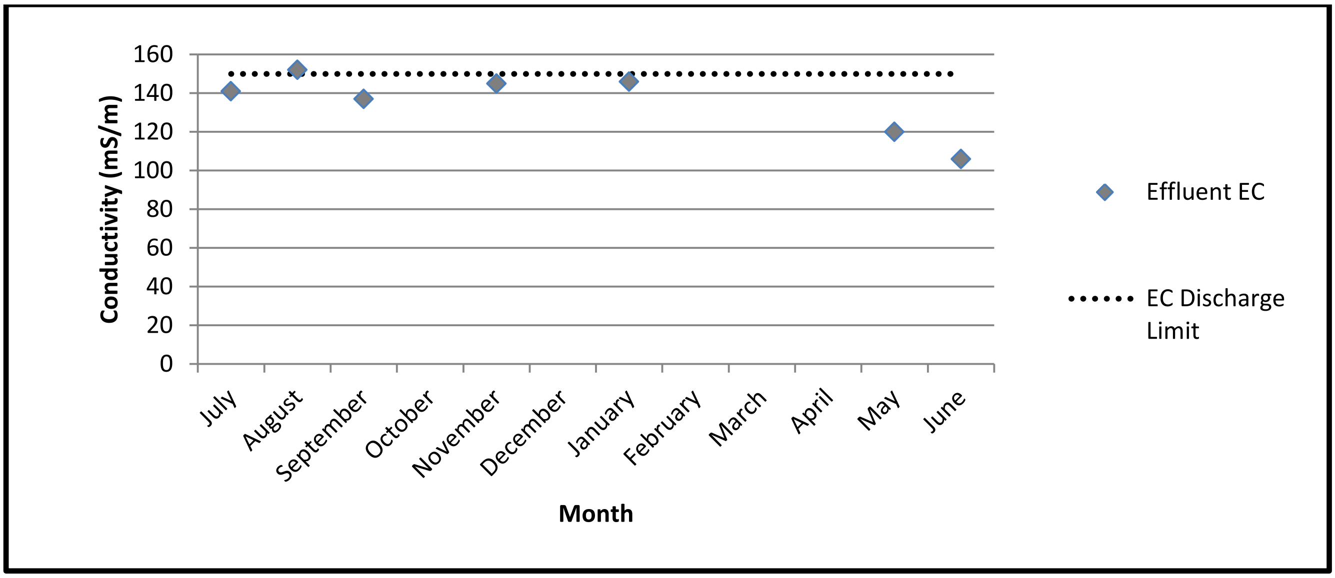

Figure 3.12 Monthly effluent **electrical conductivity (EC)** compared to the discharge limit set by the General Standard licence criteria (DWAF 2004b)

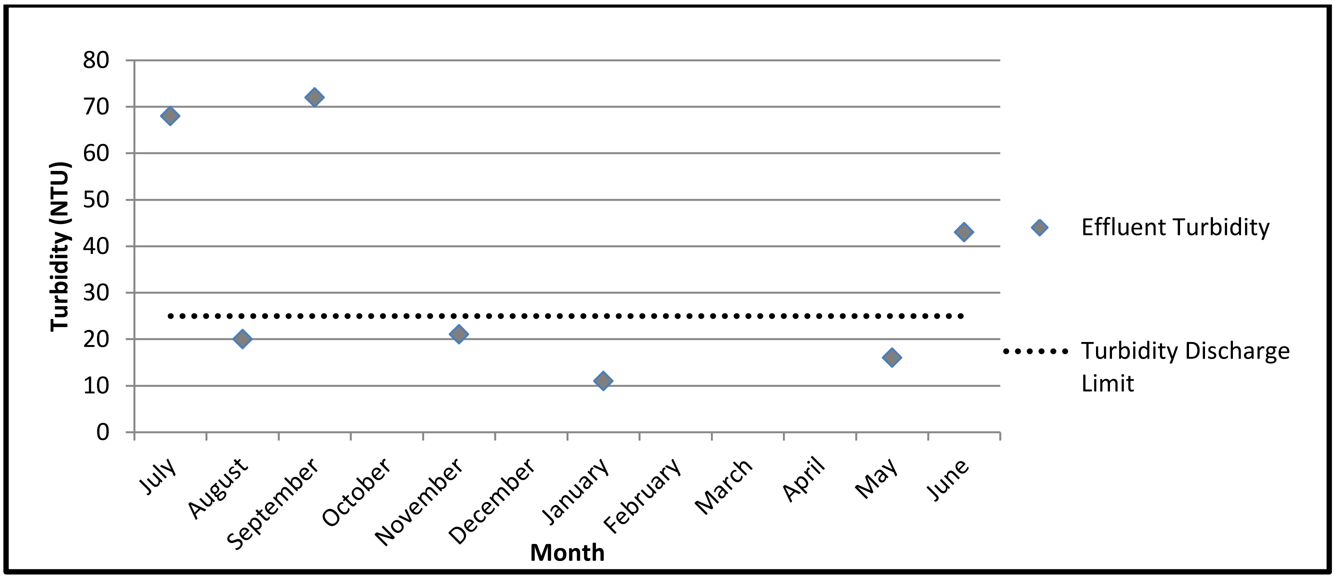

Figure 3.13 Monthly effluent **turbidity** compared to the discharge limit set by the General Standard licence criteria (DWAF 2004b)

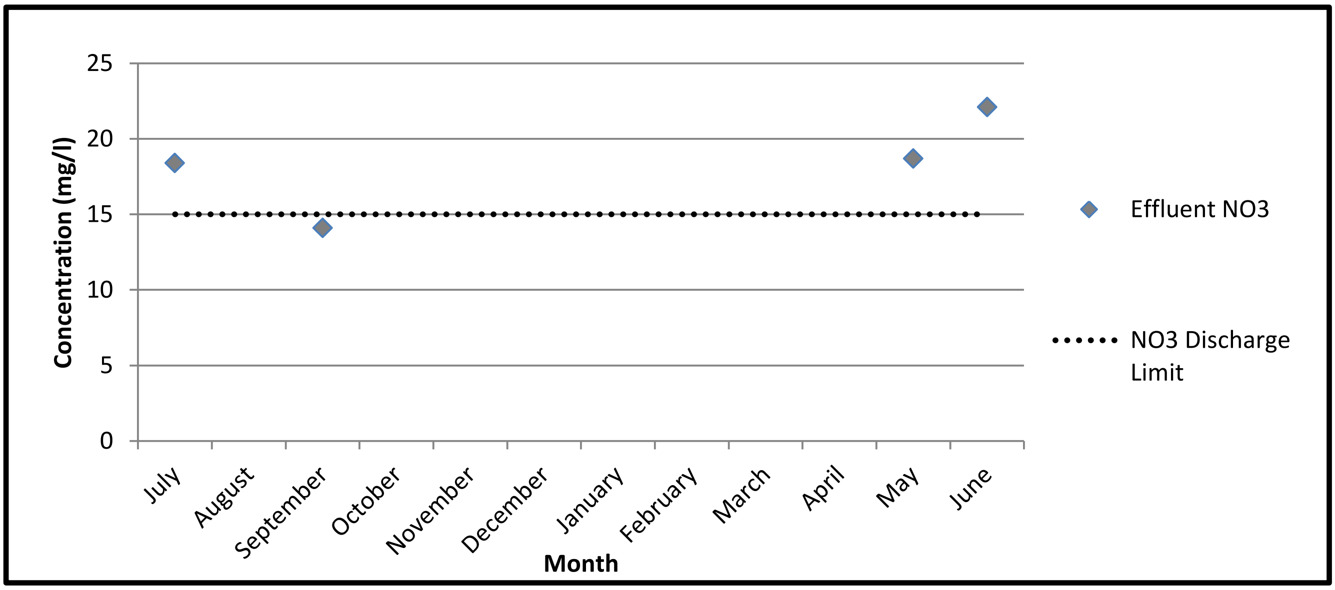

Figure 3.14 Monthly effluent **nitrate (NO_3)** concentration compared to the discharge limit set by the General Standard licence criteria (DWAF 2004b)

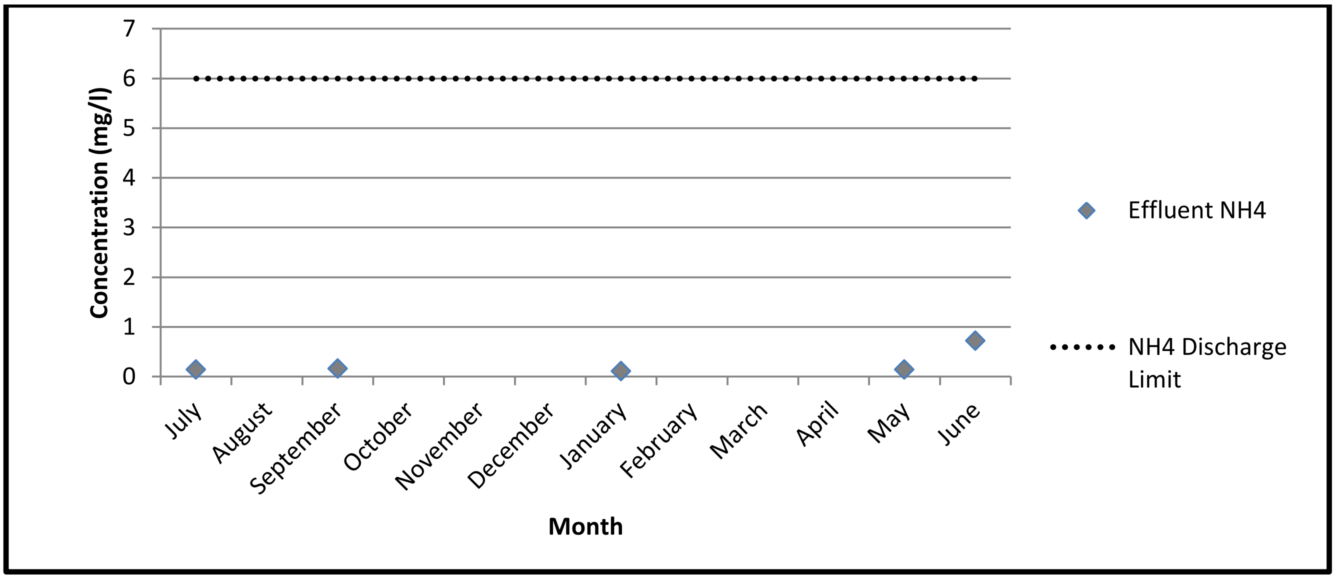

Figure 3.15 Monthly effluent **ammonium (NH_4)** concentration compared to the discharge limit set by the General Standard licence criteria (DWAF 2004b)

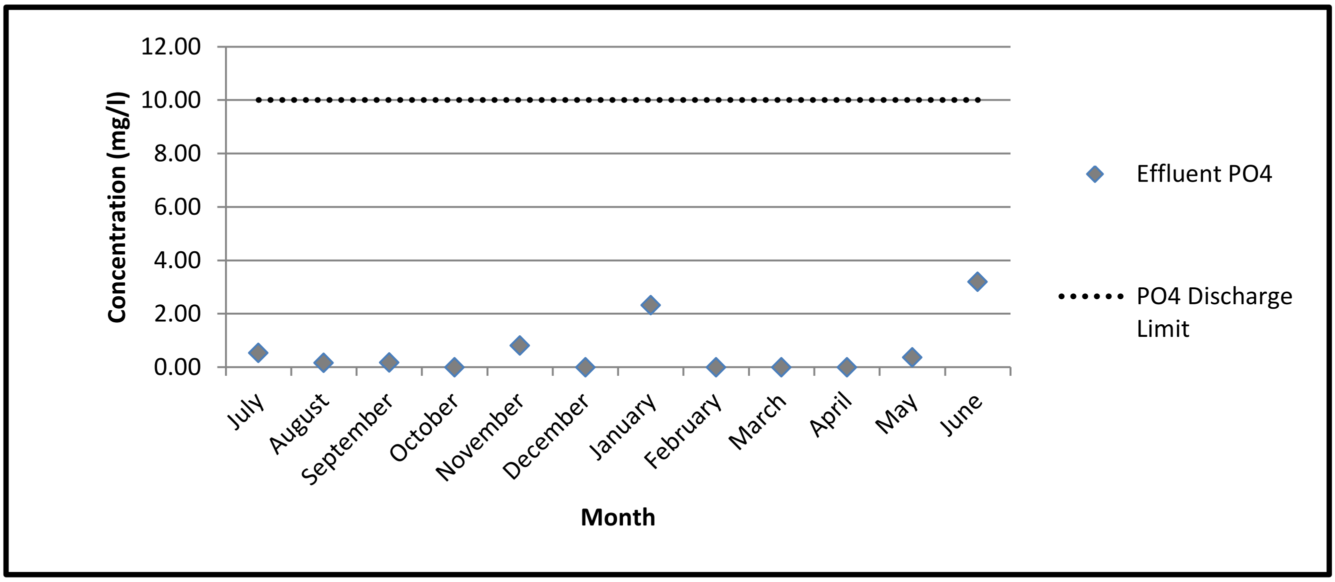

Figure 3.16 Monthly effluent **orthophosphate (PO_4-P)** concentration compared to the discharge limit set by the General Standard licence criteria (DWAF 2004b)

The SRVM's compliance data for the period July 2012 to June 2013 is given in Table 3.7 below. The compliance per determinant was calculated by dividing the number of non-compliant values and dividing it by the total number of samples (where there is no data the value is taken as being above the limit/non-compliant) (DWA 2011e). These scores were then averaged to determine the average score per category. The overall compliance score for the Kirkwood Wastewater Treatment works was 31.5% The SRVM achieved 8.3% compliance for the microbial category, 44.4% for the physical category and 41.7% for the chemical category. This relates to an overall compliance score of 31.5%. This means the SRVM is not legally complying with the General Standard licence conditions. The main reason for this low score is the failure to collect data as each missing piece of data is treated as non-compliance. The microbial non-compliance is the most serious as these concentrations of faecal coliforms can be harmful to human health.

Table 3.7 The limits and recorded values for each variable the Sundays River Municipality is required to monitor as part of **the General Standard** effluent discharge licence condition from July 2012 to June 2013

Category	Microbiological	Physical			Chemical			
Month	**Faecal Coliforms (per 100ml)**	**pH**	**EC (mS/m)**	**Turbidity (NTU)**	**COD**	**NH_3 (mg/l)**	**PO_4-P (mg/l)**	**NO_3 (mg/l)**
LIMITS	1000	5.5-9.5	70 above intake, 150 max	25	75	6	10	15
July	7900	7.4	141	68	84	0.14	0.54	18.4
August	800	7.6	152	20	48	0	0.16	-
September	-	7.5	137	72	23	0.16	0.18	14.1
October	-	-	-	-	-	-	-	-
November	9500	7.6	145	21	10	-	0.81	-
December	-	-	-	-	-	-	-	-
January	4600	7.6	146	11	41	0.11	2.32	-
February	-	-	-	-	-	-	-	-
March	680000	-	-	-	-	-	-	-
April	-	-	-	-	-	-	-	-
May	4000	-	120	16	34	0.14	0.37	18.7
June	20000	7.2	106	43	55	0.72	3.2	22.1
% Compliance per determinant	8.3%	50.0%	50.0%	33.3%	50.0%	50.0%	58.3%	8.3%
% Compliance per category	8.3%	44.4%			41.7%			
% Overall compliance	**31.5%**							

3.4 Discussion

3.4.1 The Uie River water chemistry

The temperature of the Uie River decreases as the water flows downstream (Table 3.6 and Figure 3.1) which is unusual, as river water generally moves from low temperatures in the headwaters (Site 1) to warm in the mid to lower zone (Table 3.8). This decrease in temperature is most likely due to structural factors of the river. There is more vegetation cover at Sites 2 and 3, the channel is deeper, the water has a higher velocity and both sites have a higher turbidity. All of these factors reduce solar penetration which heats the water body (Hebert & Ontario 2008). The river temperature shows an increase in the summer months and a decrease in the winter months illustrating that there is little irregularity in the climatic factors (Dallas & Day 2004). There is also no spike in temperature below the WWTW at Site 2 which indicates that the WWTW has little effect on the temperature regime of the river. The relationship between temperature and DO is generally what is to be expected. As mentioned above, temperature and DO have an inverse relationship. For the most part this is illustrated at all three sites. Site 2 shows the greatest amount of variation in DO concentrations which could be explained by the variations in monthly discharge at the WWTW (Appendix 1).

Table 3.8 General characteristics of each river zone and how they change as the river moves along its course (adapted from Dallas and Day 2004)

Characteristic	Headwater Zone	Middle Zone	Lower Zone
Physical			
Slope	Steep	Gradual	Gradual
Velocity	Fast, erosive	Slower	Slow, depositing
Substratum	Mainly boulders	Mixed boulders and sand	Sand and mud
Temperature	Normally low	Slightly warmer	Warm
Turbidity	Clear, low	Intermediate	High
Light reaching stream	Low	Intermediate	High
Riparian vegetation	Canopy-like	Concentrated on banks	Only on banks; often exotic species
Chemical			
Dissolved oxygen	High	Intermediate	Low
Nutrients	Low	Intermediate	High
Conductivity	Generally increases down the river		
pH	Generally increases down the river		

The pH of the river is relatively constant falling within the pH range of most rivers in South Africa of a pH between 6 and 8 (DWAF 1996b). The spike in the last month of sampling (June 2013) was most likely due to a faulty pH meter. As Table 3.8 shows, the pH of a river generally increases downstream and this is evident in the difference between Sites 1 to 3.

The EC concentrations in the river at Sites 1 and 2 show a similar trend and remain relatively constant. Site 3 has higher values than the other two sites. After January 2013 the EC at Site 3 almost triples between January and June 2013. The spike is most likely due to reduced flow, meaning less dilution takes place.

The Turbidity and TIN-N values are expected to increase down the course of a river. This is illustrated by the increase in these values at Site 2 compared to Site 1. However, because the concentrations are so high at Site 2 it is more likely a combination of irrigation return flow and discharge from the WWTW. The large increase could also be explained by a broken clarifier at the WWTW (Figures 3.17 to 3.19). The clarifier purifies water by separating solids and liquids, reducing the EC of the liquids (DWA 2011e). When this is not working no separation can occur. Thus one could argue that the large increase in turbidity and TIN-N concentrations between Site 1 and Site 2 shows impairment on the river from the wastewater treatment works. Nonetheless, there is a degree of recovery evident at Site 3 as the TIN-N and turbidity concentrations show a decrease. This decrease is possibly due to natural dilution as well as a small wetland between the two sites which acts as a biological filter. Thus, although the nutrients are naturally expected to increase downstream (Table 3.8), the higher concentrations at Sites 2 and 3 compared with Site 1 point to impairment of the river.

Despite the WWTW's effluent being within the range stipulated by the General Standard licence conditions for phosphates, the effluent concentrations are higher than the river concentration which is to be expected. Wastewater treatment works are well documented sources of phosphates (Oberholster et al. 2013, Jarvie et al. 2006, Gücker et al. 2006, Hospido et al. 2004, Singh et al. 2004). The increases evident in the river from January 2013 onwards coincide closely with the increases in the effluent concentrations.

Figure 3.17 Clarifier at the Kirkwood WWTW, October 2012 (left). The automated clarifier sometimes stopped and needed assistance getting moving again (right).

Figure 3.18 Large amounts of sludge in the maturation ponds due to the broken clarifier, October 2012 (left). Suspended sludge exiting the WWTW and heading to the effluent discharge point, October 2012 (right).

Figure 3.19 Water loaded with sludge downstream of effluent discharge point, July 2012 (left). Suspended sediment in the river downstream of effluent discharge point at Site 2, May 2013 (right).

3.4.2 Wastewater effluent and river health

The Macroinvertebrate Response Assessment Index scores generated for each site show a large impact on the macroinvertebrate communities at Site 2 (score of 53.3 corresponding to a D) compared to the score at Site 1 (score of 80.5 corresponding to a B). This clearly shows that there is impairment of some kind. This is supported by the SASS and number of taxa scores which are much lower scores at Site 2 than Site 1 (Figures 3.8 and 3.9 respectively). Habitat is most likely not the driver as the IHAS scores for Sites 1 and 2 are not very different (Figure 3.11). There appears to be recovery at Site 3 (score of 64.0 corresponding to a C) located approximately 1.5km downstream from Site 2. Between Sites 2 and 3 the land use bordering the river on both sides is citrus agriculture which may have an impact in terms of runoff. Nonetheless, from the recovery that takes place at Site 3 it seems that the wastewater treatment works is the main contributor to the poorer macroinvertebrate health assemblages and that the agricultural return flow is not as significant.

The EC and turbidity of the river water is lower than that of the effluent (Table 3.6) due to dilution. The turbidity of the effluent and the river both show a similar spike from July to November 2012. Thus, the turbidity at Site 2 appears to be influenced by the turbidity of the effluent. This is evident from the large amounts of sludge deposition downstream of the WWTW along with the cloudy and discoloured appearance of the water (Figures 3.17 to 3.19). As mentioned above, this is probably due to a broken clarifier at the WWTW. The high turbidity at Site 2 is a likely the major reasons for the drop in macroinvertebrate health scores. Suspended sediment in most cases is “an insidious pollutant” and can also have a large impact on a stream benthos community when suspended sediment settles, especially in large volumes such as at Site 2 (Welch 1980). The effects on benthos communities from settled sediment is reduced light penetration, reduced area to cling onto and fewer hiding places as interstices become clogged. Looking at the amount of settled sludge at Site 2, up to 23cm deep, it becomes understandable why the macroinvertebrate health scores were lower here. Few macroinvertebrate species can tolerate such conditions (Gordon et al. 2012).

The nitrate concentrations in the river were significantly higher than the concentrations of the effluent. These high nitrate levels represent hypertrophic conditions (more than 10mg/l) which usually characterise low levels of species diversity. These are characterised as highly productive systems, often encouraging the growth of nuisance plants and blooms of blue-green algae, which regularly include species toxic to man, livestock and wildlife (DWAF

1996b). According to Dallas & Day (2004), high concentrations of nitrates most likely enter the water through fertilizers and agricultural runoff. Thus, the surrounding agriculture could be one of the main contributors to the high nitrate levels in the river. In addition, the WWTW produces nitrate concentrations above the General Standard licence condition values. High nutrient levels from the WWTW are not unusual as WWTWs are well documented sources of both nitrates and phosphates (Dallas & Day 2004). However, the difficulty in quantifying the magnitude of the effect of the WWTW on the river is compounded by the lack of compliance data collected by the municipality for nitrates from October 2012 to April 2013.

3.5 Conclusion

From the above data it is clear that the Kirkwood WWTW has a negative impact the river health as indicated by the macroinvertebrate health scores. This is most clearly reflected in the high values of certain water chemistry variables at Site 2, differing considerably from Site 1. The impact of this poor WWTW performance is reflected in the macroinvertebrate health scores generated by the MIRAI model at Site 2 which show a larger decrease in score than Site 1 against the established reference conditions. The MIRAI score for Site 3 shows that the river undergoes some recovery before it enters the Sundays River. It is therefore possible to infer that if the Sundays River Valley Municipality made efforts to improve the quality of the effluent being discharged from its plant, the impact at Site 2 would be less and the recovery at Site 3 would be larger.

The overall question for this research was: will the ecological health of the receiving stream be improved if a WWTW managed to meet the General Standard licence conditions. In this case study, the Kirkwood WWTW provides evidence that this is indeed true. While no previous ecological assessment has been done on the Uie River and no ecological conditions set, the macroinvertebrate health scores show a large drop at Site 2, downstream of the discharge point, compared to the state at the upstream site. The Kirkwood WWTW was performing well below the General Standard licence conditions, with the main concern being the nitrate and suspended solids (turbidity) concentrations. If the SRVM improved the quality of the effluent being discharged from the WWTW then one would expect to see an improved ecological health of the river, closer to that of Site 1, being ensured. However, one would not expect to see Site 3 to achieve a score as high as Site 1 even if the WWTW was complying with the General Standard licence conditions. This is because the surrounding agriculture also impacts the macroinvertebrate communities through high levels of nutrient runoff.

Improving the quality of the WWTW effluent being discharged is not a simple task. The Green Drop programme aims to assist municipalities to do this over time by assessing their entire business of wastewater treatment and highlighting problem areas. The effectiveness of this depends on a municipality's resources and commitment to improve. Chapter 4 examines the situation within the SRVM from the perspective of GD which may be responsible for the high concentrations of the effluent being discharged.

Chapter 4: A narrative of change of the Sunday River Valley Municipality's wastewater treatment business with regards to the Green Drop assessment programme.

4.1 Introduction

Chapter 3 provided the present ecological state of the Uie River in relation to effluent discharge from a WWTW. It is necessary to explore compliance with wastewater treatment licence conditions and it is therefore useful to trace a brief history of administrative and institutional practice in South Africa.

4.1.1 South Africa's water governance institutions

The advent of democracy in South Africa in 1994 brought about a change in the way local water and sanitation services were administered by the government. The Constitution of South Africa (SRSA 1996) recognised that provision of services should be decentralised and that local government should be the direct provider of water and sanitation services (DWAF 1994). Provincial government was charged with the establishment and effective functioning of local government while national government, under the Department of Water Affairs (DWA), would assume a more regulatory and supporting role and be tasked with management of the nation's water resources (DWAF 2003). This trend of decentralisation has been recognised around the world, something that was not missed by decision makers in South Africa at the time. Decentralisation was seen as the most immediate and effective means to combat the gross inequalities in service provision present in the country, allowing for more effective service provision. The local government elections in 2000 represented the final phase in the local government transformation process (DWAF 2003). Since then provision of local water and sanitation services has been the responsibility of local government.

Within local government, water services are now administered by water services authorities (WSA), while sanitation is the responsibility of the Department of Human Settlements, in co-operation with DWA. The role of a WSA is often played by local or divisional municipalities, and it is their responsibility to ensure that access, planning and regulation of water services are carried out within their jurisdiction (Water Services Act: Chapter III, 1997). The provision of these services are the direct responsibility of a Water Services Provider (WSP) on behalf of the WSA (Water Services Act: Chapter IV, 1997). Water Services Providers "are the organisations that assume operational responsibility for providing water and/or sanitation services" (DWAF 2003). It is therefore the job of the water services authority to ensure that the WSP is fulfilling its legal requirements regarding the provision of these services, through a service level agreement. These WSAs can also act as a WSP, but a distinction between the two needs to be made and this will involve a case of self-regulation (NSTT 1996). It is then the task of the provincial and national governments to ensure that the WSAs are fulfilling their constitutional and legal responsibilities regarding water and sanitation service provision. However, until 2008 there was no effective tool for the DWA to monitor the performance of each WSA around the country.

Before 2008, the legislation surrounding the business of wastewater treatment was governed by a number of different pieces of legislation. The discharge of effluent was legislated as a Section 21 Water Use under the NWA (DWAF 1998). Here, regulation of wastewater operations and service provisions in South Africa involved the monitoring of effluent quality; little or no attention was given to the actual service of wastewater collection, treatment and discharge (DWA 2011e). On the other hand, technical services, such as process control and supervisory skills, which determine the day to day operations and maintenance of the plant were regulated by Regulation 2834 promulgated under the Water Act of 1956 (DWAF 1997). Two other parts of legislation, the Constitution of South Africa (SRSA 1996) and the Water Services Act (DWAF 1998) also played a part in regulating wastewater services and promoting water services provision through local government. For water managers, attempting to comply with diverse sets of legislation is time consuming, problematic and often does not happen. Although these laws are in place, it was realised that a tool was needed to assist in meeting the provisions of diverse pieces of legislation, while at the same time providing an indication of WSA performance.

4.1.2 The Green Drop Certification Programme

In 2008, two regulatory programmes were launched, namely the Blue Drop and the Green Drop certification programmes aimed at potable water treatment systems and wastewater treatment systems respectively. Both programmes assess the entire business of water treatment and provide the DWA with a national monitoring programme. Blue Drop assesses the first part of the water treatment life cycle, from the environment (freshwater sources) to the user (consumption and use) (DWA 2011d) while Green Drop assesses the second part of this life cycle, from the user (sanitation) to the environment (effluent discharge) (DWA 2011f). For this study, the Green Drop (GD) Certification Programme as implemented in the Kirkwood WWTW by the Sundays River Valley Municipality (SRVM) was the focus of investigation.

The GD Programme is an incentive and risk based form of regulation (DWA 2011e). There are no legal punitive measures for failing to achieve GD status. This does not mean participation in the GD Programme is voluntary. Municipalities, which act as WSAs, are legally compelled to provide necessary service and effluent quality information under sections 62 and 82 of the Water Services Act (DWAF 1997). Thus, the programme places pressure on WSAs to improve their performance through regular publication on how each WSA is performing against GD criteria, as well as reporting the risk rating of each wastewater treatment works (WWTW) and the overall risk rating of the WSA (DWA 2011e). This incentive based regulation under the GD Programme has three main objectives:

- "It allows municipalities and other relevant institutions the means to generate information from effluent data to inform overall improvement of wastewater management;
- It also provides for the Department of Water Affairs (water sector regulator) to have access to credible information towards improvement of regulatory decision-making; and
- Allow public access to credible wastewater performance information regarding compliance and risk management" (DWA 2011e).

The GD Programme therefore provides the DWA with a national monitoring tool of the performance and risk status of each individual treatment works within a given WSA around the country. The scores for each WWTW within a WSA are then aggregated and the WSA is given an overall score. This allows DWA to identify high risk plants or WSAs (scoring below 30%) in order to provide immediate assistance where necessary and to ensure continual improvement (DWA 2013b). By publishing the wastewater performance information for public access, it allows members of civil society, including environmental groups, Non-governmental Organizations (NGO) or a rate payers association, to put pressure on municipalities to improve their score (DWA 2011e).

In order to achieve GD status, municipalities or WSAs have to score above 90% for the GD criteria (DWA 2011e). The criteria have been chosen by the DWA and are called Key Performance Areas (KPAs). These KPAs are reviewed before every bi-annual assessment. In each assessment cycle scoring shifts to emphasise and disclose performance in different aspects of the GD process. At the start of the programme 11 KPAs were established, with the aim to amalgamate these into five KPAs by the 2016 assessments. The 11 KPA established in 2008 are shown in Table 4.1 along with the progressive development to the proposed five KPA for the 2016 assessment (DWA 2011e). The original 11 KPAs from the 2009 assessment are shown on the left of the table below the 2010/2011 assessment. The 2010/2011 assessment chose not to assess two of the previous 11 KPAs which is why they have a weighting of 0%. The process of amalgamating these into the final five KPAs in the 2016/2017 assessment is also shown. The percentage weighting for that year's assessment is shown under each KPA. Proposed percentages weightings change for each KPA per assessment to emphasis different aspects of the GD process. With every assessment the criteria become more stringent and comprehensive facilitating continuous improvement in wastewater management practices (DWA 2011b). Thus, GD provides a national monitoring tool on risk status, current performance and trend data on each WSA as well as its individual plants while making this information easily accessible to the public.

4.1.3 Green Drop within the Sundays River Valley Municipality

Since the GD Programme aims to ensure continual improvement in the wastewater treatment sector, one would expect to see an improvement in the GD scores for municipalities from the start of the programme. As mentioned earlier, the research team was fortunate to be embedded in the Sundays River Valley Municipality (SRVM), which was in need of considerable improvement strategies. One of the areas which required attention was the wastewater sector. This was clearly indicated by the municipality's performance in the first GD assessments. For the first GD report in 2009, no score was recorded as the municipality did not participate in the assessments (DWA 2009). For the second assessment in 2010/2011 the municipality scored 5.6% and the Kirkwood WWTW, one of the four WWTWs managed by the municipality, scored 3.1% (DWA 2011b). Some of the comments from the 2010/2011 assessment were:

Table 4.1 Expected change in theKey Performance Areas (KPAs) for the Green Drop Assessments.

<table>
<tr><th>KPAs</th><th>2010/2011 assessment</th><th>2012/2013 assessment</th><th>2014/2015 assessment</th><th>2016/2017 assessment</th></tr>
<tr><td>1</td><td>Process control, Maintenance and Management Skill
10%</td><td>Process control, Maintenance and Management Skill
10%</td><td rowspan="3">Wastewater Quality Process Management & Control
15%</td><td rowspan="3">Wastewater Quality Process Management & Control
15%</td></tr>
<tr><td>2</td><td>Wastewater quality monitoring Programme
10%</td><td rowspan="2">Wastewater Monitoring Programme Efficacy
15%</td></tr>
<tr><td>3</td><td>Wastewater sample analysis (credibility)
5%</td></tr>
<tr><td>4</td><td>Submission of wastewater quality results
5%</td><td>Submission of wastewater quality results
5%</td><td rowspan="2">Wastewater Quality Compliance
35%</td><td rowspan="2">Wastewater Quality Compliance
40%</td></tr>
<tr><td>5</td><td>Wastewater quality compliance
30%</td><td>Wastewater quality compliance
30%</td></tr>
<tr><td>6</td><td>Wastewater Quality Failures Response Management
10%</td><td rowspan="2">Wastewater Quality Risk Management
15%</td><td rowspan="2">Wastewater Risk Abatement
25%</td><td rowspan="2">Wastewater Risk Abatement
20%</td></tr>
<tr><td>7</td><td>Storm water and Water Demand Management
0%</td></tr>
<tr><td>8</td><td>Local Regulation
5%</td><td>Bylaws (Local Regulation)
5%</td><td>Local Regulation & Planning
10%</td><td>Local Regulation & Planning
10%</td></tr>
<tr><td>9</td><td>Wastewater Treatment Facility Capacity
10%</td><td rowspan="2">Wastewater Treatment Capacity
5%</td><td rowspan="3">Wastewater Asset Management & Performance
15%</td><td rowspan="3">Wastewater Asset Management & Performance
15%</td></tr>
<tr><td>10</td><td>Publication of Wastewater Management Performance
0%</td></tr>
<tr><td>11</td><td>Wastewater Asset Management
15%</td><td>Wastewater Asset Management
15%</td></tr>
</table>

> "The Sundays River Valley Local Municipality's performance during this assessment period has been extremely poor and requires urgent improvement",
>
> "This Green Drop assessment revealed the municipality's current inability to perform this task with the required sense of responsibility and level of efficiency",
>
> "With all of the 5 systems scoring less than 10%, it serves as indicator that the wastewater services in the area of this municipal are of a jurisdiction requires major turn around",
>
> "The Regulator is not satisfied with the overall performance of wastewater services management in the Sundays River LM" (DWA 2011a).

The main reason for the low score is that there were no monitoring programmes in place. This meant no data was being generated and nothing was being recorded which could be submitted. At one of the first meetings with the municipality at the end of 2011, the municipality stated they were not aware of the GD programme or that any such data was required from them. The municipality was therefore a suitable case study for assessing ways in which the GD Programme is capable of bringing about continual improvement in the wastewater sector.

Before every GD assessment, the information and requirements for municipalities are published as a checklist (DWA 2011e), which then provides the basis for the GD assessment. This gives municipalities adequate notice on the information they need to provide to assessors and ensures they can be adequately prepared. Municipalities thus have little excuse for not producing the necessary documentation for the assessment. The checklist for the 2011 Assessment can be found in Appendix 5.

This project used the DWA KPAs to assess the effectiveness of the GD Programme in bringing about change and improvement in the SRVM effluent management at the Kirkwood WWTW and the municipality as a whole. Each KPA has a number of subsections against which a wastewater treatment works is scored (Appendix 5). The subsections were therefore able to provide a guide for mapping the current state of practice, and how this changed over time. It also provided a good benchmarking tool for assessing whether the GD Programme is effective in bringing about continual change in the wastewater treatment sector.

As noted in Chapter 3, the link between the management of wastewater treatment, as assessed by GD, and the instream condition of a river has never been empirically linked. There is a definite need for this and this project aims to provide the basis to this link. Chapter 3 therefore provided the baseline of the instream ecological condition of the Uie River, showing that the WWTW has a definite impact on the river. This chapter therefore examines the management of wastewater treatment against GD criteria to understand how the municipality was managing its business of wastewater treatment and how this led to the quality of the effluent being discharged.

4.2 Methodology

This study was undertaken at an early stage of transdisciplinary research development in the Unilever Centre for Environmental Water Quality, particularly with regard to social-science methodologies.

The methodology used within this chapter draws from the fields of social learning (Reed et al. 2010), complexity (Cilliers 2001), institutional analysis (Mahoney & Thelen 2010, Ostrom 2009) and systems thinking (Meadows & Wright 2008). These fields formed the foundation of the broader transdisciplinary project funded by the South African and Netherlands Programme for Alternative Development (SANPAD). Together, these fields provided the insight and approaches to understand the institutional arrangements of the Sundays River Valley Municipality (SRVM) and whether the Green Drop Certification Programme, with support from the DWA Rapid Response Unit (RRU), was effective in bringing about any change.

The Rapid Response Unit (RRU) was established in 2011 so that the DWA could offer more hands-on assistance to local government and WSA in need of attention (DWA 2013b, DWA 2013a), such as the SRVM. The RRU is made up of water and wastewater specialists and "has enabled the Department [of Water Affairs] to intervene successfully in high risk operational situations where the lives of the citizens and the environment were under threat as a result of water and wastewater treatment failures" (DWA 2012a). This unit "enables the DWA to respond to crises and disasters and to implement proactive interventions aimed at pre-empting crises before they occur. The DWA targeted all WSA's with low Blue and Green Drop scores for pro-active interventions" (DWA 2013b). The SRVM was one such municipality. The main implementing agent for these pro-active interventions was Amatola Water and the RRU was the provincial party heading up the project (Amatola Water 2012).

A number of events were used as milestones to assess changes in the institutional capacity of the Sundays River Valley Municipality, namely: the second of two Strategic Adaptive Management (SAM) workshops, an intervention workshop by the DWA's RRU and the final 2012/2013 GD assessments (Figure 4.1). Between these milestones the researcher continued engagement with the municipality on a regular basis to understand the situation, monitor changes and provide assistance where possible. These in-between periods saw a number of other interventions and workshops (Appendix 6).

The main form of data collection for these milestones was unstructured interviews with municipal officials, mainly those based in the Technical Department of the SRVM, and regular interactions and engagements with other stakeholders through workshops, meetings and personal interactions within the municipality. These interactions and learnings can be termed 'participant observation'. Participant observation is the practice whereby one, as the name suggests, is both a participant in a situation (viewing and participating in the situation as an insider), as well as an observer (viewing the situation as an outsider) (Atkinson & Hammersley 1994, Jorgensen 1989). This requires immersion into the situation while still maintaining distance to make accurate observations in a reflective manner. Participant observations have been clearly identified and included to provide individual insight.

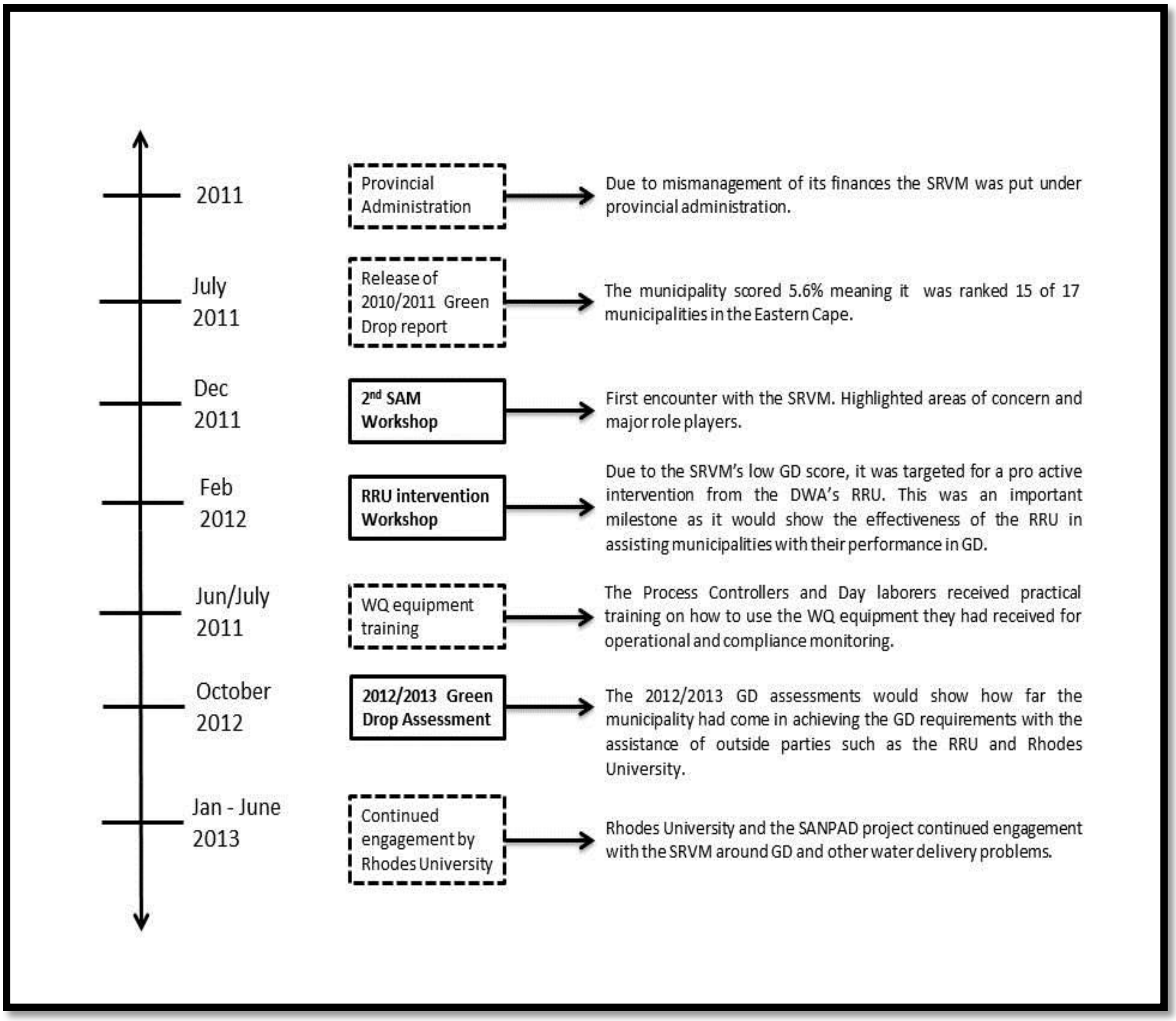

Figure 4.1 A timeline of important events within the SRVM and the project. The boxes with text in bold and unbroken borders are the key milestones chosen for assessment.

4.2.1 Milestones for assessment

4.2.1.1 Second Strategic Adaptive Management (SAM) workshop (December 2011)

The project was initiated in early December 2011, at a time when the municipality was under Provincial Administration. It was at this time that the team from Rhodes University met with stakeholders in the Sundays River Valley. Through two workshops hosted in the area, the concept and practice of Strategic Adaptive Management (SAM) was introduced in order to facilitate capacity to understand and tackle the water-related problems in the area (Rogers & Luton 2011).

The first milestone was the introduction of this study, as part of the wider “policy to practice” project (refer to Chapter 1.8 above), to the municipality which occurred at the second of the two Strategic Adaptive Management (SAM) workshops in December 2011. This workshop was run by members of the “policy to practice” team to initiate conversation among the many stakeholders in the Sundays River Valley. Water related problems and concerns were highlighted as the main project focus and formed the basis for the working relationship between the municipality and this study.

The workshop provided insight into the current situation, highlighted possible areas of focus and introduced this current study to some of the major role players. As the project members were not familiar with the situation at hand the main form of data collection was a focus on listening in order to learn as much as possible with participation being kept to a minimum at this time.

4.2.1.2 Rapid Response Unit (RRU) intervention workshop (February 2012)

The second milestone was the DWA’s Rapid Response Unit (RRU) intervention workshop held in February 2012. The RRU workshop presented to the SRVM is given to municipalities identified by the DWA as being in a critical governance and institutional practice state, in serious need of ‘turnaround’. The main aim of the RRU intervention is to provide struggling municipalities with guidelines on how to move forward and to improve Blue and Green Drop scores. In the February 2012 RRU workshop, the facilitators introduced the water cycle, the value of water quality and the different statutory controls that govern the water business. They then went through each of the KPAs and explained what was needed to meet these requirements.

This workshop was an important milestone as it showed progress achieved since the second SAM workshop and could therefore act as a starting point for analysing the effectiveness of the RRU in assisting the SRVM to improve its GD score. The main aim of the researcher during this workshop was to monitor the interactions between the SRVM and the RRU and to assess the effectiveness of the workshop in building the foundations for improving the wastewater performance in the SRVM.

4.2.1.3 Green Drop Assessment (October 2012)

The third milestone was the GD assessment which took place in October 2012.

The typical process is that assessments are carried out by teams of accredited professionals from the DWA. The assessments alternate annually between Green Drop and Blue Drop hence the next Green Drop assessment will only take place in 2014 after the conclusion of this project. The GD assessments follow the process of first assessing how the municipality and each of its WWTWs comply against a set of predetermined criteria. This is followed by a site visit to one of the treatment works chosen at random by the assessors.

The assessment of the SRVM took place on 24 October 2012. The morning session assessed the SRVM against the criteria that had been decided on for the 2012/2013 assessments. As mentioned above, these criteria were divided into nine sections, known as KPAs. These KPAs cover criteria ranging from the state of the collector system, the physical condition of the plant, the operation and maintenance of the plant, the plant's compliance, the municipal wastewater bylaws, and budget information. Some of the KPAs contain possible bonuses and penalties attached to them. The bonuses are not compulsory criteria but municipalities may be awarded points for fulfilling them, whereas the penalties are criteria which, if not met, result in a deduction in points. The KPAs therefore cover all aspects of the wastewater treatment business.

The KPAs selected for each assessment are published as a checklist for public viewing prior to the assessment (Appendix 6). Along with this checklist DWA publishes a number of related documents, such as the Green Drop Handbook, to assist municipalities (DWA 2011e, DWA 2012b). While the checklist merely provides municipalities with a list, the GD handbook (which also contains the checklist) discusses in depth the basics of wastewater treatment, the theory behind the GD Programme and comprehensively explains each KPA, its importance and the legal theory it is based on. These documents "can thus be used as a guide by municipalities to ensure that they are adequately prepared for their Assessment" (DWA 2011e). This also means that municipalities cannot use the excuse that they were not aware of what they would be assessed on as a reason for not providing necessary documentation.

The GD assessment was chosen as a milestone because it would show how the municipality had progressed in improving its GD score and reflecting its performance in wastewater operations since the RRU had begun working with it. Thus, as a participant observer, the researcher recorded the assessment and interactions enabling identification of, for example, when the municipality misunderstood questions.

4.3 Results

4.3.1 Initial Green Drop Assessment 2010/2011

The initial 2010/2011 GD assessment showed that the SRVM was a municipality in critical need of attention and turnaround. The municipality only scored 5.6% (Figure 4.2), the third lowest score in the Eastern Cape, ranking it 15th out of 17 municipalities (DWA 2011b). There were only three KPAs in which it scored marks: KPA 1 (Process Control, Maintenance and Management skill), KPA 3 (Credibility of Sample Analysis; and Treatment and Collector Capacity) and KPA 9 (Treatment and Collector Capacity). The main reason for the municipality scoring so low in the GD assessment was a lack of operating and monitoring programmes and a lack of data submission to DWA. This resulted from a lack of operational or compliance monitoring programmes in place; no data-capture was undertaken and no submission could be made.

At the time of writing, the 2012/2013 GD results had not been released. Thus, the results presented cannot be compared with the final DWA score for the municipality. Nonetheless, from the data presented below and knowledge of GD, an expected GD score will be given for the 2012/2013 assessment. It must be noted that this is not the actual score the municipality achieved for the assessments.

Table 4.2 Score sheet for the Sundays River Valley Local Municipality (SRVLM) from 2010/2011 Green Drop assessment (DWA 2011b).

Water Services Authority: **Sundays River Valley Local Municipality**

Municipal Green Drop Score: **5.6 %**

Performance Area / *Systems*	Greater Addo	Enon / Bersheba	Greater Kirkwood	Paterson
Process Control, Maintenance & Management skills	13	13	30	5
Monitoring Programme	0	0	0	0
Credibility of Sample Analyses	3	3	3	3
Submission of Results	0	0	0	0
Wastewater Quality Compliance	0	0	0	0
Failure Response Management	0	0	0	0
Bylaws	0	0	0	0
Treatment & Collector Capacity	55	55	0	0
Asset Management	0	0	0	0
Bonus Scores	0	0	0	0
Penalties	0	0	0	0
Green Drop Score (2011)	**6.9%** (↑)	**6.9%** (↑)	**3.1%** (↑)	**0.6%** (↑)
Green Drop Score (2009)	NA-0%	NA-0%	NA-0%	NA-0%
Treatment Capacity (Ml/d)	2.4	0.25	0.77	NI
Operational % i.t.o. Capacity	88%	96%	NI	NI (assume >100%)
Cumulative Risk Rating (CRR)	16	13	13	12
% i.t.o. Maximum Risk Rating	88.9% (↑)	86.7% (↓)	86.7% (↓)	80% (↓)

NI - No information

NA- Not assessed

The score sheet above (Figure 4.2) shows how each plant in the SRVLM faired against each of the KPA for this assessment period. The arrow next to each score shows whether there was an improvement, no change or deterioration in the score. The score-card also shows the score for the 2009 assessments in which the municipality was not assessed, the treatment capacity of the plant and how the plant is operating in terms of its maximum capacity. The risk rating for each plant is also given followed by the maximum risk rating of which 100% is poor thus a safe score is as close to 0% as possible.

4.3.1 Second Strategic Adaptive Management (SAM) Workshop

This workshop demonstrated that confusion and a lack of performance was reflected across a number of municipal sectors including wastewater management and treatment. A number of stakeholders were eager to improve this situation, and to move from functioning in a reactive manner to being proactive and to focus on problem-solving. The use of SAM as an approach to achieving turnaround was accepted by the majority of stakeholders. Through the workshop, an analogy of the knotted fishing line was used with the fishing line representing the entirety of water service delivery problems, with each individual problem representing a smaller knot in this tangled web. The knotted fishing line analogy implied that by trying to loosen one knot you inevitably tighten other knots. In effect, trying to focus on fixing one problem in isolation can intensify or change other problems. Therefore a concurrent, integrated approach is required. Four knots (problem areas) within the municipality were identified during the workshop. These were issues surrounding:

- Bulk storage and water supply,
- Water treatment and the quality of drinking water for people,
- Community supply, public health and experienced issues by members of the community,
- Treatment and discharge of sewage and treated water back into the river.

A variety of water related issues were raised. At this point the main focus and concern of the stakeholders was on potable water issues. Wastewater issues were raised as a knot which needed to be dealt with, but they were not seen as the main priority at this time. However, problems associated with this knot were identified as:

Lack of qualified operators: This was raised by a technician and a council member. The technician recognised that there were legal issues associated with running a plant without enough qualified personnel to cover all the shifts.

Lack of water quality monitoring equipment: This goes hand in hand with lack of skilled operators. The municipality cannot run a compliance monitoring programme without equipment and the skills to use the equipment.

Insufficient initiative: A councillor raised the question – "why was a temporary monitoring plan not implemented with the staff and personnel the municipality currently had access to?". She noted that the operators do not know when, how and what to test for but that this is because there is no equipment. The councillor was therefore questioning, without necessarily realising it, why a wastewater quality monitoring programme, which is the first KPA, was not in place.

Insufficient understanding of the sewage system by the community: A member of the technical division highlighted the issue that people dump materials into the system, such as bricks, rocks, blankets and clothes, which end up blocking it. They do this without realising that this will cause breakages and blockages causing pipes to break and overflow.

Maintenance of the system was more reactive than preventive: The municipality was trying to address a number of problems which kept appearing without warning. These problems were time intensive and prevented the setting up of preventative systems.

Design and capacity problems with some of the plants: Manholes have been built above a canal which transports potable water. When these manholes overflow the sewage runs into the canal. Other plants, such as Addo are in need of upgrade.

Finance and access to money: This was an underlying theme of all the knots that were raised.

In terms of the GD requirements released earlier in 2011 there had been little action from the municipality to rectify the final report findings. There was even some confusion by members of the technical division as to what exactly the GD assessments were. There were no operational and compliance monitoring programmes in place. There was no evidence of an asset register, annual audit report or any idea of the cost of the treatment of the sewage in cents/m^3 or R/m^3 respectively. Although there was little knowledge or understanding about the GD programme, there was enthusiasm to turn the situation around. A final outcome of this workshop was a decision to form a water committee with stakeholders from across different sectors to try and address and minute the problems identified on a regular basis.

4.3.2 RRU intervention workshop (16-17 February 2012)

By the time of the RRU intervention workshop, there had been little to no change in the wastewater treatment operations. It was still evident that stakeholders wanted to improve the situation; the water committee had been formed and had met once thus far. However nothing had been done towards meeting the GD requirements. The RRU facilitator posed the question whether people could be made to care for the environment even if they did not want to. A number of municipal and community members responded passionately about how they wanted to enact change, and their need for outside assistance from the RRU and DWA. There was, however, still some confusion from one of the technical officers who could not understand why the municipality had scored so low on the GD. He admitted that he had not been aware of what exactly the GD assessments entailed or what was needed from the municipality to improve its GD score. He expressed interest in assistance from the RRU to help the municipality become competent in the GD Programme.

The RRU team provided a number of administrative documents such as templates for log books, operations and maintenance sheets and shift sign in/out sheets to assist the municipality in reaching some of the requirements of the GD KPAs. As a further means of assisting the municipalities to utilise the information gathered at these workshops, DWA gave a R1 million grant to buy equipment and hire necessary staff.

4.3.3 2012/2013 Green Drop assessment (24 October 2012)

In the time between the RRU workshop in February and the assessment in October a number of changes took place. Each of these changes will be listed under the respective KPAs below.

<u>KPA 1: Process Control, Maintenance and Management skill</u>

Certified Registration Certificate of the Works: The municipality was able to provide copies of the registration of the Kirkwood treatment plant to the assessors.

Registration certificates of the supervisor and process controllers: These were available in hard copy but had not yet been uploaded onto the website due to technical difficulties. The municipality was understaffed with process controllers and could not fully comply with Regulation 2834. Also no shift patterns were indicated as two process controllers were covering all of the shifts at the Kirkwood wastewater treatment works.

Maintenance Team: The municipality could provide documentation through job cards about the in-house electrician and claimed to have some documentation regarding the maintenance team used which was outsourced, but stated that this documentation was most likely with the auditors. They did not have any routine or schedule agreement with these parties.

Site specific Operation and Maintenance Manual: The municipality had an operations and maintenance manual of sorts; however it was not indexed and did not provide information on the processes which needed to be followed under certain circumstances. The lead assessor noted that this prevents issues from being resolved immediately.

Operational Logbook: Instead of an operational logbook the municipality used a site diary to record necessary information.

Bonus: The municipality should be awarded a bonus for this section as there was proof of process controllers being subjected to relevant training in October 2011, which was organised by DWA and the Water Academy.

KPA 2: Wastewater Monitoring Programme Efficacy

Under this KPA it was evident to the researcher that the municipality still did not really understand the difference between compliance and operational monitoring.

Operational Monitoring: The municipality was making an effort to monitor some of the necessary components; however, there was no structure to the way in which this was done. The data were still being recorded in the site diary and not on a separate file and were not captured anywhere else as a backup. The process controllers were doing daily monitoring of up to seven variables (pH, turbidity, chlorine, electrical conductivity, chemical oxygen demand, nitrates and phosphates). The records included inflow and outflow data. However, there were not any records summarising the inflow and outflow data or the utilization of this data. The municipality has no record of sludge inflow/outflow as they have no measuring device. The supervisor said they do not test sludge, however, the researcher observed the cone test, which tests for solids in influent and effluent, being conducted.

Compliance Monitoring: This began in July 2012. Unfortunately the data collection began outside of the sampling window of July 2011 to June 2012 and so no marks can be awarded for this section in the 2012/2013 assessment. The laboratory results collected up to August

2012 were provided as evidence that a programme had begun, but because no authorisation had been granted yet, the municipality was testing the effluent against a General Authorisation. There was no evidence that the data being generated were being used to alter the running of the plant.

Laboratory used: The relevant documents for laboratories used were provided. There was no documentation showing turnaround time (how long it took for the laboratory to process and return the compliance data).

Laboratory Credibility: The municipality was not sure what methods the laboratory was using and had no documents to show the laboratory's credibility.

Use of results to amend/improve process: the results have not yet been used to amend any of the processes. The supervisor said he was still trying to put the data together to view the trends, but had not done this yet.

KPA 3: Submission of Wastewater Quality Results

Proof of data submission: no data had been submitted for the required period June 2011 to July 2012 because no data were being generated. The supervisor reported that data submission had been attempted but had not been successful due to technical problems on the website. The lead assessor understood this and noted this.

KPA 4: Effluent Quality Compliance

Copy of Authorisation: The supervisor was not sure what this was. The director was later able to provide documents to say they had started with the application process, so marks could be awarded for this criteria.

Effluent Quality Categories: No data had been generated.

Bonus: There was evidence of a Green Drop Improvement Plan (GDIP) being put together since February 2012. The document provided time-frames and responsiblities but did not provide any information on cost implications. It was still a working document and was therefore not in place as yet; bonus marks would most likely not be awarded.

Penalty: There were no monitoring records to show that the sludge treatment was being monitored or managed thus the municipality would most likely incur a penalty.

KPA 5: Wastewater Quality Risk Management

Wastewater incident management protocol: There was a generic draft incident management protocol. However, this needs to be site specific for each plant, as not every plant will face the same risks or the same degree of risks.

Evidence of implementation: No documentation showing implementation.

Wastewater Risk Abatement Plan: Still a working document which had yet to be finalised.

Energy Demand Projections: There was documentation showing energy costs and kW/hour.

KPA 6: Bylaws (Local Regulation)

Proof of bylaws: Copies of the bylaws were available.

Evidence of Enforcement: There were no examples of implementation, such as charging honey-suckers or notices served in contravention of bylaws, etc.

KPA 7: Wastewater Treatment Capacity

Documented design capacity – hydraulic and organic: There was proof of the documented design capacity of the plant as well as inflow and outflow data. However, there was no evidence of peak wet weather flows, minimum night flows or any proof of the accuracy of the measurements. The WWTW was still operating within its capacity according to these data.

Daily flows: Daily flows had been recorded but the data had not been used to work out averages, peak wet weather flow, and night flow. The municipality was supposedly in the process of calculating these figures.

Medium to long term planning for sufficient capacity: It had been ten years since the last upgrade. There were no plans to upgrade the capacity of the plant.

Medium to long term planning for sufficient collection capacity: There were no plans to upgrade the reticulation, pump stations, etc.

KPA 8: Wastewater Asset Management

Process Audit: The municipality had documentation showing the process audit from that year but it was missing a number of important pieces of information due to other documentation, such as the compliance standards, which were not yet available. No implementation of the findings from the audit was evident.

Site inspection of sewer and reticulation network: There was no site inspection of sewer and reticulation network.

Updated sanitation/wastewater infrastructure Asset register: The necessary documentation was provided without replacement costs.

Operational and maintenance budget and expenditure: There were documents showing some of the operation and maintenance budget, such as electricity usage and maintenance expenditure but not all that was required.

Maintenance records of pump stations: No documentation was provided to show this.

Bonuses

The municipality would be awarded bonus marks for its collaboration with another institution, namely Rhodes University.

4.3.4 Overall Green Drop Score 2012/2013

Unfortunately, at the conclusion of this project and the thesis, the 2012/2013 GD results had not been released yet and so a quantitative comparison cannot be reported on. However, from the current understanding of how the GD system works and the improvements made through this project in each KPA assessed by the GD (see previous section), it was possible to attempt to estimate the Kirkwood WWTWs expected score. The estimated score card is presented in Table 4.2. As is evident from this, the municipality should see a large increase in its final GD score for the Kirkwood WWTW, from 3.1% to about 40%.

Table 4.3 Actual 2010/2011 Green Drop score compared with the estimated 2012/2013 Green Drop score for the Kirkwood WWTW.

Performance Area	2010/2011 (actual score card)	2012/2013 (estimated score card)
Process Control, Maintenance and Management Skills	30	68
Monitoring Programme	0	30
Credibility of Sample Analysis	3	Not assessed
Submission of Results	0	0
Wastewater Quality Compliance	0	20
Failure Response Management	0	20
Bylaws	0	80
Treatment Collector & Capacity	0	40
Asset Management	0	45
Bonus Scores	*0*	+ *8%*
Penalties	*0*	- *1%*
Green Drop Score	**3.1%**	**38.6%**

The municipality has managed to improve its GD score for the Kirkwood WWTW from the 2010/2011 GD assessment. However, it still has a number of challenges to overcome to meet all the GD criteria consistently and ensure the wastewater business is managed in the best manner possible.

4.4 Discussion

4.4.1 Analysis of Municipal performance

The Sundays River Valley Municipality (SRVM) showed definite improvement in the short time it began working with the RRU and the GD assessments at the end of 2012. This is reflected by its provisionally estimated GD score of 38.6% for the Kirkwood WWTW. As shown above, the Kirkwood WWTW only scored 3.1% in the previous assessment because it did not have any administrative documents and evidence of a wastewater monitoring programme which prevented the collection and submission of data. However, the SRVM was now able to provide a number of these documents and had some basic programmes running. Nonetheless, the shortfall came when the municipality had to show evidence of implementation of these documents, such as implementation of the operations and maintenance manual, implementation of the bylaws or that the data it was generating, such as the daily monitoring, was being used to improve the wastewater treatment process. This lack of implementation was emphasised by the lead assessor during the GD assessments when she stated she wants "to see implementation. It is not enough to create these nice documents but they also need to be used instead of just being filed away. You get the most of your marks for implementation". Thus, the major shortfall in the municipalities GD score was the failure to implement and show evidence of this implementation.

This lack of implementation can be attributed to three issues within the municipality, namely understaffing, communication issues and a lack of operational databases. These are not stand alone issues but are compounded by a number of outside issues.

The first issue is that the SRVM put the majority of the work associated with the GD and Blue Drop turnaround on a small group of people from the technical department. In a number of interviews and occasionally during workshops, members of this team complained that they were under-staffed and needed assistance but they were not getting any support.

> "*At times it did seem these cries for help were justified, while at other times it seemed as though they merely felt daunted by the task at hand and would use this as an excuse for why things were moving slowly or not happening at all*" (Personal Observation, 26/07/2012 [Appendix 5]).

Tied into this is the second issue of communication between the different departments, especially between the finance and the technical departments. At most workshops the Technical Department complained that they had plans to move forward but that the finance department kept preventing these actions from taking place. At the majority of these meetings members from finance had been invited to attend but were not present to defend these claims. There were, however a couple of meetings where members of the Finance Department were present, such as a meeting with the RRU around creating a Green Drop Improvement Plan. At this meeting the Chief Financial Officer was present and she defended the Finance Department saying that there was massive under-spending from the Technical Department of R1.5 million in the previous financial year. Therefore, from the Finance Department's side the budget was available but orders were not coming through or being recorded so the money could not be allocated. These claims were disputed by the members of the Technical Department, as they had been told the funds were not available. This is one example of the miscommunication between the different departments in the SRVM, where one department blames another for problems whether actual or not. This leads to delays and inefficiencies which can have cumulative effects.

Communication was not only an issue within the SRVM but also between the SRVM and the implementing agents providing assistance with the turnaround. One such example related to the water quality monitoring equipment that was purchased for the municipality by the implementing agent Amatola Water. This equipment is necessary for daily operational monitoring at the treatment works, as part of the Wastewater monitoring programme (KPA 2). The technician received a call, with no prior warning, that the equipment had arrived and he was told he had to go collect it. At the time he was on site 80km away. He was completely unaware that this equipment had been purchased, or that he should be expecting delivery. Along with this there was no invoice of what equipment had been delivered so the technician had to drop what he was doing and try and work out what equipment there was, what it was for and where to store it safely. Also, because there had been no warning about the delivery, the municipality had not prepared any operational monitoring programme to start using this equipment. Thus, the miscommunication between the SRVM and the implementing agents hindered the implementation of programmes such as the daily operational monitoring of the plant which could have ensured the municipality scored higher marks.

Communication was not the only issue hindering implementation of the wastewater treatment programmes. There were certain problems the technical department claimed it was not able to attend to without assistance from other departments in the SRVM, such as grass cutting. This may appear to be a small issue but it was a starting point suggested by the RRU in February 2012. The grass and bushes around the treatment works were extremely overgrown, to the point where operators were not able to do their jobs properly during the summer months for fear of snakes. The RRU emphasised that addressing small issues, such as this, can have a big impact in improving the overall workings of the plant. Process controllers can do their jobs properly and the plants look professional – which is the first area noticed by assessors when conducting site inspections. This point was emphasised at a number of different meetings. The Technical Department claimed to have asked the Department of Community Services to attend to these issues with no action having been taken till a later stage. Only in August 2012 did the Department of Community Services send a tractor to cut the grass. Therefore there were instances where the solutions to problems were outside of the Technical Department's control. This made the addressing issues a lot more difficult.

The above examples show how implementation of the necessary GD processes was affected by departments outside of the Technical Department. This leads to the third issue which was a lack of understanding by the members of the Technical Department as to why the implementation and the GD Programme as a whole are important or necessary. Even after a year of engagement with the RRU and Rhodes University around the GD Programme, the municipality still seemed to view the GD Programme as extra unnecessary work rather than a system to ensure the municipality ran its wastewater treatment business in the best possible manner, as this impacts on human and environmental health. Without this understanding it becomes extremely difficult to implement best practice. A practical example arising from the lack of understanding of why certain processes are important and how this affects daily operations was evident in the 2012/2013 GD assessment. The lead assessor asked whether there was any reason for the massive drop in faecal coliform levels of the effluent from 7 900 to 800 faecal coliforms per 100 ml, between July 2012 and August 2012. The response from the technical department was that they did not know as they had not changed anything and that it was "mother nature". The lead assessor posed the question "what is the point of monitoring if you don't use the results?". She emphasised the DWA wants municipalities to understand the concept of monitoring, why they do it and why it is necessary. Therefore, although the previous examples showed issues where outside agents prevented the members working on the GD improvement, there was still a lack of understanding as to why these processes were necessary within the Technical Department which were preventing them from ensuring implementation.

4.4.2 Value of Rapid Response Unit in assisting the municipality to improve its water treatment operations

There were a number of positive outcomes of the RRU working with the municipality, such as the municipality starting a monitoring programme, getting copies of the operations and maintenance modules and other necessary information for the GD assessments. However, there were also some negative areas which will be illustrated below.

The main outcome of the RRU intervention workshop seemed to be an understanding by the municipality that they were legally required to take part in the Blue and Green Drop assessments. However, the municipality still did not seem to fully comprehend what was required from them. This was most likely because the workshop was presented in a complex and difficult manner. The workshop was also generic and did not take into account the municipal dynamics at the time, something Nealer & Mtsweni (2013) argue is necessary in these assessments.

Some of the stakeholders present at the RRU intervention workshop expressed concerns about the amount of work that would be needed to meet the requirements and saw the task as daunting, if not impossible, within the current situation. For months after the workshop there was still confusion as to how to start to achieve certain requirements such as where to monitor, how often, what to monitor for, how to use the data generated to alter treatment methods and how to upload the data for the compliance monitoring, all of which has been illustrated above. This sort of information was not conveyed by the RRU. When the RRU did provide assistance it was similar to the intervention workshop, which seemed to be that they approached the situation with a "get in - do the work - and get out" kind of attitude. An example here is the training of the process controllers and day workers on how to use the water quality monitoring equipment. The municipality expected the workshop to teach the process controllers and day labourers how to use the equipment, when to monitor, where to monitor, and how to record and use the data. In actuality the workshop made no effort to explain the theory behind why the tests were necessary, what the data meant or how best to record this data. One participant confided in the researcher saying he had no idea what pH was and this was not explained in the workshop. After the workshop there was no engagement by the RRU to see whether operators were performing the monitoring as shown and that they were generating credible results. The team from Rhodes University had follow up sessions with the process controllers to answer any questions and ensure the process controllers were conducting the tests correctly, that they knew what they were testing for and why they were doing the tests. This example shows how the RRU intervention lacked the necessary follow through needed in order to ensure programmes got up and running.

It took more than five months to setting up an operational and compliance monitoring programme. In this instance, the responsible agent was the SRVM rather than the RRU or Amatola Water. The SRVM felt it was the RRU's responsibility to tell them how set up these programmes as they did not know where else they could get this information. Thus, after the operators had been trained on how to use the monitoring equipment by Amatola Water and Rhodes University, there was no monitoring programme to implement. Each level in the wastewater management chain was waiting for the one above to give them the information needed. Nonetheless, the operators went ahead with what they thought they should be doing but were waiting for their supervisors' further instructions, while their supervisors were waiting for the RRU to tell them what to do. Although the RRU was took time to providing this information, the municipality made little effort to find documents which could assist them on their own. This lack of effort on the municipality's behalf most likely ties into both municipal inefficiencies and the lack of project management instituted in trying to address the problem. There was no project time-line to guide the municipality in focusing on each goal sequentially.

The RRU intervention therefore had some positives in educating the municipality on the GD Programme and giving them starting points from which to work from. They also assisted them in getting a monitoring programme started, although this could have been achieved in a shorter space of time. They also failed to ensure necessary follow-up and site specific-guidance. However, it must be noted that its purpose was to assist and guide the municipality to improvement; it was not its job to do the hard work for the municipality. This is a point that should have been made clearer from the start.

4.4.3 How the structure of the Green Drop Certification Programme affects a municipality's performance

The above presented a discussion on how the SRVM and the RRU could have performed better to ensure an improved GD score. It is also necessary to examine the structure of the GD Programme to understand how it can both enhance and hinder a municipality's performance.

In the 2009 assessments, only five out of 17 municipalities in the Eastern Cape took part in the GD assessments compared to the 17 in the 2010/2011 assessments (DWA 2011b, DWA 2009). These five municipalities are shown in Table 4.3 which shows their performance for both assessments and the number of WWTWs that they manage. As the table shows, some municipalities, namely the bigger municipalities such as the Nelson Mandela Metropolitan Municipality and Buffalo City Local Municipality, achieved GD scores above 50% in 2009 and managed to improve this score to over 80% for the 2010/2011 assessment. This is most likely because they have better resources available to them in terms of personnel, finances and skills which the smaller municipalities do not have. The Makana Municipality, which manages fewer WWTWs than the SRVM but has a higher population, achieved a very low score in its first assessment of 7%, not dissimilar to the SRVM's 5.6% in its first assessment.

However, for the follow up assessment it saw the highest gain in score, to 49%, of the five municipalities in the Eastern Cape. The major stumbling block reported by the 2010/2011 report was the lack of monitoring programmes at the WWTWs, something that the SRVM also failed to implement in the current 2012/2013 assessments. Therefore, both municipalities have lost points on failure to implement wastewater treatment monitoring programmes for their first assessment. Nonetheless, the improvement of the Makana Local Municipality's score provides hope that the SRVM is also capable of improving its GD score to such a large degree. However, this increase is not likely to be as high due to a number of reasons which are discussed below (Table 4.3).

Table 4.4 Five municipalities which participated in the 2009 Green Drop assessments and how they fared in the 2010/2011 assessments. The table also shows how many WWTW each municipality manages and how many of these WWTWs were assessed.

Municipality	No of WWTWs	2008/ 2009 score	No of WWTWs assessed (2008/2009)	2010/2011 score	No of WWTWs assessed (2010/2011)
Buffalo City Local Municipality	15	53%	4	86.70%	15
Chris Hani District Municipality	17	10%	1	30.80%	17
Makana Local Municipality	3	7%	3	49%	3
Nelson Mandela Metropolitan Municipality	7	70%	7	80.80%	7
Ukhahlamba District Municipality (2009) - Joe Gqabi District Municipality (2010/2011)	13	3%	13	22.04%	15

One part of the GD's structure which can affect a municipality's performance is the changing criteria for each assessment cycle. With each assessment cycle the GD requirements become more stringent in order to incentivise municipalities to continually improve their water treatment business (DWA 2011b). Therefore, municipalities which did not participate in the first few assessments face a greater challenge than those who did participate in the first assessments. The SRVM is one of these municipalities, having not participated in the 2009 assessment and hardly participating in the 2010/2011 assessments. The municipality therefore not only had to improve its score but the criteria it was being assessed on were more stringent than previous assessments. It was playing catch-up in an arena that had become more difficult. In the latest GD assessment, implementation was one of the main criteria attached to all KPA. Unfortunately for the SRVM, this was their major stumbling block. Had they been assessed against the criteria of the 2009 or 2010/2011 assessments they might have fared better. This brings into question the fairness of this system for municipalities who have not participated in previous GD assessment. Possibly their scores should be weighted to make up for this. However, it seems that because the GD Programme does not stipulate any form of legal penalty, this is one of the ways the programme incentivises municipalities to participate in the assessments (DWA 2011e). This has both positive and negative impacts. The positive impact being that municipalities are more likely to participate in the assessments, that they will continuously strive to improve their performance and that the quality of water treatment in South Africa will continue to improve. The negative impact is that for municipalities, such as the SRVM, who are faced with more than merely water service related problems, the task of meeting the increasingly stringent criteria becomes that much more difficult.

A second part of the GD's structure which can negatively affect the performance of a municipality is the biannual nature of the assessments (DWA 2011e, DWA 2011d). Because the Blue and Green Drop assessments are conducted in alternating years it means that a municipality's focus is constantly changing from Blue to Green Drop criteria. Once a municipality achieves high scores for both these assessments it is easier to maintain focus on both of these sectors, giving the particular sector marginally more focus due to the upcoming assessments. However, for municipalities such as the SRVM, which are facing not just water-related problems, these alternating assessments can be problematic. While working with the municipality in the year of the GD assessment, little in the way of Blue Drop was mentioned. This might have been because the 2011 Blue Drop score for the SRVM (35.55%) was higher than that of the GD score meaning the task of improvement in this sector was not as serious (DWA 2011c). However, the municipality's focus seemed entirely on meeting the next deadline, that of the GD assessments or any other assessment or audit in the immediate future, while all other activities that were not emergencies were neglected. The tasks which were neglected can turn into emergencies placing greater stress on the municipality. This mode of behaviour prevents the municipality from working in a preventative rather than reactive manner. Naturally this is not the intention of the GD Programme but it does happen in some cases, such as the SRVM.

The Green Drop Assessment is an effective programme in generating information about the performance of the wastewater treatment sector from the individual WWTW to the country as a whole. This makes it an important database as it can highlight areas of concern and areas of excellence because of the wide range of KPAs it examines. It is also effective in encouraging constant improvement in the wastewater sector illustrated in the general improvement of the scores of municipalities which have consistently participated in the programme from the start. However, the structure of the programme generally makes it harder for smaller municipalities, such as the SRVM, which lack resources to see large improvements over a short period. In the SRVM's case this was because implementation was the area of focus for this assessment, something which takes more than a year to get running properly. Although the municipality could have done better, there were a number of internal and external factors which prevented it from doing so. Internally the municipality lacked the necessary drive and understanding for implementation to occur, and there was conflict between the departments. Externally, the GD assessments discriminate against municipalities which have not participated in the programme from the start. Its emergency response teams are effective in educating municipalities about the programme, but from the evidence given above they fail to ensure continuous and site specific engagement.

The Green Drop Certification Programme assesses the entire business of wastewater from the consumer, through the reticulation system, the treatment of the wastewater to the final quality of the effluent. The GD KPAs cover these different aspects making it easy to identify areas of concern and therefore relatively easy to begin to fix these problems. Thus, as these problems are corrected one would expect to see an improvement in the quality of the final effluent. It would be almost impossible for a municipality to score 100% in each of the KPAs that make up the day-to-day and long-term operations of the plant and still produce effluent of poor quality. Therefore, in the SRVM's case, as it increases its overall GD score, due to better and safer practices, it will result in better and safer effluent for the receiving environment – the Uie River. Along with this, one would expect the macroinvertebrate health scores to improve along with the improved effluent quality. Furthermore, by achieving a higher GD score, one would expect the municipality to be complying with the General Standard licence conditions which would help the receiving environment meet the desired ecological objective. Hence, the GD Programme is effective in linking the policies and legislation of the NWA and Water Services Act in order to bring about equitable and sustainable use of South Africa's water resources.

Chapter 5: Conclusion, limitations and recommendations

5.1 General conclusion

The legislation in South Africa surrounding the business of wastewater is dichotomous. There is comprehensive coverage of the different aspects of wastewater treatment by the National Water Act (No. 36 of 1998) (DWAF 1998) and the Water Services Act (No. 108 of 1997) (DWAF 1997). However, these laws and policies are specified in a number of different documents making it time-consuming and difficult to access. Therefore, there has been a need for an umbrella document or programme to bring these laws and policies together. The Green Drop Certification Programme achieves this. Along with the Blue Drop Certification Programme, the entire life cycle of water use is covered, from water storage and potable water treatment, to sanitation and effluent discharge. These two programmes make it easier for municipalities and Water Services Authorities (WSA) to ensure that they are complying with objectives. The programmes also provide information in an easily accessible manner to the public and the WSA on how well the WSAs are performing in each of these fields.

One of the main aims of these programmes is to ensure continuous improvement in the water treatment sector. Municipalities which actively try to improve their performance in the GD can expect to see an improvement in the operations and maintenance of their wastewater treatment works leading to a better quality effluent, in line with their licence conditions, being discharged into the environment. These licence conditions are set by DWA as part of the Source Directed Controls (SDC) which are used to control impact on the receiving environment. The SDCs are one of the tools used together with RDM to ensure protection and sustainable use (DWAF 1998). Theoretically this is how the Green Drop Programme bridges the divide between the NWA and the Water Services Act. However, it was still necessary to assess this in a practical manner. For this the Sundays River Valley Municipality's case study was chosen.

The Green and Blue Drop Programmes were introduced in 2008 and have already seen a good response from most WSAs. Although there can be some negative points related to the GD Programme (Chapter 4), for the most part it has had a beneficial effect. The 2010/2011 GD assessments were the first in which all WSAs participated to some degree, up from 63% in the 2009 assessments. This shows that the GD Programme has managed to provide information for the majority of South Africa's wastewater treatment operations in a relatively short space of time, another one of the aims of the programme. Municipalities that participated in both the previous Green Drop assessments have shown continuous improvement, some more so than others. It is generally easier for larger municipalities with the resources available to them to meet the criteria than smaller municipalities. Nonetheless, this improvement is encouraging for the programme as one of its main aims is to ensure continuous improvement in the wastewater sector (DWA 2011e).

In the case of the SRVM, which scored 5.6% for its first assessment, this improvement is expected to be reflected as well. Unfortunately, because the 2012/2013 GD results had not been released at the time of writing this cannot be categorically backed up. Nonetheless, from a personal understanding of the GD Programme a score of 38.6% was estimated for the Kirkwood WWTW. The improvement in the SRVM's score was largely due to the administrative documents they were able to produce with the assistance of the RRU. The SRVM also managed to get a basic operational and compliance monitoring programme in place. However, the data generated from these monitoring programmes fell outside the assessment period for the GD 2012/2013 assessment (July 2011 to June 2012). Also, the data were not being used to alter the treatment process in any way. For the 2012/2013 GD assessments municipalities scored the majority of their marks by illustrating implementation and use of generated data. This was the major stumbling block for the SRVM. If the municipality had been monitoring the effluent and altering the wastewater treatment processes accordingly, it would most likely have been able to achieve a higher compliance in terms of the General Standard licence conditions than the 31.5% it did achieve during the period July 2012 to June 2013 (Section 3.3.3). This low performance posed a danger, not only to environmental health, but also to human health due to the large amounts of faecal coliforms being released.

The low performance of the Kirkwood WWTW appears to have a definite impact on the ecological category of the river as assessed by macroinvertebrates. This impact is quite clearly illustrated by the drop in macroinvertebrate health scores at Site 2 (53.3 which corresponds to an ecological category of D) compared to Site 1 (80.5 which corresponds to an ecological category of B) and by the apparent recovery of the scores at Site 3 (64.0 which corresponds to an ecological category of C). The impact is most likely attributed to water quality rather than habitat disturbance as the IHAS scores for Site 1 and 2 are similar. The surrounding agriculture also impacts on the river but the recovery of the orthophosphates, TIN-N and turbidity at Site 3 indicate that the impact of the WWTW is larger than that of the surrounding land use. Accordingly, the findings for the river health would most likely have reflected a different situation at Site 2 if the WWTW had been complying with the General Standard licence conditions.

The Green Drop Certification Programme is therefore a tool that has been needed to link the National Water Act and the Water Services Act. Through the above case study it was demonstrated that the Kirkwood WWTW was struggling with the treatment of wastewater. The poor business of wastewater treatment in the SRVM was leading to harmful levels of poorly treated effluent being discharged into the Uie River. This was impacting the instream macroinvertebrate, mainly through high amounts of sludge impacting the habitat template. Also of concern were the turbidity and high TIN-N and orthophosphate concentrations. While these high concentrations of TIN-N and orthophosphate could be beneficial to farmers, as illustrated in Chapter 1, the high levels of faecal coliforms make the water unfit for human contact. It must also be noted that it is unrealistic to expect the scores at Site 2 and 3 to achieve macroinvertebrate scores as high as Site 1 due to the impact from the surrounding agriculture. Nonetheless, one would expect that if the SRVM managed to continuously improve its performance in the GD Programme, the macroinvertebrate scores at Sites 2 and 3 would improve. This would provide evidence that the SDCs are effective in meeting the RDMs of the river.

5.2 Limitations

There were a number of limitations to the research encountered. The first limitation was that the final GD scores for the 2012/2013 assessment had not been released at the time of writing. This made it difficult to assess the municipality’s improvement in the GD Programme. Nonetheless, from working with the municipality and an understanding of the GD Programme, a score for the Kirkwood WWTW was predicted to enable some comparison to be made.

The second limitation was the lack of historical water chemistry and macroinvertebrate data for the Uie River. While there were some data from the Sundays River existed, the largely different sizes of both rivers and the different nature of flow, due to the interbasin transfer scheme made comparisons difficult. Nonetheless, the macroinvertebrate data collected from the Sundays River was used to help generate reference conditions for the MIRAI model.

The SRVM only began monitoring the quality of its final effluent in July 2012. Effluent data were often incomplete as illustrated above. With a more complete data set over a longer period one would be able to make more concrete observations as to the effect of the effluent on the macroinvertebrate health communities.

The lack of data could have been accounted for if the study did not have the time frame limits of a Master's degree. This would have allowed the research to be conducted over a longer time period to account for these gaps in the data set. Nonetheless, the research was structured to fit into the same time period as a Green Drop Assessment in order to map changes during that time.

5.3 Recommendations

A recommendation for future research in this field would be to run the programme over a longer period of time. A good length of time would include the period of two full Green Drop assessment cycles. This would more clearly reflect the relationship between wastewater treatment management practices and the effect on the effluent being discharged into the river, taking into account seasonal variations. From this, one could start to better understand the trends in the river in relation to the wastewater management practices which this study began to assess.

Future studies could focus on more than one municipality. An example would be a municipality that achieves a high GD score while discharging a large amount of industrial and domestic wastewater into a river. This could be conducted alongside a study of a smaller municipality such as the SRVM which achieves poorly in the GD assessments and treats a much smaller volume of domestic wastewater. A comparison on how these municipalities and their WWTWs are performing against their licence criteria and the downstream effects of the effluent on instream biota would provide a further evidence of the link between RDM and SDC in relation to the GD certification programme.

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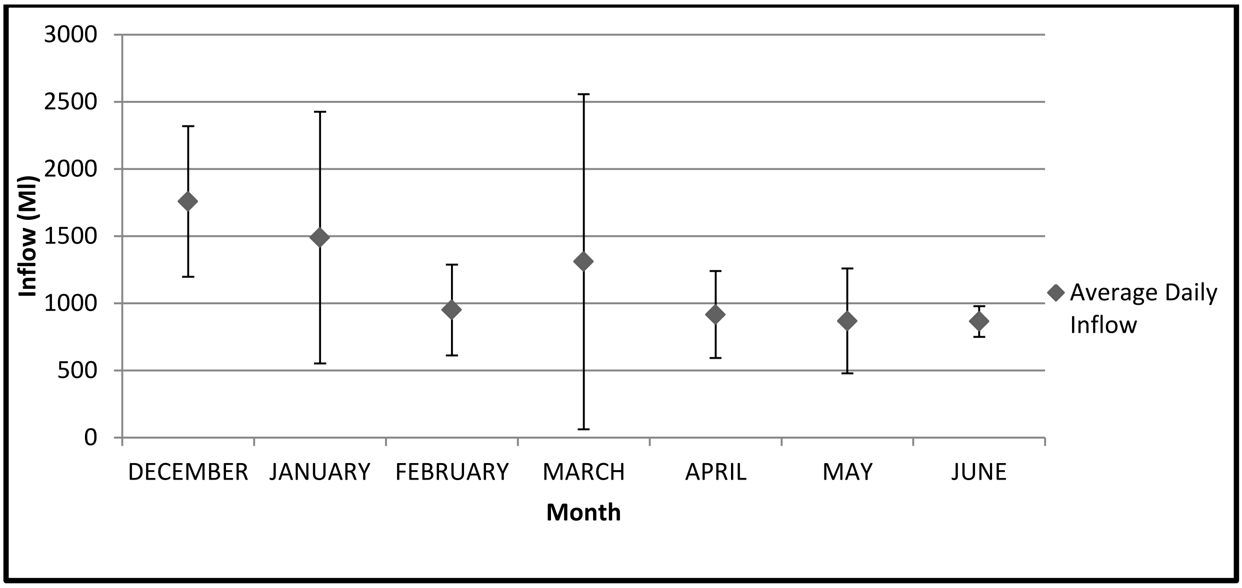
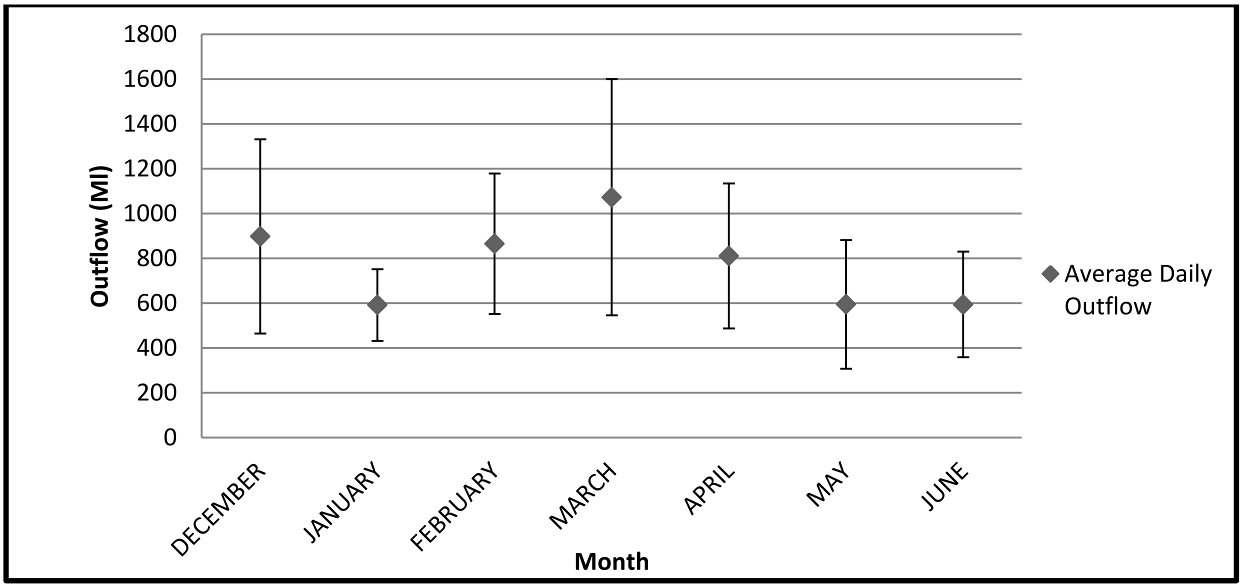
Appendix 1: Inflow and Outflow data from the Kirkwood WWTW

Month	Daily Inflow		Daily Outflow	
	Average	SD	Average	SD
DECEMBER	1757.4	561.0	897.0	433.2
JANUARY	1488.1	936.6	591.1	159.8
FEBRUARY	949.2	337.7	863.9	313.3
MARCH	1308.7	1248.4	1071.9	527.2
APRIL	914.9	324.1	810.0	324.0
MAY	867.4	390.6	593.9	287.4
JUNE	864.1	114.3	593.6	235.9





Appendix 2: Templates from the MIRAI model

Portion of MIRAI data sheet (for full data sheet refer to the actual model on CD).

Taxon	Season	Ref abun	Ref freq	Pres Abun	Pres freq	<0.1	0.1-0.3	0.3-0.6	>0.6	BEDROCK	COBBLES	VEG	GSM	WATER	QUALITY
Porifera						2	2	2	2	3	2	1	0	0	LOW
Coelenterata						2	2	1	0	2	2	1	0	0	NONE
Turbellaria						1	2	3	4	1	4	0	0	0	NONE
Oligochaeta						2	2	2	1	0	1	0	4	0	NONE
Hirudinea						2	2	1	1	0	4	1	1	0	NONE
Amphipoda						1	2	3	2	0	2	2	3	0	HIGH
Potamonautidae						1	1	3	2	0	3	1	1	0	NONE
Atyidae						2	2	0	0	0	1	4	1	0	MODERATE
Paleomonidae						0	2	2	3	0	3	0	0	0	MODERATE
Hydracarina						0	2	2	0	1	1	2	3	1	MODERATE
Notonemouridae						1	1	2	4	1	4	1	0	0	HIGH
Perlidae						1	1	1	5	1	4	1	0	0	HIGH
Baetidae 1sp						2	2	2	2	2	2	2	2	1	LOW
Baetidae 2spp						2	2	2	2	2	2	2	2	1	LOW
Baetidae >2spp						2	2	2	2	2	2	2	2	1	HIGH
Caenidae						3	2	1	1	0	2	1	3	0	LOW
Ephemeridae						2	2	3	2	0	1	0	4	0	HIGH
Heptageniidae						1	1	3	2	1	4	1	0	0	HIGH
Leptophlebiidae						3	2	2	1	1	3	2	0	0	MODERATE
Machadorythidae						5	0	0	0	0	1	0	4	0	
Oligoneuridae						0	0	1	5	2	3	1	1	1	HIGH
Polymitarcyidae						2	2	2	3	0	1	0	3	0	MODERATE
Prosopistomatidae						1	1	2	3	1	4	1	0	0	HIGH
Teloganodidae						0	0	2	4	1	4	1	0	0	HIGH
Tricorythidae						0	1	1	4	1	4	1	0	0	MODERATE
Calopterygidae						1	3	1	0	0	1	3	1	0	MODERATE
Chlorocyphidae						2	3	1	0	1	4	1	0	0	MODERATE
Chlorolestidae (Synlestidae)						3	2	1	0	0	1	4	0	0	MODERATE
Coenagrionidae						1	2	3	1	0	1	4	1	0	LOW
Lestidae						4	1	0	0	0	1	4	1	0	MODERATE
Platycnemidae						2	3	1	1	0	2	3	0	0	MODERATE
Protoneuridae						2	3	1	1	0	1	4	1	0	MODERATE
Aeshnidae						1	2	2	2	0	3	2	0	0	MODERATE
Corduliidae						2	3	1	0	0	2	1	3	0	MODERATE
Gomphidae						0	2	3	0	0	1	0	5	0	LOW
Libellulidae						1	2	3	1	1	4	0	1	0	LOW
Pyralidae (Crambidae)						1	1	3	2	0	2	3	0	0	HIGH
Belostomatidae						4	1	0	0	0	0	4	0	1	NONE
Corixidae						2	3	1	0	1	1	1	1	4	NONE
Gerridae						4	1	0	0	0	0	0	0	5	MODERATE
Hydrometridae						4	1	0	0	0	0	2	0	4	MODERATE
Naucoridae						2	2	3	0	1	1	1	1	4	LOW
Nepidae						4	1	0	0	0	0	5	0	0	NONE
Notonectidae						4	1	0	0	0	0	2	0	4	NONE
Pleidae						4	1	0	0	0	0	4	0	1	LOW
Veliidae/Mesoveliidae						5	1	1	0	0	0	0	0	5	MODERATE
Corydalidae						0	0	3	2	0	3	0	1	0	MODERATE
Sialidae						4	3	1	0	0	1	0	4	0	LOW
Dipseudopsidae						4	1	0	0	0	1	0	4	0	MODERATE
Ecnomidae						1	5	0	0	2	3	2	0	0	MODERATE
Hydropsychidae 1sp						0	1	2	4	2	3	1	0	0	LOW
Hydropsychidae 2spp						0	1	2	4	2	3	1	0	0	LOW
Hydropsychidae >2spp						0	1	2	4	2	3	1	0	0	HIGH
Philopotamidae						0	1	2	3	1	4	1	1	0	MODERATE
Polycentropodidae						0	0	3	4	4	3	0	0	0	HIGH
Psychomyiidae						0	1	2	3	4	2	1	0	0	MODERATE
Xiphocentronidae						0	1	2	3	4	2	1	0	0	MODERATE
Barbarochthonidae						0	2	3	1	2	3	2	0	0	HIGH
Calamoceratidae						4	1	0	0	0	2	2	3	0	MODERATE
Glossosomatidae						0	2	3	4	1	4	0	1	0	MODERATE
Hydroptilidae						0	3	2	2	1	2	3	1	0	LOW
Hydropsalpingidae						0	1	3	4	2	3	2	0	0	HIGH
Lepidostomatidae						1	3	2	1	2	2	2	2	0	MODERATE
Leptoceridae						0	1	3	2	2	2	2	2	0	LOW
Petrothrincidae						0	0	1	4	4	1	0	0	0	MODERATE
Pisuliidae						1	3	2	1	2	3	2	2	0	MODERATE
Sericostomatidae						0	1	3	2	0	3	2	0	0	HIGH
Dytiscidae/Noteridae						4	2	1	0	1	2	3	1	2	LOW
Elmidae						0	0	4	2	1	4	1	0	0	MODERATE
Dryopidae						0	0	2	4	1	4	1	0	0	MODERATE
Gyrinidae						1	2	2	3	0	0	0	0	5	LOW
Haliplidae						3	4	1	1	1	1	4	1	1	LOW
Helodidae						2	2	2	1	0	2	3	0	0	HIGH

Version date: Jan 2005

SASS Version 5 Score Sheet

Date:	2012/09/20
Site Code:	Site 3
Ecoregion:	20
Water Management Area:	
Quaternary Catchment:	
River:	Uie
Zonation:	
Site Description:	
Collector:	
Grid (dd.r S	S 33°25'005"
E	E 25°28'536"
Datum	
Altitude (r	2939

Temp (°C):	16.0	Cond (mS/m)	2.88
pH:	7.2	Clarity (cm):	
DO (mg/L):	773	Turbidity:	2.73
Flow:		Colour:	

Biotopes sampled:	Rating	Time (min)
SIC	4	
SOOC	0	
Bedrock	0	
Aquatic Veg	0	
MVIC	4	
MVOC	1	
Gravel	2	
Sand	1	
Mud	0	
Hand picking/Visual observatio	0	

Riparian Disturbance: eg, maize

Instream Disturbance: eg. sandwinning, cattle, petrol, sm

Taxon		S	Veg	GSM	TOT
PORIFERA (SPONGE)	5				
COELENTERATA (CNIDARIA)	1				
TURBELLARIA (FLATWORMS)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1	A		B	B
Leeches	3	A			A
CRUSTACEA					
Amphipoda	13			A	A
Potamonautidae* (Crabs)	3	A			A
Atyidae (Shrimps)	8				
Palaemonidae (Prawns)	10				
HYDRACARINA (MITES)	8				
PLECOPTERA (STONEFLIES)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA					
Baetidae 1sp	4				
Baetidae 2 sp	6				
Baetidae > 2 sp	12	B	B	B	C
Caenidae (Squaregills/Cainfles)	6	A			A
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13				
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC	12				
Tricorythidae (Stout Crawlers)	9				
ODONATA (DRAGONFLIES & DAMSELFLIES)					
Calopterygidae ST,T	10				
Chlorocyphidae	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4	1	B	A	B
Lestidae (Emerald Damselflies)	8				
Platycnemidae (Brook Damselflies)	10				
Protoneuridae	8				
Aeshnidae (Hawkers & Emperors)	8				
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6				
Libellulidae (Darters)	4			1	1
LEPIDOPTERA					
Crambidae (Pyralidae)	12				

Taxon		S	Veg	GSM	TOT
HEMIPTERA (BUGS)					
Belostomatidae* (Giant water bugs)	3				
Corixidae* (Water boatmen)	3				
Gerridae* (Pond skaters/Water striders))	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5				
MEGALOPTERA					
Corydalidae	8				
Sialidae	6				
TRICHOPTERA CADDISFLIES)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4	A			A
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5				
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5				
Limnichidae	10				
Psephenidae (Water Pennies)	10				

Taxon		S	Veg	GSM	TOT
DIPTERA (FLIES)					
Athericidae	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5				
Chironomidae (Midges)	2	A	B	B	B
Culicidae* (Mosquitoes)	1				
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5	C	B	B	C
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5				
GASTROPODA (SNAILS)					
Ancylidae (Limpets)	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (BIVALVES)					
Corbiculidae	5				
Sphaeriidae (Pills clams)	3				
Unionidae (Perly mussels)	6				
SASS Score		49	23	41	66
No. of Taxa		10	4	7	12
ASPT		4.9	5.8	5.9	5.5

Other biota:

Chlorolestidae - gsm (1) Veg (a)

Tadpole - gsm (a)

Comments:

Procedure: Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg 1m². Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers

Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.

Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical

Flow modification metrics (FM)

FLOW MODIFICATION METRICS. WITH REFERENCE TO VELOCITY PREFERENCES, WHAT ARE THE CHANGES TO THE FOLLOWING OBSERVED OR EXPECTED TO BE?	RATING	RANKING OF METRICS	% Weight	COMMENTS
Presence of taxa with a preference for very fast flowing water				
Abundance and/or frequency of occurrence of taxa with a preference for very fast flowing water				
Presence of taxa with a preference for moderately fast flowing water				
Abundance and/or frequency of occurrence of taxa with a preference for moderately fast flowing water				
Presence of taxa with a preference for slow flowing water				
Abundance and/or frequency of occurrence of taxa with a preference for slow flowing water				
Presence of taxa with a preference for standing water				
Abundance and/or frequency of occurrence of taxa with a preference for standing water				
Overall % change in flow dependance of assemblage			#DIV/0!	
Velocity Preference Scores: **GENERIC GUIDELINES FOR SCORING (0-5)** 0=No change from reference 1= Small change from reference 2=Moderate changefrom reference 3=Large change from reference 4=Serious change from reference 5=Extreme change from reference (completely dominant or absent)	**Velocity Categories:** Very Fast flowing water >0.6 m/s; Moderately fast flowing water 0.3-0.6 m/s; Slow flowing water 0.1-0.3 m/s; Standing water <0.1 m/s			
Ranking of metrics: Rank order in terms of which metric (if it changed from worst to best) would best indicate good integrity in terms of velocity categories. Do not rank metrics that are not relevant (leave them blank)	**% Weight:** Give 100% to rank 1, then say how big the impact of each of the others is as a % of that (irrespective of the rating).			

Habitat modification metrics (H)

HABITAT MODIFICATION METRICS. WITH REFERENCE TO INVERTEBRATE HABITAT PREFERENCES, WHAT ARE THE CHANGES TO THE FOLLOWING OBSERVED OR EXPECTED TO BE?	RATING	RANKING OF METRICS	%WEIGHT	COMMENTS
Has the occurrence of invertebrates with a preference for bedrock/boulders changed relative to expected?				
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for bedrock/boulders changed?				
Has the occurrence of invertebrates with a preference for loose cobbles changed relative to expected?				
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for loose cobbles changed?				
Has the occurrence of invertebrates with a preference for vegetation changed relative to expected?				
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for vegetation changed?				
Has the occurrence of invertebrates with a preference for sand, gravel or mud changed relative to expected?				
Has the abundance of any of the taxa with a preference for sand, gravel or mud changed relative to expected?				
Has the occurrence of invertebrates with a preference for the water column or water surface changed relative to expected?				
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for the water column/water surface changed?				
Overall % change in flow dependanceof assemblage			#DIV/0!	
Habitat Preference Scores: **GENERIC GUIDELINES FOR SCORING (0-5)** 0=No change from reference 1= Small change from reference 2=Moderate changefrom reference 3=Large change from reference 4=Serious change from reference 5=Extreme change from reference (completely dominant or absent)				
Ranking of metrics: Rank order in terms of which metric (if it changed from worst to best) would best indicate good integrity in terms of habitat types. Do not rank metrics that are not relevant (leave them blank)	**% Weight:** Give 100% to rank 1, then say how big the impact of each of the others is as a % of that (irrespective of the rating).			

Water quality metrics (WQ)

WATER QUALITY METRICS. WITH REFERENCE TO WATER QUALITY REQUIREMENTS, WHAT ARE THE CHANGES TO THE FOLLOWING OBSERVED OR EXPECTED TO BE?	RATING	RANKING OF METRICS	% WEIGHT	COMMENTS
Has the number of taxa with a high requirement for unmodified physico-chemical conditions changed?				
Has the abundance and/or frequency of occurrence of the taxa with a high requirement for unmodified physico-chemical				
Has the number of taxa with a moderate requirement for unmodified physico-chemical conditions changed?				
Hasthe abundance and/or fequency of occurrence of the taxa with a moderate requirement for modified physico-chemical				
Has the number of taxa with a low requirement for unmodified physico-chemical conditions changed?				
Has the abundance and/or frequency of occurrence of the taxa with a low requirement for unmodified physico-chemical				
Has the number of taxa with a very low requirement for unmodified physico-chemical conditions changed?				
Has the abundance and/or frequency of occurrence of the taxa with a very low requirement for unmodified physico-chemical				
How does the total SASS score differ from expected?				
How does the total ASPT score differ from expected?				
Overall change to indicators of modified water quality			#DIV/0!	

Water Qaulity delineations (Based on SASS5 weights) High Water Quality Preference: (SASS weights 12-15) Moderate Water Quality Preference: (SASS weights 7-11) Low Water Quality Preference: (SASS weights 4-6) Very low Water Quality Preference: (SASS weights 1-3)	**SASS Scores:** **GUIDELINES FOR SCORING (% of reference)** >90% = 0 80-90% = 1 60-80% = 2 40-60% = 3 20-40% = 4	
Water Quality Preference Scores: **GENERIC GUIDELINES FOR SCORING (0-5)** 0=No change from reference 1= Small change from reference 2=Moderate change from reference 3=Large change from reference 4=Serious change from reference 5=Extreme change from reference (completely dominant or absent)	**ASPT Values:** **GUIDELINES FOR SCORING (% of reference)** >95% = 0 90-95% = 1 85-90% = 2 80-85% = 3 75-80% = 4	
Ranking of metrics: Rank order in terms of which metric (if it changed from worst to best) would best indicate good integrity in terms of water quality requirements. Do not rank metrics that are not relevant (leave them blank)	**% Weight:** Give 100% to rank 1, then say how big the impact of each of the others is as a % of that (irrespective of the rating).	

System connectivity and seasonality (CS)

WHAT IS THE EXTENT OF THE FOLLOWING	RATINGS	COMMENTS
Weirs and causeways	2.00	
Impoundments		
Changes in seasonality		

Based on observed and derived data, with reference to migration and seasonality, how did the following change?	RATING	RANKING OF METRICS	% Weight	COMMENTS
Impact on distribution of migratory taxa		2		
Impact on abundance and/or frequency of occurrence of migratory taxa				
Impact on occurrence of taxa with seasonal distribution	2	1	100	
Impact on abundance and/or frequency of occurrence of taxa with seasonal distribution				
Overall % change in flow dependance of assemblage			**40**	

Ecological Category

INVERTEBRATE EC: BASED ON WEIGHTS OF METRIC GROUPS							
INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC GROUP	%WEIGHT FOR METRIC GROUP	COMMENTS
FLOW MODIFICATION	**FM**	#DIV/0!	*#DIV/0!*	#DIV/0!			
HABITAT	**H**	#DIV/0!	*#DIV/0!*	#DIV/0!			
WATER QUALITY	**WQ**	#DIV/0!	*#DIV/0!*	#DIV/0!			
CONNECTIVITY & SEASONALITY	**CS**	60.0	*#DIV/0!*	#DIV/0!			
						0	
INVERTEBRATE EC				#DIV/0!			
INVERTEBRATE EC CATEGORY				**#DIV/0!**			

>89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F

Guidelines for ranking of metric groups.
Which of the Metric Groups will best indicate the response of invertebrates at this site or reach/invertebrate habitat segment.

Considering the range from 5 to 0 of each of these metric groups, which one would most affect overall Invertebrate Response (PES) if it changed from 0 to 5? (irrespective of the rating). This metric group is ranked as 1, the next most responsive, ranked as 2, etc.

Guidelines for weighting of metric groups.
Give 100% to rank 1, then say how big the impact of each of the others is as a % of that (irrespective of the rating).

Appendix 3: Recorded water chemistry data for all Sites from July 2012 to June 2013

Recorded values for the water chemistry variables from July 2012 to June 2013 for Site 1. October 2012 values were not recorded due to flooding in the Eastern Cape. May 2012 values were not recorded due to no flow.

Variable	July	August	September	November	December	January	February	March	April	June
Temperature (°C)	16.5	16.5	19	23.4	20	24	25.7	22	21	16.2
pH	6.6	7.4	6.7	6.8	6.7	-	7.1	6.6	5.7	8.1
DO (mg/l)	6.3	9.0	-	7.5	7.2	6.8	6.3	5.9	6.2	7.2
EC (mS/m)	55.5	126.7	50.3	31	63	48.1	85	72.2	92.5	87
Turbidity (NTU)	0.3	-	1.1	1.5	0.3	0.8	0.4	2.4	0.5	0.1
Nitrate (mg/l)	0.5	0.5	0.5	0.5	0.3	2.2	0.5	0.1	1.3	4.3
Nitrite (mg/l)	0.005	0.01	0.03	0.03	0.01	0.2	0.02	0.01	0.01	0.02
Phosphate (mg/l)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.00
Ammonia (mg/l)	0.05	0.05	0.05	0.05	0.14	0.05	0.05	0.05	0.05	0.05

Recorded values for the water chemistry variables from July 2012 to June 2013 for Site 2. October 2012 values were not recorded due to flooding in the Eastern Cape.

Variable	July	August	September	November	December	January	February	March	April	May	June
Temperature (°C)	16	16	17.5	23.7	20.8	26	25.8	21	18	18	15
pH	7.9	7.8	7.4	7.2	7.6	-	7.9	7.3	7.0	7.3	9.0
DO (mg/l)	7.1	8.9	-	7.3	8.6	9.1	6.6	6.2	6.4	5.5	7
EC (mS/m)	708	63.6	188.6	48	95.5	58.4	104	68.6	73.7	100.3	79
Turbidity (NTU)	15.5	-	19.6	2.7	2.2	1.9	2.7	2.1	3.1	15	4.1
Nitrate (mg/l)	109.7	31.3	18.8	0.5	71.1	55.6	47.7	120.7	374.2	112.5	54.1
Nitrite (mg/l)	0.005	0.04	0.11	0.03	0.12	1.87	1.56	0.90	0.66	0.08	0.86
Phosphate (mg/l)	0.05	0.05	0.05	0.05	0.05	0.13	0.05	0.37	0.48	0.03	0.73
Ammonia (mg/l)	0.05	0.05	0.05	0.05	0.22	0.09	0.05	4.24	2.01	1.97	2.87

Recorded values for the water chemistry variables from July 2012 to June 2013 for Site 3. October 2012 values were not recorded due to flooding in the Eastern Cape.

Variable	July	August	September	November	December	January	February	March	April	May	June
Temperature (°C)	14	13.5	16	20	19.8	22.5	23.7	22	18	17.5	15.5
pH	7.7	7.4	7.2	7.3	7.4	-	7.6	7.3	6.5	7.32	8.46
DO (mg/l)	0.1	7.4	773.0	6.2	5.7	6.3	5.1	6.4	6.5	5.73	6.15
EC (mS/m)	289	274	286	94	198.9	150.9	279	339	329	662	439
Turbidity (NTU)	1.0	-	2.7	3.1	1.2	-	1.4	1.0	2.6	2.65	0.43
Nitrate (mg/l)	75.6	23.5	9.5	0.5	24.4	43.5	33.2	35.7	167.7	243.6	26.0
Nitrite (mg/l)	0.005	0.02	0.04	0.03	0.02	0.4	0.15	0.03	0.03	0.41	0.07
Phosphate (mg/l)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.15	0.05
Ammonia (mg/l)	0.05	0.05	0.05	0.05	0.18	0.05	0.05	0.16	0.20	0.21	0.14

Appendix 4: SASS, Number of Taxa, ASPT and IHAS scores for each site from July 2012 to June 2013

South African Scoring System (SASS) scores for each site from July 2012 to June 2013. Each invertebrate collected has a predefined sensitivity score associated to it. The total SASS score is thus the sum of all the sensitivity score of the invertebrates collected at that site.

SASS Score			
Month	**Site 1**	**Site 2**	**Site 3**
July	76	50	53
August	84	32	56
September	81	41	66
November	83	63	87
December	110	67	76
January	82	84	60
February	103	77	97
March	89	67	90
April	137	64	81
May	-	42	96
June	91	33	89

Total number of taxa found at each site from July 2012 to June 2013.

Number of Taxa			
Month	**Site 1**	**Site 2**	**Site 3**
July	17	11	10
August	15	8	13
September	14	9	12
November	15	12	15
December	18	11	11
January	17	15	12
February	19	14	16
March	16	14	16
April	19	12	17
May	-	11	18
June	15	9	15

Total average score per taxa (ASPT) for each site from July 2012 to June 2013. This score is worked out by dividing the total SASS score by the total number of taxa found.

Average Score Per Taxa (ASPT)			
Month	**Site 1**	**Site 2**	**Site 3**
July	4.5	4.6	5.3
August	5.6	4	4.3
September	5.8	4.6	5.5
November	5.3	4.8	5.8
December	6.1	6.1	6.9
January	4.8	5.6	5
February	5.4	5.5	6.1
March	5.6	4.8	5.6
April	7.2	5.3	4.8
May	-	3.8	5.3
June	6.1	3.7	5.9

Integrated habitat assessment score (IHAS) for each site from July 2012 to June 2013. These scores show the overall integrity of the habitat being assessed.

Integrated Habitat Assessment Score (IHAS)			
Month	**Site 1**	**Site 2**	**Site 3**
July	64%	52%	67%
August	70%	64%	70%
September	59%	70%	63%
November	60%	68%	66%
December	56%	63%	67%
January	77%	70%	85%
February	86%	63%	84%
March	79%	71%	75%
April	81%	63%	83%
May	-	60%	83%
June	58%	61%	67%

Appendix 5: Checklist of the Key Performance Areas (KPA) for the 2012/2013 Green Drop Assessment

Key Performance Area	Sub-Requirements
Process Control, Maintenance and Management Skill **10%**	(a) A copy (certified) of **Registration Certificate of Works** displaying Classification (Regulation 2834)
	*(a) Copies (certified) of **Registration Certificates of Process Controllers and Supervisors** (Regulation 2834)* *1. Copies of the classification certificates of **all** process controllers/operators and supervisors/superintendents must be uploaded on the GDS* *2. Compliance with Regulation 2834 (must comply at least 50% in each of the shifts); WSI must indicate shift patterns or measures in place when no shift work is undertaken* *3. WSI must indicate process controllers and/or supervisors that are 'shared' across different plants/sites*
	*(a) Proof of **Maintenance Team** used for general maintenance work at the plant (both mechanical and electrical)* *1. Information on in-house staff or external contractor/s* *2. Provide additional proof of competency of team (e.g. Qualification & Experience & Trade-test)* *3. Provide a site specific operation and maintenance schedule (routine / scheduled)* *4. Contract or Logbook with maintenance entries will serve as proof of the above aspects*
	(a) Proof of a 'site-specific' Operation & Maintenance Manual *1. O&M manual/s to contain: structural, mechanical, electrical detail of plant, design specifications of plant, reference to drawings, operational schedules, maintenance schedules, process detail and control, instrumentation specification/type, fault finding, monitoring, pump curves, supportive appendices*
	(a) Operational Logbook *1. A logbook is in place to record all incidents at the water treatment works* *2. Evidence is presented that the logbook process is being implemented (It is NOT required to be implemented for the entire assessment period)*
	BONUS: **Proof of Process Controllers Being Subjected to relevant training the past 24 months. Provide proof of:** o *Names of trainees and signature of attendance* o *Date and training subject field* o *Training provider and content of training*
Wastewater Monitoring Programme Efficacy **15%**	(a) Details of **Operational Monitoring:** 1. Proof of Operational Monitoring sites, determinands and frequency 2. Samples must include: o *inflow,* o *outflow,* o *process flows,* o *industrial effluent,* o *sludge;* 3. Determinands monitored: o *As per Authorisation / as per best practice per technology type;* o *Frequency : as per Authorisation /as per best practice;*
	(a) Details of **Compliance Monitoring**. 1. Sampling Sites as per Authorisation; 2. Determinands as per Authorisation; 3. Sampling frequency occurs as Authorisation Requirements *Note1: For zero-effluent treatment systems - still need to monitor for impact on catchment / environment (for both lined and unlined systems). Where oxidation ponds are producing effluent for irrigational purposes then General Limits apply.* *Note 2: A monitoring programme will not be sufficient to obtain full scores. Analyses results should proof implementation of the monitoring programme.*
	(a) Laboratory used: 1. Name lab for operational analysis (in-house or on-site) and lab for compliance analysis/checks (in-house or external) 2. Provide the turnaround in laboratory analysis (in hours: from time of submission to time of results dissemination)

	(a) Laboratory Credibility: 1. Certificate of **Accreditation** for applicable methods, *2. Or* Z-scores results following participation a recognised **Proficiency Testing Scheme** (–2 ≥ z-score ≥ 2 are unacceptable) *3. Or* Proof of Intra- and Inter-laboratory proficiency (quality assurance as prescribed in Standard Methods)
	(a) Explain how **monitoring results** are used to **amend/improve process controlling** Practical example: *[The assessor will select at random analytical parameter/s from the presented analytical results to present an audit question]*
Submission of Wastewater Quality Results **5%**	Proof of **data submission** to DWA (12 months) ***Chapter 1:*** *12 months of data submitted to DWA **on the GDS*** Chapter 2: *WSA must ensure that 12 months' sets of results are submitted and recorded on the GDS prior to the assessment.* *Note: **All compliance results' data required***
	PENALTY: Penalty will apply should wastewater results be available but not captured on GDS
	PENALTY: Penalty will apply should the Department find proof during / post assessment that the WSI is guilty of an offence as per Section 82 of the Water Services Act, by only submitting partial information (on GDS) in order to present a false impression of DWQ Performance and/or compliance.
Effluent Quality Compliance **30%**	(a) Copy of **Authorisation** (License, GA or permit, detailing Effluent Quality Limits and Discharging standards (in case of oxidation ponds)) *Copy of applicable Authorisation, containing the specified effluent quality limits or standards for discharge to a water body or for irrigation or for other applications*
	(a) Effluent Quality CATEGORIES: (1) 90% microbiological compliance; (2) 90% chemical compliance; and (3) 90% physical compliance
	BONUS **(a) A practical Green Drop Improvement Plan (GDIP) in place – with baseline (current) score, tasks, responsible person, completion date, budget, target GDC score;** **(b) Implementation evidence and proof of management of process**
	PENALTY **(a) Sludge treatment not managed / monitored (Monitoring records must be produced).** **(b) In cases of ponds systems, provide schedule for desludging of system**
Wastewater Quality Risk Management **15%**	(a) Proof of a documented **Wastewater Incident Management Protocol** • Protocol to specify alert levels, response times, required actions, roles & responsibilities and communication measures/vehicles • NB. Include Pump station failure and sewer collector system spillages
	(b) Provide **evidence of implementation** of Protocol • Wastewater Quality Failure Incident and Sewer Spillage Incident register
	(c) A practical and site specific **Wastewater Risk Abatement Plan (W2RAP)** is in place which identify and prioritise risks, with measures to mitigate inefficiencies/inadequacies that result in non-compliance
	BONUS: WSI is able to provide DWA with Energy Demand Projections and Consumption figures for the specific Wastewater Treatment Works.
Bylaws (Local Regulation) **5%**	**(a) Proof of the Bylaws** providing for the regulation of: o industrial (trade) effluent (volumes & quality) discharged into municipal system o package plants o decentralized systems o vacuum tank discharges o Spillages into the environment o Stormwater connections to sewer system.
	(a) Evidence of Bylaws enforcement by Local Authority • Proof of application of Bylaw clause in practice, supported by written notice/s to offender

	PENALTY: No evidence of any **Industrial influent monitoring.** • There must be proof in form of results to indicate WSA is performing its local regulation function as per Wastewater Services.
	BONUS: **Annual Publication of** wastewater management performance against the requirements of the site-specific License conditions or General Authorisations Name and date of publication, copy of information pertaining to audit question. Note: Communication must include compliance summary
Wastewater Treatment Capacity **5%**	(a) Documented design capacity (**hydraulic and organic**) of the wastewater treatment facility • *Design capacity as Average Dry Weather Flow (ADWF) and COD load to the plant* and (a) Documented daily **receiving flows** over the 12months of assessed period (ideally ≤ than design capacity) • *Evidence of daily flows and subsequent calculated averages. Measurement method to be explained* • *Evidence of peak wet weather flow to plant during rain events (record rain event and flow to plant)* • *Evidence of minimum nightflow (minimum monitoring: monthly)* • *Water services institution is required to provide motivation/proof of accuracy of meter readings.*
	(a) Medium to long term planning to ensure sufficient **capacity for treatment system** and to ensure effluent quality compliance; • *Detailed Work-plan which stipulates type of work, associated budget and projected timeframe, as well as the planned output of this work*
	(a) Medium to long term planning to ensure sufficient **capacity for collecting system** • *Detailed Work-plan which stipulates type of work, associated budget and projected timeframe, as well as the planned output of this work* • *Note: When the WSI is motivating that 'no work' is needed, then provide basis for such standpoint (i.e. quantified design versus operational capacity, usage of system, expected housing developments, condition of treatment system)*
Wastewater Asset Management **15%**	• Annual **Process Audit** reporting (evidence required of audit findings and recommendations) on treatment facility efficacy. The audit to include the (design) capability of the plant to meet compliance standards, as well as actual performance of plant. • Evidence/plan of **implementation of findings** during year following Audit Report required.
	(a) Site inspection of sewer reticulation network and pump-station/s. Provide evidence in form of capacity and condition assessment and recommendations of system. Report to include flow balance that provides evidence which % of total sewage is received at treatment plant. *Note: both the process audit and sewer network report could serve as baseline to the W2RAP (may run concurrently with "system description and risk identification/rating)*
	(a) Updated sanitation / wastewater **Infrastructure Asset Register** Proof of Asset Register, evidence to be submitted. Asset register to include movable equipment and immovable infrastructure / assets with matching detail (age, value, condition, etc).
	(a) Operation and maintenance **budget** and comparative **expenditure** detail for: 1 - wastewater treatment (in cents/m3), and 2 - collection system (R/m3) *The assessor will require the WSI to explain how these figures compare or are **benchmarked** to determine whether budget is (in)sufficient.* **(a) Maintenance records** of pump-stations Proof of maintenance work done on mechanical, electrical, civil per pump station
Additional Bonus	**Add 1:** WSI is able to provide evidence of **improvement partnership initiatives** with smaller municipalities **(Cross-pollination).** Green Drop scores will serve as good evidence to measure the outcomes of such initiative/s.
	Add 2: Proof of a **Storm-water management plan** detailing how storm-water entry is quantified, managed and monitored to prevent entry to sewer systems. Evidence of implementation required
	Add 3: Water Demand Management Plan which provides a strategy and/or workplan that identify, quantify, monitor and manage leakages and water losses of any kind that (may) create an artificial water demand due to higher hydraulic loading of wastewater collection and treatment infrastructure. The bonus will be maximised by providing a wastewater flow balance.

Appendix 6: Notable meetings, interviews and workshops

Date	Purpose	Parties present
30/11/2011 – 01/12/2013	Second SAM workshop	Technical Department (SRVM) SRVM councillors Co-op members Amatola Water Sundays River Valley WUA CSIR Rhodes University
16/02/2012 – 17/02/2012	RRU Intervention Workshop	Technical Department (SRVM) Rapid Response Unit SRVM councillors Farm owners Amatola Water Rhodes University
24/05/2012	Pre equipment training meeting	Technical Department (SRVM) Rhodes University
06/06/2012 – 07/06/2012	Water quality equipment training workshop	Amatola Water Technical Department (SRVM) Rhodes University
29/06/2012	Follow up water quality equipment training meeting	Technical Department (SRVM) Rhodes University
26/07/2012	Progress meeting	Technical Department (SRVM) Rhodes University
31/07/2012	RRU GDIP meeting	RRU Finance Department (SRVM) Technical Department (SRVM) Rhodes University
02/08/2012	Meeting with new Technical Director	Technical Department (SRVM) Rhodes University
15/08/2012	Meeting with Environmental Health Practitioner	Environmental Health Practitioner (SRVM) Rhodes University
15/08/2012	Progress meeting	Technical Department (SRVM) Rhodes University
28/08/2012	Progress meeting	Technical Department (SRVM) Rhodes University
04/09/2012	RRU mock GD assessment	RRU Technical Department

		(SRVM) Rhodes University
24/10/2012	2012/2013 GD assessment	DWA Technical Department (SRVM) Finance Department (SRVM) Rhodes University
19/01/2013	Progress meeting	Technical Department (SRVM) Rhodes University
21/02/2013	Progress meeting	Technical Department (SRVM) Rhodes University
04/04/2013	Progress meeting	Technical Department (SRVM) Rhodes University
11/06/2013	Progress meeting	Technical Department (SRVM) Rhodes University